4.8: Nutrient Management

Nagpur

Long term effects of fertilizer and INM (Integrated Nutrient Management) on productivity, soil fertility and quality of cotton under rainfed condition

In Bt cotton, continuous adoption (4th year) of integrated nutrient management practice (N_{60} P_{30} K_{30} S_{20} $Zn_{4.5}$ + 5 t FYM +PSB+ 2 % DAP spray) produced 18.2 q/ha of seed cotton which was significantly higher than that obtained through the application of RDF + 2 t/ha goat manure + 2 t / ha FYM (16.2 q/ha) or 15 t/ha of FYM alone (15.3 q/ha) or under farmers' practice (13.7 q/ha). Deletion of K from the recommended NPK dose significantly reduced the yield. The INM treatment also increased the yield of strip intercropped (8:2) pigeon-pea. Higher nutrient use efficiency, organic carbon and microbial population of phospho-bacteria were observed in INM and organic plots.

Efficacy of micronutrients and moisture management in improving growth, yield and fibre properties of hybrid cotton in vertisols

Studies on hybrid (NHH 44) cotton under rainfed conditions of CICR farm for four years (2004-07) on shallow soils and six years (2002-09) on medium deep soils indicated that there was no significant response to micronutrient (Zn, Mn and B) supplementation in shallow soil but medium deep soils were benefited by their application. On medium deep soils, application of 10 kg each of $ZnSO_4$ and $MnSO_4$ alongwith 3 kg Borax per ha improved seed cotton yield by 203 kg /ha (16 % higher than control). Providing 2 supplemental irrigations (at flowering and boll formation stages) alongwith the above micronutrients improved the yield by 250 kg /ha (19 % higher than control). Under irrigated conditions, shallow soils may respond to B application (@ 3 kg/'ha Borax) to the extent of 200 kg/ha (21 % higher than control).

Integrated approach for yield maximization of hybrid cotton under drip irrigation

On shallow soil, fertigation i.e. application of 50% of N120 P60 K60 through soil + 50% of N120 P60K60 through drip irrigation (fertigation) along with addition of zinc and bio-fertilizer significantly increased seed cotton yield of hybrid (NHH 44) over soil application alone.

Reddening in Bt cotton leaves was reduced by 30-40 % with foliar application of Urea @ 2% +DAP @ 2% +$MgSO_4$ @ 1% given at boll formation stage.

Synchronizing N and K supply with crop demand

At Nagpur, synchronizing the N and K supply in Bt cotton in relation to Bt cotton crop demand through the application of N and NK in 3 splits (10, 30 and 60 DAS) produced higher seed cotton yields of 24.0 q/ha and 24.5q/ha, respectively.

Synchronizing N and K supply with crop demand to enhance water and nutrient use efficiency

At Coimbatore, highest yield (3570 kg/ha) was recorded under 4 splits followed by 3 splits (3495 kg/ha), 5 splits (3463 kg/ha) and 2 splits (3120 kg/ha).There was also a progressive decrease in crop water use from 2 splits (66.2 cm) to 5 splits (63.8 cm). The increase in water use in 2 splits, 3 splits and 4 splits was 2.4, 2.5 and 1.2 cm over that in 5 splits. Consequently, highest WUE was observed in 4 splits (55 kg/ha-cm) followed by 5 splits (54.3 kg/ha-cm), 3 splits (52.7 kg/ha-cm) and 2 splits (47.1 kg/ha-cm). Thus, under the existing situation of semi arid condition, 4 splits of N only may be required for highest efficiency.

Among the fertilization techniques, application of 100 % of recommended NPK (120:60:60 kg/ha, N and K in four equal splits) with either foliar spraying of 0.15 % boron as solubor (twice) during flowering to boll development stages or magnesium sulphate @ 50 kg/ha as drip fertigation were on par with application of either 100 % of NPK with 50 kg each of zinc sulphate, magnesium sulphate and foliar spraying of boron 0.15 % as solubor or 75 % of all the above combination.

N application significantly improved the seed cotton yield of Bt cotton (RCH 2). However, there was no significant difference in the seed cotton or lint yield due to 60, 90 and 120 kg N/ha. There was significant reduction in the earliness index at higher irrigation and nitrogen levels.

There was increase in the water use efficiency due to N application @ 60 and 90 kg N/ha over no nitrogen control in Bt cotton (RCH 2) grown under irrigated conditions at Coimbatore on a vertic ustropept.

However, there was no significant difference in the water use efficiency due to 60, 90 and 120 kg N/ha. The water productivity (i.e. Rupees earned through cotton produce per m^3 of water consumed) also followed the similar trend as that of water use efficiency. N levels (60, 90 and 120 kg N/ha) did not influence the nitrogen utilization efficiency significantly. However, partial factor productivity of nitrogen (PFPN) (i.e. kg seed cotton yield per kg N applied) decreased significantly with the increase in N levels. The nitrogen use by cotton (kg N uptake/ tonne of seed cotton yield) was statistically at par for the N levels used.

Organic recycling and integrated nutrient management

At Coimbatore, an integrated plant nutrient system involving rational and appropriate use of dried neem leaves/twigs @ 5 t/ha applied as a soil cover or incorporated in the furrows along with recommended NPK (60:13:25 kg/ha) is suggested for higher production, net returns and improved physico-chemical properties of soil.

Outcome of the trials at Coimbatore, confirms that simultaneous planting of sunnhemp at the seed rate of 15 kg/ha and cotton at the normal seed rate in ridge-furrow planting, followed by burying of green manure *in situ* at 40-45 DAS (but before flowering) with 50% RD-N (30 kg) and earthing up is recommended under medium land and irrigated condition. N application can be skipped if FYM @ 5 t/ha is applied at pre-planting as maximum biological efficiency (11.6 kg dry weight/kg NPK) was observed under green manure +FYM @ 5 t/ha. Under rainfed conditions in Nagpur, application of 50% of the recommended N through organic sources and remaining N through fertilizers improved the yield and N use efficiency in Bt cotton (NCS-145) over application of 100% N through fertilizers.

Nutritional management to reduce the premature senescence in Bt cotton

The balanced fertilization package includes, application of recommended NPK with N and K in splits of either at 4,6 or 8 applications along with magnesium sulphate (50 kg as basal) and boron as solubor at 1 kg basal) combined with foliar spraying of DAP (1.5 %) + K (0.5 %) + magnesium sulphate (0.5 %) + solubor (0.15 %) twice during flowering to boll development stages.

Among the fertigation schedules tested, application of 100 per cent recommended level of fertilizer (90:45:45 kg NPK ha^{-1}) through drip recorded significantly highest (3345 kg ha^{-1}) seed cotton yield and was on par with the 125 per cent of recommended fertilizer but, significantly higher than 75% RDF (Table 20). Soil application of recommended fertilizer (3 splits) had produced (3063 kg ha^{-1}) statistically equal to the yield with fertigation of 75% RDF (3006 kg ha^{-1}). Thus, it indicates that 25 % of fertilizer saving is achieved in drip fertigation as compared to soil application of fertilizers. Economic analysis revealed that drip irrigation scheduling @ 0.8 ETc combined with fertigation of 100 per cent RDF recorded highest gross return (Rs.110623/ha), net return (Rs.70338/ha) and benefit cost ratio of 2.7

Table 20: Seed cotton yield (kg/ha) maximization techniques

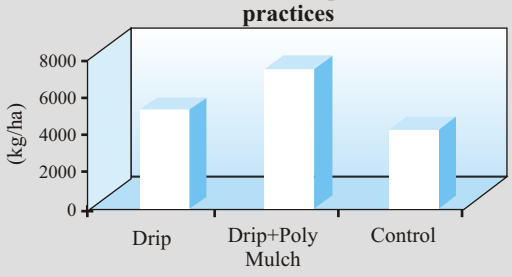
Fertilizer Levels	Seed cotton yield (kg/ha)			Water used (cm)	WUE (kg/ha-cm)	Water productivity
	I Pick	II Pick	Total			
F1.75% RDF(Fertigation)	2037	969	3006	52.7	57.0	1753
F2.100% RDF(Fertigation)	2460	885	3345	52.7	63.5	1575
F3.125% RDF(Fertigation)	2285	942	3227	52.5	61.5	1627
F1.100% RDF (Soil)	2139	924	3063	52.6	58.2	1717
SEd	102	75	111			
CD(5%)	221	NS	229			
CV(%)	11	20	9			

4.9 : Irrigation Water Management

Drip fertigation of major, secondary and micronutrients for enhancing the productivity of ELS Bt Cotton

Field experiment was conducted at Coimbatore, in factorial RBD with three water conservation techniques *viz.,* drip, drip + poly mulch and conventional irrigation along with six fertilization practices to find out the optimum water conservation method and to standardize the optimum fertilization technique for ELS Bt cotton, RCHB 708. The results revealed that the ELS Bt cotton responded significantly to poly mulch + drip and drip method. The enhancement in seed cotton yield was 27.7% due to drip and 86.5% due to drip + poly mulching .

Fig. 14 : Yield kg/ha in ELS cotton influenced by water conservation techniques & fertilisation practices



Effect of precision application of irrigation through drip on productivity and fibre quality of Bt cotton

Highest seed cotton yield of 3369 kg ha^{-1} was harvested from the plot that received irrigation through drip @ 0.8 ETc. However, surface method of irrigation @ 0.6 IW/CPE produced (3185 kg ha^{-1}) on par results with that of drip irrigation @ 0.8 Etc (Table 21).

Crop water use (Table.21) progressively increased from 0.6 ETc (38.7 cm) to 1.0 ETc (59 cm) and 0.6 IW/CPE ratio (63.3 cm). Thus, there was an average 30 % higher water use in surface irrigation applied at 0.6 IW/CPE ratio (64 cm) over the mean water use (49.3 cm) through drip. Consequently, highest WUE (in terms of kg/ha^{-cm}) was observed in 0.6 ETc (70.8) followed by 0.8 ETc (68.3), 1.0 ETc (56) and 0.6 IW/CPE (49.9), thereby indicating the highest productivity efficiency per unit water use at 0.6 and 0.8 ETc. Based on consumptive use of water, around 1464 litres of water was used per kg of seed cotton under 0.8 ETc drip (1412 litres in 0.6 ETc) in comparison to 2004 litres/kg of seed cotton in surface furrow irrigation through IW/CPE of 0.6. Thus, economizing in crop water use without impacting yield, drip irrigation scheduling at 0.8 ETc was optimum.

4.10 : Soil Moisture Conservation

Different soil moisture conservation techniques along with fertilizers were evaluated in Bt cotton (NCS 145) on a deep black soil at Nagpur. Results indicate that highest seed cotton yield as well as cotton equivalent yield was obtained through the intercropping with green gram (Fig 15). Application of 50% N of recommended dose through organic manure (FYM) +50% N through inorganic fertilizer was superior to RDF. Cotton intercropped with green gram also gave significantly higher economic yield over ridges and furrows. Seed cotton yield enhanced by about 2 q/ha by mulching with sunnhemp (over ridges and furrows practice). Higher WUE and water productivity was found under intercropping with green gram in cotton and *in situ* mulch treatments (Fig. 15).

Table 21: Water Use Efficiency (WUE) under drip and surface irrigation

Irrigation Schedule	Water used (cm)	WUE (kg/ha-cm)	Water Productivity
1. Drip 0.6ETc	38.7	72.0	1390
2. Drip 0.8 Etc	49.4	68.2	1466
3. Drip 1.0 ETc	59.0	56.0	1787
4. Surface 0.6 IW/CPE	63.3	50.3	1987

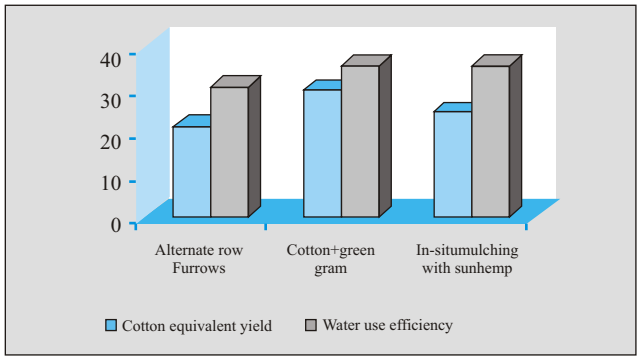


Fig. 15: Cotton equivalent yield (q/ha) and water use efficiency (kg seed cotton / ha-cm) under different soil moisture conservation measures

4.11 : Cropping Systems

Identification of innovative Bt cotton based cropping systems at Nagpur

Among the legumes, soybean offered maximum competition which significantly lowered the cotton yield. Similar to cotton + pigeon pea, cotton + cowpea /cluster bean/ radish had positive effect on seed cotton yield. There was significantly higher competition for N with cotton+ soybean, cow pea, cluster bean, and marigold. The best cropping system was Bt hybrid cotton + radish in terms of water use and nutrient uptake. Cotton + marigold, green gram or spinach were statistically similar to sole cotton yield, but offers better rural food security. The net profits were statistically similar among cotton + spinach (69%), marigold (76%), soybean (71%) and black gram (80%) as intercrop in Bt hybrid cotton. The next best group is cotton + green gram (96%), cluster bean (103%) and radish (194%) among vegetable group. The cotton plant analysis at 90 DAS indicated a significant competition for N, K in cotton with soybean and other intercrops, besides other legumes such as cowpea cluster bean.

Improving the efficiency of cotton + pigeon pea strip cropping

The pooled analysis of data indicated that cotton + pigeon pea planted in 6:2 and 12 : 2 ratio was economic and profitable for hybrid and *desi* cotton, respectively. *Desi* cotton responded favourably to plant populations beyond 28 thousand and therefore needs to be planted as close as possible. Failure to flower in 1 out of 6 years was also noticed. In hybrid cotton as well as in *desi* cotton, application of 50% RDF + Bio-fertilizers consortia (*Azotobacter, Azospirillum,* PSB, *Trichoderma viridae* and *Pseudomonas* sp as seed treatment + 2% urea/ D.A.P. + 1% Potash and micronutrient spray twice at flowering produced statistically similar yields to that of recommended dose of fertilizers.

Effects of Crop Rotation (Coimbatore)

Cotton in cotton-sorghum (pooled over 5 years) significantly out yielded (1427 kg/ha) cotton-fallow (1160 kg/ha) due to higher efficiencies in terms of nutrient use, water use and moderation of saline water effect (>3.5 EC). Besides improving efficiency of crop production, quality of seed cotton and sustainable yield index (SYI) in cotton, productivity of cotton-sorghum system was supplemented with 6547 kg/ha of grain sorghum (Table 22). Application of 90 kg N/ha (with no P & K) to sorghum also increased its grain yield by 4.2 q/ha over control (sorghum grown on residual fertility) over the years (Table 22). Based on consumptive use of water, around 4048 and 3257 litres of water were used per kg of seed cotton under cotton-fallow and cotton-sorghum, respectively. Highest WUE (30.7 kg/ha-cm) along with low water use (58.8 cm) was measured in cotton under cotton-sorghum system (24.7 kg/ha-cm and 63.6 cm respectively under cotton-fallow). In addition, highest water productivity (WP, Rs.6.86/M^3) and highest nutrient use efficiency (NUE, 17.8 kg seed cotton/kg NPK uptake) were calculated under cotton-sorghum in comparison to cotton-fallow (WP of Rs.5.52/M^3 and NUE of 13.6 kg seed cotton/kg NPK), thereby reiterating the positive effect of sorghum on cotton.

Application of INM (*viz.,* NPK@ 30:30:30+ 5t/ha of FYM added annually) followed by RDF (60:30:30 kg NPK/ha) registered significant yield increase over control during the years (Pooled data, Table 22). Although RDF (balanced NPK) was optimum under the existing condition, yet INM was better in terms of crop performance and soil fertility. Highest WUE (32.9 kg/ha-cm) along with low water use (56.5 cm) was also observed with INM practice. In addition, maximum water productivity of Rs. 7.35/M^3 was also calculated with INM practice followed by that in RDF (Rs.6.98/M^3). Yet, in case of marginal and small land holdings, RDF alone (with WUE of 31.3 kg/ha-cm and water use of 55.3 cm) was economical and was sufficient to sustain the yield.

Since productivity responses to higher levels of NPK @ 90:19:37 and 90:19:0 were similar, K application can be made once in 2-3 years depending upon crop rotation for maintenance only.

Multi-tier cropping system for Coimbatore

Three multi tier cropping systems (cotton + radish + beet root + coriander, cotton + radish + cluster bean + beetroot and cotton + coriander + vegetable cowpea+ cluster bean) were selected by consecutive experimentation of three years. Identified multi-tier systems are highly intensive one, which resulted in reduction in available nutrient status and yield reduction of base crop of cotton in some of the years.

In general, none of the systems and fertilizer levels had significantly influenced the seed cotton yield of base crop of cotton. However, systems and fertilizer levels (intercrops) had influenced significantly the intercrop yield, system productivity and profitability. Amongst the intercrops tested, coriander and cluster bean yield were significantly influenced by the systems. Fertilizer levels significantly influenced the radish and cluster bean yield. Beet root yield was influenced significantly either by system or fertilizer levels.

The highest seed cotton equivalent yield (53.2 q/ha) and gross return (Rs 1,06,435 /ha) and net return (Rs 69,386/ha) were arrived with the multi-tier intercropping of cotton with radish, beet root and coriander with the application of 100 per cent of recommended level of fertilizers to intercrops (Table 23).

Table 22: Interaction effects of cropping systems and nutrient levels on crop yield (Pooled analysis over five years)

Nutrient levels (kg/ha)	Seed cotton yield (kg/ha)			Sorghum grain yield (kg/ha)
	cotton-fallow	cotton-sorghum	Mean	
Control	1071	1313	1192	6181
RDF (60:13:25)	1246	1435	1340	6551
N (90)	1136	1456	1296	6566
NP (90:19)	1213	1446	1329	6768
NPK (90:19:37)	1176	1354	1265	6552
15 t FYM	1211	1357	1284	6712
RDF+ 5 t FYM	1126	1556	1341	6556
RDF+ 2.5 t CRI*	1100	1494	1297	6492
Mean	**1160**	**1427**	**-**	**6547**
	Crop. Sys.	**Nut. Lev.**	**Interaction**	
SE (d)	27.9	46.5	65.7	149
C.D.(0.05)	62.2	92.2	130.4	316
C.V. (%)	16.7	13.9	13.9	5.9

*Crop Residue Incorporation

Table 23: Yield, equivalent yield and economics as influenced by multi tier system and fertilizer levels

Treatments	Seed cotton yield (q/ha)	Equivalent yield (q/ha)	Gross return (Rs/ha)	Net return (Rs/ha)
T1.50%RDF(IC).+C+Co+V.C+C.b	27.4	43.8	87639	46429
T2.75%RDF(IC)+C+Co+V.C+C.b	29.1	51.7	103322	56894
T3.100%RDF(IC)+C+Co+V.C+C.b	28.6	52.9	105779	58857
T4.50% RDF(IC).+C+R+B+Co	27.3	45.8	91687	56308
T5.75% RDF(IC)+C+R+B+Co	28.6	50.3	100629	64137
T6.100% RDF(IC)+C+R+B+Co	28.4	53.2	106435	69386
T7.50% RDF(IC)+C+R+C.b+B	24.3	43.2	86334	43678
T8.75% RDF(IC)+C+R+C.b+B	26.6	53.2	106498	58200
T9.100% RDF(IC)+C+R+C.b+B	27.6	51.8	103674	56751
T10.Sole cotton	26.2	26.2	52301	27584
SEd	3.3			
CD(5%)	NS			
CV(%)	15.0			

C=Cotton, R=Radish, Co=Coriander, B=Beet root, C.b=Cluster bean,
V.C.= Vegetable Cowpea, RDF= Recommended Dose of Fertilizers

Intensification of cotton based cropping system for maximizing the use of natural resources under irrigated conditions of Sirsa

Double cropping system

To find out the profitable crop rotation system with Bt cotton hybrids (RCH 134 and MRC 6304) under north zone with normal sowing as well as transplanting of seedling system, six crop combinations (Cotton normal, Cotton transplanted followed by wheat, barley and mustard in both cases) were evaluated with recommended agronomic and plant protection measures. The boll per plant, dry matter and seed cotton yield were observed significantly higher in transplanted cotton crop. Among *rabi* crops, the yield/ha of barley after cotton was 38.63 quintal in normal cotton sown field and 39.41 quintal in transplanted cotton field. This in turn was slightly higher to wheat after cotton (38.13 quintal in normal cotton sown field, 38.00 quintal in transplanted cotton field) where as the yield/ha was minimum of mustard after cotton (13.50 quintal in normal cotton sown field, 12.90 quintal in transplanted cotton field). The highest net income per hectare of Rs 46935 and 51315 was observed in cotton followed by wheat with normal as well as transplanted cotton sown field, respectively where as minimum net income was observed in cotton-mustard cropping system.

***Kharif* intercropping system**

Experiments were carried out with the aim to find out the economical intercrop (cotton with groundnut, moong bean, cluster bean and sesamum) combination for this zone. The yield was higher in paired row crop without any intercrop because of higher plant population per hectare. The net return Rs. 50766 /ha and B : C ratio (3.2) was higher under paired row cotton without any intercrops followed by paired row cotton with mungbean inter crop Rs. 49920 /ha. None of the evaluated integrates were suitable.

4.12 : Planting Geometry

Growth and yield performance of Bt and non Bt cotton under poly mulching and planting techniques

At Coimbatore, though the single row and triangular planting produced higher number of harvestable bolls/plant, the enhanced boll load could not compensate the population loss as compared to double row planting . The poly mulched Bt under double row planting recorded the highest seed cotton yield of 5670 kg/ha as compared to 3330 kg/ha under non mulching. The triangular planting was on par with double row planting in terms of seed cotton equivalent yield.

Agronomy of population density in variety vs. Bt hybrid

High density planting maintained through narrow row spacing of 90 x 10 cm in cotton variety (Surabhi with 2241 kg/ha) resulted in seed cotton yield on par with Bt cotton hybrid (RCH-2 with 2554 kg/ha) at a spacing of 90 x 45 cm. Thus, comparable yields can be realized with the existing straight varieties with that of Bt hybrids. Moreover, significantly lower seed cotton yield was obtained in varieties (2043 kg/ha) with wider spacing viz., 75 x 30 cm (recommended spacing) and 60 x 15 cm (1936 kg/ha). Therefore, higher yield (and nutrient uptake) realized under narrow row planting (90 x 10 cm) depicted the role of high density planting for realizing higher yield especially in varieties.

4.13 : Agronomy for Extra Long Staple Cotton

Yield maximization trial was conducted at Coimbatore to identify packages to increase the productivity of ELS Bt hybrid. Breaking of sub soil compaction by chisel ploughing and adoption of drip system for irrigation and fertigation (low cost drip system) combined with foliar application of poly feed (19:19:19) @ 1 % at 75 and 105 DAS and multi K (13:0:46) at 90 DAS registered the highest seed cotton yield (2732 kg/ha). Chisel ploughing, foliar sprays and drip fertigation increased seed cotton yield of ELS hybrid over control by 5, 7, and 10 per cent respectively (Table 24). The least total quantity of water used (49.4 cm), and the amount of water required (liters) to produce one kg of seed cotton (1808 lit) and the highest water use efficiency (55.31 kg ha-cm) were calculated with the above said package.

Table 24: Seed cotton yield (kg/ha), economics, water use efficiency (WUE) of yield maximization techniques

Techniques	Seed cotton yield (kg/ha)	GR (Rs/ha)	NR (Rs/ha)	B/C ratio	Water used (cm)	WUE (kg/ha-cm)	W.Pdy (l/kg)
Y1.Control	2288	68640	41200	2.50	63.3	36.1	2767
Y2.Chisel	2431	72930	42275	2.38	63.3	38.4	2604
Y3.Foliar (2 sprays)	2410	72300	42750	2.45	63.3	38.1	2627
Y4.Chisel + Foliar (2 sprays)	2567	77010	44175	2.35	63.3	40.6	2466
Y5.Chisel + Drip	2646	79380	43150	2.19	49.4	53.6	1867
Y6.Chisel + Drip + Foliar (2 sprays)	2675	80250	42375	2.12	49.4	54.1	1847
Y7.Chisel + Drip + Foliar (3 sprays)	2732	81960	43050	2.11	49.4	55.3	1808
SEd	165						
CD(5%)	359						
CV(%)	8						

Water Management of ELS Bt Cotton

Field experiment was conducted during Winter 2007 - 08 to find out the response of ELS Bt cotton, RCHB 708 under drip, poly mulching and drip + poly mulching as compared to conventional irrigation. The highly conducive growth environment under poly ethylene mulching and poly mulch + drip system has resulted in significant increase in harvestable bolls contributing significantly to higher seed cotton yield ranging from 37.6 to 59.1 per cent higher yield than conventional method (Table 25). The yield enhancement due to drip system was 8.16 21.6 % higher than conventional method. The poly ethylene mulch + drip at 0.4 Etc recorded 30.9% higher seed cotton yield than drip at 0.8 Etc without poly ethylene mulching. Among the treatments, poly mulch + drip at 0.4 Etc was on par with poly mulch + drip at 0.8 Etc and found significantly superior to rest of the treatments.

Table 25: Yield attributes, seed cotton yield, water requirement and water use efficiency of RCHB 708 Bt as influenced by drip, poly mulching and drip + poly mulching

Treatments	Bolls/ plant	Boll wt (g/boll)	Seed cotton yield (kg/ha)	WR*	WUE
T1- Control	58.3	4.93	3825	77.54	49.4
T2 - Poly mulching	71.2	5.34	5262	45.54	115.6
T3 - 0.4 Etc (Drip)	59.8	5.41	4137	37.60	110.0
T4 - 0.4 Etc (Drip) + PM	77.4	5.60	6087	37.60	161.9
T5- 0.8 Etc (Drip)	64.3	5.29	4650	40.58	114.6
T6 - 0.8 Etc (Drip) + PM	72.8	5.47	5637	40.58	138.9
CD (P=0.05)	11.7	NS	551		

WR*includes 25. 54 cm of effective rainfall

The cropping season witnessed a heavy effective rainfall of 25.54 cm and the total water requirement ranged from 37.60 to 77.54 ha cm for various treatments. Poly mulched cotton with or without drip recorded higher water use efficiency than drip alone without poly mulching. Among the treatments, drip at 0.4 Etc + polyethylene mulching recorded the highest water use efficiency of 161.9 kg seed cotton /ha-cm in RCHB 708 Bt as against 114.6 kg seed cotton/ha-cm at drip at 0.8 Etc without poly ethylene mulching. The lowest water use efficiency of 49.4 kg/ ha-cm has been recorded under conventional method.

4.14 : Soil Depth

Seed yield and quality in released *G. hirsutum* and *G. arboreum* cultivars in relation to soil depths at Nagpur

Growth responses of *G. arboreum* (CINA 2, CINA 316, PA 255, PA 402) and *G. hirsutum* cultivars (PKV 081, PKV 8828, NH 615, NCS 145) were studied in relation to shallow, medium and deep soils. *G. hirsutum* cultivars possessed more number of squares per plant in all the soil types. In both diploid and tetraploid cotton, distribution of biomass into root, stem and fruiting parts remained higher under shallow soil growing condition, whereas leaf biomass was higher in cultivars grown in medium soil.

4.15 : Soil Microbiology

Effect of Bt cotton production technologies on soil microbial population

Rhizosphere soils were analyzed for the microbiological properties under the experiment "Long term effect of fertilizers and INM on productivity, soil fertility and quality of cotton". Higher microbial population (general) was observed in the treatment

(N_{90}:P_{45}:K_{45}:S_{20}:Zn_{20}) followed the treatment (N_{60}:P_{30}:K_{30}:S_{20}:Zn_{20} and FYM 5T). Under the physiological groups of microbes, higher population was recorded with the treatment of INM all the years.

Analysis of soil microbial population between Bt and Non Bt Bunny cotton revealed no significant differences with regard to microbial population between Bt and Non Bt cotton, but higher microbial population was recorded in Qrganic blocks which acted as absolute control in the experiment (Fig. 16).

4.16 : Cotton Simulation Modelling

The validation of the generic simulation model

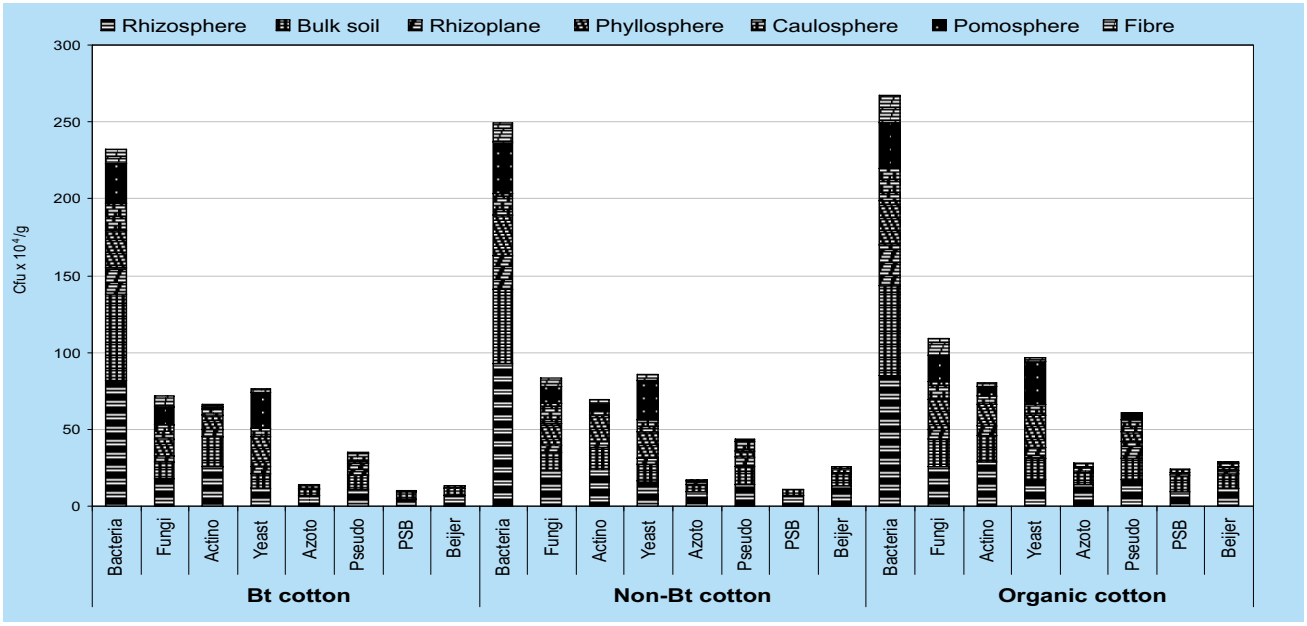


Fig. 16: Rhizosphere microbiology of Bt, Non Bt and organic cotton

Table 26: Observed and simulated seed cotton yield of RCH 2 Bt cotton under varied irrigation and nitrogen levels (Pooled over 2006-07 and 2007-08)

Treatment	Observed seed cotton yield (kg/ha)	Simulated seed cotton yield (kg/ha)	Deviation (%)
Irrigation			
Control (Protective irrigation)	2158	1906	-11.7
0.6 IW/CPE	2056	1970	-4.2
0.8 IW/CPE	1980	1968	-0.6
1.0 IW/CPE	2103	1961	-6.7
Nitrogen			
Control	1819	1866	+2.6
60 kg N/ha	2087	1960	-6.1
90 kg N/ha	2203	1980	-10.1
120 kg N/ha	2188	1998	-8.7
#RMSE = 257 (12.4%); D = 0.492; MSEs = 588685; MSEu = 7458			

(RMSE = root mean square error; D = index of agreement; MSEs = Mean systematic error and MSEu = mean unsystematic error)

INFOCROP showed that the root mean square error between the observed and simulated yield was 257.1, which was 12.4% of the mean observed seed cotton yield (Table 26). However, the model under-predicted seed cotton yield at higher N levels, warranting further fine tuning. The index of agreement (D index) between the observed and simulated seed cotton yield was 0.492.

4.17 : Cotton Mechanisation

Development of small farm equipment for cotton farmers Improved bullock drawn implements were developed for increased efficiency for the small and marginal cotton farmers.

Bullock drawn vertical rotor precision planter

A bullock drawn precision planter with an innovative vertical rotor metering mechanism having the advantages of reduced seed damage and uniform seed placement was developed. This was tested at CICR farm and the results revealed that the average depth of seed placement was 6 cm, the seed rate was 5.2 kg/ha, field germination percentage was 84 per cent and the field capacity was 4.5 hours / ha.

Iron plough with sowing attachment For primary tillage operation of ploughing and sowing of rabi crops like gram.

Ridger For making ridges in between the rows in standing crop of cotton for enhanced soil moisture conservation and also act as a channel for irrigation. It can also create ridges and furrows before sowing.

Iron Plough

Adjustable hoe

Ridger

Bund former

Adjustable hoe For interculture operation in cotton based cropping systems. Various sizes of blades (9", 12" & 18") can be accommodated in a frame, with quick coupling and decoupling.

Bund former For making bunds in the fields to facilitate easy surface irrigation

Identification of suitable genotypes for mechanical picking

Four genotypes namely, PKV 08, Khandwa 2, G Cot 16, and NH 452 at three spacings 90x10, 90x20 and 90x30 cm were planted to study the effect of closer spacing on plant characteristics affecting mechanical picking. Among them G. Cot 16 was found to be most compact and suitable genotype amenable to mechanical picking.

Evaluation of different defoliants for their suitability to mechanical picking of cotton

Three defoliants namely Dropp (Thiadizuron) (50 % WP), Roundup (41 % SL) and Ethrel (39 % SL) were applied at 1% concentration (5000 ppm) over varieties PKV 08, Khandwa 2, G Cot 16, and NH 452 with three different spacings 90x10, 90x20 and 90x30 cm. The results indicated that defoliation in variety Khandwa 2 was the highest (78 per cent) and was significantly superior over all other varieties which were in turn at par with each other. Various spacings used did not show any significant difference among them in respect of per cent defoliation.

Among the different defoliants tested, Ethrel showed maximum per cent of defoliation (73%) which was statistically at par with Dropp (71%). Defoliant D2 (Round up) recorded lesser level of defoliation (60%). The variety x defoliant and variety x spacing x

defoliant effects were significant. Maximum per cent of defoliation was observed in the variety Khandwa 2 by using defoliant Dropp followed by using defoliant Ethrel in same variety. Maximum per cent defoliation was recorded in the variety Khandwa 2 in the spacing 90x10 cm and 90x30 cm by using defoliant Dropp.

On Farm Trials for improvement of productivity and quality of Bt cotton at village level in Sirsa and Hanumangarh Districts

The studies were undertaken in two villages each in Sirsa district of Haryana (Aleekan and Burj bhangu) and Hanumangarh district of Rajasthan (Sherekhan and Salemgarh masani). An area of around 400 ha was covered in the study with one hundred and seventy eight farmers where select higher yielding and better quality Bt cotton hybrids were promoted along with available technological back up. The farmers were trained on integrated nutrient management and integrated pest management aspects along with quality of cotton. The area covered by three prescribed Bt cotton hybrids (RCH-134; MRC-6304; NCS-913) significantly increased during 2007-08. In general, the illegal Bt hybrids showed poor yields when compared to legal ones and hence farmers were urged to discourage such hybrids. The prescribed Bt hybrids of project farmers showed 7.22 to 8.12 q/ha higher seed cotton yield as compared to varieties in Rajasthan and 5.0 to 5.1 q/ha more seed cotton yield in Haryana during the 2007-08 season. The requirement of spray was less in Bt cotton as compared to non Bt cotton varieties. The farmers were educated about the importance of cotton leaf curl virus disease in reducing yield and it was demonstrated that illegal Bt cotton hybrid and non-descript cotton varieties showed higher leaf curl virus disease incidence and thereby led to lower production. The role of quality was highlighted. The overall poor quality characteristics and lesser price for the illegal Bt hybrids and non-descript varieties were explained. The average yield increase over varieties in case of Bt hybrids in both the states came to 636 kg/ha. Keeping the price of seed cotton at Rs 2500/- per quintal during the season, the net monetary gain out of the project came to Rs. 63 lakhs in addition to long term benefits in terms of technological dissemination.

4.18 : Morphoframe / Boll Load Management

Nagpur

Physiological manipulation of Bt plant morphoframe for enhanced productivity under varied agroclimatic conditions

In a rainfed field experiment at Nagpur, MECH 184 Bt, Bunny Bt and NHH 44 were given foliar sprays of plant growth regulators and nutrients during flowering. The treatments consisted of control, water spray, Gibberellic acid 100 ppm, Kinetin 50 ppm, Naphthalene acetic acid 0.45ml /l, Urea 2%, Single super phosphate and Muriate of potash (1%). .

The treatments both plant growth regulators and nutrients particularly Gibberellic acid, Muriate of potash and Urea given as foliar spray during flowering showed a tendency to decrease leaf reddening in all the three cultivars. Urea as 2% spray significantly increased number of green bolls in the Bt cultivars. However, the treatment effects on seed-yield realization remained non-significant.

At Coimbatore, the genotypes utilized for the experiments are Bunny Bt and Non Bt, Mallika Bt and Non Bt, JKCH 99 Bt and NCS 138 Bt. The treatments were control, Ethrel @ 5.7 & 8.56 mM foliar spray and mechanical removal of squares on the day of foliar spray. There was a significant difference between control and plants treated with Ethrel @ 5.7 and 8.56 mM in NR activity, root and shoot growth, LAI and other parameters. It has been now identified that application of ethylene in the form of ethrel was found to be suitable to bring about a change in crop ideotype that will help in enhancing the yield by 30-40% over the control.

Sirsa

The effect of 500 ppm, 650 ppm and 800 ppm concentration of defoliant (ethrel) was evaluated at Sirsa on the crop of Bt. hybrids RCH-134 and MRC-6301. The yield/plant was higher when defoliant was sprayed at 145 DAS with 800 ppm concentration in both the hybrids.

4.19 : Studies on Abiotic Stress

Heat and drought

Cultivar LRA 5166 was grown under high temperature and low humidity during summer season (2007) in China pots and drought treatment was inducted during flowering. The leaf temperature remained higher-approaching 41.9 ^{0}C and the relative humidity was 30%. The study revealed that dry matter distribution in root and leaves remained lower in stressed plants. Water stress induction under high temperature markedly increased stomatal resistance and decreased the leaf relative water content by 24.5 per cent. During the period of recovery from drought, the relative water content increased in the stressed plants and the difference narrowed down to 5.9 per cent between control and water stress treatments.

13 genotypes *viz.*, LRA 5166, NHH 44, CAT 3640, CAT 3845, CAT 3874, CAT 1911, CAT 3719, CAT 379, Bunny and Bunny bt (*G. hirsutum*), AC 7602, AC 6755, AKA 8401 (*G. arboreum*) were sown in pots during March, 2008. Water stress was inducted during seedling stage to study the growth and leaf relative water content responses of the genotypes under high temperature and low relative humidity environment. The study showed that imposition of water stress at high temperature decreased root and leaf growth at seedling stage. There was not marked difference in shoot growth between the treatments. Leaf relative water content declined under water stress condition (78.6% in water stressed plants as against 84.4% in control -mean over 13 genotypes). Dry matter distribution in roots during seedling stage remained markedly higher due to water stress under higher temperature environment.

Screening of cotton genotypes for drought tolerance

11 cotton genotypes *viz.*, LRA 5166, NHH 44, CAT 3640, CAT 3845, CAT 3874, CAT 1911, CAT 3719, CAT 379 (*G. hirsutum*), AC 7602, AC 6755, AKA 8401 (*G. arboreum*) were grown in pots and water stress was inducted at flowering during the main season. The genotypes with relatively better drought tolerance traits were identified.

Morpho physiological and biochemical trends indicated that leaf water potential was maintained significantly higher in *G. hirsutum* genotypes both in control and stressed plants as compared to *G. arboreum* genotypes. Among the genotypes, CAT 3640 recorded relatively higher leaf water potential under water stress condition. Higher leaf solute concentration was noticed in *G. arboreum* genotypes indicating a trend towards higher osmotic adjustment during water stress condition. It remained relatively higher in AC 6755 (*G. arboreum*). With regard to stomatal traits, stomatal resistance significantly increased due to water stress particularly in *G. hirsutum* genotypes which may facilitate dehydration avoidance of leaf water status during the stress period. Transpiration rate decreased due to water stress and it remained relatively higher in control plants of *G. hirsutum* genotypes. Nitrate reductase activity was maintained higher in CAT 3719, CAT 379 (*G. hirsutum*) and AC 7602 (*G. arboreum*) during water stress.

Total biomass production however decreased due to water stress. Among the genotypes, it remained higher in genotypes CAT 3874 (*G. hirsutum*) and AC 6755 (*G. arboreum*). Biomass distribution trends indicated that root and shoot biomass production increased while it was decreased due to water stress in the leaf and fruiting parts. Among the components, the dry matter distribution in stem remained markedly higher in control and water stressed treatments in genotypes belonging to both the species. During recovery, stressed plants tended to increase biomass production in the vegetative parts. Root-shoot ratio increased under drought stress and the ratio did not show any marked difference among genotypes in both the species under stress induction and during recovery status. Water stress inducted during flowering decreased seed-cotton yield and it was more prominent in diploid cotton genotypes whereas *G. hirsutum* genotypes mostly showed yield stability.

Biochemical studies on abiotic stresses with particular reference to heat and drought in cotton, Nitrate reductase activity was estimated at 90 DAS in leaf samples of cotton genotypes (14 *G. hirsutum* and 5 *G. arboreum* lines) under control and moisture stress conditions. Nitrate reductase activity has been found to increase during stress in only four genotypes.

Water-logging

Seven Bt cotton hybrids *viz.,* RCHB 708, Mallika, RCH 20, RCH 2, Bunny, MECH and MRC 6918 were raised in the field. As a result of water logging, plant

growth in terms of plant height was significantly affected from 60th day and continued up to 90th day and there after the growth was faster attaining the same height to that of control. Reproductive parts like squares and flowers were either delayed or reduced as a result of water logging. For instance, on 90th day, total reproductive parts were 34 in control plants compared to 20 in water logged plants irrespective of the Bt cotton tried.

Similarly, water logging retarded the production of leaves until 90 days of sowing. Among the Bt hybrids, the maximum production of leaves was noticeable at 120 days after sowing. RCHB 708, Mallika and MRC 6918 put forth the highest number of leaves with 120 leaves in control compared to 106 leaves in control with senescence occurring thereafter. RCHB -708 and MRC 6918 produced the maximum leaf of 120 under normal condition compared to 106 as recorded on 120th day. Irrespective of the Bt cotton hybrid, water logging, in general, affected the leaf production significantly at all stages.

Boll number was significantly influenced by water logging. Control plants recorded 25 bolls per plant compared to 20 bolls in plants that suffered water logging irrespective of the Bt cotton (Table 27). Among the Bt cotton, RCHB 708 and Mallika recorded the maximum boll number per plant followed by MRC 6918. Significant reduction was evident in water logging with an average boll weight of 5.22 g/ boll due to water logging, while the control plants recorded 5.47 g/ boll.

About 24 % decline in yield was obvious due to water logging irrespective of the genotypes studied. Among the Bt hybrids, maximum yield was observed in MRC 6918 followed by RCH 20,Bunny, RCHB 708, MECH and RCH 2. Water logging at 30 days after sowing brought down the yield significantly depending on the Bt cotton hybrid. Bunny and RCHB 708 appeared to be more tolerant. The other hybrids like MECH, MRC 6918 and RCH 20 were moderately tolerant.

Hoagland nutrient solution which contains all the major secondary and micro nutrients were sprayed as foliar spray in various dilutions 10 days after water logging. Biochemical estimations were done 20 days later. Chlorophyll content in the leaves declined significantly in all he treatments under water logging

Table 27: Effect of water logging on boll number, weight and yield

Bt Cotton	Treatment	Boll number	Boll weight (g)	Yield per plant (g)
RCH 708	Control Water log	32 25	3.95 3.55	126.4 88.7
Mallika	Control Water log	22 19	6.04 5.74	132.8 109.0
RCH 20	Control Water log	24 19	6.21 5.97	149.0 113.4
RCH 2	Control Water log	22 15	5.09 4.91	11.9 74.8
Bunny	Control Water log	23 20	6.10 5.91	140.9 118.2
MECH	Control Water log	22 18	5.73 5.53	126.0 99.5
MRC 6918	Control Water log	29 23	5.40 5.22	156.0 120.0
Mean	Control Water log	25 20	5.47 5.22	132.2 100.8
C.D. (5%)	3	0.24	18.2	

treatment. Among the treatments, DAP 1% + 1% KCl spray could maintain better status chlorophyll in both control and waterlogged situation followed by DAP2% and Hoagland solution of full strength (Table 28). Nitrate reductase activity also followed the same trend to that of chlorophyll with significant decline in the enzyme activity after 20 days under water logged situation. Activity of Nitrate reductase was better where foliar sprays of DAP 1% + 1 % KCl, DAP 2% and Hoagland solution of full strength was sprayed. Photosynthetic rate was significantly affected by water logging with about 50% reduction in photosynthetic rate by 20th day of water logging with gradual recovery soon after withdrawal of water logging. None of the nutrient spray could bring about significant improvement in photosynthetic rate (Table 28).

Table 28: Foliar application of nutrients on chlorophyll content, Ps rate and NR activity under water logged conditions

Treatment		Chlorophyll (mg/g fresh wt)	NR activity (µmol NO_2/g/h^{-1})	Ps rate (µmol CO_2/m^{-2} s^{-1})
Hoagland 25%	Control WL	3.23 2.85	4.84 3.12	20.17 5.68
Hoagland 50%	Control WL	3.25 2.84	4.93 3.41	22.60 6.82
Hoagland 100%	Control WL	3.34 3.10	4.83 3.55	21.08 6.88
DAP 2%	Control WL	3.35 3.06	4.91 3.53	21.94 7.25
DAP 1% + 1% KCl	Control WL	3.44 3.19	5.11 3.62	21.64 7.80
Water Spray	Control WL	3.13 2.82	4.84 3.18	21.0 6.58
C.D. (5%)	0.22	0.33	2.15	

Chlorophyll content in the leaves started declining gradually after the onset of water logging in all the hybrids studied. For instance, Bunny cotton the chlorophyll content started declining from 3.33 to 2.66 mg/g by 20th day.

Similarly, nitrate reductase activity started declining gradually from 4.82 to 4.00 µ mol after 15 days of water logging. However, the decrease was at a faster rate after this period with 2.82 µ mol by 20th day. Among the Bt cotton, Bunny exhibited comparatively higher activity of nitrate reductase than other Bt cottons.

During the recovery period (after water logging), the nitrate reductase activity was more in water logged plants compared to control plants irrespective of the hybrids. Among the Bt hybrids, Bunny had better activity of 4.52 µ mol in control plant and water logged plants during the recovery period recorded 4.89 µ mol. Photosynthetic rate also followed the same trend with activity being higher in plants recovering from the water logged situation and the differences were statistically significant.

4.20 : Fibre Development

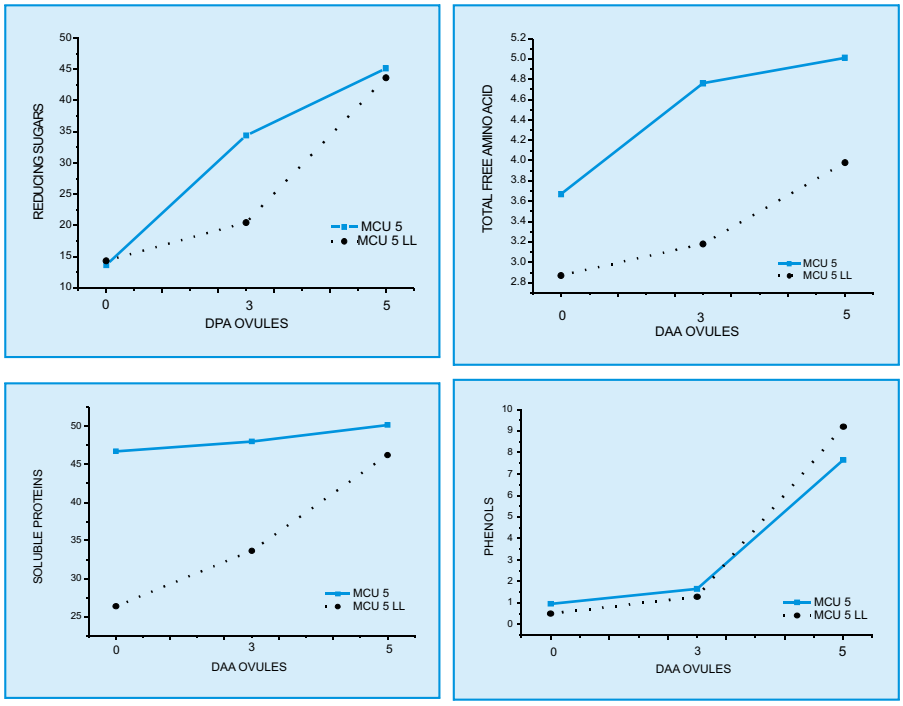
Physiological, biochemical and molecular elucidation of fibre development process in cotton for enhancing fibre yield

Biochemical analysis of the ovules of genotype MCU 5 and its lintless mutant MCU 5LL revealed that reducing sugar content showed a steep increase from anthesis in MCU 5 ovules and the content increased till 10 DPA. It was 13.67 mg.g^{-1}FW at anthesis and reached

34.41 and 45.15 mg.g^{-1}FW on 5th and 10th DPA. In contrast, the ovules of MCU 5 LL showed a slow start till 5 DPA (20.45 mg.g^{-1}FW) then increased to 43.66 mg.g^{-1}FW by 10 DPA (Fig.17). Similarly, the total free amino acid and phenol content was less in the initial stages in MCU 5 LL ovules. While there was no marked variation among the two genotypes in the amount of proline accumulated. These solutes are the important factor for creating positive turgor for fiber cell protrusion.

Genomic DNA extracted from 5 day old ovules was utilized for the RAPD analysis of cotton genotypes-MCU 5 and its mutant MCU 5LL. One hundred oligo-primers were tested for its amplification. Most of them failed to amplify in both the species. Among them twenty primers which showed good expression in the preliminary experiments was selected for further standardization. The amplified products of the primer 3` GAGAGGCTCC 5` gave two additional bands of the size of 2040(± 10) bp and 630 (± 10) bp and a band sized 1160 (± 10) bp with the primer 3`TCCGTGCTGA 5 ,in the MCU 5 and which are lacking in the MCU 5LL . All the other 18 primers gave similar banding pattern and 100 % polymorphism among the mutants.

Fig. 17: Differential accumulation of biochemical constituents in MCU 5 & MCU 5 LL ovules at 0-5 DAA



4.21 : Seed Oil

Seed oil content in Bt cotton hybrids

Oil content in 5 Bt and its corresponding non Bt hybrid was found to be in the range 18-23%. However, there was narrow difference in the oil content of non-Bt and respective Bt hybrids.

Name of hybrid	Per cent oil content	
	Bt	Non- Bt
RCH 2	20.8	21.4
KDCHH 441	22.6	20.7
NCEH - 2R	19.7	19.3
JK Varun	21.8	20.2
Bunny	18.3	20.4

4.22 : Socio Economic Dimensions of Cotton Farming

Accessibility to Mass Media and Information Technology of Potential Users in Cotton Based Production System

Information was collected from 250 randomly selected farmers comprising of progressive, less progressive and backward villages from Nagpur and Wardha district in Vidharbha region of Maharashtra and analysed with respect of access to and use of modern Mass Media i.e. Electronic Media-Radio & Television, Print Media-Newspaper and farm magazines and Information Technologies-Internet, cellular/mobile phones, etc by various categories of farmers. Study revealed that 49 per cent progressive farmers regularly used newspapers like Lokmat, Navbharat, Lokmat Samachar and Sakal for getting information on cotton. Majority (56 & 46 per cent) of the progressive farmer respondents listen to agriculture related programmes, especially on cotton crop 'regularly' from radio and watch TV programmes, respectively. The viewers were also influenced by ETV programme 'Annadata' as 28 per cent progressive farmers watched 'regularly' the use of pesticide, organic cultivation, market information and price trend whenever transmitted from the channel. Overall, the utilization of mass media such as newspapers, printed literature, radio, television and cell phone was comparatively higher i.e. 42.3, 17.0, 49. 7, 44.0 and 42. 7 per cent in progressive villages, respectively, as compared to less progressive and backward villages. Though most of the farmers were not subscriber of newspapers at their own, they read cotton related information at Grampanchayat or shops or restaurant in the villages. However, the overall utilization of various mass media was very poor among villagers irrespective of their status. The farmers who utilized various media were not so satisfied with the coverage, content and timeliness. The utilization of Kisan Call Centre by the villagers was not to the expectation. The extension workers and media personnel should therefore disseminate up to date information through these media regularly to speed up the process of adoption of cotton related innovations.

Social dynamics of cotton production in distress areas

The study was conducted in two highly suicide prone districts of Wardha and Yeotmal in Vidarbha region of Maharashtra. A sample of 200 farmers having land holding up to 2 ha and more than 2 ha from 40 randomly identified villages and where comparatively larger number of suicides occurred were selected. The data was analyzed for sub-construct powerlessness, meaninglessness, isolation and self-estrangement of alienation from land. The data reveals that a very high percentage of respondents 85, 57 and 81 respectively fall under the score medium to high degree between scores 33.34 to 66.66 and 66.67 in case of powerlessness, meaningless and isolation, while majority of 58.5 per cent exists in self-estrangement of high degree level (66.67 and above). The high level of alienation arises because of farmers' perception that they can neither control the market forces and nor can influence the farm policies of government. The social dynamic indicators show large percentage (72.5%) under rainfed land holding, more than half (51.5%) proportion had low annual income up to Rs. 25,000/- only. Expenditure on events per annum was more than the net income. Three-forth of respondents (76.5%) have single cropping patterns and there is migration of one- fourth respondents in search of job to various places. Since the net return in cotton farming is very less due to increased cost of production, 91% borrowed loan. The possible causes and issues of agrarian distress as reported by the respondent farmers were high costs and low returns, deteriorating financial condition, lack of contingent support from Govt. agency, deterioration in quality of life, fall in social and economic status, crop failures and alcoholism.

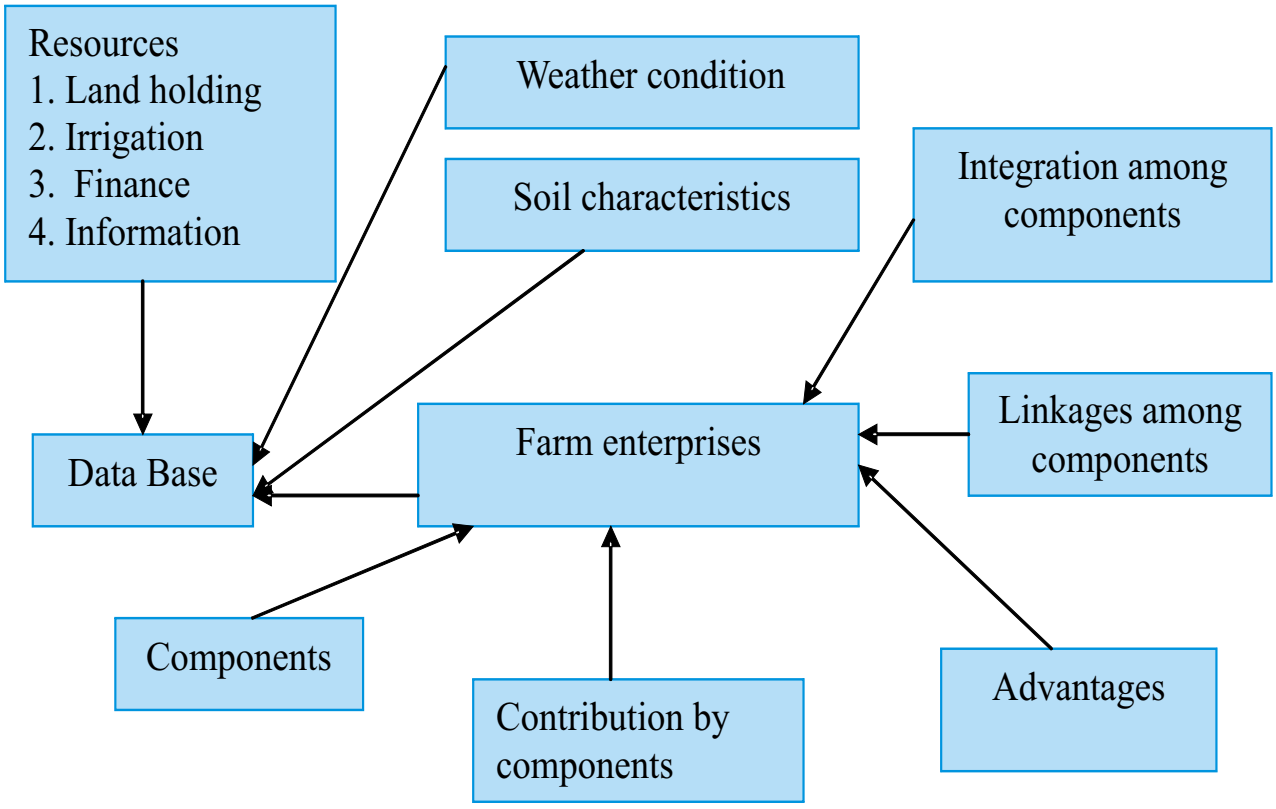
Gender role in Cotton - Role of Women in Cotton Based Cropping Systems

Expost facto research design with simple random sampling was followed using survey methodologies for data collection. Data were collected from 60 cotton farmers in Erode district of Tamil Nadu and 60 cotton farmers from Coimbatore district of Tamil Nadu. More than 60 per cent of the cotton growers perceived that the major activities performed by the farmwomen in cotton are stubble removal, sowing, gap filling, intercropping, thinning, weeding, fetching water for pesticide application, de-topping, labour supervision, harvesting of crop and intercrop and cotton grading. More than 70 per cent of the cotton growers perceived that a high share of waged work was provided by

women at peak times namely at weeding and harvesting. According to 82% of them, the major farm activities which cause health hazards are weeding, mixing concentrated chemicals with water and filling spray tanks, mixing and subsequently working in the fields, working in a recently sprayed field and applying pesticides was opened by 73%. Farm women in cotton based production systems have employment for four months in a year. Hence, they suggested that viable value added agriculture and processes need to be promoted in cotton farming and possibilities of identifying the shift in cropping pattern or crop diversification may be proposed to provide employment opportunities to the farm women through out the year. Majority of the farmers suggested that the technology transfer activities related to post harvest and processing practices need to be given special focus so as to motivate and build the capacity of farm women into value added agriculture.

Documentation and Validation of Farmers' Indigenous Knowledge on Farming System Approaches (FSA) in Cotton

During the year, Rapid Rural Appraisal was conducted in the cotton growing villages of Coimbatore district, Tamil Nadu (non-sample area). Consultation with the scientists of Central Institute for Cotton Research (CICR) and Tamil Nadu Agricultural University (TNAU) and perusal of past literature was done. Using the results of the survey and discussion, the following framework for preparation of Inventory of Farmers Knowledge on Farming System Approaches in Cotton was developed



Based on the survey results, the components ranked by the respondents viz., Crop (I), Dairy (II), Poultry (III), Goats and Sheep (IV), Biogas (V), Sericulture (VI), Vermiculture (VII), Silviculture (VIII), Mushroom cultivation (IX), Farm machineries (X), Rabbits rearing (XI), Piggery (XII) and aquaculture (XIII) were selected as important components to be recorded in the cotton based farming system. Indicators to assess the contribution by components, parameters to analyze the advantages of individual components and indices for studying the sustainability of diversified and non-diversified farms were also identified.

Post Evaluation of Farmers' Field Schools (FFS) on Cotton

In order to document the problems faced by farmers during pre-implementation period of FFS, the variables *viz.*, Productivity of cotton, Net returns from cotton, Pesticides used, Spraying Operations and division of labour, signs and symptoms of pesticide poisoning, Input use in cotton cultivation, Knowledge level of Farmers, Attitude towards IPM and Capacity building programme were selected and operationalised for the construction of interview schedules and questionnaires. To collect data on Pest Management behaviour in cotton, the parameters *viz.*, Irrigation (number of operations per crop cycle), Weeding (number of weeding operations per crop cycle), Organic as well as inorganic fertilization (rates in kg of commercial products/ha) and Pesticides application (toxicity class, rates and number of applications of the formulated products per crop cycle/ha) were selected and operationalised. To assess the Farmers ecological knowledge on cotton farming, the questions *viz.*, List of names of the insects commonly found in cotton fields (Identification score, IS), to define whether the listed insects were pests or predators (Functional score FS) and to describe the feeding habits of the insects, the plant damages in the case of pests and the predatory capacity in the case of beneficial insects (Ecology score ES) were selected and operationalised. To assess the impact created by FFS on cotton farming, the parameters *viz.*, changes in Natural Capital (natural resource stocks from which resource flows are derived, including land, water, biodiversity, landscapes etc.,), Social capital (Social assets networks, membership in groups, relationships and the wider institutions of society), Human capital (Assets such as skills, knowledge, ability to work, health, creativity etc.,), Physical capital (Infrastructure-roads, wells, hospitals, energy, communications etc.,) tools and equipments) and Financial capital (Financial assets-savings, loans, credit, remittances, pension and other transfers) were selected and operationalised.

Performance and behavior of Bt cotton under scanty rainfall situation

The performance of Bt hybrids under low rainfall situation was assessed with assumption that combined effect of early maturity and protection of early formed bolls in Bt cotton, leads to better performance of Bt under low rainfall situation. The total quantity of rainfall received during the cropping period was 438.2 mm out of which 275.9 mm were calculated as effective portion.

The significantly highest seed cotton yield was recorded from RCH 708 Bt (2853 kg ha^{-1}) followed by RCH 20Bt (2408 kg ha^{-1}) .The performance of LRA 5166 was better than non Bt (RCH2 and RCH20) but lesser than Bt (RCH 708 Bt and RCH 20 Bt). Bt hybrids produced mean of 32,31,27, 38 per cent higher yield than non Bt respectively with total, first, second and third pickings. The results point out that Bt hybrids can also perform better under low scanty rainfall situation in comparison to isogenic non Bt hybrids and existing variety (LRA 5166).

Farm Level Economic Benefits of Bt Cotton in Tamil Nadu

Area under Bt cotton increased from 5000 ha to 70000 ha in Tamil Nadu over the past four years. Salem, Perambalur and Coimbatore are the major Bt cotton areas in Tamil Nadu. The average number of sprays reduced from 5 to 3 with reduction in cost by 60 per cent. The yields of Bt cotton are higher than the yields of non Bt cotton by 26 per cent and was found true under irrigated as well as rainfed conditions. Human labour was the major input (35-40 per cent) in both the cases, with higher share of fertilizers and pesticides in case of non Bt (20%, 20%), when compared with Bt cotton (13%, 9%). Regression results on the impact of Bt cotton showed a significant impact on yield, value of output and pesticide cost. Bt cotton farmers attributed more profit (72.14 per cent), less pesticide (52.31 per cent) and comparatively more bolls (49.15 per cent) for the choice of Bt cotton. Seed dealers and seed companies played a major role in the

dissemination of Bt cotton.

Adoption, Impact and Returns to Research Investment on Improved Cotton Cultivars in Tamil Nadu

Education, non farm income, farm size, irrigation, market distance and presence of private seed sector and district dummies were the variables considered for the Tobit analysis, The presence of private seed sector outlets in the locality favoured adoption significantly. The results suggest that Coimbatore and Salem districts provided a better environment for adoption of improved varieties or hybrids than Dharmapuri. Irrigation appears to be a more dominant variable; seed and fertilizer shops are the major source of information as well as of seed for varieties / hybrids, Fellow farmers and relatives also play a major role as sources of information. State Department of Agriculture and co-operatives are also involved in the dissemination of the technology.

Economic Analysis of Contract Farming (CF) in Cotton in Tamil Nadu

The Tripartite model of contract farming was followed. The Department of Agriculture - Chief Coordinator TNAU and CICR to render R&D support, the Cotton Corporation of India (CCI) acted as alternate procurement agency. The Commissionerate of Agriculture gives extension support as well as training to the farmers. Commercial Banks provides credit facilities to the identified farmers with insurance coverage, CCI Operations cover all the cotton growing states in the country comprising of Punjab, Haryana and Rajasthan in Northern Zone, Gujarat, Maharashtra and M.P. in Central Zone, Karnataka, A.P. and Tamil Nadu in Southern Zone as also in Orissa. In the north, the total area covered under CF went up to 9279 ha (1038 cotton farmers) during 07-08 from 4811 ha (1254 farmers) in 2005-06. In Central zone, the area under CF rose from 8332 ha to 13086 ha, while it was 6887 ha to 13393 ha in the South zone during the same period.

CCI operated its contract farming in Avinashi taluk of Coimbatore district covering an area of 200 acres. ELS Bt cotton - Rasi XL708 and Rasi RCH20 were the Bt hybrids taken up for the scheme. XL708 ELS (34 mm & above - 60 acres Irrigated, RCH 20 ELS (32 mm & above) 140 acres rainfed. Total cost of cultivation was higher in case of non contract farming when compared to contract farming by a difference of Rs.2500/- which was due to higher labour use in the former case. B:C ratio over total cost and cost of production per quintal was remunerative under contract farming (1.64; Rs.1581.60/q) compared to non contract farming (1.08; Rs.1911.19/q) in cotton. The returns to scale was more than unity in case of contract farming depicting increasing returns to scale. The yield and price uncertainty ratio was very less under contract farming when compared to the non contract farming

4.23 : Total Factor Productivity analysis:

Review of literature on various studies pertaining to Total Factor Productivity (TFP) was made to extricate the objectives and tools of analysis for the present study on cotton. Four objectives were finalized for the study using Tornquist Theil index to analyse TFP of cotton in India. Sources of data notified were Directorate of Economics and Statistics, MOA, GOI, Fertilizer Statistics of India, CCPC reports at the concerned universities, Season and crop reports at state level, Economic Appraisal reports at the State level, Marketing Abstracts and Statistical reports at the district level. Negative growth rate of cotton area over the years 1980-81 to 2007-08 was recorded in Punjab with positive production and yield during the same period. In case of Haryana and Rajasthan, positive growth rate was recorded with regard to area, production and yield of cotton. In Punjab and Haryana states, the TFP of cotton declined since mid 90's due to over-mechanisation, stagnant yield and high input costs. But TFP for Rajasthan state was comparatively high due to traditional farming, less mechanization, soil and natural suitability of cotton crop in this state. Total Factor Productivity index of cotton in Gujarat ranged from 0.7376 to 1.6824 during the period 1982-04. In Maharashtra, it ranged from 0.7748 to 1.3337 during the period 1995-04. TFP index of cotton in Madhya Pradesh ranged from 0.8264 to 1.6857 during the period 1996-04. Among the southern cotton growing States, TFP was almost more than 1 in Andhra Pradesh since 1994-95 whereas in Karnataka, it declined from 1.66 to 0.47 during the same period. In case of Tamil Nadu, it showed a decline from 0.93 to 0.52.

4.24 : Cotton Information System

Indian Cotton Portal

Newer version of contents of CICR website was uploaded at the new web location with new domain name **www.cicr.org.in**. In the new cotton web portal, many user friendly pages for the user to navigate, especially, cotton research, cotton market, cotton press release, cotton seed industry, cotton textile Industry etc have been included. The new website has been linked with other Government Departments and cotton related websites. Separate web section for Technology Mission on Cotton and AICCIP have also been integrated. Since the control to update the website is available as and when required, a special cell has been created at CICR Regional Station, Coimbatore to update the contents of the CICR web site instantaneously.

Information Retrieval System

Large volume of diversified information on cotton has been collected in Cotton Repository. User friendly, menu driven information retrieval system using the programming tool Visual Basic.NET has been developed. The data sets mainly projected on state level as well as district level which include District wise cotton area, production and productivity; Cloth/Yarn production sector wise as well as state wise; raw cotton consumption state wise as well as staple wise mills consumption; Details of cultivars released; variety wise cotton area; Hybrid, irrigated, rainfed area under cotton; Fertiliser and pesticide consumption etc have been included. CD version of the information retrieval system is ready for distribution and the same will be converted into web enabled version i.e ASP.NET so that the entire information on cotton will be floated at Indian Cotton Portal for global access.

Bt Cotton Production

Performance and behavior of Bt cotton under scanty rainfall situation

The performance of Bt hybrids under low rainfall situation was assessed with assumption that combined effect of early maturity and protection of early formed boles in Bt cotton, leads to better performance of Bt under low rainfall situation. The total quantity of rainfall received during the cropping period was 438.2 mm out of which 275.9 mm were calculated as effective portion.

The significantly highest seed cotton yield was recorded from RCH 708Bt (2853 kg ha^{-1}) followed by RCH 20Bt (2408 kg ha^{-1}) .The performance of LRA 5166 was better than non Bt (RCH 2 and RCH 20) but lesser than Bt (RCH 708Bt and RCH 20Bt). Bt hybrids produced mean of 32,31,27,38 per cent of higher yield than non Bt respectively with total, first, second and third pickings. Data on quality parameters revealed that RCHB 708 non Bt recorded the highest staple length (35.7 mm), fibre strength (23.6 g/tex) and fibre quality index. The results indicate that Bt hybrids perform better under low scanty rainfall situation in comparison to isogenic non Bt hybrids and existing variety (LRA 5166).