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Genetic improvement and registration of naturally coloured *Gossypium hirsutum* cotton genotypes suitable for textile industry

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ABSTRACT : Breeding efforts were made to improve the naturally coloured *Gossypium.hirsutum* cotton genotypes with respect to yield and fibre quality through intraspecific, interspecific and three way crosses between coloured and superior white genotypes followed by selections independently in three populations. Stable genotypes with uniform colour and high yield potential and improved fibre qualities were developed. Eight of the 32 advanced coloured genotypes in three populations tested under three replicated trials were superior to white linted check, Sahana (2138 kg/ha) for seed cotton yield. Three of these, dark brown (DDB 12 with 2986 kg/ha, medium brown (DMB 225 with 2934 kg/ha) and green (DGC 78 with 1381 kg/ha) were potential for seed cotton yield and quality in the respective colour. The genotype DDB 12 had 21.6 mm fibre length and 18.6 g/ tex strength; DMB 225(medium brown), had 22.9mm and 20.4 g/tex while green linted DCG 78 had 25.8mm and 22.2g/tex, span length and strength, respectively. These genotypes performed better consistently over three years of testing for yield and fibre quality. Yarn and fabrics were manufactured which were suitable for mill spinning and eco fabrics of commercially acceptable range could be produced. The simultaneous development of medium, dark brown and green shades along with white cotton will help in the creation of variability in the textile industry. Efforts need to be done to further improve the fibre properties which are being done using the stable colour cotton lines developed in the present study for crossing with superior white cultivars for introgression and selection. Biotechnological approaches have been initiated to diversify the lint colour.

Key words : Genetic improvement, *Gossypium hirsutum*, interaspecific, interspecific, naturally coloured

Naturally coloured cotton inhibits the formation of disturbances in the human ecology, pollution of environment by synthetic dyestuffs, also eliminates the bleaching and dyeing costs and an excessive energy usage. With the development of dyeing industry the conversion of white coloured fibres into desirable and fashioned colours inhibited studies of the researchers on the naturally colored cotton having not a good yield performance and fibre quality. However, such factors like disturbances in the human ecology, pollution of environment by synthetic dyestuffs and dyeing costs caused the turn of the attention of researchers to the naturally coloured cotton germplasm. The naturally coloured cotton created new alternatives in the textile industry to obtain the healthy and using friendly clothing, furnishing and household products (Œwiêch and Frydrych, 1998; 1999; Œwiêch *et al.*, 1999; Vreland, 1999).

Previous studies along with the advantage of inherent colour have also shown the flame resistance of brown cotton (Kimmel and Day, 2001; Williams, 1994) and colour change (darkening instead of fading) occurring with certain laundering methods (Oktem *et al*, 2003; Vanzandt, 1994). It is also reported that naturally colored cottons bring medical remedy for over 50 different somatic and psychosomatic disorders of man (Vreerland, 1993). The study demonstrates that naturally pigmented cottons have excellent sun protection properties (high UV protection factor (UPF values), which are far superior to conventional bleached or unbleached cotton (Gwendolyn and Patricia, 2005) (green cotton UPF = 30 to 50 +; tan UPF= 20 to 45; brown UPF = 40 to 50+; bleached conventional UPF = 4; unbleached conventional UPF = 8).

On one hand, the knowledge of all these desirable features of the naturally pigmented cottons, there is no second thought for the adaptation of these cottons; on the other hand history shows that though they co existed with white cotton they were left behind in the mid way. The low yielding, short fibre coloured cottons were not suitable for machine spinning; therefore they failed to face the rapid industrial turnover. Off late attention is diverted to study the possibility for using these eco cottons commercially but very few systematic studies and reports are available on the breeding programmes and still very rare information on the fibre quality of naturally colored cottons(Œwiêch and Frydrych 1998,1999; Œwiêch *et al.,* 1999).

The present study was done at UAS, Dharwad encompassing breeding to improve the naturally coloured *G. hirsutum* cotton with respect to yield and fibre quality to make these cottons commercially viable to both the farmer and textile industry. Among the four cultivated species of cotton, colour lint is reported in *G. arboreum* among diploid and in *G. hirsutum* in tetraploid cottons. White *G. barbadense* that are inherently superior sources of fibre quality and white *G. hirsutum* cottons are a source for both yield and fibre quality have been used for improvement of colour cotton.

MATERIALS AND METHODS

The dark brown selection DDBS 98, white released varieties, Abadhitha of *G. hirsutum* and Suvin *G. barbadense* with characters as given in Table 1 were used in the crossing programme to develop 3 populations as detailed in Fig. 1. The green genotype used in the crossing was very low yielding and had unstable colour expression.

In all the selection cycles from 2000–2001 to 2005–2006 individual plants were selected in field after peak boll bursting based on morphological observation on lint colour, yield/plant and fibre length. Individual plants were sown in plant to progeny rows and again individual plants were selected. In advanced generations, during 2006 – 2007 progeny row selections were effected.

Population I consisted of eighteen colour cotton genotypes from the cross DDBS 98 (Dark brown *hirsutum*) x Abadhitha (white *hirsutum*) and one green from (Green *hirsutum* x Abadhitha); population II had ten genotypes from DDBS 98 (Dark brown *hirsutum*) x Suvin (white *barbadense*); and population III had seven genotypes from three way crosses [three selections from [(Colour *hirsutum* x white *hirsutum*) x white *barbadense*] and 4 selections from [(Colour *hirsutum* x white *barbadense*) x White *hirsutum*]. These stable genotypes were sown under three independent trials along with colour parent DDBS 98 and white commercial check, Sahana. The trials were laid in three replications with two rows/genotype and spacing of 90 x 20 cm under rainfed condition at ARS, Dharwad Farm and standard agronomic practices were followed to raise healthy crop.

The seed cotton yield was analyzed for randomized block design trial. Observations on boll weight were taken as average of twenty bolls/ genotype. The ginning outturn (GOT) was calculated (using 300g seed cotton to get seed and lint weight) using the standard formula , GOT =[(Lint weight / seed cotton weight) x 100] and seed index (SI) was weight of 100 seeds and lint index (LI) was calculated using the formula, LI= [(SI x GOT) / (100 – GOT)].

The fibre quality was analyzed at Central Institute of Research on Cotton Technology (CIRCOT), Regional Unit, Dharwad, using HVI machine.

The genotype, DMB 225 which had significantly higher yield based on progeny row results of the year 2006-2007 was grown in one ac under isolation in 2007-2008 with a spacing of 90 x 20cm following the same package of practices as in commercial white *hirsutum* varieties and the lint was tested for its suitability for commercial yarn and fabric production.

RESULTS AND DISCUSSION

Population I was developed from intra

Table 1. Yield and fibre quality traits of the parents used in the study

Entry	Lint colour	SCY (kg/ha)	Boll weight (g)	SI	LI	GOT	SL (mm)	UR (%)	Micronaire value	Maturity ratio	Tenacity (g/t)	Elongation (%)
DDBS 98	Dark brown	796	3.2	10	3.1	25	18.5	50	4.9	0.8	13.2	4.1
Abadhita	White	1677	4.2	9	6.7	40	27.1	46	4.2	0.8	18	4.9
Suvin	White	535	2.7	9	4.2	32	38.1	48	3.1	0.8	30.9	4.8

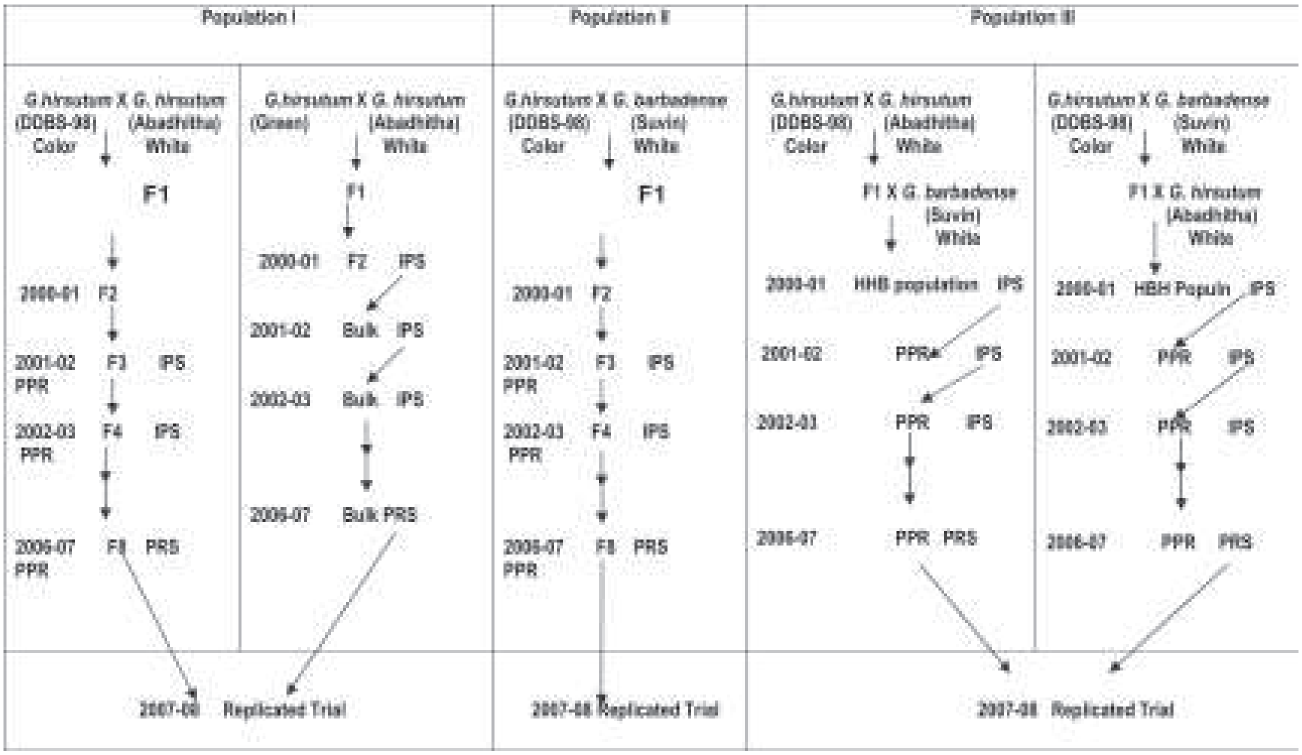

Fig. 1. Schematic diagram of crossing and selection procedures followed to develop the three populations

specific crosses, among the eighteen improved brown linted genotypes and one green genotype, DG 78 were tested along with white variety Sahana and dark brown parent DDSG 98. All the test entries were superior for both yield and fibre properties as compared to original dark brown parent DDSG 98. Also some of the genotypes were numerically superior to even the white commercial cultivar Sahana for seed cotton yield and boll weight, but inferior with respect to lint index and GOT. Three genotypes DDB 12 (2986 kg/ha) with dark brown, DMB 225 (2934 kg/ha) with medium brown and DDB 210 (2834 kg/ha) with dark brown colour were significantly superior for seed cotton yield than Sahana (2138 kg/ha) (Table 2 and Fig. 2).

With respect to fibre quality parameters though most of the selected genotypes were better than original parent DDBS 98 but were not *on par* with white check Sahana. Among the high yielding genotypes medium brown coloured selection DMB 225 had better fibre length of 22.9 mm (2.5% span length) and 20.4 g/tex strength and micronaire of 4 (Table 2). As it was very difficult to get stable green colour plants, in each generation individual plants selected on basis of uniform green shade and fibre length were bulked and advanced to next generation to repeat the same. The green genotype thus developed, DG 78 was much stable with respect to green colour and though its yield was not comparable to improved brown selections, it had good fibre quality of 25.8mm span length and 22.2 g/tex strength (Table 2).

The population II, consisting of stable lines from interspecific cross between dark brown *G. hirsutum* and white *G. barbadense*, among ten genotypes only one cream coloured selection, DCR 110 was numerically superior to white check, Sahana for seed cotton yield, lint index and GOT and even *on par* for fibre quality. Most of these selections were of medium brown lint. The genotypes DMB 105 had very good fibre properties of 26.2mm span length and 21.5 g/ tex tenacity (Table 3).

The III population derived from three way crosses using both white *hirsutum* and *barbadense*, only 7 selections could be advanced to replicated trial as most of them had very light colour. Though none of them was better than

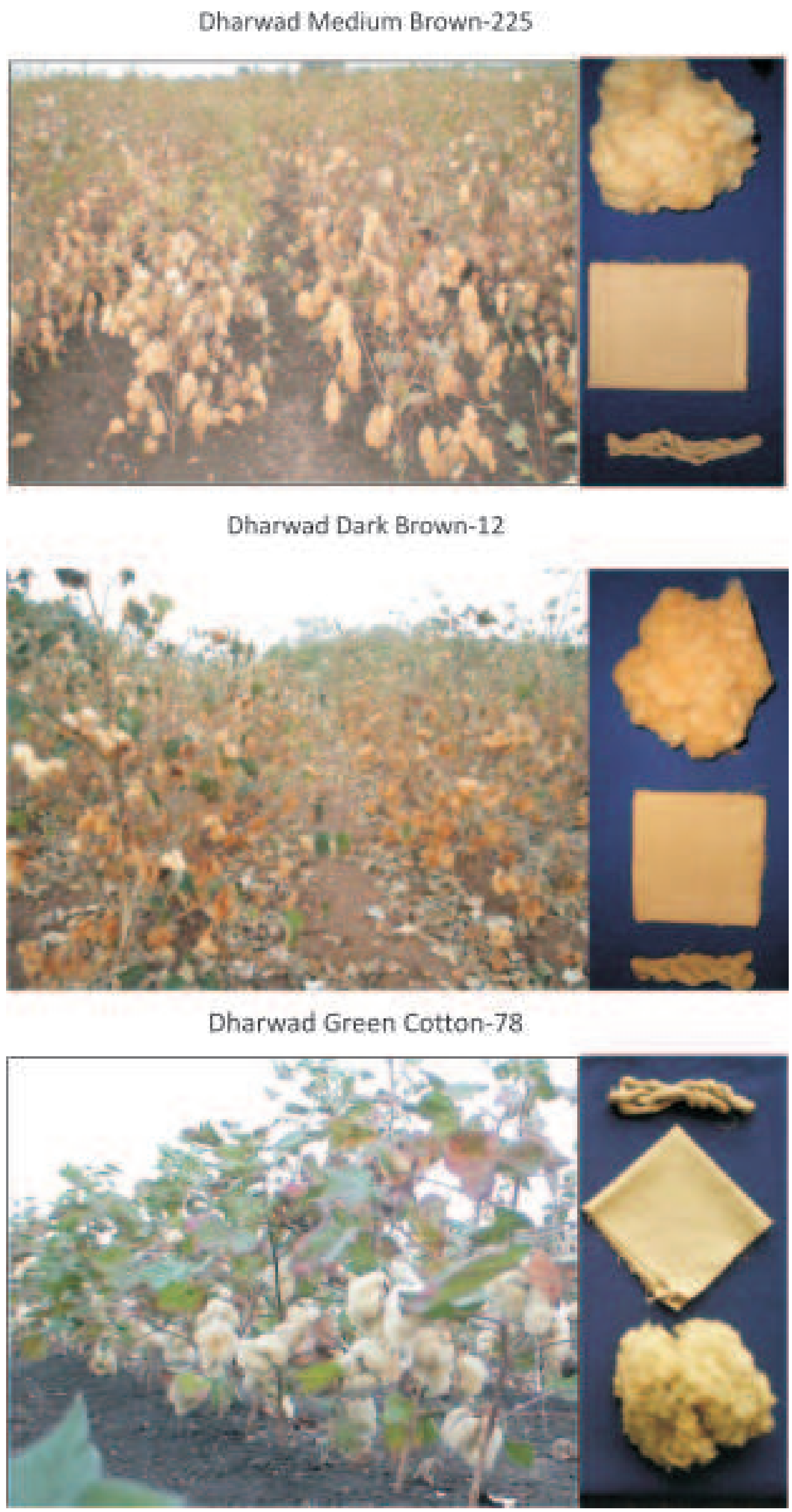

Fig. 2. Improved Naturally Coloured Cotton Genotypes

Table 2. Performance of naturally coloured cotton genotypes of the population I for yield and related characters in replicated trial

Entry	Lint Colour	SCY (kg/ha)	Boll weight (g)	SI	LI	GOT	S L (mm)	UR (%)	Mic value	Maturity ratio	Tenacity (g/tex)	Elongation (%)
DDB 12	Dark brown	2986*	4.3	9	3.5	28	21.0	52	3.4	0.80	18.6	5.7
DMB 225	Medium brown	2934*	4.5	9	4.1	31	21.6	52	3.0	0.71	20.0	5.7
DDB 210	Dark brown	2834	4.1	9	4.9	35	20.6	52	4.4	0.84	16.4	5.9
DDB 202	Dark brown	2524	4.1	9	3.9	30	21.3	53	3.5	0.78	19.8	5.8
DMB 207	Medium brown	2499	4.3	9	4.2	32	21.8	51	4.4	0.83	15.5	5.6
DDB 214	Dark brown	2494	4.3	8	3.8	32	19.0	55	3.8	0.80	17.0	5.7
DDB 208	Dark brown	2226	4.3	8	3.8	32	21.2	54	3.7	0.79	17.4	6.2
Sahana	Medium brown	2138	4.0	9	6.3	38	26.4	49	3.8	0.75	21.2	6.0
DDB 206	Dark brown	2016	4.1	9	3.6	28	21.5	51	3.2	0.75	18.3	5.8
DDB 204	Dark brown	2014	3.8	9	3.3	27	19.7	52	3.2	0.75	18.1	6.0
DMB I 201	Medium brown	1987	4.1	9	4.2	32	21.3	51	3.3	0.75	18.9	6.0
DDB 211	Dark brown	1925	3.7	8	4.2	34	21.4	50	4.0	0.83	17.1	5.7
DMB 205	Medium brown	1779	4.3	9	4.3	32	22.6	49	3.6	0.77	18.1	5.8
DMB I 203	Medium brown	1665	3.8	9	4.5	33	22.4	51	3.2	0.73	20.7	6.0
DDB 212	Dark brown	1652	3.8	9	4.6	34	20.8	52	4.2	0.87	16.6	5.5
DDB 213	Dark brown	1556	3.5	8	4.3	35	20.4	54	4.3	0.84	16.5	5.6
DMB I 202	Medium brown	1398	3.6	9	4.6	34	22.8	52	4.0	0.82	20.4	5.8
DMB I 205	Medium brown	1385	4.4	10	4.7	32	21.9	52	3.2	0.72	20.5	6.0
DMB I 204	Medium brown	1383	3.6	9	4.5	33	20.4	52	3.8	0.79	17.6	6.0
DGC 78	Green	1381	4.1	10	3.7	27	25.8	48	2.8	0.78	22.2	6.2
DDBS 98	Dark Brown	805	3.1	10	3.1	25						
CD (p=0.05)		614					16.1	50	5.1	0.8	13.3	4.1
CV (%)		17.32										

Table 3. Performance of naturally coloured cotton genotypes of the population II for yield and related characters in replicated trial

Entry	Lint colour	SCY (kg/ha)	Boll weight (g)	SI	LI	GOT	S L (mm)	UR (%)	Mic value	Maturity ratio	Tenacity (g/tex)	Elongation (%)
DCR110	Cream	1950	3.9	9	6.2	41	26.6	49	4.1	0.77	19.9	5.9
Sahana	White	1935	3.8	9	6.1	40	26.9	49	4.1	0.76	20.4	5.7
DMB 106	Medium brown	1768	3.6	9	5.2	37	23.1	51	3.9	0.77	18.6	6.0
DMB 107	Medium brown	1748	4.1	9	6.0	40	24.8	50	4.1	0.79	18.4	6.0
DMB 109	Medium brown	1705	4.3	9	4.8	35	22.8	51	4.5	0.84	16.8	6.0
DDB 108	Dark brown	1620	3.2	9	3.7	29	21.0	52	3.1	0.73	18.5	5.8
DMB 104	Medium brown	1604	3.6	9	4.1	31	21.7	51	3.3	0.74	18.7	5.7
DMB 102	Medium brown	1483	4.1	9	4.9	35	25.2	49	3.0	0.72	20.3	5.7
DMB 103	Medium brown	1457	3.5	9	3.6	29	23.4	50	2.9	0.71	20.0	5.7
DMB 101	Medium brown	1450	3.8	9	4.3	32	23.8	49	3.4	0.72	18.4	5.8
DMB 105	Medium brown	1176	3.6	9	3.4	27	26.2	47	2.4	0.71	21.5	5.8
DDBS-98	Dark brown	798	3.2	10	3.1	25	17.9	50	4.9	0.8	13.1	4.1
CV (%)		12.95										
CD (p=0.05)		295										

Table 4. Performance of naturally colored cotton genotypes of the population III for yield and related characters in replicated trial

Entry	Lint colour	SCY (kg/ha)	Boll weight (g)	SI	LI	GOT	S L (mm)	UR (%)	Mic value	Maturity ratio	Tenacity (g/t)	Elongation (%)
Sahana	White	1973	4.2	10	6.70	40	25.9	49	4.0	0.77	20.6	5.9
DDB 5	Dark brown	1851	3.5	8	3.84	32	22.8	50	3.8	0.80	18.4	5.8
DC 12	Cream	1402	4.1	10	3.72	27	24.3	50	3.2	0.77	20.4	6.0
DMB 1	Medium brown	1226	3.7	9	3.29	27	20.5	52	2.7	0.77	19.1	5.6
DMB 2	Medium brown	1186	3.8	9	3.63	29	21.4	52	2.8	0.73	19.6	5.8
DMB 4	Medium brown	1088	3.5	9	3.59	29	23.7	49	3.1	0.74	20.0	5.7
DC 5	Cream	781	3.3	9	4.27	32	24.1	48	3.2	0.74	19.0	5.9
DMB 3	Medium brown	735	2.7	9	3.27	27	22.7	49	3.0	0.76	20.6	5.9
DDBS 98	Dark brown	738	3.2	10	3.1	25	18.1	50	5.0	0.8	13.3	4.1
CV (%)		24.24										
CD (p=0.05)		442										

Sahana but were better than coloured parent. The highest yielding genotypes among colour selections in this population were dark brown, DDB 5 which had 22.8mm span length and one more medium brown type DMB 3 had the highest strength of 20.6g/tex. The cream coloured genotypes DC 12 and DC 5 had fibre length of 24mm (Table 4).

Across all the populations using different approaches, intraspecific, interspecific and three way cross followed by selections, in interspecific approach using, *G.barbadense*, it was observed that the segregation had very good fibre quality in the early generation but as selections were made for darker shades in the advanced generations the fibre quality and the yield were reduced and those selections with good quality had light shades. In studies of white *G. hirsutum* cotton improvement by utilizing the *G. barbadense* for superior fibre quality similar observations of reduction in fibre quality in the selections in advanced generations have been observed. However in the intraspecific population using *G. hirsutum,* there was significant increase in the yield and thus through this approach it was possible to improve seed cotton yield and boll weight along with moderate improvement of fibre quality parameters. The colour in fibre lint is governed by major gene, multiple alleles and modifiers (Khan *et al.,* 2009) and the expression of colour depends on the modifiers which may be present in the same species of *G.hirsutum*. It was observed in our study also that *G.hirsutum* colour genotypes can be improved by intraspecific hybridization followed by selection approach that is by using the white superior *G.hirsutum* genotypes. Once genotypes with dark brown colour with high yield and medium/ light brown genotypes with good fibre quality parameters are available in the *G.hirsutum* species, these can be intermated to combine colour, yield and fibre quality into single genotype.

The study indicated the progress in the improvement of naturally coloured cottons to make them commercially viable. Among all the genotypes put together, DDB 12 (dark brown), DMB 225(medium brown) and DCR 110 (cream) were best in that shade of brown. The green genotype DCG 78 has good fibre traits. The genotypes, DDB 12, DMB 225 and DCG 78 were grown in larger plots over three years and tested for their productivity and suitability for yarn and fabric manufacture. Dark and medium brown genotypes were found to be *on par* with white linted variety, Sahana with respect to yield and suitable for various fabric productions (Table 5 and 6, Fig.2). The three colour cotton have been registered under Plant Germplasm Registration at NBPGR with National Id /Registration No IC0594176 INGR13031 for Dharwad medium

Table 5. Performance of improved colour cotton genotypes in replicated trial over years

Entry	Lint colour	Speed cotton yield (kg/ha)			**Mean**	Boll weight (g)	GOT	LI
		2007-2008	2008-2009	2009-2010				
DMB 225	Medium brown	2734	2616	2568	**2639**	4.5	31	4.1
DOB 12	Dark brown	2834	2436	2635	**2635**	4.1	30	3.9
DGO 78	Green	1381	1518	1412	**1437**	4.1	20	3.7
Saliana	White	2438	2645	2585	**2555**	4.1	37	5.4
CV (%)		17.32	19.2	20.3				
CD (p=0.05)		614	582	550				

Table 6. Fibre quality parameters of improved coloured genotypes

Entry	Lint Colour	SL mm	Strength (g/tex)	SL ratio	Elogation (%)	UR (%)	Mic value	Maturity ratio
DMB 225	Medium brown	22.8	20.6	0.90	5.8	52	3.5	0.80
DDB 12	Dark brown	22.2	20.0	0.90	5.7	52	3.4	0.80
DGC 78	Green	24.3	20.4	0.84	6.0	50	3.2	0.77
Sahana	White	25.8	20.7	0.80	5.8	48	4.2	0.81

brown 225, IC0594174INGR13029 for Dharwad dark brown 12 and IC0594175 INGR13030 for Dharwad green cotton 78.

The green genotype DCG 78 though has comparatively less yield potential, its necessary to promote this genotype as it has superior fibre quality traits. The simultaneous development of medium and dark brown and green shades along with white cotton will help in the creation of variability required for the textile industry. These three genotypes were presented in the Zonal Research and Extension Committee Meeting of the university during 2009-2010 and have been approved for commercial cultivation of these genotypes under contract farming under the technical supervision of the university.

Efforts need to be done to further improve the fibre properties which are being done using the stable colour cotton lines developed in the present study for crossing with superior white cultivars for introgression and selection. Also there is a necessity to diversify the lint colour which is attempted through biotechnological approaches. The Flavonoid 3'-5' hydroxylase gene from petunia and snapdragon which is the enzyme responsible for turning the pathway of pigmentation towards blue shades has been cloned. The transformation of these genes in the improved genotypes is initiated. The expression of these genes in lint may help in creation of a shade not naturally available.

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Induction of polyploidy in wild cotton species (*Gossypium armourianum* and *G. aridum*) by colchicine treatment

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ABSTRACT : In cotton, wild species generally have inbuilt resistance of desirable genes for biotic and abiotic stresses and possessing useful fibre qualities such as length and strength. Among the antimitotic agent, colchicine is widely used to induce doubling of the chromosomes in plant species. Attempt has been made to increase the ploidy level in two wild cotton species *viz.*, *Gossypium armourianum* L and *G. aridum* L to make crosses with tetraploid *G. hirsutum* L. A dose dependent increase in ploidy level was observed. Significant difference was noticed in induction of polyploidy and plant growth rate that depend on dose of colchicine, duration of the treatments and type of plant material used. Increase in concentration of colchicine or duration of the treatment showed negative effects on seed viability in both the species under study. The colchicine treatment is more effective when the length of hypocotyls is between 4-8 mm. The root meristem of *G. armourianum* L treated with 0.7 per cent colchicine exhibited more tetraploid cells in 20 h of treatment. Increase in concentration of colchicine with increase in duration leads to chromosomal abnormalities in both the wild species. Among the three methods employed in inducing polyploidy in wild diploid cotton, application of colchicine on seed was more efficient and reliable than application on seedling and stem.

Key words : Colchicine, cotton, polyploidy, tetraploid, wild species

Ploidy manipulation has been considered as a valuable tool in genetic improvement of several plant species including commercial crop such as cotton. The wealth of desirable genes present in wild species deserves special attention and needs systematic exploration and utilization. Such attempts will lead to development of varieties having in built inherent resistance to major pests and diseases through modified structural characters of the plants, such as flared or deciduous bracts, tight and straight calyx, coarse and pubescent stem, thick and stiff boll rind etc, which would result in greater attraction of vegetative parts than fruiting parts for oviposition (Mehetre, 1993). Crop plants are represented by a variety of ploidy levels including 2x, 3x, 4x, 6x and aneuploids. Cotton plants able to cross pollinate with a number of wild related species and exchange chromosome segments through homoeologous recombination. The polyploidisation between an A genome diploid and a D genome diploid created the AD allotetraploid group of cotton in more than 2 million years ago (Senchina *et al.*, 2003). Induction of polyploidy in interspecific or intergeneric hybrids results in duplication of the two genomes present in a hybrid and formation of an allopolyploid. This allows for continued introgression of desired genes in to the cultivated gene pools (Olsen *et al.,* 2006).

In wide hybridization of cotton, incompatibility plays as a bottleneck in introgression of genes from wild species to cultivars. The major reason may be the ploidy level differences prevailing in cotton species. *Gossypium aridum* (D_4) and *G. armourianum* (D_{2-1}) are wild American cotton species belonging to D genome, the source for traits such as drought, sucking pest resistance and fibre strength. The characteristic emission of a strong odour of lemon oil from leaves of *G. armourianum* known to contribute resistance to sucking pests. Imparting resistance to pests from wild species to cultivated types has not been rewarded to the desirable extent mainly because of different causes like genetic and chromosomal factors (Mehetre, 1993 and Thombre and Mehetre, 1982). Earlier studies indicated the scope for utilization of *G. armourianum* x *G. hirsutum* and *G. aridum* x *G. hirsutum* crosses for the improvement in respect of fibre strength and sucking pest resistance. Colchicine is a widely used chemical, known for its mutagenic action that is capable of changing the ploidy level in plant species. This can effectively arrest the cell division at an early anaphase and the chromosomes have been duplicated resulted in polyploid cells (Alishah and Bagherieh, 2008).

In the light of the above facts, attempts have been made to explore the possibilities of doubling the chromosome of the wild diploid *G. armourianum* and *G. aridum* species thereby making crosses with tetraploid *G. hirsutum.* Analysis was done on phenotypic and cytological effects of various doses and duration of colchicine treated seeds, seedlings and stem cuttings.

MATERIALS AND METHODS

Seed treatment : Cotton seeds were sown in petriplates lined with wet paper towels incubated at 25^0C for germination. After 24 h, seeds were washed thoroughly and immersed in aqueous solution of colchicine with the concentration of 0.5, 0.7, 0.9, 1.0, and 1.5 per cent for 4, 8, 12, 16, 20 and 24 h. After completion of their incubation, the seeds were rinsed thoroughly and washed with distilled water and kept in petridishes and incubated in 25^0C. After getting 4-8 cm emergence of hypocotyl region, the root tips were excised and the ploidy level was determined by squash method.

Seedling treatment : Seeds were grown in earthen pots under normal condition (14 h light period at 29^0C with 60 % relative humidity). Various concentrations of aqueous colchicine solution (0.5, 0.7, 0.9, 1 and 1.5%) were applied for 24 h at 4 h interval on the apical meristematic region of the young plants at 4 leaved stage. The cotton plug method was followed. Cotton plantlets were kept at room temperature to avoid water evaporation. Plants were screened for the survival percentage. The morphological abnormalities were recorded. The root tip squash preparation was done.

Stem cutting treatments : Fifteen cuttings of 10 cm of each wild species were collected for the study. The cuttings were immersed in aqueous solution of colchicine with the concentration of 0.5, 0.7, 0.9, 1.0 and 1.5 per cent for 4, 8, 12, 16, 20 and 24 h. One set of cuttings of each wild species were planted with out any treatment in earthen pots as control. The cuttings were washed thoroughly, planted in earthen pots, and kept in a controlled conditions.

Chromosome counting : The root tips of controls and the treated seeds were prefixed in 2 mM of 8 hydroxyquinoline for ethyl alcohol-glacial acetic acid (3:1) for 24 h at 4^0C and finally stored in 70 per cent ethanol at 4^0C. Hydrolysis was done in 1 N HCl for 10-15 min at 60^0C (45-60 min at room temperature) and stained with 2 per cent aceto orecin. Twenty five cells from each sample were screened and the number of cells was determined by squash method for microscopic visualization. Suitable microphotographs were taken for determining the chromosome numbers.

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) for this experiment is presented in Table 1. The results indicated that the effects of colchicine dose (D) (p= 0.01), genotype (species) (G), D x treatment duration (T as well as D x T x G were all significant (p= 0.05). However, the effects of replication, D x G and D x T were not significant. The combined effects of colchicine with different duration G x D, D x T (p = 0.01) and the effects of G x D x T (p = 0.05) on tetraploid cells were not statistically significant. A dose dependent increase in germination was noticed in wild cotton species *viz., G. armourianum* and *G. aridum* in seeds, seedlings and stem cutting treatments. The increasing concentration of colchicine more than 1 per cent leads to decrease the rate of germination. Similarly lower concentration does not have much effect. Similar trend was observed in case of the period of application (duration) of colchicine. In seed treatment, the response of the seed germination was better in 4-8 mm long hypocotyl region. Seeds treated with 0.9 per cent colchicine was found highly effective than other higher concentrations of colchicine in both the wild cotton species. However, the maximum seed germination of 83.5 per cent was obtained in *G. aridum* while it was 71.4 per cent in *G. armourianum* (Fig.1). The lower concentrations such as 0.5, 0.7 have not shown any ploidy enhancement

In seedling treatments (apical meristem), higher concentrations *viz.,* 1.0, and 1.5 per cent injured the apical meristem of both the species. Lower concentration (0.5 %, 0.7 %) doesn't show any change in their phenotype.

Table 1. ANOVA results for colchicine effects on polyploidy in seeds and stem cuttings

Source of variation	Degree of freedom (df)	Means of squares Seed treatment		Degree of freedom (df)	Means of squares Stem cutting treatment	
		STC	NVS		SCN	SCT
Replication (R)	3	7.08 ns	12.45	3	0.77**	42.08 ns
Genotype (G)	1	13.01 ns	33.80	1	0.48*	72.71
Dose (D)	3	132.05	48.92	3	1.17**	79.23
Time (T)	3	51.14	39.38	1	0.53*	91.51
G x D	3	70.21	22.45	3	0.23*	35.71 ns
G x T	3	31.51 ns	19.58	1	0.41 ns	59.3 0 ns
D x T	9	42.24	36.19	3	0.36*	31.32
G x D x T	9	29.16	29.45	3	0.58**	19.11
Error	93	14.08	12.15	45	0.103	11.31

STC – Number of seeds with tetraploid cells; NVS- Number of viable seedlings after treatments; SCN- Stem cuttings with normal growth; SCT- - Stem cuttings with tetraploid cells

However, success was obtained only in 0.9 per cent + 20 h in *G. aridum* and 1.0 per cent with 16 h in *G. armourianum*, while the higher concentration of 1.2 per cent colchicine + 12 h expressed phenotypic changes at the beginning but later the plant type appeared normally. The combined effects of 0.9 per cent colchicine (0.9 + 16 h, 0.9 + 20 h, 0.9 + 24 h) and 1 per cent colchicine concentration (1.0 + 16 h, 1.0 + 18 h, 1.0 + 20 h) exhibited polyploidisation to some extent. Maximum polyploidisation occurred in 0.9 per cent + 20 h treatment in *G. aridum,* while in *G. armourianum* maximum was observed in 1.0 per cent + 16 h treatment (Fig. 2 and 3). The higher colchicine concentration + higher duration expressed chromosomal abnormalities and mixoploidy. Among the two wild species studied, *G. armourianum* responded better in 1 per cent colchicine concentration with 16 h duration than *G. aridum* thereby revealed that *G. aridum* is more sensitive to colchicine than *G. armourianum.* Data revealed that growth rate of the apical meristem declined when the concentration of colchicine increased. The survival percentage of seedlings was 33 per cent in 0.9 + 20 h in *G. aridum* while in *G. armourianum* the survival percentage is 24 per cent (Fig.4). Lower concentrations does not have effect and few plants survived in the concentration of 0.5 per cent with 24 h duration and expressed

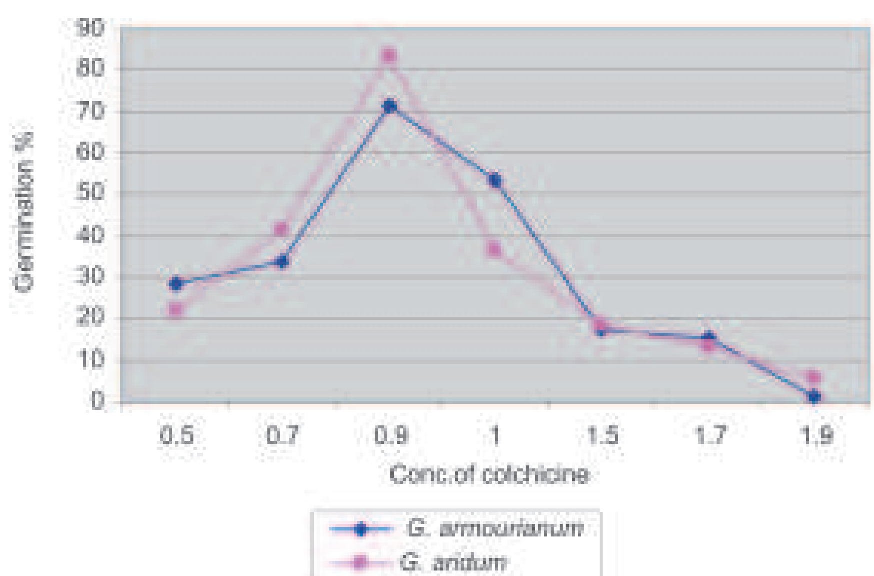


Fig.1. Effect of colchicine on seed germination in *G.armourianum* and *G.aridum*

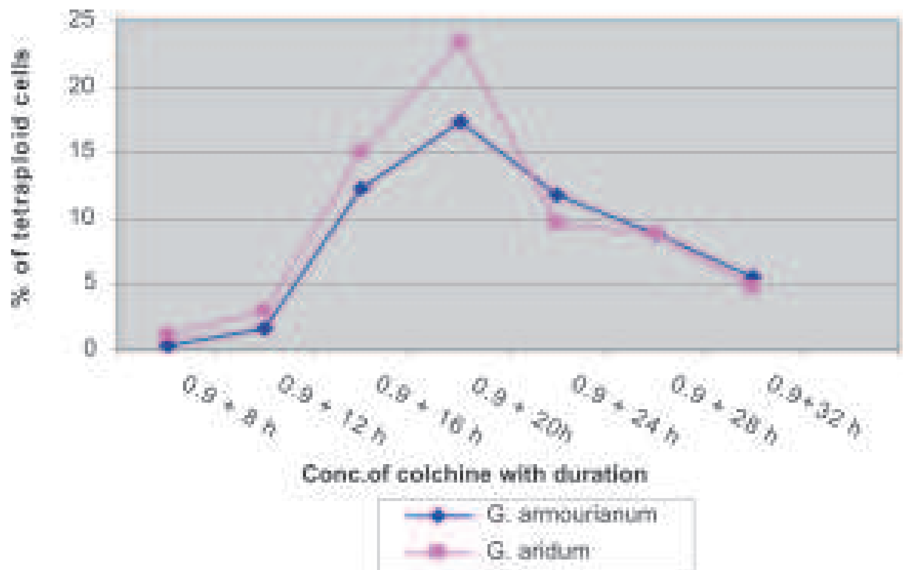


Fig. 2. Effect of colchicine in an effective concentration of 0.9% in seedling treatment

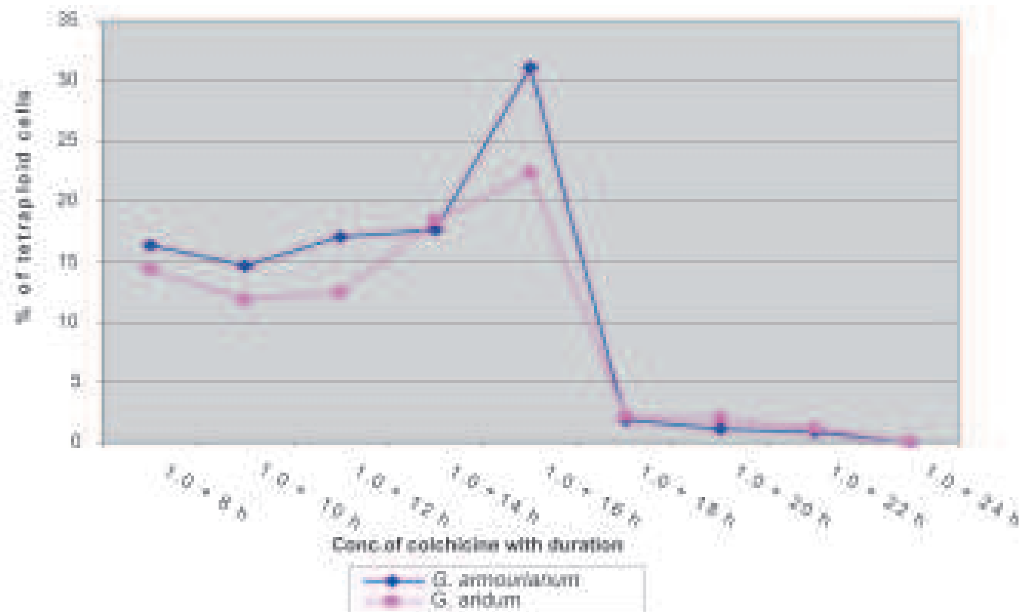


Fig.3. Effect of colchicine in an effective concentration of 1.0% with different duration in seedling treatment

morphological variation in newly formed leaves, however, in due course of time further growth has completely arrested.

In stem cutting treatments, cuttings treated with 1 per cent colchicine in 24 h duration and 1.5 per cent colchicine in 16 h duration showed moderate growth on the 16th and 22nd day of planting, respectively. In most of the cases, there was slow growth at the beginning and in later stages, it was completely stopped. Among the 16 plants survived, 2 plants in *G. armourianum* and a single plant in *G. aridum* exhibited tetraploids as it was confirmed through stomatal studies and enhanced abnormal plant growth. It was observed that among the materials studied (seeds, seedlings and stem cuttings) for the polyploid induction, seed treatment (root tips) was found better in inducing polyploid plants than seedling treatment (apical meristem) and stem cutting treatment which was confirmed through root mitosis and stomatal studies of the epidermal peelings.

In all the cases, the polyploid plants showed enhanced leaves and overall plant structure. The results indicated that increasing the dose of colchicine and duration declined the growth rate suggesting that apical meristem zone is very sensitive to mutagenic agents like colchicine. The data on plant growth, survival reveals that the growth rate of seedling decreased with increasing concentrations of colchicine suggesting that active cell division of the apical meristem is highly affected by the increasing dosage of colchicine. Similar results were earlier reported by Alishah and Bagherieh (2008) in cotton species *viz., G. arboreum* L and *G. herbaceum* L. The seedling survival was 2-32 per cent in *G. armourianum* while it was 2-28 per cent in *G. aridum.*

The study implies that the rate of polyploidisation in a cell depends on both the dose of colchicine and the duration of treatment. Even lower doses along with less duration like 6 and 8 h does not have any positive effect in seedling treatment. However, in *G. armourianum,* 11 days old seedling treated with 0.9 per cent colchicine for 12 h duration exhibited thickening of the first formed dark coloured leaves. The leaf colour have been changed from pale green to dark green. De Jesus Gonzalex and Weathers (2005) suggested that increasing doses of colchicine with moderate duration (period) generally induce polyploidy in *Artemisia annua* which enhance the alkaloid content of Artimisinin.

The study revealed that the optimum treatment leads to a reasonable induction of tetraploid cells. The colchicine treatments with medium doses of 0.8 for 10 h or 12 h are the optimum dose for the induction of polyploid in wild cotton species. The doses above 0.8 and duration above 12 h are highly affected the growth rate thereby indicating that increasing the dose of colchicine would lead to a decline growth rate in plants. It suggested that the apical meristem of the seedling are highly sensitive than the seeds to the mutagenic agent colchicine. Data suggested that for polyploidy induction, 16 h incubation of the *G. armourianum and G.aridum* seeds with 0.8 and 0.9 per cent colchicine respectively gave the best results. The optimum dose of colchicine and the incubation time depends on the species and the environmental conditions.

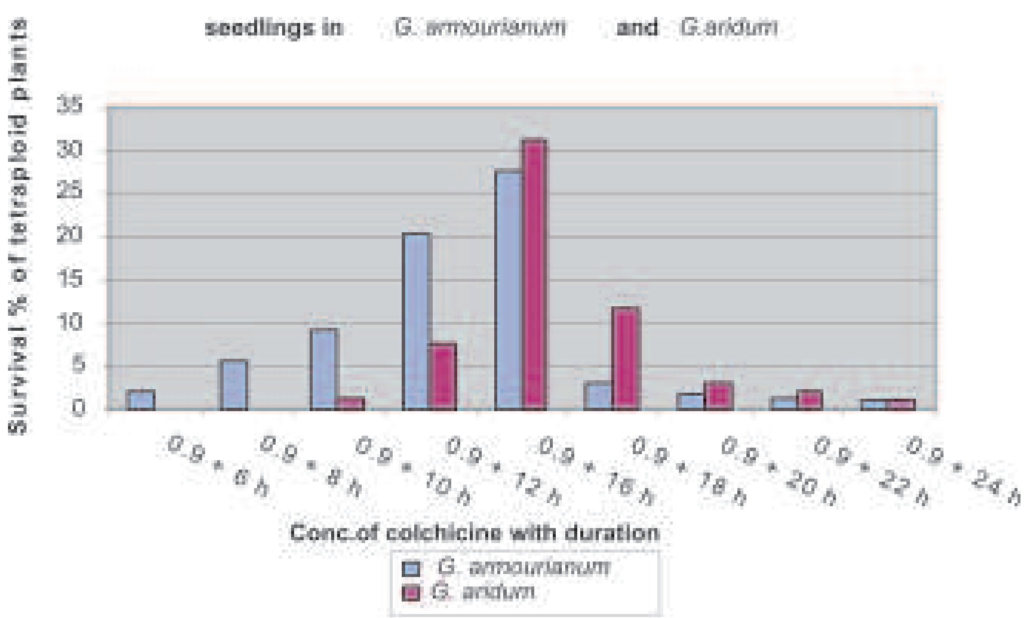
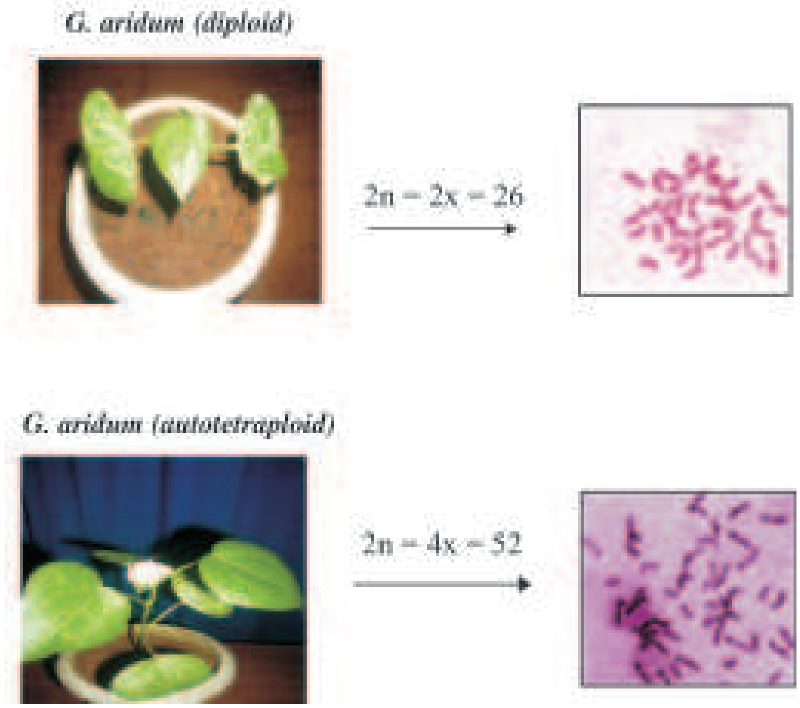


Fig.4. Effect of colchicine on survival percentage of tetraploid

Plate 1. Induction of polyploidy in cotton



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Combining ability studies for yield and quality traits in upland cotton (*Gossypium hirsutum L.*)

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ABSTRACT: Present study was undertaken to determine the inherent potential of parental stocks to produce high yielding hybrids. For this purpose, 52 upland cotton hybrids were developed crossing 13 lines with four testers in a line x tester mating design during *kharif,* 2009.These hybrids along with their 17 parents (13 males and 4 females) were evaluated during *kharif*, 2010 at Cotton Research Station, Sirsa.The combining ability analysis revealed that both additive and non additive variances were present in the expression of all the characters with former playing major role for majority of the characters. Highest *sca* effects for seed cotton yield were recorded for hybrids H1226 x HS1 and H1098 x DELTA SL.However, they were poor in *per se*. The study of *gca* effects revealed that male parent DELCOT 517 was the best general combiner for seed cotton yield, number of bolls, plant height, number of monopods, ginning outturn and lint index. Male parent REX 66 and AUBURN NE 165 were best general combiners for boll weight, days to first flower, seed index, ginning outturn and lint index. For quality character, ginning outturn male parents DELCOT 517 and REX 66 showed highest *gca* effects. The respective best combiners for various traits could be used for improvement in that trait. Considering the economic importance of various characters DELCOT 517, AUBURN NE 165, F 1378, REX 66 and RS 875 among the males and H1226 among the females may be used in future breeding programmes.

Key words : Combining ability, *Gossypium hirsutum*, quality traits, yield

Combining ability plays an important role in the identification of parents and production of superior lines or hybrids. The genotypes found good in performance might not necessarily produce desirable progenies when used in hybrids development. It is therefore, necessary to identify promising lines based on crosses using appropriate mating design. The combining ability study is very important for the selection of parents and crosses which give highest improvement for the character under consideration and also provide information on the nature of genetic variation present in material under study.

Combining ability is most widely used biometrical genetical approach in plant breeding. Success of development of high yielding and widely adapted hybrid depends on the specific combining ability of parental crosses. Thus, present study was conducted to identify desirable parents and promising hybrids on the basis of combining ability.

MATERIALS AND METHODS

The experiment was sown on May 06,2010 at CCS Haryana Agricultural University, Cotton Research Station, Sirsa during *kharif*, 2010. Fifty two upland cotton hybrids were developed by crossing 13 lines with 4 testers in a line x tester mating design during *kharif,* 2009.These hybrids along with their 17 parents (13 males and 4 females) and one standard check (HHH223) were evaluated during *kharif*, 2010 in a randomized block design with three replications. Each entry was accommodated in one row of 6 m length with a spacing of 100 x 60 cm.All the recommended cultural practices were followed to raise a good crop. Observations were recorded for 9 characters, namely, days to first flower, plant height, monopods, bolls, seed cotton yield/plant (g), boll weight (g), ginning outturn (%), seed index (g) and lint index (g).Data were recorded on 5 randomly selected plants from each entry from all replications and mean of 5 plants was taken for further analysis. The line x tester analysis was done as per the method suggested by Kempthrone (1957).

RESULTS AND DISSCUSSION

Selection of parents with great care is

necessary for a successful hybridization programme. This selection should be based on the basis of their combining ability. The parents that combine well with each other are most desirable ones. However, genetic diversity also play a pivotal role in the evolution of promising hybrids. Data presented in Table 1 revealed that mean sum of squares due to specific combining ability variance were significant for almost all the characters except line x tester interaction for plant height and lines for number of monopods. This indicated that both additive and non additive variances were present with the predominance of additive variance for most of the characters. These findings were akin to the findings of Giri *et al.,* (2006), Bhaskaran and Ravikesavam (2008) and Patel *et al*., (2009)

Best combining male and female parents for various traits are presented in Table 2. The perusal of data revealed that among four female parents, H1226 was best general combiner for seed cotton yield/plant and number of monopods. Female parent H1117 was second best general combiner, which combined well for plant height, number of monopods and ginning outturn followed by H1098, which was best combiner for days to first flower, seed index and lint index.

Among male parents, DELCOT 517 was best general combiner for seed cotton yield/ plant, lint index, ginning outturn, number of bolls, number of monopods and plant height. The second best general combiner for seed cotton yield was F1378, which was also found to be second best combiner for number of bolls. However, best combiner for number of boll was F1378. Male parent REX 66 and AUBURN NE165 were found to be best combiners for boll weight.

Male parent DELCOT 517 and HS 1 were best combiners for number of monopods. For days to first flower, plant height and seed index, male parents RS 875, AUBURN NE 165, REX 66 and P 367 respectively, were identified as best combiners.

Best specific cross combinations for different characters have been presented in Table 2. The perusal of data revealed that cross combinations, H1226 x HS1 and H1098 x DELTA SL were the best specific combinations for seed cotton yield/plant. Both these crosses involved poor x poor combining parents and were thus the result of dominant type of gene action, which can possibly be used for producing productive hybrids. Both these crosses were also found to be best specific cross combination for number of bolls

The cross combination HS182 x RS875 and H1117 x AUBURN NE 165 recorded highest *sca* effect for boll weight. The *sca* effect of these crosses is mainly additive which is fixable. The cross H1117 x G17 also exhibited top *sca* for seed index where as it was good x good combiner combination. For monopods best specific cross combination HS182 x PIL58 involved both the parents as good combiners, indicating thereby that these characters were governed by additive and additive x additive type of gene action which is fixable.

High negative *sca* effects for days to first flower were depicted by hybrid H1117 x HS-1 (poor x poor) and H1098 x REX66 (good x poor). These crosses were combination of one good and one poor combining parent, indicating that both additive and dominance variance were important for these characters. For lint index, highest sca effects were recorded for hybrids H1098 x P367(average x poor) and HS182 x DELCOT 517 (poor x good), respectively possibly due to additive

Table 1. Combining ability analysis for nine characters in upland cotton

Source of variation	D.F	Characters								
		Days to first flower	Plant height (cm)	Monopods/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield/ plant(g)	Ginning outturn (%)	Seed index	Lint index
Replications	2	2.399	128.220	0.040	64.340	0.023	86.269	2.061	0.194	0.008
Lines	12	43.268*	269.687*	1.607	453.200*	0.551*	1980.186*	4.723*	2.152*	0.696*
Testers	3	76.454*	2375.735*	20.067*	1480.890*	2.457*	6029.316*	4.578*	2.475*	1.236*
Lines x testers	36	14.844*	107.387	1.731*	443.370*	0.121*	1760.132*	1.760*	0.521*	0.097*
Error	102	4.716	79.686*	0.310	29.957	0.041	257.378	1.116	0.086	0.058

*Significant at 5 per cent level of significance

Table 2. Best general combining parents and best specific combining hybrids on the basis of their combining ability

Sr.No.	Characters	Best general combiner				
		Male		Female	Best specific cross	
		1st parent	2nd parent		1st	2nd
1	Days to first flower	RS875 (-2.835*)	AUBURN NE 165 (-1.985*)	H1098 (-2.079*)	H1117 x HS1 (-4.543*)	H1098 x REX 66 (-3.629*)
2	Plant height (cm)	DELCOT5 17 (6.967*)	P 367 -4.133	H1117 (9.755*)	H1098x PIL58 (9.722*)	H1117x RS 875 (9.395*)
3	Monopods/ plant	DELCOT5 17 (0.756*)	HS1 (0.431*)	H1117 (0.810*)	HS182x PIL58 (1.428*)	HS 182xMC82 (1.417*)
4	Bolls/ plant	F1378 (12.673*)	DELCOT 517 (6.2908*)	H1226 (8.907*)	H1098 xDELTA SL (34.379*)	H1226 x HS1 (20.393*)
5	Boll weight (g)	AUBURN NE 165 (0.262*)	REX 66 (0.225*)	HS182 (0.242*)	HS182x RS875 (0.484*)	H1117 x AUBURN NE165 (0.376*)
6	Seed cotton yield /plant(g)	F1378 (23.647*)	DELCOT 517 (20.972*)	H1226 (9.991*)	H1226 x HS1 (55.876*)	H1098 x DELTA SL (51.829*)
7	Ginning outturn (%)	DELCOT5 17 (0.914*)	REX 66 (0.814*)	H1117 (0.403*)	H1098 x G17 (1.820*)	HS182x F1378 (1.359*)
8	Seed index	AUBURN NE165 (0.529*)	P 367 (0.379*)	H1098 (0.254*)	H1117x G17 (0.886*)	H1098 x P367 (0.713*)
9	Lint index	REX 66 (0.374*)	DELCOT 517 (0.341*)	H1098 (0.131*)	H1098x P367 (0.277*)	HS182x DELCOT 517 (0.251*)

x dominance gene action which is not fixable.

For increased plant height and ginning outturn hybrids H1098 x PIL58 and H1098 x G17, respectively exhibited highest *sca* effects. The cross combination H1117 x NCAC15 showed highest *sca* for dwarfness. All these were combination of good x poor combining parents, indicating that additive type of gene action to be more important which is fixable.

The *per se* performance of the hybrids was not necessarily associated with the *gca* effects of the parents. These findings are in agreement to the findings of Kalpande *et al.*, (2008), Panhwar *et al.,* (2008), Deosarkar *et al.*, (2009) and Laxman (2010). The cross combinations showing highest *sca* effects for seed cotton yield *viz.,* H1226 x HS1 and H1098 x DELTA SL were generally not having high *per se* for yield and its component traits. The cross combinations having high *per se* for yield and related characters were not generally good in their *sca* effects.

Among female parents H1226 was best general combiner, as it recorded highest *gca* effect for seed cotton yield and number of bolls. In general, none of the male and female parent was found to possess high *gca* effects for all the characters under study. The respective best combiners for various traits could be used for improvement in that trait. However, considering the economic importance of various characters DELCOT 517, AUBURN NE165, F1378, REX 66 and RS 875 among the males and H1226 among the females may be used in future breeding programmes.

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Economics of GMS based *desi* cotton (*Gossypium arboreum L.*) hybrid seed production in north zone

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ABSTRACT : The increasing demand of *desi* cotton hybrid seed and its cheaper seed production cost due to GMS property can play an important role in boosting the economy of farmers in north zone. In this zone sowing is done in about 1.22 lakh ha area under *desi* cotton and approximately 4575 q hybrid and varieties seed is required annually. To promote the hybrid seed production in this zone, economics of hybrid seed production of *intra arboreum* GMS based hybrid CICR 2 (CISAA 2), was worked out and /ac net profit during 2006, 2007 and 2008 was observed Rs 78703, 69362 and 69310, respectively. It is concluded that cotton hybrid seed production using GMS line as female parent is a profitable enterprise in north zone.

Key words: Cotton, economics, *Gossypium arboreum,* hybrid seed production

In North zone presently about 80 per cent of cotton area is under cultivation of *Bt* hybrids which helped in increasing the cotton production in this zone from 31 lakh bales in 2003-2004 to 39 lakh bales in 2008-2009 and the productivity has also been increased from 372 to 545.7 kg/ha from almost the same area (Anonymous, 2009). In this zone approximately 10 per cent area is under *desi* (*G. arboreum*) cotton hybrids as well as verieties. In *desi* cotton, several GMS based hybrids with very high yield potential such as CICR 2, AAH 1, Moti are available for cultivation. The yield potential upto 40 q/ha has been picked from GMS based hybrid CICR 2 by several farmers. In addition to its shattering resistance and wilt tolerance properties, the area under *desi* cotton hybrids has not increased mainly because of non availability of good quality hybrid seed. As per estimate about 4575 q of *G. arboreum* hybrid seed is required annually for sowing in presently cultivated 1.22 lakh ha area. Keeping this in view the high yielding ability coupled with remunerative prices, there is a potential in increasing of *desi* cotton area under north zone especially after the availability of GMS based hybrids. The cotton hybrid seed production was earlier considered non profitable in north zone with conventional hybrids due to higher labour costs and this problem has been solved after the development of a number of GMS based *desi* cotton hybrids. The increasing demand of *desi* cotton hybrid seed and its cheaper seed production cost due to GMS property can play an important role in boosting the economy of farmers in this zone.

MATERIALS AND METHODS

The experiment on economics of hybrid seed production of *intra arboreum* GMS based hybrid CICR 2 (CISAA 2), was conducted for three consecutive years from 2006-2007, 2007-2008 and 2008-2009. Each year the experiment was conducted in 0.5 ac with female to male parent ratio of 4:1. The female parent was sown at 100 x 60 cm spacing whereas the male parent was sown at 67.5 x 60 cm spacing in the adjoining area. Recommended agronomic practices and plant protection measures were adopted for raising the healthy crop. The fertile plants were rouged out (2-3 inspections) at the time of flower initiation from 1:1 ratio of sterile and fertile plants in GMS based female parent. The hybridization was started with the onset of flowering around second week of August and continued daily till first week of October. Because of GMS property in its female parent, the labourers were employed only for pollination between 8.30 AM to 12.30 PM during crossing period and for pollination work in 0.5 ac area, 12 labourers were engaged for 4 h (half day) every day for 55 days, hence the total mandays considered were 660/2 = 330 only. After pollination a thread was tied on pedicel of the crossed flower as a mark of indentification which can be harvested separately at maturity. The seed cotton obtained from these crossed bolls was sun dried and ginned to obtain the hybrid seeds.

The lint obtained from the hybrid seed and from the male parent was sold on prevailing market price and added in the income. The components of direct expenditure involved in production of hybrid seed taken into account were (i) direct cost such as charges for field preparation by tractor, irrigation charges, labour charges for sowing, breeder seed cost of both female and male parents, labourer charges for rouging and thinning, fertilizer cost, manual and tractor weeding charges, labourer charges for ginning and cleaning, pest control expenditure, labourer charges for pollination, cost of threads, labourer charges for picking as well as (ii) indirect expenditure such as management cost @ 10 per cent of direct expenditure, rent charges of land for six months and interest on direct expenditure at the rate of 10 per cent. The management cost, interest on the expenditure and rental value of land was determined based on prevailing rates for 3 years. The payment of wages to daily paid labourer was estimated on governments fixed

Table 1. Economics of GMS based hybrid seed production of *intra arboreum* hybrid CISAA 2 during 2008-2009

A.	**Expenditure details**	**Expenditure cost (Rs/ac)**
1.	**Expenditure on field operations, fertilizers and pesticides**	
	- Field preparation charges (one deep ploughing @ Rs 200 + two cultivator ploughing @Rs 100 each x 2= 200+ one *suhaga* @ Rs 100)	500
	- Irrigation charges:(5 irrigation @ Rs 60 each)	300
	- Sowing charges: @ Rs 135/labourer x 4	540
	- Breeder seed cost of both female and male parent (4:1 ratio at 1 x 60 cm and 67.5 x 60 cm spacing): 1.250 kg @ Rs 500/kg	625
	- Fertilizer cost (NPK 70:24:24+ $ZnSO_4$ 10 kg/ac) Area 152 kg @ Rs 2.50/kg =Rs 380 + SSP 150 @ Rs 2/kg = Rs 300 + Murate of potash = Rs 45 + ZnSO4 = Rs60	785
	- Weeding charges 4 labourer for 2 hand weeding @ Rs 135 and two tractor operated weeding @ Rs 100	740
	- Rouging and thinning : 4 labourer @ Rs 135	540
	- Pest control (1 Endosulphan = Rs 200 +2 synthetic = Rs 200 + 1 Tracer = Rs 1000 + 1 Bavistin = Rs 50)	1450
	Total	**5480**
2.	**Pollination expenditures**	
	- Pollination : 12 labourer @ Rs 67.5/half day for 55 days (330 mandays)	44550
	- Cost of threads	800
	Total	**45350**
3.	**Expenditure on picking and ginning**	
	- Picking cost: 8 labourer @ Rs 135	1080
	- Ginning and cleaning : 4 labourer @ Rs 135	540
	Total	**1620**
4.	**Indirect expenditures**	
	- Interest expenditure on direct expenditure (10%)	5245
	- Management cost (10% of direct)	5245
	- Rent charges of land for six months	7500
	Total	**17990**
	Total cost of production (1+2+3+4) (Rs 5430+45350+1620+17990)	**70440**
B.	**Production and income:**	
	- Total seed cotton yield of hybrid cotton : 432 kg	
	- Total hybrid seed production : 290 kg, cleaned and delinted seed 266 kg	
	- Cost of cleaned seed : 266 kg @ Rs 500= 133000	
	- Cost of lint from hybrid seed cotton : 135 kg @ Rs 40 = Rs 5400	138400
	- Cost of seed cotton yield from male plants : 50 kg @ Rs 27/kg	1350
	Total income	**139750**
	Total cost of production	**70440**
	Net profit : A-B (139750-70440)	**69310**

rates. Similarly for estimating the income/ac, the sale cost of hybrid seed at Rs. 500/kg, cost of lint from hybrid seed cotton and seed cotton produced from male parent on prevailing market rates were taken into account. Based on these parameters the cost of GMS based hybrid seed was worked out/ac and/kg hybrid seed.

RESULTS AND DISCUSSION

The economics of GMS based hybrid seed production of *intra arboreum* hybrid CISAA 2 with female to male parent ratio of 4:1 was estimated during three years from 2006-2007, 2007-2008, 2008-2009 based on existing labour and inputs rates. The expenditure for various production activities *i.e.* field preparation, irrigation, sowing, weeding, rouging, pest control charges and breeder seed cost was observed Rs. 5480/ac during 2008-2009. The expenditure Rs 5060 in 2006-2007 and Rs. 5300 in 2007-2008 for these components were slightly less due to the less labour charges and input cost as compared to 2008-2009 (Table 2). Under this zone, the suitable crossing period in term of availability of more flowers for crossing and higher cross boll setting percentage, is from second week of August to first week of October (Meena *et al.,* 2003). The seed setting efficiency during this period was observed upto 81.5 per cent in *G. hirsutum* and 88.6 per cent in *G. arboreum* cotton (Meena and Tuteja,1997). In GMS based hybrid seed production system, the emasculation process is completely eliminated and only pollination between 8.30 AM to 12.30 PM is required during the crossing period for which 330 mandays labour was utilized on government rates fixed @ Rs 135/day and Rs 44550 were paid as labour charges. The expenditure of Rs 800 for thread cost was also incurred to tie as identification mark on pedicel of the pollinated buds totaling the pollination expenditure of Rs 45350 during 2008-2009. The pollination expenditure during 2006-2007 and 2007-2008 was Rs 33800 and Rs 40400, respectively. The expenditure of Rs 1620 for picking and ginning of the crossed bolls/ac seed production programme was observed during current year which was slightly less than previous years because of less labour rate. The indirect expenditure such as rent of land, interest on expenditure and management cost was also taken into consideration for estimating the expenditure which was Rs 15512 in 2006-2007, Rs 16928 in 2007-2008 and Rs 17990/- in 2008-2009. Considering all the components, the total expenditure involved/ac on GMS based hybrid cotton seed production was Rs 55572 in 2006-2007, Rs 64068 in 2007-2008 and Rs 70440 in 2008-2009. While estimating the income during current season 2008-2009, Rs 138400 was recorded from 266 kg hybrid seed obtained from one ac field and sold at Rs 500/kg among the farmers. Rs 5400 from the sale of the lint of hybrid seed cotton and Rs 1350 from the seed cotton obtained from male parent was also added to the income. Considering all the components, the total income was observed Rs 139750/ac which

Table 2. Economics of GMS based hybrid seed production during 2006 to 2008

A. Expenditure/Income detail:	Expenditure/ income		
	2006-2007	2007-2008	2008-2009
- **Production expenditure:** Charges of field preparation, irrigation, sowing, weeding, rouging, thinning, breeder seed cost, fertilizer cost, pest control	5060	5300	5480
- **Pollination expenditure:** Labour charges for pollination, cost of threads	33800	40400	45350
- **Expenditure on picking and ginning:** Labour charges for picking, ginning and cleaning	1200	1440	1620
- **Indirect expenditure:** 10 per cent interest and management cost on direct expenditure and rent charges of land for six months.	15512	16928	17990
- **Total expenditure**	55572	64068	70440
- **Total income:** Cost of hybrid seed, lint from hybrid seed cotton and seed cotton from male plants	134275	133430	139750
- **Net profit**	**78703**	**69362**	**69310**

is Rs. 504/kg of hybrid seed. During 2006-2007 and 2007-2008 the income was Rs. 134275 and Rs. 133430, respectively. After deducting the total expenditure of Rs 70440 from total income of Rs 139750, the net profit during 2008-2009 was estimated to Rs 69310/ac in hybrid seed production which is Rs 253/kg under this zone (Table 1). The net profit in GMS based hybrid seed production during 2006-2007 and 2007-2008 was Rs 78703 and Rs 69362, respectively (Table 2). Brar and Garg (2004) also reported hybrid seed production in *G. hirsutum* non profitable because of involvement of more labours in hand emasculation - pollination and poor cross boll setting percentage but in the present study the higher net profit was observed because of utilization of GMS line as female parent where nearly 70 per cent of total labour was saved by elimination of emasculation process and also increasing the cross boll setting percentage. It is concluded that cotton hybrid seed production using GMS line as female parent is a profitable enterprise in north zone.

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Screening of thermo sensitive genetic male sterility(TGMS) lines of diploid cotton (*Gossypium arboreum* L) for critical temperature for sterility and fertility point

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Abstract : Male sterility is an effective mean of producing hybrid cotton since it does not need labour intensive hand emasculation and pollination. In cotton, mainly two types of male sterility systems *viz.,* Cytoplasmic Genetic Male Sterility (CGMS) and Genetic Male Sterility (GMS) systems could be used for hybrid seed production. GMS is preferred than CGMS as it overcomes the drawbacks of cytoplasmic effect and problem of fertility restoration. Thermo Sensitive Genetic Male Sterility (TGMS) is a two line method of hybrid seed production where the sterile flowers are converted into fertile and fertile into sterile at a particular temperature. Once this is stabilized it is possible to convert any elite variety into TGMS and develop heterotic hybrids. TGMS system in *Gossypium arboreum* and photoperiod sensitive genetic male sterility (PGMS) system in *G. hirsutum* has been identified for the first time. The line remains sterile till temperature reaches 24^{0}C and show complete pollen fertility at temperature less than 18^{0}C. PGMS lines in *G. hirsutum* show complete pollen sterility when temperature rises above 40^{0}C for continuous period of time. Present investigation is first kind of report of TGMS based cotton hybrids in diploid cotton.

The two line systems of hybrid seed production hold promise for breeding specific genotypes bearing response to temperature and photoperiod fluctuations. There is certain amount of risk in exploiting heterosis by means of TGMS, if temperature fluctuation occurs at critical stages of flowering. Therefore, knowledge on critical thermo sensitive stages for fertility alteration is useful to determine the most suitable time of sowing for seed multiplication and hybrid seed production. The present study was, therefore, undertaken to characterize and stabilize the identified lines in *Gossypium arboreum* cotton for developing two line hybrids. For successful exploitation of two line hybrids, knowledge on critical thermo sensitive stages for fertility alteration useful to determine the most suitable time of showing for seed multiplication and hybrid seed production.

Seven lines of TGMS were taken which were isolated from one-one (1-1) material based on its phenotypic as well as its TGMS behaviour. Ga TGMS1, Ga TGMS2, Ga TGMS3, Ga TGMS4, Ga TGMS5, Ga TGMS6 and Ga TGMS7 were screened during 2011-2012. The sterility and fertility of flower is taken simple phenotypic observation given and expressed in per cent. For controlled conditions the room was provided with AC to control temperature. The temperature was recorded with data logger (HTC easy log) min to min during night h. The plants were exposed to lower temperature of 18^{0}C for about 8 h.

Seven TGMS lines performance during September month prior to growth chamber presented in Table 1. Ga TGMS1 produced 100 per cent sterile flower during first two weeks and in the third and fourth week, it recorded 94.11 and 96.07 per cent sterility, respectively. Ga TGMS2 showed 100 per cent sterility in first, second and fourth weeks. The third week recorded 94.50 per cent sterility. Ga TGMS3 recorded 100 per cent sterility across the four weeks. Ga TGMS4 expressed 100 per cent sterile flowers across the month. Ga TGMS5 expressed 97.87 and 96.96 during first two weeks, whereas in the third and fourth weeks, it expressed 100 per cent sterility. The Ga TGMS6 and Ga TGMS7 recorded 100 per cent sterility across all the four weeks. All seven lines showed more than 90 per cent sterility levels during high temperature regimes. The plants showed consistent and constitutive expression of sterility only were included in the study. Variants deviated the sterility levels were excluded from the study.

Performance of TGMS lines *in vitro* (growth chamber at 18^{0}C for 8 h) : Performance of lines data presented in Table 2 and Fig. 1. Ga

Table1. Performance of TGMS lines in green house prior to growth chamber (18^0C for 8 h) in 4 weeks during September

Genotypes	Sterile flowers				Total flowers				Percentage of sterility			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Ga TGMS 1	40	29	32	49	40	29	34	51	100	100	94.12	96.08
Ga TGMS 2	40	35	35	55	40	35	37	55	100	100	94.59	100
Ga TGMS 3	44	31	39	49	44	31	39	49	100	100	100	100
Ga TGMS 4	40	35	44	51	40	35	44	51	100	100	100	100
Ga TGMS 5	46	32	28	45	47	33	28	45	97.87	96.97	100	100
Ga TGMS 6	43	35	32	46	43	35	32	46	100	100	100	100
Ga TGMS 7	45	32	33	49	45	32	33	49	100	100	100	100
Min Temp(^{0}C)	20.79	21.06	20.56	19.56	20.79	21.06	20.56	19.56	20.79	21.06	20.56	19.56

TGMS1, during the first 4 days in growth chamber, produced only sterile flowers, on fifth day, it recorded two partial fertile flowers along with five sterile flowers, whereas on sixth day, it produced all type of flowers. On seventh day, it produced three and four partial fertile and fertile flowers,

Fig. 1. Performance of TGMS lines *in vitro*

a) Sterile flower

b) Partial fertile flower

c) Fertile flower

Plate 1: Sterile, partial fertile and fertile flowers of TGMS line

Table 2. Performance of TGMS lines *in vitro*

Genotypes	Type of flowers	Number of days induced (18^{0}C for 8 h)												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Ga TGMS 1	Sterile flowers	4	6	5	6	5	1	0	0	0	0	0	0	0
	Partial fertile flowers	0	0	0	0	2	4	3	0	0	0	0	0	0
	Fertile flowers	0	0	0	0	0	3	4	7	5	4	4	6	4
Ga TGMS 2	Sterile flowers	4	7	5	6	2	0	0	0	0	0	0	0	0
	Partial fertile flowers	0	0	0	0	7	4	2	0	0	0	0	0	0
	Fertile flowers	0	0	0	0	0	3	6	6	6	4	6	5	3
Ga TGMS 3	Sterile flowers	5	7	5	7	5	0	0	0	0	0	0	0	0
	Partial fertile flowers	0	0	0	0	1	4	1	0	0	0	0	0	0
	Fertile flowers	0	0	0	0	0	2	6	6	5	3	5	4	4
Ga TGMS 4	Sterile flowers	5	5	7	7	5	0	0	0	0	0	0	0	0
	Partial fertile flowers	0	0	0	0	2	4	1	0	0	0	0	0	0
	Fertile flowers	0	0	0	0	0	5	4	8	6	6	8	3	4
Ga TGMS 5	Sterile flowers	4	7	4	5	0	0	0	0	0	0	0	0	0
	Partial fertile flowers	0	0	0	0	5	4	3	0	0	0	0	0	0
	Fertile flowers	0	0	0	0	0	3	3	5	3	5	4	3	2
Ga TGMS 6	Sterile flowers	5	7	4	7	1	0	0	0	0	0	0	0	0
	Partial fertile flowers	0	0	0	0	4	6	1	0	0	0	0	0	0
	Fertile flowers	0	0	0	0	0	2	3	7	4	4	5	3	4
Ga TGMS 7	Sterile flowers	4	5	5	7	0	0	0	0	0	0	0	0	0
	Partial fertile flowers	0	0	0	0	6	6	2	0	0	0	0	0	0
	Fertile flowers	0	0	0	0	0	2	5	6	4	7	4	7	2

respectively. No sterile flowers from eight to thirteenth day but it produced only fertile flowers.

Ga TGMS2 produced during first four days only sterile flowers. Fifth to seventh days, it produced three types of flowers. But, from 8 to 13 days of induction of 18^0C it produced only fertile flowers. Ga TGMS3 expressed first 4 days as sterile and in the last 6 days only the fertile flowers were production.During fifth to seventh day, it produced all types of flowers, but most of them were fertile and partial fertile flowers. Ga TGMS4 line showed consistent sterility during first 4 days in growth chamber whereas, the last 6 days 100 per cent fertile flowers were produced. During 5 to 7 days of induction of low temperature(<18^0C), it produced all type of flowers, but less number of sterile flowers and more number of fertile and partial fertile flowers.

Ga TGMS5 showed first four days 100 per cent sterile flowers, whereas last six days 100 per cent fertile flowers. Transition phase taken place between fifth to seventh day of low temperature induction in growth chamber. Ga TGMS6 recorded 100 per cent fertile flowers during first four days, next three days as intermediate. The last six days of low temperature, induction make them 100 per cent fertile. Ga TGMS7 expressed 100 per cent fertile and 100 per cent sterile during first four days and last six days, respectively during low temperature induction in growth chamber. The sterile, partial fertile and fertile flowers under study presented in Plate 1.

Seven TGMS lines under growth chamber (8 h of 18^0C) expressed similar results. It may be due to their original origin is from basic single 1-1 TGMS line. All lines during first 4 days recorded only sterile flowers, indicating that in 4 days of 8 h of 18^0C does not show any effect on sterility levels. It may be due to meiosis processes occurred and had enough growth of bud for sterility beyond the low temperature induction to induce fertility. All the lines from fifth to seventh day of induction of low temperature had recorded all types of flowers(sterile, partial fertile and fertile flowers) indicating that these three days are critical for transition stage, at which the sterile flowers started to convert into partial fertile and fertile, respectively. Last 6 days of study, seven TGMS lines recorded only fertile flowers. Finally in the present study, 5 days of induction of 18^0C for about 8 h required to start the conversion of sterile flowers in to fertile by passing the partial fertile flowers. Ultimately, 7 days of induction of 18^0c for about 8 h required to induce 100 per cent fertility levels to ensure 100 per cent selfed seeds. It clearly indicated that the flower buds which exposed from pin headed size to anthesis for about 7 days of 18^0C for about 8 h were producing fertile flowers only, indicating that 7 days of 18^0C for about 8 h was required to induce complete fertility (Palve *et al.*, 2011). TGMS lines causing male sterility at higher temperature and fertility under lower temperature have also been reported (Khadi *et al.*, 2003, Govinda Raju *et al.*, 2004; and Palve *et al.*, 2011).

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Heterosis for seed cotton yield component traits and fibre properties of American cotton (*Gossypium hirsutum* L)

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ABSTRACT : A line x tester analysis was undertaken to estimate the magnitude of heterosis in *Gossypium hirsutum* for yield, its component traits and fibre quality parameters in 50 GMS (genetic male sterility) based cross combinations. These hybrids along with 15 parents and check hybrid CSHH 198 were planted during 2011-2012 at the Central Institute for Cotton Research, Regional Station, Sirsa. The analysis of variance indicated that the mean squares of genotypes were significant for seed cotton yield, bolls/plant, boll weight, ginning outturn, 2.5 per cent span length and strength (g/tex) except micronaire value indicated the presence of variability among hybrids and their parents. Studies revealed that none of the cross combinations exhibited significant economic heterosis over the check hybrid CSHH 198 for seed cotton yield, boll weight and micronaire value. Significant economic heterosis was found for bolls, monopods and sympods/plant, seed index, ginning percentage, 2.5 per cent span length and fibre strength.

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

Cotton is an important commercial crop which provides raw material to the textile industry. India is the pioneer country for the cultivation of hybrids on commercial scale. In recent years, the manifestation of heterosis has received increased attention from cotton breeders. Cotton is highly amenable for heterosis breeding and commercial exploitation of heterosis has achieved a spectacular success in India. Increasing labour cost is hampering the hybrid seed production through conventional method. Therefore, the present study was undertaken to find out the suitable GMS hybrid with heterosis for seed cotton yield and other traits.

The experimental material consisted of 15 parents of cotton *viz.,* 5 genetic male sterile lines GMS26, GMS20, GMS27, GMS21 and GMS17 used as females and 10 testers 003 NAH, 004 NAH, OK 2885, CNH 911, CSH 2912, CSH 2832, CSH 3129, H103, CSH 2907 and CSH 2810 used as males were crossed at the Central Institute for Cotton Research, Regional Station, Sirsa in line x tester crossing programme during 2010-2011 to generate a total of 50 hybrids. These 50 hybrids along with 15 parents and one check hybrid CSHH198 were grown in a randomized block design (RBD) with three replications with a spacing of 100 x 60 cm between row to row and plant to plant, respectively. Five competitive plants were selected randomly to record the data and for estimation of economic heterosis for the characters *viz.,* bolls/plant, boll weight, ginning percentage as per standard method suggested by Rai (1978).

The analysis of variance indicated that the mean squares of genotypes for all the characters investigated were significantly different, indicated the presence of variability among hybrids and their parents.

The range of mean values for seed cotton yield varied from 586 kg/ha (CNH 911)) to 1451 kg/ha (CSH 2912)) in parents and it ranged from 633 kg/ha (GMS 27 x 004 NAH) to 1821 kg/ha (GMS 17 x CSH 3129) for cross combinations. For bolls/plant, mean values of the parents was observed lowest in CNH 911 (33.7 bolls/plant) and highest in CSH 3129 (65.3 bolls/plant) and for hybrids it was found to be lowest in GMS 17 x CNH 911 (36.9 bolls/plant) and highest in GMS 17 x CSH 2907 (64.4 bolls/plant). The mean values for average boll weight ranged from 2.88(CSH 2912) to 4.73 g (004 NAH) in parents and 2.89g (GMS 27 x 004 NAH) to 4.27 g (GMS 20 x CNH 911) in hybrids. For ginning percentage, the range of mean values among the parents was observed lowest in 004 NAH (31.1 %) and highest in GMS27(36.7 %) and for hybrids it varied from 31.6 per cent in GMS 26 x 004 NAH to 37.1 per cent in GMS 27 x CSH 2907. The mean value for 2.5 per cent span length ranged from 25.7 mm

Table 1. Estimates of economic heterosis of GMS based hybrids for seed cotton yield and other traits

Hybrids/Cross	Seed cotton yield (kg/ha)	Bolls/ plant	Boll weight (g)	GOT (%)	2.5 per cent span length (mm)	Micronaire value	Bundle strength (g/tex)
GMS 26 x 003 NAH	-18.6	-6.5	-20.8	8.2*	-6.0	-9.6	-9.3
GMS 26 x 004 NAH	-29.6	-24.2	-20.0	-3.5	-7.1	-9.6	-11.5
GMS 26 x OK 2885	-17.7	-12.6	-20.1	7.8*	-3.2	-21.2	-7.1
GMS 26 x CNH 911	-28.7	-11.6	-16.3	8.5*	0.4	-13.5	-9.7
GMS 26 x CSH 2912	2.4	-9.9	-21.1	-0.1	-3.9	-9.6	-10.6
GMS 26 x CSH 2832	-18.6	4.5	-24.9	10.3*	-7.1	-21.2	-13.3
GMS 26 x CSH 3129	-4.9	1.4	-14.8	5.4*	-4.6	-11.5	-12.4
GMS 26 x H103	-21.4	-8.9	-26.7	6.6*	-2.1	-7.7	-10.2
GMS 26 x CSH 2907	-9.5	-16.0	-25.4	5.3*	-2.5	-11.5	-6.2
GMS 26 x CSH 2810	-38.7	-4.1	-31.5	7.2*	-2.1	-11.5	-9.3
GMS 20 x 003 NAH	-38.7	7.9*	-20.4	5.5*	-0.4	-7.7	-11.9
GMS 20 x 004 NAH	-32.3	-10.8	-12.1	4.0*	0.4	-9.6	-11.9
GMS 20 x OK 2885	-15.9	-13.2	-13.1	6.2*	-3.2	-13.5	-12.8
GMS 20 x CNH 911	-14.0	-16.3	-6.6	5.9*	1.1	-25.0	-0.9
GMS 20 x CSH 2912	-46.1	-6.5	-17.4	5.2*	-2.5	-13.5	-10.6
GMS 20 x CSH 2832	-47.0	3.2	-24.8	3.2	-3.6	-15.4	-6.2
GMS 20 x CSH 3129	-13.1	9.8*	-9.1	3.8	0.4	-11.5	-8.8
GMS 20 x H103	-33.2	2.4	-26.0	8.0*	-7.5	-13.5	-13.3
GMS 20 x CSH 2907	-36.0	-17.7	-26.6	11.0*	-0.4	-9.6	-11.1
GMS 20 x CSH 2810	-55.2	-4.5	-28.0	7.7*	-4.3	-11.5	-14.2
GMS 27 x 003 NAH	-40.6	-10.2	-20.3	4.7*	-3.9	-19.2	-14.6
GMS 27 x 004 NAH	-62.5	-13.8	-36.8	10.8*	5.3*	-15.4	4.0*
GMS 27 x OK 2885	-5.8	-14.2	-14.2	5.2*	3.6*	-11.5	-1.8
GMS 27 x CNH 911	-26.8	-9.8	-20.9	4.7*	1.8*	-7.7	-4.9
GMS 27 x CSH 2912	-3.1	-6.9	-24.0	12.1*	-6.4	-13.5	-12.8
GMS 27 x CSH 2832	-8.6	-11.8	-22.8	4.9*	-1.4	-19.2	-8.0
GMS 27 x CSH 3129	-22.3	-11.8	-23.4	7.8*	-1.8	-21.2	-7.1
GMS 27 x H103	-3.1	0.8	-18.2	7.1*	1.4	-11.5	-7.1
GMS 27 x CSH 2907	2.4	-10.4	-23.5	13.1*	0.0	-13.5	-4.9
GMS 27 x CSH 2810	-17.7	-18.5	-32.3	6.6*	1.1	-15.4	-2.2
GMS 21 x 003 NAH	-35.1	-8.1	-25.0	7.9*	-2.5	-9.6	-11.5
GMS 21 x 004 NAH	-57.0	-12.2	-13.8	6.4*	1.8*	-7.7	-5.3
GMS 21 x OK 2885	-22.3	2.3	-18.1	7.4*	0.7	-15.4	-1.3
GMS 21 x CNH 911	-36.0	-14.2	-9.7	8.7*	0.7	-3.8	-6.2
GMS 21 x CSH 2912	-38.7	-20.7	-16.6	6.5*	0.7	-7.7	-8.8
GMS 21 x CSH 2832	-38.7	-5.3	-29.1	8.0*	-1.4	-19.2	-6.2
GMS 21 x CSH 3129	-39.6	3.7	-10.9	7.4*	-1.1	-11.5	-9.7
GMS 21 x H103	-47.9	6.5	-15.0	7.9*	-3.6	-11.5	-11.9
GMS 21 x CSH 2907	-51.5	-4.1	-23.3	1.3*	0.0	-7.7	-9.3
GMS 21 x CSH 2810	-53.4	5.0	-22.6	4.0*	-1.4	-13.5	-9.7
GMS 17 x 003 NAH	-16.8	1.8	-21.8	10.8*	-3.2	-9.6	-10.6
GMS 17 x 004 NAH	-8.6	16.4*	-26.6	9.5*	1.1	-3.8	-6.6
GMS 17 x OK 2885	-9.5	-12.0	-15.1	12.9*	-0.7	-17.3	-11.5
GMS 17 x CNH 911	-19.5	-32.5	-19.6	9.8*	-0.4	-15.4	-8.0
GMS 17 x CSH 2912	-9.5	11.1*	-27.1	6.4*	-1.8	-23.1	-10.6
GMS 17 x CSH 2832	-25.0	10.0*	-20.7	8.1*	-1.1	-9.6	-6.6
GMS 17 x CSH 3129	7.9	1.2	-21.1	8.5*	2.5*	-25.0	-3.1
GMS 17 x H103	-36.0	1.8	-34.1	11.1*	-1.1	-11.5	-8.8
GMS 17 x CSH 2907	-14.0	17.9*	-19.5	8.4*	-0.7	-21.2	-6.2
GMS 17 x CSH 2810	-26.8	3.9	-15.3	9.0*	0.0	-23.1	-6.2

* Significant at p= 0.05

(CSH 2810) to 29.2mm (CSH 3129) and 26.0 (GMS 20 x H103) to 29.6 mm (GMS 27 x 004 NAH) in parents and hybrids, respectively. The mean values among the parents varied from 4.0 (CSH 3129) to 5.0 (CNH 911) and for cross combination varied from 3.9 (GMS 20 x CNH 911, GMS 17 x CSH 3129) to 5.0 (GMS 21 x CNH 911, GMS 17 x 004 NAH) for fibre fineness. In parents, the lowest mean for bundle strength was observed by CSH 2912 (18.7/tex) and highest by CSH 2907 (23.1g/tex) likewise for cross combinations, the lowest mean value was observed by the cross GMS 27 x 003 NAH (19.3g/tex) and highest was by GMS 27 x 004 NAH (23.5 g/tex).

Heterosis estimates over the conventional check hybrid CSHH 198 for different characters are presented in Table 1. The results indicated that the phenomenon of heterosis was of general occurrence, however, its magnitude varied with the characters. It is indicated that among 50 cross combinations, the cross combination GMS 17 x CSH 3129 recorded the highest seed cotton yield of 1821 kg/ha and however, none of the crosses exhibited significant positive heterotic values over the check hybrid CSHH 198. It was found that three GMS based cross combinations (GMS 26 x CSH 2912, GMS 27 x CSH 2907 and GMS 17 x CSH 3129) numerically could cross the performance of the check hybrid CSHH 198 so these hybrids are beneficial for hybrid seed production. These results are in accordance with the previous study of Tuteja *et al.,* (2005), Khosla *et al.,* (2007) and Tuteja *et al.,* (2011,a b). For boll number, six crosses exhibited significant positive heterosis and the cross combination GMS17 x CSH 2907 showed maximum heterotic effects by a magnitude of 17.9 per cent.With regards to boll weight, none of the hybrids exhibited significant positive heterosis. All the cross combinations showed negative heterotic effects for boll weight as the parents involved in the present study do not have variability for this trait.

The ginning percentage is an important character. Forty six cross combinations displayed positive and significant heterosis for ginning percentage but the cross combination GMS 17 x CNH 911 showed maximum heterotic effects by a magnitude of 9.8 per cent. For 2.5 per cent span length only 5 cross combinations showed significant and positive heterosis and maximum heterosis in the cross GMS 27 x 004 NAH (5.3%).The results are in conformity with Rajamani *et al.,* (2009) and Patil *et al.*, (2011). For fibre fineness all the cross combinations showed negative heterosis effect and decrease in micronaire value is an indication of fibre fineness. The results are in the agreement with earlier research findings of Rajamani *et al.,* (2009) but are against the Patil *et al.*, (2012). Only one cross GMS27 x 004 NAH (4.0%) displayed significant and positive heterotic effects for fibre strength while remaining all the crosses showed negative heterotic effect as the parents involved in the present study do not have variability for this trait.

The cross combination involving female parent GMS 17 and male parents 004 DA, CNH 911 recorded significant positive heterosis for most of the characters. For seed cotton yield cross combinations GMS 26 x CSH 2912, GMS 27 x CSH 2907, GMS 17 x CSH 3129 showed heterosis in positive direction. Thus, to reduce the cost of hybrid seed production and to overcome the labour problems, these crosses may be used further for development of GMS based hybrids in cotton and some new parents having good general combining ability may be tested for exploitation of heterosis at commercial level.

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Correlation and path coefficient analysis in upland cotton (*Gossypium hirsutum* L.)

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ABSTRACT : Correlation and path coefficient analysis were carried out with 41 genotypes of cotton that were obtained from different cotton research centres across the country for yield and yield component traits. The character association studies revealed that seed cotton yield/plant had positive significant correlation with sympodia and bolls/plant, boll weight, seed index and lint index. The path coefficient analysis revealed that bolls, monopodia and sympodia/plant, days to 50 per cent flowering, boll weight, ginning outturn, seed index, lint index, uniformity ratio, 2.5 per cent span length and micronaire exhibited direct positive effect on seed cotton yield/plant signifying that these are the major yield contributing traits for improvement of seed cotton yield.

Key words: Correlation, cotton, path analysis

Gossypium includes 50 species, four of which are cultivated, 44 are wild diploids and two are wild tetraploids. Out of the four cultivated species, *Gossypium hirsutum* L. and *Gossypium barbadense* L. commonly called as new world cottons are tetraploids (2n = 4x = 52), whereas, *G. herbaceum* L. and *G. arboreum* L. are diploids (2n = 2x = 26) and are commonly called as old world cottons.

Seed cotton yield is complex and polygenically controlled character and highly influenced by a number of component traits. Correlation studies provide an estimate on the degree of association between characters, whereas path coefficient analysis helps to resolve the correlation into direct and indirect contribution of different component characters to yield.

The present study was carried out with 41 genotypes of cotton (*Gossypium hirsutum* L). These genotypes were grown in *kharif,* 2010 in a randomized complete block design with three replications at Regional Agricultural Research Station, Lam, Guntur. Each entry was consisted of 2 rows of 6m length with an inter and intra row spacing of 105 x 60cm. The observations were recorded on 5 randomly selected competitive plants from each genotype/replication on 14 component characters *viz.,* days to 50 per cent flowering, plant height (cm), monopodia, sympodia and bolls/plant, boll weight (g), seed index (g), lint index (g), ginning outturn (%), 2.5 per cent span length (mm), bundle strength (g/tex), micronaire (10^{-6}g/in), uniformity ratio (%) and seed cotton yield/plant (g). The fibre quality characters were analyzed to estimate genotypic and phenotypic correlation coefficients (Falconer, 1964) and path coefficient relationships.

Genotypic correlation coefficients in general were higher than phenotypic correlation coefficients (Table 1). The seed cotton yield/plant exhibited significant positive correlation of sympodia and bolls/plant, boll weight, seed index and lint index at both genotypic and phenotypic levels. This signifies simultaneous selection of these characters would improves seed cotton yield. These results are in confermation with earlier findings of Karunakar Raju (2005) and Vijaya Lakshmi *et al.,* (2008).

At both the levels plant height showed positive significant association with sympodia and bolls/plant as reported by Muthu *et al.,* (2004), Tuteja *et al.,* (2006), and Vijaya Lakshmi *et al.,* (2008). Bolls/plant exhibited positive significant association with sympodia/plant at both the levels in conformity with Neelima *et al.,* (2005) and Shazia Salahuddin *et al.,* (2010). At both the levels, seed index was significantly and positively correlated with boll weight and lint index in agreement with Karunakar Raju (2005) and Vijaya Lakshmi *et al.,* (2008). 2.5 per cent span length showed significantly positive association with bundle strength whereas negative correlation with micronaire and uniformity ratio at both the levels in broad agreement with Leela Pratap *et al.,* (2007), and Vijaya Lakshmi *et al.,*

Table 1. Phenotypic (above diagonal) and genotypic (below diagonal) correlations for yield and other traits in 41 genotypes of cotton *Gossypium hirsutum* L.

Characters	Days to 50 per cent flowering	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Bolls/ plant	Boll weight (g)	Seed index (g)	Lint index (g)	Ginning outturn (%)	2.5 per cent span length (mm)	Bundle strength (g/tex)	Micro-naire (10^{-6}g/in)	Uni-formity ratio (%)	Seed cotton yield/ plant (g)
Days to 50 per cent flowering	—	-0.0550	-0.2240*	-0.0189	-0.0687	-0.2855**	0.0051	-0.1368	-0.0630	0.0695	-0.1060	-0.1394	0.0440	0.0665
Plant height (cm)	-0.1225	—	0.1931*	0.3619**	0.3869**	0.2549**	-0.0788	-0.0740	-0.1162	-0.2249*	-0.0157	-0.0046	0.1644	0.1318
Monopodia/plant	-0.6631**	0.1093	—	0.0816	0.1859*	0.0494	-0.0135	0.0206	-0.1446	-0.1706	-0.0065	0.1017	0.1661	0.0655
Sympodia/plant	-0.2071*	0.4816**	-0.0788	—	0.2990**	0.1042	0.0452	0.1324	-0.0299	-0.1296	-0.1069	-0.0046	0.1116	0.1968*
Bolls /plant	-0.1822*	0.5582**	0.1727	0.4235**	—	0.1543	-0.0325	0.0882	0.0071	-0.1416	0.0595	-0.0457	0.0302	0.2687**
Boll weight (g)	-0.4148**	0.3563**	0.1424	0.1722	0.2492**	—	0.2617**	0.3390**	0.0428	0.1561	0.1998*	-0.0040	-0.1807*	0.2144*
Seed index (g)	0.0089	-0.0712	-0.0638	0.1167	-0.0424	0.2852**	—	0.6828**	0.1261	0.2500**	-0.0443	0.2774**	-0.1683	0.2398**
Lint index (g)	-0.1845*	-0.1164	0.0935	0.2991**	0.1020	0.4065**	0.8324**	—	0.1238	0.0391	-0.0879	0.2504**	-0.0830	0.2438**
Ginning outturn (%)	-0.2363**	-0.1049	-0.5059**	-0.1798*	0.1483	0.0092	0.1990*	0.2046	—	0.0309	-0.0329	0.0556	0.1532	0.1673
2.5per cent span length(mm)	0.0977	-0.2712**	-0.3901**	-0.2076*	-0.2305*	0.1578	0.2724**	0.0481	0.0321	—	0.5430**	-0.3226**	-0.5791**	0.0311
Bundle strength (g/tex)	-0.1539	-0.0656	-0.1237	-0.1865*	0.0049	0.2191*	-0.0551	-0.1181	-0.0297	0.5660**	—	-0.3492**	-0.2646**	0.0111
Micronaire (10^{-6}g/in)	-0.2513**	0.0087	0.4013**	0.0909	-0.1399	0.0147	0.3146**	0.2973**	0.1420	-0.3680**	-0.3974**	—	0.3165**	0.0931
Uniformity ratio (%)	0.0223	0.2014*	0.3567**	0.1041	0.0525	-0.2051*	-0.1744	-0.1075	0.2294*	-0.6522**	-0.3060**	0.3564**	—	0.1221
Seed cotton yield/plant (g)	0.0184	0.1675	0.0920	0.4830**	0.4453**	0.3689**	0.4445**	0.5269**	0.4075**	0.0555	-0.0304	0.1852*	0.3237**	—

, * Significant at 5 per cent level and Significant at 1 per cent level respectively.

Table 2. Direct and indirect effects (genotypic) of seed cotton yield and other traits in cotton *Gossypium hirsutum* L.

Characters	Days to 50 per cent flowering	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Bolls/ plant	Boll weight (g)	Seed index (g)	Lint index (g)	Ginning outturn (%)	2.5 per cent span length (mm)	Bundle strength (g/tex)	Micro-naire (10^{-6}g/in)	Uni-formity ratio (%)
Days to 50 per cent flowering	**0.0003**	0.0000	-0.0002	-0.0001	-0.0001	-0.0001	0.0000	-0.0001	-0.0001	0.0000	0.0000	-0.0001	0.0000
Plant height (cm)	0.0520	**-0.4247**	-0.0464	-0.2045	-0.2371	-0.1513	0.0302	0.0495	0.0445	0.1152	0.0279	-0.0037	-0.0855
Monopodia/plant	0.2046	-0.0337	**-0.3086**	0.0243	-0.0533	-0.0439	0.0197	-0.0289	0.1561	0.1204	0.0382	-0.1239	-0.1101
Sympodia/plant	-0.0382	0.0889	-0.0145	**0.1847**	0.0782	0.0318	0.0216	0.0552	-0.0332	-0.0383	-0.0344	0.0168	0.0192
Bolls /plant	-0.1340	0.4104	0.1269	0.3113	**0.7351**	0.1832	-0.0311	0.0749	0.1091	-0.1695	0.0036	-0.1029	0.0386
Boll weight (g)	-0.1519	0.1305	0.0521	0.0630	0.0913	**0.3662**	0.1044	0.1488	0.0034	0.0578	0.0802	0.0054	-0.0751
Seed index (g)	0.0004	-0.0031	-0.0028	0.0052	-0.0019	0.0126	**0.0442**	0.0368	0.0088	0.0120	-0.0024	0.0139	-0.0077
Lint index (g)	-0.0411	-0.0259	0.0208	0.0666	0.0227	0.0905	0.1854	**0.227**	0.0456	0.0107	-0.0263	0.0662	-0.0239
Ginning outturn (%)	0.0510	0.0226	0.1092	0.0388	-0.0320	-0.0020	-0.0430	-0.0442	**-0.2159**	-0.0069	0.0064	-0.0307	-0.0495
2.5per cent span length(mm)	0.0766	-0.2127	-0.3059	-0.1628	-0.1808	0.1237	0.2137	0.0377	0.0252	**0.7842**	0.4439	-0.2886	-0.5115
Bundle strength (g/tex)	0.0277	0.0118	0.0222	0.0335	-0.0009	-0.0394	0.0099	0.0212	0.0053	-0.1017	**-0.1797**	0.0714	0.0550
Micronaire (10^{-6}g/in)	-0.0513	0.0018	0.0820	0.0186	-0.0286	0.0030	0.0643	0.0608	0.0290	-0.0752	-0.0812	**0.2043**	0.0728
Uniformity ratio (%)	0.0223	0.2017	0.3572	0.1043	0.0526	-0.2053	-0.1747	-0.1076	0.2297	-0.6532	-0.3064	0.3569	**1.0014**
Correlation with Seed cotton yield/plant(g)	**0.0184**	**0.1675**	**0.0920**	**0.4830****	**0.4453****	**0.3689****	**0.4445****	**0.5269****	**0.4075****	**0.0555**	**-0.0304**	**0.1852***	**0.3237****

*, ** Significant at 5 per cent level and significant at 1 per cent level, respectively, Residual effect = 0.2963, Bold and diagonal values indicate direct effects
*, ** Significant at 5 per cent level and significant at 1 per cent level, respectively, Residual effect = 0.8795, Bold and diagonal values indicate direct effects

(2008). At both the levels, bundle strength exhibited significantly positive correlation with boll weight whereas negative association with uniformity ratio as reported by Neelima *et al.,* (2005). Micronaire value had positive significant association with uniformity ratio in accordance with Vijaya Lakshmi *et al.,* (2008).Characters of sympodia and bolls/plant, boll weight seed index and lint index were positive and significant at phenotypic and genotypic levels.

The path coefficient analysis (Table 2 and 3) indicated that bolls/plant, uniformity ratio, days to 50 per cent flowering, 2.5 per cent span length, seed index, ginning outturn and sympodia/plant showed positive direct effect on seed cotton yield .Direct section of these characters would help in seed cotton yield improvement in cotton. These results are in conformity with Vijaya Lakshmi *et al.,* (2008). The traits boll weight, lint index, micronaire value and monopodia/plant also exhibited positive direct effect on seed cotton yield as reported by Muthu *et al.,* (2004).These characters will also taken into consideration while selecting the characters for improvement of yield. Whereas plant height and bundle strength exerted negative direct effect on seed cotton yield/plant in accordance with the Karunakar Raju (2005).

Thus, the character association and path coefficient analysis revealed that major emphasis should be laid on selection process with more sympodia and bolls/plant with high boll weight, seed index and lint index for better genotypes with superior desirable fibre quality traits and for realizing higher seed cotton yield.

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Studies on metroglyh analysis in cotton (*Gossypium hirsutum* L)

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ABSTRACT : An experiment was conducted during *kharif,* 2009 to assess the pattern of morphological variation through metroglyph technique in 45 cotton genotypes (*Gossipium hirsutum L.*). Based on this technique genetic variability was evaluated for 5 characters *viz., kapas* yield (kg/ha) , 2.5 per cent span length (mm), *kapas* attachment, locule opening and monopodia angle. The mean values were used for plotting the genotypes in a graph. All genotypes were grouped into 9 distinct groups, which differed among themselves. Group V had the largest genotypes (11) followed by group VI having 8 genotypes with moderate *kapas* yield and medium span length. Group II consisted of 7 genotypes with moderate *kapas* yield with low span length. Group IX had 3 genotypes classified into high seed cotton yield with high span length consisting of flared *kapas* attachment, wide locule opening and acute monopodia angle. The genotypes of group V, VI, VIII and IX could be used as parents representing wide genetic variability helpful in future hybridization breeding programme for achieving yield and fibre quality characters.

Key words: Cotton, fibre quality, metroglyph, morphological variation, seed cotton yield

Cotton is the most important fibre and cash crop. It is fulfilling the domestic need as well as earning foreign exchange for the country.The genus *Gossypium* belongs to the family Malvaceae is divided into two species *viz., G. hirsutum* and *G. barbadense*. The species, *G. hirsutum* largely cultivated in India with a fibre length ranging from 25 – 32 mm. Ninety per cent of world cultivated cotton is under this species. Germplasm have high level of genetic diversity which provides a basic material for launching a crop improvement programme. Genetic diversity is the basic requirement in any crop improvement programme.The hybrids involving the parents with high diversity among them are expected to exhibit higher amount of heterotic expression and broad spectrum of variability in segregating generation. Metroglyph analysis and index scoring have been used as useful tool to assess genetic variability among population. Several workers (Kabir *et al.,* 1993, Ahmed Khan *et al.,* 2005, Kashif and Ahmed Khan, 2007, Khan *et al.*, 2007, Punitha *et al.*, 2010) used this technique in various crops to study the pattern of morophological variations. So, the present study, was conducted to study the morphological variations in 45 cotton genotypes of *G.hirsutum* species.

The materials used in this study comprised of 45 cotton genotypes collected from different parts of India. Investigations were carried out in the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore during 2009. These genotypes were raised in a randomized block design with three replications. Each genotype was raised in four rows of 6m length spaced at 90cm between rows and 45cm between plants. Five randomly selected plants from each genotype in each replication were taken for recording observations of five characters such as *kapas* yield(kg/ha), 2.5 per cent span length (mm), *kapas* attachment, locule opening and monopodia angle. The mean for each genotype was worked out for each characters and range recorded. The mean value was used to construct the metroglyph analysis as per the model suggested by Anderson (1957). In this study, the glyphs were first plotted on the basis of two extremely variable traits namely *kapas* yield (X axis) and 2.5 per cent span length (Y axis) and all the other characters were represented by rays on the glyph. Each ray represents a particular character obtained by dividing the range of variation into three equal classes giving the grade low, moderate and high for each character. The length of rays assigned to the characters depends upon the index scores of accession for those characters. The glyph positions and rays were used to assess the variability pattern and correlated traits for assessment of their divergent groups. Each cotton genotypes denoted a numbers from 1-45 is represented as a glyph which is the intersection point of mean values of X and Y coordinates.

The index score and ray position for different characters are presented in Table 1.The 45 glyphs showed in the scatter diagram were divided into three groups for *kapas* yield as low (800-1200 kg), moderate (1201 – 1600 kg) and high (1601 – 2000 kg). Similarly three categories of 2.5 per cent span length such as low (25-28mm), medium (28.1 to 31.0mm) and high (31.1to 34mm) were also made, so as to classify all the individuals into nine groups. Variations for other three characters were represented by the variations in the length of the corresponding rays on all the circles. The length of each ray as a result was short, medium and long. The respective grouping were flared, fluffy and medium for *kapas* attachment; wide, acute and straight for locule opening; acute, straight and right angle for monopodia angle.

Different cotton genotypes fall in different groups are presented in Table 2. Group I with low *kapas* yield and low span length had only one genotype showed combination of fluffy *kapas* attachment, acute locule opening and straight monopodia angle. Fig.1 showed the categorization of cotton genotypes into nine groups through metroglyph diagram. Group II consisted of seven genotypes with moderate *kapas* yield with low span length. In this group four glyph exhibited acute monopodia angle and only one glyph expressed combination of wide locule opening and acute monopodia angle and fluffy *kapas* attachment. Three lines included in group III with higher *kapas* yield and lower 2.5 per cent span length. In this group, only one glyph exhibited flared *kapas* attachment, wide locule opening , right angle and monopodia angle. Group IV consisted of three genotypes with low *kapas* yield and medium span length. In this group all genotypes were wide locule opening and acute monopodia angle, only one glyph showed flared *kapas* attachment, wide locule opening and acute monopodia angle. Mean values for the different characters are presented in Table 3.

Table 1. Index score and ray position for different characters

S. No.	Character	Glyph position	Range	Index scores Low	Medium	High
1	*Kapas* yield (kg/ ha)	X axis	770 -2011	700 -1100.0	1100.1 – 1500.0	1500.1- 2100.0
2	2.5 per cent span length (mm)	Y axis	25.8 – 33.6	25.0 – 28.0	28.1 -31.0	31.1- 34.0
3	*Kapas* attachment		-	Flared	Fluffy	Medium
4	Locule opening		-	Wide	Acute	Straight
5	Monopodia angle		-	Acute	Straight	Right angle

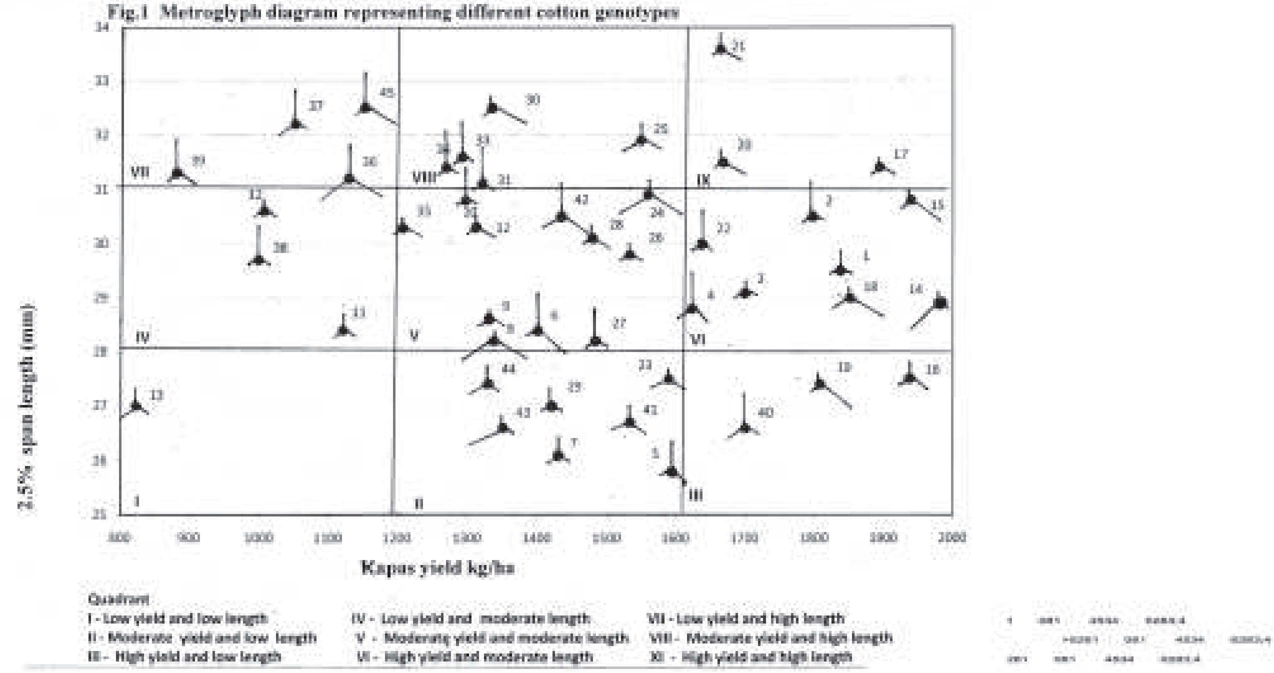
Table 2. Selected cotton genotypes falling in different groups

Groups	Land races	Land races serial numbers as/diagram
I	1	P 13 – 2
II	7	SVPR2, NISC 50, 28I, NISC 43, TCH 1652,NISC40, Anjali
III	3	NISC 44, Sumangala, TCH 1656
IV	3	F2381, SVPR 4, P 23 -1
V	11	KC3, CCH 724(5), F2380, P1750, TCH1705, TCH1722, TCH 1569, TCH1724, MCU 12(1), TCH1648, TCH1718
VI	8	MCU 13, F 2383, TCH1743, TCH 1717, CCH 724, TCH 1608, TCH 1715, NH 615.
VII	4	TCH 1627, Surabhi, TCH 1728, TCH 1649
VIII	5	TCH 1710, TCH 1599, TCH 1719, MCU 12(2), TCH 1711
IX	3	Bunny *Bt*, TCH 1734,TCH 1738

Table 3. Mean values for the different characters in cotton genotypes

S.No	Entries	*Kapas* yield	2.5 per cent span length	*Kapas* attachment	Locule opening	Monopodia angle
1	CCH 724	1837	29.5	Fluffy	Wide	Acute
2	TCH 1608	1796	30.5	Medium	Wide	Acute
3	NH 615	1700	29.1	Flared	Wide	Acute
4	F 2383	1624	28.8	Medium	Acute	Straight
5	NISC 50	1593	25.8	Medium	Wide	Straight
6	F 2380	1400	28.4	Medium	Wide	Right angle
7	28 I	1430	26.1	Fluffy	Wide	Acute
8	CCH 724 (5)	1337	28.2	Flared	Straight	Right angle
9	P 1750	1330	28.6	Flared	Wide	Straight
10	MCU 12(1)	1296	30.8	Medium	Wide	Acute
11	F 2381	1120	28.4	Fluffy	Wide	Acute
12	P 23-1	1005	30.6	Flared	Wide	Acute
13	P 13-2	822	27	Fluffy	Acute	Straight
14	TCH 1743	1980	28.9	Flared	Straight	Straight
15	TCH 1715	1939	30.8	Flared	Wide	Right angle
16	TCH 1656	1937	27.5	Fluffy	Wide	Straight
17	Bunny *Bt*	1894	31.4	Flared	Wide	Acute
18	TCH 1717	1851	29	Flared	Acute	Right angle
19	Sumangala	1808	27.4	Flared	Wide	Right angle
20	TCH 1734	1668	31.5	Flared	Wide	Straight
21	TCH 1738	1664	33.6	Fluffy	Wide	Straight
22	MCU 13	1637	30	Medium	Wide	Acute
23	Anjali	1589	27.5	Flared	Acute	Straight
24	TCH 1718	1559	30.9	Fluffy	Straight	Right angle
25	TCH 1719	1548	31.9	Fluffy	Acute	Straight
26	TCH 1705	1532	29.8	Flared	Wide	Acute
27	KC 3	1483	28.2	Medium	Wide	Acute
28	TCH 1722	1478	30.1	Flared	Wide	Straight
29	SVPR 2	1419	27	Fluffy	Straight	Acute
30	TCH 1711	1334	32.5	Flared	Wide	Right angle
31	TCH 1599	1320	31.1	Medium	Wide	Acute
32	TCH 1724	1311	30.3	Flared	Wide	Straight
33	MCU 12(2)	1291	31.6	Medium	Wide	Acute
34	TCH 1710	1268	31.4	Medium	Wide	Acute
35	TCH 1569	1206	30.3	Flared	Wide	Straight
36	Surabhi	1128	31.2	Medium	Straight	Right angle
37	TCH 1728	1050	32.2	Medium	Acute	Acute
38	SVPR 4	997	29.7	Medium	Wide	Acute
39	TCH 1627	880	31.3	Medium	Wide	Straight
40	NISC 44	1700	26.6	Medium	Acute	Acute
41	TCH 1652	1533	26.7	Fluffy	Acute	Straight
42	TCH 1648	1433	30.5	Medium	Acute	Right angle
43	NISC 43	1350	26.6	Flared	Straight	Acute
44	NISC 40	1329	27.4	Fluffy	Acute	Acute
45	TCH 1649	1151	32.5	Medium	Wide	Right angle

Fig.1 Metroglyph diagram representing different cotton genotypes



Group V consisted of moderate *kapas* yield with medium span length had 11 genotypes. In this group only one glyph exhibited flared *kapas* attachment, wide locule opening and acute monopodia angle. Four genotypes showed flared *kapas* attachment, wide locule opening and straight monopodia angle. Group VI consisted of eight genotypes with high *kapas* yield and medium span length of which two glyphs showed combination of flared *kapas* attachment, wide locule opening and acute monopodia angle. In Group VII consisted of four genotypes showed low *kapas* yield with higher span length. In this group, all the genotypes showed low grade of medium *kapas* attachment. Group VIII with moderate *kapas* yield and medium span length had five genotypes of which three genotypes showed combination of medium *kapas* attachment, wide locule opening and acute monopodia angle. In group IX consisted of three genotypes with high *kapas* yield with high span length. In this group Bunny *Bt* recorded flared *kapas* attachment wide locule opening and acute monopodia angle was observed.

In general nearly 25 per cent of the genotypes belong to Group V which exhibited medium *kapas* yield and medium span length had favourable combination of wide locule opening and acute monopodia angle. In Group IX all genotypes had wide locule opening and flared *kapas* attachment favourable of easy picking and attractive fluffy characteristics of *kapas*. Group VI consisted of genotypes *viz.,* CCH 724, TCH 1608 and NH 615 showed combination of flared/ medium *kapas* attachment, wide locule opening and acute monopodia angle. From these results, those genotypes in different group could be used to have maximum variability of good combinations of characters for future hybrid programme for the improvement of cotton population. The study therefore indicated the variation existing within a group as well as among the groups provides an opportunity to plant breeder to select desirable genotypes.

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Status of fibre quality and yield of promising strains of American cotton (*Gossypium hirsutum L*)

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ABSTRACT : Seventeen promising strains of *Gossypium hirsutum L.* were evaluated for seed cotton yield, fibre quality parameters and their further use in breeding programme. Analysis of data revealed significant differences for yield and fibre traits. The strains H 1316 was the highest in seed cotton yield followed by strains SR1, H 1451 and H 1354. In general the strains *viz.,* H 1354, SR 2, FYT/09-16 and FYT/09-17 were found to be the superior against local checks H1117 and H1226 for fibre quality parameters, but no single strain was observed to be superior in all the characteristics. However, based on FQI and yield, the strains H 1354, SR 2, FYT/09-16, FYT/09-17, H 1316 and SR1 were the most promising against top five strains and may be utilized in future breeding programmes for the development of desirable varieties.

Key words: Bundle tenacity, cotton, elongation, micronaire value, span length

Cotton is the most important fibre crop and is a major raw material for the textile industries throughout the world. Cotton fibres still are in more demand even with introduction of synthetic fibres, because the apparel prepared by it is socially and scientifically more comfortable to wear. The final performance of cotton crop is assessed by its seed cotton yield and fibre characteristics. The characteristics of cotton fibre vary not only between various samples of a strain, but also between fibres on the single seed of that strain. The final quality of a cotton strain depends upon the inherited characters of that cotton and the environmental conditions prevailing during cultivation and also post harvest handling (Nagwekar *et al.*, 1983). Trotman (1964) stated that cotton fibres continue to develop even after the boll opens and hence possibility of immature fibres is more if the picking is done before maturity. Fibre quality is deteriorated by immature, pest and disease affected bolls (Mohtkar and Darade, 1989). Information of cotton quality, although helps all those involved in the cotton growing chain such as the farmers, the ginners, the traders and the textile mills but the maximum benefit goes to the textile mills. Main fibre quality parameters such as 2.5 per cent span length, uniformity ratio (UR), fineness, bundle strength and elongation play a vital role in assessing the quality of cotton used for preparation of blend for spinning in textile mills.

Keeping in view the above facts, an experiment was conducted at CCS Haryana Agricultural University, Hisar during *kharif,* 2010 with the objective to identify the strains having superior fibre quality parameters along with high seed cotton yield for their further use in breeding programme. Seventeen strains were grown in randomized block design in three replications including two released varieties of Haryana state (H 1117 and H 1226) as local check. The field soil was loamy in texture and free from salt. All cultural practices were followed to raise the healthy crop as per recommendations in the package practices. At the time of maturation, seed cotton samples of each strain were collected at random from second picking in each replication. All the samples were ginned carefully in the laboratory and the lint samples were tested for quality parameters by using standard methods (Sundaram *et al.*, 2002). The fibre characteristics namely 2.5 per cent span length, UR, micronaire value, bundle tenacity and elongation were examined on HVT Expert 1201(HVI). The seed cotton yield, boll weight and ginning percentage were also obtained as per standard methods. The statistical analysis of the data was done with the methods suggested by Panse and Sukhatme (1978). The fibre quality index (FQI), counts (C) and count strength product (CSP) were calculated by using the formulae Anonymous (2000). The same are defined as follows:-

Table 1. Yield and fibre characteristics of some promising strains of American cotton (*Gossypium hirsutum L*)

S.No.	Cotton strains	Seed cotton yield (kg/ha)	Boll weight (g)	Ginning outturn (%)	2.5 per cent span length (mm)	Uniformity ratio	Micronaire value (µg/in)	Bundle tenacity (g/tex)	Elongation (%)	FQI	Counts	CSP
1	SR1	2987*	3.8	34.8	25.4	50*	5	19.9	5.5	226	28	1993
2	H1300	2667*	4.1*	33	25.9	47	4.7	20.4	5.3	244	32	2025
3	SR2	2446	4.4*	35.2	28.3*	48	4.8	21.9*	5.3	283*	39*	2092*
4	H1316	3128*	4.7*	36.9*	25.4	49	4.7	19.4	5	227	28	1995
5	H1354	2695*	3.8	34.5	28.0*	50*	5.1	22.5*	5.5*	279*	39*	2085*
6	CCH724-5	2305	4.1	35.2	26.6	52*	4.8	21.6*	5.5*	262*	35*	2056*
7	H1451	2757*	4.2*	35.9*	25.3	50	5	20	5.5	226	28	1993
8	H1363	2490	3.9	34.8	26.8*	44	4.6*	19.3	5.1	232	29	2004
9	H422	2078	4.2*	35.4	26.8	43	5	19.8	5.3	237	30	2012
10	FYT/09-14	2490	4	35.8*	26.6	48	4.5*	20.3	5.3	255	34	2044
11	FYT/09-16	2284	3.7	35.3	28.5*	44	4.8	22.5*	5.4	293*	41*	2110*
12	FYT/09-17	2325	4	36.0*	27.9*	49	4.7*	21	5.5*	270*	37*	2070*
13	FYT/09-19	2243	3.7	35.8	26.5	50*	4.6*	21.2*	5.3	262	35	2056
14	H1435 NP48	2305	3.6	32.1	24.5	51*	5	20.2	5.7*	221	27	1985
15	H1462 NP47	2416	3.5	36.3*	25.2	50	4.7	20	5.5*	232	29	2004
16	H1117 (check)	2357	4	34.2	24.7	49	5.2	19.2	5.4	208	25	1962
17	H1226 (check)	2416	3.4	33.4	24.8	50	4.4*	19.9	5.4	235	30	2009
	General mean	**2493**	**3.9**	**35**	**26.3**	**48**	**4.8**	**20.5**	**5.4**	**247**	**32**	**2029**
	$SE_m\pm$	73	-	-	0.42	0.8	0.03	0.4	0.04	-	-	-
	CD (p=0.05)	212	-	-	1.21	2.3	0.1	1.16	0.11	-	-	-

*Top five strains

$$(1)\quad FQI = \frac{LS}{M^{1/2}}$$

$$(2)\quad C = 0.196\ FQI - 16$$

$$(3)\quad CSP = 1.74\ FQI + 1600$$

Where, L is 2.5 per cent span length (mm),
S is bundle tenacity (g/tex) at 3.2 mm gauge length and
M is micronaire value *i.e.* fibre fineness.

The differences within strains were statistically significant (Table 1) for all the fibre characteristics and yield traits. The strain H1316 was found significantly at top in seed cotton yield followed by strains SR1, H1451 and H 1354. Strain H 1316 was recorded maximum boll weight followed by strains SR2, H 1451 and H422 whereas ginning outturn was observed highest in strain H1316 followed by strains H1462NP47, FYT/09-17 and H1451. In fibre quality characteristics the strains FYT/09-16 and SR 2 were found significantly superior in 2.5 per cent span length followed by H1354 and FYT/09-17 in comparison to rest of the strains. Except strains H422, H 1363, FYT/09-16 and H 1300 all the strains categorized as excellent in length uniformity ratio. The strains SR1, H1451, H1422, H1435 NP48, H 1354 and H 1117 were emerged slightly course in micronaire value while rest of the strains was classified as average micronaire value (fineness). The significantly maximum bundle tenacity was observed for strains H 1354 and FYT/09-16 both were *at par* followed by SR2 and CCH724-5 when compared to others. The highest elongation (5.7 %) was observed for strain H1435 NP48 whereas all other strains recorded elongation between 5.0 to 5.5 per cent. Out of 17 strains under study the strains H1354, SR2, FYT/09-16 and FYT/09-17 were found to have best expression for quality parameters, but no single strain was found superior in all the characteristics. Some strains were superior for one character, while others emerged superior for other characters. However, based on predicted values of FQI, CSP and counts, the strains FYT/09-16 was at the top followed by SR2, H 1354 and FYT/09-17. The correlation between seed cotton yield and fibre quality index was found negative. Thus, there is a need to breed a variety having combined superiority for all fibre characteristics in a single genotype along with high yielding capacity. The hybrid cotton research programme may be effective to evolve such a genotype having best combination of all the quality characteristics. From the foregoing discussion it may be concluded that the strains FYT/09-16, H1354, SR2, FYT/09-17, H1316 and SR1 may be further utilized in such a breeding programme for the development of desirable genotypes.

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Effect of zinc and boron application on rainfed cotton in vertisol under semi arid agroecosystem

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ABSTRACT: A field study was conducted during 2009-2010 on the experiment initiated during 2006-2007 on vertisol to assess the effect of zinc and boron on soil fertility and productivity of rainfed cotton under semi arid agroecosystem. The results indicated that significantly higher cotton yield and uptake of N, P, K, Zn and B was observed with the combined application of zinc and boron along with 125 per cent RDF. The highest availability and actual gain of N, P and K was observed with integrated use of zinc and boron alongwith 125 per cent RDF. Zinc application alongwith 125 per cent RDF resulted in higher availability and actual gain of zinc in soil whereas, application of boron alongwith 125 per cent RDF resulted its higher availability and actual gain.

Key words: Boron, cotton productivity, nutrient uptake, zinc

India ranks first in area, third in production and second in consumption next to China (Awasya *et al.*, 2006). Vertisols and associated soils are the predominant soil group in the region. Productivity of cotton in this region is generally low because of erratic rainfall behaviour and imbalance fertilization. Intensive cropping with high yielding varieties of cotton may result in the deficiencies of secondary and micronutrients in the vertisol. The deficiency of micronutrients has become major constraints to productivity, stability and sustainability of soil (Yadav and Meena, 2009). Maintaining high yields through the use of high grade NPK fertilizers necessitates the use of secondary and micronutrients (Mamatha *et al.,* 2009). In Indian soils, zinc and boron ranks first and second deficient micronutrient**.**

Zinc and boron has a key role in plant metabolism such as photosynthesis, translocation, enzyme activation as well as water retention. In many instances, cotton production is constrained by soil fertility and its ability to accumulate nutrients (Dorahy *et al.,* 2004). Moreover, there has been little research on the effects of B and Zn on cotton crop especially under rainfed conditions in the semi arid tropical regions. Therefore, the present study was taken to assess the effect of zinc and boron application on cotton productivity, nutrient uptake and balance in vertisol under semi arid conditions.

MATERIALS AND METHODS

A field experiment was initiated during 2006-2007 to study the effect of zinc and boron application on cotton productivity in vertisol at Research Farm of AICRP for Dryland Agriculture, Dr. PDKV, Akola and the present study was undertaken during 2009-2010 to assess the soil fertility and cotton productivity. The initial soil characteristics (2006-2007) of the experimental field were calcareous ($CaCO_3$ - 9.3 %), slightly alkaline in reaction (pH 8.1), low in available nitrogen (175 kg/ha), medium in phosphorus (14.8 kg/ha) and high in potassium content (315 kg/ha). The zinc content was just near the critical limit (0.64 mg/kg) and deficient in boron (0.32 mg/kg).

The experiment was conducted in randomized block design with six treatments *viz.*, T_1-Control, T_2-(100%RDF), T_3-(125 % RDF), T_4-(125% RDF) + 25 kg zinc sulphate/ha,T_5-(125% RDF) + 5 kg borax/ha and T_6-(125% RDF) + 25 kg zinc sulphate/ha + 5 kg borax/ha replicated four times. The recommended fertilizer dose applied to cotton was 50:25:00 kg N, P_2O_5 and K_2O/ha. Full dose of phosphorus and half dose of N were applied through single super phosphate and urea as a basal dose. Remaining half dose of nitrogen was applied 30 days after sowing. The zinc and boron were applied in the form of zinc sulphate and borax as a basal, respectively.

Cotton PKV Rajat was sown at a distance of 60 x30 cm during the first week of July. The seed cotton and cotton stalk yield were recorded. The soil and plant samples from each plot were collected at the time harvesting, dried and ground. The soil samples were analyzed for available N, P and K (Jackson, 1973), available Zn (Lindsay and Norvell, 1978) and available boron (Keren, 1996). The plant samples were analysed using standard procedure for N, P, K, Zn and B (Piper, 1966, Lindsay and Norvell, 1978 and Bingham, 1982) and based on the nutrient content, nutrients uptake were computed.

RESULTS AND DISCUSSION

Seed cotton and stalk yield: The application of zinc and boron had significant improvement on seed cotton and cotton stalk yield (Table 1). The significantly higher (9.25 q/ha) seed cotton yield was recorded in treatment T_6 while lowest seed cotton yield (6.05 q/ha) was recorded under control. The seed cotton yield recorded in all treatments was found *at par* with each other except control treatment. Cotton is known to be sensitive to boron and zinc, and it responds quite favouarably to zinc and boron fertilization on Zn and B deficient soils (Soomro *et al.,* 2008). Mamatha *et al.,* (2009) also observed that application of zinc sulphate @ 25 kg/ha in Typic Chromustert significantly increased seed cotton yield over control.

Similarly higher (36.48 q/ha) cotton stalk yield was also recorded in treatment T_6 and lowest (18.59 q/ha) was recorded in control T_6 was found superior over rest of the treatments.

Nutrient uptake : The results indicated that the uptake of nutrients (NPK) by cotton was found significantly influenced by zinc and boron (Table 2). The highest total uptake of N, P and K (70.72, 20.16 and 66.67 kg/ha) was observed with combined application of zinc and boron along with 125 per cent RDF. The results further revealed that the individual application of zinc or boron along with 125 per cent RDF also recorded significant increase in the uptake of major nutrients (N, P and K). This clearly indicated that the use of either zinc or boron or both are beneficial for improving yield and uptake of major nutrients by cotton crop.

Table 1. Effect of zinc and boron on productivity of cotton

Treatments		Yield (q/ha)	
		Seed cotton	Cotton stalk
T_1	Control (No fertilizers)	6.05	18.59
T_2	RDF (100%) (50:25:00 NPK kg/ha)	8.13	31.21
T_3	RDF (125%) (62.5:31.25:00 NPK kg/ha)	8.41	31.57
T_4	RDF (125%) + Zn (25 kg zinc sulphate/ha)	8.99	32.27
T_5	RDF (125%) + B (5 kg Borax/ha)	9.01	32.97
T_6	RDF (125%) + Zn + B (25 kg zinc sulphate + 5 kg Borax/ha)	9.25	36.48
	SE (m) +	0.54	2.44
	CD (p=0.05)	1.64	7.35

Zinc and boron uptake: The results revealed that the uptake of zinc by cotton was significantly influenced by various treatments. The maximum total uptake of zinc (162.86 g/ha) by cotton was recorded by the combined use of zinc and boron along with 125 per cent RDF. Sakarvadia *et al.,* (2009) also observed that application of 50 kg $ZnSO_4$/ha resulted in maximum uptake of zinc by seed cotton and stalk.

The results further revealed that the boron uptake by cotton was found significantly influenced by various treatments. The significantly highest total boron uptake (127.10 g/ha) was observed due to the integrated use of zinc and boron along with 125 per cent RDF. Similar results were observed by Malewar *et al.,* (1992) who reported that the application of P and B rates of different levels to cotton significantly increased the uptake of boron in cotton.

Soil fertility and net gain of NPK: The data (Table 3) further revealed that higher available N, P and K was observed in T_6 followed by T_4 and T_5. This clearly indicated that when soils are deficient in zinc or boron, their individual application is beneficial for improving

Table 2. Effect of zinc and boron on uptake of nutrients by cotton

Treatments		N	P	K	Zn	B
		(kg/ha)			(g/ha)	
T_1	Control (No fertilizers)	34.13	7.35	28.45	72.94	50.15
T_2	RDF (100%) (50:25:00 NPK kg/ha)	54.30	13.86	49.24	124.85	85.94
T_3	RDF (125%) (62.5:31.25:00 NPK kg/ha)	61.31	15.83	53.46	124.85	91.63
T_4	RDF (125%) + Zn (25 kg zinc sulphate/ha)	61.52	16.05	53.78	141.94	100.26
T_5	RDF (125%) + B (5 kg Borax/ha)	65.00	16.41	59.06	140.43	109.42
T_6	RDF (125%) + Zn + B (25 kg zinc sulphate + 5 kg Borax/ha)	70.72	20.16	66.67	162.86	127.10
	SE (m) +	0.11	0.06	0.10	0.15	0.97
	CD(p=0.05)	0.34	0.18	0.29	0.23	2.94

soil fertility. Similar findings were also recorded by Sankaranarayanan *et al., (*2010).

The balance sheet of nutrients was calculated from the initial fertility status of soil (2006-2007) and final soil fertility status after the completion of the experiment (2009-2010). The data further revealed that maximum net gain (36.02 kg/ha) of N, P and K (36.02, 5.99 and 11.48 kg/ha respectively) was obtained in treatment receiving (125 %RDF + 25 kg $ZnSO_4$/ha) + 5 kg borax/ha. Whereas negative balance was observed in control which might be due to non addition of inorganic fertilizer to it and nutrient uptake by cotton.

Table 3. Effect of zinc and boron on soil fertility and net gain /loss of N, P and K

Treatments		Available nutrients			Net gain/ loss		
		N	P	K	N	P	K
T_1	Control (No fertilizers)	174.11	12.59	311.79	-0.89	-2.21	-3.21
T_2	RDF (100%) (50:25:00 NPK kg/ha)	187.32	15.9	315.78	12.32	1.1	0.78
T_3	RDF (125%) (62.5:31.25:00 NPK kg/ha)	191.22	17.91	321.24	16.22	3.11	6.24
T_4	RDF (125%) + Zn (25 kg zinc sulphate/ha)	199.43	19.61	324.29	24.43	4.81	9.29
T_5	RDF (125%) + B (5 kg Borax/ha)	202.69	18.06	325.4	27.69	3.26	10.4
T_6	RDF (125%) + Zn + B (25 kg zinc sulphate + 5 kg Borax/ha)	211.4	20.79	326.48	36.4	5.99	11.48
	SE (m) +	6.10	0.64	2.98			
	CD(p=0.05)	18.38	1.92	8.98			
	Initial status (2006-2007)	175	14.8	315			

Available zinc and boron and its gain or loss: The application of zinc sulphate @ 25 kg/ha alongwith 125 per cent RDF recorded significantly highest (0.84 mg/kg) zinc content of soil followed by conjoint use of zinc and boron alongwith 125 per cent RDF (0.83 mg/kg) which were found to be *at par* with each other (Table 4). The DTPA extractable zinc status in soil significantly increased with the application of increasing levels of Zn after the harvest of cotton (Khurana *et al.,* 1996).

The highest value of available boron (0.44 mg/kg) was recorded with the application of boron alongwith 125 per cent RDF followed by combined application of zinc and boron along with the 125 per cent RDF.

The highest gain of zinc was observed with the application of 25 kg zinc sulphate along with 125 per cent RDF. While, highest gain of boron was observed due to application of boron (5 kg borax kg/ha) alongwith 125 per cent RDF. The loss of these nutrients was observed in control treatment.

Thus, it can be concluded that combined application of zinc and boron along with 125 per cent RDF resulted in higher cotton productivity, nutrient uptake and residual soil fertility with higher nutrient balance in vertisols under semiarid agroclimatic conditions.

Table. 4. Effect of zinc and boron on availability and net gain/ loss of zinc and boron

Treatments	Available micronutrients (mg/kg)		Net gain/ loss (mg/kg)	
	Zn	B	Zn	B
T_1 Control (No fertilizers)	0.57	0.31	-0.07	-0.01
T_2 RDF (100%) (50:25:00 NPK kg/ha)	0.68	0.34	0.04	0.02
T_3 RDF (125%) (62.5:31.25:00 NPK kg/ha)	0.70	0.36	0.06	0.04
T_4 RDF (125%) + Zn (25 kg zinc sulphate/ha)	0.84	0.39	0.2	0.07
T_5 RDF (125%) + B (5 kg Borax/ha)	0.75	0.46	0.11	0.14
T_6 RDF (125%) + Zn + B (25 kg zinc sulphate + 5 kg Borax/ha)	0.83	0.44	0.19	0.12
SE (m) +	0.02	0.01		
CD(p=0.05)	0.06	0.04		
Initial status (2006-2007)	0.64	0.32		

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Irrigation strategy through cyclic use of saline and non-saline water for sustaining cotton (*Gossypium hirsutum* L)

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ABSTRACT : A field experiment was conducted during *kharif,* 2008 and 2009 at CCS Haryana Agricultural University, Hisar to design the irrigation strategy for cotton (*Gossypium hirsutum* L.) through cyclic use of saline and non saline water by considering growth, yield, water productivity and economics of the crop production. Pooled analysis of seed cotton yield indicated that maximum seed cotton yield was obtained with 2C:1S and minimum was registered with all saline water (7.8 dS/m EC) irrigation treatment. Considering seed cotton yield under 2C:1S as potential (100%), the relative yields recorded with all C, 1C:1S, 1S:1C, 2S:1C, 1S:RCW, 1C:RSW and all S treatments were 99.6, 96.5, 87.8, 73.4, 89.1, 85.2 and 68.1 per cent, respectively. The seed cotton yield has linear inverse relation with the salinity build up in the soil profile. During the first season, the maximum water productivity on the basis of irrigation water as well as total water use were 2.40 and 0.63 kg/m3 in 2C:1S treatment while their minimum values were 1.46 and 0.39 kg/m3 in all saline treatment. During these two seasons, maximum increase (15.4 per cent) in the average value of the ECe in the soil profile was observed in all saline irrigation treatment followed by 12.1 per cent in 2S:1C. The mean B:C ratio in both all canal as well as 2C:1S treatments was equal (1.45). Hence, it was concluded that in cyclic mode, use of canal water for irrigation at initial stages resulted in yield improvement by 24 to 45 per cent over saline water alone in cotton.

Key words : B:C ratio, conjunctive use, irrigation, saline water, upland cotton, water productivity

Cotton (*Gossypium hirsutum* L.) is an important commercial crop of India grown for fibre, fuel and edible oil. It is a potential source of employment for 60 million people who depend on its cultivation, trade and processing. It is cultivated in 10.3 mha with the average Indian productivity is 510 kg lint/ha. In India, nearly 65 per cent of the cotton is grown under rainfed conditions. Besides this, cotton is also grown extensively on salt affected soils. In India, 32-84 per cent of groundwater is rated poor (Minhas *et al.,* 1998). Although cotton is known to be one of the most salt tolerant field crops (Mass and Hoffman, 1977), indiscriminate use of such waters can significantly reduce plant size, boll weight, boll number and yield (Thomas, 1980).

Soil salinity is a major crop production constraint affecting about 77 million ha worldwide (5-7% of arable land). This problem has been observed to be getting further aggravated (Munns *et al.,* 2002). Arid saline lands require more attention compared to other regions as far as management of saline soil is concerned (Tanji, 1990). Various irrigation management strategies have been proposed for using saline and sodic waters for irrigation (Boumans *et al.*, 1988; Minhas *et al.*, 2003, Qadir and Oster, 2004). These strategies include blending and/or cyclic use of canal and saline waters. However, selection of a particular strategy needs site specific analysis and experimentation. Therefore, the present study was undertaken to design the irrigation strategy for cotton through cyclic use of saline and non saline water in cotton where canal supplies are inadequate and/ or are not assured, and evaluate the effect of such options on cotton growth, yield, water productivity, economics and salt buildup in the soil.

MATERIALS AND METHODS

A field experiment was conducted during *kharif,* 2008 and 2009 at the Research Farm, Department of Soil Science, CCS Haryana Agricultural University, Hisar. ($29^0 1_0$N and 75°46' E, at 215 m above mean sea level). The soil of the experimental field was sandy loam (Typic Ustochrepts) in texture, low in available nitrogen (92 kg/ha), medium in available phosphorus (11 kg/ha), high in available potassium (289 kg/ha) and slightly alkaline in pH (8.2). The bulk density of the soil profile 0-150 cm ranged from 1.46-1.52 mg/m3. The hydraulic conductivity decreased with soil depth and varied from 4.48 x 10-7 m/s to 9.56 x 10-7 m/s. The CEC ranged from 12.7 to 16.7 Cmol/kg soil in the profile. The experiment consisted of eight treatments as all canal irrigation (all C), 1 canal: 1 saline (1C:1S), 1 saline: 1 canal (1S:1C), 2 canal: 1 saline (2C:1S), 2 saline: 1 canal (2S:1C), 1 saline: rest with canal water (1S:RCW), 1 canal: rest with saline water (1C:RSW), all saline (all S) and was replicated thrice in a randomized block design. The size of each experimental plot was 4.5 m x 3.0 m. A buffer zone spacing of 1 m and 2.5 m was provided between plots and blocks, respectively. Cotton variety H 1226 was sown on May 07, 2008 and May 22, 2009 in rows of 67.5 cm apart. Recommended package of practices were followed for raising the crop. The total rainfall received during the entire croping seasons of 2008 and 2009 were 510 and 375 mm, respectively. Irrigation schedule was based on the recommendations for the non saline irrigated soils. The electrical conductivity of canal water and saline water were 0.4 and 7.8 dS/m, respectively. Recommended dose of 87.5 kg of nitrogen/ha, 30 kg of phosphorous/ha and 25 kg of zinc sulphate/ha were applied. The crop was harvested on November 05, 2008 and November 10, 2009. Soil samples were collected from 0-15, 15-30, 30-60, 60-90 and 90-120 cm layers at sowing and at harvest of the crop from each replication. The soil samples were air-dried, ground to pass through a 2 mm sieve and analyzed for electrical conductivity of the saturation extract (ECe).

RESULTS AND DISCUSSION

Growth and yield studies : The growth of the cotton assessed in terms of plant height which did not vary significantly (p=0.05) in all C, 1C:1S, 2C:1S and 1S:RCW treatments during the year 2008 and in all C, 2C:1S during year 2009 (Table 1). The maximum plant height was 181.22 and 161.33 cm in all canal irrigation during 2008 and 2009, respectively. Plant height was the lowest in all S treatment and a reduction of 17.8 and 18.8 per cent was observed during 2008 and 2009, respectively. The yield of the cotton assessed in terms of boll/plant which did not vary significantly (p=0.05) in all C, 1C:1S, 2C:1S treatments in year 2008 and in all C, 2C:1S in year 2009 (Table 1). The maximum boll/plant was 25 and 22 in all C treatment during 2008 and 2009, respectively. Boll/plant was the lowest in all S treatment and a reduction of 20.0 and 18.2 per cent was observed during 2008 and 2009, respectively. The yield of the cotton was assessed in terms of boll weight which did not vary significantly (p=0.05) in all C, 1C:1S, 2C:1S and 1S:RCW in year 2008 and in all C, 2C:1S in year 2009 (Table 1).

Data pertaining to seed cotton yield presented in Table 2 revealed that the yield was more significantly influenced in 2009 as compared to 2008. In year 2008, the yield was significantly (p=0.05) higher in all canal irrigation treatment in comparison to 2S:1C, 1C:RSW and all saline treatments. Whereas, in year 2009, the yield was significantly higher in all canal irrigation treatment in comparison to 1S:1C, 2S:1C, 1S:RCW, 1C:RSW and all saline treatments. All plant parameters and seed cotton yield during the second season was lower than the first season which may be due to low rainfall and salt build up in the soil. Pooled analysis of

Table 1. Growth parameters and yield attributes of cotton as affected by irrigation practices

Treatments/ Irrigation practices	Plant height (cm)			Boll/plant			Boll weight (g)		
	2008	2009	**Mean**	2008	2009	**Mean**	2008	2009	**Mean**
All C	181.22	161.33	**171.28**	25	*22*	**23.5**	3.16	3.02	**3.09**
1C:1S	169.22	145.00	**157.11**	22	19	**20.5**	3.05	2.92	**2.99**
1S:1C	167.66	141.00	**154.33**	21	19	**20.0**	2.92	2.83	**2.88**
2C:1S	179.33	151.00	**165.17**	26	21	**23.5**	3.13	3.00	**3.07**
2S:1C	154.00	137.67	**145.84**	19	19	**19.0**	2.92	2.85	**2.89**
1S:RCW	174.33	146.00	**160.17**	21	19	**20.0**	3.00	2.85	**2.93**
1C:RSW	169.06	135.00	**152.03**	22	19	**20.5**	2.95	2.82	**2.89**
All S	148.88	131.00	**139.94**	20	18	**19.0**	2.77	2.72	**2.75**
C. D. (p=0.05)	12.07	13.84		3.50	1.36		0.20	NS	

NS- None significant; C=Canal, S=Saline, RCW=Rest canal water, RSW=Rest saline water

Table 2. Effect of irrigation practices on seed cotton yield and economics of cotton

Treatments/ Irrigation practices	Seed cotton yield (t/ha)			Net returns (Rs/ha)			B : C ratio		
	2008	2009	**Mean**	2008	2009	**Mean**	2008	2009	**Mean**
All C	2.79	1.77	**2.28**	42920	18320	**30620**	1.62	1.27	**1.45**
1C:1S	2.74	1.67	**2.21**	41020	13720	**27370**	1.60	1.21	**1.41**
1S:1C	2.47	1.54	**2.01**	30760	7740	**19250**	1.45	1.12	**1.29**
2C:1S	2.88	1.70	**2.29**	46340	15100	**30720**	1.67	1.23	**1.45**
2S:1C	1.90	1.46	**1.68**	9100	4060	**6580**	1.14	1.06	**1.10**
1S:RCW	2.53	1.55	**2.04**	33040	8200	**20620**	1.48	1.12	**1.31**
1C:RSW	2.37	1.52	**1.95**	26960	6820	**16890**	1.40	1.10	**1.25**
All S	1.75	1.36	**1.56**	3400	-540	**1430**	1.05	0.99	**1.02**
C. D. (p=0.05)	0.334	0.21							

seed cotton yield indicated that maximum yield (2.29 t/ha) was obtained with 2C:1S and minimum (1.56 t/ha) was registered with all saline water irrigation. Considering seed cotton yield under 2C:1S as potential (100%), the relative grain yields (per cent of potential yield) recorded with all C, 1C:1S, 1S:1C, 2S:1C, S:RCW, C:RSW and all S were 99.6, 96.5, 87.8, 73.4, 89.1, 85.2 and 68.1 per cent, respectively. The seed cotton yield has linear inverse relation with the salinity build up in the soil profile. During the year 2008, the linear relationship was y = - 0.410 x + 4.330 with R^2 = 0.718 and in 2009, it was y = - 0.106 x + 2.076 with R^2 = 0.771 where y represents the seed cotton yield (t/ha) and x represents the ECe (dS/m). Negative coefficient of x indicates the decrease in the yield with the increase in salt contents in the soil profile. With the increase

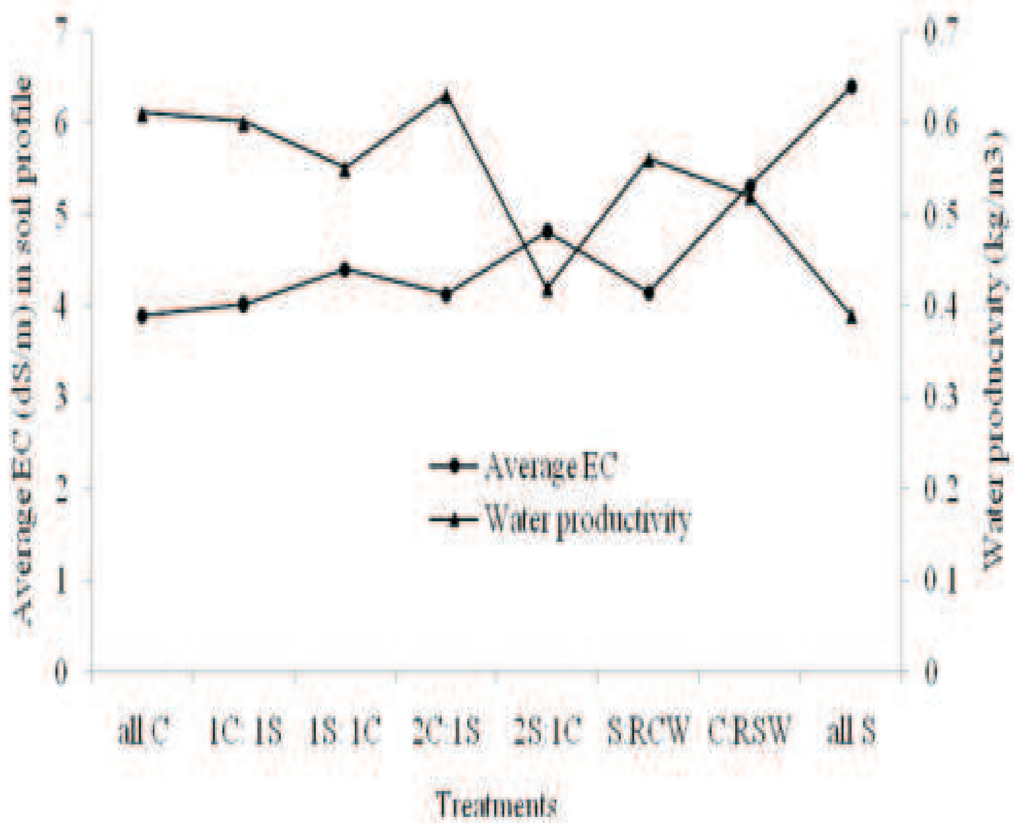

Fig. 1. Variation of water productivity (kg/m3) with average EC of soil profile in different treatments during 2008

Table 3. Water use and water productivity under different treatments by cotton crop during the year 2008 and 2009

Treatments	Amount of water use (cm)										Water productivity (kg/m3)					
	Soil moisture depletion		Effective rainfall/ canal		Post sown irrigation				Total water		For irrigation water		For total water use	
					Saline		use							
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
All C	7.9	8.2	25.7	18.1	12	18	0	0	45.6	44.3	2.33	0.98	0.61	0.40
1C:1S	8.1	8.4	25.7	18.1	6	12	6	6	45.8	44.5	2.28	0.99	0.60	0.38
1S:1C	7.6	7.8	25.7	18.1	6	6	6	12	45.3	43.9	2.06	0.86	0.55	0.35
2C:1S	8.2	8.5	25.7	18.1	12	12	0	6	45.9	44.6	2.40	0.94	0.63	0.38
2S:1C	7.3	7.5	25.7	18.1	0	6	12	12	45.0	43.6	1.58	0.81	0.42	0.33
1S:RCW	7.7	7.9	25.7	18.1	6	12	6	6	45.4	44	2.11	0.86	0.56	0.35
1C:RSW	7.8	8	25.7	18.1	6	6	6	12	45.5	44.1	1.98	0.84	0.52	0.34
All S	7.3	7.4	25.7	18.1	0	0	12	18	45.0	43.5	1.46	0.76	0.39	0.31

of salt content in soil, the osmotic effect increases, thus, extraction of water from the soil is adversely affected. Photosynthesis is the process in which plants combine water, carbon dioxide and light to make carbohydrates for energy. Due to moisture stress, photosynthesis is decreased, results poor growth and development. Thus, presence of more salts in soil negatively impacts the plant growth.

The most effective cyclic use strategy was 2C:1S and even this mode performed the best during 2008. Among the cyclic mode, the initial irrigation with good quality waters followed by saline water at a later stage performed better. This result is consistent with the observation that crops are more sensitive during the initial growth stages and their tolerance to salinity increases with the advancement of growth.

Water use and water productivity: The water use and water productivity of cotton crop under different treatments during year 2008 and 2009 was calculated on the basis of depletion of water from root zone, effective rainfall and post

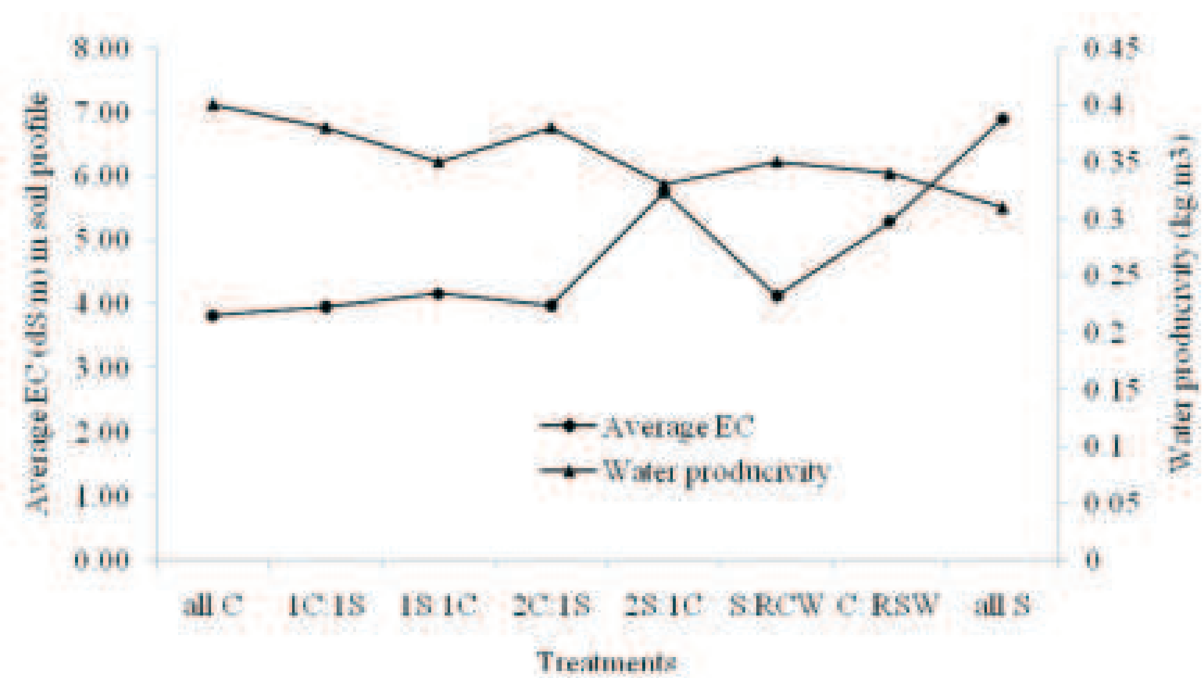

Fig. 2. Variation of water productivity (kg/m3) with average EC of soil profile in different treatments during the year 2009

sown irrigations (Table 3). The soil moisture depletion was relatively less in all saline irrigation in comparison with other treatments, whereas, it was maximum in 2C:1S treatment during two seasons. During the first season, the maximum water productivity on the basis of irrigation water as well as total water use was 2.40 and 0.63 kg/m3 in 2C:1S treatment while their minimum values were 1.46 and 0.39 in all S treatment (Table 3). During the second season, the maximum water productivity on the basis of irrigation water as well as total water use was 0.98 and 0.40 kg/m3 in all C treatment while their minimum values were 0.76 and 0.31 in all S treatment (Table 3). This variation in water productivity was registered due to low yield in the second season.

Salt build up: The initial (at sowing during 2008) and final (at harvest during 2009) salinity (ECe) profiles are depicted in Fig. 1 and 2. The initial salinity (ECe) distributions in the 0-15 cm layer was ranging from 3.84 to 5.16 dS/m and the average ECe of the soil profile down to 120 cm depth was ranging from 3.90 to 5.97 dS/m at the time of sowing of the crop during the first season. However, values increased in the range of 4.15 to 6.76 dS/m at the time of harvest of the crop in the same layer (0-15 cm). The increase in electrical conductivity of order 1.60 dS/m occurred between sowing and harvest in the saline (S) treatment. In the succeeding year, the initial salinity (ECe) distributions in the 0-15 cm layer was ranging from 4.20 to 7.62 dS/m and the average ECe of the soil profile down to 120 cm depth was ranging from 3.90 to 6.21 dS/m at time sowing of crop. However, ECe values increased in the range of 4.04 to 7.50 dS/m at the time of harvest of the crop in the same layer (0-15 cm) and its average value varied from 3.82 to 6.89 dS/m at harvesting in various treatments. Due to low rainfall in the second season over two years of experimentation resulted more number of irrigations, increase in the average value of the ECe by 12.1 and 15.4 per cent in 2S:1C and all S treatments and significant decrease in yield. The salt build up was maximum in the surface layers in all the saline water treatments which decreased with the depths continuously. The higher ECe near the soil surface may be due to upward movement of salts under the evaporative flux.

Economics: The data presented in Table 2 revealed that the seed cotton yield, net returns and B:C ratio were maximum under 2C:1S in year 2008 and all canal water irrigation in year 2009. The mean B:C ratio of these two years is slightly higher in 2C:1S as compared to all C treatment. Maximum net returns of Rs. 46340/ha in 2C:1S during the first season (2008) and Rs. 18320/ha in all canal water irrigation treatment during the second season (2009) were recorded (Table 2). Minimum net returns of Rs. 3400/ha and -540/ha were realized from all S treatment during 2008 and 2009, respectively. Water productivity and average salinity of the profile (0-120 cm) in different treatments during the two seasons are shown in Fig. 1 and 2. These figures revealed that the increasing level of salinity is inversely affecting the water productivity and its effect was maximum in all S treatment. With the application of initial irrigation with saline water, the water productivity declined significantly as compared with canal water irrigation. However, substitution of initial irrigation with canal water considerably increased the yields and monetary returns compared to saline water application.

Hence, it was concluded that in cyclic mode, use of canal water for irrigation at initial stages resulted in yield improvement by 24-45 per cent over saline water alone in cotton and reduced the salt build up considerably when compared with all saline water irrigation. The results provide very good information for the use of poor quality water in conjunction with scarce canal water for alleviating the adverse effect of salt buildup on the seed cotton yield through cyclic mode when canal water is applied at the initial stages and saline water at later growth stages.

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Comparative efficiency of weed control methods and nutrient losses in cotton under different ecosystems of Karnataka

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ABSTRACT : Weed competition in cotton resulted in extremely poor yield besides inferior lint quality. On farm trials carried out for 5 years under 2 different ecosystems existing in Belgaum and Dharwad districts of Karnataka revealed that effective weed management could be envisaged by herbicides or integrated methods as an alternative measure to the tedious and expensive traditional methods. Diuron @ 0.75 kg a.i./ha as pre emergence coupled with 2 inter culture at one month interval provided satisfactory weed control similar to 2 hand weeding followed by 2 intercultural operations. Weeds removed 5 to 6 times of nitrogen, 5 to 12 times of phosphorus and 2 to 5 times of potash of the crop at early stages and thus reduced the cotton yields from 54 to 85 per cent. For every 30 kg of dry matter produced by weeds there was one kg reduction in lint production.

Key words : Cotton, nutrients, weed control, yield

Cotton (*Gossypium hirsutum* L.) as a commercial crop has a significant role in agriculture, industrial development, employment generation and national economy of India. Millions of people from the fields to the factories get employment due to this crop. Cotton is also a major source of raw material for textile, animal and poultry feed and vegetable oil industry of the country. India covers about 29 per cent of total world cotton area and is the second largest producer of raw cotton. The productivity of cotton in the country is low as compared to the other cotton growing countries. There are many constraints, the weed infestation is one of the most serious. Cotton being wide spaced, heavily manured, often irrigated, coupled with slow growing habit at the initial stage and heavy weed population infestation immediately after emergence (Chaugle and Khare, 1961, Bishnoi *et al.* , 1993). The magnitude of problem assumed added dimension particularly with the prevalent practice of growing cotton after cotton; thus establishing a set of weed flora in the region (Gill and Brar, 1975). There are several pre emergence/pre planting and post emergence herbicides recommended for cotton and their adoption would help to remove initial weed competition in cotton. Of them, diuron is the most promising pre emergence herbicide (Das, 2008). Yield loss to the extent of 10 to 90 per cent was observed due to weed competition (Singh, 1993, Singh and Katti, 1972; Singh *et al.*, 1973, Robinson, 1976). With a view to evaluate the most effective and economic weed management practice and computing the nutrient losses in upland cotton, series of on farm trials were conducted at Belgaum and Dharwad.

MATERIALS AND METHODS

On farm trials were conducted for a period of 5 years from 2004-2005 to 2008-2009 at farmers fields in Belgaum and Dharwad. Treatments comprised of chemical, conventional and integrated methods of weed control. Three treatments *viz.,* application of diuron @ 0.75 kg a.i./ha as pre emergence, post emergence and a combination of pre plus post emergence constituted the chemical methods. The herbicides were sprayed with an Aspee backpack sprayer fitted with flood jet nozzle using a spray volume of 600 l/ha. Superimposing 2 interculture with *Khurpi* at monthly interval after pre emergent diuron comprised of integrated method, while 2 hand weeding superimposed by 2 interculture was adopted as the conventional method. These 5 treatments were compared with the unweeded control. The crop was raised as per the recommended Package of practices of University of Agricultural Sciences, Dharwad, except weed control treatments.

Biological composition and preponderance of weeds was recorded by visual assessment. Dry weight of weeds was recorded on 40 days after sowing. Composite sample obtained from the collected weed bulk was utilized for analyzing the N, P and K content by the standard methods. Simultaneously 5 random plants were uprooted, cleaned, dried and put to similar analysis. The crop was rainfed in both the locations. The soil was medium black at Dharwad and shallow at Belgaum. The available N, P and K were 124.6 and 127.8 kg/ha, 10.9 and 11.2 kg/ha, 175.4 and 181.2 kg/ha and 7.4 and 7.1 kg/ha, respectively in the soils of both sites.

RESULTS AND DISCUSSION

Weed spectrum : The biological composition and preponderance of weeds presented in Table 1 revealed that out of 10 monocot and 12 dicot weeds, *Cyperus*, *Cynodon*, *Paspalum* and *Euphorbia* were quite predominant. It was further observed that weed intensity in medium black soils of Dharwad was relatively higher than that at Belgaum. Visual observations indicated that grassy weeds predominated at the earlier stage while broad leaf weeds were abundant at the latter stage of crop growth.

Table 1. Biological composition and preponderance of weeds

Weed species	Belgaum		Dharwad	
	2005-2007	2007-2009	2005-2007	2007-2009
Monocot weeds				
Cynodon dactylon L. Pers.	A	A	A	F
Cyperus rotundus L.	F	F	F	O
Commelina benghalensis L.	A	A	R	R
Inebra arabica Jacq.	F	A	O	O
Echinochloa crusgalli (L.) Beauv	R	R	-	-
Eleusine indica (L.) Gaertn.	F	O	R	R
Paspalam scrobiculatum L.	A	A	O	O
Saccharum spontaneum L.	R	O	-	-
Setaria glauca Beauv	R	R	F	F
Panicum maximum Jacq.	A	A	F	F
Dicot weeds				
Alysicarpus rugosus (Willd) Dc.	A	A	O	R
Boerhavia diffusa L.	A	A	A	A
Celosia argentia L.	-	-	O	O
Convolvulus arvensis L.	R	R	R	R
Corchorus acutangulus Lam.	F	F	R	R
Digera arvensis Forsk.	F	F	O	O
Euphorbia hirta L.	A	A	A	R
Lagascea mollis Cav.	A	A	R	R
Phyllanthus niruri L.	R	R	A	A
Psoralea corylifolia L.	A	R	-	-
Xanthium strumarium L.	O	O	-	-

(A) Abundant, (F) Frequent, (O) Occasional, (R) Rare, and (-) Absent

Effect of weed management practices : Data presented in Table 2 revealed that both at Belgaum and Dharwad pre as well as post emergence application of diuron @ 0.75 kg a.i./ ha individually or in combination, though inflicted considerable mortality to the growing weeds, maximum suppression in terms of dry weight was recorded in the conventional or integrated method of weed control. Examplary effect of hand weeding plus interculture, marked by 90 to 98 per cent reduction in weed weight was comparable with diuron (pre emergence) combined with interculture treatment (77 to 96%) at Belgaum and Dharwad, respectively. Efficacy of hand weeding superimposed with interculture or diuron (pre emergence) has been reported by earlier researchers (Singh and Katti, 1972). Although solitary application of diuron as pre-emergence reduced the weed intensity substantially in the treated plots, its action as post emergence remained low at Belgaum. Contrary to this, post emergence spray of diuron at Dharwad performed comparatively better than pre emergence in three out of five years of study. Different trends noted at two locations may be attributed to the difference in the time of weed emergence and density. Efficacy of pre emergent herbicides over post emergence has been reported by Gidnavar *et al.,* (1976).

Data further revealed that supplementing pre emergence diuron with interculture was more promising than that with post emergence at either locations. Even though superimposing two interculture to prolong the longevity of diuron gave a satisfactory weed management in cotton and its substitution with post emergence spray of diuron appears to be vitally important under certain ecosystem. This view is well supported by similar effects observed in diuron + diuron (pre + post emergence) and diuron + interculture for three years at Belgaum and four years at Dharwad. Present studies confirm that diuron is a versatile herbicide in black cotton soils to knock down a broad spectrum of weeds in cotton.

Competition for nutrients : Data given in Table 3 clearly brought out the influence of weed persistence in various management

Table 2. Dry matter production of weeds (q/ha) as influenced by different weed management practices

Treatments	Belgaum					Mean increase over weedy check (%)	Dharwad					Mean increase over weedy check (%)
	2005	2006	2007	2008	2009		2005	2006	2007	2008	2009	
Diuron (Pre)	35.6	40.6	42.1	3.0	11.8	**70**	24.6	14.8	3.6	4.9	3.8	**86**
Diuron (Post)	42.0	52.2	60.6	25.5	15.4	**55**	15.0	5.0	13.7	3.9	14.4	**86**
Diuron (Pre fb post)	38.1	37.4	15.1	1.4	14.5	**74**	2.8	18.7	1.3	5.8	3.2	**91**
Diuron (Pre fb interculture)	6.0	35.0	40.0	7.0	10.6	**77**	3.5	3.9	1.4	3.8	2.6	**96**
H W fb Interculture	4.9	34.3	1.3	0.2	0.3	**90**	3.0	1.6	1.2	0.9	1.9	**98**
Weedy check	98.4	119.7	76.1	102.0	34.3	-	49.3	65.8	86.0	66	99.5	-

fb = following by; HW=hand weeding

practices and their consequent detrimental effects on nutrient utilization. As a result of negligible nutrient competition due to constant weed free condition observed in conventional management, cotton crop obtained maximum quantity of plant nutrients (NPK). Comparing this with other methods, it is clear that both chemical as well as integrated methods adequately curtailed the competition for nutrients. As against this, an intense growth of weeds in weedy check extended severe competition for N, P and K with the result that crop was deprived off by 5 to 6 times of nitrogen, 5 to 12 times of phosphorus and 2 to 5 times of potassium. Almost identical results have been reported by Rethinam and Sankaran (1979).

Yield response : Cotton yield had a direct bearing with the nutrient competition held by weeds in different management practices in two ecosystems. Mean yield of 545 kg/ha and 869 kg/ha, calculated on five years basis obtained in hand weeding + interculture (conventional method) exhibited the highest increase of 85 per cent and 67 per cent at Belgaum and Dharwad, respectively over weedy check (Table 4). These increases, however, were *at par* with those recorded in diuron + integrated method as 82 and 65 per cent. Consistently higher yields recorded both in conventional and integrated weed management practices as mainly due to long term weed control producing least dry weight of weeds and minimum competition for nutrients at critical stage. These results confirm the findings of Singh and Katti (1972).

Among the chemical methods, single spray of diuron as pre emergence gave relatively higher yields than that observed under post emergence application. This may be due to the delay caused in controlling weeds and non elimination of crop weed competition in the latter methods, which is evident from the higher dry weight of weeds at both the locations. Sequential spray of diuron as pre plus post emergence inflicted greater mortality to fresh growth of weeds and gave a season long weed control. Knocking down a wider spectrum of weeds ultimately resulted in a satisfactory crop growth and enhancement of yields in two ecosystems by 77 per cent at Belgaum and 63 per cent at Dharwad over the weedy check. High growth of weeds in weedy plots reduced the cotton yields significantly.

Table 3. Nutrient uptake by weeds and cotton plants during 2008 and 2009

Treatments	Year	Nutrient uptake (kg/ha)					
		Cotton			Weed		
		N	P	K	N	P	K
Chemical	2008	39.2	9.6	53.5	16.0	3.9	10.1
	2009	45.6	8.9	70.8	10.6	2.0	14.1
Integrated	2008	31.9	8.2	45.5	12.9	3.1	17.2
	2009	34.4	7.6	53.0	9.6	2.2	10.6
Conventional	2008	38.3	9.1	50.1	0.2	0.3	0.9
	2009	45.6	8.7	60.7	0.1	0.1	0.1
Weedy check	2008	13.8	3.8	15.0	67.4	19.8	29.5
	2009	14.0	3.2	19.7	75.0	38.0	109.1

Table 4. Seed cotton yield (kg/ha) as influenced by different weed management practices

Treatments	Belgaum					Mean increase over weedy check (%)	Dharwad					Mean increase over weedy check (%)
	2005	2006	2007	2008	2009		2005	2006	2007	2008	2009	
Diuron (Pre)	606	291	222	282	190	70	407	321	576	850	646	62
Diuron (Post)	217	199	143	290	122	54	208	408	610	833	414	58
Diuron (Pre fb post)	531	236	421	340	233	77	376	273	672	779	791	63
Diuron (Pre fb interculture)	1038	320	324	287	142	82	418	448	702	883	707	65
H W fb Interculture	1232	388	477	384	246	85	338	573	745	941	746	67
Weedy check	48	24	101	119	106		35	949	176	191	96	

fb = following by; HW=hand weeding

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Growth, yield and quality characteristics of *Bt* cotton (*Gossypium hirsutum L.*) as influenced by foliar feeding of nutrients

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Abstract : A field experiment was conducted at PAU, Regional Research Station, Faridkot during *kharif,* 2010 and 2011 to study the effect of foliar application of nutrients on growth, yield and quality characteristics of *Bt* cotton. There were 10 foliar treatments (*viz.,* T_1- Control, T_2-Boron (0.1%), T_3-$ZnSO_4$ (0.5%), T_4-$MnSO_4$ (1.0%), T_5-$MgSO_4$ (1.0%), T_6-$MgSO_4$ (1.0%) + $ZnSO_4$ (0.5%), T_7-$FeSO_4$ (0.5%), T_8-$FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%), T_9-Urea (2%) at flowering and DAP (2%) at boll development stage and T_{10}-KNO_3 (2%) twice at flowering and boll development stage). Pooled data indicated highest seed cotton yield (3439 kg/ha) (T_6) as compared to other treatments primarily due to improved number of sympods (22.6) and bolls/plant (54.0). This resulted in an increased seed cotton yield of 45.2 per cent over the control. Boll weight also improved significantly with application of $MgSO_4$ (1.0%) + $ZnSO_4$ (0.5%) as compared to control and Boron (0.1%) though statistically *at par* with rest of the treatments. Pooled data indicated significantly enhanced lint and seed yield by foliar application of nutrients. Higher net returns of Rs 112645/ha were recorded with $MgSO_4$ (1.0%) + $ZnSO_4$ (0.5%) closely followed by application of sole $MgSO_4$ (1.0%) (Rs.104873/ha). Significantly improved B:C ratio with the application of $MgSO_4$ (1.0%) + $ZnSO_4$ (0.5%) over that of control also indicated its superiority in improving yield contributing characters and seed cotton yield.

Key words : B:C ratio, leaf reddening, net returns, seed cotton yield, sympods

Bt cotton is being predominantly cultivated in Punjab owing to its associated benefits. However, certain physiological problems have also mushroomed with *Bt* cultivation, of which reddening of leaves also called "*Lalya*" is a prime malady. Micronutrients play an important role in changing growth and physiological characteristics of cotton. For adequate plant growth and production, although micronutrients are needed in small quantities however, their deficiencies cause a great disturbance in the physiological and metabolic processes in the plant. To exploit the role of various micronutrients in alleviation of leaf reddening and seed cotton yield, a field experiment was conducted for two years to draw conclusive inferences.

MATERIALS AND METHODS

The experiment was conducted during *kharif,* 2010 and 2011 at PAU, Regional Research Station, Faridkot (30 ^{0} 40'N and 74 ^{0} 44 'E) in south western zone (Zone IV) of Punjab situated at 200 m above MSL. The soil of the experimental field was loamy in texture, slightly alkaline (pH 8.5), normal EC (0.43 mmhos/cm), medium in O.C (0.48 %), low in available P (7.5 kg/ha) but high in available K (750 kg/ha). The experiment was conducted with 10 foliar treatments of nutrients (T_1-Control, T_2-Boron (0.1%), T_3-$ZnSO_4$ (0.5%), T_4-$MnSO_4$ (1.0%), T_5-$MgSO_4$ (1.0%), T_6-$MgSO_4$ (1.0%) + $ZnSO_4$ (0.5%), T_7-$FeSO_4$ (0.5%), T_8-$FeSO_4$ (0.5%)+ $ZnSO_4$ (0.5%), T_9-Urea (2%) at flowering and DAP (2%) at boll development stage and T_{10}-KNO_3 (2%) twice *i.e.* at flowering and boll development stage in complete randomized block design with three replications. *Bt* hybrid MRC 6304 was selected for the studies because of relatively occurrence of prominent leaf reddening symptoms as compared to other hybrids at farmer's fields was sown in first fortnight of May by dibbling 3-4 seeds/hill which were later thinned to one seedling/hill. The recommended fertilizer dose (*i.e* 75 kg N, 30 kg P_2O_5 and 50 kg K_2O/ha) was applied as per package of practices. Foliar sprays of all the nutrients were applied at two growth stages *i.e.* flowering and boll development. Data on growth, leaf reddening (%leaves), yield attributes and quality parameters were recorded from 5 randomly selected plants in each treatment plot. Seed cotton yield (q/ha) was calculated from whole plot. All other recommended production and protection practices were uniformly applied. The rain received during the crop season was 406.8mm and 587.5mm for 2010 and 2011, respectively. The data were recorded on plant height (cm), bolls/plant, boll weight (g), seed cotton yield (kg/ha), ginning outturn (%), lint index and seed index was analyzed statistically as per the standard procedure proposed.

RESULTS AND DISCUSSION

Growth parameters: The pooled data on various growth parameters such as plant height, leaf area index (LAI) and monopods/plant indicated non significant differences except for significant improvement in LAI values and sympods/plant of some foliar treatments over control (Table 1). Leaf reddening symptoms could be recorded only for year 2010 because of its non appearance during 2011 owing to comparatively better rain fall and more rainy days particularly during early growth (Table 1). T_1 exhibited maximum leaf reddening (15.1%) followed by T_7 (8.6%), T_2 (15.1%), T_4 (8.1%) and T_9 (7.8%) and other treatments. Though, leaf reddening appeared in all the treatments but for those involving magnesium sulphate *i.e* T_5 and T_6 leaf reddening symptoms were lowered to a considerable extent. LAI was significantly affected by foliar application of nutrients. Combination of $MgSO_4$@ (1.0%) + $ZnSO_4$ @ (0.5%) had highest LAI (6.00) than rest of the treatments. It was significantly better than T_1, T_4, and T_9 and T_{10} treatments, respectively. Sankaranarayanan *et al.,* (2010) has also reported significant and positive influence of $MgSO_4$ on leaf area index sympods/plant was also significantly affected by foliar application of nutrients. Significantly improved sympods/plant (22.6) was recorded with application of $MgSO_4$ (1.0%) + $ZnSO_4$ (0.5%) than control (15.3) and $ZnSO_4$ (0.5%) (19.5) though *at par* with rest of the treatments.

Seed cotton yield and yield parameters: The data in the Table 1 indicated significant effect of foliar treatments on seed cotton yield, number of bolls and boll weight. The pooled data revealed highest seed cotton yield (3439 kg/ha) with application of *i.e* T_6 though *at par* with T_5 but significantly better than all other treatments. Eweida *et al.*, (1979) reported significantly increased seed cotton yield with the foliar application of magnesium and zinc separately and also with combination of zinc sulphate and magnesium sulphate. Application of Zn (Soomro *et al.*, 2000, Zakaria *et al*, 2008) and magnesium sulphate significantly increased seed cotton yield/plant as compared with the untreated control. Foliar sprays of $MgSO_4$ (0.5%) at 60, 75 and 90 days after planting raised the seed cotton yield by more than 18 per cent in comparison to control. The increased seed cotton yield for T_6 treatment over the other treatments was primarily due to less leaf reddening (%) which further improved bolls/plant (54.0) and boll weight. Foliar application ($MgSO_4$ (1.0%)+ $ZnSO_4$ (0.5%) increased the boll weight and seed cotton yield by 19.2 and 45.2 per cent compared with the control (3.94 g and 2368 kg/ha), respectively. The least seed cotton yield was observed under control (T_1).

Quality parameters: The pooled data indicated that important quality parameters *i.e.* ginning outturn (GOT), halo length and seed index of *Bt* cotton (Table 2) were not significantly influenced by foliar application of nutrients. However, Sankaranarayanan *et al.,* (2010) reported that specific fibre quality parameters, such as ginning per cent and uniformity ratio were significantly enhanced by micronutrient fertilization. The pooled value for lint yield was also significantly higher (1166.7kg/ha) under combined application of T_6 than all other treatments except T_5. Seed yield was also significantly enhanced by combination of $MgSO_4$ (1.0%)+ $ZnSO_4$ (0.5%) as compared to other treatments but was *at par* with T_5 treatment. Zakaria *et al.,* (2008) found that application of Zn significantly increased seed cotton and lint yield/ha as compared to control.

Water productivity and monetary parameters: Improved water productivity indices in favour of T_6 and T_5 also indicated its superiority over other treatments (Table 1). Besides reduction of leaf reddening , improved yield contributing characters assisted in realizing higher net returns (112645 Rs/ha) and B:C ratio (4.51) with application of T_5 and T_6 than rest of the treatments .

Table 1. Effect of different foliar treatments on growth parameters, yield and yield attributing characters and monetary parameters of *Bt* hybrid MRC 6304

Treatments	Pooled Mean (2010 and 2011)				Leaf reddening in 2010 (%)	Pooled mean of seed cotton yield and yield characters and econmics (2010 and 2011)						
	Plant height (cm)	LAI	Monopods/ plant	Plant stand/ ha		Sympods/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield (kg/ha)	Net Returns (Rs/ha)	B: C ratio	Water Produ-ctivity (g/m^3)
T_1	112.3	5.37	1.0	19458	15.1	15.3	38.5	3.94	2368	72514	3.23	491.5
T_2	122.7	5.63	1.0	19449	8.1	20.8	47.5	4.28	2546	79175	3.47	527.8
T_3	120.6	5.93	1.1	20027	7.2	19.5	48.6	4.45	2957	94570	3.97	611.2
T_4	122.8	5.41	1.1	19253	8.1	21.5	47.1	4.67	2710	85341	3.68	559.8
T_5	128.3	5.97	1.2	18631	4.1	20.9	52.3	4.65	3231	104873	4.29	668.5
T_6	119.0	6.00	1.2	19449	4.0	22.6	54.0	4.70	3439	112645	4.51	710.8
T_7	120.7	5.65	1.2	19958	8.6	20.8	47.6	4.50	2728	85998	3.71	562.8
T_8	120.6	5.60	1.3	19547	6.9	20.0	45.0	4.65	2982	95538	4.00	616.1
T_9	117.8	5.26	1.2	19792	7.8	20.0	47.3	4.44	2774	87734	3.76	574.1
T_{10}	120.0’	5.41	1.2	19370	7.0	21.1	50.1	4.64	2935	93780	3.95	605.7
CD (p=0.05)	NS	0.5	NS	NS	-	2.7	5.3	0.34	377	14167	0.45	76.8

Table 2. Effect of different foliar treatments on physical parameters, lint and seed yield of MRC 6304 hybrid

Treatments	Pooled Mean (2010 and 2011)				
	GOT (%)	Halo length (mm)	Seed index (g)	Lint yield (kg/ha)	Seed yield (kg/ha)
T_1	33.4	28.8	9.1	791.0	1577.8
T_2	33.6	29.2	9.5	855.2	1691.2
T_3	34.2	28.2	9.3	1013.2	1943.7
T_4	33.8	28.1	9.4	917.5	1793.3
T_5	34.0	27.7	9.5	1099.9	2131.8
T_6	33.9	28.0	9.7	1166.7	2272.3
T_7	33.4	28.7	9.1	914.2	1814.1
T_8	34.4	27.9	9.2	1027.3	1955.4
T_9	34.0	27.8	9.2	946.5	1828.1
T_{10}	34.6	28.5	9.4	1018.9	1917.0
CD (p=0.05)	NS	NS	0.4	136.2	244.8

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Physiological manipulations of cotton productivity with Stance 110SC in vertisols under rainfed conditions

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ABSTRACT : In the present study, Stance 110 SC, a combination product of Cyclanilide and Mepiquat chloride in different concentrations was compared with other recommended growth retarding chemicals for cotton *viz.,* Cyclanilide, Mepiquat chloride and Chloromequat chloride for its performance on cotton. Due to all the growth regulator treatments, the plant growth retarded, number of sympodial branches, bolls/plant and the harvest index increased. Significant yield improvement was achieved with the the foliar application of Stance 110SC @225ml/ha followed by Stance 110 SC @ 200 ml/ha without any deleterious effect on fibre quality. The increased yield was associated with significant increase in sympodial, boll/plant, increased boll weight and harvest index. In addition, no phytotoxicity symptoms were noticed on cotton due to foliar spray of Stance 110 SC either at 225ml/ha or at 200ml/ha.

Key Words : Boll, cotton, Stance110SC

Cotton acreage in India has been continuously rising for the last four years and it touched a record 12.2 million ha in 2011-2012 season (Anonymous, 2012). The production of cotton in India for the year 2011-2012 was 345 lakh bales. Some common production constraints like boll fall due to high temperature, moisture stress, and absence of winter rains/dews affected India's cotton production. The production of cotton can be increased by using plant growth regulators (Singh *et al.,* 2009). Stance 110 SC is a plant growth regulator (PGR), composed of mepiquat chloride, which is used in most cotton PGRs, and a new chemical, cyclanilide, a presumed auxin transport inhibitor. Mepiquat chloride reduces internodal growth by inhibiting the production of gibberellic acid, the hormone responsible for internodal elongation. Cyclanilide is a chemical that shares the characteristics of TIBA (2,3,5-triiodobenzoic acid), a known auxin transport inhibitor (Marianne *et al.*, 2006). Auxin is a hormone that is necessary to allow gibberellic acid to be metabolized from an inactive form (GA20) to an active form (GA1). The inhibition of auxin transport may not inhibit all GA biosynthesis within the plant, but it does reduce internodes' growth within the plant. The combination of these two chemicals offers a new method of controlling vegetative growth in cotton, and may offer a quicker response in cotton. Stance 110 SC has other physiological effects on cotton that might influence the production and harvest methods, quality and yield. Stance 110SC plant regulator offers cotton growers a more convenient and effective tool for manipulating cotton plant in more productive way. Its dual mode of action controls growth, promotes earliness, increases fruit retention, reduces boll rot and results in a more manageable crop.

MATERIALS AND METHODS

A field experiment was laid out in randomized block design with seven treatments and three replications during *kharif,* 2010-2011 and 2011-2012 at Regional Agricultural Research Station Lam, Guntur. The location is having sub humid tropical climate and is situated at 16.18^0N latitude, 80.29^0N longitude and at 31.5 MSL altitudes. The soil of the experimental area is clay loam in texture, slightly alkaline with pH 7.8, low in organic carbon content (0.38%), low in available nitrogen (188kg/ha), medium in available phosphorus (28kg/ha) and high in available potassium. The objective of the study is to evaluate Cyclanilide 22 + Mepiquate Chloride 88 – 110 SC (Stance 110 SC) for plant growth management, Boll retention and improvement in yield of cotton in black cotton soils under rainfed conditions. The variety used for the study is Mallika BG II which is an *intra hirsutum* hybrid with medium maturity and tall plant growth. The net plot area was 4.8 x 6 m^2.

The experiment was sown with 105 x 60 cm spacing. The average rainfall is 850mm with 45-50 rainy days. There were 7 treatments *viz.*, T_1- Control, T_2- Cyclanilide 22 + Mepiquate Chloride 88 : 110 SC(Stance 110 SC) 175 ml or g /ha,T_3 - Cyclanilide 22 + Mepiquate Chloride 88 : 110 SC(Stance 110 SC) 200 ml or g /ha,T_4 - Cyclanilide 22 + Mepiquate chloride 88 : 110 SC(Stance 110 SC) 225 ml or g /ha,T_5- Cyclanilide (2.8% SC) 177 ml or g /ha,T_6 - Mepiquate chloride (5% AS) 396 ml or g /ha,T_7 – Chlormequate chloride (50 % SL) (Lihocin 50 SL) 60 ml or g /ha. The date of planting was on 12.07.2010 and 22.07.2011.Three foliar sprays were given at 15 days interval from 45DAS. The crop was observed for phytotoxicity symptoms like chlorosis, necrosis, leaf epinasty and hyponasty symptoms. The data on number of squares, flowers and bolls/plant before and after spraying of each foliar spray was collected in ten tagged plants. The data on seed cotton yield and yield attributes like sympodia and bolls/plant, boll weight was recorded at the time of harvest. Harvesting was done on 3.12.2010 and 9.12.2011.Seed cotton samples were analysed for fibre quality parameters with High Volume instrument available with CIRCOT laboratory of Regl. Agricultural Research Station, Lam, Guntur. The data was analysed statistically by following the standard procedures.

RESULTS AND DISCUSSION

No phytotoxicity symptoms were noticed due to the foliar application of growth regulators at different stages of crop growth. Significant reduction in plant growth and increase in squares, flowers and bolls/plant were noticed from 15 days after second foliar spray due to all the treatments. In the present study, due to the application of Stance 110 SC and other growth regulators except T_5 the plant height was reduced. This is due to the ability of Stance to reduce internodal length. The results are in conformity with the findings of Szoeke (1995) who stated that the reduction in plant height was due to reduced inter nodal length. Mepiquat chloride suppresses the production of the plant growth hormone, gibberellic acid, which is a growth stimulant that induces cell elongation and the suppression of gibberellic acid results in decreased cell elongation and an overall elongation of stems and branches.

The number of squares, flowers and bolls/ plant were more in all the growth regulator treatments, when compared to control. When the data on final seed cotton and yield parameters was recorded, significant differences were noticed in boll/plant, boll weight and harvest index due to T_4 and T_3 indicating higher retension of bolls/plant in these treatments. and

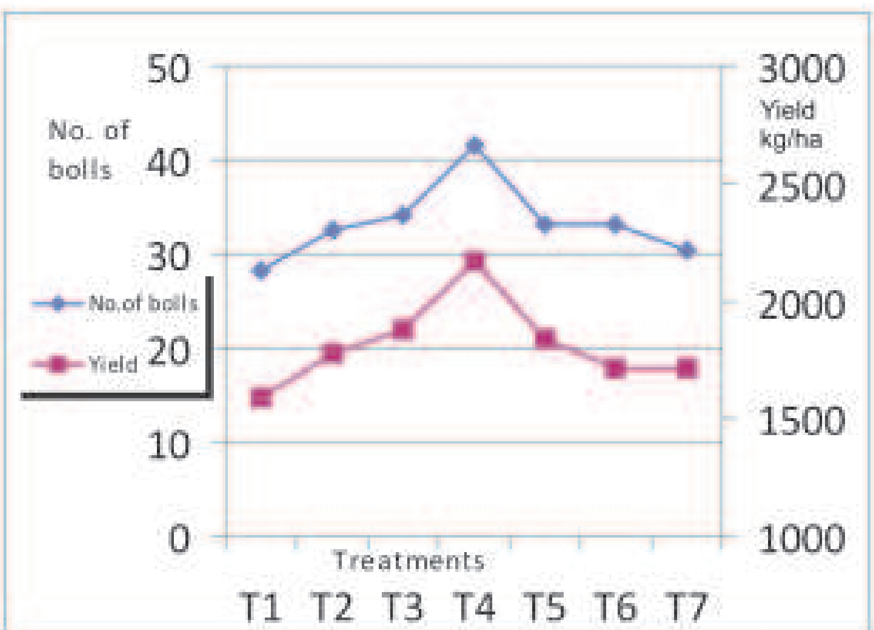

Fig. 1

Table 1. Effect of Stance on plant growth parameters at 45DAS

Treatments	Plant height	Squares/ plant	Flowers/ plant
T	56.27	14.00	0.73
T^1	57.53	14.00	0.53
T^2	55.47	14.13	0.67
T^3	55.53	13.27	0.6
T^4	52.73	13.07	0.87
T^5	59.2	14.53	0.73
T^6	57.73	12.67	0.73
^{7}SEm +	3.804	1.473	0.297
CD (p= 0.05)	NS	NS	NS
CV (%)	11.7	18.7	74.1

Randy *et al.*, (2012) and (Reddy *et.al.,* 1996) reported that the growth regulator mixture containing Mepiquat chloride reduces the apical growth and increases the lateral shoot formation. Plant growth regulators like Stance 110SC have the potential to promote crop earliness, square and boll retention, higher nutrient uptake, and keeping vegetative and reproductive growth in harmony to improve lint yield and quality (Bonner, 1993 and Prakash Koler, 2008). Research has shown that there was a tendency for more bolls to develop on the first two fruiting positions and on the lower 10 reproductive branches due to growth retardant spray following treatment. The present study results are in conformity with the findings of the above. Foliar spraying of Stance 110 SC, a combination product of Cyclinilide and Mepiquat chloride at early stages reduced the plant height, increased the number of branches and the early formed sympodial branches produced more number of bolls/plant.

Of all the growth regulator treatments tried, significantly higher seed cotton yield was achieved through the foliar application of T_4 and T_3 and this increased seed cotton yield was associated with higher number of sympodia, bolls/ plant, harvest index and boll weight.

Regarding fibre quality, no significant variation was noticed due to foliar application of growth regulator treatments imposed in the present study.

From the experimental results, it is concluded that foliar application of Stance 110 SC @ 200ml/ha can be done three times from 45DAS onwards at 15 days interval with no phytotoxic, symptoms increased the seed cotton significantly without causing any deleterious effects on fibre quality. Fig. 1 shown the graphical representation of the effect of treatments on number of bolls and yield of cotton.

Table 2. Effect of Stance on plant growth parameters 15 days after 1st foliar application (60DAS)

Treatments	Plant height (cm)	Square/ plant	Flowers/ plant	Bolls/ plant	Sympodia/ plant
T	61.77	14.37	1.00	0.47	12.00
T^1	62.00	14.37	1.33	0.73	21.00
T^2	55.60	16.67	1.17	1.00	15.67
T^3	56.33	17.33	1.33	0.27	17.00
T^4	53.33	15.00	0.97	0.47	19.00
T^5	59.67	14.83	0.97	0.67	16.00
T^6	58.67	14.17	0.97	0.60	20.67
^{7}SEm+	3.314	1.040	0.162	0.364	1.10
CD (p= 0.05)	NS	NS	NS	NS	3.11
CV (%)	9.9	11.8	25.4	105.0	10.10

Table 3. Effect of Stance on Plant growth parameters 15 days after 2nd foliar application (75DAS)

Treatments	Plant height (cm)	Squares/ plant	Flowers/ plant	Dry matter production/ plant (g)	Sym-podia/ plant
T_1	97.70	33.73	4.53	207	20.00
T_2	82.93	32.67	4.53	157	25.33
T_3	80.80	36.73	5.47	136	25.66
T_4	82.47	45.67	6.13	103	27.66
T_5	84.67	34.47	5.27	204	25.00
T_6	82.00	34.27	4.60	203	24.33
T_7	81.93	33.93	4.30	243	22.66
SEm+	2.509	2.055	0.26	12.72	1.08
CD (p= 0.05)	7.731	6.331	0.819	39.19	3.35
CV (%)	5.1	9.9	9.2	12.80	17.7

Table 4. Effect of Stance on plant growth parameters 15 days after3rd foliar application (90DAS)

Treatments	Plant height (cm)	Squares/ plant	Flowers/ plant	Bolls/plant
T_1	110.60	9.87	3.00	28.30
T_2	93.00	10.30	3.33	32.53
T_3	94.67	17.97	5.00	34.20
T_4	86.33	27.17	4.67	41.53
T_5	106.00	13.07	4.33	33.20
T_6	98.00	12.07	4.00	33.07
T_7	97.00	10.27	4.00	30.40
SEm+	1.84	0.84	0.329	2.167
CD (p= 0.05)	5.68	2.60	1.015	6.678
CV (%)	3.3	10.2	14.1	11.3

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Table 5. Effect of Stance on yield and yield attributing componentsn and fibre quality characters

Treatments	Boll weight (g)	SCY/ plant (g)	Dry weight/ plant(g)	Harvest index	SCY (kg/ha)	Lint index	Seed index	GOT (%)	2.5 per cent span length (mm)	Bundle strength (g/tex)	Micronaire (10^{-6} g/inch)	Elongation (%)	Uniformity ratio
T_1	4.29	75.33	259	0.345	1591	4.60	10.57	36.66	30.47	23.30	4.21	6.27	47.00
T_2	4.42	87.16	244	0. 373	1776	4.76	10.05	39.33	30.88	23.77	4.39	6.30	45.47
T_3	4.89	95.00	245	0.390	1879	4.82	9.66	43.17	31.29	23.37	4.35	6.23	46.43
T_4	4.98	106.66	237	0.408	2170	5.15	10.14	43.83	30.64	24.27	4.26	6.37	46.13
T_5	4.68	88.83	254	0.368	1838	5.14	10.00	42.00	30.20	23.13	4.31	6.30	48.23
T_6	4.46	89.66	255	0.378	1710	4.83	9.66	42.67	29.72	21.90	4.39	6.23	46.20
T_7	4.29	85.50	245	0.368	1709	4.67	10.42	37.33	29.70	22.57	4.38	6.27	47.30
SEm+	0.135	3.839	3.76	0.012	88.54	0.123	0.28	1.76	0.62	0.65	0.23	0.10	0.95
CD (p= 0.05)	0.390	11.08	10.90	0.034	255.63	0.354	NS	5.1	NS	NS	NS	NS	NS
CV (%)	7.2	10.5	3.7	7.7	12.0	6.2	6.7	10.6	3.5	4.9	9.5	2.8	3.5

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Performance of cotton cultivars under salinity condition

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ABSTRACT: An experiment was conducted to study the effect of salinity on seven cultivars of cotton *viz.,* H 1098 i, HD 123, RCH 134*Bt*, KDCHH 9810BG II, SOLAR 72BG II, GRAND BG II and NCS 856BG II. The seeds were sown at four salinity levels in micro plots of Soil Department, CCS HAU, Hisar during *kharif* seasons. Increasing salinity of irrigation water generally above 2.5 dS/m led to a gradual decrease in seed cotton yield. An irrigation water of 7.5 dS/m led to ~47 per cent decrease whereas a level of 5.0 dS/m led to ~30 per cent reduction in cotton production. On the basis of experiment findings *Bt* hybrids RCH 134 *Bt* followed by KDCHH 9810BG II performed better in terms of yield whereas *desi* cotton cultivar HD 123 gave the poorest performance. Single boll weight generally decreased with increase in the level of salinity in all the cultivars but RCH134*Bt* showed relatively lesser reduction. Fresh weight of plants at the time of harvesting was not affected by salinity levels. Physiological parameters like rate of transpiration generally decreased with increasing level of salinity in six cultivars except KDCHH 9810BG II. Rates of assimilation consistently decreased with increasing salinity levels in H 1098 i and GRAND BG II whereas RCH 134*Bt* and NCS 856*Bt* II showed opposite trend upto 5.0 dS/m. Even the most sensitive variety HD 123 did not show any appreciable decrease even upto the highest level of salinity (7.5 dS/m). Stomatal conductance generally decreased under saline conditions in most of the varieties studied indicating that this was not the major factor affecting rates of assimilation or transpiration under saline conditions. Internal CO_2 concentration generally increased due to salinity except in HD 123 and NSC 856*Bt* II where it consistently decreased with increasing level of salinity. On the basis of results obtained from the experiment it is revealed that RCH 134*Bt* is tolerant to salinity followed by KDCHH 9810BG II whereas HD 123 (*desi* cotton) is highly sensitive to salinity.

Key words: Cotton, photosynthesis, salinity, transpiration, yield

Cotton is the world's most important fibre crop and the second most important oilseed crop. The effects of salinity stress on cotton growth and physiology is a prerequisite to successful salinity management and control. Salinity effects on cotton may vary with the growth stage, time and extent of salinity stress. Excessive salt in the soil leads to a sequence of physiological and biochemical metabolic disorders in cotton crop mainly as a consequence of osmotic effects (dehydration), nutritional imbalance and toxicity of salt ions (Na^+ and Cl^-) which finally decreases plant growth, lint yield and quality. Salinity induced injury also include the changes in allocation patterns such as an increased allocation to root at the expense of leaf growth (Bhattarai and Midmore, 2009). Although cotton is classified as one of the most salt-tolerant crop and considered as a pioneer crop in reclamation of saline soils, its growth, yield and fibre quality are negatively affected by excessive salts in the soil (Qadir and Shams, 1997; Higbie *et al.,* 2010). In general, soil salinity delays and reduces germination and emergence, decreases cotton shoot growth, and may finally lead to reduced seed cotton yield and fibre quality at moderate to high salinity levels (Khorsandi and Anagholi, 2009). Biological or economic yield reduction is the main effect of salinity at the whole-plant level, and is usually attributed to various physiological and biochemical processes at the cellular or molecular levels (Meloni *et al.,* 2003). Although salinity effects occur at almost all growth stages, including germination, seedling, vegetative and mature stages of field-grown cotton, it is generally believed that germination and young seedling stages are more sensitive to salinity stress than other stages (Qadir and Shams, 1997).

Freitas *et al.,* (2011) reported that salt stress had significantly reduced the growth of cotton plant. Excessive salt in the soil leads to a series of physiological and biochemical metabolic disorders in cotton plants. The external manifestations of salt damage are usually the inhibition of seed germination, emergence and seedling growth, reduced biomass and economic yield, etc., while the internal effects are mainly the physiological and biochemical changes (Dong, 2012).

More than the last thirty years, numerous studies have been performed on the response of cotton plants to saline soils and/or irrigation with saline water. Progress has been made in all aspects of plant soil salinity of cotton. This paper covers the research work on salinity stress effects on *Bt* and non *Bt* cotton.

MATERIALS AND METHODS

Seven cultivars [H 1098 i (American non *Bt*), HD 123 (*G. arboreum* L. non *Bt*), RCH 134*Bt*, KDCHH 9810BG II, SOLAR 72BG II, GRAND BG II and NCS 856BG II] with four salinity levels (0.5, 2.5, 5.0 and 7.5 dS/m) were sown in 2 rows in the micro plots using completely randomized design (CRD) with three replications in Research Area, Department of Soil Science, CCS HAU, Hisar. Recommended package of practices were followed in growing healthy crop. Effect of salinity on fresh weight, yield, single boll weight, chlorophyll content (SPAD), excised leaf water loss (ELWL) were recorded. Excised leaf water loss (%) was computed by the formula:

$$\text{ELWL (\%)} = \frac{\text{Fresh weight} - \text{weight after 6 h}}{\text{Fresh weight} - \text{dry weight}} \times 100$$

Observations were also recorded on gas exchange parameters *viz.,* transpiration rate (mmol/m/s), rate of assimilation (μmol/m/s), stomatal conductance (mol/m/s) and intercellular CO_2 (ppm) in young leaves using an open system LCA 4 ADC portable infrared gas analyzer (Analytical Development Company, Hoddeson, England). The data used was mean values of three replications with four measurements/replication.

RESULTS AND DISCUSSION

In the present study, increasing salinity of irrigation waters above 2.5 dS/m led to a gradual decrease in cotton productivity (Fig. 1). An irrigation water E.C. of 7.5 dS/m led to ~47 per cent decrease whereas a level of 5.0 dS/m led to ~30 per cent reduction in cotton production. In terms of overall performance of a cultivar, RCH 134*Bt* stood at the 1st position followed by KDCHH 9810BG II whereas HD 123 gave the poorest performance. However, SOLAR 72BG II showed

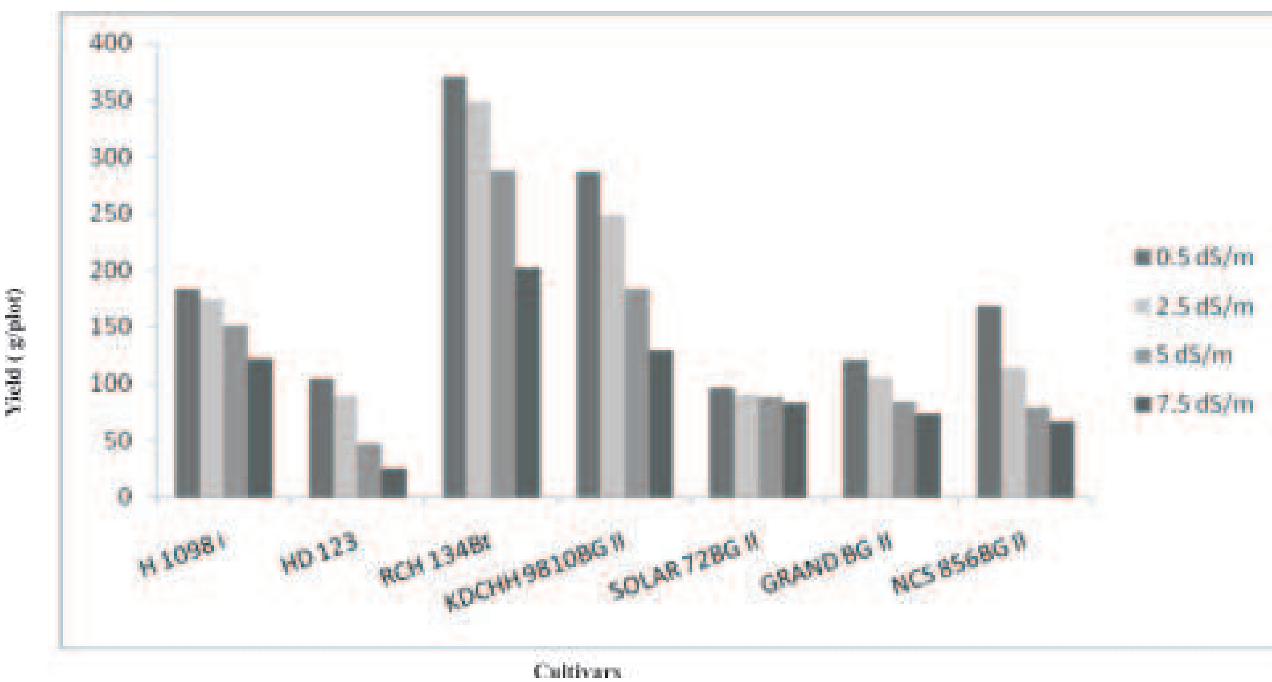

Fig. 1 Effect of salinity on yield of cotton (g/plot)

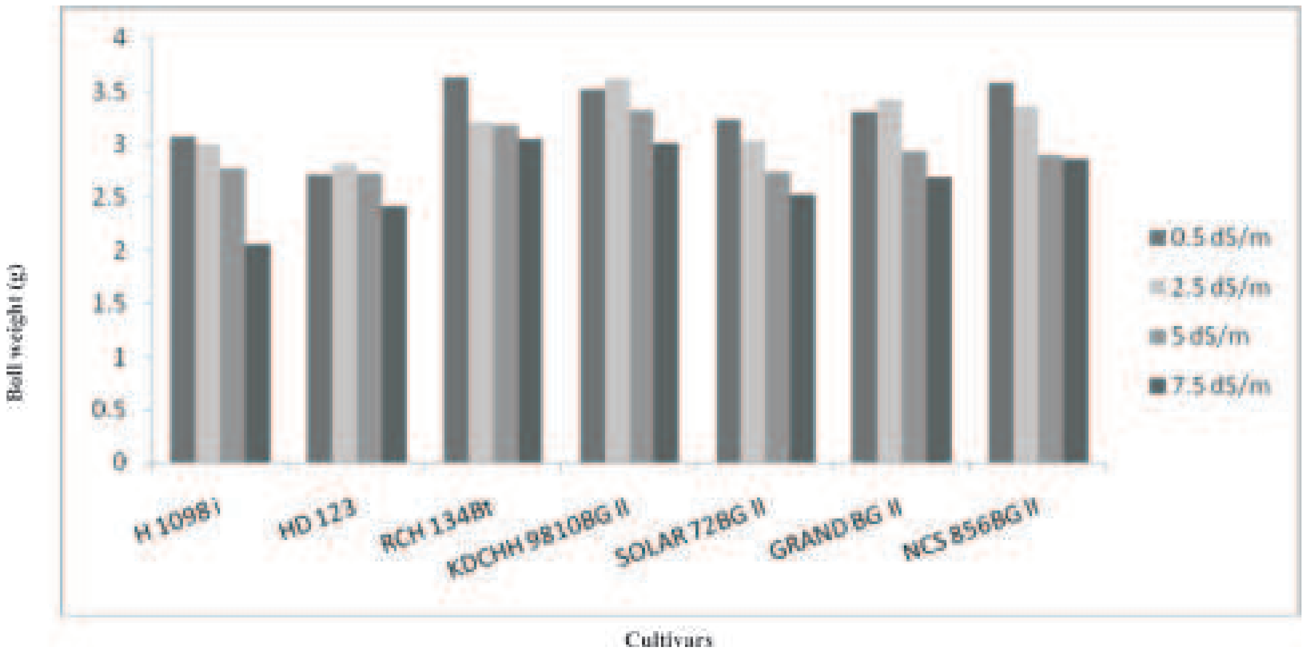

Fig. 2 Effect of salinity on single boll weight (g) in cotton

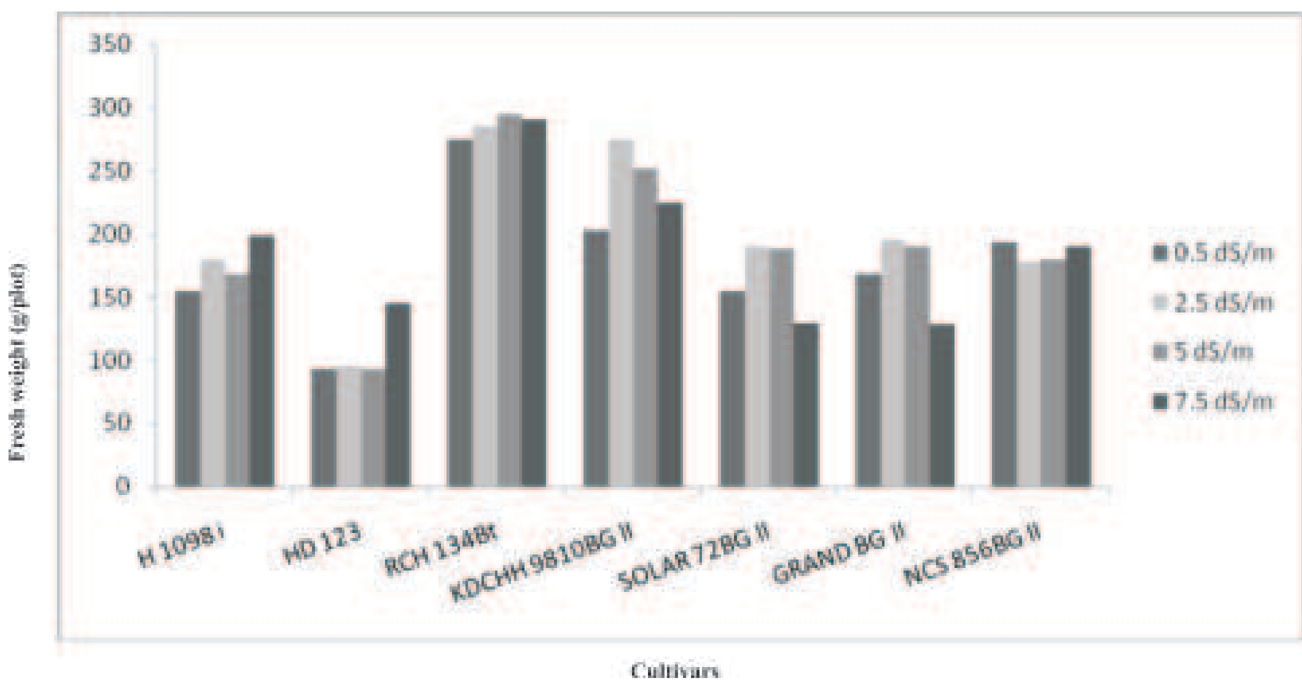

Fig. 3 Effect of salinity on fresh weight of plants (g/plot)

least reduction in yield with the increase in the level of salinity of irrigation waters whereas HD 123 showed maximum reduction with increase in the level of salinity of irrigation water.

Single boll weight generally decreased with increase in the level of salinity (Fig. 2) in all the cultivars. RCH 134*Bt* showed relatively lesser reduction in weight with increase in the

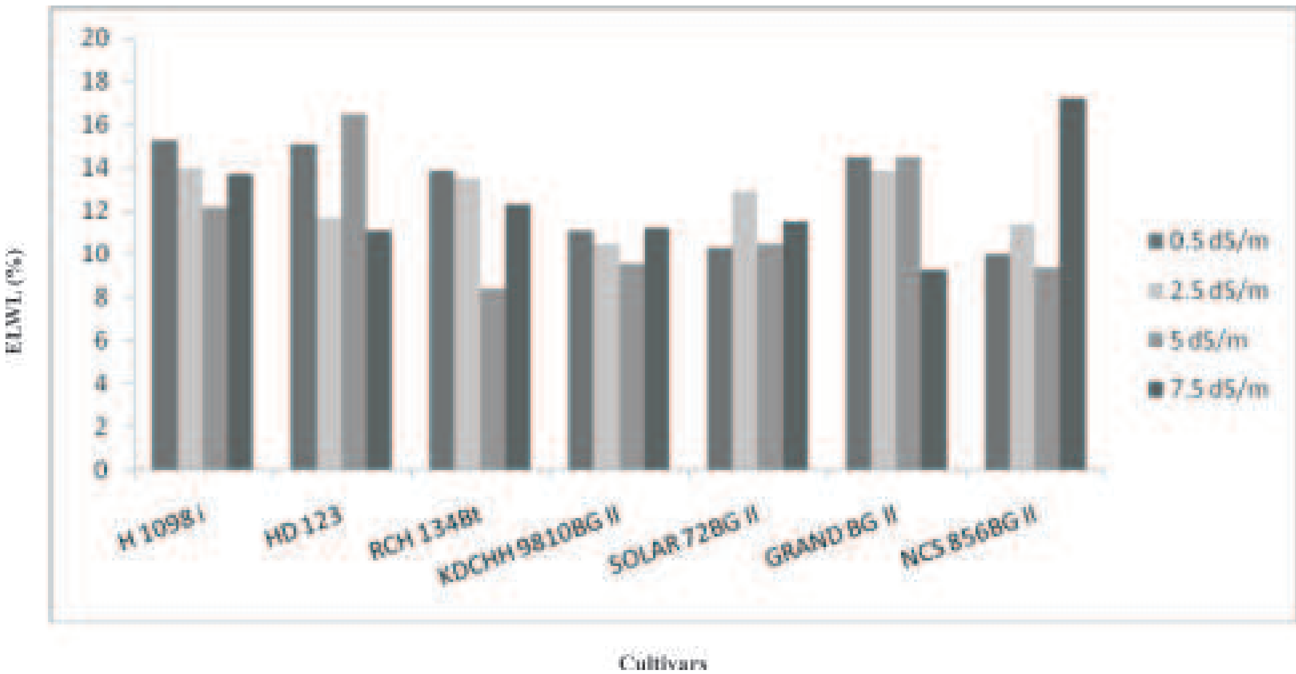

Fig. 4 Effect of salinity on ELWL (%) in cotton

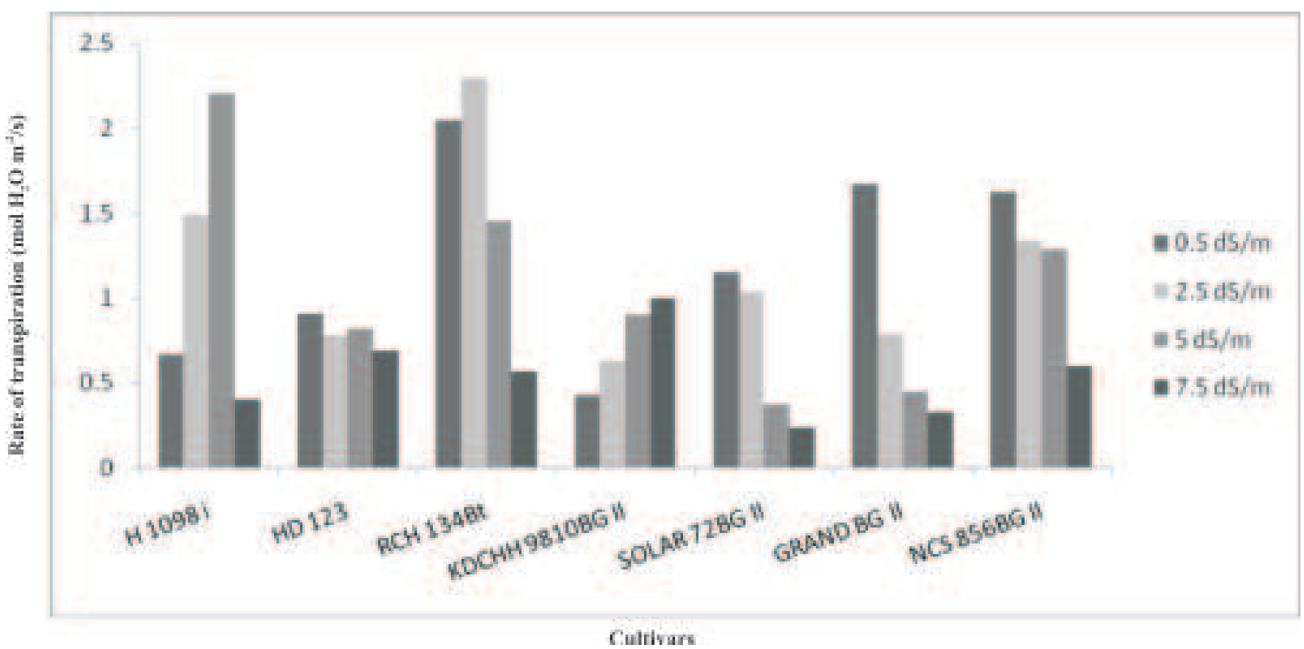

Fig. 5 Effect of salinity on rate of transpiration (mol H_2O m^{-2}/s) in cotton

level above 2.5 dS/m (Fig. 1 and 2). Similar results were reported by Zhang *et al.*, (2012) which revealed that increased salinity from moderate to strong levels reduced seed cotton yield by decreasing the number of bolls/m^2 and boll weight. Fresh weight of plants at the time of harvesting was not affected by salinity or even increased due to salinity indicating that transfer of materials for cotton production is being reduced under saline conditions (Fig. 3).

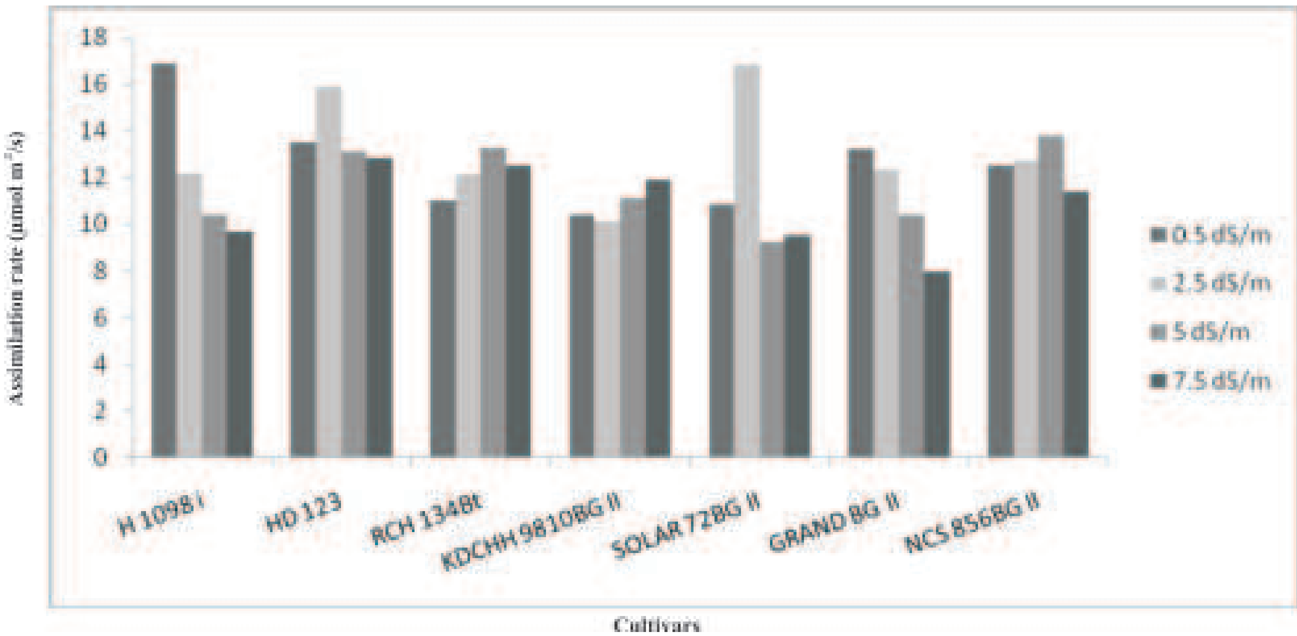

Fig. 6 Effect of salinity on rate of assimilation CO_2 (µmol m^{-2}/s) in cotton

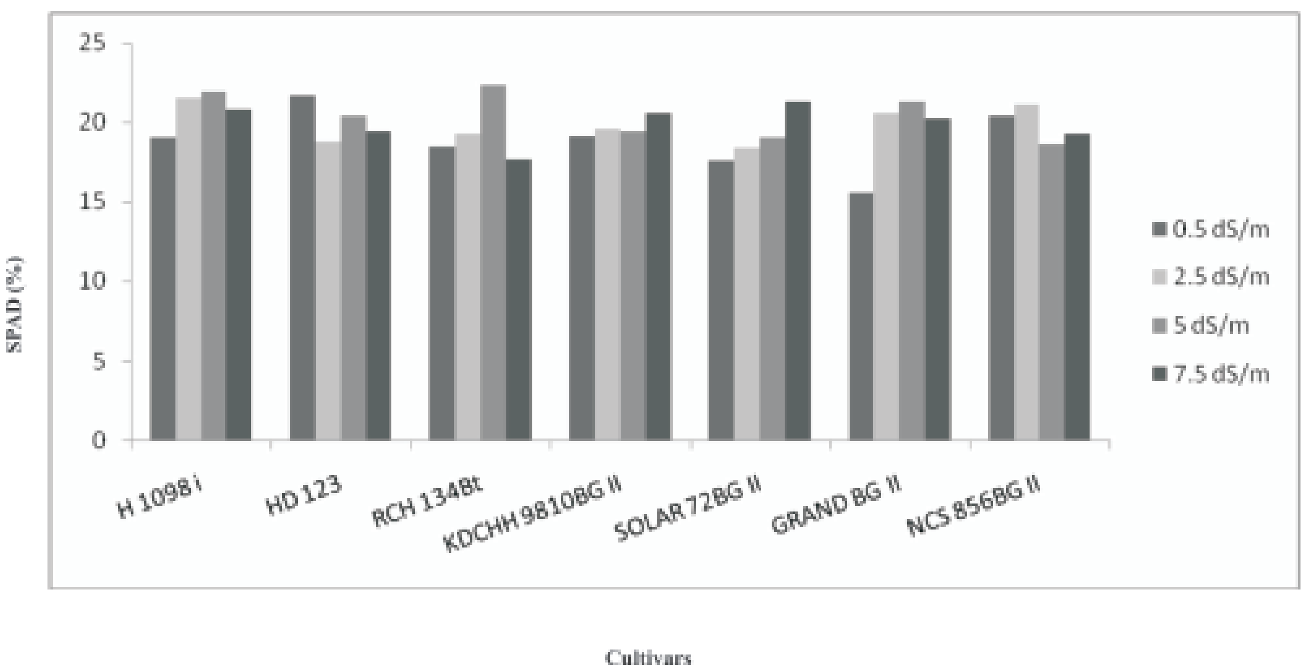

Fig. 7 Effect of salinity on chlorophyll concentration as SPAD (%) reading in cotton

According to Zhang *et al.,* (2012) soil salinity had a negative effect on seed cotton yield, but the negative effect was compensated by increased plant density under strong salinity conditions. The medium plant density yield better than the low or high plant density under moderate salinity. Higbie *et al.,* 2010 compared NaCl treatment with the control (daily 100 ml tap water), which significantly reduced plant height, leaf area, fresh weight, and dry weight.

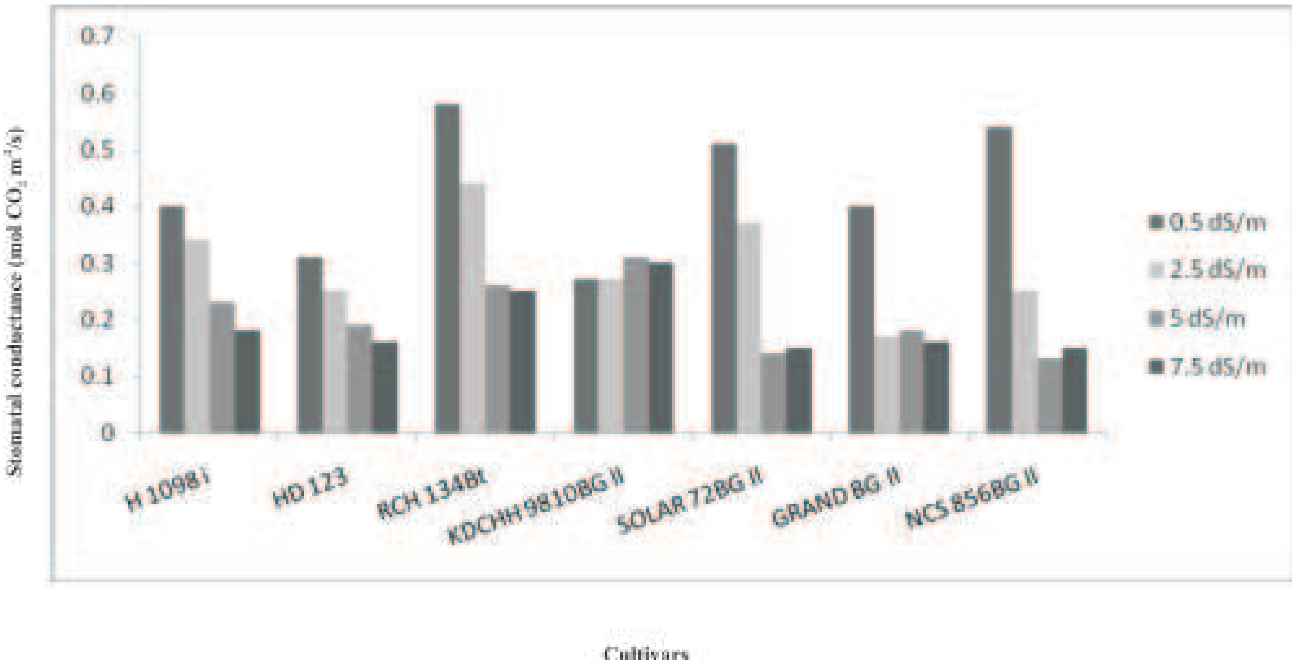

Fig. 8 Effect of salinity on rate of stomatal conductance (mol CO_2 m^{-2}/s) in cotton

Amongst the various physiological parameters studied, the data for ELWL (%) is given in Fig. 4. Excised leaf water loss (ELWL), an indication of rates of transpiration however had no correlation with it. Rate of photosynthesis, transpiration and stomatal conductance got affected by salinity levels as reported earlier (Meloni *et al.*, 2003; Desingh and Kanagaraj, 2007). Rate of transpiration generally decreased with increasing level of salinity in five of the seven cultivars tested. The lower transpiration rates may be due to limited damaging effects of

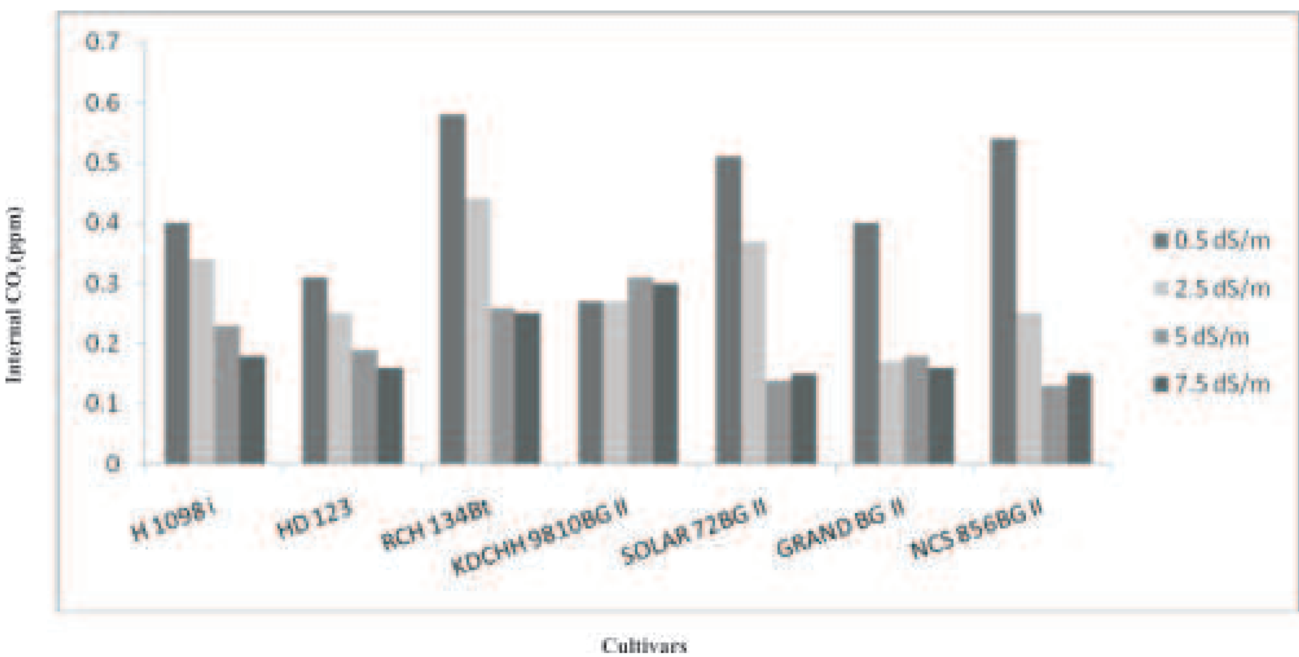

Fig. 9 Effect of salinity on internal CO_2 (ppm) in cotton leaves

the influx of large quantities of salt and to allow further acclimation (Fig. 5). Rate of assimilation/ photosynthesis consistently decreased with increasing salinity levels only in H 1098 i and GRAND BG II. Decrease may be due to stomatal closure or by direct effect of salt on the photosynthetic apparatus. Desingh and Kanagaraj (2007) also showed that photosynthetic rates decreased with increasing salinity in cotton (Fig. 6). Other cultivars showed increase in rate of assimilation to some extent at lower level of salinity. SPAD readings (%), which is an indication of chlorophyll status, generally increased under saline conditions (Fig. 7). Higbie *et al.,* (2010) reported similar results where NaCl stress also significantly increased leaf chlorophyll content.

Stomatal conductance generally decreased under saline conditions in most of the varieties studied (Fig. 8). Salinity generally resulted in reduced stomatal aperture which influences CO_2 diffusion and ultimately led to reduced photosynthesis. Internal CO_2 concentration generally increased due to salinity in most of cultivars except in HD 123 and NSC 856BG II where it consistently decreased with increasing level of salinity (Fig. 9).

On the basis of these results obtained it is evident that *Bt* hybrids RCH 134*Bt* followed by KDCHH 9810BG II is tolerant to salinity, whereas HD 123 (*desi* cotton) is highly sensitive to salinity.

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Microclimate of cotton crop under different growing environments

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ABSTRACT: The present investigation was carried out during the *kharif,* 2007 and 2008 at Research Farm, Department of Entomology, CCS HAU, Hisar. The study was aimed to find out the microclimatic conditions under different growing environments of American cotton. The diurnal profile of temperature and relative humidity were measured at three levels of canopy with the help of psychrometer at different phenophases of cotton. The temperature profiles were inverse *i.e.* increase in temperature with height inside the crop canopy during morning and evening h, whereas, during noon h profiles were nearly isothermal. Diurnal temperatures were higher in unsprayed cotton crop as compared to sprayed crop. Temperature was in higher proportion in unsprayed condition as compare to sprayed condition for all the treatment combinations. The relative humidity profiles were lapse *i.e.* decrease in humidity with crop height in all the treatments under sprayed and unsprayed conditions. But the rate of decrease in humidity with height was less at morning h as compared to other h of the day. The diurnal spread of relative humidity profiles was less in case of sprayed crop in comparison with unsprayed crop. Among the growing environments the diurnal spread of relative humidity profiles was higher in 15th May sown crop as compared to 15th April sown crop.

Key words: Cotton, microclimate, relative humidity, temperature

Indian textile industry largely use (57 per cent) cotton as its raw material and contributed about 24 per cent of industrial production in the form of sharing about 4 per cent GDP and providing employment to 25 per cent of industrial work force next only to agriculture (Swaminathan, 1999). Both fibre and seed yield of cotton is barred by variety of reasons and only sucking pests alone cause 21.20 per cent (Dhawan *et al.*, 1988) qualitative and quantitative loss. The development of different pest population is the result of the interaction of a susceptible plant, a pest and a favorable environment. The environment, therefore, is an important component in this interaction (Campbell and Norman, 1998), since several pest and diseases can cause no losses under unfavorable environmental conditions.

A very important component of the environment is crop microclimate, which is related to macroclimate and crop characteristics, like plant architecture, leaf area, and plant population. Among the crop characteristics that affect microclimate, plant population is one of the most important (Campbell and Norman, 1998), mainly when ultra narrow row is used as an alternative to reduce costs with weed control (Vories *et al.*, 2001). Plant population is a factor that can change radiation interception and balance, which determine temperature, humidity, and wind regimes inside the crop canopy. Therefore, they control wetness duration, allowing various portions of leaves and canopies to become wet and dry at different times. So, the present investigation was designed to acquire more insight and quantification of microclimate under different growing environments. This study also enumerates extent of microclimatic variation among normal and sucking pest infestation in cotton crop.

MATERIALS AND METHODS

The study was conducted at Research Farm, Department of Entomology, CCS Haryana Agricultural University, Hisar. It is situated in the sub tropical region at an elevation of 215.2 m with a longitude of 75^{o} 46'E and latitude of 29^{o} 10' N. The climate of Hisar region owes to its continental location on the outer margins of the monsoon region *i.e.* 1600 km away from the ocean. It has arid subtropical monsoonal climate. South westerly monsoon current in the summer brings rain generally from last week of June to middle of September. From October to the end of June next, the weather remains extremely dry, except for a few light showers received due to westerly disturbances. About 80 per cent of annual precipitation is received in the south west monsoon season. Summers are very hot (maximum temperature touches 45°C or sometimes more) and winters are fairly cool (minimum temperature around 1 to 2°C or sometimes less). Some time temperature may fall below 0°C in the month of December and January. The average annual rainfall is 450 mm.

The experiment was laid out in split plot design, main plot comprising three dates of sowing 15 April, 1 May, 15 May during *kharif* 2007 and 2008 and sub plots with two American cotton varieties HS 6 and H 1226 were sown keeping a distance of 60 cm from row to row. In sub sub plots two different treatments comprising of sprayed and unsprayed condition for sucking pests were kept. Imidacloprid 17.8 EC was sprayed @ 40 ml/ac when the sucking pest population reached at economic threshold level. All the other agronomic practices were followed as per the recommended package of practices by the University for raising the crop under irrigated conditions.

For recording meteorological observations, following methods were adopted. Dry and wet bulb temperatures were measured at a difference of 2 h from 800 to 1600 h at 3 levels of crop canopy : lower, middle and upper with the help of Assmann Psychrometer at different phenophases of cotton. These values were used to find out relative humidity within the crop canopy with the help of psychometric tables. Temperature and humidity profile were quantified utilizing above observations to quantify microclimatic situation under abiotic stresses and normal conditions.

RESULTS AND DISCUSSION

Diurnal profiles of air temperature and relative humidity at 50 per cent flowering, 50 per cent boll formation and 50 per cent boll opening in cotton varieties HS 6 and H 1226 in different growing environments under sprayed and unsprayed conditions during 2007 and 2008 are presented in Table 1-3.

Temperature profiles: Maximum temperatures were observed at 1200 h in all the growing environments and both cultivars under sprayed as well as unsprayed conditions, whereas minimum temperatures were recorded at 0800 h during 2007. Similarly higher temperatures were also recorded in all the growing environments and both cultivars at 1200 h as compared to other h of the day under unsprayed and sprayed conditions during 2008.

The morning (0800 h) and evening (1600 h) temperature profiles were inverse *i.e.* temperature was found to increase with increase in the height of the crop canopy, whereas, noon h profiles were nearly isothermal. Diurnal temperatures were higher in unsprayed cotton crop as compared to sprayed crop at all the canopy levels. This can be explained by more destruction of green material due to sucking pest attack and thus more penetration of solar radiation. The diurnal temperatures were higher in 15 May sown crop as compared to other date of sowing. This might be because of more radiation penetration due to poor foliage growth in 15 May sown crop. The diurnal spread of temperature profiles was higher in early sown cotton crop as compared to late sown crop. The diurnal spread of temperature profiles was nearly same in both the cotton cultivars. The diurnal temperatures were comparatively higher in HS 6 cultivar as compared to H 1226, almost at all canopy levels, although the difference was non significant. Air temperatures in cotton crop were higher in 2007 as compared to 2008. The crop canopy was cooler than above during morning and late afternoon h, might be due to radiational cooling as result of radiation emission by the crop canopy and soil surface. However, the crop canopy was warmer during noon h, this might be due to more absorption of radiation by the lower canopy and soil surface. LOU Shanwei *et al*., (2010) also studied the microclimate of cotton.

Relative humidity profiles: The relative humidity profiles were lapse *i.e.* the humidity decreased with increase in the canopy height in all the treatments under sprayed and unsprayed conditions. But the rate of decrease in humidity with height was less at 0800 h as compared to other parts of the day. The relative humidity was higher in sprayed crop as compared to unsprayed crop. The diurnal spread of relative humidity profiles was less in case of sprayed crop in comparison with unsprayed crop. The relative humidity values were higher in sprayed as compared to unsprayed crop in all the growing environments and at all the canopy levels. This might be because of poor canopy in unsprayed

Table 1. Diurnal profiles of temperature and relative humidity under sprayed and unsprayed condition at 50 per cent flowering phase in cotton cultivars under different growing environments (Pooled data of 2007 and 2008)

Profiles	Treatment	Sprayed 0800 h			Unsprayed 0800 h			Sprayed 1200 h			Unsprayed 1200 h			Sprayed 1600 h			Unsprayed 1600 h		
		L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Temp-	**Date of sowing**																		
erature	15th April	27.9	28.2	28.4	29.2	29.4	29.9	33.7	33.5	33.4	35.2	35.1	34.8	30.2	30.0	30.8	30.6	30.2	30.9
(°C)	1st May	28.0	28.4	28.7	30.1	30.2	30.4	33.9	33.8	33.6	35.6	35.3	35.0	30.5	30.2	30.6	30.7	30.8	31.0
	15th May	28.4	28.6	29.0	30.6	30.7	30.9	34.0	33.9	33.8	35.8	35.6	35.2	30.7	30.9	31.0	30.8	31.0	31.2
	Cultivars																		
	HS 6	28.4	28.6	29.1	30.0	30.1	30.6	34.1	33.7	33.6	35.6	35.5	35.1	30.1	30.1	30.9	31.0	31.0	31.5
	HI226	28.1	28.4	28.3	29.9	30.0	30.2	33.6	33.5	33.4	35.5	35.2	34.9	30.8	30.6	30.7	30.4	30.3	30.6
Relative	**Date of sowing**																		
humi-	15th April	89.0	86.0	80.0	78.0	74.0	72.0	73.0	70.0	66.0	69.0	67.0	63.0	79.0	74.0	78.0	76.0	72.0	74.0
dity	1st May	87.0	84.0	79.0	76.0	72.0	71.0	70.0	69.0	67.0	68.0	66.0	61.0	76.0	72.0	74.0	74.0	70.0	72.0
(%)	15th May	85.0	81.0	78.0	73.0	71.0	70.0	68.0	67.0	62.0	64.0	61.0	59.0	73.0	71.0	72.0	73.0	69.0	71.0
	Cultivars																		
	HS 6	85.0	81.0	77.0	71.0	68.0	67.0	68.0	67.0	62.0	64.0	60.0	58.0	74.0	70.0	72.0	72.0	68.0	70.0
	HI226	89.0	86.0	81.0	80.0	78.0	74.0	73.0	70.0	68.0	70.0	69.0	64.0	78.0	75.0	77.0	77.0	73.0	75.0

Where, L_1 = Lower canopy; L_2 = Middle canopy; L_3 = Upper canopy

Table 2. Diurnal profiles of temperature and relative humidity under sprayed and unsprayed condition at 50 per cent boll formation phase in cotton cultivars under different growing environments (Pooled data of 2007 and 2008)

Profiles	Treatment	Sprayed 0800 h			Unsprayed 0800 h			Sprayed 1200 h			Unsprayed 1200 h			Sprayed 1600 h			Unsprayed 1600 h		
		L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Temp-	**Date of sowing**																		
erature	15th April	27.9	28.1	28.6	28.4	28.6	28.9	35.7	35.6	35.4	35.8	35.7	35.6	30.6	30.4	30.8	30.8	30.2	31.4
(°C)	1st May	28.2	28.4	28.8	28.6	29.1	29.2	35.8	35.7	35.5	35.9	35.8	35.7	30.7	30.5	30.9	30.9	30.4	31.6
	15th May	28.5	28.8	29.6	29.3	29.4	29.9	35.9	35.8	35.6	36.0	35.9	35.8	30.9	30.7	31.0	30.8	30.7	31.8
	Cultivars																		
	HS 6	28.5	28.8	29.2	28.9	29.0	29.9	35.2	35.0	34.9	35.4	35.2	35.0	30.4	30.1	30.7	30.6	30.4	30.9
	HI226	27.9	28.1	28.8	28.6	29.1	28.8	36.4	36.4	36.1	36.4	36.4	36.4	31.1	31.0	31.1	31.1	30.5	32.3
Relative	**Date of sowing**																		
humi-	15th April	78.0	74.0	72.0	74.0	72.0	70.0	56.0	53.0	51.0	54.0	51.0	49.0	76.0	71.0	74.0	74.0	70.0	72.0
dity	1st May	76.0	73.0	71.0	73.0	71.0	70.0	54.0	52.0	50.0	52.0	50.0	48.0	73.0	70.0	71.0	72.0	68.0	70.0
(%)	15th May	74.0	72.0	70.0	72.0	70.0	69.0	52.0	51.0	48.0	51.0	49.0	47.0	72.0	69.0	70.0	71.0	66.0	69.0
	Cultivars																		
	HS 6	75.0	72.0	71.0	71.0	70.0	69.0	58.0	54.0	52.0	58.0	54.0	51.0	78.0	73.0	75.0	74.0	71.0	73.0
	HI226	77.0	74.0	72.0	75.0	72.0	70.0	50.0	50.0	47.0	47.0	46.0	45.0	69.0	67.0	68.0	71.0	65.0	68.0

Where, L_1 = Lower canopy, L_2 = Middle canopy, L_3 = Upper canopy

Table 3. Diurnal profiles of temperature and relative humidity under sprayed and unsprayed condition at 50 per cent boll opening phase in cotton cultivars under different growing environments (Pooled data of 2007 and 2008)

Profiles	Treatment	Sprayed 0800 h			Unsprayed 0800 h			Sprayed 1200 h			Unsprayed 1200 h			Sprayed 1600 h			Unsprayed 1600 h		
		L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Temp-erature (°C)	**Date of sowing**																		
	15th April	26.0	26.4	26.8	28.2	28.6	28.4	33.3	33.8	33.0	33.9	33.6	33.4	28.5	28.0	29.1	28.8	28.2	29.4
	1st May	26.6	26.9	27.0	28.5	28.8	28.7	33.6	33.3	33.2	34.0	33.8	33.6	28.7	28.4	29.6	28.9	28.6	29.8
	15th May	26.9	27.1	27.3	28.6	28.9	28.9	28.6	33.9	33.6	33.5	34.3	33.9	33.6	28.9	28.6	29.8	29.2	28.7
	Cultivars																		
	HS 6	26.8	26.8	27.1	28.6	28.9	28.9	33.4	34.1	33.5	34.0	34.0	33.7	32.1	29.0	29.3	29.2	28.7	29.5
	HI226	26.2	26.7	27.0	28.3	28.6	28.4	30.3	33.2	33.0	33.6	33.8	33.6	28.4	27.9	28.9	29.1	28.6	29.1
Relative hum-idity (%)	**Date of sowing**																		
	15th April	86.0	84.0	80.0	81.0	80.0	78.0	50.0	49.0	47.0	48.0	47.0	45.0	82.0	80.0	81.0	80.0	75.0	78.0
	1st May	85.0	84.0	79.0	80.0	77.0	75.0	49.0	46.0	44.0	48.0	44.0	43.0	78.0	76.0	79.0	75.0	72.0	74.0
	15th May	82.0	81.0	76.0	78.0	75.0	73.0	48.0	45.0	42.0	47.0	44.0	40.0	76.0	74.0	78.0	74.0	70.0	72.0
	Cultivars																		
	HS 6	80.0	78.0	77.0	78.0	76.0	75.0	43.0	45.0	48.0	40.0	43.0	46.0	77.0	75.0	77.0	76.0	72.0	74.0
	HI226	89.0	88.0	80.0	81.0	79.0	76.0	46.0	48.0	50.0	45.0	47.0	49.0	82.0	79.0	80.0	78.0	73.0	75.0

Where, L_1 = Lower canopy; L_2 = Middle canopy; L_3 = Upper canopy condition due to biotic stress. Among the growing environments the diurnal spread of relative humidity profiles was higher in 15 May sown crop as compared to 15 April sown crop. In case of cotton cultivars, diurnal spread of relative humidity profiles was nearly same during both the crop seasons.

The relative humidity was higher in H 1226 in comparison to HS 6 at all canopy levels and all the stages of the crop during whole the day. This was due to lower temperature recorded in H1226 and the fact that temperature and humidity are inversely related. Relative humidity was higher in crop canopy as compared to top of the canopy in all the treatment combinations.

Based on the above results it is concluded that the 15 April sown crop was cooler and more humid compared to late sown crop at all the phenophases. The canopy of H 1226 was also cooler and with more humidity over HS 6 crop canopy. The crop in sprayed environments showed lower temperature and higher humidity in comparison with sprayed environment.

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Effect of tillage and manuring on soil properties and productivity of rainfed cotton on vertisol

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ABSTRACT: A field experiment was carried out to study the effect of tillage and manuring on soil properties and productivity of rainfed cotton on vertisol during 2006-2007 at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in factorial randomized block design with twelve treatments and three replications. The treatments consisted of conventional tillage, minimum tillage, full (50:25:00 NPK kg/ha) and half recommended dose of inorganic fertilizer with FYM and green manuring in combination. The results indicated that application of 15 t FYM/ha along with 50 per cent recommended dose of fertilizer recorded significantly higher per cent water stable aggregates, hydraulic conductivity, soil fertility, seed cotton and stalk yield of cotton with lower bulk density of soil. While numerically higher per cent water stable aggregates, organic carbon, total nitrogen content, available nutrients (N, P and K), seed cotton and stalk yield were recorded in minimum tillage as compared to conventional tillage.

Key words: Manuring, seed cotton, soil fertility, tillage

Cotton is one of the important cash crop and plays a vital role in the economy of the farmers as well as the country. Vidarbha is major cotton growing region in Maharashtra and cotton is grown predominantly as rainfed crop on black cotton soil having an area of 17 lakh ha with average productivity of 225 kg lint/ha. Major causes of low productivity of cotton in Vidarbha are erratic rainfall and imbalanced use of fertilizers. Organic carbon status of Indian soils has declined because of tropical climate. Due to energy crisis the fertilizer production around the world is very much affected and fertilizers are becoming very expensive. Therefore, to minimize the expenses on fertilizers, organic sources (FYM, crop residues and green manures) can be used for sustaining the crop yield and soil productivity. These practices not only increase the crop yield but also improve physical, chemical and biological properties of soil

Besides tillage, addition of organic manures helps to bring the soil tilth. They are not only the source of nutrients but also improve the physical properties resulting in better soil structure, increase water holding capacity, hydraulic conductivity in soil and more favourable environment for root growth and better infiltration of water. Among the organic manures, farm yard manure is the most important source. *Dhaincha* (*Sesbania aculeata*) as a source of organic manure increased total nitrogen and available phosphorus in the soil and the percentage of water stable aggregates in the soil were higher under green manure treatments with low pH and C/N ratio. However, such information is scanty on vertisol under semi arid climatic conditions of central India. Therefore, the present study was undertaken to study the effect of tillage and manuring on soil properties and productivity of rainfed cotton on vertisol.

The present investigation was carried out during *kharif,* 2006-2007 at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola. The soil of the experimental field is a medium deep vertisol (Typic Haplusterts), moderately alkaline in reaction (pH 8.1), low in available N (180.2 kg/ha) and P (12.1 kg/ha) and high in available potassium (365.5 kg/ha). The experiment was laid out in factorial randomized block design with 12 treatments and three replications. The treatments consisted of tillage (conventional and minimum), nutrient management *viz.,* 100 per cent RDF, 50 per cent RDF, with graded doses of farmyard manure and green manuring. Farm yard manure and green manuring (*Dhaincha*) were used as source of organic matter. Organic materials *viz.,* farm yard manure (FYM) was applied one month before sowing and was thoroughly mixed with the soil. *Dhaincha* was sown in between two rows of cotton and buried 40 days after sowing. The recommended dose (50 kg N, 25 kg P_2O_5/ha) was applied to cotton (PKV Rajat). Full quantity of the recommended dose of phosphorus was applied as a basal dose through single super phosphate. Nitrogen was applied through urea in two split applications, half at the time of sowing and half at 35 DAS to cotton.

The seed cotton yield was recorded treatment wise for further interpretations. The soil samples were collected from 0–30 cm depth at the harvest of cotton. These soil samples were processed for physical and chemical analysis by adopting standards methods.

The results in respect of effect of tillage on physical properties of soil was found to be non significant except infiltration rate (Table 1). However, numerically higher hydraulic conductivity and per cent water stable aggregates was observed in minimum tillage as compared to conventional tillage. Mikha and Rice (2004) also observed similar results. The infiltration rate was significantly higher in conventional tillage as compared to minimum tillage. Higher infiltration rate in deep tillage was attributed to reduced bulk density and increased porosity.

The soil physical properties were significantly influenced by nutrient management. The lowest (1.30 Mg m^{-3}) bulk density was recorded in treatment 50 per cent RDF + 15 t/FYM ha followed by treatment 50 per cent RDF + green manuring (1.31 Mg m^{-3}). The maximum reduction in bulk density in these plots attributed to the maximum addition of organic materials through FYM and green manuring. The application of 15 t FYM/ha along with 50 per cent RDF recorded highest hydraulic conductivity (0.73 cm/h) which was superior over rest of treatments. The improvement in HC in 15 t FYM/ha + 50 per cent RDF treatment was 5.8, 8.9 and 12.3 per cent higher than that of 10 t FYM /ha, green manuring and 5 t FYM/ha along with 50 per cent RDF, respectively.

The highest water stable aggregates (69.37%) were found in treatment 50 per cent RDF + 15 t FYM/ha which was superior over rest of treatments. The improvement of WSA in this treatment was 3.1 and 7.5 per cent higher than green manuring + 50 per cent RDF and 10 t FYM/ ha + 50 per cent RDF, respectively. The treatments receiving FYM or green manure recorded higher per cent water stable aggregates than treatments receiving only chemical fertilizers. This might be due to the presence of polysaccharides in organic manure which helps to form soil aggregates by binding clay particles with its structural configuration (Malewar and Hasnabade, 1995).

The soil fertility was slightly higher in minimum tillage compared to conventional tillage (Table 1). However, the results were statistically non significant. While, the soil fertility was significantly influenced by nutrient management. The highest values of available N, P and K were recorded with the application of 15 t FYM/ha + 50 per cent RDF. The available NPK in 15t FYM/ha + 50 per cent RDF was 7.1,

Table 1: Effect of tillage and manuring on soil properties of soil at harvest

Treatments	BD (Mg m^{-3})	HC (cm h)	WSA (%) > 0.25mm	Available nutrients (g/ha)		
				N	P	K
Tillage						
Conventional tillage (CT)	1.32	0.67	63.5	207.9	12.7	373.3
Minimum tillage (MT)	1.33	0.65	64.6	212.0	13.0	374.1
SE (m)±	0.004	0.006	0.38	1.75	0.1	1.43
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Manuring						
RDF (100%)	1.34	0.61	61.0	223.3	13.1	370.0
RDF (50%)	1.33	0.60	58.8	164.7	12.0	362.9
RDF (50%) + 5t FYM/ha	1.32	0.65	63.1	183.0	12.6	370.8
RDF (50%) + 10t FYM/ha	1.32	0.69	64.5	223.4	13.2	378.9
RDF (50%) + 15t FYM/ha	1.30	0.73	69.4	239.1	13.7	392.2
RDF (50%) + green manuring	1.31	0.67	67.3	220.1	12.4	367.3
SE (m)±	0.008	0.01	0.67	3.03	0.22	2.48
CD (p=0.05)	0.025	0.03	1.95	8.91	0.66	7.27

4.2 and 5.9 per cent higher over 100 per cent RDF. The increase in available N might be due to direct addition of N through FYM and green manure to the available pool of soil (Malewar and Hasnabade, 1995). The available P and K in treatment of 10t FYM/ha + 50 per cent RDF were significantly higher than green manuring + 50 per cent RDF. However, the available N was statically *on par* in these treatments. The availability of phosphorus increased in conjunctive use of organic and inorganic might be due to minimization of P fixation in soil and direct addition of P in soil.Singh *et al.*, (2001) explained that significant increase in available K content has been due to either FYM or green manure along with fertilizers N, suggesting that FYM and green manure helped to maintain the supply of K by releasing the K from reserve source. Bellakki and Badanur (1997) reported that continuous use of FYM and sunhemp either alone or in combination with chemical fertilizers recorded significantly higher potassium than the other.

The higher organic carbon was observed in minimum tillage compared to conventional tillage (Table 2) although, result was statistically non significant. Lower organic C with intensive tillage is frequently reported in the literature, and appears to be due to rapid microbial decomposition by incorporation of crop residues during tillage (Doran *et al.,* 1994). The significantly higher total N (0.059%) was recorded in minimum tillage as compared to conventional tillage (0.057%). The soil organic carbon significantly differed due to nutrient management (Table 2). The highest organic carbon (6.03 g/kg) was found in treatment 50 per cent RDF + 15 t FYM/ha followed by treatment 50 per cent RDF + 10 t FYM/ha (5.87 g/kg) which was found to be *at par* with treatment 50 per cent RDF + 15 t FYM/ha. Bellakki and Badanur (1997) also reported that organic carbon content in soils increased significantly with incorporation of FYM or sunhemp either alone or in combination with fertilizer as compared with recommended dose of fertilizers.

The significantly higher values of total nitrogen (0.059%) were recorded in treatments 50 per cent RDF + 15 t FYM/ha and 50 per cent RDF + green manuring followed by treatment 100 per cent RDF (0.058%) which were found to be *at par* with each others. Ogunwole (2005) reported that the long term complementary use of FYM @ 5 t/ha or more and NPK fertilizers at an appropriate rate will improve the total nitrogen content of soil. Interaction effect of tillage and nutrient management on organic carbon and total nitrogen was found to be significant (Table 2). The highest organic carbon (6.12 g/kg) and total nitrogen (0.062%) was recorded in 50 per cent RDF + 15 t FYM/ha in minimum tillage. Mikha and Rice (2004) reported that the total nitrogen of soil increased due to increased organic residue with manure addition where no tillage significantly increased soil total N.

The results indicated that minimum tillage produced higher seed cotton yield compared to conventional tillage but difference was not

Table 2: Effect of tillage and manuring on soil organic carbon and total nitrogen and yield of cotton

Treatments	Tillage											
	O.C. (g/kg)			Total N (%)			Seed cotton (kg/ha)			Cotton stalk (kg/ha)		
Manuring	CT	MT	**Mean**	CT	MT	**Mean**	CT	MT	**Mean**	CT	MT	**Mean**
RDF (100%)	5.70	5.55	**5.62**	0.059	0.058	**0.058**	1262	1295	**1278**	3041	3149	**3095**
RDF (50%)	4.1	4.60	**4.35**	0.057	0.058	**0.057**	953	1002	**978**	2430	2596	**2513**
RDF (50%) + 5t FYM/ha	5.45	5.8	**5.62**	0.056	0.057	**0.056**	1138	1219	**1178**	2944	3195	**3069**
RDF (50%) + 10t FYM/ha	5.85	5.9	**5.87**	0.056	0.058	**0.057**	1300	1396	**1348**	3279	3349	**3314**
RDF (50%) + 15t FYM ha	5.95	6.12	**6.03**	0.057	0.062	**0.059**	1500	1594	**1547**	3625	3732	**3678**
RDF (50%) + green manuring	5.61	5.59	**5.60**	0.058	0.060	**0.059**	1155	1245	**1200**	2987	3010	**2998**
Mean	**5.44**	**5.59**		**0.057**	**0.059**	**-**	**1218**	**1292**		**3051**	**3172**	
	Tillage	Manure	Int.	Tillage	Manure	Int.	tillage	Manure	Int.	tillage	Manure	Int.
SE (m)±	0.036	0.063	0.089	0.0002	0.00036	0.0005	35.8	62	87.7	36.0	62.0	88.0
CD (p=0.05)	NS	0.186	0.261	0.0006	0.0011	0.0015	NS	182	257	105	182	NS

significant (Table 2). Tennakoon and Hulugalle (2006) also observed non significant effect on the cotton yield due to minimum tillage on a vertisol. However, effect of tillage on cotton stalk yield was found to be significant. The higher (31.71 q/ha) stalk yield was recorded in minimum tillage as compared to conventional tillage (30.51 q/ha). The effect of nutrient management was found to be significant with respect to seed cotton and stalk yield. Incorporation of FYM along with inorganic fertilizers increased the yield of cotton with increasing level of FYM (Table 2). The highest seed cotton yield (15.47 q/ha) was obtained with the application of 50 per cent RDF + 15 t FYM/ha and was superior over rest of the treatments. The increase in the yield due to 50% RDF + 15 t FYM/ha was 14.8 and 21.0 per cent higher over 10 t FYM + 50 per cent RDF and 100 per cent RDF, respectively. Raheja *et al*., (1971) reported that continuous application of FYM with N improved the crop yield significantly.

The highest stalk yield (36.78 q/ha) was recorded in treatment having 50 per cent RDF + 15 t FYM/ha and this treatment was significantly superior over all other treatments. The treatment 50 per cent RDF + 10 t FYM/ha (33.14 q/ha) was next in performance. The significantly highest (15.94 q/ha) seed cotton yield was recorded with treatment 50 per cent RDF + 15 t FYM/ha in minimum tillage followed by treatment 50 per cent RDF + 15 t FYM/ha in conventional tillage (15.00 q/ha) which were found to be *at par* (Table 2). These treatments were found to be *at par* with 50 per cent RDF+10 t FYM/ha under both tillage treatments.

In view of the above, it can be stated that application of 15 t FYM/ha with 50 per cent RDF in minimum tillage was found to be beneficial in improving physico chemical properties of soil and productivity of rainfed cotton on vertisol.

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Optimization of irrigation water and nutrients to cotton through drip fertigation in Karaikal

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ABSTRACT : A field experiment was conducted during summer, 2007 to study the optimization of the critical inputs such as irrigation water and fertilizer for cotton through drip fertigation in coastal deltaic region of Karaikal. The treatment consisted of three different levels of soil moisture (I_1- 0.4 and 0.6 ETc, I_2- 0.5 and 0.7 ETc and I_3- 0.6 and 0.8 ETc, during before and after flowering stages, respectively) and four different doses of nutrients (N_0- 0, N_1- 50 %, N_2- 75% and N_3- 100 % RFD through fertigation) were taken up in combination with farmers' practice as control. The experiment was conducted in factorial randomized block design with three replications. Supply of irrigation water through drip to a tune of 0.5 and 0.7 ETc (I_2) and 0.6 and 0.8 ETc (I_3) was *at par* and proved significantly superior to a tune of 0.4 and 0.6 ETc (I_1) during before and after flowering stages of the crop in influencing seed cotton yield. Similarly, fertilizers applied at recommended dose (100 % RFD) had registered the highest seed cotton yield (2635 kg/ha) followed by 75 per cent RFD (2431 kg/ha) but were *at par* with each other.

Key words: Cotton, drip fertigation, farmers practice, ETc, input use efficiencies, RFD

Cotton has retained its unique fame and name as the "King of fibres" and "White gold" because of its higher economical value among cultivable crops for quite a long period. Water and nutrients are the two most important critical inputs for producing vigorous healthy plants and improving the yield of any crop. With continuous declining of water in India as compared to other countries, enhancing agricultural productivity/ drop of water has become essential to meet food demands forever growing population (Rajak Daleshwar *et al.*, 2006). Thus, available water for irrigation needs to be utilized judiciously. At the same time improper using of fertilizer quarrels the environmental problem ultimately degrade the soil health. Many researchers have studied the relationships between N removal and lint yield of cotton crop grown under surface irrigation. Bassett *et al.,* 1970 reported that mature cotton plants take up 10 kg N for every 100 kg lint produced. Thus, the importance of scientific water management and the need to adopt advanced techniques like drip irrigation are to be exploited to achieve the twin objectives of higher productivity and better water and nutrient use efficiency of field crops. Fertigation is the technique that provides the means to add N and other plant nutrients and chemicals at the right time and the right place and increases the application frequency and, therefore, increases fertilizer recovery. Application of fertilizer with irrigation water improves seed cotton yield and fertilizer recovery and provides better timing to meet crop demand throughout the cotton growing season. The major drawback of the drip irrigation system is its high initial investment; however, cost can be recovered in a short span if proper nutrient, water management and design principle are followed. Therefore field studies were conducted on drip irrigation under varying levels of soil moisture regime and nutrients for cotton.

A field experiment was conducted during summer, 2007 to study the optimize the critical inputs such as irrigation water and fertilizer for cotton through drip fertigation in coastal deltaic region of Karaikal. Soil was sandy clay loam in texture with neutral soil reaction, low in organic carbon (0.35%) and available nitrogen (102.79 kg/ ha), medium in available phosphorus (13.16kg /ha) and high in available potassium (299.59 kg/ha). The experiment was conducted in factorial randomized block design with three replications. The treatments consisted of three different levels of soil moisture (I_1- 0.4 and 0.6 ETc, I_2- 0.5 and 0.7 ETc and I_3- 0.6 and 0.8 ETc during before and after flowering stages, respectively) and four different doses of nutrients (N_0- 0; N_1- 50 %, 30-15-15kg; N_2- 75%, 45-22.5-22.5 kg and N_3- 100 % RFD, 60-30-30 kg NPK/ha through fertigation) were taken up in combination along with farmers' practice as control. The quantity of water to be applied by one lateral in different irrigation treatments was computed based on the following formula.

$$V = r.\ E_o.\ K_{pan}.\ K_c.\ A$$

Where,

- V - Volume of water to be delivered by one lateral. (lpH)
- E_o - USWA open pan evaporation (mm/day)
- K_{pan} - Pan coefficient
- K_c - Crop coefficient
- r - Unit constant
- A - Area covered by one lateral (m^2)

Time of operation of drip system to deliver the required volume of water/lateral as per the irrigation treatment was computed based on the formula.

$$\text{Time of operation (H)} = \frac{\text{Volume of water to be delivered (V) by one lateral (l)}}{\text{Emitter discharge rate (lpH) x number of emitters}}$$

The conventional furrow method of irrigation with full dose of fertilizer recommended doses was included as an absolute control for the purpose of comparison, farmers' practice method. The recommended dose of fertilizer for the test variety of cotton is 60: 30: 30 kg NPK/ha. The calculated quantity of phosphorus was applied as basal in band as per treatments while nitrogen and potassium nutrients were applied through fertigation as per the treatments. Drip irrigation system was installed at 120 and 50 cm lateral and dripper spacings, respectively. Drip irrigation was scheduled at once in two days. Furrow irrigation was scheduled at once in a week. In drip fertigation, the urea as a source of nitrogen and muriate of potash as a source of potassium application was regulated through a fertilizer tank and was applied in seven splits *i.e.* 10 per cent of fertilizers were applied in two splits at vegetative stage and two splits were applied at matured stage, while 20 per cent of fertilizers were applied 3 splits at flowering stages. Besides, treatments, all packages of practices were followed as per recommendation uniformly to all the treatments. The agronomic fertilizer use efficiency (AFUE) in terms of seed cotton yield/ kg of nutrient applied and economic fertilizer use efficiency (AFUE) in terms of kg seed cotton yield/rupee invested on fertilizer were calculated based on the following formula

$$AFUE = \frac{\text{Seed cotton yield (kg/ha)}}{\text{Quantity of nutrient applied (kg/ha)}}$$

$$EFUE = \frac{\text{Seed cotton yield (kg/ha)}}{\text{Amount spent on fertilizer (kg/rupee)}}$$

The total water use and water use efficiencies under surface and drip methods of irrigation are presented in Table I. The total water use inclusive of effective rainfall in furrow irrigation of farmers practice was 593.54 mm whereas it was only 401.90, 447.74 and 484.10 mm for I_1, I_2 and I_3 irrigation treatments, respectively. This resulted in 20 to 35 per cent of water saving when compared to farmers' practice. Similar results of water saving under drip irrigation was reported by Veeraputhiran

Table 1. Total water use and water use efficiency (WUE) (kg/ha/mm) under drip and surface irrigation methods (Farmers' practice)

Treatments	Total h of drip operation (h)	Irrigation water applied (mm)	Effective rainfall (mm)	Total water used (mm)	Per cent water saving over farmers' practice	WUE (kg/ha/ mm)	Seed cotton yield (kg/ha)
I_1 (0.4 and 0.6 ET)	41.40	248.4	153.5	401.9	32	4.21	1692
I_2 (0.5 and 0.7 ET)	49.04	294.2	153.5	447.7	25	5.15	2360
I_3 (0.6 and 0.8 ET)	55.10	330.6	153.5	484.1	18	4.66	2257
Farmers' practice (Surface	irrigation)	440.0	153.5	593.5	__	3.45	1357
C.D (p = 0.05)	443						

(Data statistically not analyzed except seed cotton yield)

Table 2. Influence of irrigation and fertilizer levels on the nutrients use efficiency under drip fertigated cotton in comparison with farmers' practice

Treatments	Agronomic use efficiency (AUE)								Economic use efficiency (EUE)							
	Nitrogen use efficiency				Potassium use efficiency				Nitrogen use efficiency				Potassium use efficiency			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
0 (Control)	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
RFD (50 %)	34.9	73.5	57.1	**55.2**	69.8	146.9	114.3	**110.4**	3.2	6.8	5.3	**5.1**	9.5	20.0	15.5	**15.0**
RFD (75 %)	43.4	56.5	61.7	**53.9**	86.9	112.9	123.5	**107.8**	4.0	5.2	5.7	**5.0**	11.8	15.3	16.8	**14.6**
RFD (100 %)	42.4	45.4	44.2	**44.0**	84.7	90.8	88.3	**88.0**	3.9	4.2	4.1	**4.0**	11.5	12.3	12.0	**11.9**
MEAN	**30.1**	**43.8**	**40.8**	**38.3**	**60.4**	**87.7**	**81.5**	**76.5**	**2.8**	**4.0**	**3.8**	**3.5**	**8.2**	**11.9**	**11.9**	**10.4**
Farmers' practice (Control)				**22.1**				**44.2**				**2**				**6**
MEAN	**30.1**	**43.8**	**40.8**	**38.3**	**60.4**	**87.7**	**81.5**	**76.5**	**2.8**	**4.0**	**3.8**	**3.5**	**8.2**	**11.9**	**11.9**	**10.4**
Farmers' practice (Control)	22.1		44.2		2.0		6.0									

(2000). The supply of irrigation water through drip irrigation to a tune of 0.5 and 0.7 ET (I_2) before and after flowering stages of the crop registered higher WUE (5.15 kg/ha/mm) while low level of WUE (4.21 kg/ha/mm) was registered by the I_1 treatment in which irrigation water was supplied to a tune of 0.4 and 0.6 ETc before and after flowering stages. The lowest WUE of 3.45 kg/ha/mm was recorded in the farmers' practice of growing cotton. Adequate and timely availability of water, nutrients and their synergistic interaction had stimulated to record higher water use efficiency under drip fertigation (Veeraputhiran, 2000).

The fertilizer use efficiency was considerably increased due to drip fertigation as compared to surface irrigation with soil application (Table 2). This could be attributed to the regular application of N and K (as high as 7 splits) combined with irrigation water in the active root zone of the crop that would have resulted in minimum loss of nutrients from the root zone. The agronomic use efficiency and economic use efficiency of nitrogen and potassium were found to be higher in drip fertigation with 50 per cent RFD at optimum soil moisture (I_2). Substantial increase in FUE under drip fertigation over conventional soil application was also reported by Bharambe *et al.*, 1997 in hybrid cotton.

Among the irrigation levels, supply of irrigation water through drip to a tune of 0.5 and 0.7 ETc (I_2) before and after flowering stages of the crop had recorded highest seed cotton yield of 2360 kg/ha followed by drip irrigation at 0.6 and 0.8 ETc (I_3) before and after flowering stages (2257 kg/ha) which were *at par* with each other (Table 1). All the growth and yield parameters were favourably influenced by these two treatments and as a result the seed cotton yield was also higher by 39.48 and 33.39 per cent in I_2 and I_3 over I_1, respectively. The lowest seed cotton yield of 1692 kg/ha was registered when irrigation water was provided to a tune of 0.4 and 0.6 ETc (I_1) before and after flowering stages.

Among the nutrient levels, fertilizers applied at recommended dose (100 % RFD) had registered the highest seed cotton yield (2635 kg/ha) followed by 75 per cent RFD (2431 kg/ha) which were *at par* with each other. The cotton grown with no fertilizer application (control) and supplied with half dose of the recommended fertilizer (50 % RFD) had registered significantly lower seed cotton yield (1651 and 1695 kg/ha, respectively) and remained *at par* with each other. Benke (1996) also reported that drip fertigation at recommended dose increased seed cotton yield as compared to soil application.

From the above studies it can be concluded that among the irrigation and fertilizer levels in drip fertigation, irrigation at 0.5 and 0.7 ETc or 0.6 and 0.8 ETc during pre and post flowering stages coupled with 75 per cent RFD would result in enhanced input use efficiency and higher yield.

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Evaluation of some typical soils of Jalgaon district of Maharashtra for suitability of cotton

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ABSTRACT: Eight typical pedons from Jalgaon district were studied and evaluated for their suitability to rainfed cotton as per the criteria proposed by NBSS & LUP. Soil drainage, pH, $CaCO_3$, high smectitic clay are the dominant parameters limiting the suitability of cotton. Due to severe limitation of drainage and pH, pedon 7 and 8 are rated as marginally suitable but suitable (S_1) in respect of pH and moderately suitable (S) owing to moderate limitation of drainage. The moderate limitation of clay content (P_3 to P_8) and $CaCO_3$ (P_1, P_2^2) rated these pedons as moderately suitable (NBSS and LUP) but suitable. The criteria proposed by NBSS and LUP seems to be more robust.

Key words: Cotton, drainage, rainfed, productivity, suitability

Cotton (*Gossypium hirsutum*) is grown in varied pedo edaphic agroecoregions of India covering an area of 11.1 m ha with a productivity of 478 kg/ha far below the world's average of 763 kg/ha. Approximately 65 per cent of cotton in the country is produced under rainfed conditions dominantly in central and southern states. The rainfed cotton frequently faces gamble of monsoon *i.e.* aberrant precipitation coupled with intermittent dry spells which significantly limit the productivity. Some soils belonging to different soil series of Jalgaon district were evaluated for suitability of cotton (Sidhu *et al.,* 1998). Although cotton is grown in sizable area in Jalgaon with a productivity of 265 kg/ha. The introduction of *Bt* cotton started replacing banana and sugarcane crops facing problem of abiotic and biotic stresses and hence causing declined productivity. Keeping in view the above, some typical soils of Jalgaon were evaluated for their suitability for rainfed cotton by two criteria.

The area of study forms a part of Yawal and Rawer tehsils of Jalgaon district of Maharashtra and lies between 20° to 21° N latitude and 74°55' to 76°28' E longitude. In the south of Tapi river, there are hill ranges with intervening valleys of the lesser altitude than those of the Satpura. The area experiences mean annual rainfall of about 764.4 mm, 87 per cent of which is received during the months from June to September. The mean annual PET is about 2310 mm. The mean annual temperature is 27.7. The minimum and maximum temperatures are 21.4°C (January) and 34.9°C (May), respectively. The soil moisture and temperature regimes are *Ustic* and *Isohyperthermic*, respectively.

The horizon wise soil samples were processed and analysed by following standard methods (Jackson, 1979). The soils were classified taxonomically. The productivity index of these soils was assessed by the method outlined by Requier *et al.*, (1970). Suitability of soils for cotton was assessed based on crop requirement described by Anynomous (1994). The soil characteristics have been expressed on weighted mean (WM) basis. The soil site characteristics were expressed in terms of degree of limitation (0, 1, 2, 3, 4) as per standard definition (Anynomus, 1976). The evaluation of soil site characteristics was done as per the criteria (simple limitation method).

The weighted mean of climate, landscape and soil characteristics have given in Table 1. The soil site criteria proposed by and Anynomous (1994) has been shown in Table 2 and 3 respectively. All the pedons were classified as good based on their productivity index ranging from 47.1 (P6) to 58.8 (other pedons).

The rainfall and temperature during growing period do not pose any limitation. However intermittent drought/sudden increase or decrease in day/night temperature may affect productivity. The computation of limitation levels (Table 4) indicate that P7 and P8 pose moderate limitation of drainage (imperfect) and grouped as moderately suitable (Anonymous, 1994) but marginally suitable (Sys *et al.,* 1991). Bhaskar *et al.,* (1988) and Pundarikakshudu *et al.,* (1992)

Table 1. Climate, landscape and soil characteristics of the pedon (weighted mean)

Characteristics	Soils							
	Vertic Haplustept (P1)	Typic Haplustept (P2)	Typic Haplustept (P3)	Typic Haplustept (P4)	Vertic Haplustept (P5)	Typic Haplustept (P6)	Typic Haplustept (P7)	Typic Haplustept (P8)
Climatic characteristics								
Total rainfall (mm)	764	764	764	764	764	764	764	764
Mean air temp. (°C)	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Relative humidity (%)	47.9	47.9	47.9	47.9	47.9	47.9	47.9	47.9
Site characteristics								
Slope (%)	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3
Erosion	Slight	Slight	Slight	Slight	Slight	Slight	Slight	Slight
Drainage	Mod.well	Mod.well	Mod.well	Mod.well	Mod.well	Mod.well	Imperfect	Imperfect
Soil characteristics								
Surface texture	C	C	C	C	C	C	C	C
Clay (%)	50.8	54.2	68.7	68.3	60.3	61.2	73.6	73.2
Depth (cm)	142	145	128	131	128	80	138	127
Coarse fragments (v/v)	1.5	2.3	1.9	1.8	5.6	4.6	2.8	2.1
AWC (%)	14.5	15.3	15.8	15.5	11.9	12.7	18.1	18.2
$CaCO_3$ (%)	11.5	12.5	6.3	5.5	5.9	5.8	8.2	8.4
Soil fertility								
CEC (cmol(p+)/kg	42.1	44.3	51.4	51.3	50.5	49.6	51.7	51.1
Organic carbon (%)	0.61	0.54	0.47	0.57	0.42	0.50	0.57	0.63
Base saturation (%)	95.4	95.0	96.8	96.7	95.2	96.6	95.4	95.5
EC (dS/m)	0.22	0.22	0.23	0.22	0.14	0.13	0.36	0.30
ESP (%)	0.54	0.57	0.72	0.65	0.71	0.54	1.12	0.87

Table 2. Climatic, landscape and soil requirements for cotton*

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1		S2	S3	N1	N2
	0	1	2	3	4	
	100 95	85	60	40	25	0
Precipitation of growing cycle (mm)	1050-900	900-750	750-625	625-500	-	<500
Average maximum temperature Warmest month (°C)	>34	34-30	<30	-	-	-
Topography (t)						
Slope (%)	0-1	2-Jan	4-Feb	6-Apr	-	>6
Drainage	good	-	moderate	imperfect	poor	poor
Physical soil characteristics (s)						
Texture/structure	C<60s, SiC, Co, SiCL, Si, SiL, CL	C<60v, SC, C<60s, L	C<60v, SL, SCL	FS, S, LS, LcS	-	Cm, SiCm, cS
Coarse fragm. (vol %)	0-3	15-Mar	15-35	35-55	-	>55
Soil depth (cm)	>100	100-75	75-50	50-25	-	<25
$CaCO_3$ (%)	0-10	20-Oct	20-30	30-40	-	>40
Soil fertility characteristics (f)						
Apparent CEC (cmol (+)/ kg soil)	>24	24-16	<16 (-)	<16 (+)	-	-
Base saturation (%) Sum of basic cations (cmol (+)/ kg soil)	>80	80-50	50-35	<35	-	-
pH (H_2O)	6.7-7.0	7.0-7.6	7.6-8.0	8.0-8.5	-	>8.2
Organic carbon (%)						
Salinity and alkalinity (n)						
ECe (dS/m)	0-8	10-Aug	12-Oct	16-Dec	16-22	>22
ESP (%)	0-15	15-20	20-30	30-40	-	>40

Table 3. Climate, landscape and soil requirement for cotton*

Soil-site characteristics	Degree of limitation					
	0 (None)	1 (Slight)	2 (Moderate)	3 (Severe)	4 (Very severe)	
	S1		S2	S3	N1	N2
Rainfall during growing	750-950	600-750	450-600	<450	-	-
Mean temperature growing season (°C)	22-28	28-32	>32	-	-	-
Slope (%)	<1	3-Jan	5-Mar	>5	-	-
Erosion	e_0	e_1	e_2	e_3	-	-
Drainage	Well	Moderaterly well	Imperfect	Poor and excessive	-	-
Soil characteristics						
Texture (clay %)	35-50	25-35	<25 >60	-	-	-
Depth (cm)	>100	80-100	60-80	30-60	<30	
$CaCO_3$ (%)	<5	10-May	20-Oct	>20	-	-
Soil fertility						
CEC (cmol (+)/ kg soil)	>30	20-30	<20	-	-	-
BS (%)	>80	50-80	35-50	<35	-	-
O.C. (%) (0-15 cm)	>1	0.75-1.0	0.5-0.75	<0.5	-	-
ECe (dS/m)	<2	-	4-Feb	8-Apr	-	-
ESP	<5	10-May	15-Oct	-	-	-
pH (1:2.5)	6.5-8.5	-	8.5-9.0	>9.0	-	-

Table 4. Degree of limitation and suitability

Landscape/ Soil characteristics	Pedons							
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
Slope	2*(1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)
Erosion	- (1)	- (1)	- (1)	- (1)	- (1)	- (1)	- (1)	- (1)
Drainage	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	3 (2)	3 (2)
Texture	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)
$CaCO_3$	1 (2)	1 (2)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
pH	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)	3 (0)	3 (0)
Organic carbon	1 (2)	1 (2)	1 (3)	1 (2)	1 (3)	1 (2)	1 (2)	1 (2)
ESP	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Suitability	S2 (S2)	S2 (S2)	S2 (S3)	S2 (S2)	S2 (S3)	S2 (S2)	S3 (S2)	S3 (S2)

Figures in the parenthesis denotes limitation and suitability as per Anonymous (1994)
*Sys *et al.,* (1991)

indicated that there is appreciable reduction in yield of cotton under imperfect drainage condition. The pH range indicated that all the pedons are suitable (Anonymous, 1994) but moderately suitable (P1 to P6) and marginally suitable (P7, P8) as per the criteria described by Sys *et al,* (1991). The pedons (P3 to P8) had more than 60 per cent clay (smectitic) and more than 10 per cent $CaCO_3$ (P1 and P2), these soils pose moderate limitations and hence grouped as moderately suitable (Anonymous, 1994) but suitable (Sys *et al.,* 1991). As these soils had high smectitic clay may pose problem of drainage when get super saturated during monsoon and hence excess water to be drained through channels. Having gone through merit/ demerits of the methods of suitability criteria for rainfed cotton in central India, it may inferred that depth and clay content play decisive role in suitability of cotton (Bhaskar *et al.*,1988; Yadav *et al.,* 1999). The evaluation based on limitation of single factor may under rate the suitability, as the productivity is the result of combined influence of pedo edaphic factors including agro managements and hence it necessitates to work on one or two robust parameters which can be directly linked with productivity.

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Productivity of *Bt* cotton based double cropping system in ayacut areas of vertisols

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ABSTRACT : The field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur during *kharif* and *rabi* seasons of 2011-2012 to identify suitable crops that can be raised after the harvest of *Bt* cotton in vertisols in ayacut areas with limited water and work out the economics for realizing maximum returns from the system as a whole. Cotton followed by baby corn recorded significantly higher cotton equivalent yield of 3883 kg/ha followed by cotton mustard cropping sequence 3309 kg/ha with additional net returns of Rs.18,438/ha. *Bt* cotton followed by a field crop like baby corn or cotton mustard can be recommended in vertisols of ayacut areas under limited irrigation facilities to enhance the land use efficiency and also for achieving remunerative returns.

Key words : *Bt* cotton, cropping system

Cotton the "King of Fibres" and said to be the "White Gold" is mostly grown under rainfed conditions in Andhra Pradesh. The cotton crop is grown in black soils of Krishna zone where the annual rainfall is around 900mm. The cotton crop is sown from second fortnight of July to second fortnight of August as rainfed crop. After the cotton crop generally, the field is kept fallow. The *Bt* cotton by virtue of its resistance to bollworms, the crop duration has been reduced by 15-30 days as compared to non *Bt* and the NSP canal water is released during September October months. Under these circumstances there is a scope to raise some short duration crop in *rabi* after harvesting *Bt* cotton wherever irrigation source is available which can increase the production efficiency of the system as a whole by enhancing the land use efficiency. Keeping this in view, present study was conducted to identify suitable crops that can be raised after the harvest of *Bt* cotton in vertisols in ayacut areas with limited water and work out the economics for realizing maximum returns from the system as a whole which could be practically feasible and economically viable.

MATERIALS AND METHODS

The field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur during *kharif* and *rabi* seasons of 2011-2012. The soil of the experimental site is clay loam in texture, slightly alkaline with pH 7.8, low in available organic carbon (0.38 %), low in available nitrogen (188 kg/ha), medium in available phosphorus (28 kg/ha) and high in available potassium (856 kg/ha). The total precipitation received during the crop season was 835.6 mm in 52 rainy days. The trial was laid out in split plot design with three replications. The treatments consisted of three *Bt* cotton hybrids of different duration as main treatments *i.e.,* NCS 138 BG II (Kisan Early) 150 days duration (H_1) NCS 913 BG II (Ranjit) 150 days duration (H_2) and NCS 145 BG II(Bunny) 170 days duration (H_3), were sown on 18.7.2011 and were grown with standard package of practices with a spacing of 90 x 60 cm in a plot size of 7.2 x 28 m. Growth and yield parameters like monopodia, sympodia and bolls/plant, boll weight, seed cotton yield, seed index, lint index, GOT (%) and fibre quality were recorded in the *Bt* cotton entries. After the cotton crop was harvested various crops were sown as sub plots as per the treatments during the first week of January 2012 with a plot size of 7.2 x 3m. The crops raised were greengram (LGG 460, 30 x 10cm), baby corn (Pioneer 30 v 92, 45 x 20cm) clusterbean (Local 45 x 10cm) soybean (JS 335 30 x 15cm), *Diancha* (Local, 30 x 10cm), mustard (Sita 45 x 15cm) , sesamum (Gowri, 30cmx10cm) and sunflower (APSH,45 x 15cm). The total yield and net returns obtained from individual crop sequences were analysed statistically after converting them into cotton equivalent yield by adopting the standard procedures described by Gomez and Gomez (1984). 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) was calculated on dividing the production of the sequence by total duration of the sequence and these values in terms of Rs/ha/day were obtained by net return of the sequence divided by total duration of the sequence (Singh and Verma,1998).

The data presented in the Table 1 revealed that the three *Bt* cotton entries of different duration recorded similar yields. However, the entry Bunny has recorded higher yield (2836 kg/ha) followed by Kisan Early (2665 kg/ha). Cotton followed by baby corn recorded significantly higher cotton equivalent yield of 3883 kg/ha among all the treatments and followed by cotton mustard cropping sequence 3309 kg/ha. Interaction effect of cotton entries with the sequence crops in recording cotton equivalent yield was found to be non significant.

Land use efficiency : Perusal of the data from Table 2 revealed that maximum land use efficiency of 71-73 per cent was recorded with cotton followed by gingelly or mustard or sunflower as the system has been accommodated with long duration crops. Whereas the lowest land use efficiency of 61-65 per cent was recorded in cotton followed by baby corn or greengram or soybean. Therefore, the land use efficiency differed by virtue of the cotton entries and the duration of the crops that was taken after cotton. The results are in conformity with the findings of Kumpawat (2001) and Narayana *et al.,* (2009).

Production use efficiency : The highest production use efficiency in terms of kg/ha/ day was recorded in all the three cotton entries subsequently grown by baby corn (16.86,16.81,17.4) and followed by cotton mustard sequence (12.55,12.43,12.98) and similar trend was recorded in production use efficiency in terms of Rs/ha/day (353.16,350.49,374.52) and (240.21, 231.80, 256.97), respectively. This might be because of high yield of baby corn in short period of time and good market price.

Economics : Cotton baby corn sequence gave the highest net returns of Rs 82091/ha followed by cotton mustard sequence (Rs 63563/ ha) in vertisols of ayacut areas. Similar trend was observed regarding the benefit cost ratio(BCR). This might be due to low cost of cultivation and high yield coupled with high market price for baby corn that prevailed during the season. These results are in conformity with the findings of Verma *et al.*, (2003). Therefore, it can be concluded that *Bt* cotton followed by a field crop like baby corn or mustard in *rabi* season in vertisols of ayacut areas under limited irrigation facilities can be recommended to

Table 1. Cotton equivalent yield, economics of *Bt* cotton based double cropping

Treatments	Cotton equivalent yield (kg/ha)	Net returns	BCR
***Bt* cotton hybrids**			
Kisan Early	2665	42955	1.77
Ranjit	2593	40651	1.74
Bunny	2836	48427	1.86
SEm +	74		
CD (p=0.05)	NS		
Sequence crops			
Greengram	2316	31787	1.59
Baby corn	3883	82091	2.33
Soybean	2413	34891	1.64
Clusterbean	2217	28619	1.54
Diancha (seed)	2303	31371	1.58
Mustard	3309	63563	2.08
Sesamum	2369	33483	1.62
Sunflower	2771	46347	1.82
SEm +	99		
CD (p=0.05)	249		
Interaction			
Hybrids x sequence crops	NS		

Table 2. Yield, duration of the crop sequence, LUE and PUE of *Bt* cotton based double cropping

Treatments	Yield (kg/ha)		Duration (days)		LUE	PUE	
	cotton	(*Rabi* crop)	Cotton	Second crop	(%)	kg/ha/ day	Rs/ha/ day
KisanEarly- Greengram	1858	460	155	78	63.84	9.84	133.28
Kisan Early- Baby corn	1858	4859	155	72	62.19	16.86	353.16
Kisan Early- Soybean	1858	1259	155	75	63.01	10.30	145.50
KisanEarly- Clusterbean	1858	620	155	90	67.12	8.95	113.70
KisanEarly-*Diancha* (seed)	1858	750	155	102	70.41	8.81	117.14
Kisan Early- Mustard	1858	1324	155	107	71.78	12.55	240.21
Kisan Early- Gingelly	1858	408	155	110	72.60	8.88	124.57
Kisan Early- Sunflower	1858	1295	155	108	72.05	10.39	171.60
Ranjit-Greengram	1786	445	150	75	61.64	9.81	125.77
Ranjit-Baby corn	1786	4963	150	76	61.92	16.81	350.49
Ranjit-Soybean	1786	1286	150	75	61.64	10.25	140.05
Ranjit-Clusterbean	1786	598	150	95	67.12	8.61	102.74
Ranjit-*Diancha* (seed)	1786	792	150	100	68.49	8.86	114.11
Ranjit-Mustard	1786	1280	150	105	69.86	12.43	231.80
Ranjit-Gingelly	1786	396	150	105	69.86	8.89	118.58
Ranjit-Sunflower	1786	1312	150	110	71.23	10.28	166.13
Bunny-Greengram	2017	455	160	78	65.21	10.28	151.23
Bunny-Baby corn	2017	4985	160	72	63.56	17.40	374.52
Bunny-Soybean	2017	1345	160	75	64.38	10.90	168.80
Bunny-Clusterbean	2017	615	160	90	68.49	9.40	131.43
Bunny-*Diancha* (seed)	2017	765	160	102	71.78	9.28	135.31
Bunny-Mustard	2017	1341	160	107	73.15	12.98	256.97
Bunny-Gingelly	2017	385	160	110	73.97	9.20	137.79
Bunny-Sunflower	2017	1320	160	108	73.42	10.85	189.40

enhance the land use efficiency and for achieving remunerative returns.

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Yield and economics of *Bt* cotton (*Gossypium hirsutum* L) as influenced by integrated foliar nutrition under irrigated conditions

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Abstract: A field experiment was carried out during 2009-2010 at Main Agricultural Research Station Farm, Raichur to study the response of *Bt* cotton (*Gossypium hirsutum* L) to foliar nutrition under irrigated condition. The results revealed that among foliar application of major and secondary nutrients, $MgSO_4$ @ 1.0 per cent + KNO_3 @2.0 per cent spray registered significantly higher seed cotton yield (2506 kg/ha). Significantly higher gross returns (Rs 67,656/ha), net returns (Rs 40,917/ha) and B: C ratio (2.66) was registered with foliar application of $MgSO_4$ @ 1.0 per cent + KNO_3@ 2.0 per cent, $MgSO_4$ @ 1.0 per cent and DAP @ 2.0 per cent sprays, respectively. Among foliar application of growth regulators and micronutrient significantly higher seed cotton yield was obtained with spraying of NAA @ 10 ppm + $ZnSO_4$ @ 0.5 per cent (2469 kg/ha) over NAA @ 10 ppm (2327 kg/ha) and control (water spray) (2183 kg/ha). Significantly higher gross returns and net returns registered with foliar application of NAA @ 10 ppm + $ZnSO_4$ @ 0.5 per cent (Rs 66,679/ha and Rs 39,051/ha, respectively) and significantly higher B: C ratio (2.56) was registered with foliar application of NAA @ 10 ppm spray.

Key words: *Bt* cotton, growth regulator, major micronutrients, secondary nutrients

India ranks first in area and second in production after China with an average productivity of 526 kg lint/ha which is very low as compared to world's average productivity of 767 kg lint/ha. The maximum yield potential of *Bt* cotton is yet to be trapped under irrigated conditions which is low for various reasons. Of these, monocropping practice, decline in soil fertility status, imbalanced nutrition and non adaptability of prime production practices, apart from pest and disease menance and physiological disorders are major constraints for such a low productivity. Indian government is now looking for many ways to improve the production of cotton in order to boost the economy.

Among the agronomic practices, crop nutrition is of great importance. *Bt* cotton has high nutritional demand during its grand growth phase since it has heavy boll bearing capacity on account of retention of more number of early formed bolls. This has necessitated to supply secondary and micro nutrients in required quantities with other major nutrients and growth regulators to control physiological disorder *viz.*, pre mature shedding of buds and bolls for higher crop production. Most of the previous work was carried out on non *Bt* cotton and was aimed at generating information on effect of few individual nutrients on productivity.

Keeping in view the above points, the present study was conducted to investigate the effect of foliar application of major and secondary nutrients, growth regulators and micronutrients alone and in combinations on yield of *Bt* cotton and to workout the economic feasibility of integrated foliar nutrition under irrigation.

A field experiment was conducted under irrigation during 2009-2010 at Main Agricultural Research Station Farm, Raichur situated in north eastern dry zone (Zone 2) of Karnataka. The experimental plot containing medium deep black soil having 383.00 kg/ha available nitrogen, 37.58 kg ha available phosphorous, 286.80 kg/ha available potassium, 0.31 ppm zinc. There were 15 treatment combinations comprising 5 major and secondary nutrients foliar sprays at flower initiation, boll formation and boll development stages in main plot (M_1: Control (water spray), M_2: KNO_3 @ 2.0 %, M_3: $MgSO_4$ @ 1.0 %, M_4: DAP @ 2.0 % and M_5: $MgSO_4$ @ 1.0 % + KNO_3 @ 2.0 %) and 3 growth regulator and micronutrient sprays at flower initiation and boll development stages in sub plot (S_1: Control (water spray), S_2: NAA @ 10 ppm and S_3: NAA @ 10 ppm+ $ZnSO_4$ @ 0.5 %). Treatments were replicated thrice in split plot design. The crop was sown on 20^{th} August 2009 with a plot size of 7.2 x 5.4 m. All the growth and yield parameters and seed cotton yield were recorded and statistically analyzed.

Seed cotton yield: The data revealed that spraying of $MgSO_4$ @ 1.0 per cent + KNO_3 @ 2.0 per cent at flower initiation, boll formation and boll development stages recorded maximum seed cotton yield (2506 kg/ha) and was significantly superior over other treatments except spraying of $MgSO_4$ @ 1.0 per cent (2446 kg/ha) which inturn was *on par* with DAP @ 2.0 per cent (2389 kg/ha) spray. Both $MgSO_4$ and DAP spray were significantly superior over KNO_3 @ 2.0 per cent spray (2283 kg/ha). The significantly lowest seed cotton yield was recorded with control (water spray) (2008 kg/ha). Increase in seed cotton yield with $MgSO_4$ + KNO_3 and $MgSO_4$ sprays was 24.8 and 21.8 per cent, respectively over control. Seed cotton yield is governed by several factors, which have direct influence on seed cotton yield and yield components *viz.,* bolls/plant, mean boll weight, bolls harvested/plant (Table 1). Several workers have reported increase in seed cotton yield with spraying of $MgSO_4$ (Kumar and Yadav, 2010), $MgSO_4$ + KNO_3, DAP (Mehetre *et al.*, 1990 and Sasthri *et al.*, 2000) and KNO_3 (Kaur *et al.*, 2007).

The seed cotton yield was significantly higher with spraying of NAA @ 10 ppm + $ZnSO_4$ @ 0.5 per cent twice at flower initiation and boll development stages (2469 kg/ha) as compared to NAA @ 10 ppm (2327 kg/ha) and control (2183 kg/ha) (Table 1). The yield increase with spraying of NAA @ 10 ppm + $ZnSO_4$ @ 0.5 per cent at flower initiation and boll development stages over NAA @ 10 ppm and control increase was to an extent of 6.11 and 13.12 per cent, respectively. The higher seed cotton yield with spraying of NAA @ 10 ppm + $ZnSO_4$ @ 0.5 per cent at flower initiation and boll development stages was due to more flower and boll retention/ha as compared to other treatments. These results are in conformity with the findings of Setty *et al.,* (2002). Similarly, several workers have reported increase in seed cotton yield with spraying of NAA (Satyanarayana Rao and Janawadwe, 2006 and Vishwanath *et al.*, 2010, Singh and Sidhu, 1997 and Sundaravadivel *et al.,* 1998).

Economics : Spraying of DAP, $MgSO_4$ and $MgSO_4$ + KNO_3 recorded significantly higher net returns (Rs. 40183, 40917 and 39483/ha, respectively) as compared to control (Rs 31100/ha) (Table 1). Significantly lower net returns were obtained with control. The higher net returns were mainly because of higher seed cotton yield with these treatments. Net returns realized with DAP (Rs 40183/ha) was maximum and inturn was *on par* with $MgSO_4$ (Rs 40917/ha) and $MgSO_4$ + KNO_3 (Rs. 39483/ha) sprays. This may be because of lower cost incurred in DAP treatment. Similar trend was also observed with respect to benefit cost ratio. These results were in conformity with the findings of Brar and Brar (2004) and Setty *et al.*, (2002) and Basavanneppa

Table 1. Yield and economics of *Bt* cotton as influenced by integrated foliar nutrition

Treatments	Rs/ha			Benefit cost ratio	Seed cotton yield (kg/ha)
	Cost of cultivation	Gross returns	Net returns		
Foliar spray of major and secondary nutrients (M)					
M_1 Control					
M_2 KNO_3 (2.0 %)	23124	54225	31100	2.35	2008
M_3 $MgSO_4$ (1.0 %)	26448	61653	35164	2.33	2283
M_4 DAP (2.0 %)	25131	66048	40917	2.63	2446
M_5 $MgSO_4$ (1.0 %) + KNO_3 (2.0 %)	24328	64512	40183	2.66	2389
	28172	67656	39483	2.40	2506
S. Em.±	42	752	710	0.02	27.85
C.D. (p=0.05)	136	2453	2316	0.08	90.83
Folair spray of growth regulator and micronutrient (S)					
S_1 Control					
S_2 NAA @ 10 ppm	24185	58941	34756	2.44	2183
S_3 NAA @ 10 ppm + $ZnSO_4$ (0.5 %)	24534	62836	38301	2.56	2327
	27628	66679	39051	2.41	2469
S. Em.±	30	533	503	0.01	19.72
C.D. (p=0.05)	87	1571	1484	0.05	58.19

et al., (2009).

Among growth regulator and micronutrient applications, NAA + $ZnSO_4$ and NAA alone at flower initiation and boll development stages recorded significantly higher net returns (Rs 39051/ha and Rs 38301/ha, respectively) and found significantly superior over control which received water spray alone (Rs 34756/ha) (Table 1). Net returns realized with NAA + $ZnSO_4$ spray though were *on par* with NAA spray but were 12.35 per cent higher over control. Similar observations were reported by Setty *et al.*, (2002) and Satyanarayan Rao and Janawade (2006). Benefit cost ratio did not follow trend of net returns due to variation in cost of cultivation. Interactions between foliar application of major and secondary nutrients and growth regulator and micronutrient were found to be non significant.

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Impact of secondary treated distillery spentwash on chlorophyll content, red leaf index and sucking pests of *Bt* cotton

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ABSTRACT : A field experiment was conducted during *kharif,* 2010-2011 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the impact of secondary treated distillery spentwash on chlorophyll content, red leaf index and sucking pests of *Bt* cotton. Results indicated that application of 1.5 N through distillery spentwash significantly increased the total chlorophyll content (1.23 mg/g fresh weight) at 120 DAS, lowest red leaf index (1.21) on 1st December and significantly higher seed cotton yield (2566.1 kg/ha) was recorded than the rest of the treatments. Application of 1.5 N through fertilizers recorded significantly highest population of jassids (3.20/3 leaves), thrips, (19.07/3 leaves) and aphids (6.06/3 leaves), whereas, all application levels of spentwash reduced the population of sucking insects.

Key words : *Bt* cotton, chlorophyll content, distillery spentwash, red leaf index, sucking pests

Cotton (*Gossipium* spp) the "King of Fibre" is the leading fibre crop in the world. It is grown over an area of 33.2 mha with a production of 26.3 mt and productivity of 727 kg lint/ha. In India it is grown on an area of 10.12 mha with a production of 295 lakh bales and productivity of 502 kg lint/ha. In Karnataka it is grown over an area of 3.95 lakh ha with production of 9 lakh bales and productivity of 387 kg/ha (Anonymous, 2010).

Low productivity of cotton in India is accounted to aberrant rainfall, low organic carbon in soil, inadequate application of fertilizers, insufficient plant protection, lack of nutrient availability due to poor soil conditions and water logging and thus a complex of which results in premature leaf reddening in *hirsutum* cotton. Red leaf syndrome is wide spread, but its occurrence is not consistent. The yielding ability is not drastically reduced when it occurs at post flowering stage in upland cotton, but its yield is reduced when it occurs at flowering or vegetative stage. The farmers ignore this problem because of adverse condition. Cancerous proliferation of this syndrome covers their entire field and out breaks of this disorder renders their field completely red. Leaf reddening was found to reduce the yield to an extent of 10 – 60 per cent as reported by Dhopte (2001). With introduction of hybrids and *Bt* cotton the problem of leaf reddening has become more serious. Keeping this in view an experiment was conducted during *kharif,* 2010-2011 to study on the impact of secondary treated distillery spentwash on chlorophyll content, red leaf index and sucking pests of *Bt* cotton.

The distillery spentwash used in the present investigation was collected from Sri Lakashmi Narayana Distillery Unit, Garag located near MARS, UAS, Dharwad during *kharif,* 2010-2011. Analysis of spentwash has been giveven in (Table 1). The general characteristics of the soil were pH 7.63 (1:2.5 soil : water), EC of 0.20 dS/m, organic carbon content of 0.47 per cent and 203.70, 35.23, 395.50 kg/ha of available N (alkaline $KMnO_4$), P_2O_5 (Olsen's P) and K_2O (NH_4OAc), respectively. The experiment was laid out in RCBD design replicated thrice with gross and net plot size of 6.3×4.8 m and 3.6×3.6m, respectively with the following treatments.

- T_1 : 1 N (Nitrogen) through spentwash (90.90 m^3/ha)
- T_2 : 1.5 N through spentwash (136.36 m^3/ha)
- T_3 : 1 N through fertilizer (RDF – 100 : 50 : 50 N, P_2O_5 and K_2O kg/ha, respectively)
- T_4 : 1.5 N through fertilizer
- T_5 : 0.25 N through spentwash (22.72 m^3/ha) + 0.75 N through fertilizer
- T_6 : 0.5 N through spentwash (45.45 m^3/ha) + 0.5 N through fertilizer
- T_7 : 0.75 N through spentwash (68.18 m^3/ha) + 0.25 N through fertilizer

T_8 : Recommended package of practices (RDF + FYM)
T_9 : Control (no fertilizers and no spentwash)

The quantity of spentwash used was based on recommended nitrogen requirement of *Bt* cotton. Forty per cent spentwash was applied 15 days before sowing of *Bt* cotton. Remaining 60 per cent was applied in three equal splits (15, 30 and 60 DAS) and remaining P_2O_5 was supplied through single super phosphate. The cultural practices were followed as recommended. The seeds of Bunny BG II *Bt* cotton were dibbled with a spacing of 90 × 60 cm. The red leaf index was scored into 5 grades (Dasture *et al.,* 1957). The red leaf index was taken as zero when all the leaves in five plants were green and red leaf index was taken as four (maximum) when all leaves in five plants were wholly red. Chlorophyll content was determined in 80 per cent acetone extract. The absorbance of leaf extract was measured at 663 nm and 645 nm in colorimeter. The sucking pests *viz.*, thrips (*Thrips tabaci* Lind), aphids (*Aphis gossypii* Glov.) and jassids (*Amrasca biguttela biguttela* Ishida) were observed in three leaves selected randomly from top, middle and bottom of five tagged plants at the lower surface of the leaves.

Effect on chlorophyll content and red leaf index : Significantly higher red leaf index was noticed on 1st December (2.90) in control, which was reduced significantly with application of RDF (2.13) and spentwash (1.21 to 2.23). Significantly minimum red leaf index (1.21) and highest chlorophyll content (1.23 mg/g fresh weight) were noticed with the application of 1.5 N through spentwash than the rest of the treatments followed by 1 N through spentwash (1.83 red leaf index and chlorophyll content 1.11 mg/g fresh weight). The principal cause of red leaf is due to nitrogen and magnesium deficiency. Increasing doses of nitrogen, potassium and micronutrients might have increased the supply of nitrogen and magnesium in leaves and reduced the formation of anthocyanin pigment at the cost of chlorophyll. Similar results were also reported by the Prabhakar (1981). Red leaf index was minimum with foliar application of nitrogen, magnesium and phosphorus. Similarly, Krishnegowda (2004) reported that, application of 200 per cent RDF recorded lowest red leaf index in cotton. The chlorophyll content was increased and this might be due to supply of the nitrogen, magnesium, iron through spentwash which are essential for chlorophyll synthesis in plant. Red leaf index was reduced because of increased chlorophyll content with the application of nutrients through spentwash which in turn led to increased photosynthetic efficiency of plant. This resulted in higher *kapas* yield.

Effect on sucking pest and yield : Application of 1.5 N through fertilizers recorded significantly highest population of jassids (3.20/3 leaves), thrips (19.07/3 leaves) and aphids (6.06/3 leaves). This might be due to luxuriant growth of cotton which attracted the sucking pest. These results are in conformity with the Krishnegowda (2004). Whereas, application of spentwash and recommended package of practices improved soil physical and biological properties. During decomposition of spentwash, the organic manures produces organic acids as well as antibiotic substances (phenols) and intermediate products. These products were absorbed by plants and increased their resistance to pests and disease. Sundaramurthy, (1999) reported that raw distillery effluent was found to reduce the incidence of *Aphis gossypii* (by 85.9%) and *Bemisia tabaci*, two major sap feeding insects. Besides bollworm incidence was also significantly decreased in cotton crop treated with fenvalerate in combination with raw distillery effluent. This might be due to the changed

Table 1. Characteristics and chemical composition of secondary treated spentwash

Characteristic	Value
Colour	Dark brown
Odour	Bad
pH	8.1
Electrical conductivity (dS/m)	18
BOD (mg/l)	5360
COD (mg/l)	15000
Total nitrogen (mg/l)	1100
Total phosphorus (mg/l)	200
Total potassium (mg/l)	11,500
Total magnesium (mg/l)	790
Total calcium (mg/l)	1500
Total iron (mg/l)	70.5
Total zinc (mg/l)	10.5
Total copper (mg/l)	4.5
Total manganese (mg/l)	10.2

Table 2. Chlorophyll (mg/g fresh weight) content and red leaf index of *Bt* cotton as influenced by application of spentwash and fertilizers

Treatment	Chlorophyll (DAS)			Red leaf Index				
	60	90	120	1st Oct	15th Oct	1st Nov	15th Nov	1st Dec
T_1 1 N through spentwash	0.82	1.12	1.11	0	0.1	0.33	1.53	1.83
				-1	-1.05	-1.15	-1.59	-1.68
T_2 1.5 N through spentwash	0.85	1.25	1.23	0	0	0.2	0.84	1.21
				-1	-1	-1.09	-1.35	-1.49
T_3 1 N through fertilizers	0.72	0.84	0.81	0.33	0.83	1.47	2.16	2.37
				-1.15	-1.35	-1.57	-1.78	-1.83
T_4 1.5 N through fertilizesr	0.81	0.98	0.98	0	0.2	0.67	1.77	2.06
				-1	-1.09	-1.29	-1.66	-1.75
T_5 0.25 N through spentwash + 0.75 N through fertilizers	0.75	0.92	0.89	0.11	0.60	1.20	2.03	2.23
				(1.05)	(1.26)	(1.48)	(1.74)	(1.79)
T_6 0.5 N through spentwash + 0.5 N through fertilizers	0.78	0.95	0.94	0	0.24	1.00	1.80	2.17
				(1.00)	(1.11)	(1.41)	(1.67)	(1.78)
T_7 0.75 N through spentwash + 0.25 N through fertilizers	0.80	1.03	1.01	0	0.29	0.80	1.77	2.17
				(1.00)	(1.14)	(1.34)	(1.66)	(1.78)
T_8 RPP (RDF + FYM)	0.79	0.95	0.90	0	0.32	0.90	1.90	2.13
				(1.00)	(1.15)	(1.38)	(1.70)	(1.77)
T_9 Control (no spentwash and no fertilizers)	0.60	0.76	0.66	0.67	1.40	2.43	2.50	2.90
				(1.29)	(1.54)	(1.85)	(1.87)	(1.97)
S.Em±	0.02	0.04	0.04	0.03	0.05	0.06	0.04	0.05
CD (p=0.05)	0.05	0.12	0.11	0.10	0.15	0.17	0.13	0.14

Note: DAS - Days after sowing; Data in parenthesis are vX+1 transformed value

Table 3. Sucking pest population and *kapas* yield of *Bt* cotton as influenced by application of spentwash and fertilizers

Treatment	Jassids/ 3 leaves (DAS)		Thrips/ 3 leaves (DAS)		Aphids/3 leaves (DAS)		*Kapas* yield /plant (g)	*Kapas* yield (kg/ha)
	80	95	80	95	80	95		
T_1 1 N through spentwash	2.07	3.07	15.08	22.73	3.70	3.45	135.3	2436.7
	(1.43)	(1.75)	(3.88)	(4.77)	(1.92)	(1.85)		
T_2 1.5 N through spentwash	2.13	2.94	14.23	22.50	3.65	3.40	142.4	2566.1
	(1.46)	(1.71)	(3.77)	(4.74)	(1.91)	(1.84)		
T_3 1 N through fertilizers	2.24	3.13	15.10	23.17	4.25	3.89	108.2	1930.3
	(1.55)	(1.77)	(3.88)	(4.81)	(2.06)	(1.97)		
T_4 1.5 N through fertilizesr	3.20	4.03	19.07	28.90	6.06	5.21	115.8	2075.7
	(1.79)	(2.01)	(4.36)	(5.37)	(2.46)	(2.28)		
T_5 0.25 N through spentwash + 0.75 N through fertilizers	2.07	2.53	12.18	23.00	4.16	3.04	133.1	2392.5
	(1.44)	(1.59)	(3.48)	(4.80)	(2.04)	(1.74)		
T_6 0.5 N through spentwash + 0.5 N through fertilizers	1.97	3.05	13.53	22.67	3.37	3.07	141.3	2545.9
	(1.39)	(1.75)	(3.67)	(4.75)	(1.83)	(1.75)		
T_7 0.75 N through spentwash + 0.25 N through fertilizers	1.73	3.00	12.40	22.80	3.45	3.00	137.1	2469.4
	(1.31)	(1.73)	(3.52)	(4.77)	(1.86)	(1.73)		
T_8 RPP (RDF + FYM)	1.90	2.60	13.07	21.17	3.41	3.03	114.3	2048.2
	(1.37)	(1.60)	(3.61)	(4.60)	(1.84)	(1.74)		
T_9 Control (no spentwash and no fertilizers)	2.00	3.03	14.35	22.67	3.55	3.11	77.1	1359.0
	(1.41)	(1.74)	(3.78)	(4.75)	(1.88)	(1.76)		

Note: DAS - Days after sowing; Data in parenthesis are v transformed; RPP-Recommended package of practicess biochemistry of plants resulting into induced resistance provided by different organic amendments. Reduction in sucking pest population incidence due to application of spentwash resulted in higher yield.

Data presented in Table 2 indicated/plant *kapas* yield and *kapas* yield under different treatments of crop nutrition. Addition of spentwash (T_1, T_2, T_5, T_6 and T_7) resulted increase/plant *kapas* yield significantly (133.1 to 142.4 g/plant) and *kapas* yield (2392.5 to 2566.1 kg/ha) as compared to chemical fertilizer (108.2 to 115.8 g/plant and 1930.3 to 2075.7 kg/ha), RPP (114.3 g/plant and 2048.2 kg/ha) and control (77.1 g/plant and 1359.0 kg/ha). Significantly higher seed cotton yield (2566.1 kg/ha) was recorded with T_2. However it was *at par* with T_6, T_7, T_1 and T_5. The results are in conformity with the findings of Baskar *et al.*, 2003. The use of distillery spentwash hence not only increased the crop yield but also reduced red leaf index and sucking pest than application of chemical fertilizers. It has substituted for 100 per cent N, 36 per cent of P_2O_5 and 100 per cent of K_2O in *Bt* cotton.

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Effect of Thidiazuron on somatic embryogenesis in cotton

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ABSTRACT : The present study investigated induction of high frequency of somatic embryogenesis in cotton *(Gossypium hirsutum)* by Thidiazuron in two commercial hybrids *viz .,* Fateh and LHH 144 and their parental inbreds. For callusing, MS medium was supplemented with different concentrations and combinations of growth regulators. Among different explants taken *viz.,* hypocotyls, cotyledonary node segments and young leaves, callus initiation and proliferation was best from hypocotyl tissue. It was observed that embryogenic callus was obtained only on Thidiazuron (2 mg/ l) supplemented with MS medium. Percentage frequency of somatic embryogenesis was further increased in all the genotypes by replacing sucrose (30 g/ l) with glucose (30 g/ l). In case of Fateh highest frequency of embryogenic calli (89.7%) was obtained in glucose supplemented medium followed by Fateh male parent (77.8%) and Fateh female parent (73.3%). In LHH144 male parent, highest frequency of embryogenic calli (81.5%) was in glucose supplemented medium and 63.3 per cent in sucrose supplemented medium followed by hybrid 79.2 per cent than female parent 72 per cent. Overall the hybrid Fateh and its parents seem to possess a better genetic constitution for *in vitro* culturing.

Key words*: Gossypium hirsutum*, kinetin, somatic embryogenesis, Thidiazuron , tissue culture

Somatic embryogenesis is an important tool for rapid cloning of useful germplasm including inbreds, male sterile lines and rare hybrids as reported by Obembe *et al.,* (2011). Once high frequency of somatic embryogenesis is obtained, embryogenic cell cultures can be used for protoplast isolation, plant regeneration and further genetic transformation. Somatic embryogenesis and plant regeneration in cotton has been reported by Haq (2005) and Khan *et al.,*(2010). Thidiazuron (TDZ) is a herbicide with an intrinsic cytokinin like activity. It's now considered to be more potent than most of the commonly used cytokinins currently available for tissue culture in most of the major crops. (Zhang *et al.,* 2000 and Ouma *et al.*, 2004.). The present paper reports the effect of TDZ on somatic embryogenesis in cotton using various explant sources from *in vitro* raised seedlings.

Kumar and Pentel (1998) have reported *in vitro* regeneration by somatic embryogenesis in an Indian cultivar MCU5. Therefore, comprehensive procedure to regenerate plants are needed to employ advanced techniques in the improvement of cotton. Thus present study was undertaken to induce high frequency of somatic embryogenesis in hybrids *viz.*, Fateh and LHH144 and their parental inbreds. The female parents of Fateh and LHH144 were LH660 and PIL43 and the male parents were Suman and PIL8, respectively.

For raising the *in vitro* plantlets, healthy seeds of different varieties of cotton *viz.,* Fateh and LHH144 and their parental inbreds were surface sterilized with $HgCl_2$ (0.1%) for 10 min. These were then rinsed thrice with sterile water and 4-5 seeds were aseptically placed on solid MS basal medium prepared in glass jars. The cultures were placed at 32±2^{0}C temperature and light intensity of 5000 lux. The callus cultures were established by taking different explant sources *viz.*, young leaves, hypocotyl and cotyledonary node segments from *in vitro* grown 5-7 day old plantlets.

For callusing, different media were tested as follows:

M_1 MS + 2,4-D (0.1 mg/ l) + Kinetin (0.5 mg/ l)+Glucose(30g/ l)
M_2 MS + Thidiazuron (2 mg/ l) + Glucose (30 g/ l)
M_3 MS + Thidiazuron (2 mg/ l) + Sucrose (30 g /l)
M_4 MS +2,4-D(0.5mg/ l) + Kinetin(0.5 mg/ l) + Sucrose(30g/ l)
M_5 MS + Thiadiazuron (4 mg/ l) + Sucrose (30 g /l)

The callus cultures were placed at 30±2°C in complete darkness. Five week old callus was examined under stereomicroscope for study of somatic embryogenesis. Effect of sucrose (3%)

Table 1. Genotypic variability for callus formation in cotton (*Gossypium hirsutum* L.) using hypocotyl and leaves as explant source in two *intra hirsutum* hybrids, Fateh and LHH144 and their parental inbreds

Genotype	Medium used											
	M_1						M2					
	Explants cultured		Explants showing callusing		Callusing obtained (%)		Explants cultured		Explants showing callusing		Callusing obtained (%)	
	Hypocotyl	Leaves	Hypocotyl	Leaves	Hypocotyl	Leaves	Hypocotyl	Leaves	Hypocotyl	Leaves	Hypocotyl	Leaves
Fateh (female parent)	30	32	12	9	40.0	28.1	30	25	22	11	73.3	44.0
Fateh (male parent)	30	26	10	7	33.5	26.9	27	23	21	7	77.8	30.4
Fateh (hybrid)	30	22	13	6	43.3	27.3	29	24	26	10	89.7	41.7
LHH144 (female parent)	24	30	10	5	41.7	16.7	27	22	22	5	81.5	22.7
LHH144 (male parent)	22	30	9	7	40.9	23.3	25	20	18	6	72.0	30.0
LHH144 (hybrid)	29	30	12	8	41.4	26.7	24	28	19	9	79.2	32.7

and glucose (3%) and orientation of explant was also studied on somatic embryogenesis in callus cultures from hypocotyl segments in TDZ supplemented medium.

Among different explant sources *i.e.* hypocotyls, cotyledonary node segments and young leaves, the callus initiation was found to be best from hypocotyl tissue (89.7%) (Table 1) followed by young leaves (44%) (Table 2). Callus induction from cotyledonary node segments was found to be very poor. Therefore callus induction from leaves and cotyledonary nodes were not used for further studies. Embryogenic calli induction from hypocotyl segments have earlier been reported by Sun *et al.,* (2003) and Avdin *et al.,* (2004). Out of the different media used for somatic embryogenesis, callus growth was found to be more rapid and profuse in M_2 medium in all genotypes studied.

Interestingly, embryogenic calli was obtained only on TDZ supplemented medium and not in 2,4D and kinetin supplemented medium. Somatic embryogenesis induction *via* TDZ supplemented medium has also been reported in variety of crops by Ouma *et al.,* (2004); Han *et al.,*(2009). Percentage frequency of somatic embryogenesis was further increased in all genotypes by replacing sucrose (30 g/l) with glucose (30 g/l) (Table 3). This indicates that glucose was a better carbon source than sucrose. During maintenance, the calli exhibited frequent necrosis and browning due to secretion of large amount of phenolics. This was prevented by adding 2g/l of activated charcoal in the medium.

Differential response was also shown by different genotypes of cotton. The hybrid Fateh and its parental inbreds showed highest frequency of embryogenesis (Table 1) in order of hybrid Fateh (89.7%) followed by its male parent (77.8%) and then the female parent (73.3%). While in case of hybrid LHH144, highest somatic embryogenesis was shown by male parent (81.5 %) followed by hybrid (79.2 %) and then the female parent (72%). This genotypic variation has also been reported by Wu *et al.,* (2004). The size and orientation of explants on the medium also affected callus initiation and production. Vertically placed small explants produced less calli as compared to horizontally placed explants. In all explants, the callus initiation started from cut ends due to wound response .Thus the age, size and orientation of explants affects the callus induction. In addition, environmental factors such as temperature and light intensity also played an important role in callus initiation from *in vitro* cultured explants. Raising the temperature from 25 to 29^{0}C produced a better response in terms of callus initiation.

Table 2. Effect of sucrose and glucose on percentage of somatic embryogenesis in calli of two *intra hirsutum* hybrids, Fateh and LHH144 and their parental inbreds in cotton raised from hypocotyl segments in TDZ supplemented

Genotype	Medium used					
	M_1			M_2		
	Explants cultured	Explants showing callusing	Callusing obtained (%)	Explants cultured	Explants showing callusing	Callusing obtained (%)
Fateh (female parent)	30	17	56.7	30	21	70.0
Fateh (male parent)	30	22	73.3	30	26	86.7
Fateh (hybrid)	30	18	60.0	30	24	80.0
LHH144 (female parent)	30	19	63.3	30	22	73.3
LHH144 (male parent)	30	13	43.3	30	17	56.7
LHH144 (hybrid)	30	23	76.7	30	25	83.3

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Field evaluation of Thiamethoxam 75 SG as soil application against sucking pests in cotton

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ABSTRACT: Efficacy of thiamethoxam 75 SG as soil application was tested for the control of sucking insect pests on irrigated upland cotton during 2009 and 2010. The results indicated that thiamethoxam 75 SG @ 113 g a.i./ha recorded highest reduction (84.83 %) of leaf hopper nymphs and remained *at par* with imidacloprid 17.8 SL and actara 25 WG (86.43 and 84.20 %, respectively), while on the other hand, reduction in population of whitefly adults was significantly higher in thiamethoxam 75 SG @ 113 g a.i./ha (55.23 %) followed by its lower dose of 94 g a.i./ha (51.02 %). For thrips, on the basis of pooled analysis of 7 and 10 days of spray the thiamethoxam 75 SG @ 113 g a.i./ha recorded 57.94 and 56.67 per cent reduction of thrips population but otherwise remained *at par* with imidacloprid 17.8 SL and imidacloprid 70 WG. Among all the treatments, thiamethoxam 75 SG @ 113 g a.i./ha recorded significantly higher yield of seed cotton *i.e.* 23.61 q/ha than all other treatments. Although, thiamethoxam proved better for the control of sucking pests, but per cent reduction of natural enemies in all the thiamethoxam treatments varied from 23.32 to 30.66; 25.10 to 32.67 and 23.66 to 30.89 per cent after 3, 7 and 10 days of spray, respectively.

Key words : Cotton, soil application, sucking pests, thiamethoxam

Cotton (*Gossypium* spp) is the most important crop in India and plays a vital role in agricultural, industrial, social and monetary affairs of the country. In Punjab, it was cultivated on an area of 0.54 million ha with a production of 1.43 million bales and average lint yield of 452 kg/ha in 2009-2010 (Anonymous, 2011). Among the various factors responsible for the lower production of cotton, the damage by insect pests mainly sucking pests (jassids and whitefly) and bollworms (American bollworm, spotted bollworm and pink bollworm), is the major constraint. Cotton leaf hopper, is one of the major sucking pests of cotton causing 12 per cent loss to the crop during vegetative phase (Dhawan *et al.,* 1988). Among neonicotinyl compounds, imidacloprid/ acetamiprid has been recommended as a foliar sprays but their application also destructed the bioefficacy of natural enemies in cotton agro ecosystem. Among these, imidacloprid appeared to be the first to open up the way for soil application in cotton (Torres and Ruberson, 2004). Imidacloprid found promising against sucking pests (Dhawan and Simwat, 2002) has been evaluated against jassid in Punjab. In the present study, efficacy of thiamethoxam 75 SG as a soil application was tested for the control of sucking insect pests cotton on during 2009 and 2010.

MATERIALS AND METHODS

Thiamethoxam 75 SG of M/s Syngenta (India) Pvt. Limited, Pune was evaluated @ 75, 94 and 113 g a.i./ha (as soil drench) for the control of sucking insect pests like leaf hopper(*Amrasca biguttula bigutulla*), whitefly (*Bemisia tabaci*) and thrips (*Thrips tabaci*) on cotton during 2009 and 2010. This was compared with imidacloprid 17.8 SL @ 20g a.i/ha (as foliar spray), imidacloprid 70WS @110 g a.i/ha (as soil drenching) and Thiamethoxam 25WG (Actara) @ 25g a.i/ha (as foliar spray) as standards, which are recommended insecticide for the control of leaf hopper. Besides, this untreated control was also kept. Seven treatments including control were applied in randomized block design with three replications. The plot size was 150 sq. m. The plants of cotton cultivar LH 2076 were drenched once with the help of manually operated knapsack sprayer using 50-60 ml of water/plant during 2009 and 2010. The observations leaf hopper nymphs and whitefly adults were recorded on 3 fully formed leaves/plant before spray and 3, 7 and 10 days after spray. The populations of natural enemies like coccinellids, predatory bugs, chrysopa and spiders were recorded on whole plant basis. Seed cotton yield was also recorded on whole plot basis. The observation on the phytotoxicity symptoms (*viz.,* leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty etc.), if any, on cotton crop due to application of thiamethoxam 75 SG @ 113 and 225g a.i./ha were also recorded upto 14 days after the treatment.

RESULTS AND DISCUSSION

During the period of investigation, jassid thrips and whitefly appeared as the major pest among the sucking pest complex. The infestation of cotton aphid, *Aphis gossypii* Glover was scanty.

Leaf hopper [*Amrasca biguttula biguttula* (Ishida) : Before the insecticidal treatment, different plots harboured 7.50 to 10.67 leaf hopper nymphs/3 leaves and the treatments were statistically *at par* among themselves (Table 1). Two experiments were conducted during 2009 and the per cent reduction in population of leaf hopper nymphs varied from 55.57 to 82.14 per cent in different treatments after 3 days of spray. Among treatments the per cent reduction of leaf hopper nymphs was maximum in the thiamethoxam @ 113 g a.i./ha (67.70 %) which otherwise remained *at par* with imidacloprid 17.8 SL @ 20 g a.i./ha (82.14) and actara 25 WG @ 25 g a.i./ha (80.92 %) followed by Imidacloprid 70 WS @ 110 g a.i./ha (70.85 %) as compared to all other treatments in the first experiment. Similar trend was observed in the second experiment conducted during 2009 (Table 2). During 2010, thiamethoxam @ 113 g a.i./ha resulted in 64.70 per cent reduction in leaf hopper nymphs population which otherwise remained *at par* with imidacloprid 17.8 SL and imidacloprid 70 WG treatments (81.80 and 71.42 %, respectively) in the first experiment. Similar trend was observed in the second experiment conducted during 2010. The pooled analysis of two years data showed that among the thiamethoxam treatments, the maximum reduction in population of leaf hopper nymphs was observed in thiamethoxam 113 g a.i./ha (65.63 %). However, thiamethoxam 25 WG (Actara) @ 25 g a.i./ha and imidacloprid 17.80 SL @ 20 g a.i./ha registered 81.24 and 80.89 per cent reduction in the leaf hopper nymphs population (Table 2).

After 7 days of spray, the per cent reduction of leaf hopper nymphs was significantly higher (83.62 %) in thiamethoxam @ 113 g a.i./ha which otherwise remained *at par* with imidacloprid 17.8 SL and actara 25 WG (85.76 and 81.33 %, respectively) as compared to all other treatments in the first experiment conducted during 2009 and almost similar trend was observed in two experiments conducted during 2010 (Table 1). On the basis of pooled analysis for 7 days after spray, although the maximum reduction (80.70 %) in leaf hopper nymphs population was recorded in thiamethoxam 75 SG @ 113 g a.i./ha and remained statistically *at par* the imidacloprid 17.8 SL and thiamethoxam 25 WG treatments which recorded 84.71 and 83.12 per cent reduction in the nymphal population of leaf

Table 1. Efficacy of thiamethoxam 75 SG as soil application (drench) against leaf hopper on cotton

Treatment	Dose (g a.i./ha)	Pre treatment population of leaf hopper nymphs/ 3 leaves				**Pooled mean**
		2009		2010		
		Expt I	Expt II	Expt I	Expt II	
		3 days after spray				
Thiamethoxam 75 SG	75	9.67	7.50	8.33	8.00	**8.37**
	94	9.67	10.33	7.67	7.00	**8.67**
	113	10.00	7.33	10.67	9.00	**9.25**
Imidacloprid 17.8 SL	20	9.33	10.33	9.33	8.67	**9.41**
Imidacloprid 70 WS	110	9.67	9.33	10.00	8.33	**9.33**
Actara 25WG	25	9.67	8.33	9.33	8.33	**8.91**
Control	-	9.33	9.67	10.33	9.00	**9.58**
CD (p=0.05)	-		NS	NS	NS	**NS**

Table 2. Efficacy of thiamethoxam 75 SG as soil application against leaf hopper in cotton

Treatment	Dose (g a.i./ha)	Per cent reduction of leaf hopper nymphs over control 2009 Expt 1	2009 Expt 2	2010 Expt 1	2010 Expt 2	**Pooled**
		3 days after spray				
Thiamethoxam 75 SG	75	55.57 (48.22)	57.23 (49.16)	55.23 (47.99)	56.23 (48.58)	**58.15 (49.67)**
	94	63.17 (52.68)	62.11 (52.03)	60.84 (51.27)	58.84 (50.11)	**61.66 (51.72)**
	113	67.70 (55.43)	67.70 (55.36)	64.70 (53.72)	62.44 (52.20)	**65.63 (54.10)**
Imidacloprid 17.8 SL	20	82.14 (65.28)	79.80 (63.40)	81.80 (64.99)	79.81 (63.37)	**80.89 (64.07)**
Imidacloprid 70 WS	110	70.85 (57.73)	72.18 (58.64)	71.42 (58.17)	65.99 (54.53)	**70.11 (56.85)**
Actara 25WG	25	80.92 (64.54)	80.92 (64.44)	83.58 (66.41)	78.89 (62.78)	**81.24 (64.33)**
CD(p=0.05)	-	(11.54)	(10.20)	(11.12)	(8.73)	**(1.20)**
		7 days after spray				
Thiamethoxam 75 SG	75	65.13 (53.82)	62.61 (52.29)	61.13 (51.50)	62.13 (52.02)	**63.42 (52.77)**
	94	69.18 (56.41)	70.62 (57.63)	69.27 (56.36)	65.94 (54.31)	**68.92 (56.10)**
	113	83.62 (66.10)	79.28 (63.15)	80.44 (64.65)	79.44 (63.09)	**80.70 (63.93)**
Imidacloprid 17.8 SL	20	85.76 (67.89)	84.42 (66.74)	84.11 (67.12)	82.89 (66.30)	**84.71 (66.96)**
Imidacloprid 70 WS	110	76.33 (61.21)	78.11 (62.28)	78.83 (62.64)	76.44 (61.13)	**77.43 (61.61)**
Actara 25WG	25	81.33 (65.14)	82.77 (66.06)	85.13 (67.48)	83.24 (66.13)	**83.12 (65.73)**
CD(p=0.05)		(9.40)	(7.25)	(10.09)	(9.45)	**(1.68)**
		10 days after spray				
Thiamethoxam 75 SG	75	68.44 (55.81)	67.22 (55.07)	71.11 (57.49)	65.11 (53.81)	**68.22 (55.67)**
	94	76.11 (60.77)	73.44 (58.98)	77.44 (61.64)	71.78 (57.92)	**75.02 (60.01)**
	113	87.95 (69.90)	85.06 (67.44)	86.06 (68.49)	80.28 (63.71)	**84.83 (67.14)**
Imidacloprid 17.8 SL	20	86.42 (68.51)	85.76 (69.89)	87.95 (70.06)	85.62 (68.09)	**86.43 (68.37)**
Imidacloprid 70 WS	110	77.67 (62.04)	76.13 (61.02)	77.44 (61.76)	74.44 (59.72)	**76.42 (60.93)**
Actara 25WG	25	83.11 (66.02)	83.11 (66.02)	87.78 (69.94)	82.77 (66.08)	**84.20 (66.59)**
CD(p=0.05)		(7.78)	8.22	(8.95)	(8.92)	**(1.54)**

Figure in parenthesis are arc sine transformation

hopper, respectively (Table 2). Similarly, after 10 days of spray, the per cent reduction of leaf hoppernymph varied from 67.22 to 87.95 per cent, being highest in thiamethoxam 75 SG @ 113 g a.i./ha which on the other hand remained at par with imidacloprid 17.8 SL and actara 25 WG during both experiments in 2009 crop season. Almost similar trend was observed during 2010 crop season experiments. The per cent reduction in the leaf hopper nymph varied from 65.11 to 87.95 per cent in 1st and 2nd experiment. Thiamethoxam 75 SG @ 113 g a.i./ha recorded 86.06 and 80.28 per cent reduction but remained *at par* with the other insecticidal treatments.

On the perusal of pooled analysed data, thiamethoxam 75 SG @ 113 g a.i./ha recorded highest reduction of 84.83 per cent and remained *at par* with imidacloprid 17.8 SL and actara 25 WG (86.43 and 84.20 %, respectively). On the other hand thiamethoxam at its higher dose found to be superior as compared to its lower doses.

Whitefly adults [(*Bemisia tabaci (*Gennadius)] : Two experiments were conducted during 2009. In both the experiments the per cent reduction in population of whitefly adults varied from 31.30 to 56.72 per cent in different treatments after 3 days of spray. The reduction in population of whitefly adults was significantly higher in thiamethoxam 75 SG @ 113 g a.i./ha (54.83 %) and remained *at par* with other insecticidal treatments in the first experiment. Similar trend was observed in the second experiment conducted during 2009 and during 2010 (Table 3). During 2010, the reduction in population of whitefly adults in thiamethoxam 75 SG @ 113 g a.i./ha (43.35 %) and remained *at par* with other insecticidal treatments.

The pooled analysis of the two years showed that the reduction in population of

Table 3. Efficacy of thiamethoxam 75 SG as a soil application against cotton whitefly on cotton

Treatment	Dose (g a.i./ha)	Per cent reduction of whitefly adults over control			**Pooled**
		2009		2010	
		Expt 1	Expt 2	Expt 1	
		3 days after spray			
Thiamethoxam 75 SG	75	31.30 (33.99)	35.25 (36.38)	30.25 (33.31)	**32.27 (34.59)**
	94	39.44 (38.85)	40.14 (39.28)	39.50 (38.91)	**39.70 (39.04)**
	113	54.83 (47.78)	46.13 (42.74)	43.35 (41.13)	**48.11 (43.89)**
Imidacloprid 17.8 SL	20	52.39 (46.35)	42.73 (40.78)	46.37 (42.89)	**47.17 (43.35)**
Imidacloprid 70 WS	110	56.72 (48.92)	48.30 (43.99)	50.09 (45.03)	**51.71 (45.96)**
Actara 25WG	25	49.56 (44.72)	43.34 (41.11)	42.57 (40.61)	**45.15 (42.20)**
CD (p=0.05)	-	(7.56)	(5.24)	(4.20)	**(3.33)**
		7 days after spray			
Thiamethoxam 75 SG	75	42.14 (40.38)	35.81 (36.69)	46.81 (43.15)	**40.48 (39.48)**
	94	52.67 (46.53)	42.83 (40.83)	50.67 (45.38)	**48.72 (44.24)**
	113	61.33 (51.55)	47.22 (43.38)	54.66 (47.67)	**54.41 (47.53)**
Imidacloprid 17.8 SL	20	31.00 (33.69)	31.00 (33.76)	30.11 (33.22)	**30.48 (33.50)**
Imidacloprid 70 WS	110	42.00 (40.38)	41.33 (39.97)	39.80 (39.02)	**41.04 (39.82)**
Actara 25WG	25	36.67 (37.17)	32.13 (34.41)	38.33 (38.12)	**36.27 (37.01)**
CD (p=0.05)	-	(8.26)	(5.76)	(7.51)	**(3.21)**
		10 days after spray			
Thiamethoxam 75 SG	75	49.44 (44.66)	38.44 (38.28)	48.11 (43.90)	**45.33 (42.29)**
	94	55.13 (47.93)	46.80 (43.14)	51.13 (45.63)	**51.02 (45.57)**
	113	60.44 (51.01)	48.13 (43.90)	57.11 (49.08)	**55.23 (47.99)**
Imidacloprid 17.8 SL	20	39.44 (38.89)	32.48 (34.72)	37.45 (37.69)	**36.46 (37.11)**
Imidacloprid 70 WS	110	45.67 (42.48)	43.33 (41.14)	40.33 (39.40)	**43.11 (41.02)**
Actara 25WG	25	41.11 (39.85)	36.77 (37.30)	38.44 (38.29)	**38.78 (38.49)**
CD (p=0.05)	-	(3.94)	(6.12)	(3.89)	**(2.67)**

Figure in parenthesis are arc sine values

whitefly adults was significantly higher in imidacloprid 70 WG @ (51.71 %) and thiamethoxam 75 SG @ 113 g a.i./ha (43.89 %) being *at par* with each other as compared to all other insecticidal treatments. After 7 days of spray, the per cent reduction in population of whitefly adults varied from 31.00 to 61.33 per cent in different treatments. The reduction in population of whitefly adults was significantly higher in thiamethoxam 75 SG @ 113 g a.i./ha (61.33 %) and remained *at par* with thiamethoxam 75 SG @ 94g a.i./ha (52.67 %) as compared to all other treatments in the first experiment conducted during 2009. Almost similar trend was observed in the second experiment conducted during 2009 and 2010. The pooled analysis of the two years showed that the reduction in population of whitefly adults was significantly higher in imidacloprid 75 SG @ 113 g a.i. /ha (54.41 %) as compared to all other treatments (Table 3).

After 10 days of spray, the per cent reduction in population of whitefly adults varied from 38.44 to 60.44 per cent in different treatments during 2009. The reduction in population of whitefly adults was significantly higher in thiamethoxam 75 SG @ 113 g a.i./ha (60.44 %) and remained *at par* with thiamethoxam 75 SG @ 94g a.i./ha as compared to all other treatments in the first experiment. Almost similar trend was observed in the second experiment conducted during 2009 yet remained statistically *at par* among each other. Similar trend was recorded in the experiment conducted during 2010(Table 3). The pooled analysis of the two years showed that the reduction in population of whitefly adults was significantly higher in thiamethoxan 75 SG @ 113 g a.i./ha (55.23 %) followed by its lower dose of 94 g a.i./ha (51.02 %).

Thrips (*Thrips tabaci* Lindeman) : Two experiments were conducted during 2009. After 3 days of spray, thiamethoxam 75 SG was not effective against thrips. Almost similar trend was observed in the pooled analysis. However, after 7 and 10 days of spray the percent reduction of thrips over control in thiamethoxan 75 SG @ 113 g a.i./ha varied from (53.11 to 61.66 and 49.33 to 62.67 %) irrespective of the experiment conducted during 2009 and 2010, respectively and remained *at par* with the imidacloprid 17.8 SL and imidacloprid 70 WG throughout the study. On the basis of pooled analysis of 7 and 10 days of spray the thiamethoxam 75 SG @ 113 g a.i./ha recorded 57.94 and 56.67 per cent reduction of thrips population but otherwise remained *at par* with imidacloprid 17.8 SL and imidacloprid 70 WG (Table 4).

Seed cotton yield : The pooled analysis of two years trials showed that seed cotton yield was significantly higher in treated plots than in control. Among all the treatments, thiamethoxam 75 SG @ 113 g a.i./ha recorded significantly higher yield than all other treatments (Table 5).

Effect on natural enemies : The per cent reduction of natural enemies (lady bird beetles, green lace wing, spiders) was lower in all the thiamethoxam treatments as compared to all other treatments after 3, 7 and 10 days of spray in all the experiments conducted during 2009 and 2010 (Table 6). The pooled analysis of two years showed that per cent reduction of natural enemies in all the thiamethoxam treatments varied from 23.32 to 30.66; 25.10 to 32.67 and 23.66 to 30.89 per cent after 3, 7 and 10 days of spray, respectively. Rogers *et al.,* (2007) reported that survival of adult green lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) was reduced after feeding on flowers from plants treated with a soil application of imidacloprid

Table 4. Efficacy of thiamethoxam 75 SG as a soil application against cotton thrips on cotton

Treatment	Dose (g a.i./ha)	Per cent reduction of thrips over control			**Pooled**
		2009		2010	
		Expt 1	Expt 2	Expt 1	
		3 days after spray			
Thiamethoxam 75 SG	75	32.67 (34.76)	28.67 (32.25)	35.00 (36.20)	**32.11 (34.49)**
	94	36.37(36.99)	33.37(35.09)	39.37(38.81)	**36.37(37.07)**
	113	40.67(39.58)	37.11(37.49)	41.67(40.16)	**39.81(39.10)**
Imidacloprid 17.8 SL	20	70.30(57.17)	67.64(55.64)	72.80(58.73)	**70.25(56.93)**
Imidacloprid 70 WS	110	59.33(50.49)	56.78(48.98)	56.67(48.91)	**57.59(49.35)**
Actara 25WG	25	52.43(46.39)	46.11(42.72)	51.10(45.63)	**49.87(49.91)**
CD (p=0.05)	-	(10.51)	(11.47)	(10.49)	**(1.58)**
		7 days after spray			
Thiamethoxam 75 SG	75	34.67(35.85)	31.66(34.09)	39.66(38.98)	**35.33(36.44)**
	94	38.78(38.48)	35.47(36.50)	46.11(42.75)	**40.12(39.26)**
	113	59.06(50.36)	53.11(46.93)	61.66(51.85)	**57.94(49.56)**
Imidacloprid 17.8 SL	20	61.44(51.66)	58.11(49.66)	65.78(54.32)	**61.78(51.81)**
Imidacloprid 70 WS	110	57.33(49.25)	53.77(47.16)	59.00(50.20)	**56.70(48.84)**
Actara 25WG	25	41.11(39.66)	40.78(39.58)	44.11(41.51)	**41.99(40.38)**
CD (p=0.05)	-	(10.44)	(9.28)	((9.66)	**(1.62)**
		10 days after spray			
Thiamethoxam 75 SG	75	36.80(37.30)	33.80(35.53)	40.13(39.25)	**36.91(37.39)**
	94	39.67(38.99)	36.67(37.18)	47.77(43.70)	**41.37(39.99)**
	113	58.00(49.59)	49.33(44.60)	62.67(52.33)	**56.67(48.83)**
Imidacloprid 17.8 SL	20	45.00(42.11)	41.33(39.98)	44.33(41.73)	**43.55(41.28)**
Imidacloprid 70 WS	110	57.33(49.31)	48.33(43.99)	52.33(46.33)	**52.67(46.51)**
Actara 25WG	25	29.80(33.04)	29.13(32.62)	33.80(35.51)	**30.91(33.75)**
CD (p=0.05)	-	(8.79)	(7.10)	(8.12)	**(3.03)**

Figure in parenthesis are arc sine values

Table 5. Effect of thiamethoxam 75 SG on seed cotton yield

Treatment	Dose (g a.i./ha)	Yield (q/ha) 2009 Expt 1	2009 Expt 2	2010 Expt 1	2010 Expt 2	Pooled
Thiamethoxam 75 SG	75	23.12	24.21	22.10	21.25	**22.67**
	94	23.87	24.80	22.80	21.90	**23.34**
	113	24.00	25.08	23.12	22.25	**23.61**
Imidacloprid 17.8 SL	20	23.43	24.55	22.90	22.20	**23.27**
Imidacloprid 70 WS	110	23.36	24.77	22.10	21.80	**23.01**
Actara 25WG	25	23.35	24.23	22.70	22.10	**23.09**
Control	-	21.80	23.10	21.20	20.60	**21.67**
CD (p=0.05)	-	0.23	0.45	0.36	0.42	**0.42**

(Marathon 1% G, label rate and twice label rate) in the greenhouse.

Phytotoxicity : Thiamethoxam 75 SG @ 150 and 300 g a.i/ha did not show any phytotoxicity to cotton crop *viz.*, injury on leaf tips and leaf surface, no wilting, no vein clearing, no necrosis, no epinasty and hyponasty etc in the experiments conducted during 2009 and 2010.

The present investigation confirmed the fact that neonicotinoids, including thiamethoxam 75 SG are highly effective and specific in their action against cotton sucking pests (Patil *et al.,* 2004). No phytotoxicity

Table 6. Effect of thiamethoxam 75 SG as a soil application on population of natural enemies on cotton

Treatment	Dose (g a.i./ha)	Per cent reduction of natural enemies* over control 2009 Expt 1	2009 Expt 2	2010 Expt 1	Pooled
		3 days after spray			
Thiamethoxam 75 SG	75	27.77(31.72)	20.10(26.48)	22.10(28.01)	**23.32(28.81)**
	94	31.53 (34.10)	26.20 (30.73)	25.53 (30.26)	**27.75(31.75)**
	113	35.10 (36.31)	28.10 (31.89)	28.77 (32.41)	**30.66(33.58)**
Imidacloprid 17.8 SL	20	65.07(53.78)	62.40(52.17)	65.07(53.76)	**64.18(53.22)**
Imidacloprid 70 WS	110	42.67(40.76)	45.33(42.30)	42.33(40.57)	**43.44(41.21)**
Actara 25WG	25	45.33(42.30)	47.33(43.45)	52.43(46.38)	**48.36(44.04)**
CD (p=0.05)	-	(4.83)	(5.86)	(5.11)	**(3.39)**
		7 days after spray			
Thiamethoxam 75 SG	75	24.77(29.81)	26.43(30.84)	24.10(29.31)	**25.10(30.05)**
	94	34.47 (35.91)	29.13 (32.64)	27.47 (31.57)	**30.36(33.40)**
	113	37.47 (37.70)	30.27 (33.30)	30.27 (33.30)	**32.67(34.82)**
Imidacloprid 17.8 SL	20	66.73(54.77)	60.73(51.22)	60.20(51.10)	**62.73(52.37)**
Imidacloprid 70 WS	110	44.00(41.53)	47.67(43.64)	46.67(42.54)	**46.45(42.94)**
Actara 25WG	25	52.43(46.38)	50.43(45.23)	48.53(43.23)	**51.09(45.61)**
CD (p=0.05)	-	(5.58)	(6.17)	(5.92)	**(2.81)**
		10 days after spray			
Thiamethoxam 75 SG	75	22.10(27.99)	24.77(29.72)	24.10(29.31)	**23.66(29.08)**
	94	31.80(34.30)	27.47 (31.57)	26.13(30.65)	**28.47(32.21)**
	113	34.13(35.72)	28.93 (32.48)	29.60(32.84)	**30.89(33.74)**
Imidacloprid 17.8 SL	20	65.73(54.17)	58.40(49.86)	59.40(50.43)	**61.18(51.45)**
Imidacloprid 70 WS	110	43.50(41.25)	47.67(43.64)	44.83(42.01)	**45.33(42.30)**
Actara 25WG	25	50.77(45.42)	48.43(44.08)	46.77(43.12)	**48.66(44.21)**
CD (p=0.05)	-	(5.38)	(6.43)	(7.03)	**(2.71)**

Figure in parenthesis are arc sine transformation
* Population of natural enemies includes coccinellids predatory bugs, chrysopa and spiders

symptoms were observed (on the basis of crop health and visual score) in the plots treated with thiamethoxam at both the doses. Due to their safety to natural enemies and systemic action at 113 g a.i./ha soil application of thiamethoxam has not only been accepted, but also got prime position in IPM and IRM programmes (Dhawan and Simwat, 2002; Dandale *et al.,* 2001; Vadodaria *et al.,* 2001; Wadnerkar *et al.,* 2004).

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Influence of abiotic factors on major sucking insect pests in cotton cultivars

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ABSTRACT : Studies on population dynamics of sucking insect pests on *Bt* cotton and influence of weather parameters on their incidence were carried out at CCS Haryana Agricultural University, Hisar during *kharif,* 2006. Two *Bt* genotypes *viz.*, RCH 134 *Bt* and RCH 317 *Bt* and their corresponding non *Bt* genotypes, one hybrid (HHH 223) and one variety (H 1226) were evaluated. The experiments were laid out under unsprayed and sprayed conditions Two major sucking pests *i.e.* leafhopper, *Amrasca biguttula biguttula* Ishida and whitefly, *Bemisia tabaci* Gennadius infested the crop from 22nd std. week to 41st std. week. The results indicated that no significant difference was recorded in sucking pest (cotton leafhopper and whitefly) populations among *Bt* and non *Bt* genotypes. Among the weather parameters, temperature and mean RH showed a positive correlation with leafhopper. Effect of rainfall was favourable for the activity of both whitefly and leafhopper.

Keywords : Abiotic factors, *Bt* cotton, management, sucking pests

India is the fortunate country where four species of cotton *viz., Gossypium hirsutum, G. arboreum, G. herbaceum and G. barbadense* along with intra and inter specific hybrids are cultivated under diverse agro climatic conditions. Among the vast array of insect pests *viz.*, whitefly; *Bemisia tabaci* Gennadius, leafhopper; *Amrasca biguttula biguttula* Ishida are major sucking insect pests. These insects not only cause tremendous reduction (50-60 per cent) in yield but also adversely affect the quality of lint and seed. The population build up of these sucking insect pests largely depends upon abiotic factors. Suitable abiotic factors enhance the build up of these insect pests. These factors also helps in designing the eco friendly management practices which helps in preventing the development of insecticide resistance in insects.

MATERIALS AND METHODS

The study was carried out at the Research Farm of Cotton Section, Department of Plant Breeding, CCS Haryana Agricultural University, Hisar under two sets of conditions *viz.*, unsprayed and sprayed for sucking pests during *kharif,* 2006. There were total six genotypes *i. e.* two *Bt* (RCH 134, 317) and their corresponding non *Bt* genotypes, one hybrid (HHH 223) and one variety (H 1226) with four replications were grown in plot size of 6.75 x 3.4m^2. Line to line spacing was 67.5 cm and plant to plant at 60 cm in case of hybrids and 30 cm in case of the variety. The observations on sucking pests were recorded at weekly intervals, starting from the first week of June to the end of September. Recommended dosages of the insecticides *i.e.* imidacloprid (Confidor 200SL) and thiamethoxam (Actara 25WP) @ of 40 ml/g/ac were sprayed against sucking insect pests on the genotypes as and when the population of sucking pests reached to economic threshold leaves. The nymphal population of leafhopper and adults of whitefly were recorded from lower surface of 3 leaves/ plant (one each from upper, middle and lower plant canopy) from randomly selected 5 plants/ plot.

RESULTS AND DISCUSSION

1. Leafhopper ; *Amrasca biguttula biguttula* Ishida population

a) Unsprayed conditions : Data presented in Table 1 indicated that the population of cotton leafhopper remained below economic threshold leavesin all the genotypes throughout the period of study. However, from 29th to 31st week, the higher population (0.70 – 0.88 nymphs/leaf) was recorded than other weeks, and the maximum was during 29th week. Leafhopper population declined in 3^{4}th week onwards. Amongst the genotypes, minimum mean population was recorded in RCH 134 *Bt* (0.18 nymphs/leaf) followed by RCH 317 *Bt* (0.19 nymphs/leaf) while maximum mean incidence was recorded in H 1226 (0.36 nymphs/leaf). Overall non significant difference was recorded among the genotypes except H 1226 which showed significant difference with other genotypes during 30th week only. Mean leafhopper population/leaf did not vary significantly among the two *Bt* cotton hybrid and their non *Bt* counterparts.

b) Sprayed conditions : Data presented in Table 2 indicated that under sucking pest control conditions the population of cotton leafhopper remained below economic threshold in all the genotypes throughout the period of study, except in H 1226 (2.22 nymphs/leaf). The population crossed economic threshold once during 30th week in this genotype. However, from 29th to 32nd week the population recorded was higher than other weeks (0.36- 1.36 nymphs/ leaf), being maximum during 30th week. The population of leafhopper declined 33rd week onwards. Amongst the genotypes, the population recorded in RCH 317 non *Bt* (0.26 nymphs/leaf), RCH 134 non *Bt* (0.28 nymphs/leaf) and RCH 317 *Bt* (0.29 nymphs/leaf) was relatively less than other entries. Maximum mean population was recorded in H 1226 (0.42 nymphs/leaf) followed by RCH 134 *Bt* (0.34nymphs/leaf). Leafhopper population was positively correlated with evening relative humidity (r=0.40) and rainfall (r=0.11) (Table 5).

These results are in accordance with Aggarwal *et al.,* (2007). However, the leafhopper population decreased over optimum range with the decrease in air temperature and increase in relative humidity (Bishnoi *et al.*,1996) Results of the present studies revealed that the mean leafhopper population/leaf did not vary significantly among the *Bt* and non *Bt* hybrids. Similarly, Kumar and Stanley (2006) observed that there was a non significant difference among the sucking pests in *Bt* and non *Bt* genotypes.

2. Whitefly *Bemisia tabaci* Gennadius population

a) Unsprayed conditions: Data presented in Table 3 indicated that under unsprayed condition, the population of cotton whitefly remained below economic threshold in all the genotypes throughout the period of study. However, mean maximum population was recorded during 39th week (3.77 adults/leaf) followed by 40th week (2.97 adults/leaf). Amongst the genotypes, least mean population of whitefly (0.80 adults/leaf) was recorded in H 1226, while mean maximum population was recorded in RCH 317 non *Bt* (1.54 adults/leaf). The difference in *Bt* and their non *Bt* genotypes was non significant throughout the period of study, but during later stage of crop growth significant difference was recorded among H 1226 and HHH 223 with *Bt* and non *Bt* genotypes. On the basis of mean values of whitefly population in *Bt* and non *Bt* genotypes it was observed that *Bt* genotypes recorded higher population than non *Bt* genotypes.

Whitefly population was positively correlated with morning relative humidity (r=0.05) and sunshine h (r=0.41) while negatively correlated with evening relative humidity (r= -0.42), rainfall (r= -0.34), average temperature (r= -0.49) and average wind speed (r= -0.71) presented in Table 5.

b) Sprayed conditions: Data presented in Table 4 indicated that under sucking pest control conditions the population of cotton whitefly remained below economic threshold in all the genotypes throughout the period of study. However, maximum mean population was recorded during 37th week (3.28 adults/leaf) to 39th week (3.62 adults/leaf). Amongst the genotypes, minimum mean population was recorded in H 1226 (1.16 adults/leaf) followed by RCH 134 non *Bt* (1.38 nymphs/leaf) and HHH 223 (1.39 adults/leaf) while maximum mean population was recorded in RCH 317 *Bt* (1.67 adults/leaf).

The results of present studies indicated that the whitefly population was negatively correlated with temperature and evening relative humidity. The present findings are in conformity with Gupta *et al.,* (1998) they reported a significant negative linear relation exits between the whitefly population and the minimum temperature and similar negative relationship was established between the whitefly population and evening RH under

Table 1. Population of cotton leafhopper (*Amrasca bigutulla bigutulla*) on *Bt* and non *Bt* cotton genotypes under unsprayed conditions

Genotype	Mean population of leafhopper during different periods of observation (Nymphs/leaf) Standard week																				**Mean**
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	
RCH 134 *Bt*	0.08	0.15	0.00	0.03	0.43	0.06	0.15	0.78	0.55	0.43	0.22	0.13	0.02	0.03	0.02	0.02	0.03	0.18	0.08	0.15	
	(1.04)	(1.07)	(1.00)	(1.02)	(1.20)	(1.03)	(1.07)	(1.33)	(1.24)	(1.19)	(1.10)	(1.06)	(1.01)	(1.02)	(1.01)	(1.01)	(1.02)	(1.09)	(1.04)	(1.07)	**0.18**
RCH 134	0.00	0.18	0.03	0.02	0.50	0.11	0.03	0.87	0.95	0.41	0.37	0.16	0.02	0.03	0.08	0.10	0.05	0.30	0.05	0.05	
non *Bt*	(1.00)	(1.09)	(1.02)	(1.01)	(1.22)	(1.06)	(1.02)	(1.37)	(1.39)	(1.19)	(1.17)	(1.08)	(1.01)	(1.02)	(1.04)	(1.05)	(1.02)	(1.14)	(1.02)	(1.02)	**0.22**
RCH 317 *Bt*	0.00	0.03	0.02	0.05	0.33	0.07	0.03	0.93	0.66	0.55	0.43	0.18	0.00	0.00	0.00	0.05	0.12	0.28	0.11	0.00	
	(1.00)	(1.02)	(1.01)	(1.02)	(1.15)	(1.03)	(1.02)	(1.39)	(1.29)	(1.24)	(1.20)	(1.09)	(1.00)	(1.00)	(1.00)	(1.02)	(1.06)	(1.13)	(1.05)	(1.00)	**0.19**
RCH 317	0.00	0.10	0.03	0.05	0.65	0.11	0.07	0.80	0.63	0.51	0.30	0.15	0.02	0.05	0.06	0.08	0.05	0.20	0.05	0.03	
	(1.00)	(1.05)	(1.02)	(1.02)	(1.28)	(1.06)	(1.03)	(1.34)	(1.28)	(1.23)	(1.14)	(1.07)	(1.01)	(1.02)	(1.03)	(1.04)	(1.02)	(1.09)	(1.02)	(1.02)	**0.20**
HHH 223	0.03	0.05	0.02	0.02	0.55	0.06	0.02	0.82	1.03	0.81	0.49	0.20	0.00	0.03	0.03	0.03	0.02	0.27	0.13	0.10	
non *Bt*	(1.01)	(1.02)	(1.01)	(1.01)	(1.24)	(1.03)	(1.01)	(1.34)	(1.41)	(1.35)	(1.22)	(1.10)	(1.00)	(1.02)	(1.02)	(1.02)	(1.01)	(1.12)	(1.06)	(1.05)	**0.24**
H 1226	0.00	0.20	0.05	0.03	0.62	0.26	0.02	1.10	1.15	1.48	0.35	0.11	0.06	0.07	0.05	0.05	0.07	0.38	0.08	0.06	
	(1.00)	(1.09)	(1.02)	(0.02)	(1.27)	(1.12)	(0.01)	(1.45)	(1.45)	(1.55)	(1.15)	(1.05)	(1.03)	(1.03)	(1.02)	(1.02)	(1.03)	(1.17)	(1.04)	(1.03)	**0.36**
Mean	**0.02**	**0.12**	**0.03**	**0.03**	**0.51**	**0.11**	**0.05**	**0.88**	**0.83**	**0.70**	**0.36**	**0.16**	**0.02**	**0.04**	**0.04**	**0.06**	**0.06**	**0.27**	**0.08**	**0.07**	**0.22**
SE(m) ±	(0.01)	(0.03)	(0.01)	(0.01)	(0.04)	(0.03)	(0.01)	(0.05)	(0.06)	(0.07)	(0.04)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.04)	(0.01)	(0.01)	
CD (p=0.05)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(0.04)	(N.S)	(N.S)	(0.20)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(0.04)	

Figures in parentheses are $\sqrt{n+1}$ transformation

Table 2. Population of cotton leafhopper (*Amrasca bigutulla bigutulla*) on *Bt* and non *Bt* genotypes of cotton under sprayed conditions

Genotype	Mean population of leafhopper during different periods of observation (Nymphs/leaf) standard week																				**Mean**
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	
RCH 134 *Bt*	0.15	0.20	0.06	0.18	0.20	0.15	0.63	0.88	1.20	1.11	0.55	0.40	0.11	0.06	0.12	0.22	0.15	0.22	0.13	0.10	
	(1.07)	(1.09)	(1.03)	(1.08)	(1.09)	(1.07)	(1.28)	(1.37)	(1.48)	(1.45)	(1.24)	(1.18)	(1.05)	(1.03)	(1.06)	(1.10)	(1.07)	(1.10)	(1.06)	(1.05)	**0.34**
RCH 134	0.06	0.20	0.15	0.13	0.22	0.40	0.55	1.20	1.05	0.63	0.37	0.15	0.06	0.03	0.11	0.06	0.03	0.03	0.06	0.03	
non *Bt*	(1.03)	(1.09)	(1.07)	(1.06)	(1.10)	(1.18)	(1.24)	(1.48)	(1.43)	(1.28)	(1.17)	(1.07)	(1.03)	(10.2)	(1.05)	(1.03)	(1.02)	(1.02)	(1.03)	(1.02)	**0.28**
RCH 317 *Bt*	0.03	0.06	0.03	0.06	0.11	0.18	0.68	1.47	1.25	0.68	0.22	0.10	0.10	0.05	0.06	0.11	0.11	0.20	0.13	0.13	
	(1.02)	(1.03)	(1.02)	(1.03)	(1.05)	(1.09)	(1.30)	(1.57)	(1.50)	(1.29)	(1.10)	(1.05)	(1.05)	(1.02)	(1.03)	(1.05)	(1.05)	(1.09)	(1.06)	(1.06)	**0.29**
RCH 317	0.02	0.10	0.06	0.06	0.02	0.20	0.73	1.36	1.10	0.75	0.10	0.05	0.05	0.03	0.05	0.05	0.03	0.25	0.11	0.03	
non *Bt*	(10.1)	(1.05)	(1.03)	(1.03)	(1.01)	(1.09)	(1.32)	(1.53)	(1.45)	(1.32)	(1.05)	(1.02)	(1.02)	(1.02)	(1.02)	(1.02)	(1.02)	(1.12)	(1.06)	(1.02)	**0.26**
HHH 223	0.06	0.23	0.18	0.20	0.23	0.18	0.53	1.15	1.32	0.95	0.38	0.10	0.05	0.05	0.06	0.05	0.02	0.31	0.11	0.18	
non *Bt*	(10.3)	(1.11)	(1.08)	(10.9)	(1.11)	(1.09)	(1.24)	(1.44)	(1.52)	(1.39)	(1.17)	(1.05)	(1.02)	(1.02)	(1.03)	(1.02)	(1.01)	(1.14)	(1.05)	(1.09)	**0.32**
H 1226	0.06	0.02	0.13	0.15	0.33	0.41	0.50	1.35	2.22	1.80	0.58	0.13	0.10	0.03	0.05	0.07	0.06	0.30	0.08	0.15	
non *Bt*	(1.03)	(1.01)	(1.06)	(10.7)	(1.15)	(1.19)	(1.22)	(1.53)	(1.79)	(1.67)	(1.26)	(1.06)	(1.05)	(1.02)	(1.02)	(1.03)	(1.03)	(1.14)	(1.04)	(1.07)	**0.42**
Mean	**0.06**	**0.13**	**0.10**	**0.13**	**0.18**	**0.25**	**0.60**	**1.23**	**1.36**	**0.99**	**0.36**	**0.15**	**0.08**	**0.04**	**0.08**	**0.09**	**0.07**	**0.22**	**0.10**	**0.10**	**0.32**
SE(m) ±	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.08)	(0.04)	(0.05)	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	
CD (p=0.05)	(N.S.)	(0.05)	(0.05)	(N.S.)	(0.05)	(0.05)	(N.S.)	(N.S.)	(0.11)	(0.16)	(0.09)	(0.07)	(N.S.)	(N.S.)	(N.S.)	(N.S.)	(0.04)	(0.05)	(N.S.)	(0.05)	

Figures in parentheses are $\sqrt{n+1}$ transformation

Table 3. Population of cotton whitefly (*Bemisia tabaci*) on *Bt* and non *Bt* genotypes of cotton under unsprayed conditions

Genotype	Mean population of whitefly during different periods of observation (adults/leaf) Standard week																				**Mean**
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	
RCH 134 *Bt*	1.11	0.20	0.80	2.17	0.46	2.90	1.17	0.30	0.73	0.58	0.48	0.50	0.60	0.58	1.72	2.57	2.25	2.53	2.40	1.50	
	(1.44)	(1.09)	(1.33)	(1.74)	(1.21)	(1.97)	(1.47)	(1.14)	(1.31)	(1.25)	(1.21)	(1.22)	(1.26)	(1.26)	(1.61)	(1.88)	(1.80)	(1.88)	(1.84)	(1.58)	**1.28**
RCH 134	0.89	0.16	0.68	2.03	0.47	2.95	1.12	0.38	0.46	0.53	0.33	0.57	0.53	0.68	1.85	2.15	2.79	2.44	2.08	1.35	
non *Bt*	(1.37)	(1.08)	(1.28)	(1.74)	(1.21)	(1.98)	(1.45)	(1.17)	(1.21)	(1.24)	(1.15)	(1.25)	(1.24)	(1.29)	(1.69)	(1.76)	(1.94)	(1.85)	(1.75)	(1.53)	**1.22**
RCH 317 *Bt*	0.63	0.06	0.63	1.40	0.33	1.47	1.27	0.18	0.56	0.86	0.30	0.73	0.52	0.62	2.03	3.73	3.85	5.02	4.05	2.63	
	(1.28)	(1.03)	(1.27)	(1.54)	(1.15)	(1.57)	(1.50)	(1.09)	(1.25)	(1.36)	(1.14)	(1.31)	(1.23)	(1.27)	(1.73)	(2.17)	(2.19)	(2.44)	(2.23)	(1.89)	**1.54**
RCH 317	1.00	0.11	0.73	1.87	0.51	2.02	1.03	0.27	0.46	0.66	0.48	0.60	0.32	0.53	1.93	3.18	2.85	5.23	3.93	2.46	
non *Bt*	(1.41)	(1.05)	(1.31)	(1.69)	(1.23)	(1.73)	(1.42)	(1.12)	(1.21)	(1.29)	(1.22)	(1.26)	(1.15)	(1.24)	(1.70)	(2.04)	(1.96)	(2.47)	(2.19)	(1.83)	**1.51**
HHH 223	0.52	0.13	0.50	1.51	0.35	1.58	0.98	0.24	0.58	0.35	0.25	0.56	0.32	0.75	1.49	2.67	3.48	5.61	4.03	1.45	
non *Bt*	(1.23)	(1.06)	(1.22)	(1.55)	(1.16)	(1.59)	(1.41)	(1.11)	(1.25)	(1.16)	(1.12)	(1.25)	(1.15)	(1.32)	(1.57)	(1.91)	(2.11)	(2.56)	(2.22)	(1.56)	**1.37**
H 1226	0.58	0.15	0.42	0.55	0.08	0.93	0.92	0.33	0.31	0.60	0.35	0.31	0.36	0.70	1.30	2.25	1.89	1.80	1.35	0.90	
non *Bt*	(1.24)	(1.07)	(1.19)	(1.24)	(1.04)	(1.38)	(1.38)	(1.15)	(1.14)	(1.26)	(1.16)	(1.14)	(1.16)	(1.30)	(1.51)	(1.80)	(1.70)	(1.67)	(1.53)	(1.38)	**0.08**
Mean	**0.79**	**0.14**	**0.63**	**1.59**	**0.37**	**1.98**	**1.08**	**0.28**	**0.52**	**0.60**	**0.37**	**0.55**	**0.44**	**0.64**	**1.72**	**2.76**	**2.85**	**3.77**	**2.97**	**1.72**	**1.29**
SE(m) ±	(0.07)	(0.03)	(0.08)	(0.14)	(0.04)	(0.08)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.05)	(0.03)	(0.04)	(0.12)	(0.10)	(0.10)	(0.14)	(0.14)	(0.09)	
CD (p=0.05)	(N.S0	(N.S)	(N.S)	(N.S)	(0.11)	(0.24)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(N.S)	(0.08)	(N.S)	(N.S)	(N.S)	(0.30)	(0.41)	(0.42)	(0.27)	

Figures in parentheses are $\sqrt{n+1}$ transformation

Table 4. Population build up of cotton whitefly (*Bemisia tabaci*) on *Bt* and non *Bt* genotypes of cotton under sprayed conditions

Genotype	Mean population of whitefly (*Bemisia tabaci*) during different periods of observation (adults/leaf) Standard week																				**Mean**
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	
RCH 134 *Bt*	1.34	0.52	1.22	2.70	1.00	3.19	1.37	0.65	0.99	0.74	0.66	0.89	0.91	0.79	2.35	3.20	2.80	2.75	2.45	1.20	
	(1.53)	(1.23)	(1.49)	(1.91)	(1.41)	(2.04)	(1.54)	(1.28)	(1.41)	(1.32)	(1.29)	(1.37)	(1.38)	(1.34)	(1.81)	(2.04)	(1.95)	(1.93)	(1.86)	(1.46)	**1.58**
RCH 134	1.28	0.25	0.90	2.10	0.86	2.99	1.22	0.45	0.63	0.69	0.62	0.78	0.75	0.82	1.93	2.63	2.77	2.69	2.13	1.05	
non *Bt*	(1.51)	(1.12)	(1.38)	(1.76)	(1.36)	(1.99)	(1.49)	(1.20)	(1.28)	(1.30)	(1.27)	(1.33)	(1.32)	(1.35)	(1.71)	(1.90)	(1.94)	(1.92)	(1.77)	(1.41)	**1.38**
RCH 317 *Bt*	1.40	0.33	1.10	2.02	0.72	1.95	1.70	0.38	0.90	1.06	0.70	0.84	0.80	0.86	1.78	2.89	2.95	4.82	3.90	2.23	
	(1.55)	(1.15)	(1.44)	(1.74)	(1.31)	(1.72)	(1.64)	(1.17)	(1.38)	(1.43)	(1.30)	(1.36)	(1.34)	(1.36)	(1.66)	(1.95)	(1.99)	(2.40)	(2.21)	(1.74)	**1.67**
RCH 317	1.23	0.23	0.99	1.95	0.80	1.93	1.28	0.35	0.66	0.80	0.68	0.77	0.48	0.66	2.10	3.30	2.49	4.67	3.74	2.26	
non *Bt*	(1.49)	(1.11)	(1.41)	(1.72)	(1.34)	(1.71)	(1.51)	(1.16)	(1.28)	(1.34)	(1.30)	(1.33)	(1.22)	(1.29)	(1.75)	(2.06)	(1.86)	(2.36)	(2.16)	(1.75)	**1.57**
HHH 223	0.90	0.25	1.08	1.37	0.86	1.33	1.08	0.63	0.94	0.58	0.45	0.86	0.47	0.98	1.70	2.75	2.88	4.81	2.85	1.15	
non *Bt*	(1.38)	(1.12)	(1.44)	(1.54)	(1.36)	(1.53)	(1.44)	(1.27)	(1.39)	(1.26)	(1.20)	(1.36)	(1.21)	(1.41)	(1.64)	(1.93)	(1.97)	(2.40)	(1.96)	(1.44)	**1.39**
H 1226	1.05	0.26	0.84	1.23	0.65	1.27	1.17	0.46	0.71	0.82	0.42	0.17	0.56	0.87	1.53	4.90	1.74	2.00	1.30	0.65	
non *Bt*	(1.43)	(1.12)	(1.35)	(1.48)	(1.28)	(1.49)	(1.47)	(1.21)	(1.31)	(1.35)	(1.19)	(1.31)	(1.25)	(1.37)	(1.59)	(2.32)	(1.65)	(1.72)	(1.51)	(1.27)	**1.16**
Mean	**1.20**	**0.31**	**1.02**	**1.90**	**0.81**	**2.11**	**1.30**	**0.49**	**0.80**	**0.78**	**0.59**	**0.81**	**0.66**	**0.83**	**1.90**	**3.28**	**2.60**	**3.62**	**2.73**	**1.49**	**1.46**
SE(m) ±	(0.05)	(0.04)	(0.06)	(0.09)	(0.04)	(0.09)	(0.03)	(0.06)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.09)	(0.22)	(0.07)	(0.13)	(0.11)	(0.17)	
CD (p=0.05)	(N.S.)	(N.S.)	(N.S.)	(N.S.)	(N.S.)	(0.28)	(0.09)	(N.S.)	(N.S.)	(0.09)	(N.S.)	(N.S.)	(0.08)	(N.S.)	(N.S.)	(N.S.)	(0.20)	(0.40)	(0.34)	(N.S.)	

Figures in parentheses are $\sqrt{n+1}$ transformation correlation study. These results are not in support with the findings of Rote and Puri (1991) they reported that whitefly population was positively associated with temperature and negatively associated with relative humidity. The present studies indicated that there was not significant difference in sucking pest population under *Bt* and non *Bt* genotypes. These observations conform to the observation earlier reported by Kumar and Stanley, (2006). The sucking pest population was significantly less in RCH 134 *Bt* and RCH 317 *Bt* as compared to other *Bt* hybrids reported by Sharma and Dhawan (2005).

Table 5. Correlation coefficient (=r) for different abiotic factors affecting sucking pest population** (cotton season, 2006)

Standard week	Leafhopper population	Whitefly population	Temperature °C			Relative humidity %			Bright sunshine h	Rainfall (mm)	Avg. WS Km/h
			Maxi-mum	Mini-mum	**Average**	Morn-ing	Even-ing	**Average**			
22	0.02	0.79	40.2	27.2	**33.7**	66.1	39.4	**52.8**	7.1	0	9.1
23	0.12	0.14	38.6	24.3	**31.5**	72.9	35.9	**54.4**	8.5	0	6.4
24	0.03	0.63	39.2	24.0	**31.6**	62.4	47.7	**55.1**	5.3	21.3	9.2
25	0.03	1.59	36.2	23.6	**29.9**	74.7	42.1	**58.4**	8.8	2	6.1
26	0.51	0.37	37.7	24.4	**31.1**	85.0	55.7	**70.4**	7.0	51.4	7.8
27	0.11	1.98	38.8	28.9	**33.8**	74.4	47.9	**61.1**	10.3	0	9.0
28	0.05	1.08	33.8	26.1	**29.9**	90.1	71.3	**80.7**	01	52.3	8.7
29	0.88	0.28	36.2	26.5	**31.4**	86.1	56.6	**71.4**	4.7	0	6.5
30	0.83	0.52	33.4	25.9	**29.7**	88.9	74.4	**81.6**	4.7	39	7.3
31	0.70	0.60	33.6	25.8	**29.7**	84.7	63.0	**73.9**	7.7	0	9.1
32	0.36	0.37	34.3	25.9	**30.1**	81.6	56.3	**68.9**	9.3	5	8.6
33	0.16	0.55	36.4	26.3	**31.3**	79.0	56.3	**67.6**	9.5	2.9	5.8
34	0.02	0.44	34.9	25.2	**30.1**	82.0	57.9	**69.9**	8.2	0	7.4
35	0.04	0.64	33.7	23.7	**28.7**	88.1	65.3	**76.7**	6.3	68.4	7.9
36	0.04	1.72	32.5	23.6	**28.1**	92.1	61.7	**76.9**	8.4	0	5.0
37	0.06	2.76	35.2	24.1	**29.6**	82.1	51.0	**66.6**	9.8	0	4.5
38	0.06	2.85	35.3	24.0	**29.7**	86.9	54.1	**70.5**	8.3	1.4	5.0
39	0.27	3.77	35.0	19.0	**27.0**	82.3	36.7	**59.5**	9.7	0	3.4
40	0.08	2.97	36.2	19.1	**27.6**	78.4	35.0	**56.7**	9.2	0	3.2
41	0.07	1.72	35.6	18.3	**27.0**	69.1	32.4	**50.8**	9.6	0	4.8
r (Leafhopper)			-0.22	+0.24	+0.05	+0.38	+0.40*	+0.42*	-0.26	+0.11	+0.17
r (Whitefly)			-0.12	-0.58	-0.49	+0.05	-0.42*	-0.25	-0.71	+0.41*	-0.34

* Significant at 5% ** Per leaf population

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Comparative effectiveness of *Bt* events (BG1 and BGII) on biology of *Spodoptera litura* (Fabricius)

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ABSTRACT : *Bt* cotton hybrids *viz.,* Ankur Jai BGII, Ankur Jai BGI, Ankur Jai non *Bt,* RCH 134 BGII, RCH 134 BGI and RCH 134 non *Bt* were used for evaluation of their effect on *Spodoptera litura* (Fabricius) larvae. The larval survival was observed low on both BGII genotypes at 60 and 90 days after sowing (DAS). But, on 120 DAS survival of first instar larvae increased indicating decreased expression of Cry 2Ab in BGII cotton. At 140 DAS survival of first instar larvae decreased on BGII *Bt* and non *Bt* genotypes associated with increasing age of the crop. Top leaves of BGII, BGI and non *Bt* genotypes were fed to compare their effect on some biological parameters. At 60 DAS, no larvae survived on BGII genotypes however longest larval and pupal periods were observed. At 90 DAS, no larvae survived on both the BGII genotypes. No effects of BGI genotypes were observed on biological parameters of *S. litura.* It was observed from the study that Cry toxin Cry 2Ab also had decreased expression at later stages of crop growth.

Key words : biological parameters, cotton, fecundity, *Spodoptera litura*

Transgenic cotton in India has resulted in effective control of cotton bollworms with 50-60 per cent reduction in insecticide usage and enhanced yield. Cotton hybrids containing Cry1ac of *Bacillus thuringiensis* (*Bt*) gene provided protection against all major bollworms and especially *Helicoverpa armigera* (Hubner) responsible for heavy yield losses for more than three decades. The *Bt* cotton was introduced in Haryana during 2005 and currently, grown over an area of 0.46 million ha with yield of 694 kg/ha. This boom in production is due to introduction of *Bt* cotton through efficient control of bollworm complex.

Tobacco caterpillar, *Spodoptera litura* (Fabracius) a foliage pest of cotton and other crops became more serious pest of cotton after the introduction of *Bt* cotton. The population of *S. litura* increased 119 per cent after introduction of *Bt* cotton (Cry 1Ac) that caused considerable losses in cotton by defoliating it (Jeyakumar *et al.,* 2007). Zhang *et al.,* (2005) revealed decreased survival rate of newly moulted *S. litura* and increased time required to reach second instars. In India, lower larval mortality and higher survival index for *S. litutra* on MECH 162 *Bt* raised concern over increasing importance of the pest with wide spread cultivation of *Bt* cotton over large areas (Vennila *et al.,* 2006). Jeyakumar *et al.,* (2007) indicated increasing trend in the population of *S. litura* on *Bt* cotton, based on survey of 14 villages in Haryana.

On the contrary, no significant differences between *Bt* and non *Bt* hybrids on biological parameters of *S. litura* was reported by Basavaraja *et al.,* (2008). Wan *et.al.*(2008) also did not find significant differences in larval population of the insect on conventional plants treated with chemical insecticide and on *Bt* cotton plants. Highest per cent larval mortality on young leaves followed by squares, middle leaves and young green bolls of RCH 2 *Bt* was observed at 168 h after the treatment (Govindan *et al.,*2010).

Keeping in view the seriousness of *S. litura* on *Bt* cotton, a new gene (Cry 2Ab) was introduced in cotton (BG II). Various studies indicated the effectiveness of BGII against *S. exigua* and *S. frugiperda* but has not been tested against *S. litura.* To test its effectiveness against *S. litura,* the present investigation was planned with the objective of studying the effect of transgenic *Bt* cotton (Cry 1Ac + Cry 2Ab) on biological parameters of *S. litura* at different days after sowing of crop.

MATERIALS AND METHODS

Cotton hybrids consisting BG1, BGII and non *Bt* formats of two cultivars *viz.,* Ankur Jai, and RCH 134 were sown on 15th of May by dibbling with 67.5 x 60 cm spacing at Entomology

Research Farm, CCS Haryana Agricultural University, Hisar. The experiment was laid out in randomized block design (RBD), replicated three times with the plot size of 32.4 sq.m. Thinning of plants was accomplished after one month of sowing. All other cultural practices were applied as per the recommendations.

Impact of *Bt* events on biological parameters of *S. litura* : The stock culture of *S. litura* maintained on castor leaves in the laboratory was available for conducting various experiments. Succulent and fresh cotton leaves were taken from each plot from three different plants at 60, 90,120 and 140 days after sowing (DAS) for studying the larval survival of first instar larvae. At the same time top leaves (fully opened fourth leaf) were also brought for studying some biological parameters of third instar larvae. These leaves were offered to *S. litura* in petriplates (5 cm dia.). Ten first instar larvae, immediately after hatching, were released in each petriplate, replicated thrice, in order to study larval survival under laboratory conditions. The food was changed daily and dead larvae were counted. The larval survival was recorded upto 5 days and the moribund larvae were counted as dead.

The top leaves of different genotypes were kept in glass jars (21×15cm) and 5 third instar larvae were released for feeding in each jar and labeled according to the genotypes kept in them. Three replicates were kept for each genotype. Jars were closed with muslin cloth and fastened with the rubber bands. The food was replenished daily till pupation. The biological parameters *viz.,* larval period (days), larval weight (mg), larval survival (%), pupal period (days), pupal weight (mg) and adult emergence (%) were recorded. Fecundity of the females that emerged from the larvae reared on all genotypes was also recorded. A pair of adult that emerged on same day on individual genotype was kept in jars (21x15 cm) and closed with muslin cloth and fastened with the help of rubber bands. Cotton swab dipped in sugar solution (15%) was provided as food to the adults inside the jar. The *zig zag* folded papers were provided inside the jar for egg laying. The eggs laid on zig zag folded papers and also on muslin cloth were counted with the help of microscope.

RESULTS AND DISCUSSION

First instar larval survival: The survival of first instar larvae of *S. litura* varied significantly on leaves of 60 days old crop. The larval survival was found lower on genotype Ankur Jai BGII (5.00%) which was followed by RCH 134 BGII (6.67%) (Table 1). On BGI and non *Bt* genotypes, survival ranged from 76.67 to 90.00 per cent. In all the *Bt* and non *Bt* genotypes, larval survival was *on par* except RCH 134 non *Bt*. Almost similar trend was recorded at 90 DAS as larval survival remained lowest on both BGII genotypes *i.e.* Ankur Jai BGII and RCH 134 BGII compared to BGI and non *Bt* genotypes. At 120 DAS, larval survival on BGII genotypes increased drastically and found to be *on par* with all other genotypes tested.

The BGII genotypes of Ankur Jai and RCH recorded 90.00 per cent and 86.67 per cent larval survival of *S. litura,* respectively. Almost similar trend was observed at 140 (DAS), as all the genotypes were *on par* with each other. But survival of larvae of *S. litura* in all the genotypes including *Bt* and non *Bt* genotypes was observed on the decreasing side.

Impact on various biological parameters: At 60 DAS, differences between larval periods of BGI, non *Bt* and BGII genotypes were highly significant (Table 2). As no larvae survived on genotype Ankur Jai BGII till pupation, larval period on genotype Ankur Jai BGII could not be recorded. As a result, observations on other parameters were also not accomplished. Larval period was longest on genotype RCH 134 BGII (34.00days). BGI and non *Bt* genotypes larval period was 22.53 and 24.47 days, respectively. At 90 DAS, no larvae survived till pupation on both BGII genotypes. The larval period among all the genotypes ranged from 22.87 - 27.67 days and was statistically *on par* among them. Although at 120 DAS, differences between larval periods of different genotypes were significant with increase on BGII genotypes.

The larval period was significantly less among all the BGI and non *Bt* genotypes (19.67 - 21.93 days) when compared with BGII genotypes (27.40-28.93 days). All the non *Bt* and BGI genotypes were statistically *at par* with each other. There were non significant differences

Table 1. Effect of transgenic *Bt* events on larval survival (%) of first instar of *Spodoptera litura*

Genotypes	Per cent survival of first instar larvae at various days after sowing (DAS)			
	60	90	120	140
Ankur Jai BGI	81.67(64.78)	76.67(61.69)	93.33(76.33)	80.00(63.90)
Ankur Jai BGII	5.00(12.92)	13.33 (18.56)	90.00 (71.54)	66.67(54.76)
Ankur Jai non *Bt*	90.00(71.54)	93.33(78.41)	100.00(85.91)	80.00(64.61)
RCH 134 BGI	80.00(63.90)	88.33(70.09)	93.33(76.33)	83.33(66.61)
RCH 134 BGII	6.67 (13.63)	11.67(16.72)	86.67(68.83)	56.67(48.91)
RCH 134 non *Bt*	76.67(61.90)	88.33(72.17)	93.33(76.33)	90.00(73.62)
SEm(±)	-3.73	-6.79	-3.56	-5.23
CD(p=0.05)	-11.62	-21.14	(N.S.)	(N.S.)

The values in parentheses are angular transformed values

among BGII genotypes. But at 140 DAS, the larval period was increasing compared to 120 DAS as it reached 36.33 and 36.00 days on genotypes Ankur Jai BGII and RCH 134BGII, respectively. The larval period on BGI and non *Bt* genotypes also showed increasing trend compared with the observations at 120 DAS.

The larval weight was recorded on tenth day after releasing the larvae under investigation. At 60 DAS, larval weight varied significantly among genotypes. The larval weight on Ankur Jai BGII was lowest (5.97 mg) followed by RCH 134 BGII (13.13 mg) (Table 2). But no effect of BGI (Cry 1Ac) was observed on larval weight of *S. litura* at 60 days after sowing. At 90 DAS, no larvae survived till pupation, but those larvae which survived till tenth day were weighed. On that basis, larval weight was found minimum on genotype RCH 134 BGII (17.41mg). Similarly, no effect of genotype was observed on BGI and non *Bt* genotypes as larval weight ranged from 249.53 to 378.33 mg. The larval weight at 120 DAS revealed an increasing trend on BGII genotypes. The genotype Ankur Jai BGII recorded 229.33 mg larval weight which was highest compared to observations at 60 and 90 DAS. The larval weight of BGI and non *Bt* was also observed increasing compared with 90 DAS. At 140 DAS, the larval weight decreased for all the genotypes compared with 120 DAS observations. But observations at 140 DAS showed that the larval weight did not decrease to a level as it was at 60 and 90 DAS.

The larval survival on RCH 134 BGII was minimum (13.33%) and on Ankur Jai BGI and non *Bt,* 100.00 per cent larval survival was observed (Table 2). Similar trends were observed at 90 DAS. As no larvae survived on BGII genotypes, it was excluded from the analysis and differences between observations of BGI and non *Bt* genotypes were non significant. Larval survival also increased at 120 DAS and was 60.00 per cent on Ankur Jai BGII and 40.00 per cent on RCH 134 BGII. At 140 DAS, larval survival on BGII genotypes decreased coinciding with crop senescence. The larval survival on BG1 and non *Bt* genotypes also decreased.

The pupal period varied significantly at 60 DAS between BGI and BGII genotypes. The longest pupal period was recorded on RCH 134 BGII genotype (11.00 days). With BGI and non *Bt* genotypes were on par (Table 3). At 90 DAS, same trend was noticed between BGI and non *Bt* genotypes. The pupal period at 120 DAS decreased and the pupal period between BGI, non *Bt* and BGII was found *on par.*

The pupal period remained non significant at 140 DAS (Table 3). The adult emergence recorded was minimum on RCH 134 BGII genotype at 60 DAS (Table 4). Fecundity also followed the same trend. The observations at 90 days after sowing for adult emergence between BGI and non *Bt* genotypes were non significant. The fecundity varied significantly between BGI and non *Bt* genotype but with minor differences. The highest fecundity was observed on genotype RCH 134 non *Bt* (1791.00eggs/female). The fecundity varied significantly among various genotypes and the lowest was observed on RCH 134 BGII (7.33 eggs/female) and on Ankur Jai BGII it was 207.67 eggs/female (Table 4). The adult emergence was again observed decreasing at 140 DAS. No egg laying was observed on BGII genotypes. All these parameters decreased at 140 DAS as compared with the observations at 60, 90, 120 DAS.

The larval survival of first instar of *Spodoptera litura* (Fabricius) was found lowest at

Table 2. Effect of transgenic *Bt* cotton top leaves on larval parameters of *Spodoptera litura* after different days after sowing (DAS)

Genotypes	Larval period (DAS)				Larval weight (mg) (DAS)				Larval survival (%) (DAS)			
	60	90	120	140	60	90	120	140	60	90	120	140
Ankur Jai BGI	24.47	24.20	21.47	24.07	518.20	275.55	443.20	337.70	100.00(85.91)	86.67(70.91)	100.00(85.91)	73.33(59.19)
Ankur Jai BGII	**	**	27.40	36.33	5.97	20.52	229.33	79.01	-	-	60.00(50.75)	13.33(19.05)
Ankur Jai non *Bt*	24.47	27.67	21.93	22.20	525.60	249.53	484.60	342.80	100.00(85.91)	80.00(66.69)	80.00(66.69)	80.00(70.35)
RCH 134 BGI	22.53	25.34	21.53	24.93	448.03	259.22	459.33	255.08	86.67(70.91)	73.33(59.19)	86.67(74.19)	73.33 59.19)
RCH 134 BGII	34.00	**	28.93	36.00	13.13	17.41	160.35	30.75	13.33(19.05)	-	40.00 (38.84)	33.33(34.99)
RCH 134 non *Bt*	22.53	22.87	19.67	21.80	368.37	378.33	453.08	307.07	86.67(70.91)	86.67(70.91)	93.33(78.41)	73.33(62.85)
SEm (±)	1.93	0.92	0.94	1.42	35.62	24.42	27.28	30.96	(5.81)*	(7.68)*	(7.61)*	(9.43)*
CD(p=0.05)	6.14	2.61	2.65	4.43	100.35	68.78	76.85	87.24	-18.54	(N.S.)	-23.73	-29.38

*The values in parentheses are angular transformed values; **Larvae died before pupation; Larval weight were taken on tenth day after release

Table 3. Effect of transgenic *Bt* cotton top leaves on pupal parameters of *Spodoptera litura* after different days of sowing (DAS)

Genotypes	Pupal period (DAS)				Pupal weight (mg) (DAS)			
	60	90	120	140	60	90	120	140
Ankur Jai BGI	7.49	8.36	7.59	10.67	230.40	161.70	156.80	125.20
Ankur Jai BGII	-	-	8.33	11.33	-	-	69.30	14.55
Ankur Jai non *Bt*	7.07	8.28	7.72	8.00	203.47	136.11	123.98	104.91
RCH 134 BGI	8.25	9.03	7.35	10.67	171.70	139.60	146.76	124.93
RCH 134 BGII	11.00	-	8.33	13.67	21.08	-	52.28	9.63
RCH 134 non *Bt*	7.30	8.14	7.67	7.66	208.77	171.97	163.48	104.13
SEm (±)	0.7	0.75	0.46	1.56	16.44	20.97	14.64	16.45
CD(p=0.05)	2.23	N.S.	N.S.	N.S.	46.48	N.S.	41.25	46.35

Table 4. Effect of transgenic *Bt* cotton top leaves on adult parameters of *Spodoptera litura* after different days after sowing (DAS)

Genotypes	Adult emergence (%) (DAS)				Fecundity (Eggs/female) (DAS)			
	60	90	120	140	60	90	120	140
Ankur Jai BGI	80.00(68.05)	53.33(47.28)	73.33 (59.19)	40.00 (38.84)	1131.67 (33.62)	1224.67 (34.99)	1254.67 (35.41)	334.00 (18.28)
Ankur Jai BGII	-	-	33.33 (34.99)	6.67 (11.55)	-	-	207.67(14.12)	0.00 (1.41)
Ankur Jai non *Bt*	60.00(54.78)	40.00(38.84)	53.33 (46.90)	46.67 (43.06)	1142.00 (33.79)	1128.67 (33.58)	744.00 (27.24)	276.67(16.58)
RCH 134 BGI	60.00(50.75)	53.33(46.90)	73.33 (66.12)	53.33 (47.28)	1018.67 (31.80)	1177.67 (34.32)	1008.33 (31.67)	260.00 (16.15)
RCH 134 BGII	13.33(19.05)	-	20.00 (26.55)	6.67 (11.55)	493.00 (21.90)	-	7.33 (2.54)	0.00 (1.41)
RCH 134 non *Bt*	53.33 (46.90)	60.00(51.12)	80.00 (66.69)	46.67 (39.40)	1150.33 (33.88)	1791.00 (42.33)	1317.33 (36.26)	307.33 (17.44)
SEm (±)	(9.46)*	(6.66)*	(9.55)*	(9.72)*	(1.71)**	(0.55)**	(1.45)**	(0.88)**
CD(p=0.05)	-30.18	(N.S.)	(N.S.)	(N.S.)	-5.45	-1.71	-4.52	-2.81

*The values in parentheses are angular transformed values
**The values in parentheses for fecundity are square root transformed values

60 and 90 days after sowing (DAS) on top leaves of BGII genotypes as compared with BGI and non *Bt* genotypes as it ranged from 76.67-93.33 per cent among various genotypes. Larval survival observed increasing after 90 DAS *i.e.* 120 and 140 DAS but there were no significant differences between BGII, BGI and non *Bt* genotypes.

The larval period of third instar of *S. litura* when fed on top leaves of BGI, BGII and non *Bt* genotype showed that on Ankur Jai BGII genotype, no larvae survived till pupation so larval period could not be recorded on top leaves. Only few larvae survived on RCH 134 BGII genotype but took longer duration (34.00 days) to complete larval period as compared with BGI and non *Bt* genotype at same stage. At 90 DAS, similar results were noticed in case of BGI and non *Bt* genotypes but no larvae survived on any of the BGII genotypes. The observations further revealed that BGII (Cry 2Ab) genotypes of cotton were highly effective against *S. litura* at 60 and 90 days after sowing of the crop. Similar pattern of observations were also reported by Basavaraja *et al.,* (2008) and Vennila *et al.,* (2006). In case of BGII genotypes, it was concluded that survival of the larvae till pupation was very low at 60 DAS. Increased larval period on transgenic cotton was also noticed in *S. exigua* (Hubner) while feeding on transgenic cotton (Wu *et al.,* 2009). Zhang *et al.,* (2005) also reported that larval survival of *S. litura* decreased and time required to reach second instar was prolonged.

In case of BGI and non *Bt* genotypes, no effect was observed on larval weight on top leaves. The genotype Ankur Jai BGI and non *Bt* recorded larval weight higher than RCH 134 BGI and non *Bt* genotypes. This showed that BGI and non *Bt* genotypes had no effect on larval weight of *S. litura* at 60 and 90 DAS. No significant differences were recorded between larval weights on BGI and non *Bt* genotypes at 80 120 and 140 days after sowing as also reported by Basavaraja *et al.,* (2008). At 120 DAS, the larval weight increased on BGII genotypes but no effect was on BGI and non *Bt* genotypes. This indicates that BGII genotypes are less effective at later stages of crop against *S. litura*..

At 140 DAS, the larval weight decreased as compared with observations at 120 DAS but it was still higher than the larval weight recorded at 60 and 90 DAS which in turn revealed that Cry 2Ab toxin was present in plants. But a decrease in larval weight of other genotypes *i.e.* BGI and non *Bt* genotypes was also observed. It might be due to the ageing of the crop. Hence, it seems that results achieved on BGII genotypes at 140 DAS might be the combined effect of Cry 2Ab and age of the crop. These finding supports work accomplished by Adamczyk *et al.*, (2001) who stated that Cry 2Ab toxin was present throughout the growing season.

The larval survival, pupal period, pupal weight, adult emergence and fecundity, all followed similar trend at 60 and 90 DAS of crop. These findings are in resemblance with findings of Tindall *et al.,*(2009) who noticed that Cry1Ac:Cry1F induced significantly greater mortality (90-100%) of fall armyworm, *S. frugiperda* compared with non *Bt* genotypes.

At 120 DAS, the larval survival of *S. litura* on BGII genotypes was increasing. The pupal period of BGII genotypes was noticed non significant with BGI and non *Bt* genotypes. It was revealed that pupal period of BGII decreased. The pupal weight and adult emergence increased for BGII genotypes but these parameters were observed normal among BGI and non *Bt* genotypes. The fecundity of BGII genotypes was very low which revealed that Cry 2Ab had some impact on fecundity also when larvae were fed for long time on the genotypes. Low fecundity was observed in adults that emerged by feeding of larvae on BGII genotypes. The genotypes *i.e.* RCH 134 BGII had only 7.33 eggs/female and Ankur Jai BGII exhibited 207.67 eggs/female. The larvae which survived on bollgard II genotypes grew more slowly and produced small pupae that yielded adults with reduced longevity and fecundity as was noticed by Mahon and Olsen (2009)

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Bioefficacy of newer insecticidal combinations against sucking pest complex of cotton

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ABSTRACT: A field investigation was conducted to study the bioefficacy of newer insecticidal combinations (acetamiprid + cypermethrin, acetamiprid + quinalphos and acetamiprid + chlorpyrifos) along with their sole counterparts against the sucking pest complex of cotton, their effect on natural enemies, yield and phytotoxicity at Department of Agricultural Entomology, Marathwada Krishi Vidyapeeth, Parbhani. During the entire period of experimentation, the results were quite promising and the mean results revealed that combination treatments acetamiprid + quinalphos (40+2000) g, acetamiprid + chlorpyrifos (40+2000) g and acetamiprid + cypermethrin (40+200) g a.i./ha were significantly superior in controlling sucking pests, *viz.,* aphids, leafhoppers, thrips and whiteflies and increasing the yield of seed cotton. Among sole insecticides, acetamiprid 20 g a.i./ ha was found to be superior for minimizing aphids, leafhoppers, thrips and whiteflies population. Newer insecticidal combinations recorded highly toxic and dangerous to natural enemies upto 14 days after spraying. However, sole insecticides recorded less harmful to the natural enemies. The results on phytotoxicity symptoms showed that only leaf injury was observed upto 3 days after spraying in higher concentration of combi products, whereas, other phytotoxic symptoms like wilting, vein clearing, necrosis, epinasty and hyponasty were not observed in any of the treatments.

Key words : Natural enemies, newer insecticidal combinations, phytotoxicity, sucking pest complex, yield

Cotton (*Gossypium* spp) "King of Fibers" is cultivated in India with profuse problems of which, the insect pests remain most serious constraint in achieving regular yield. In India, the pest problem in cotton is so intricate that more than 55 per cent of total insecticides are consumed by cotton crop while area under cotton utilization is only 5 per cent of the total cultivated area. The pest management, therefore, becomes an important functional component in cotton cultivation. The pest management accounts for 25-45 per cent of the variable costs of growing the cotton crop in most of the less developed countries (Anonymous, 2002). The use of insecticides has played a major role in increasing cotton productivity for the last two decades. However, the indiscriminate and injudicious use of single insecticide has led to many problems including the resurgence of sucking pests, development of insecticidal resistance in some insects and residues in food stuff, consequence is that the chemical control has become less effective. Many a time several insect pests attack the crop simultaneously and it is difficult to control them with any one insecticide. Hence, there is need to explore newer molecules and improve the efficacy of conventional insecticides by mixing them with newer molecules. The application of combination products containing mixture of conventional with newer insecticide has also been reported to be an effective approach for addressing resistance and resurgence issues.

Acetamiprid is a novel neonicotinoid insecticide, having cyanoamidine structure which affects ACh of insect central nervous system. It has high systemic and translaminar activity and hence gives excellent efficacy against sucking pest complex including strains resistant to other chemistries. In this context, the present investigation was carried out to study the bio efficacy of newer insecticidal combinations (acetamiprid + cypermethrin, acetamiprid + quinalphos and acetamiprid + chlorpyrifos) along with their sole counterparts against the sucking pest complex of cotton, their effect on natural enemies, yield and phytotoxicity effect on cotton.

MATERIALS AND METHODS

The research work comprising of field bio efficacy trials was conducted during *kharif,* 2004-2005 and 2005-2006 under rainfed conditions at

Experimental Farm, Department of Agricultural Entomology, Marathwada Krishi Vidyapeeth, Parbhani. Bioefficacy experiments were laid out in randomized block design with three replications and 14 treatments. Popular hybrid cotton variety Ganga (PHH 316) was sown at a spacing of 90 x 60 cm. Recommended package of practices except insect pest control measures were followed to raise the crop. A total of two sprayings were applied with high volume knapsack sprayer. Insecticides were applied on the crop depending on economic threshold level and second subsequent spraying was given at 15 days interval.

Five plants were selected at random from each treatment/replication and tagged for observations on sucking pest complex and natural enemies. The population of aphids, *Aphis gossypii* Glover, leafhoppers, *Amrasca biguttula biguttula* Ishida, thrips, *Thrips tabaci* Lindeman and whiteflies, *Bemisia tabaci* Gennadius was recorded from top, middle and bottom leaves before spraying, 3, 7 and 14 days after first and second spraying. Simultaneously a record of natural enemies also maintained before spraying, 3, 7 and 14 days after first and second spraying. The seed cotton yield was recorded on whole plot basis after each picking and computed to ha basis. The data were compiled, averages were worked out, percentage converted into transformed values and statistically analyzed to compare the results. Values of different parameters of both the years were subjected to pooled analysis.

In the field phytotoxicity was studied in each treatment/replication, from 10 randomly selected and tagged plants at 1, 3, 7 and 14 days after spraying. The total numbers of leaves showing phytotoxicity, if any, were counted. The data collected were converted into percentage. The extent of phytotoxicity was assessed with visual observations using 0 (no phytotoxic symptoms) to 10 (100% phytotoxic) scale.

RESULTS AND DISCUSSION

Bioefficacy of newer insecticidal combinations against sucking pest complex : No significant difference in the pre treatment counts of aphids, leafhoppers, thrips and whiteflies was noticed.

Cotton aphids (*Aphis gossypii*) : The analysis of pooled data indicated that all the treatments were significantly superior over control during both the years of experimentation.

Observations on aphids population 3 days after first spraying recorded significantly lowest aphid population (0.73 aphids/3 leaves) in treatment acetamiprid + chlorpyrifos (40 + 2000 g a.i./ha), followed by acetamiprid + quinalphos (40 + 2000 g a.i./ha) (1.16 aphids/3 leaves). Whereas, among sole insecticides acetamiprid 20 g a.i./ha recorded significantly lower aphid population (5.10 aphids/3 leaves) over other sole insecticides. Similarly 7 days after first spraying acetamiprid + chlorpyrifos (40+2000 g a.i./ha) achieved the best results (1.99 aphids/3 leaves) and was found *at par* with acetamiprid + quinalphos (40 + 2000 g a.i./ha) (2.66 aphids /3 leaves). However at 14 days after first spraying acetamiprid + chlorpyrifos (40+2000 g a.i./ha) (6.66 aphids/3 leaves) was noticed significantly effective treatment in reducing aphid population, followed by acetamiprid + quinalphos (40 + 2000 g a.i./ha) (7.16 aphids/3 leaves) and acetamiprid + cypermethrin (40+200 g a.i./ha) (7.69 aphids/ 3 leaves).

During second spraying the treatment acetamiprid + chlorpyrifos (40+2000 g a.i./ha) recorded significantly lowest aphid population (0.60 aphids / 3 leaves) followed by acetamiprid + quinalphos (40 + 2000 g a.i./ha) (0.93 aphids/ 3 leaves) at 3 days after spraying. The trend in population reduction of aphids recorded at 7 days after spraying remained unchanged at 15 days after second spraying also. The results indicated that neonicotinoid insecticides when combined with other conventional insecticides proved effective against aphids. Present results are also in close agreement with the reports of Franco (1999), Santos and Santos (1999) and Tomquelski *et al.,* (1999). Among sole insecticides acetamiprid 20 g a.i./ha proved significantly superior over rest of individual insecticides. These results are in conformity with the work of Singh and Kumar (2005).

Cotton leafhoppers (*Amrasca biguttula biguttula*) : All the treatments were noticed significantly superior over control during both the years of experimentation.

Data on leafhoppers population 3 days after first spraying revealed that the treatment

Table 1. Bioefficacy of newer insecticidal combinations against aphids and leafhoppers

Sr. No.	Treatments	Dose (g) a.i./ha	Aphids							Leafhoppers						
			Pre count	After first spraying (DAS)			After second spraying (DAS)			Pre count	After first spraying (DAS)			After second spraying (DAS)		
				3	7	14	3	7	14		3	7	14	3	7	14
1	Acetamiprid (0.4%)+	10+50	18.1	5.39	9.19	10.7	4.86	6.43	9.16	1.59	1.06	1.33	1.89	0.96	1.46	1.79
	Cypermethrin (2% EC)		-4.2	-2.38	-3.1	-3.33	-2.31	-2.61	-3.09	-1.33	-1.18	-1.26	-1.48	-1.15	-1.34	-1.46
2	Acetamiprid (0.4%)+	20+100	18.68	3.76	6.86	8.83	3.06	4.79	7.63	1.93	0.83	1.03	1.53	0.73	1.06	1.47
	Cypermethrin (2% EC)		-4.57	-2.05	-2.7	-3.04	-2.86	-2.39	-2.83	-1.41	-1.07	-1.17	-1.37	-1.05	-1.21	-1.34
3	Acetamiprid (0.4%)+	40+200	16.93	1.7	3.9	7.69	1.39	2.29	4.29	2.43	0.36	0.76	1.46	0.13	0.39	0.8
	Cypermethrin (2% EC)		-4.15	-1.46	-2.08	-2.85	-1.36	-1.65	-2.18	-1.53	-0.89	-1.06	-1.31	-0.78	-0.94	-1.11
4	Acetamiprid (0.4%)+	10+500	16.96	5.19	8.56	11.03	4.33	6.73	9.23	1.69	1.03	1.16	1.86	0.96	1.26	1.79
	Quinalphos (20 % EC)		-4.14	-2.38	-3	-3.38	-2.19	-2.68	-3.11	-1.34	-1.17	-1.23	-1.47	-1.16	-1.28	-1.42
5	Acetamiprid (0.4%)+	20+1000	18.99	2.63	6.1	9.13	1.93	4.09	7.33	1.83	0.63	1	1.46	0.7	0.93	1.29
	Quinalphos (20 % EC)		-4.35	-1.75	-2.55	-3.09	-1.54	-2.12	-2.79	-1.35	-1	-1.17	-1.35	-1.03	-1.15	-1.3
6	Acetamiprid (0.4%)+	40+2000	19.86	1.16	2.66	7.16	0.93	1.79	3.83	1.69	0.06	0.49	1.29	0.1	0.19	0.76
	Quinalphos (20 % EC)		-4.44	-1.28	-1.77	-2.76	-1.18	-1.5	-2.07	-1.34	-0.74	-0.96	-1.29	-0.76	-0.83	-1.1
7	Acetamiprid (0.4%)+	10+500	19.66	4.56	9	11.33	4.36	6.3	5.49	2.16	0.99	1.23	1.86	0.89	1.3	1.63
	Chlorpyrifos (20 %EC)		-4.44	-2.24	-3.07	-3.43	-2.2	-2.64	-3.07	-1.5	-1.14	-1.24	-1.47	-1.15	-1.29	-1.4
8	Acetamiprid (0.4%)+	20+1000	18.56	3.26	6.69	9.49	2.46	4.7	6.79	1.63	0.76	0.99	1.56	0.7	0.99	1.36
	Chlorpyrifos (20 %EC)		-4.32	-1.93	-2.67	-3.15	-1.71	-2.27	-2.68	-1.34	-1.05	-1.16	-1.38	-1.02	-1.18	-1.32
9	Acetamiprid (0.4%)+	40+2000	17.33	0.73	1.99	6.66	0.6	1.83	3.66	1.96	0.2	0.59	1.33	0.13	0.33	0.79
	Chlorpyrifos (20 %EC)		-4.13	-1.09	-1.56	-2.67	-1.02	-1.52	-2.03	-1.63	-0.82	-1.01	-1.31	-0.78	-0.9	-1.12
10	Acetamiprid (20 SP)	20	17.84	5.1	9.56	11.43	4.46	6.66	9.66	1.89	1.2	1.46	1.96	1	1.56	1.89
			-4.18	-2.35	-3.16	-3.44	-2.21	-2.65	-3.04	-1.44	-1.19	-1.32	-1.51	-1.14	-1.38	-1.48
11	Quinalphos (25 EC)	500	19.12	6.89	10.36	13.66	5.63	7.93	10.56	1.86	1.43	1.46	2.06	1.13	1.83	2.03
			-4.38	-2.71	-3.28	-3.76	-2.44	-2.89	-3.3	-1.44	-1.3	-1.31	-1.55	-1.21	-1.47	-1.54
12	Chlorpyrifos (20 EC)	500	20.73	7.03	11.09	14.43	5.76	8.49	10.83	2.19	1.39	1.43	2.13	1.16	1.79	2.03
			-4.57	-2.76	-3.25	-3.85	-2.49	-2.99	-3.35	-1.5	-1.27	-1.27	-1.55	-1.21	-1.45	-1.52
13	Cypermethrin (10 EC)	75	20.96	9.66	13.76	17.73	9.09	11.66	13.33	1.93	1.59	1.56	2.13	1.29	1.76	2.06
			-4.59	-3.17	-3.76	-4.25	-3.05	-3.47	-3.71	-1.45	-1.36	-1.33	-1.55	-1.27	-1.43	-1.54
14	Untreated control	——	20.79	23.69	24.03	24.76	25.49	26.63	28.4	1.73	1.83	2.36	3.16	3.59	3.93	4.2
			-4.57	-4.9	-4.93	-5	-5.08	-5.18	-5.33	-1.41	-1.43	-1.58	-1.83	-1.92	-2	-2.03
	SE±		0.2942	0.109	0.096	0.073	0.099	0.089	0.086	0.096	0.101	0.098	0.1	0.085	0.078	0.125
	CD (p=0.05)		N.S.	0.316	0.28	0.213	0.287	0.26	0.25	N.S.	0.293	0.287	0.291	0.248	0.227	0.365

Table 2. Bio-efficacy of newer insecticidal combinations against thrips and whiteflies and effect on cotton yield.

Sr. No.	Treatments	Dose (g) a.i./ha	Thrips							Whiteflies							Yield (kg/ ha)
			Pre count	After first spraying (DAS)			After second spraying (DAS)			Pre count	After first spraying (DAS)			After second spraying (DAS)			
				3	7	14	3	7	14		3	7	14	3	7	14	
1	Acetamiprid (0.4%)+	10+50	38.66	4.43	7.13	12.03	4.56	6.93	8.26	2.66	1.33	1.86	2.36	1.23	1.46	1.99	1028
	Cypermethrin (2% EC)		-3.49	-2.2	-2.72	-3.53	-2.24	-2.71	-2.92	-1.69	-1.28	-1.47	-1.61	-1.27	-1.36	-1.51	
2	Acetamiprid (0.4%)+	20+100	37.43	3.99	5.93	10.56	3.8	5.4	6.49	2.13	0.56	1.16	1.76	0.59	1.16	1.59	1234
	Cypermethrin (2% EC)		-3.56	-2.12	-2.5	-3.32	-2.06	-2.42	-2.62	-1.53	-1.05	-1.26	-1.43	-1.01	-1.24	-1.38	
3	Acetamiprid (0.4%)+	40+200	37.33	2.86	3.76	8.53	1.96	3.33	4.53	2.53	0.23	0.53	1.3	0.23	0.39	0.81	1384
	Cypermethrin (2% EC)		-3.29	-1.83	-2.05	-3	-1.55	-1.94	-2.21	-1.64	-0.83	-1	-1.28	-0.85	-0.93	-1.11	
4	Acetamiprid (0.4%)+	10+500	38.89	4.76	7.9	11.13	4.13	6.16	7.63	2.23	0.86	1.36	2.06	1.06	1.29	1.83	1131
	Quinalphos (20 % EC)		-3.82	-2.28	-2.88	-3.4	-2.14	-2.56	-2.8	-1.56	-1.18	-1.3	-1.51	-1.22	-1.3	-1.46	
5	Acetamiprid (0.4%)+	20+1000	39.05	3.96	6.49	10.06	3.33	4.56	5.66	2.66	0.33	0.89	1.56	0.43	0.76	1.2	1295
	Quinalphos (20 % EC)		-3.99	-2.12	-2.64	-3.24	-1.94	-2.24	-2.44	-1.69	-0.9	-1.14	-1.37	-0.95	-0.11	-1.26	
6	Acetamiprid (0.4%)+	40+2000	38.13	2.49	3.46	8.89	1.4	2.69	4.23	2.49	0.06	0.33	1.06	0.09	0.23	0.66	1479
	Quinalphos (20 % EC)		-3.71	-1.72	-1.98	-3.04	-1.37	-1.76	-2.14	-1.61	-0.77	-0.9	-1.19	-0.77	-0.85	-1.05	
7	Acetamiprid (0.4%)+	10+500	39.76	5.1	8.23	12	5.59	7.86	9.26	2.29	0.93	1.63	2.13	1.13	1.3	1.76	1075
	Chlorpyrifos (20 %EC)		-3.9	-2.34	-2.94	-3.52	-2.46	-2.89	-3.11	-1.56	-1.18	-1.37	-1.52	-1.23	-1.27	-1.42	
8	Acetamiprid (0.4%)+	20+1000	39.16	4.09	6.69	10.13	4.43	5.69	6.76	2.26	0.36	0.96	1.66	0.46	0.93	1.26	1277
	Chlorpyrifos (20 %EC)		-3.81	-2.15	-2.67	-3.25	-2.21	-2.48	-2.67	-1.56	-0.94	-1.15	-1.39	-0.96	-1.15	-1.26	
9	Acetamiprid (0.4%)+	40+2000	39.56	2.93	3.96	8.66	2.46	3.36	4.53	2.03	0.13	0.36	1.1	0.16	0.3	0.73	1428
	Chlorpyrifos (20 %EC)		-3.8	-1.84	-2.1	-3.01	-1.71	-1.95	-2.21	-1.49	-0.8	-0.91	-1.22	-0.81	-0.88	-1.07	
10	Acetamiprid (20 SP)	20	38.16	3.7	6.59	11.33	4.26	5.96	7.56	2.46	1.09	1.86	2.29	1.3	1.39	2.06	830
			-3.56	-1.96	-2.58	-3.42	-2.14	-2.49	-2.75	-1.63	-1.2	-1.47	-1.58	-1.26	-1.3	-1.52	
11	Quinalphos (25 EC)	500	38.36	5.43	8.46	11.96	5.66	7.59	9.09	2.33	1.13	1.69	2.26	1.36	1.43	2	1022
			-3.6	-2.27	-2.97	-3.52	-2.47	-2.83	-3.06	-1.57	-1.29	-1.39	-1.55	-1.29	-1.32	-1.47	
12	Chlorpyrifos (20 EC)	500	37.49	7.46	11.06	11.76	7.79	9.23	10.83	2.4	1.06	1.73	2.29	1.33	1.39	1.99	1014
			-3.55	-2.79	-3.39	-3.49	-2.87	-3.11	-3.35	-1.57	-1.18	-1.39	-1.54	-1.26	-1.3	-1.46	
13	Cypermethrin (10 EC)	75	37.79	6	8.83	12.19	6.36	8.03	9.63	2.56	1.56	1.89	2.5	1.46	1.59	2.16	947
			-3.88	-2.56	-3.05	-3.55	-2.61	-2.9	-3.15	-1.64	-1.38	-1.46	-1.62	-1.31	-1.39	-1.54	
14	Untreated control	——	38.96	40.66	42	42.49	42.4	42.69	43.83	2.5	2.96	3.26	3.46	3.86	4.19	4.59	683
			-3.89	-6.05	-6.21	-6.28	-6.22	-6.24	-6.31	-1.62	-1.78	-1.86	-1.92	-2.01	-2.09	-2.13	
	SE ±		0.136	0.071	0.077	0.068	0.091	0.079	0.076	0.098	0.095	0.102	0.092	0.077	0.09	0.092	0.614
	CD (p=0.05)		N.S.	0.207	0.225	0.197	0.269	0.229	0.222	N.S.	0.275	0.296	0.269	0.225	0.261	0.267	NS

acetamiprid + quinalphos (40+2000 g a.i./ha) recorded significant reduction in leafhoppers population (0.06 leafhoppers / 3 leaves), followed by acetamiprid + chlorpyrifos (40+2000 g a.i./ ha) (0.20 leafhoppers/3 leaves), acetamiprid + cypermethrin (40+200 g a.i./ha) (0.36 leafhoppers/3 leaves) and acetamiprid + quinalphos (20+1000 g a.i./ha) (0.63 leafhoppers/ 3 leaves). Whereas, among sole insecticides acetamiprid 20 g a.i./ha recorded superior treatment (1.20 leafhoppers/ 3 leaves) over rest of sole insecticides. Similarly on 7 days after first spraying the minimum jassid population (0.49 leafhoppers/ 3 leaves) was recorded in treatment acetamiprid + quinalphos (40+2000 g a.i./ha), followed by acetamiprid + chlorpyrifos (40+2000 g a.i./ha) (0.59 leafhoppers/3 leaves) and acetamiprid + cypermethrin (40+200 g a.i./ha) (0.76 leafhoppers /3 leaves). The efficacy of all the sole insecticides was *on par* with untreated control. However, at 14 days after spraying the treatments acetamiprid + quinalphos (40+2000 g a.i./ha) (1.29 leafhoppers/ 3 leaves) sustained to be most effective treatment as compared to remaining treatments.

During second spray, significantly lowest leafhoppers population (0.10 leafhoppers/3 leaves) was recorded in acetamiprid + quinalphos (40+2000 g a.i./ha) followed by acetamiprid + chlorpyrifos (40+2000 g a.i./ha) and acetamiprid + cypermethrin (40 + 200 g a.i./ha) (0.13 leafhoppers/3 leaves) at 3 days after spraying. Among sole insecticides non significant differences were observed. The trend in population reduction of leafhoppers recorded at 7 days after spray remained unchanged at 15 days after second spraying also. These results are in conformity with results of Das and Veda (2004) who concluded that all the doses of ready mix formulation Lancer Gold (51.8 % SP) (imidacloprid + acephate) significantly reduced leafhoppers infestation over their individual counterparts. Overall comparative study revealed that among sole insecticides acetamiprid 20 g a.i./ha proved highly efficient against leafhoppers over rest of the sole insecticides. The trend of results found in present studies coincides with that reported by Singh and Kumar (2005).

Cotton thrips (*Thrips tabaci*) : All the treatments were registered significant superiority in reducing thrips population over control during both the years of experimentation.

Observations on thrips population 3 days after first spray exhibited that the treatment acetamiprid + quinalphos (40+2000 g a.i./ha) (2.49 thrips / 3 leaves) achieved best results and was found *at par* with acetamiprid + cypermethrin (40+200 g a.i./ha) (2.86 thrips / 3 leaves). However, the treatment acetamiprid 20 g a.i./ha was found significantly superior in reducing thrips population (3.70 thrips/3 leaves) over rest of sole insecticides. Similarly 7 days after first spray acetamiprid + quinalphos (40+2000 g a.i./ha) (3.46 thrips/3 leaves), acetamiprid + chlorpyrifos (40+2000 g a.i./ha) (3.96 thrips/ 3 leaves) and acetamiprid + cypermethrin (40 + 200 g a.i./ha) (3.76 thrips / 3 leaves) found significantly superior treatments. The data on 14 days after first spray indicate that all the treatments were effective in reducing thrips population.

The analysis of pooled data after second spray indicate that at 3 days after spraying acetamiprid + quinalphos (40+2000 g a.i./ha) (1.40 thrips / 3 leaves) and acetamiprid + cypermethrin (40+200 g a.i./ha (1.96 thrips / 3 leaves) significantly suppressed thrips population. However, among the sole insecticides acetamiprid 20 g a.i./ha (4.26 thrips / 3 leaves) recorded significantly good control. The trend in population reduction of thrips recorded at 7 days after spray remained unchanged at 15 days after second spraying also. The present study gets support from the fact that acetamiprid + conventional insecticide or imidacloprid + conventional insecticide were reported to be effective against thrips documented by Santos and Santos (1999), where acetamiprid + endosulfan (20 g + 350 g a.i./ha) recorded more than 95 per cent control of cotton thrips. However, Das and Veda (2004) reported all the doses of imidacloprid + acephate significantly effective against thrips on cotton over individual counterparts.

Cotton whiteflies (*Bemisia tabaci*) : It was observed that all the treatments offered very good protection against whiteflies. The mean whitefly population on 3 days after first spray evidenced that significantly lowest whitefly population (0.06 whiteflies/3 leaves) was noticed in the treatment acetamiprid + quinalphos (40+2000) g a.i./ha followed by acetamiprid + chlorpyrifos (40+2000 g a.i./ha) (0.13 whiteflies/3 leaves), acetamiprid + cypermethrin (40+200 g a.i./ha) (0.23 whiteflies/3 leaves) and acetamiprid + quinalphos (20+1000 g a.i./ha) (0.33 whiteflies/3 leaves). Among sole insecticides non significant differences were observed between the treatments (1.09 to 1.56 whiteflies/3 leaves). Similarly 7 days after first spray the treatment acetamiprid + quinalphos (40+2000 g a.i./ha) registered significant control over whiteflies (0.33 whiteflies/3 leaves), followed by acetamiprid + chlorpyrifos (40+2000 g a.i./ha) (0.36 whiteflies/3 leaves) and acetamiprid + cypermethrin (40+200 g a.i./ha) (0.53 whiteflies/3 leaves). However, 14 days after first spray the treatment acetamiprid + quinalphos (40+2000 g a.i./ha) was noticed most effective treatment in reducing whitefly population (1.06 whiteflies/3 leaves) followed by acetamiprid + chlorpyrifos (40+2000 g a.i./ha) (1.10 whiteflies/3 leaves), acetamiprid + cypermethrin (40+200 g a.i./ha) (1.30 whiteflies/3 leaves) and acetamiprid + quinalphos (20+1000 g a.i./ha) (1.56 whiteflies/3 leaves).

During second spray, significantly lowest whitefly population was recorded in the treatment acetamiprid + quinalphos (40+2000 g a.i./ha) (0.09 whiteflies / 3 leaves), which was *at par* with acetamiprid + chlorpyrifos (40+2000 g a.i./ha) (0.16 whiteflies/3 leaves), acetamiprid + cypermethrin (40+200 g a.i./ha) (0.23 whiteflies/3 leaves), acetamiprid + quinalphos (20+1000 g a.i./ha) (0.43 whiteflies/3 leaves), acetamiprid + chlorpyrifos (20+1000 g a.i./ha) (0.46 whiteflies/3 leaves). However, the sole insecticides showed non significant differences among themselves. The trend in population reduction of thrips recorded at 7 days after spray remained unchanged at 15 days after second spraying also. The analogous results on efficacy of acetamiprid + conventional insecticide or imidacloprid + conventional insecticide against whiteflies have also been reported by Natwick *et al.,* (1999) and Das and Veda (2004).

Impact of newer insecticidal combinations on natural enemies : Overall results revealed that all the newer insecticidal combinations were highly detrimental to the natural enemies upto 14 days after spray and did not record a single natural enemy. However, sole insecticides were observed less harmful to the natural enemies on 14 days after spray during both the sprayings. Foliar application of neonicotinoids showed adverse impact on natural enemies. These results are in close agreement with the findings of Verghese and Beevi (2004), Nasreen *et al.,* (2004), Youn *et al.,* (2003) and Uthamasamy *et al.,* (2003).

Effect of newer insecticidal combinations on cotton yield : All the insecticidal treatments recorded the highest seed cotton yield over untreated control. Whereas, the combi products *viz.,* acetamiprid + quinalphos (40+2000 g a.i./ha), acetamiprid + chlorpyrifos (40+2000 g a.i./ha) and acetamiprid + cypermethrin (40+200 g a.i./ha) proved effective in increasing seed cotton yield over rest of treatments. In various insecticidal combinations yield ranged between 1479 to 1028 kg/ha. The pooled means of two season indicated non significant difference in yield. Several workers have also obtained similar results (Das and Veda, 2004).

Phytotoxicity of newer insecticidal combinations in cotton : The results indicated that only phytotoxicity symptom with leaf injury was observed upto 3 days after spraying in higher concentration of combi products like acetamiprid + quinalphos (40+2000 and 20+1000 g a.i./ha), acetamiprid + chlorpyrifos (40+2000 and 20+1000 g a.i./ha) and acetamiprid + cypermethrin (40+200 and 20+100 g a.i./ha). However, other phytotoxic symptoms like wilting, vein clearing, necrosis, epinasty and hyponasty did not observed in any of the treatments.

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Population dynamics of cotton aphid and its predators on *Bt* cotton and its impact of *Bt* cotton fed aphids on biology of *Chrysoperla carnea* Steph

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ABSTRACT : The population dynamics of cotton aphid, *Aphis gossypii* Glover and its predators *viz., Cheilomenes sexmaculata* Fab., *Chrysoperla carnea* Steph. and *Ischiodon scutellaris* Fab. was studied on RCH 2 *Bt* and non *Bt* cotton hybrids. The mean number of aphids was 23.82 and 21.37/leaf in RCH 2 *Bt* and non *Bt*, respectively, indicating no significant variation. The dynamics of predators was aphid density dependent in both *Bt* and non *Bt* hybrids. Mean population of coccinellids, *Chrysoperla* and syrphids was 0.89, 0.78 and 1.0/plant in RCH 2 *Bt* which was almost similar to the incidence on RCH 2 non *Bt*. There was strong and positive correlation between population of predators and aphid on both *Bt* and non *Bt* cotton. Laboratory feeding experiments using *Bt* and non *Bt* cotton carried out to study the effect of *Bt* fed aphids on predator *C. carnea* indicated no difference in incubation period, longevity of grubs and adults, fecundity and aphid consumption potential indicating safety of Cry1Ac to *C. carnea* through intoxicated aphid host.

Key words : *Chrysoperla*, cotton, cry, predators

During 2002 India resorted to *Bt* cotton cultivation based on demand for a full proof and viable solution to the quite intense bollworm problem. India gained status of mega biotech country with 7.8 m ha coverage under *Bt* cotton (Anonymous, 2006). Nearly 64 *Bt* cotton cultivars are being grown in the country at present. Transgenic plants produced cry protein in high doses and in most of their tissues through out the season. The insecticidal toxin could become available to the predatory insects in a new and modified form through non susceptible or sublethally effected non target herbivores prey feeding on *Bt* plants (Jepson *et al.,* 1994) which could constitute an important pathway for ecological impacts of *Bt* cotton (Andow and Hilbeck, 2004). The investigation need to be undertaken to test such potential impacts (Lovie and Arpaia, 2005). Therefore, the present investigation was conducted with the objective to assess the impact of *Bt* cotton hybrids on predatory insects which acts as stabilizing force for important insect pests in cotton agro-ecosystem.

MATERIALS AND METHODS

The studies on natural incidence of insect predators *viz.,* predominant species of ladybird beetle *Cheilomenes sexmaculata* Fab., green lacewing, *Chrysoperla carnea* Steph. and hover flies / syrphid fly *Ischiodon scutellaris* Fab. were carried out through field experiments conducted during 2004-2005 and 2005-2006 at Agricultural Research Station, Dharwad, using RCH 2*Bt* hybrid. The crop was sown on 16.06.2004 and 24.06.2005 for respective seasons in unreplicated block of 10.8 x 6.0 m^2 size with 90 x 60 cm spacing. Similarly a block of RCH 2 non *Bt* was sown at the same time for comparative study. No plant protection measures were imposed on any block or during any period of crop growth during both the seasons. Between *Bt* and Non-*Bt* blocks an isolation distance of 10 m was maintained to avoid migration effect. Observations were recorded from 10 randomly selected plants at weekly interval from July to December *i.e.* 28^{th} to 51^{st} standard week for incidence of aphids as well as predatory insects. The population of aphids was recorded by counting the nymphs and adult females on three leaves, one each from top, middle and bottom portion of plant and then averaged as population/ leaf. Similarly adults and grubs of, *C. sexmaculata,* grubs of *C. carnea* and maggots of syrphid fly were recorded on whole plant basis and averaged to population/plant. The seasonal mean incidence of aphid as well as predators population in RCH 2 *Bt* and non *Bt* was compared through paired "t" test to assess the impact. The correlation between incidence of predators and aphid population was assessed in both *Bt* and non *Bt* crop.

A laboratory study was also conducted during 2004 for assessing the impact of *Bt* cotton fed aphids on biology of *C. carnea*. The seedlings of RCH 2*Bt* and non *Bt* cotton were raised in pots on 20.08.2004. Ten pots were maintained for both RCH 2 *Bt* and non *Bt*. Late sowing was done to coincide the aphid incidence on the plants with optimum expression period for cry 1 Ac *i.e.* 50-80 days after sowing (DAS) to have proper impact (if any) on aphids. The aphid colonies developed on these plants were used to feed *C. carnea* grubs in the laboratory. Feeding potentiality, impact on growth and development was assessed by rearing *C. carnea* from hatching to pupation on aphids infesting potted plants of RCH 2 *Bt* and non *Bt* . All the instars were reared in specimen tubes (1.0 x3.5 cm) till pupation by feeding known number of nymphs of aphids everyday. For each treatment there were 10 grubs and each set was replicated five times. After every 24 h, grubs were shifted with brush tip to new specimen tube marked for same treatment and replication. The old specimen tube was taken for counting the aphids remaining in the tube to know each day feeding potential. Host material *i.e.* nymphs of aphids from RCH 2 *Bt* and non *Bt* plants for respective treatments were increased gradually as instar advanced. After pupation and emergence of adults, pairs of males and females for each ten treatment were isolated (2 pairs from each replication) and released separately for mating and oviposition. Adult food (10% honey) was provided in each oviposition cage. The observations was recorded on nymphal and prepupal duration, adult longevity, sex ratio, fecundity, incubation period and total aphids consumed.

RESULTS AND DISCUSSION

Pooled data of both years recorded that the relative abundance of aphids and three predators *viz.*, *C. sexmaculata*, *C. carnea* and *I. scutellaris* could not vary much between *Bt* and non *Bt* crops (Table 1). The number of aphids ranged between 8.58/ leaf (34th week) to 42.15/ leaf (50th week) with a mean of 23.82/ leaf in RCH 2 *Bt*. Since beginning of the incidence at 28th week population remained above ETL (>10.0/ leaf) till end of the season and with increasing trend and heavy buildup was noticed during December. Population dwindled to below ETL during 31st, 34th and 35th week. This incidence appeared to be numerically more in respective weeks as compared to the incidence in non *Bt* crop, which supported the buildup of aphids to economic thresholds (10/leaf) and above from September onwards only. The incidence was 7.43/ leaf (36th week) to 37.08/ leaf (46th week) with a mean of 21.37/ leaf. RCH 2 *Bt* supported the population of aphids as well as predators similarly to that of its non *Bt* version. The statistical analysis of all these parameters (Table 2) could not show any significant difference in a paired row "t" test. Thus the theoretic possible impact of cry protein on predators through passive exposure was not supported by the results of present study. Similarly, form earlier reports present it was confirmed that *Bt* cotton did not affect the population dynamics of aphids (Wu and Guo, 2003 and Hegde *et al.,* 2004). Therefore, the likely adverse effect of *Bt* protein on aphid incidence and further on its predators was not evident in the present investigation.

A density dependent variation with respect to prey was shown by all the three predators after their appearance in the season. Mean number of coccinellids, *Chrysoperla* and syrphids was 0.89, 0.78 and 1.0/plant in RCH 2 *Bt* and 0.91, 0.75 and 1.04/plant in RCH 2 non *Bt*, respectively. There was no significant difference between the predatory population on *Bt* and non *Bt* cotton crops (Table 2). The population of predator always depends on its prey. As there was no variation in the host population between two types of cotton, the dependent predator also did not show any difference and there was strong and positive correlation between aphid and predatory population (Table 3). Amongst three predators syrphids exhibited a high degree of host dependent, population buildup (r = 0.94 and 0.96) followed by *Chrysoperla* and coccinellids. This clearly indicated that *Bt* toxin has no effect on major arthropod predators appearing in cotton crop. The dynamics of major predators in *Bt* and conventional cotton fields were almost same in a similar study conducted

Table 1. Relative abundance of aphids and predatory insects on RCH 2 *Bt* and non *Bt* cotton hybrid (pooled data of 2004 and 2005 *kharif* seasons)

Month	Standard week	Aphids/ leaf		Coccinellids/ plant		Chrysoperla/ plant		Syrphids / plant	
		Bt	Non *Bt*	*Bt*	Non *Bt*	*Bt*	Non *Bt*	*Bt*	Non *Bt*
July	28	10.69	9.67	0	0	0	0	0	0
		-3.42	-3.27	-1	-1	-1	-1	-1	-1
	29	17.92	15.65	0	0	0	0	0	0
		-4.35	-4.08	-1	-1	-1	-1	-1	-1
August	30	26.04	24.73	0.7	0.62	0	0	0	0
		-5.2	-5.07	-1.3	-1.27	-1	-1	-1	-1
	31	9.87	8.17	0.45	0.47	0.03	0.02	0	0
		-3.3	-3.03	-1.2	-1.21	-1.01	-1.01	-1	-1
	32	15.93	12.57	0.6	0.5	0.01	0.03	0	0
		-4.11	-3.68	-1.26	-1.22	-1	-1.01	-1	-1
	33	12	8.18	0.25	0.4	0.02	0.01	0	0
		-3.61	-3.03	-1.12	-1.18	-1.01	-1	-1	-1
	34	8.58	6.22	0.55	0.48	0.06	0.04	0	0
		-3.1	-2.69	-1.24	-1.21	-1.03	-1.02	-1	-1
September	35	5.94	7.67	0.6	0.52	0.14	0.14	0	0
		-2.63	-2.94	-1.26	-1.23	-1.07	-1.07	-1	-1
	36	10.55	7.43	0.7	0.74	0.33	0.25	0	0
		-3.4	-2.9	-1.3	-1.32	-1.15	-1.12	-1	-1
	37	13.29	9.92	0.46	0.8	0.54	0.52	0	0
		-3.78	-3.3	-1.21	-1.34	-1.24	-1.23	-1	-1
	38	14.03	11.87	0.29	0.65	0.7	0.61	0	0
		-3.88	-3.59	-1.14	-1.28	-1.3	-1.27	-1	-1
October	39	17.05	13.1	0.41	0.52	0.46	0.53	0.32	0.4
		-4.25	-3.75	-1.19	-1.23	-1.21	-1.23	-1.15	-1.18
	40	19.26	17.13	0.33	0.30	0.47	0.5	0.46	0.53
		-4.5	-4.26	-1.15		-1.21	-1.22	-1.21	-1.23
	41	25.77	25.45	0.49	0.44	0.48	0.56	1.01	0.91
		-5.17	-5.14	-1.22	-1.2	-1.22	-1.25	-1.42	-1.38
	42	31.43	28.3	0.84	0.76	0.67	0.68	1.15	1.27
		-5.69	-5.41	-1.36	-1.32	-1.29	-1.3	-1.47	-1.5
	43	35.91	32.73	1.09	0.83	0.95	1.12	1.65	1.64
		-6.08	-5.81	-1.45	-1.35	-1.39	-1.46	-1.63	-1.62
November	44	34.03	33.22	1.13	0.97	1.36	1.28	1.88	2.05
		-5.92	-5.85	-1.46	-1.4	-1.54	-1.51	-1.7	-1.74
	45	30.75	34.58	1.27	1.18	1.56	1.45	1.69	1.86
		-5.63	-5.97	-1.51	-1.48	-1.6	-1.56	-1.64	-1.69
	46	37.91	37.08	1.39	1.37	1.78	1.59	2.07	2.06
		-6.24	-6.17	-1.55	-1.54	-1.67	-1.61	-1.75	-1.75
	47	33.51	33.7	1.76	1.53	1.91	1.81	2.32	2.39
		-5.87	-5.89	-1.66	-1.59	-1.71	-1.67	-1.82	-1.84
December	48	39.23	36.17	1.71	1.83	2.04	2.1	2.75	2.77
		-6.34	-6.1	-1.65	-1.68	-1.74	-1.76	-1.94	-1.94
	49	38.25	33.62	1.75	2.26	1.88	1.71	2.8	2.99
		-6.26	-5.88	-1.66	-1.81	-1.7	-1.64	-1.95	-2
	50	42.15	32.17	2.06	2.71	1.66	1.47	3.17	2.99
		-6.57	-5.76	-1.75	-1.93	-1.63	-1.57	-2.04	-2
	51	41.62	33.62	2.62	2.06	1.65	1.67	2.8	3.1
		-6.53	-5.88	-1.9	-1.75	-1.63	-1.63	-1.95	-2.02
Mean		**23.82**	**21.37**	**0.89**	**0.91**	**0.78**	**0.75**	**1**	**1.04**
		-4.98	**-4.73**	**-1.38**	**-1.38**	**-1.33**	**-1.32**	**-1.41**	**-1.43**

Figures in the parentheses are √x + 1 transformations

by Wang and Xia (1997) however there was reduction in eggs parasitisation of third generation noctuid eggs. As cry1Ac has target specific action against selected lepidopteron pests the safety of insects belonging to other orders is naturally endorsed. There was no

Table 2. Test statistics for relative abundance of aphids and insect predators on RCH 2 *Bt* and non *Bt* cotton.

Year	Aphids/ plant RCH2 *Bt*	Aphids/ plant Non *Bt*	"t" test	Coccinellids/ plant RCH2 *Bt*	Coccinellids/ plant Non *Bt*	"t" test	*Chrysoperla* / plant RCH2 *Bt*	*Chrysoperla* / plant Non *Bt*	"t" test	Syrphids / plant RCH2 *Bt*	Syrphids / plant Non *Bt*	"t" test
2004	23.35	21.74	NS	0.95	1.02	NS	0.85	0.88	NS	1.02	1.05	NS
	-4.93	-4.77		-1.4	-1.42		-1.36	-1.37		-1.42	-1.43	
2005	24.28	21.01	NS	0.83	0.8	NS	0.68	0.66	NS	0.99	1.03	NS
	-5.03	-4.69		-1.35	-1.34		-1.29	-1.29		-1.41	-1.42	
Pooled	**23.82**	**21.37**	NS	**0.89**	**0.91**	NS	**0.78**	**0.75**	NS	**1.00**	**1.04**	NS
	-4.98	**-4.73**		**-1.38**	**-1.38**		**-1.33**	**-1.32**		**-1.41**	**-1.43**	

Test of significance between *Bt* and non *Bt* cultivars for the incidence of

significant difference among *Bt* and non *Bt* cultivars with respect to seasonal mean incidence of major insect predators *viz.,* coccinellid, *Chrysoperla*, syrphids and spiders as reported by Hegde *et al.,* (2004) and Udikeri *et al.*, (2003).

Further, the most potential predator *Chrysoperla carnea* was found to remain unaffected in terms of its potentiality when fed with aphids infesting RCH 2 *Bt.* The figures of biological (Table 4) parameters of *C. carnea* remained statistically *on par* for two batches reared on aphids that colonized on *Bt* and non *Bt* plants. The incubation period was 3.22 and 3.72 days respectively, when aphids host was RCH 2 and RCH 2 non *Bt*. The duration of each instar stage was slightly more for the *C. carnea* reared on aphids with non *Bt* cotton host but non significant. Similarly pupal period (10.65 days), adult longevity (47.23 and 50.17 days for male and female, respectively) was more in non *Bt*. The fecundity was also high (102.90 / female) in *C. carnea* population reared on non *Bt* crop colonized aphids. The total aphid consumption was also more (523.22) in this treatment. However none of the parameter recorded significant variation. Thus of *C. carnea* remained same irrespective of aphid host. Similarly, Mascarenhas and Luttrel (1997) and Hilbeck (2001) also demonstrated that the *Chrysoperla* fed on intoxicated aphids survived and continued its progeny as good as *Chrysoperla* fed on non toxicated aphids. However, the negative effect of mortality and delayed development in predatory stages were observed when *C. carnea* was fed on intoxicated early instar larvae of lepidopteran pests *viz.*, *Helicoverpa armigera* and syrphids larvae was well documented by Mascarenhas and

Table 3. Correlation coefficient (r) for aphid incidence and predatory population on *Bt* and non *Bt* cotton

Year	Coccinellids/plant RCH2 *Bt*	Coccinellids/plant Non *Bt*	*Chrysoperla* / plant RCH2 *Bt*	*Chrysoperla* / plant Non *Bt*	Syrphids / plant RCH2 *Bt*	Syrphids / plant Non *Bt*
2004	0.62*	0.50*	0.72*	0.70*	0.74*	0.73*
2005	0.78*	0.79*	0.81*	0.85*	0.94*	0.96*

* Significant (p = 0.01)

Table 4. Comparative biology of *Chrysoperla carnea* reared on cotton aphids fed on *Bt* and non *Bt* hybrids

Aphids raised on	Incubation period	Development period (Days) I instar	II instar	III instar	Pupal period	Adult longevity (Days) Male	Adult longevity (Days) Female	Fecundity Eggs/ female)	Aphids consumed/ grub
RCH 2 *Bt*	3.22	2.95	3.73	4.10	10.27	45.30	48.13	97.50	510.80
RCH 2 non *Bt*	3.72	3.27	3.51	4.35	10.65	47.23	50.17	102.90	523.22
"t" test	NS	NS	NS	NS	NS	NS	NS	NS	NS

20 individuals were observed for each biological parameter

Luttrel (1997). Thus there is every chance of bio magnification of cry proteins over the generations and affect predatory population through intoxicated hosts which need continuous monitoring and necessary action for their sustainability in the ecosystem.

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Tritrophic interactions of *Helicoverpa armigera* (Hubner) in cotton ecosystem

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ABSTRACT : The seasonal incidence of *Helicoverpa armigera* (Hubner) in cotton under rainfed cropping system of Akola (Vidarbha) was recorded during 2004-2005 and 2005-2006. The weather parameters and incidence of prevalent natural enemies were correlated with *H. armigera* incidence to study the tritrophic interactions. In terms of per cent early instar larval parasitization, *Bracon* sp seemed to be the dominant parasitoid with 16.7 per cent, followed by *E. argenteopilosus* (14.3%), *Chelonus* sp. (7.7%), *C. chlorideae* (7.4%) whereas, Tachinid fly in pupal stage had 37.5 per cent parasitization. The correlation pattern of weather parameters with *H. armigera* larval incidence was not consistent over the crops and the season. The infestation of *H. armigera* was more closely associated with crop phenology rather than the weather parameters. On similar lines, the correlation of weather parameters with natural enemies was seldom statistically significant, indicating the influence of pest population rather than weather parameters.

Key words: Cotton, *Helicoverpa armigera,* natural enemies, tritrophic interactions, weather parameters

Helicoverpa armigera **(Hubner) (Noctuidae :** Lepidoptera) is considered to be the most important and dynamic insect species in India, attacking more than 181 host plants belonging to 45 botanical families in the Indian subcontinent including 21 economically important species (Manjunath *et al.*, 1989). *H. armigera* inflicts enormous losses by virtue of its preference for reproductive organs in crops like cotton and legume crops. Even reports of total loss of the crop are not uncommon, indicating destructive potential of the pest. For *H. armigera*, the availability of various host plants in desired crops phenology plays an important role in triggering population increase.

Use of agrochemicals forms is the first line of defense, its indiscriminate use has resulted in development of high levels of resistance to various insecticides (Kranthi *et al.*, 2002). Similarly, *H. armigera* suffers considerable mortality through biotic and abiotic factors and as a direct effect of the host plants, much of which occurs at the larval instars. In India, altogether 100 parasitoids of *H. armigera* have been reported (Nikam and Gaikwad, 1989). Among these, *Eriborus argenteopilosus* (Cameron), *Campoletis chlorideae* (Uchida) and Tachinid fly are important (Srinivas and Jayaraj 1989). The *H. armigera* larval parasitoids, *Eriborus* sp *C. chlorideae*, and larvo pupal parasitoid, Tachinid fly in chickpea, pigeonpea and cotton ecosystem along with Braconid larval parasitoid are the major biotic factors active in suppression of *H. armigera* populations. Present study was framed with a view to study the population dynamics of *H. armigera*, its correlation with weather parameters and interaction of the natural enemies in the field as detailed information on these aspects is not available in Vidarbha region.

MATERIALS AND METHODS

Seasonal incidence of *H. armigera* and its natural enemies on cotton was recorded in 2004-2005 and 2005-2006 under rainfed cropping system of Akola at Central Research Scheme farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The incidence of pod borer was recorded on PKV hybrid 2 cotton during 35th to 44th meteorological week. The observations were recorded on randomly selected plants of large unreplicated plots (500 m^2) under pesticide free conditions.

The data on activity of various natural enemies was recorded in order to quantify the natural field mortality of *H. armigera*. For this, the field collected larvae were reared under laboratory conditions at Department of Entomology, Dr. PDKV, Akola. The collection of eggs and larvae of *H. armigera* was done at 7 days interval in reported period on 25 plants in plot of 500 m^2 under unprotected conditions. The eggs obtained from field crops were reared individually in the plastic vials. Larvae were reared on fresh cotton squares, flower and bolls collected from unsprayed fields. The pre pupal larvae were collected and reared till pupation. Pupae were kept under observations till emergence of *H. armigera* adults or emergence of parasitoid. The observation on total mortality and extent of parasitization due to different natural enemies was recorded at weekly intervals.

The incidence of larval parasitoids of *H. armigera viz., E. argenteopilosus*, *Bracon* sp. *C. chlorideae*, *Chelonus* sp and larva pupal parasitoid, Tachinid fly in late instar larva and pupae was recorded in cotton ecosystem to assess the role of these major biotic factors for the management of *H. armigera* in cropping system.

The data on weather parameters was procured from Meteorology Observatory, Dr. PDKV, Akola. Weather parameters of (n-1)th week of standard meteorological weeks were correlated with *H. armigera* larval counts and natural enemies in the following week (n)th. Also, the influence of natural enemies on population of *H. armigera* was correlated.

RESULTS AND DISCUSSION

Seasonal incidence of *H. armigera*: The incidence of American bollworm on cotton was recorded on PKV hybrid 2, during 35th to 44th meteorological week (MW). Larval population was observed in the cotton fields during 36th (0.2 larva/plant) and 35th (0.1 larva/plant) MW in season I and II, respectively. The peak incidence was observed during 39th (1.2 larvae/plant) and 40th (1.2 larvae/plant) MW in season I and II, respectively and therefore the population steadily declined. The favoured temperature range for increase in *H. armigera* larval population was in the range of 20.8–34.1^{0}C, whereas, the relative humidity (RH) was in the range of 56-84 per cent during season I and II. These results are in conformity with the findings of Sarode *et al.,* (2003) and Saini *et al.,* (2004).

Influence of weather parameters on incidence of *H. armigera* (2004-2005): Positively significant correlation of *H. armigera* eggs was observed with minimum temperature (r = 0.635*), morning RH (r = 0.729*) and evening RH (r = 0.693*). The larval population of *H. armigera* was positively correlated (r = 0.644*) with maximum temperature.

Influence of weather parameters on incidence of *H. armigera* (2005-2006): Minimum temperature was correlated in significantly positive manner (r = 0.688*) with *H. armigera* eggs, whereas, larval population did not have significant correlation with weather parameters.

Influence of weather parameters on natural enemies of *H. armigera* (2004-2005) : None of the natural enemy population had significant correlations with the weather parameters except the Tachinid fly in *H. armigera* larva while significantly positive correlation (r=0.696*) was recorded with maximum temperature.

Influence of weather parameters on natural enemies of *H. armigera* (2005-2006) : The correlation of natural enemy population with the weather parameters was non-significant except for Tachinid fly in larval population which had significantly positive correlation with maximum temperature (r = -0.666*).

Although, different natural enemies had significant correlation pattern with various weather parameters, but a consistent trend of correlations over season and crops was not observed indicating likelihood of close association of natural enemies with the *H. armigera* larval density rather than the weather parameters.

Influence of weather parameters on interactions of natural enemies with *H. armigera* (2004-2005): Significantly positive correlation of *H. armigera* larval population with natural enemies *viz., E. argenteopilosus* (r = 0.816**); *Bracon* sp (r = 0.643*); *C. chlorideae* (r=0.698*) and Tachinid fly in larva (r = 0.746*) and *H. armigera* pupal population with Tachinid fly (r = 0.689*) was observed.

Influence of weather parameters on interactions of natural enemies with *H. armigera* (2005-2006): During successive second year, significantly positive correlation of *H. armigera* larval population with natural

Table 1. Seasonal incidence of *H. armigera* and its natural enemies on cotton (2004-2005 and 2005-2006)

MW	2004 - 2005									2005 - 2006								
	H. armigera population			Natural enemie's population						*H. armigera* population			Natural enemie's population					
	Egg	Larvae	Pupae	*E. argenteo-pilosus*	*Bracon* sp	*C. chlorideae*	*Chelonus* sp	Tachinid fly (on larvae)	Tachinid fly (on pupae)	Egg	Larvae	Pupae	*E. argenteo-pilosus*	*Bracon* sp	*C. chlorideae*	*Chelonus* sp	Tachinid fly (on larvae)	Tachinid fly (on pupae)
35	5	0	0	0	0	0	0	0	0	6	3	0	0	0	0	0	0	0
36	7	5	0	0	0	0	0	0	0	9	8	2	0	0	0	0	0	0
37	14	12	4	0	2	0	0	0	1	17	14	3	2	0	0	0	0	0
38	16	22	5	0	2	0	0	0	0	15	23	6	3	0	0	1	2	2
39	18	29	7	3	0	2	0	1	0	20	26	8	0	2	0	2	2	2
40	20	28	8	3	0	0	1	2	3	22	30	9	3	2	0	0	1	0
41	14	28	7	0	1	2	0	2	2	18	29	9	0	2	2	0	0	2
42	15	22	6	1	0	1	0	0	0	13	27	7	0	0	2	0	2	1
43	6	13	4	0	0	0	0	1	0	8	19	5	0	0	0	0	1	0
44	2	8	3	0	0	0	0	0	0	2	9	4	0	0	0	0	0	0

Table 2. Correlation coefficients ('r' values) of *H. armigera* populations on cotton (2004-2005) with weather parameters and natural enemies populations

Factors	Temperature (^{0}C)		Relative humidty (%)		Rainfall	*H. armigera*		
	Maximum	Minimum	Morning	Evening	(mm)	Eggs	Larvae	Pupae
H. armigera eggs	-0.124	0.635*	0.729*	0.693*	0.493	-	-	-
H. armigera larrvae	0.644*	-0.036	0.238	-0.026	0.131	-	-	-
H. armigera pupae	0.637	-0.118	0.080	-0.097	-0.037	-	-	-
E. argenteopilosus	0.332	0.310	0.564	0.296	0.259	0.752	0.816**	0.722
Bracon sp	0.021	0.457	0.520	0.491	0.139	0.796	0.643*	0.694
C. chlorideae	0.487	0.055	0.268	-0.068	-0.325	0.341	0.698*	0.714
Chelonus sp	0.071	0.202	0.301	0.278	0.428	0.453	0.326	0.186
Tachinid fly (on larvae)	0.696*	0.124	0.293	0.029	0.045	0.433	0.746*	0.650
Tachinid fly (on pupae)	0.242	0.328	0.481	0.379	0.344	0.782	0.774	0.689*

Simple linear correlation values : 0.632 (at p = 0.05) and 0.765 (at p = 0.01) @ n-2 = 8
Significance at p= 0.01:** and significance at p=0.05: *

enemies viz., *E. argenteopilosus* (r = 0.656*), *Bracon* sp (r = 0.690*), *C. chlorideae* (r = 0.658*) and Tachinid fly in larva (r = 0.637*) and highly significant correlation of *H. armigera* pupal population with Tachinid fly in pupa (r = 0.775*) was recorded in cotton ecosystem.

Findings of Romeis and Shannower (1996) also reported extent of parasitism up to 86 per cent in absence of insecticides. They also envisaged the prime role of *Trichogramma chilonis*, *Campoletis chloridae*, *Carcellia illota* and *Goniopthallamas halli* in exerting considerable stress on *H. armigera* larvae.

***H. armigera* and natural enemy interactions (2004-2005) :** the parasitization of *H. armigera* early instar larvae by *E. argenteopilosus* was observed during 39th to 42nd MW with highest parasitization in 40th MW (10.7%). The parasitization by *C. chlorideae* in 2004-2005 was observed during 39th to 42nd MW with highest being during 41st MW (7.1%). Parasitization by *Chelonus* sp. was observed during 40th MW with 3.6 per cent in 2004-2005, while it was observed during 38th and 39th MW with peak in later MW while it was 7.7 per cent parasitization during 39th MW. In 2004-2005, *Bracon* sp was observed during 37th to 41st MW with highest parasitization during 37th MW (16.7%). In late larval stage, parasitization of *H. armigera* by Tachinid fly was observed during 39th to 43rd MW with 7.7 per cent in later MW in 2004-2005. Earlier, the suppression of population of first instar larvae was found to be highest on cotton during August and September (Raja Sekhar *et al.,* 1995), which is similar to the present studies.

***H. armigera* and natural enemy interactions (2005-2006) :** It was observed in 41st and 42nd MW with highest parasitization in 42nd MW (7.4%). Ichneumonids contributed about two third of total mortality of early instar larvae. In previous studies, Ichneumonids were the major larval parasitoid preferring young larvae up to 2nd instar (Nikam and Gaikwad 1989), which is similar with present investigations, while in 2005 - 06, the parasitization was observed during 37th to 40th MW with being highest in 37th MW (14.3%). In 2005-2006, the parasitization was observed during 39th to 41st MW with highest being in 39th MW (7.7%).

The extent of parasitization was recorded during 38th to 43rd MW with 8.7 per cent in former MW in 2005-2006. Parasitization by Tachinid fly in pupal stage was observed during 37th to 41st MW with peak being during 40th (37.5%) MW during first season. In 2005-2006, Tachinid fly was found during 38th to 42rd MW with highest 8.7 per cent parasitization being during 38th MW. During both the seasons, no egg parasitism was observed.

The activity of Tachinid fly on late instar larvae and pupae of *H. armigera* with 5 per cent parasitization in matured larvae by Tachinid fly was found in November in the month of November and 7.6 per cent in December is reported in cotton (Anonymous, 2002), which are in line with the findings of the present studies. Higher larval incidence of *H. armigera* and lower per cent parasitization trend was reported and low level of natural control was important factor for lower severity of *H. armigera* in cotton (Jat *et al.,* 2003). The biotic mortality factors *viz., C. chlorideae, Eriborus* sp and fungus were found under laboratory conditions on larval population of *H. armigera* (Mishra and Shirivastava, 2000). Except for egg parasitoids, parasitism rates were usually lower in cotton. Moderate levels of parasitism by Tachinids in late instars in the season was also reported (Titmarsh, 1985), which supports the present findings.

Though, the simple linear correlation of weather parameters with eggs and larval incidence of *H. armigera* was not consistent over the crops and season, the correlation pattern between natural enemies and *H. armigera* population was significantly correlated in a positive manner indicating the role of biocontrol agents in ecosystem. It also reflects the immense potential of these density dependent factors for the management of notorious pest like *H. armigera* in cotton. It can be inferred from the data that the incidence of *H. armigera* was more closely associated with crop phenology rather than weather parameters. On similar lines, the natural enemies had strong correlation pattern with *H. armigera* incidence rather than the weather parameters. Similarly, it could be concluded that Ichneumonids were associated

Table 3. Correlation coefficients ('r' values) of *H. armigera* populations on cotton (2005-2006) with weather parameters and natural enemies populations

Factors	Temperature (^{0}C)		Relative humidty (%)		Rainfall	*H. armigera*		
	Maximum	Minimum	Morning	Evening	(mm)	Eggs	Larvae	Pupae
H. armigera eggs	0.128	0.668*	-0.043	0.439	0.244	-	-	-
H. armigera larvae	0.002	-0.108	-0.132	-0.101	-0.169	-	-	-
H. armigera pupae	0.037	-0.247	-0.227	-0.205	-0.222	-	-	-
E. argenteopilosus	0.085	0.333	-0.120	0.250	0.017	0.821	0.656*	0.671
Bracon sp	0.502	-0.028	-0.566	-0.344	-0.500	0.574	0.690*	0.760
C. chlorideae	0.034	-0.142	-0.248	-0.141	0.110	0.333	0.658*	0.620
Chelonus sp	-0.223	0.226	0.140	0.271	-0.163	0.297	0.330	0.329
Tachinid fly (on larvae)	-0.666*	0.105	0.561	0.380	0.278	0.227	0.637*	0.505
Tachinid fly (on pupae)	0.039	0.134	-0.221	0.113	-0.134	0.576	0.803	0.775**

Simple linear correlation values : 0.632 (at p = 0.05) and 0.765 (at p = 0.01) @ n-2 = 8
Significance at p= 0.01: ** and significance at p=0.05: *

Table 4. Seasonal incidence of *H. armigera* larvae on cotton in 2004-2005 and 2005-2006 along with per cent parasitization by natural enemies

MW	*H. armigera* population			Per cent parasitization by natural enemies																				
	Larvae			Pupae			*E. argenteopilosus*			*Bracon* sp			*C. chlorideae*			*Chelonus* sp			Tachinid fly (on larvae)			Tachinid fly (on pupae)		
	Season		**Mean**	Season		**Mean**	Season		**Mean**	Season		**Mean**	Season		**Mean**	Season		**Mean**	Season		**Mean**	Season		**Mean**
	I	II		I	II		I	II		I	II		I	II		I	II		I	II		I	II	
35	0	3	**1.5**	0	0	**0.0**	0.0	0.0	**0.0**	0	0	**0.0**	0.0	0	**0.0**	0	0	**0.0**	0	0	**0.0**	0	0	**0.0**
36	5	8	**6.5**	0	2	**1.0**	0.0	0.0	**0.0**	0	0	**0.0**	0.0	0	**0.0**	0	0	**0.0**	0	0	**0.0**	0	0	**0.0**
37	12	14	**13.0**	4	3	**3.5**	0.0	14.3	**7.1**	16.7	0	**8.3**	0.0	0	**0.0**	0	0	**0.0**	0	0	**0.0**	25.0	0	**12.5**
38	22	23	**22.5**	5	6	**5.5**	0.0	13.0	**6.5**	9.1	0	**4.5**	0.0	0	**0.0**	0	4.3	**2.2**	0	8.7	**4.3**	0	8.7	**4.3**
39	29	26	**27.5**	7	8	**7.5**	10.3	0.0	**5.2**	0	7.7	**3.8**	6.9	0	**3.4**	0	7.7	**3.8**	3.4	7.7	**5.6**	0	7.7	**3.8**
40	28	30	**29.0**	8	9	**8.5**	10.7	10.0	**10.4**	0	6.7	**3.3**	0.0	0	**0.0**	3.6	0	**1.8**	7.1	3.3	**5.2**	37.5	0	**18.8**
41	28	29	**28.5**	7	9	**8.0**	0.0	0.0	**0.0**	3.6	6.9	**5.2**	7.1	6.9	**7.0**	0	0	**0.0**	7.1	0	**3.6**	28.6	6.9	**17.7**
42	22	27	**24.5**	6	7	**6.5**	4.5	0.0	**2.3**	0	0	**0.0**	4.5	7.4	**6.0**	0	0	**0.0**	0	7.4	**3.7**	0	3.7	**1.9**
43	13	19	**16.0**	4	5	**4.5**	0.0	0.0	**0.0**	0	0	**0.0**	0.0	0	**0.0**	0	0	**0.0**	7.7	5.3	**6.5**	0	0	**0.0**
44	8	9	**8.5**	3	4	**3.5**	0.0	0	**0.0**	0	0	**0.0**	0.0	0	**0.0**	0	0	**0.0**	0	0	**0.0**	0	0	**0.0**

with the parasitization of early instar (I-III) larvae and Tachinid fly with late instar larvae and pupae of *H. armigera*.

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Estimation of yield losses and optimization of sprays schedule for grey mildew disease in *Bt* cotton

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ABSTRACT : Field experiments were conducted at Agriculture Research Station, Dharwad Farm during 2008-2009 to 2010-2011 to know the yield losses and optimization of sprays schedule for grey mildew (*Ramularia areola*) disease in *Bt* cotton. Significantly low grey mildew per cent disease index (10.03 PDI), the maximum yield of 3349.46 kg/ha and 25.54 per cent increase in the yield over untreated control was recorded in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS. The results indicated that grey mildew was more severe on Bunny *Bt* genotype and maximum upto 20.35 per cent avoidable yield loss was recorded in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (17.98%). Hightest incremental benefit cost ratio of 3.02 was obtained with carbendazim (0.1%) at 80 and 95 DAS followed by carbendazim (0.1%) at 65, 80 and 95 DAS (2.92).

Key words: Cotton, crop loss, grey mildew, optimization, spray schedule

India now produces around 325.48 lakh bales of cotton ranging from short staple to extra long staple from an area of 110.00 lakh ha with productivity of 503 kg/ha (Anonymous, 2011). In Karnataka, the area under cotton crop is 4.66 lakh ha with a production of 10.15 lakh bales with an average productivity of 370 kg/ha (Anonymous, 2011). However, the production potential of the crop has not been fully exploited due to numerous biotic and abiotic factors. The crop suffers from many fungal diseases, of which foliar diseases take a heavy toll. Among the diseases, grey mildew (*Ramularia areola*) causes yield losses upto 21.15 per cent (Chattannavar, *et al.,* 2010), Keeping this in view, the present investigations were under taken to study the yield loss due to grey mildew on Bunny *Bt* cotton cultivar.

MATERIALS AND METHODS

The field experiments were conducted at Agriculture Research Station, Dharwad Farm during 2008-2009 to 2010-2011 to know the yield loss due to grey mildew. The susceptible variety Bunny *Bt* was sown in randomized block design with nine treatments and a control under natural epiphytotic conditions. In treatments, plots were protected with carbendazim (0.1%) with 1 to 5 sprays at 15 days intervals to control grey mildew in nine treatments at different days after sowing. A total rainfall of 855.8 mm was recorded during 2008 as against the normal 747 mm. During the initial of months of May and June, the rainfall was not enough to wet the profile and hence sowings were commenced from July 23 onwards after receiving 93 mm rainfall. Total rainfalls recorded during July, August and September was above normal. However, during October and November there was a long dry spell for almost 35 days. Even during the last week of September and first week of October there was dry spell. This created moisture stress situation.

During 2009, total rainfall received was 1077 mm. About 30.64 per cent excess rainfall was received as compared to normal rainfall of 747 mm. During the initial months of *kharif* (May and July) the rainfall was enough to wet the profile and hence sowings were commenced from June 15 onwards after receiving 93 mm rainfall. Total rainfall during July, September, October, November and December was above normal. A steep rise in the rainfall during July affected early stage of the crop and it was exhibiting sickly appearance; and during September again there was steep rise in rainfall which also affected the crop growth. There was lot of variation in the temperature ranging between 16 to 30 ^{0}C which impacted the diseases and at certain times it was scorchy h during the day which might have affected the diseases.

During 2010, a total of 853 mm of rainfall was received. The sowing was done during first week of July. During July there was more than normal rainfall. The growth was normal upto September. During October and November also there was continuous cloudy weather and more rainfall (than normal) which caused more grey mildew disease. Leaf area covered by white mycelial infection was recorded to know the total loss by using five randomly selected plants in a plot. From these selected plants per cent leaf area covered by white mycelial infection was recorded. In the experiments, per cent disease index was recorded by using five randomly selected plants in a plot by adopting 0 - 4 grading scale (Sheo Raj,1988). These grades were converted into per cent disease indices (PDI) by using the formula given by Wheeler (1969).

RESULTS AND DISCUSSION

Yield loss estimation and optimization of sprays schedule for grey mildew disease in *Bt* cotton during 2008-2009 revealed that carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS recorded significant lowest grey mildew per cent disease index (11.10 PDI) followed by carbendazim (0.1%) at 35, 50, 65 and 80 DAS (11.60 PDI) while carbendazim (0.1%) at 95 DAS (16.20 PDI) was least effective (Table 1). The *kapas* yield variation among the treatments was significant. However, the maximum yield of 3463 kg/ ha was recorded in carbendazim (0.1%) at 50, 65, 80 and 95 DAS followed by carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS (3453 kg/ha). However, during October and November there was a long dry spell of almost 35 days. Even during the last week of September and first week of October there was a dry spell. This created less prevalance of grey mildew.

Yield loss estimation and optimization of sprays schedule for grey mildew disease in *Bt* cotton during 2009-2010 indicated that carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS recorded significant lowest grey mildew per cent disease index (6.50 PDI) followed by carbendazim (0.1%) at 50, 65 80 and 95 DAS (7.20 PDI) while carbendazim (0.1%) at 35 DAS (15.00 PDI) was least effective (Table 1). The *kapas* yield variation among the treatments was significant. However, the maximum yield of 3621 kg/ ha was recorded in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (3464 kg/ha). There was lot of variation in the temperature ranging between 16 to 38^0 C which impacted the grey mildew disease and at certain times it was scorchy h during the day might have affected the development of disease.

During 2010-2011, yield loss estimation and optimization of sprays schedule for grey mildew disease in *Bt* cotton exhibited that carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS recorded significant lowest grey mildew per cent disease index (12.50 PDI) followed by carbendazim (0.1%) at 50, 65 80 and 95 DAS (13.90 PDI) while carbendazim (0.1%) at 35 DAS (25.70 PDI) was least effective (Table 1). The *kapas* yield variation among the treatments was significant. However, the maximum yield of 2838 kg/ ha was recorded in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (2698 kg/ha). During October and November there was continues cloudy weather and more rainfall (than normal) which caused more grey mildew disease.

The pooled data of three years indicated that yield loss estimation and optimization of spray schedule for grey mildew disease in *Bt* cotton showed that carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS recorded significant lowest grey mildew per cent disease index (10.03 PDI) followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (11.13 PDI) while carbendazim (0.1%) at 35 DAS (18.53 PDI) was least effective (Table 1). Maximum per cent disease control (PDC) was recorded in case of carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS (60.56 PDC) followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (56.23 PDC) and carbendazim (0.1%) at 35, 50, 65 and 80 DAS (53.99 PDC). These results are in conformity with the reports of Rattaiah, (1973), carbendazim was most inhibitory to hyphal growth of *R. areola.*

The *kapas* yield variation among the treatments was significant. However, the significant maximum yield of 3304 kg / ha was recorded in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (3209 kg/ha).

The maximum per cent increase in yield over control was recorded in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS treatment (25.54%) followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (21.92%) and carbendazim (0.1%) at 35,

Table 1. Yield loss estimation and optimization of sprays schedule of grey mildew disease in *Bt* cotton (Bunny *Bt*) (pooled data - 2008-2009 to 2010-2011)

Tr. No	Treatments	Per cent disease intectior at 120 DAS**				Disease control (%)	Yield (kg/ha)				Increased yield over control (%)	Avoidable yield losses (%)
		2008-2009	2009-2010	2010-2011	**Pooled**		2008-2009	2009-2010	2010-2011	**Pooled**		
T_1	Carbendazim (0.1%)	14.9	15	25.7	**18.53**	27.13	2906	3084	2294	**2761**	4.92	4.69
	35 DAS**	(22.69)*	-22.81	-32.38	**-25.14**							
T_2	Carbendazim (0.1%)	15.1	10.5	24.4	**16.66**	34.49	2947	3186	2353	**2829**	7.48	6.96
	35 and 50 DAS	-22.9	-18.89	-29.6	**-23.58**							
T_3	Carbendazim (0.1%)	13.6	9.0	19.3	**13.96**	45.10	3058	3281	2414	**2918**	10.87	9.8
	35, 50, and 65 DAS	-21.66	-17.46	-26.09	**-21.72**							
T_4	Carbendazim (0.1%)	11.6	8.0	15.5	**11.7**	53.99	3389	3375	2531	**3098**	17.73	15.06
	35, 50, 65 and 80 DAS	-19.87	-16.46	-23.21	**-19.85**							
T_5	Carbendazim (0.1%)	11.1	6.5	12.5	**10.03**	60.56	3453	3621	2838	**3304**	25.54	20.35
	35, 50, 65, 80, and 95 DAS	-19.5	-14.8	-20.74	**-18.64**							
T_6	Carbendazim (0.1%)	12.3	7.2	13.9	**11.13**	56.23	3463	3464	2698	**3209**	21.92	17.98
	50, 65, 80, and 95 DAS	-20.5	-15.59	-21.9	**-19.62**							
T_7	Carbendazim (0.1%)	12.7	9.3	15.1	**12.36**	51.40	3372	3349	2571	**3097**	17.69	15.03
	65, 80, and 95 DAS	-20.88	-17.72	-23.86	**-20.84**							
T_8	Carbendazim (0.1%)	16.1	10.1	18.3	**14.83**	41.68	3265	3235	2374	**2958**	12.39	11.03
	80 and 95 DAS	-23.69	-18.56	-25.31	**-22.81**							
T_9	Carbendazim (0.1%)	16.2	13.1	23.1	**17.46**	31.34	2890	3198	2340	**2809**	6.75	6.32
	95 DAS	-23.71	-21.17	-28.73	**-24.33**							
T_{10}	Control	21.3	19.4	35.6	**25.43**	-	2737	2995	2164	**2632**	-	-
		-27.51	-26.15	-36.66	**-29.46**							
	CD (p=0.05)	3.013	2.794	4.995	1.209		299.259	336.802	324.019	226.867		
	SEm±	1.014	0.94	1.681	0.407		101.105	113.357	109.055	76.375		

**Days after sowing, * Figures in parentheses indicate angular transformed values

Table 2. Economic analysis of experiment on yield loss estimation and optimization of sprays schedule on grey mildew disease in *Bt* cotton (Bunny *Bt*) (pooled data - 2008-2009, to 2010-2011)

Tr. No.	Treatment	Cost of chemical (Rs/ kg)	Quality required/ ha*	Total cost of chemical/ ha (Rs)	Cost of cultivation (Rs)	Total Cost of cultivation (Rs)	Additional 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	Carbendazim (0.1%) 35 DAS**	610	0.5kg	305	39305	39610	1450	2761	110440	70830	3710	2.56
T_2	Carbendazim (0.1%) 35 and 50 DAS	610	1.0kg	610	39945	40555	2395	2829	113160	72605	5485	2.29
T_3	Carbendazim (0.1%) 35, 50, and 65 DAS	610	1.5kg	915	40890	41805	3645	2918	116720	74915	7795	2.14
T_4	Carbendazim (0.1%) 35, 50, 65 and 80 DAS	610	2.0kg	1220	42290	43510	5350	3098	123920	80410	13290	2.48
T_5	Carbendazim (0.1%) 35, 50, 65, 80, and 95 DAS	610	2.5kg	1525	43820	45345	7185	3304	132160	86815	19695	2.74
T_6	Carbendazim (0.1%) 50, 65, 80, and 95 DAS	610	2.0kg	1220	43045	44265	6105	3209	128360	84095	1697	2.78
T_7	Carbendazim (0.1%) 65, 80, and 95 DAS	610	1.5kg	915	41985	42900	4740	3097	123880	80980	13860	2.92
T_8	Carbendazim (0.1%) 80 and 95 DAS	610	1.0kg	610	40790	41400	3240	2958	118320	76920	9800	3.02
T_9	Carbendazim (0.1%): 95 DAS	610	0.75kg	458	39795	40253	2093	2809	112360	72107	4987	2.38
T_{10}	Control	-	-	-	38160	38160	-	2632	105280	67120	-	-

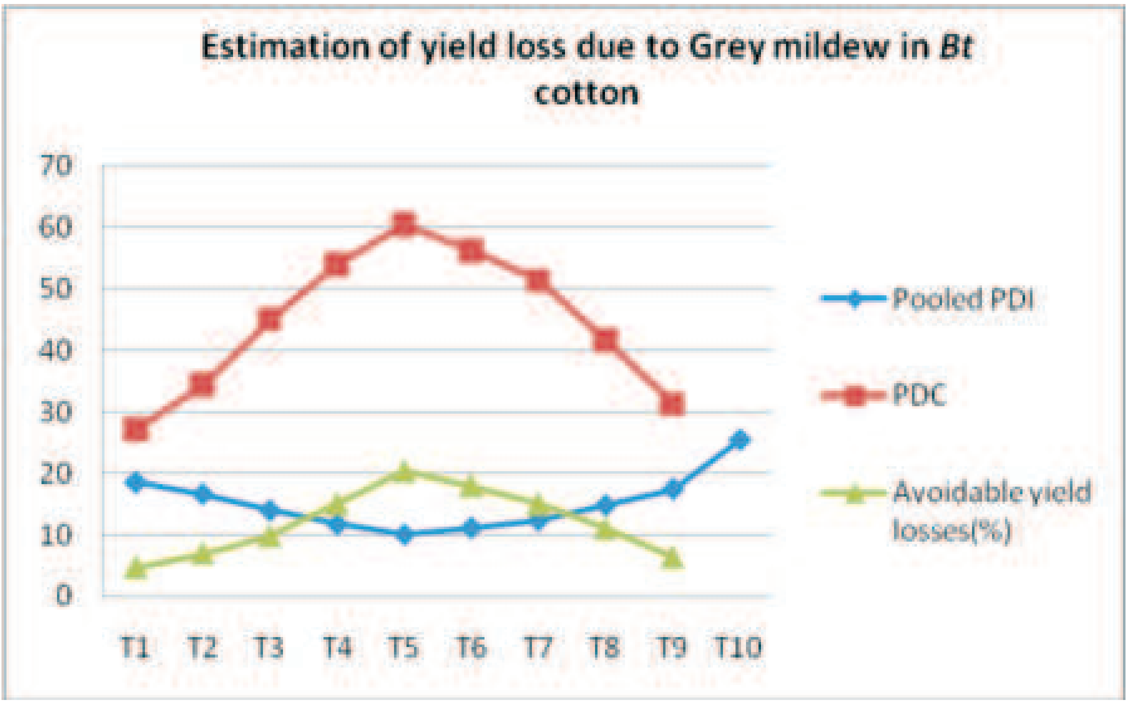

Fig. 1. Yield loss estimation and optimization of sprays schedule on grey mildew disease in Bt cotton (Bunny Bt) pooled data of 2008-2009, 2009-2010 and 2010-2011

50, 65, and 80 DAS (17.73%). The results indicated that grey mildew was more severe on Bunny *Bt* genotype and maximum upto 20.35 per cent avoidable yield loss was recorded in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS and followed by carbendazim (0.1%) at 50, 65, 80 and 95 DAS (17.98%). These results are in conformity with the reports of Chattannavar *et al.,* (2010).

Among the treatments maximum spray cost was spent in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS with total return of Rs 132160. Maximum yield of 3304 kg/ha was obtained in carbendazim (0.1%) at 35, 50, 65, 80 and 95 DAS and net returns of Rs 86815 was recorded. Unprotected plots resulted in net returns of Rs 67120. Highest incremental benefit cost ratio of 3.02 was obtained with carbendazim (0.1%) at 80 and 95 DAS followed by carbendazim (0.1%) at 65, 80 and 95 DAS (2.92) (Table 2). Our results are in confirmity with the results of Bhattiprolu, 2012.

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Evaluation of cotton genotypes against Alternaria and Helminthosporium leaf spot diseases

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ABSTRACT: Three hundred and seventy six cotton genotypes were screened for Alternaria leaf spot and 215 genotypes against Helminthosporium leaf spot disease during *kharif,* 2003 to 2010 under natural epiphytotic conditions. Two entries *viz.*, TCH 1717 and RAJHH 783 were free from infection and 47 genotypes expressed resistant reaction to Alternaria leaf spot. Among 91 moderately resistant genotypes three entries *viz.*, NDLH 1938, BS 279 and GSB 41 recorded resistant reaction to Alternaria leaf spot during two consecutive years. Four entries *viz.*, CCH 1212, H 1454, KH 901 and F 1861 recorded resistant reaction to Helminthosporium leaf spot. Two entries *viz.*, H 1454 and F 1861 recorded resistant reaction to both Alternaria and Helminthosporium leaf spots while 29 entries were moderately resistant to both leaf spots. Three entries *viz.*, GJHV 374, CNHO 12 and CPD 812 were resistant to Alternaria leaf spot and moderately resistant to Helminthosporium leaf spot.

Key words : Alternaria leaf spot, cotton genotypes, evaluation, Helminthosporium leaf spot

Cotton is an important commercial crop in India with a production of 325 lakh bales in 2010-2011 from an area of 110 lakh ha. Andhra Pradesh stood 3rd in area (17.10 lakh ha), production (65.68 lakh bales) and productivity (653 kg/ha) during 2010 – 2011 (Anonymous, 2011). Cotton crop is affected by a number of foliar diseases throughout the season, which accounts upto 20 to 30 per cent losses in cotton (Mayee and Mukewar, 2007). Fungal leaf spots are caused by *Alternaria, Helminthosporium, Cercospora* and *Myrothecium* species in cotton. Among the leaf spot diseases, Alternaria leaf spot caused by *Alternaria macrospora Zimm* is most common appearing wherever cotton is grown. Helminthosporium leaf spot is caused by *Helminthosporium gossypii* Tucker in India. These diseases under congenial conditions cause severe defoliation and cause yield losses to the tune of 30 to 33 per cent in unprotected fields. Five foliar sprays with 0.1 per cent propiconazole during 35 to 95 days after sowing at 15 days intervals protected cotton crop from these leaf spots (Bhattiprolu and Prasada Rao, 2009; Bhattiprolu, 2010). Growing disease resistant variety / hybrid helps to minimize losses caused by these diseases. This strategy helps in reducing protection costs for small and marginal 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

Three hundred and seventy six cotton genotypes were screened for Alternaria leaf spot and 215 genotypes were screened against Helminthosporium leaf spot diseases during *kharif,* 2003-2010. All the material was received under All India Coordinated Cotton Improvement Programme and was sown on 11.07.03, 19.07.04, 27.07.05, 05.08.06, 20.07.07, 14.07.08, 19.08.09 and 14.07.10. Each entry was sown in two replications with a spacing of 120 x 60 cm and 10 hills/row. 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 per cent; 2 = 6-20 per cent; 3 = 21-40 per cent and 4 = >40 per cent leaf area is diseased (Sheo Raj, 1988). Disease scoring was done at 90 and 120 days after sowing (DAS) under natural conditions. Depending on the scores recorded per cent disease intensity (PDI) was calculated.

Depending upon the grade of infection, germplasm was classified into immune, resistant, moderately resistant, moderately susceptible and susceptible lines (Sheo Raj, 1988).

RESULTS AND DISCUSSION

Pooled data on Alternaria leaf spot reaction for six years showed that among 376 genotypes screened two entries *viz*., TCH 1717 and RAJHH 783 were free from infection and 47 genotypes expressed resistant reaction while 91 showed moderately resistant reaction. Eighty nine entries recorded moderately susceptible reaction and 147 genotypes were susceptible to (Table 1). Three entries NDLH 1938, BS 279 and GSB 41 recorded moderately resistant reaction to Alternaria leaf spot during two consecutive years. Chattannavar *et al* (2009) screened 196 cotton hybrids/ varieties/genotypes under unprotected field conditions during *kharif,* 2007 at Dharwad and recorded four highly resistant and seven moderately resistant genotypes. Three genotypes (CCC 4, FDK 172 and FDK 173) of *Gossypium arboreum* out of 141 genotypes of *Gossypium* species recorded moderate resistance during *kharif,* 2008 at Dharwad (Chattannavar *et al.*, 2010).

Table 1. Grouping of cotton genotypes based on their reaction to Alternaria leaf spot disease

Rating	Reaction		Genotypes
0	Immune	(2)	TCH 1717, RAJHH 783
1	Resistant	(47)	GJHV 374, CPD 812, H 1300, CNHO 12, PSCHH 1037, GJHV 502, CPT 511, LRA 5166, TCH 1734, GJHV 476, CCH 818, TSH 9974, HS 286, CIHS 16, H 1454, LH 2139, RS 2569, BS 37, F 1861, CSH 3114, BS 277, CCB 1-1, RHcb 011, DB 11, TCB 45, ARBH 1051, GSHH 2729, FHH 140, LHH 1403, ARCHH 6256, MRC 7361, XCH 7201, GTHH 193,GTHH 191, BHH 12, TCHH 5150, HHH 490, MRC 7377, BHH 16, GSHH 2361, RAJHH 790, RHH 0622, RAHH 455, SHH 451, HSHH 26, CSHG 3118, Sanjivani 021
2	Moterately resistant	(91)	F 2036, H 1246, TSH 9704, VBCH 2204, PSCHH 213, SCH 1023, H 1282, H 1250, GSGHH 52, CSH 2572, CSH 510, PCHH 78, BCHH 311, GISV 97016, GISV 97612, SSB-3, Tulasi 27, RAH 216, CPD 813, GSHH 97/612, RAHH 246, ARCHH 9790, JKCH 55, MR 786, P 403, CPD 2001, ARBH 2002, NDLH 1939, CA 101, GSHV 158, RAH 902, CCH 1212, F 2177, RS 2557, LH 2153, TCH 1732, KH 902, SCH 701, KH 901, CSH 3158, CPD 2003, GISV 257, BS 27, CSH 10, F 2228, TCH 1716, GSHH 155, CCH 2623, SCS 415, NDLH 1938, TCH 1715, BS 277, RHH 61, GISV 218, BS 279, ARBH 813, RHC 9854, RAB 10, TCB 26, GSB 40, RAB 8, CCB 5, DB 12, Suvin (CC), CCB 6, DB 10, TCB 1 GSB 41, ARBH 1001, P 2150, GJHV 500, F 2276, LH 2152, BGDS 801, HS 288, ADB 531, TSH 0250, BS 39, GSHV 159, ARBH 2002, BS 51, GSB 39, TCB 26, RAS 12, ARBHH 1052, RAHH 951, HAGHH 2064, NSPL 423, LC (DHH 11), RAH 0707, FHH 168

Among 215 genotypes screened against Helminthosporium leaf spot during 2004 to 2009, none of the entries were found immune. Four entries *viz*., CCH 1212, H 1454, KH 901 and F1861 recorded resistant reaction while 76 expressed moderately resistant reaction (Table 2). Forty one entries recorded moderately susceptible reaction and 94 genotypes were susceptible.

Two entries *viz*., H 1454 and F 1861 recorded resistant reaction to both Alternaria and Helminthosporium leaf spots. Twenty nine entries *viz.,* RAH 216, GSHH 97/612, RAHH 246,

Table 2. Grouping of cotton genotypes based on their reaction to Helminthosporium leaf spot disease

Rating	Reaction		Genotypes
0	Immune	(O)	None
1	Resistant	(4)	CCH 1212, H 1454, KH 901, F 1861
2	Modertely resistant	(76)	SSBH 17, RAHH 160, IH 2076, P 72-9-37, JKCH 2022, GJHV 374, CPD 812, H 1300, CNHO 12, RAH 216, CPD 814, GISV 108, GSHH 97/612, NDL 612, RAHH 246, JKCH 55, RAH 61, BS 277, CPD 1050, GISV 218, RHC 9854, BS 279, ARBH 225, CPD 1019, P 57-6, RAH 216, DB 11, TCB 108, RHCB 001, TCB 47, DB 1, Suvin (CC), MR 786, GDN 502, P 403, CPD 2001, ARBH 2002, ZC (LRA 5166), NDLH 1839, CA 101, TCH 1734, F 2177, RS 2557, CCH 818, TSH 9974, HS 286, CISH 16, LH 2153, TCH 1732, KH 902, SCH 701, BS 28, RAH 901, CSH 3158, CPD 2003, GISV 257, ARBH 2004, NDLH 1939, LH 2139, RS 2569, CSH 10, F 2228, TCH 1716, CCH 2623, SCS 415, BS 51, NDLH 1938, TCH 1715, RHC 9854, RAB 10, TCB 26, GSB 40, RAB 8, CCB 5, DB 12, TCB 1

MR 786, CPD 2001, ARBH 2002, NDLH 1939, CA 101, F 2177, RS 2557, TCH 1732, KH 902, SCH 701, CSH 3158, GISV 257, CSH 10, F 2228, TCH 1716, CCH 2623, SCS 415, NDLH 1938, TCH 1715, RHC 9854, RAB 10, TCB 26, GSB 40, RAB 8, DB 12 and TCB 1 were moderately resistant to both leaf spots. Three entries GJHV 374, CNHO 12 and CPD 812 were resistant to Alternaria leaf spot and moderately resistant to Helminthosporium leaf spot. Three entries CCB 5, CCB 6 and GSB 41 (moderately resistant to Alternaria leaf spot) were also moderately resistant to Myrothecium leaf spot at Guntur during 2008 and 2009 (Anonymous, 2009 and 2010). Such genotypes with resistance to two or more foliar diseases are useful in breeding programme.

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Bionomics of leafhopper, *Amrasca biguttula biguttula* (Ishida) on *Bt* cotton under laboratory conditions

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ABSTRACT: Bionomics of leafhopper, *Amrasca biguttula biguttula* (Ishida) on *Bt* cotton was studied under laboratory conditions. The average developmental periods of egg, first, second, third, fourth and fifth nymphal instars were 6.65 ± 0.63, 2.25 ± 0.35, 3.00 ± 0.62, 2.90 ± 0.51, 2.60 ± 0.39 and 1.55 ± 0.55 days, respectively. The total nymphal period was 12.30 ± 2.42 days. The pre mating and mating, pre oviposition, oviposition and post-oviposition periods were 1.55 ± 0.44 and 4.52 ± 0.36 minutes, 3.25 ± 0.75, 6.60 ± 0.96 and 2.00 ± 0.94 days, respectively. The fecundity averaged to 17.50 ± 3.10 eggs. The longevity of male was 13.05 ± 1.18 and female was 18.30 ± 1.66 days. The life cycle ranged from 27 to 35 days. The average lengths and breadths of the egg, first, second, third, fourth and fifth nymphal instars were 0.62 ± 0.04 and 0.18 ± 0.02, 0.69 ± 0.04 and 0.20 ± 0.03, 1.10 ± 0.19 and 0.29 ± 0.05, 1.32 ± 0.07 and 0.43 ± 0.03, 1.91 ± 0.15 and 0.56 ± 0.03, 2.37 ± 0.17 and 0.57 ± 0.04 mm, respectively. The average length and breadth of male was 2.44 ± 0.04 and 0.70 ± 0.02 while female was 2.73 ± 0.03 and 0.72 ± 0.03 mm, respectively.

Keywords: *Amrasca biguttula biguttula,* bionomics, *Bt* cotton, leafhopper

Cotton (*Gossypium* spp) popularly known as "White Gold" is a major commercial crop and is grown for its lint and seed which are important raw materials for textile and oil industries. It is grown under diverse agro climatic conditions around the world. India has an area of 111.61 lakh ha, production of 312 lakh bales with a productivity of 475 kg/ha. Among the sucking pests of this crop in early stages, leafhopper is as one of the important sap feeders. Both nymphs and adults suck the sap from under surface of the leaf. The desaping by the leafhoppers cause specking symptoms leading to crinkling, distortion of leaves and reddening all along the sides of leaves with downward curling and such a type of symptom is called "Hopper burn" and becomes one of the limiting factor in economic productivity of the crop. Earlier the biology of *A. biguttula biguttula* was studied and in the present study; the bionomics was studied on *Bt* cotton to know the difference in the biometric parameters as the menace of leafhopper on *Bt* cotton is increasing since last 4-5 seasons.

The bionomics of cotton leafhopper, *A. biguttula biguttula* (Ishida) was studied from November to January 2010-2011, on *Bt* cotton hybrid RCH 2 under the laboratory conditions at 25-30°C and 60-70 per cent relative humidity at College of Agriculture, Raichur. Field collected final instar nymphs were used for initiating the pure culture. The final instar nymphs of *A. biguttula biguttula* were released in potted cotton plants covered with musline cages. The final instar nymphs were identified based upon the extent of wing pads developed upto fourth abdominal segment. Such final instar nymphs were maintained in rearing cages till they moulted finally to reach adult stage. The male and female sexes were identified based on the genetilia and abdominal characters (Thirumalaraju, 1984). Later, a pair of newly emerged male and female leafhoppers were introduced into a microcage of size 7 × 5 cm for oviposition and fecundity studies and such microcages were fixed to the cotton leaf in such a way that the leaf was inserted into it from one side and the other side of it was covered with the musline cloth.

For pre ovipositional periods, a pair of freshly emerged adult leafhoppers from pure culture was released into the microcage containing single cotton leaf. Daily microcage was opened and the leaves were processed using lacto phenol acid fuchsion chemical and observed for oviposition and continued till the first egg was laid and duration was recorded. The process was continued till the last egg was laid. Duration between the first egg laid and the last egg laid was recorded, to determine the oviposition period. Similarly, the total number of eggs laid by different pairs was recorded. The incubation period was studied by keeping the oviposited leaves under room temperature in the laboratory (25-30°C and relative humidity was 60-70 %). The stalk of oviposited leaf was kept in a small vial containing water. The duration between the egg laid and the emergence of first instar nymph was recorded as the incubation period. The nymphal instars were studied by transferring freshly hatched nymphs into the plastic containers containing cotton leaf with leaf stalk dipped in a small vial containing water. The number of instars and days required for each instar were recorded based on the moulted or casted skin. In each instar, the length and width of the nymph was measured by Leica microscope using software. The adult leafhoppers longevity was recorded by enclosing the newly emerged adults in the microcage, fixed to a single cotton leaf with food, where as the adults were simply released in the plastic containers without cotton leaf for recording the adult longevity without food. Observations were made on all the morphological stages *viz*., egg, nymphal and adult stages. The measurements (mm) on length and breadths of these stages were taken by Leica microscope using software.

The female leafhoppers laid the eggs in the leaf tissue singly on midrib and other veins. The colour of egg could not be observed since it was inserted inside the tissue but it was observed that the egg was translucent as it took stain. The egg was slightly hooked towards the anterior end and the other end being broadly pointed. Just before hatching, a pair of brownish red eyes shined through the chorion near the anterior end of the egg. The egg, on an average, measured 0.62 ± 0.04 mm in length and 0.18 ± 0.02 mm in breadth. The incubation period ranged from 6.00 to 8.00 days with an average period of 6.65 ± 0.63 days (Table 1). Similar observations for eggs and oviposition site were made by Thirumalaraju (1984), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009) who observed the similar morphological characters of egg and the morphometric observations. The mean incubation period was 6.65 ± 0.63 days (Table 1). These present findings are in close association with the findings of Sharma and Sharma (1996), Sharma and Sharma (1997), Thirumalaraju (1984), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009) who recorded the incubation period as 6.44, 6.27, 4-5, 6-7 and 6.53 days, respectively.

The newly hatched first instar nymph was transparent and yellowish in colour. Eyes were conspicuous, reddish brown and oval shaped. The duration of first instar nymph ranged from 2.00 to 3.00 days, with an average of 2.25 ± 0.35 days (Table 1). The average length and breadth of first instar nymph was 0.69 ± 0.04 mm and 0.20 ± 0.03 mm, respectively. The newly hatched first instar nymph was transparent and yellowish in colour with conspicuous reddish brown and oval eyes. The first instar duration and morphometry are in close conformity with the findings of Bhalane and Paiel (1981), Thirumalaraju (1984), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009). However, the duration and morphometry of the first instar in the present findings had slight variation with the findings of the above scientists which might be attributed to the change in experimental set up, variation in the laboratory temperature and relative humidity and genotype used for the studies.

The second instar nymph had superficially white eyes and dark reddish colour underneath. The rudimentary wing pads along the posterior side of meso and meta thorax were present. The duration of second instar nymph ranged from 2.00 to 4.00 days, with an average of 3.00 ± 0.62 days. The mean length and breadth of second instar nymph was 1.10 ± 0.19 mm and 0.29 ± 0.05 mm, respectively (Table 1). These present findings are in close association with the findings of Bhalane and Paiel (1981), Thirumalaraju (1984), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009). However, the duration and morphometry of the first instar in the present findings had slight variation with the findings of the above scientists which might be attributed to the changes and variations as explained above.

Similarly, the third and fourth instar nymphs were yellowish green with small wing pads with mean duration of 2.90 ± 0.51 days and 2.60 ± 0.39 days, respectively. The mean length and breadth of third and fourth instars were 1.32 ± 0.07 mm and 0.43 ± 0.03 mm, and 1.91 ± 0.15

Table 1. Biology and morphometry of leafhopper, *A. biguttula biguttula* on *Bt* cotton under laboratory conditions

Stage of development*	Range (Days)	Mean ± SD	Morphometry of different stages of leafhopper, *A. biguttula biguttula*			
			Length (mm)		Breadth (mm)	
			Range	Mean ± SD	Range	Mean ± SD
Egg	6.00 - 8.00	6.65 ± 0.63	0.52 - 0.66	0.62 ± 0.04	0.14 – 0.22	0.18 ± 0.02
Nymphal period						
I instar	2.00 - 3.00	2.25 ± 0.35	0.62 - 0.75	0.69 ± 0.04	0.14 – 0.23	0.20 ± 0.03
II instar	2.00 - 4.00	3.00 ± 0.62	0.93 - 1.30	1.10 ± 0.19	0.19 – 0.34	0.29 ± 0.05
III instar	2.00 - 4.00	2.90 ± 0.51	1.22 - 1.35	1.32 ± 0.07	0.38 – 0.48	0.43 ± 0.03
IV instar	2.00 - 3.00	2.60 ± 0.39	1.70 - 2.14	1.91 ± 0.15	0.51 – 0.60	0.56 ± 0.03
V instar	1.00 - 2.50	1.55 ± 0.55	2.09 - 2.56	2.37 ± 0.17	0.52 – 0.62	0.57 ± 0.04
Total nymphal period	13.00 - 16.50	12.30 ± 2.42	-	-	-	-
Premating period	1.00 - 2.00	1.55 ± 0.44	-	-	-	-
Mating period (min)	4.15 - 5.01	4.52 ± 0.36	-	-	-	-
Pre ovipositional period	2.50 - 4.00	3.25 ± 0.75	-	-	-	-
Ovipositional period	6.00 - 9.00	6.60 ± 0.96	-	-	-	-
Fecundity (number)	16.00 - 19.00	17.50 ± 3.10	-	-	-	-
Post ovipositional period	1.00 - 3.00	2.00 ± 0.94	-	-	-	-
Adult longevity						
Male (with food)	12.00 - 16.00	13.05 ± 1.18	2.35 - 2.54	2.44 ± 0.04	0.65 – 0.74	0.70 ± 0.02
Male (without food)	12.00 - 14.00	12.50 ± 0.52	-	-	-	-
Female (with food)	15.50 - 20.00	18.30 ± 1.66	2.68 - 2.76	2.73 ± 0.03	0.68 – 0.77	0.72 ± 0.03
Female (without food)	14.00 - 19.00	15.50 ± 1.92	-	-	-	-
Total life cycle	27.00 - 35.00	31.00 ± 1.94	-	-	-	-

* Mean of 10 observations

mm and 0.56 ± 0.03mm, respectively. The fully developed fifth instar nymph was greenish yellow and the mean duration was 1.55 ± 0.55 days. The average length and breadth was 2.37 ± 0.17 mm and 0.57 ± 0.04 mm, respectively. The total nymphal period ranged from 13.00 to 16.50 days with an average of 12.30 ± 2.42 days (Table 1). Observations recorded on nymphal characters, instars, duration of each instar and morphometry are in close conformity with the findings of Bhalane and Paiel (1981), Thirumalaraju (1984), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009). However, the duration and morphometry of the instars in the present findings had slight variation with the findings of the above scientists which might be attributed as stated earlier.

The mean premating period was 1.55 ± 0.44 days (Table 1). These findings were in close conformity with the findings of Sharma and Sharma (1996), Sharma and Sharma (1997) and Hanumanthappa Madar (2003) who reported the premating period as 1.7, 2.55 and 1.45 days, respectively. Mating period was 4.52 ± 0.36 min, respectively. Mating was observed to take place during early h from 7.00 am to 8.00 am and during late evening h from 5.30 pm to 7.00 pm. The average mating period lasted for 4.52 ± 0.36 min (Table 1). These findings are supported by the findings of Thirumalaraju (1984) and Hanumanthappa Madar (2003) who recorded the mating period as 5.00 min of *Empoasca devastans*, 4.20 and 5-10 min of *A .biguttula biguttula,* respectively.

The pre oviposition was 3.25 ± 0.75 days (Table 1). These findings are in close conformity with the findings of Sharma and Sharma (1996), Sharma and Sharma (1997), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009) who reported the pre oviposition periods as 3.1, 3.45, 3.75 and 3.30 days, respectively. The Oviposition was noticed during morning and evening h. The oviposition period was 6.60 ± 0.96 days. The oviposition period as reported by Singh (1978) and Hanumanthappa Madar (2003) was 15.5 days of *Empoasca devastans* and 9.75 days of *A.biguttula biguttula* which was in close conformity with the present findings. However, the present results are not in conformity with the findings of Shivanna *et al.,* (2009), Sharma and Sharma (1996) This variation might be attributed to the change in the experimental set up and also the laboratory conditions which might have influenced the behaviour of leafhopper. Fecundity ranged from 16.00 to 19.00 eggs with a mean of 17.50 ± 3.10 eggs (Table 1) which is in close agreement with the findings of Sharma and Sharma (1997), Thirumalaraju (1984), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009) who recorded the fecundity of leafhopper as 17.5, 16-22, 14-24 and 17-24 eggs, respectively . Post oviposition period was 2.00 ± 0.94 days (Table 1) which is in the line of findings of Sharma and Sharma (1996), Sharma and Sharma (1997) and Shivanna *et al.,* (2009) who recorded the post oviposition period as 3.1, 3.9 and 3.8 days, respectively.

Adults were green in colour with a pair of black dots on both the sides of the vertex of the head and sides of the apical end of the tegmina. In the females, genetilia was present on the pointed abdomen and were slightly bigger than males. The longevity of fed female was 14.00 to 19.00 days with an average of 15.50 ± 1.92 days and longevity of unfed ranged from 15.50 to 20.00 h with and average of 18.30 ± 1.66 h. The average length and breadth of female leafhopper was 2.73 ± 0.03 mm and 0.72 ± 0.03 mm, respectively (Table 1). Males had blunt and round abdominal tip with prominent adeageus. The longevity of fed male was 12.00 to 16.00 days with an average of 13.05 ± 1.18 days and longevity of unfed ranged from 12.00 to 14.00 h with an average of 12.50 ± 0.52 h. The average length and breadth of male leafhopper was 2.44 ± 0.04 mm and 0.70 ± 0.02 mm, respectively while female measured 2.73 ± 0.03 mm in length and 0.72 ± 0.03 mm in breadth, respectively (Table 1). The observations on morphometry of adults are in line with the findings of Thirumalaraju (1984), Hanumanthappa Madar (2003) and Shivanna *et al.,* (2009) who observed similar results on cotton, sunflower and *Bt* cotton. The total life cycle from egg to adult emergence ranged from 27.00 to 35.00 days with a mean of 31.00 ± 1.94 days (Table 1). The results for adult longevity and total life cycle are in close association with the results of Shivanna *et al.,* (2009) who reported that the life cycle was 19.00 to 35.00 days, the present results varied slightly with the results of Thirumalaraju (1984) and Hanumanthappa Madar (2003) who recorded the total life cycle as 15 - 21 days and

18-24 days, respectively. This variation may be attributed to environmental conditions prevailed in the laboratory.

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Studies on feeding potential of *Cryptolaemus montrouzieri* Mulsant on *Phenacoccus solenopsis* Tinsley

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ABSTRACT: The study on predatory potential of the predator, *Crytolaemus montrouzieri* revealed that both the stages (adults and grubs), feed extensively on egg, nymph (2nd instar) and adult stages of mealybug, *Phenacoccus solenopsis*. But the grubs (larvae) were more voracious feeder. A single grub of the predator consumed minimum of 727 eggs and maximum 764 eggs with an average of 746 eggs of cotton mealybug. A pair of adult (female and male) of the predatory beetle consumed 7761 to 7923 eggs with an average of 7847 eggs. A female consumed more eggs (4326) than a male (3520 eggs). Further, it was found that the grubs of the predator fed on the nymphal instar (2nd) of cotton mealybug, a single grub consumed 218 nymphs and a adult consumed 189 nymphs for its development. About 17 adult female mealybugs required to complete the development of adult stage of the predator.

Keywords : *Cryptolaemus montrouzieri*, feeding potential, mealybug, *Phenacoccus sotenopsis*

The economy of the entire Gujarat state is very much dependent on success or failure of this cash crop. Among the different constraints that limits the yield of cotton in India, the insect pests are considered to be the most serious which causes annual production loss to the tune of about 40 per cent in terms of quantity and quality (Dhawan and Sarika, 2009). During the recent years, mealy bug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) has been encountering the cotton crop in different areas of Gujarat state and markedly flaring up year by year and become a major pest that may be a great problem in future (Jhala *et al.*, 2008).

The predator play an important role in controlling the pest population naturally. The information regarding the feeding potential of predator, *C. montrouzieri* on the cotton mealybug, *P. solenopsis* is very scanty as the mealybug species is newly emerged as a serious problem on cotton in India. Hence present study was carried out.

A laboratory experiment was conducted at Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh. In order to determine the feeding potential of grub and adult stages of the predators, 50 first instar larvae and adults were kept separately in the glass vials (5 x 2.5 cm). The larvae and adults were provided with counted number of eggs, nymphs and adult mealy bugs. The number of eggs, nymphs and adult mealybugs consumed after 24 h were counted during its developmental period was recorded as feeding potential of each larval instar and adults.

Larva: Feeding potential of *C. montrouzieri* on cotton mealybug, *P. solenopsis* was studied for this purpose first instar larvae collected from laboratory culture were kept in glass vials (5 x 2.5 cm). The larvae of *C. montrouzieri* were reared separately to avoid cannibalism. The larvae were provided with counted number of eggs, nymphs and adults of the mealybug. The number of eggs, nymphs and adults consumed by each instars of the predator were recorded.

Adult: The newly emerged adult beetles of *C. montrouzieri* were kept separately in plastic containers (10 x 5 cm) and each adult were provided with counted number of eggs, nymphs and adults of mealybug, *P. solenopsis*. Number of eggs, nymphs and adults consumed during 24 h were counted and fresh new mealybugs were reintroduced daily. Thus, feeding potential of an adult was worked out.

Feeding on egg stage of the prey: The 1st, 2nd, 3rd and 4th instar grub of the predator consumed 68 to 75, 86 to 93, 165 to 177 and 395 to 425 eggs of the prey, respectively with an average of 71.60 ± 2.88, 90.08 ± 2.37, 172.30 ± 3.24 and 412.08 ± 9.39 eggs, respectively. The total eggs consumed by a grub (1 to 4 instars) ranged from 727 to 764 with an average of 746.06 ± 10.10. When adults of *C. montrouzieri* reared on eggs of the prey, the consumption rate was 4250 to 4380 eggs with an average of 4326.22 ± 34.95 eggs/ female. While, it was 3480 to 3570 eggs with an average of 3520.44 ± 24.55 eggs/ male. Earlier, the feeding potential of predator on prey eggs has been reported as 26, 51, 174 and 472 eggs by 1st, 2nd, 3rd and 4th instar by Naik *et al.*, (2003).

Feeding on nymphal stage of the prey: The 1st, 2nd, 3rd and 4th instar of grub consumed 2 to 4, 8 to 12, 75 to 83 and 118 to 133 nymphs, respectively with an average of 2.66 ± 0.75, 9.62 ± 1.26, 79.30 ± 2.31 and 126.26 ± 4.35 nymphs, respectively. Total nymphs of the prey consumed by a grub was in the range of 205 to 228 with an average of 217.84 ± 5.32. When adults of *C. montrouzieri* fed on nymphs of the prey, the consumption rate was 221 to 239 nymphs with an average of 230.54 ± 5.13 nymphs/female. While, it was 138 to 155 nymphs with an average of 147.86 ± 4.47 nymphs/male. The predatory potential of the grub was 218 nymphs of the prey and the adult female of *C. montrouzieri* consumed 230 nymphs of the mealybug. While a male consumed only 148 nymphs. More or less similar results have been reported by Naik *et al.,* (2003) and Gosalwad *et al.,* (2009).

Table 1. Feeding potential of predator, *C. montrouzieri* on eggs of mealybug, *P. solenopsis*

Predator stage	Number of eggs consumed		Av. ± S.D.
	Minimum	Maximum	
Grub			
First	68	75	71.60 ± 2.88
Second	86	93	90.08 ± 2.37
Third	165	177	172.30 ± 3.24
Fourth	395	425	412.08 ± 9.39
Total grub period	**727**	**764**	**746.06 ± 10.40**
Adult			
Male	3480	3570	3520.44 ± 24.55
Female	4250	4380	4326.22 ± 34.95
Total adult period	**7761**	**7923**	**7846.66 ± 40.56**

Feeding on adult stage of the prey: The 1st, 2nd, 3rd and 4th instar of grub consumed 1 to 2, 2 to 4, 3 to 5 and 8 to 11 adults, respectively with an average of 1.16 ± 0.37, 2.38 ± 0.64, 4.14 ± 0.67 and 9.22 ± 1.07 adults, respectively. Total adults consumed by the grub was in the range of 14 to 22 with an average of 16.90 ± 1.45.

Table 2. Feeding potential of *C. montrouzieri* on nymphs of mealy bug, *P. solenopsis*

Predator stage	Number of eggs consumed		Av. ± S.D.
	Minimum	Maximum	
Grub			
First	2	4	2.66 ± 0.75
Second	8	12	9.62 ± 1.26
Third	75	83	79.30 ± 2.31
Fourth	118	133	126.26 ± 4.35
Total grub period	**205**	**228**	**217.84 ± 5.32**
Adult			
Male	138	155	147.86 ± 4.47
Female	221	239	230.54 ± 5.13
Total adult period	**363**	**390**	**378.40 ± 6.31**

When adults of *C. montrouzieri* fed on adults of the prey, the consumption rate was 18 to 24 adults with an average of 22.52 ± 1.76 adults/female. While, it was 13 to 16 eggs with an average of 15.08 ± 0.94 adults/male. More or less similar results have been reported by Naik *et al.,* (2003) and Gosalwad *et al.,* (2009).

Table 3. Feeding potential of *C. montrouzieri* on adults of mealy bug, *P. solenopsis*

Predator stage	Number of adults consumed		Av. ± S.D.
	Minimum	Maximum	
Grub			
First	1	2	1.16 ± 0.37
Second	2	4	2.38 ± 0.64
Third	3	5	4.14 ± 0.67
Fourth	8	11	9.22 ± 1.07
Total grub period	**14**	**22**	**16.90 ± 1.45**
Adult			
Male	13	16	15.08 ± 0.94
Female	18	24	22.52 ± 1.76
Total adult period	**33**	**40**	**37.60 ± 1.98**

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Instability and decomposition of cotton production across major states in India

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ABSTRACT : The instability and sources of variability in area, production and productivity of cotton in the nine major states were studied for the period I (1985-1994) and period II (1995-2009).The percentage change in the cotton production was highest for Gujarat, followed by Maharashtra and Andhra Pradesh. The change in cotton production between the periods has come largely due to change in mean yield (59.83 %) with Gujarat and Maharashtra. The largest contribution of change in variance of cotton production was by Gujarat (78.52 %) followed by Maharashtra (20.8 %). The increase in the cotton production variance is attributed to increase in yield variance with much of it from Gujarat and Maharashtra.

Key words: Components of change, instability, production, variability

India has the largest area under cotton production followed by China, United States and Pakistan. Cotton is grown in nine major states in three different zones, Punjab, Haryana and Rajasthan in north zone; Maharashtra, Gujarat and Madhya Pradesh in central zone and Andhra Pradesh. Karnataka and Tamil Nadu in the south zone. Cotton is a crop which witnessed periodical technological interventions and the strategy of technology break through and incentive policy package was the ushering in of the cotton revolution in India and during the post reforms (1990s) period opening up of the domestic markets due to new international trade accord and the World Trade Organization (WTO) was another change that affected agriculture. Later period witnessed the revolution of *Bt* technology and the expiration of the Multi Fibre Agreement (MFA) in 2004.

In this context the study was conducted to estimate the instability and decomposition of cotton production across nine major cotton growing states in India. The purpose of this paper is to provide a systematic study of the components of change in the variability of India's cotton production.

MATERIALS AND METHODS

Data on area, production and productivity of cotton from 1981-1982 to 2008-2009 for the nine major cotton growing states were obtained. For the analysis of instability the data was divided into two periods *i.e.* period I (1985-1994) and period II (1995-2009). The instability in area, production and productivity of cotton was analysed using the following method :

Instability index = Standard deviation of natural logarithm (Y_{t+1}/Y_t) Where, Y_t is the area/ production /yield in the current year and Y_{t+1} is for the next year. This index is unit free and it measures deviations from the underlying trend.

The sources of variability in the raw cotton production and export were analyzed using the Hazell's decomposition method. This method used statistical identities to provide decomposition of the components of change in the variance. Before the analysis was carried out, the time series data on area and productivity and exports were first detrended to remove the systemic or trend component. The analytical framework employed in the present study was the same as that used by Hazell to study the production instability in Indian agriculture where the states and districts, were the unit of observation. The component of change in production and variance are given in the Tables 1 and 2

RESULTS AND DISCUSSION

Area, production and productivity of cotton in India : The major cotton growing states put together over 99 per cent of the area and production in the country. The average area, production and productivity of cotton were

Table 1. Component of change in the average production of raw cotton

Sources of change	Symbol	Component of change
Change in mean unit value	ΔP	$Q \Delta P$
Change in mean quantity	ΔQ	$P \Delta Q$
Interaction between changes in mean quantity and mean unit value	$\Delta Q, \Delta P$	$\Delta Q \Delta P$
Chang in unit value - quantity covariance	$\Delta COV (Q, P)$	$\Delta COV (Q, P)$

analyzed.

The statewise area of cotton is given in Table 3. It is evident that during the first period, the area under cotton was the highest in Maharashtra (35.50 %) followed by Gujarat (16.32 %), Karnataka (9.20 %), Andhra Pradesh (8.17%), Punjab (8.51 %), Madhya Pradesh (7.21 %), Haryana (5.91 %), Rajasthan (5.45 %), Tamil Nadu (3.16 %). The average cotton area in India was 74.89 lakh ha (Period I) and increased to 88.16 lakh ha (Period II). Thus there was an increase of 17.73 per cent in area under cotton. In the states of Maharashtra, Gujarat, Andhra Pradesh, Haryana, Rajasthan and Madhya Pradesh the average area of cotton has increased but in percentage share of cotton area showed an increase only for Gujarat (20.51 %), Andhra Pradesh (11.94 %) and Haryana (5.68 %). The average production was highest in Punjab (17.03 lakh bales) with a highest share (18.91%) followed by Maharashtra (18.42 %) and Gujarat (17.56%). While in period II, Gujarat was the largest producer of cotton with average production of 43.49 lakh bales with a share of 26.13 per cent followed by Maharashtra (20.40 %). The percentage change in cotton production was the highest for Gujarat (174.97 %) followed by Andhra Pradesh (128.41 %) and Maharashtra (104.56) in period II. The average production of cotton in the country showed an increase of 84.78 per cent between the two periods (Donald *et al.,* 2004).

During period I, the productivity was highest in Punjab (451 kg/ha) followed by Haryana (365 kg/ha). These states are in the north zone where cotton is grown under irrigated conditions and cultivated during *kharif* season

Table 2. Components of change in the variance of production

Sl. No.	Source of change	Nature of effect	Components of change
1.	Change in mean unit value	Δp	$2\ Q_1 \Delta\ P COV(P_1, Q_1) + [2\ P_1 \Delta P + (\Delta P)^2]\ V(Q_1)$
2.	Change in mean quantity	ΔQ	$2 P_1 \Delta\ Q\ COV(P_1, Q_1) + [2\ Q_1 \Delta\ Q + (\Delta\ Q)^2]\ V(P_1)$
3.	Change in unit value variance	$\Delta V(P)$	$(\ Q_1)^2 \Delta V(P)$
4.	Change in quantity variance	$\Delta V(Q)$	$(\ P_1)^2 \Delta V(Q)$
5.	Interaction between changes in mean unit value and mean quantity	$\Delta P, \Delta Q$	$2 \Delta\ P \Delta\ Q\ COV(P_1 Q_1)$
6.	Change in unti value- quantity covariance	$\Delta COV (P, Q)$	$[2\ Q_1\ P_1 - 2COV(P_1, Q_1)]\ \Delta COV(P,Q) - [\Delta COV(P,Q)]^2$
7.	Interaction between changes in mean quantity and unit value variance	$\Delta\ Q, \Delta V(P)$	$[2\ Q_1 \Delta\ Q + (\Delta\ Q)^2] \Delta V(P)$
8.	Interaction between changes in mean unit value and quantity variance	$\Delta\ P, \Delta V(Q)$	$[2\ P_1 \Delta\ P + (\Delta\ P)^2] \Delta V(Q)$
9.	Interaction between changes in quantity and unit value and changes in unti value- quantity covariance	$\Delta\ P \Delta\ Q \Delta COV(P, Q)$	$[2\ P_1 \Delta\ Q + 2\ Q_1 \Delta\ P + 2 \Delta\ Q \Delta\ P]\ \Delta COV(P, Q)$
10	Change in residual	ΔR	$\Delta COV(Q,P)$ — sum of the other components

Table 3. Statewise area, production and productivity under cotton

S. No	States	Area (lakh ha)			Production (Lakh bales)			Productivity (kg/ha)		
		Period I	Period II	Change (%)	Period I	Period II	Change (%)	Period I	Period II	Change (%)
1	Andhra Pradesh	6.12	10.52	71.96	9.29	21.22	128.41	257	336	30.52
		-8.17	-11.94		-10.32	-12.75				
2	Gujarat	12.22	18.09	47.95	15.82	43.49	174.96	218	383	75.99
		-16.32	-20.51		-17.56	-26.13				
3	Haryana	4.43	5.68	28.26	9.63	13.78	43.12	365	420	14.88
		-5.91	-6.44		-10.69	-8.28				
4	Karnataka	6.89	4.91	-28.79	7.23	7.04	-2.68	187	245	31.32
		-9.2	-5.56		-8.03	-4.23				
5	Madhya Pradesh	5.4	557	3.24	3.17	6.23	96.47	101	184	81.94
		-7.21	-6.32		-3.52	-3.75				
6	Maharashtra	26.63	30.45	14.37	16.59	33.94	104.56	106	189	77.61
		-35.56	-34.54		-18.42	-20.4				
7	Punjab	6.43	5.74	-10.66	17.03	16.21	-4.82	451	485	7.57
		-8.59	-6.52		-18.91	-9.74				
8	Rajasthan	4.08	4.79	17.4	6.76	8.2	21.19	277	306	10.24
		-5.45	-5.43		-7.51	-4.93				
9	Tamil Nadu	2.37	1.63	-31.28	4	2.82	-29.47	284	303	6.85
		-3.16	-1.85		-4.44	-1.7				
	India	**74.89**	**88.16**	**17.73**	**90.05**	**166.4**	**84.78**	**204**	**318**	**55.64**
		-100	**-100**		**-100**	**-100**				

Figure in parentheses indicate percentage to column total

Table 4. Instability in area, production and productivity of cotton in India

S. No.	States	Period I			Period II		
		Area	Production	Productivity	Area	Production	Productivity
1	Andhra Pradesh	19.09	24.24	27.57	19.82	27.63	22.81
2	Gujarat	20.78	53.04	38.27	8.51	39.07	37.78
3	Haryana	13.04	19.59	21.42	10.32	31.69	35.28
4	Karnataka	18.49	24.78	20.04	23.83	38.93	21.78
5	Madhya Pradesh	7.99	23.92	24.93	3.39	26.10	24.76
6	Maharashtra	3.83	46.07	46.79	5.5	31.90	30.69
7	Punjab	12.58	25.03	29.96	15.62	31.93	30.35
8	Rajasthan	13.41	48.27	46.30	15.87	45.60	46.40
9	Tamil Nadu	18.48	35.62	19.71	29.38	42.29	20.58
	India	**5.37**	**17.66**	**14.67**	**8.25**	**18.53**	**16.5**

in the indo gangetic alluvial soils. Being irrigated, the productivity is higher in the zone than that in the other zones and even higher than national average. During period II, the productivity of cotton was better in all the states. The analysis of percentage change in productivity of cotton revealed that the productivity increased between the two periods. The introduction of *Bt* cotton has brought about significant increase in the productivity of cotton in the country. Cotton is such a crop wherein the technology break through and penetrated it's cultivation over the decades bringing out significant changes in area, production and productivity (Steena and Toor, 2007).

Instability in area, production and productivity of cotton : The instability affects both the production as well as productivity and it could be attributed to a number of factors like technology intervention, natural or climatic factors, etc. The instability of cotton in different states in India are given in Table 4. The results revealed that instability in area increased from 5.37 per cent in period I to 8.25 per cent in period II, production instability increased from 17.66 per cent to 18.53 per cent and productivity instability increased from 14.67 per cent to 16.50 per cent. Among the three, the increase in instability was highest for area under cotton. Instability in cotton production is expected to vary across regions and states. The statewise analysis revealed that during the period I, Maharashtra showed the least instability of (3.83%) in area (Shende and Suryawansh, 2004), Madhya Pradesh showed least instability of (23.92%) in production and Tamil Nadu showed least

Table 5. Components of change in the average production of cotton in India between periods

S.No	States	Percentage contribution to change in India's production				
		Change in mean yield	Change in mean area	Interaction between changes in mean area and mean yield	Change in yield and area covariance	**Total change**
1	Andhra Pradesh	3.86	12.03	3.02	-0.08	**18.84**
2	Gujarat	19.86	9.91	6.70	2.62	**39.09**
3	Haryana	2.54	6.15	0.96	-0.40	**9.26**
4	Karnataka	4.25	-4.13	-1.25	0.66	**-0.48**
5	Madhya Pradesh	3.80	-0.06	-0.04	0.17	**3.88**
6	Maharashtra	21.02	4.22	3.00	-0.05	**28.20**
7	Punjab	3.61	-3.10	-0.37	-0.58	**-0.44**
8	Rajasthan	0.85	2.95	0.22	-0.24	**3.78**
9	Tamil Nadu	0.03	-2.05	-0.01	-0.09	**-2.12**
	India	**59.83**	**25.93**	**12.23**	**2.01**	**100.00**

Table 6. Decomposition of change in variability of production of cotton in India

S.	Source of change	Percentage contribution to change in variability									
		Andhra Pradesh	Gujarat	Haryana	Karn-ataka	Madhya Pradesh	Mahar-ashtra	Punjab	Rajasthan	Tamil Nadu	**India**
1.	Change in mean yield	1.15	1.82	1.08	-1.66	-0.04	-0.08	0.48	0.45	0.03	**3.23**
2.	Change in mean area	0.70	-0.25	0.39	-0.14	0.00	0.56	-0.91	0.37	-0.02	**0.70**
3.	Change in yield variance	1.10	14.60	1.21	-1.61	0.22	16.04	3.21	-0.44	-0.02	**34.31**
4.	Change in area variance	-0.95	2.50	-0.95	-0.60	0.01	0.00	0.49	0.53	0.31	**1.34**
5.	Interaction between changes in mean yield and mean area	12	-0.50	0.04	0.21	0.00	-0.01	-0.01	0.01	0.00	**-0.14**
6.	Change in area and yield covariance	-0.27	17.33	-1.52	2.20	0.23	-0.32	-4.15	-0.64	-0.16	**12.72**
7.	Interaction between changes in mean area and yield variance	2.39	11.52	1.08	0.81	0.00	4.90	-0.62	-0.25	0.01	**19.83**
8.	Interaction between changes in mean yield and area variance	-0.54	4.52	-0.32	-0.42	0.02	0.00	0.12	0.08	0.00	**3.48**
9.	Interaction between changes in mean area and yield and change in area and yield covariance	-0.33	22.27	-0.89	-0.17	0.15	-0.30	-0.02	-0.22	0.04	**20.52**
10.	Change in residual	-0.44	4.70	-0.75	1.66	0.05	-0.03	-0.68	-0.46	-0.03	**4.02**
	Total contribution of states	**2.92**	**78.52**	**-0.63**	**0.27**	**0.64**	**20.77**	**-2.08**	**-0.57**	**0.16**	**100.00**

instability of (19.71%) in productivity. The scenario was different in period II wherein area instability was least for Madhya Pradesh. Similar trend was found for production and productivity.

Components of change in the average cotton production in India : Data in Table 5 showed statewise decomposition of change in average production. Among the components of change 59.83 per cent of the increase was from yield increase, 25.93 per cent from mean area, 12.23 per cent from increase in area and yield interaction and 2.01 per cent from increase in the yield and area covariance at all India level. The largest contributors are Gujarat (39.09 %), Maharashtra (28.20 %) and Andhra Pradesh (18.84 %). The highest change was seen in Maharashtra (21.02%) and Gujarat (19.86%). The change in cotton production between the two periods in the country has come largely due to the change in mean yield (59.83%) while the change in mean area has contributed to the tune of 25.93 per cent. This yield led to change in the cotton output. Among the states, Maharashtra and Gujarat are the major ones in change in mean yield. The major contributors to the change in average production of the country was Gujarat and Maharashtra wherein the adoption of *Bt* cotton was fast increasing during period II.

Decomposition of change in variance of cotton production in India : The decomposition of the change in the variance of cotton production across states are given in Table 6. All the entries in the Table are expressed as per cent change in the variance of cotton production in India and hence rows and columns sum to 100 per cent. A striking feature of the analysis was that the largest contribution to change in variance of cotton production was by Gujarat (78.52 %) followed by Maharashtra (20.77 %) between first and second period in the country. The 34.31 per cent increase in the India's cotton production variance is attributed to increase in yield variance and much of this came from change in yield variance in Maharashtra and Gujarat.

The interaction between changes in mean area and yield variance contributed to 20.52 per cent of variability. Although these changes in the interaction terms in part arose from increase in the yield variability, but by no means was the yield variability, the only factor responsible. Unless it could be argued that the increase in yield instability induced the changes. This might happen when the increases in the yield variability induced a change in the farmer's behaviour so that the mean or variances of areas sown with the different crops were affected. The area in Punjab, Karnataka and Tamil Nadu is declining in the recent period. Therefore, efforts must be directed to reverse the trend. In view of the introduction of *Bt* cotton and productivity of cotton is increasing in all states, it is essential that the increased productivity should be sustained in the ensuing years also. Change in yield is the major contributor to the change is cotton output. The area and productivity changes in the states of Gujarat and Maharashtra have enormous bearing on cotton output in the country. Further, yield variability has turned out to be a major source of change in variance of cotton output. Here again, the variance in cotton production in Gujarat and Maharashtra are contributing to the variance in cotton output in. Hence, measures like irrigation facility, evolving improved varieties and taking plant protection measures etc. to reduce change in yield variance particularly in the states of Gujarat and Maharashtra would help in reducing variance in cotton output in the country.

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Ergonomic assessment of women in cotton picking activity

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ABSTRACT : Farm woman has a major role in cotton cultivation. An ergonomic study was undertaken to determine the physiological and biomechanical stress of women involved in cotton picking. Field experiment was carried out for one h on 60 farm women of Haryana belonging to two age groups *i.e.* 25-35 and 35-45 years. Farm women collected 4.9 kg of cotton during one h of cotton picking activity. Average working heart rate of woman increased upto 102 b/min during the activity over the resting heart rate of 78 b/min. Energy expenditure was more in older age group (7.7 kj/min) than younger group (7.0 kj/min). Women perceived heavy to moderately heavy exertion after the activity. Grip strength increased upto 9.6 per cent during the activity whereas, it decreased by 14.3 per cent at the end of the activity. Severe discomfort was reported in fingers (m.s.=4.8) as they get abrasions while in picking cotton bolls followed by mid back (m.s.=4.4) and wrists (m.s.=4.1). There is a need for ergonomic intervention to reduce drudgery of women in cotton picking.

Key words: Drudgery, musculoskeletal discomfort, perceived exertion, physical fitness

Rural women constitute at least one third of the country's economically active population, particularly in the unorganized agrarian sector. Although they constitute nearly 60-70 per cent of the labour force in agriculture, yet their participation especially in developing countries is being increasingly recognized. India is a major cotton producing country and occupies about 23 per cent area under it. Haryana State has a significant contribution to nation's production. However, its maximum area under cotton is about 492 thousand ha (Anonymous, 2011).

Cotton picking is more or less a farmwoman's responsibility in most part of India, especially in Haryana. She works intensely from morning to evening in cotton picking season ranging for 50-60 days of work during the months of October to December. Traditionally, she uses a cloth sheet/ head cloth for collecting picked cotton by tying it in the form of bag on her shoulders and back. She picks up the cotton bolls using her fingers and palm and puts them in her shoulder bag turning her hands, wrist and shoulders. She stoops, bends a number of times to pick the cotton bolls and walks from one plant to another carrying this weight on her shoulder. At the end of the day she gets tired and suffers from musculo skeletal discomfort in various body parts. Hence, cotton picking with existing method leads to drudgery of the woman and retards her working efficiency.

Despite their importance to agricultural production, women face severe handicaps as they have to do the arduous activity of picking cotton for longer duration and in uncomfortable environment. But there is hardly any literature that reveals the ergonomic stress of women and their drudgery in cotton picking activity. The present study was undertaken to assess the ergonomic cost of farm women of two age groups involved in cotton picking activity.

MATERIALS AND METHODS

The study was carried out on 60 physically fit farm women involved in cotton picking belonging to two age groups *i. e.* 44 respondents from 25-35 years and 16 from 35-45 years of age of Hisar district of Haryana state. Field experiment was carried out for an h in the month of October November for cotton picking activity. During the experiment, various parameters *viz.,* time and activity profile, physiological and bio mechanical stress studied were as follows:

Assessment of physical fitness

Procedure for physical fitness : Physical fitness of women was measured using step stool ergometer. Selected subjects were given enough of rest and then her resting heart rate was measured with the heart rate monitor. After the complete rest, the subject was asked to perform the stepping activity on the step-test ergometer for a maximum of 5 min with a uniform stepping rate of 30 steps/min. During the stepping activity, the heart rate was recorded every min. After 5 min of stepping activity, the subject was asked to stop the activity, and sit comfortably on resting chair. Then the recovery pulse rate was recorded after every min for a period of 5 min.

Physical Fitness Index (PFI) was calculated by using the formula given below and interpretation of scores was done as given by Varghese *et al.*, (1994)

$$PFI = \frac{\text{Duration of stepping (sec)}}{\text{Sum of 1st, 2nd and 3rd min Recovery HR}} \times 100$$

Health status through aerobic capacity (VO_2 max) : VO_2 max was calculated using the following regression equation (Saha, 1978):

VO_2 max (ml/kg x min) = 0.377 x PFI score - 12.767

Determination of body composition and lean body mass

Body composition : Body composition of the selected subjects was measured using Lange's skinfold calliper. Biceps, triceps, sub-scapular and suprailliac muscles were measured to calculate lean body mass (LBM) which has direct relation with heart rate of the person. Following formulae (Durnin and Rahaman, 1967) were used to calculate body density, lean body mass and body composition of the selected subjects:

Body density (D) =	1.1599 – (0.0717 x log of sum of 4 skin folds)
Per cent fat =	(4.95 – 4.5) /D x 100
Fat weight =	Body weight x per cent fat/100
Lean body mass (kg) =	Body weight – Fat weight

Body mass index (BMI): Body mass index was derived by measuring weight and height of the woman using Quetelet Index in the formula given by Garrow (1981). Accordingly, body type as per BMI according to Quetelet's Index was graded as ectomorph, mesomorph and endomorph

$$Q.I. = \frac{\text{Weight (kg)}}{\text{Height(m)}^2}$$

Assessment of ergonomic parameters: Ergonomic assessment consisted of time and activity profile, physiological workload and biomechanical stress.

Physiological workload: It refers to the physical or muscular effort required on the part of the worker to accomplish a task or an activity. The period during which the work continues is known as work period and period during which the physiological functions return to resting level is known as recovery period. Hence, to evaluate total physiological expenditure, physiological reactions both during the work and during the recovery period were considered. Hence, HR was recorded using polar heart rate monitor firstly at rest and then after every min for 30 min during the experiment till the recovery of the subject. From the values of HR, total cardiac cost of work (TCCW) and physiological cost of work (PCW) were calculated.

TCCW	=	Cardiac cost of work (CCW) + Cardiac cost of recovery (CCR)
CCW	=	(Avg. working HR- Avg Resting HR) x Duration of activity
CCR	=	(Avg. Recovery HR- Avg Resting HR) x Duration of recovery.

Physiological cost of work (PCW) = TCCW / Total time of the activity.

Energy expenditure: Energy expenditure during work was also calculated by AHR using the regression equation given by Varghese *et al.*, (1994):

Energy expenditure (kj/min) = 0.159 x Avg working HR (bpm) – 8.72.

Rating of perceived exertion- Though heart rate is widely used parameter to estimate physical workload yet it is difficult to measure it for the short duration tasks. Hence subjective perceptions of exertion of the subjects known as Rating of perceived exertion(RPE) was determined (Varghese *et al.*, 1994) on a 5 point continuum ranging from very light exertion (1) to very heavy exertion (5). Mean was calculated for all the subjects to get an average score.

Biomechanical stress: Biomechanical stress is the stress on muscles of the body while working. It was determined measuring grip fatigue and postural stress as under.

Grip fatigue: Grip dynamometer was

used to measure the stress of grip muscles. Grip strength was measured at rest *i. e.* before the start of activity (Sr) separately for the right as well as the left hand and then again immediately after the completion of activity (Sw). Grip fatigue was calculated (Oberoi and Singh, 2007) as under

$$\text{Grip fatigue (\%)} = \frac{S_r - S_w}{S_r} \times 100$$

Musculo skeletal discomfort : A human body map was used to measure the musculo skeletal discomfort and intensity of pain in different body parts resulting from postural discomfort (Corlette and Bishop, 1976). Five-point scale ranging from very severe pain (5) to very mild pain (1) was used to quantify the stress on muscles used in work. The body discomfort score of all the subjects is added and averaged.

RESULTS AND DISCUSSION

The results of the study have been discussed as under:

Physical characteristics : Mean age, height and weight of the Haryana farm women involved in picking cotton was 29.9 years, body height 154.5 cm and body weight 49.1 kg (Table 1). Mean value of aerobic capacity (VO_2 max) was 1.76 l/min and BMI was 21.0 falling in the normal category. Categorization of women respondents according to BMI in Fig. 1 indicated that an equal number of women were falling in normal range and low weight normal (38 % each). More than half of the cotton pickers (55%) were having mesomorph body type followed by ectomorph (36.7%) and endomorph (8.3%) (Fig. 2). Average fat percentage of subjects was 26.1 per cent. However, between the two age groups, the average age of younger and older age group was 27.4 and 37.3 yrs having body weight of 51.7 and 48.1 kg with not much height difference. They were having VO_2 max ranging between 1.83 - 1.57 l/min. On physical fitness index scale, majority of cotton pickers recorded high average (82.0%) followed by good (13.0%) and below average (5.0%) (Fig. 3). Statistically, there was a significant positive correlation between body weight of respondents with height, BMI and VO^2 max (r =0.407, 0.628 and 0.504 respectively).

Time and activity profile

Time and activity profile : Cotton pickers hung *jholi i.e.* a temporary bag made from a cloth by knotting at their shoulders and back to collect picked cotton bolls. On an average, they carried 4.9 kg of cotton bolls in their bag in one cycle, hence, picked 20.24 kg of cotton in a day during 4-5 cycles of activity (Table 2). Cotton pickers walked from one plant to another to pick cotton bolls. The data in Table 2 showed that an average woman covered a distance of 2.72 km during cotton picking (4-5 cycles). The distance travelled was 2.86 km by younger age group and it was more than older age group (2.58 km). They emptied the filled *jholi* in one corner of the field making heap that was stored away at the end of the day.

Physiological stress : Physiological stress of cotton picker was determined on the basis of various parameters like average heart rate, energy expenditure, physiological cost of work (PCW) and rating of perceived exertion (RPE) while

Table 1. Physical characteristics of the women picking cotton

N=60

Variables	Age groups		Total
	25-35 yrs (n=44) Mean ± SD	35-45 yrs (n=16) Mean ± SD	Mean ± SD (n=60)
Age (yr)	27.4 ± 3.00	37.3 ± 3.00	29.9 ± 5.34
Height (cm)	154.6 ± 3.61	154.1 ± 2.06	154.5 ± 3.30
Weight (kg)	51.7 ± 5.74	48.1 ± 6.24	49.1 ± 6.28
VO_2 max (l/min)	1.83 ± 0.18	1.57 ± 0.13	1.76 ± 0.29
BMI (kg/m)	21.65 ± 2.15	20.75 ± 3.42	21.0 ± 3.14
LBM (kg)	37.25 ± 4.06	36.23 ± 4.49	36.52 ± 4.34
Fat percentage	27.95 ± 5.02	21.17 ± 1.98	26.14 ± 5.34

performing the activity (Table 3). Working mean heart rate of a woman during cotton picking activity increased to 102 b/min over the resting heart rate of 78 b/min. Mean heart rate was more in older group (103 b/min) than younger group (101 b/min). Peak heart rate for younger and older age group was 113 b/min and 109 b/min respectively. Kaur *et al.*, (2007) also reported the increase in average working heart rate of Punjab women upto 117.47 b/min while picking cotton bolls.

Average energy expenditure for cotton picking activity was 7.3 kj/min. During cotton picking energy expenditure for older age group (7.7 kj/min) was higher than the younger age group (7.03 kj/min). Average TCCW and PCW were observed as 6358 beats and 21.3 b/min. TCCW for younger and older age group was 6274 and 6442 beats, respectively and PCW was 21.1 b/min and 21.6 b/min, respectively. After the activity, the psycho physiological responses were recorded in terms of rating of perceived exertion. Cotton picking was perceived as heavy activity by both younger (m.s. =4.2) and the older (m.s.=4.5) age groups.

Fig. 1 Body Mass Index

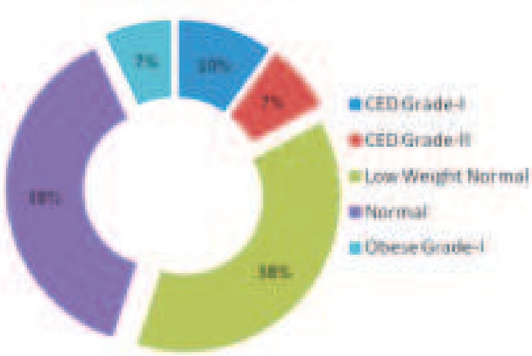
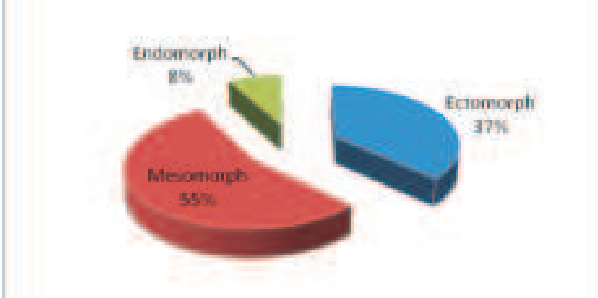


Fig. 2 Body Type of the Respondents



Biomechanical stress

Biomechanical stress is expressed in terms of grip fatigue and musculo-skeletal discomfort.

Grip Fatigue : Data in Fig. 4 showed that there was 10.6 per cent (younger group) and 8.7 per cent (older group) increase in grip strength during the activity whereas it decreased after the experiment (12.6% and 15 %, respectively) as the muscles get tired with passage of time. This might be due to the reason that body got warm up during the activity. However, the increase was more in younger age group than older age group. At the end of the day, grip strength decreased. Interestingly, the decrease was more in older age group (15.0%) than in younger age group (12.6%).

Musculo skeletal discomfort : The data in Fig. 5 showed the musculo-skeletal discomfort of cotton pickers. As hands are mainly involved continuously in cotton picking, so very severe pain was reported in fingers and palms (mean score = 4.8 and 4.5, respectively). Moreover, they

Fig. 3 Physical Fitness of the Respondents

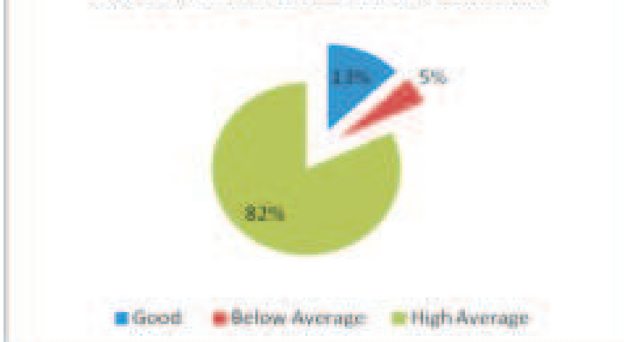
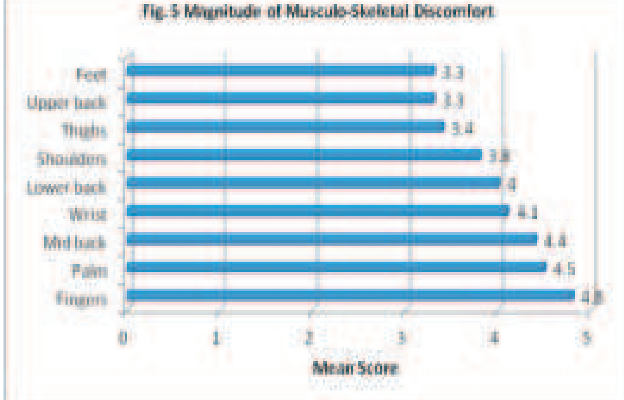


Fig. 4 Change in Grip Strength

get abrasions while picking cotton bolls from hard and pointed cotton shells. This was followed by severe discomfort in mid back (mean score = 4.4),

Fig. 5 Magnitude of Musculo-Skeletal Discomfort



wrists (mean score = 4.1) and lower back (mean score = 4.0). Severe to moderate discomfort was reported in shoulders (mean score = 3.8), thighs (mean score= 3.4) and upper back and feet (mean score = 3.3 each). During the activity, cotton gets collected at the bottom of bag forming a boll like structure which droops down at her back. This touches her lower thighs and popliteal area and causes hindrance while walking during the activity. This may be due to reason that that they used to stoop and change their posture 48 times for picking cotton bolls from lower plants. Secondly, they used to bend to pick the cotton bolls fallen on the ground while putting them in the pockets of bag at their back. For this they used to twist their hands and wrist putting stress

Table 2. Time and activity profile of women engaged in cotton picking. (N=60)

Parameters	Age group		**Average (n=60)**
	25-35 yrs (n=44)	35-45 yrs (n=16)	
Load of cotton picked (kg/h)	5.15	4.7	**4.9**
Load of cotton picked (kg/day)	25.75	23.5	**24.5**
Distance travelled (km/day)	2.86	2.58	**2.72**
Time spent (min)/day	512	459	**485.5**

Table 3 Physiological and psycho physiological stress in cotton picking. (N=60)

Activity	Age group		**Average (n=60)**
	25-35 yrs (n=44)	35-45 yrs (n=16)	
Average Heart rate (b/min)	101	103	**102**
Peak Heart rate	109	113	**111**
Average energy expenditure (kj/min)	7.0	7.7	**7.3**
Peak energy expenditure (kj/min)	8.6	9.2	**8.9**
Classification of workload	Very heavy	Very heavy	**Very heavy**
TCCW (beats)	6274	6442	**6358**
PCW (b/min)	21.1	21.6	**21.35**
RPE (Mean score)	4.2	4.5	**4.35**

on their shoulders too. Moreover, this stooping and bending was done while carrying weight of cotton bolls in the bag hung on their shoulders which they occasionally shifted at their head to relieve their shoulders for time being. The results are in line with the findings of Rana (2000) showing very severe to severe pain in the fingers, wrist, low back and upper back.

CONCLUSIONS

Summarisingly, mean age of rural woman picking cotton was 29.9 years having body weight and height of 49.1 kg and 154.5 cm, respectively. Aerobic capacity was found to be 1.76 l/min. She used a head cloth tied in the form of a bag to collect cotton bolls moving from one plant to another. She collected 4-5 bags/day totaling about 24.5 kg of cotton during 4-5 cycles. Physiological cost of cotton picking was 21.3 b/min. Cotton pickers reported severe pain in fingers as these got punctured while plucking cotton pods from hard and wooden shells of the plant. They also reported breathing problems due to residues of insecticides being used for cotton crop. During the activity, women usually adopted unnatural body postures leading to drudgery in the form of various kinds of musculoskeletal discomfort especially in wrists, lower back, upper back etc. Fingers got abrasions due to pricks from hard cotton shell.

Hence, there is a need for ergonomic interventions to reduce women's drudgery in cotton picking. This can be done by devising tools for cotton pickers to help them to carry out the activity with ease. Protective measures also need to be used to counteract the remains of insecticides during picking. Therefore, development and intervention of three drudgery reducing technologies is recommended *viz.*, i) ready to wear cotton picking bag exerting lesser pressure on the neck and shoulders, having shaped pockets at the front to put the picked cotton bolls that could relieve them from many musculoskeletal problems, ii) finger guards to protect them from injury from boll shells, and iii) a face mask to cover the head region of the body to protect them from the effects of insecticides during picking. Moreover, adequate rest pauses coupled with training on use of proper body postures along with light exercises for back and shoulders need to be given during the work to delay the onset of fatigue and its recuperation. This would help the user to carry out the work with much ease and comfort, relieving her from drudgery and increasing the efficiency.

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Studies on various constraints faced by farm women in technological information for cereal and cotton crops

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ABSTRACT : A study on various constraints faced by the farm women in utilizing the technical information regarding different cereals and oil crops was conducted in six district of Haryana. Further one block from each district and two villages from each block were selected purposely. Thus, twelve villages from six districts were selected on the basis of crops grown. So proportionate random sample were drawn from each village which is comprising of 485 rural women who were selected purposely as the main crop grown in the district. The results of the study showed that among all the constraints rice growers, in Karnal and Kurukshetra districts, faced lack of technical expertise, physical and time constraints and in Jind and Kaithal districts, physical and time constraints were perceived most serious constraints by the wheat grower. Most serious constraints such as physical, social and language were faced by the cotton growers.

Key words : Constraints, cotton, farm women, rice, technological information, wheat

An overwhelming majority of women in rural India is associated directly or indirectly with agricultural production, processing and distribution and in most of studies conducted revealed that their participation in livestock related activities was found higher. About 89.3 per cent of female work force is concentrated in agriculture sector. It is essential to plan and execute the location specific, need based and cost effective training programmes for farm women and their needs should be identified in consultation not only with trainers but also participants themselves. Rapid change in recommendations of modern scientific farming requires to up date the latest technical know how and skill of its end users for result oriented and remunerative farming.

Various grain and cash crops have major contribution in meeting the requirements of human being. Sugarcane and cotton (cash crops), wheat, chickpea and pearl millet (grain crops) are important crops raised in Haryana state.

Therefore, it is necessary to increase the rate of adoption level of different latest agricultural technologies and know-how for raising these crops and also by eliminating the various constraints faced by farm women in the process of transfer of technology. Farm women are socially at low level in availing and using of technological information and mostly the lip service of these information are provided to the them. They face numbers of constraints in this regard. Keeping in view, the present study was designed with a specific objective of identifying the constraints faced by the farm women in utilizing the technical information regarding different cereals and oil crops.

The present study was conducted in six districts of Haryana. One block from each district and two villages from each block were purposively selected. Thus, twelve villages from six districts were selected purposely on the basis of crops grown in the area. Major crops grown in selected districts were wheat, rice, cotton were included in the study. From rice growing area (Karnal and Kurukshetra) Majra Rodan and Koyar villages were selected from Indri block of Karnal whereas Ban and Sonti villages were selected from Ladwa block of Kurukshetra districts and Kharak Pandoo and Pinjupura villages of Kaithal block (Kaithal district)and Makhand and Uchana Khurd were selected from Uchana block of Jind district were selected purposively. In case of cotton growing districts, Khariya and Panniwala Mota villages of Raniya block of Sirsa district and Thuyan and Dhabi Kalan villages from Bhattu block of Fatehabad district, respectively were selected. From 12 selected villages a proportionate random sample of 170, 165 and 150 farm women actively involved in farming was selected. So a proportionate purposive random sample was drawn for each village which is comprised of 485 rural women. Constraint faced by them were assessed for each of the crop. The structured interview schedule was developed and pre tested on non sampled farm women. The interview was conducted personally by the investigator with the women farmers individually. The collected data were processed, tabulated and analyzed by using frequency, percentage, weighted mean score, rank etc.

Constraints faced by the respondents in technical information for different crop cultivation : The data given in Table 1 incorporated the constraints perceived by the farm women in getting technical information such as time, lack of competency of resource person, lack of technical expertise, lack of confidence in the use of technology received, physical, social, economic constraints and language problem etc. An attempt was made in the present investigation to assess the constraints perceived by the farm women in the use of different information sources of information for selected crop cultivation operations.

The data of Karnal and Kurukshetra districts wise reported in Table1 revealed that lack of technical expertise (I, MS 2.82), physical constraints (II, MS 2.57), time constraints (III, MS 2.52) were perceived most serious by the farm women in getting technical information from various information sources for rice cultivation practices. Whereas, constraints which were not so serious perceived by farm women were lack of confidence (IV, MS 1.64), social constraints (V, MS 1.59), economic constraints (VI, MS 1.48), language problem (VII, MS 1.40) and lack of competency of the resource person (VIII, MS 1.33) regarding rice cultivation. The data of wheat cultivation area in Table 1 pointed out the fact that most serious constraints experienced by the farm women, were physical (I, MS 2.58) and time constraints (II, MS 2.55) in getting technical information. Serious constraint perceived were social constraints (III, MS 1.90), lack of technical expertise (IV, MS 1.68) by the respondents whereas lack of competency of the resource person (V, MS 1.52), language problem (VI, MS 1.47), economic constraints (VII, MS 1.44), (VIII, MS 1.35) were perceived as not so serious constraints by the farm women of Jind and Kaithal districts in gaining technical information.

The results related to Sirsa and Fatehabad districts also reported in Table 1 indicated that most serious constraints perceived by the farm women were physical (I, MS 2.63), social constraints (II, MS 2.61), language problem (III, MS 2.53) and time constraints (IV, MS 2.50) experienced in getting technical information and lack of technical expertise (V, MS 1.80), lack of competency of the resource person (VI, MS 1.73), economic constraints (VII, MS 1.72) were perceived serious constraint by the farm women in getting technical information. Only one constraints *i.e.* lack of confidence (VIII, MS 1.55) was perceived not so serious constraint by the respondents in getting technical information regarding cotton cultivation practices of Sirsa and Fatehabad districts..

It can be concluded that in Karnal and

Table1: Constraints faced by respondents in getting technical information for different crop cultivation (N=485)

Sr. No.	Constraints	Karnal and Kurukshetra (N=170) Rice cultivation		Jind and Kaithal (N=165) Wheat cultivation		Sirsa and Fatehabad (N=150) Cotton cultivation	
		Weighted mean	Rank	Weighted mean	Rank	Weighted mean	Rank
1	Time constraints	2.52	III	2.55	II	2.50	IV
2	Lack of competency of resource person	1.33	VIII	1.52	V	1.73	VI
3	Lack of technical expertise	2.82	I	1.68	IV	1.80	V
4	Lack of confidence	1.64	IV	1.35	VIII	1.55	VIII
5	Physical constraints	2.57	II	2.58	I	2.63	I
6	Social constraints	1.59	V	1.90	III	2.61	II
7	Economic constraints	1.48	VI	1.44	VII	1.72	VII
8	Language problem	1.40	VII	1.47	VI	2.53	III

*Maximum score 3; Not so serious (low) 1 – 1.66; Serious (medium) 1.67 – 2.32; Most serious (high) 2.33 – 3.00

Kurukshetra districts the most serious constraints faced by the farm women were lack of technical expertise, physical and time constraints . But in Jind and Kaithal districts, physical, time constraints were perceived most serious by the respondents in getting technical information from various technical information sources about wheat cultivation practices.On contrary to this in Sirsa and Fatehabad districts, most serious constraints perceived by farm women were physical, social and language constraints respectively in order of preference. Same conclusions were arrived at by Natiker *et al.*, (1995), and Tantray and Dar (1996) and Trivedi and Patel (1996).

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Impact of *Bt* cotton (Bollgard II) on crop productivity: A decomposition analysis

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ABSTRACT : *Bt* cotton (BG II) hybrid has emerged as an advantageous alternative to *Bt* cotton (BG I) hybrids by inhibiting bollworm and cotton semiloopers, thereby improving farm production and income. This study focuses on analysing socio economic dynamics in adoption of *Bt* cotton (BG II) transgenic technology and farmers' constraints therein using the garret's ranking, considering primary data from *Bt* cotton progressive states of Madhya Pradesh. Field data collected in central India during the crop season 2010-2011 showed that the socioeconomic characteristics, average age of the respondents growing *Bt* cotton (BG I) and (BG II) was about (52 years), the majority of the respondents were literate (78%), having their education ranging from primary school to college level. Decomposition analysis of productivity difference between *Bt* cotton (BG II) and *Bt* cotton (BG I) indicated that the contribution of technological component in the productivity difference was positive and higher than the contribution of input differentials which signifies that with the existing level of input use in the control areas, the farmers could have increased the productivity level on growing *Bt* cotton (BG II) hybrid.

Key words : , Adoption constraint, *Bt* cotton (BG II), socioeconomic characteristics

Bt cotton is a genetically modified (GM) crop that contains genes from the soil bacterium *Bacillus thuringiensis*. These *Bt* genes make the plant resistant to certain insect pests, especially the cotton bollworms and related species, which are very damaging in many cotton growing regions of the India and are responsible for intense chemical pesticide applications (Zehr, 2010). The major cotton growing states in India are Maharashtra, Gujarat, Andhra Pradesh and Madhya Pradesh. The cotton yield reduction due to various pests attack is more than 50 per cent. The *Bt* cotton (Bollgard I) is a insect resistant transgenic crop against primary bollworms as American bollworm, pink bollworm and spotted bollworms of cotton which was commercialised in India during 2002. The commercialization of *Bt* cotton has spread in 2011 to 10.6 million ha from 50,000 ha in 2002.

A study was conducted on the adoption and economics of *Bt* cotton in four major *Bt* cotton growing states *i.e.* Andhra Pradesh, Gujarat, Maharashtra and Tamil Nadu. It was *Bt* cotton that offered good resistance to bollworms pests, the productivity in *Bt* cotton higher than non *Bt* cotton under both irrigated and rainfed conditions and the cost of cultivation was higher in *Bt* cotton due to high seed cost but the profit was found to be higher due to higher yield (Gandhi and Namboodiri, 2006). The bollgard I transgenic cotton is not able the control the secondary lepidopteran pests like tabacco caterpillar (*Spodoptera* sp*)* and cotton semiloopers. Their control can be possible only by chemical spray, but many of these also kill beneficial insects. The bollgard II *Bt* cotton provides effective season long control against key lepidopteran insect pests of tabacco caterpillar and cotton semiloopers. It can increase efficacy for control of bollworms and provides convenient insect management for cotton crop. The bollgard II event of *Bt* cotton was commercialized in 2006 by Genetic Engineering Approval Committee (GEAC). With this background, the present study is an attempt to decompose the total change in/ha output due to *Bt* cotton (BG II) into the technical change with the change in the input level and to examine socio economic dynamics in adoption of *Bt* cotton (BG II) transgenic technology and farmers' constraints therein.

The data has been collected through multistage sampling from a cotton progressive state of central India during 2010-2011. Madhya Pradesh state was selected purposely which covered about 6 per cent area of total *Bt* cotton in India. Within purposely selected Burhanpur district, two blocks were selected on the basis of highest area and production of *Bt* cotton. Further

4 villages were selected from each chosen block. Primary data have been collected through random sampling of 60 farmers from 4 villages of selected district. The *Bt* cotton farmers interviewed consisting of 37 *Bt* cotton (BG II) and 23 *Bt* cotton (BG I) farmers. The detail information from the *Bt* cotton producing farmers on socio economic and farming profile, input use and output, costs and returns were collected by using structured questionnaires. The data used for this analysis were collected from primary as well as secondary sources. Secondary data regarding area, production and productivity of *Bt* cotton in Madhya Pradesh were collected from the Agricultural Departments of respective district.

Analytical tools : The introduction of new technology in agriculture has many beneficial effects including increased output, employment, resource saving, etc. Subsequently, the method was used by several other workers as Umesh and Bisaliah (1986) and Kiresur *et al.*, 2011) to evaluate the technological gap in crop as well as dairy farming.

If *Bt* cotton (BG II) is an improvement over *Bt* cotton (BG I) then its' effects in terms of gain in productivity, should have occurred in two stages. Initially, more output is made available from the existing resource base under the new production technology (Bollgard II technology).

A descriptive analysis was carried out to compare the socio economic characteristics of sample farmers as well as productivity of major crops cultivated in the region. A production function technique was employed to decompose the differences in output of *Bt* cotton crop to assess the contribution of *Bt* cotton (BG II) technology and input effect. Cobb Douglas production function was used for the analysis as slope coefficients directly represent the elasticity of production in this functional form. The general form of the function used in the analysis was as below.

$$\ln Y_i = \alpha + \sum_{j=1}^{4} \beta_j \ln X_{ij} + u_i \quad \text{.........................(1)}$$

Where, Y_i is the output/ha for i^{th} farmer, X_{ij}'s are the/ha j^{th} input pertaining to i^{th} farmer, ? and β's are the scale and slope coefficients and u_i is independent and identically distributed random errors having normal distribution [$N(0, \sigma_u^2)$].

The input variables (X_j's) included in the model were quantity (in Rs/ha) of seed (X_1), fertilizer (X_2), machinery use (X_3) and labour (X_4). Production function was fitted and estimated separately for *Bt* cotton bollgard II and bollgard I areas.

The decomposition equation from the above production function was specified as below.

$$\text{Log}\,[Y^*/Y] = \log\,[?^*/?] + [(\beta_1^* - \beta_1)\log X_1 + (\beta_2^* - \beta_2)\log X_2 + (\beta_3^* - \beta_3)\log X_3 + (\beta_4^* - \beta_4)\log X_4] + [\beta_1^*\log(X_1^*/X_1) + \beta_2^*\log(X_2^*/X_2) + \beta_3^*\log(X_3^*/X_3) + \beta_4^*\log(X_4^*/X_4)] + (u^* - u) \quad \text{.......................................(2)}$$

where, Y^* and Y are the value of output/ha for the *Bt* cotton bollgard II and bollgard I crop farmers; X_j^*s and X_j's are the costs of j^{th} input at bollgard II and bollgard I farmers.

The equation (2) involves decomposing the natural logarithm of the ratio of gross returns at *Bt* cotton Bollgard II and Bollgard I farmers. The first bracketed expression on the right hand side is a measure of percentage changes in returns due to shift in scale parameter (?) of the production function; is attributable to the neutral component of technology. The second bracketed expression, the sum of the arithmetic changes in output elasticities each weighted by the logarithm of input used in *Bt* cotton (BG I) farmers, is a measure of change in output due to shifts in slope parameters of the production function (non neutral component of technology). The third bracketed term refers to the gap attributable to differences in the input use weighed by the slope coefficients of the production function fitted for *Bt* cotton (BG II) farmers explains the input effect.

General characteristics of sample farmers : An understanding of general characteristics of sample farmers is expected to provide a bird's eye view of the general features prevailing in the study area. Therefore, an attempt has been made in the study to analyse some of the important characteristics of the sample farmers. The general characteristics of the respondents are presented in the Table 1.

Socio economic profile of sample farmers: The number of selected farmers in the Madhya Pradesh state was 60, of which *Bt* cotton bollgard II farmers were 62 per cent *viz.*, 37 and *Bt* cotton bollgard I farmers and the rest with 38 per cent *viz.*, 23 (Table 1). The farmers from SCs and STs comprised 17 and 10 per cent, respectively in total sample size and the OBCs and others formed 56 and 17 per cent in total sample size respectively. The sample farmers have joint and nuclear families in a proportion of 38 and 62 per cent, respectively in total sample. The general characteristics on age, education, size of family and occupation of farmers was also presented in Table 1. The data in Table 1 that the average age of the respondents of *Bt* cotton bollgard I and bollgard II was about 52 years. It could be further observed that majority of the respondents were literate (88%), having their education ranging from primary school to college level. The remaining 12 per cent of growers were illiterates. From the data in Table 1, it could also be seen that the average size of the family was about 8 adults. It could also be seen from the same Table that 83 per cent of the respondents mainly depending on agriculture sector and the remaining 17 per cent of the respondents depends on subsidiary occupations for income.

Sources of productivity difference between *Bt* cotton BG I and BG II growers : A comparative analysis of productivity and input use for the *Bt* cotton crops grown in the selected region was done and presented in Table 2 and 3. Decomposition analysis was used to estimate the contribution of various sources to the productivity difference between bollgard II and bollgard I *Bt* cottons. The decomposition analysis showed that /ha production of *Bt* cotton (BG II) was 24.73 per cent higher than that of *Bt* cotton (BG I) (Table 2). The *Bt* cotton (BG II) technology component alone contributed 24.89 per cent to the total change in output, while the contribution of all other inputs was found negative but to a small extent (-1.02%). The major contributor amongst all the inputs to the productivity difference was the plant nutrients (0.43%). The only other input with positive but very low contribution was the human labour (0.05%). The effectiveness of *Bt* cotton (BG-II) technology in timely control of insect pests has led to the increase in cotton output. The seed cost, irrigation cost, land preparation and pesticides were found to be negatively contributing to the total gross returns, due to high negative magnitude of their input efficiencies.

The input used pattern presented in Table 3 revealed that cost of producing *Bt* cotton (BG I) and *Bt* cotton (BG II) were Rs 62853/ha and Rs 63139/ha, respectively. The average gross returns were Rs. 93630/ha and Rs 119903/ha for *Bt* cotton (BG I) and *Bt* cotton (BG II), respectively. The net return from *Bt* cotton (BG I) and *Bt* cotton (BG II) were Rs. 30778/ha and Rs. 56764/ha, respectively. This study showed that *Bt* cotton (BG II) hybrid production is more profitable than *Bt* cotton (BG I). The average

Table 1. Socio economic profiles of sample farmers in Madhya Pradesh

Particulars	*Bt* cotton (BG I and BG II)		Burhanpur
Bt cotton farmers	BG I		23 (38)
	BG II		37 (62)
Community of sample farmers	SC		10 (17)
	ST		6 (10)
	OBC		34 (56)
	Others		10 (17)
Type of Family	Joint		23 (38)
	Nuclear		37 (62)
	BG I	**BG II**	
Average family size (Number of family labourer)	7	8	8
Average age of farmer (yrs)	52	52	52
Education levels:			
A.) Illiterate	4	3	7 (12)
B.) Primary	15	17	32 (53)
C.) Secondary	4	12	16 (27)
D.) Higher secondary and above	-	5	5 (8)
Main occupation agriculture	21	29	50 (83)
Subsidiary occupation agriculture	2	8	10 (17)
Total	**23**	**37**	**60 (100)**

Figures within parentheses indicate percentage of sample farmers and percentage to the total

Table 2. Estimates of decomposition of output changes between BG I and BG II technology and inputs in *Bt* cotton production in Madhya Pradesh (Percentages)

Sources of output difference	Per cent contribution
A. Technical change	24.89
• Neutral technological difference	303.58
• Non-neutral technological difference	-278.69
Total	**24.89**
B. Due to difference in input use level	
• Land preporation	-0.01
• Seed	-0.96
• Plant nutrient	0.43
• Irrigation	-0.52
• Human labour	0.05
• Pesticide	-0.01
Total	**-1.02**
Total estimated difference in output	**23.87**
Total observed difference in output	**24.73**

Table 3. Input use pattern (Rs/ha) for cotton (BG I) and *Bt* cotton (BG II) growers (2010-2011)

Particulars	Burhanpur (Madhya Pradesh) (N=60)	
	Bt cotton (BG I) Mean	*Bt* cotton (BG II) Mean
Land preparation	3932	3934
Seeds cost	1687	1859
Plant nutrients	16443	17725
Irrigation	8153	6750
Human labour	30487	30058
Pesticide	3360	2812
Gross cost	62853	63139
Yield	25	32
Gross revenue	93630	119903
Net returns	**30777**	**56764**

return to each rupee spent in production is a vital criterion for measuring the profitability of growing any enterprises. The estimated coefficients and related statistics of Cobb Douglas production function of *Bt* cotton (BG I) and *Bt* cotton (BG II) are shown in Table 5. The regression coefficient of plant nutrient and cost of irrigation were positive and not significant for both the *Bt* cotton (BG I) and BG II production. The impact of the variables such as seed cost was negatively significant for both *Bt* cotton (BG I) and BG II production of which seed cost showed the negative effect on production. The coefficient of pesticides cost for *Bt* cotton BG II and BG I production were found significant indicating that they exerted significant influence on the output. The coefficient of land preparation, seed cost, plant nutrient, cost of irrigation, human labour cost and pesticides cost for *Bt* cotton BG II and BG I production were not found significant indicating that they did not exert any significant influence on the output.

Table 4. Production function estimates of BG I and BG II *Bt* cotton production systems

Particulars	Symbol	BG II	BG I	**Pooled**
Number of observations	n	37	23	**60.00**
Intercept	b_o	12.37	9.34	**11.42**
Land preparation	L	-0.19	0.39	**-0.03**
		-0.24	-0.41	**-0.20**
Seeds cost	S	-0.40***	-0.44**	**-0.14**
		-0.17	-0.24	**-0.16**
Plant nutrients	N	0.06	0.11	**0.09**
		-0.04	-0.07	**-0.03**
Irrigation	I	0.03	0.06	**0.03**
		-0.03	-0.12	**-0.03**
Human labour	H	0.08	-0.12	**0.01**
		-0.36	-0.44	**-0.26**
Pesticide	P	-0.04*	0.04	**0.01**
		-0.02	-0.05	**-0.02**
Dummy variable BG II	Bt	-	-	**0.26**
				-0.03
Coefficient of multiple determination	R^2	0.44	0.33	**0.73**
Adjusted R^2	$?^2$	0.39	0.29	**0.69**
F value	F	15.65	11.29	**20.02**

Figures in parenthesis indicate standard errors of coefficients
***, ** and * indicate that the mean values between BG II and BG I observations are signifcantly different at 1, 5 and10 per cent, respectively.

CONCLUSION

The analysis revealed that the productivity difference between *Bt* cotton (BG II) and *Bt* cotton (BG I) farmers was largely attributable to improved *Bt* technology. The plant protection had positive influence on output on *Bt* cotton (BG II) farms while it was negative influence on *Bt* cotton (BG I) farms. The plant protection chemical, human labour and other inputs were used optimally by *Bt* cotton (BG II) farmers as against excessive use by *Bt* cotton (BG I) farmers. The decomposition analysis carried out to disaggregate the effect of various factors which caused differences in output between *Bt* cotton (BG II) beneficiaries and *Bt* cotton (BG I) beneficiaries revealed that *Bt* cotton (BG II) hybrid contributed mostly for the variation. Therefore, it is necessary to motivate the farmers for cultivation of improved hybrid Bt cotton (BG II) with appropriate extension strategies and policy measures.

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NEW RECORD

Evolution of five groups of anthers in thermo sensitive genetic male sterility (TGMS) cotton (*Gossypium arboreum* L)

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In *Gossypium* sps the flowers had single anther column with group of anthers is common feature, but the present study in *Gossypium arboreum* thermo sensitive genetic male sterility 5 (Ga TGMS 5) revealed the presence of single anther column with five groups or bundles of anthers opposite to petals, both cases the flowers are epipetalous in nature. **It is the first kind of information to the botanical world.** The normal flower and flower with five groups of anthers were presented in Plate 1, evolutionary role of these mutants is not yet traced. **This is the first kind of information in cotton.**

In *Gossypium* spp the flowers had single anther column with group of anthers is common feature. But the present study in Ga TGMS 5 revealed the presence of single anther column with five groups or bundles of anthers, both cases the flowers are epipetalous in nature. Evolutionary role of this mutant is not yet traced. These results are in harmony with Brongniart *et al.*, (1845).

Brongniart, Richard and De Jussieu., 1845 XXIX. Report on a memoir by M. P. Duchartre, entitled Observations on the organogeny of the flower of the Malvaceæ? *Annals and Magazine of Natural History* **16** : 240-47.

a) Normal

b) Five groups of anthers

Plate 1: Normal and mutant with five groups of anthers

FORM IV

(See Rule 8)

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