4.9: Nutrient Management

Nagpur

Studies on long term effect of fertilizer and INM on productivity, soil fertility and quality of cotton-soybean cropping system

The residual effect of continuous application of inorganic, organic and INM treatments was evaluated using sorghum crop. Higher grain yield was obtained where FYM alone or in combination with 75% inorganic fertilizer was applied. Higher values of organic carbon (0.61%), available nitrogen (114 kg/ha), phosphorus (9.2 kg/ha) and available zinc (0.61 ppm) were recorded in the organic manure treated plots as compared to pure inorganic fertilizer treatments.

Effect of different levels of fertilizers on yield Cry protein and gossypol content expression of Bt hybrids

Field experiment was laid out a split plot design in 3 replications with 3 Bt hybrids (Bunny Bt, RCH2 Bt and JKCH99 Bt) and their 3 non- Bt counterparts. Fertilizer (N,P,K) at 3 rates viz., 90:45:45, 120:60:60 and 150:75:75 were applied. Seed oil content was in the range 21 – 23%. Gossypol content varied in the range 0.43-0.64%. Total protein content (Lowry's method) was found to be 0.32-0.45 mg/g fresh weight of leaf. Bt hybrids, in general, contained more total protein than their non-Bt parts. Yield data showed no significant difference among different nitrogen doses, for Bunny Bt, Bunny N-Bt and RCH2 Bt hybrids. Oil content was found to be higher with 150:75:75 compared to the other two lower doses.

Coimbatore

Effect of nutrients and surfactant on metabolic activity and productivity of Bt cotton

Nutrient consortia of diammonium phosphate (1%) + potassium chloride (0.5%) + magnesium sulphate (0.5%) + ferrous sulphate (0.25%) + zinc sulphate (0.25%) + micronutrients was taken up for large scale field trial with and without surfactant (non ionic soap solution + 0.1% proponol) from 60 days after sowing at 15 days interval in Bunny Bt cotton. Irrespective of treatments, the photosynthetic rate, NR activity and chlorophyll content increased up to 90 days after sowing and declined by 120th day. The photosynthetic rate was 21.1 μ mol CO_2 m^{-2} s^{-1} at 90th day and declined to 17.4 μ mol CO_2 m^{-2} s^{-1}. Nutrients sprayed along with surfactant recorded significantly higher rate of photosynthetic rate at all stages of growth. Surfactant when used along with nutrient solution facilitated the opening of stomata significantly. For instance, at 90th day about 35% of the stomata remained opened after 30 minutes of nutrient spray while only 21-22 % of the stomata remained opened in control or plants that were sprayed without surfactant. Similar trend was observed at 60th and 120th day after sowing. Soon after foliar spray of nutrients, potassium absorption by the leaves was significantly more in plants where nutrients applied along with surfactant recording 46.0 ppm on 60th day compared to 41.5 ppm in nutrient spray without surfactant. Similar trend was observed at 90th and 120th day. Control plants which did not receive potassium through nutrient application recorded significantly lower amount of potassium in the leaves. For instance at 120th day, only 25 ppm of potassium was estimated in control plants (water spray) compared to 32- 40 ppm in plants that received nutrients spray.

About 27-29 bolls were harvested from nutrient spray treatments while only 24 bolls could be harvested from the control plants. The final yield was significantly more in plants that were sprayed with nutrient along with surfactant followed by nutrients without surfactant (Fig.14). The study revealed the importance of surfactant in nutrient absorption through foliage there by increasing the metabolic activity significantly which in turn could have enhanced the yield potential.

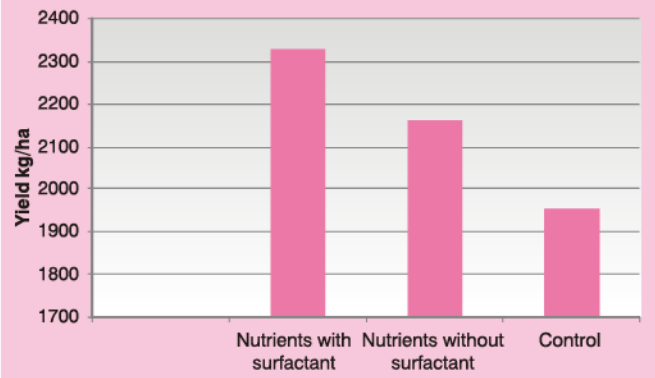

Fig. 14 : Effect of nutrients on productivity

Influence of surfactants on moisture absorption by cotton leaf surface

Moisture absorption by leaf surface was significantly more from the lower surface of the leaf 13.2% to 15.8% irrespective of the surfactants used. However, moisture absorption was further improved when both sides were immersed in solution to the tune of 19.7 % to 22.3%. Moisture absorption through upper surface of the leaf was significantly low 5.8% to 7.5%. All purpose spray adjuvant (APSA) and Triton-X surfactants facilitated moisture absorption process significantly. For instance, irrespective of the leaf surface, moisture absorption was 15.5% when APSA was added while Triton- X recorded 14.5% compared to 12.9 % in control (Water).

4.10 : Cropping Systems

Evaluation of Bt cotton based inter cropping systems

Nagpur

Eight cropping systems viz. Bt hybrid cotton (Bt) sole, Bt + pigeon pea, Bt + maize, Bt + soybean, Bt + castor, Bt + field bean, Bt + roselle, Bt + marigold were evaluated in main plots with four levels of fertilizers viz., F_1: 100 % RDF + Urea/ DAP 2%+1% $MgSO_4$ +10 kg ha^{-1} Borax spray, F_2: 100 % RDF + Soil application of $MgSO_4$ 25 kg and 10 kg ha^{-1} Borax, F_3: 125 % RDF + Urea/ DAP 2%+1% $MgSO_4$ and 10 kg ha^{-1} Borax, F_4: 125 % RDF + soil application of $MgSO_4$ 25 kg and 10 kg ha^{-1} Borax as sub plots plant densities 90 x 45 and 90 x 30 as sub sub plots in split plot design. Bt hybrid seed cotton yield, nutrient uptake and nutrient use efficiencies were not influenced by intercropping systems. Fertilizer application @ 125% RDF + soil application of $MgSO_4$ 25 kg and 10 kg ha^{-1}Borax and plant density 90 x 30 cm significantly improved nutrient uptake and also input use efficiency. All the intercrop yields except pigeon pea, soybean and castor were significantly higher than control but were not significantly altered by fertilizer doses or plant density of cotton. Bt cotton intercropped with roselle produced significantly higher cotton equivalent yields, nutrient use efficiency, C: B ratio and net returns Bt cotton biomass was highest with field bean intercropping due to positive legume effect.

Coimbatore

Weed management in multitier cropping system

Integrated weed management was evaluated under multitier cropping system. Hand weeding thrice at 15, 30 and 60 DAS gave the highest seed cotton yield (2110 kg/ha). The highest net return (Rs. 1,39,535/ha) was observed with pre emergence application of pendimethalin @ 0.75 kg a.i./ha followed by hand weeding at 30 DAS and application of pendimethalin @ 1.25 kg a.i./ha at 60 DAS lay by method for weed control. The least net return (Rs. 1,17,649/ha) was produced with weed control measures by adopting pendimethalin @ 0.75 kg a.i /ha as pre emergence followed by hand weeding at 30 DAS and post emergence application of targa super @ 50 g/ha at 60 DAS.

Incorporation (*in-situ*) of cereals on productivity of succeeding cotton

Incorporation of *in-situ* off season grown cereal crop before cotton significantly improved cotton growth and yield. Highest seed cotton yield (1762 kg/ha), total rainfall use efficiency (2.83 kg/ha-mm), partial factor productivity (14.7 kg/kg of nutrients) and economics of nutrient use efficiency (1.13 kg/Rs. invested on nutrients), gross return (Rs. 98,686/ha), net return (Rs. 70,588/ha) and benefit cost ratio (3.51) realized with *in-situ* incorporation of 45 days grown *ragi* by along with *Trichoderma viridi* followed by cotton crop. Cotton-fallow rotation produced the lowest seed cotton yield (1129 kg/ha), total rainfall use efficiency (1.8 kg/ha-mm), partial factor productivity (9.4 kg/kg of nutrients) and economics of nutrient use efficiency (0.72 kg/Rs invested on nutrients), gross return (Rs. 63,206 /ha) and net return (Rs. 44,176/ha).

Exploiting new geometry and nutrients management strategies for maximizing the productivity of Bt cotton based intercropping systems

In a novel method, short duration intercrops like coriander and radish were introduced on the other side of the ridge so that the cotton plant geometry is maintained exactly as that of pure crop of cotton. Bt cotton + coriander, Bt cotton + radish and sole cropping were studied under two geometry (90 x 60 cm as normal recommended geometry) and modified geometry of 120 x 45 cm so that the cotton plant population is same under both geometry and evaluated under four fertilizer treatments. The results indicated that the intercropping systems recorded on par seed cotton yield with sole cotton and among the intercropping systems, Bt cotton + coriander system recorded highest seed cotton equivalent yield (5062 kg/ha), followed by Bt cotton + radish system (4312 kg/ha) as against the lowest (3553 kg/ha) recorded under sole cotton. Bt cotton + radish system recorded the highest (1.43) land equivalent ratio followed by Bt cotton + radish system (1.21). Among the geometries, 120 x 45 cm recorded significantly higher seed cotton yield and seed cotton equivalent yield than 90 x 60 cm suggesting that wider row spacing is advantageous to Bt cotton than wider plant to plant spacing within the row. Among the fertilizer treatments, application of 125 % recommended NPK (RDF is 90:45:45) with foliar spraying of DAP 1.5%, K 0.5%, $MgSO_4$ 0.5% and Boron as solubor 0.15% (twice during flowering to boll development stages) recorded the highest seed cotton yield, seed cotton equivalent yield, net return and benefit cost ratio (Table 14).

Table 14 : Productivity and economics of Bt cotton based intercropping system

Treatment	SCY (kg/ha)	Intercrop yield (kg/ha)	Cotton equivalent yield (kg/ha)	Net return (Rs/ha)	Land equivalent ratio
Bt cotton + coriander	3447	8250	5062	2,23,670	1.43
Bt cotton + radish	3397	6370	43.12	1,85,680	1.21
Sole cotton	3553	6370	3553	1,47,720	-

Sirsa

Studies on soil plant narrations in intercropped *kharif* legumes with Bt cotton under irrigated condition

Experiment on cotton intercropped with mungbean variety SML 668 with different geometry was carried out with less spreading Bt hybrids viz. MRC 7017 and Bioseed 6488 to find out its suitability. The seed cotton yield in sole cotton 2173 kg/ha with MRC 7017 and 2178 kg/ha with Bioseed 6488 was significantly higher than the paired row system. In treatments with intercrop, 400 kg/ha yield of mungbean with MRC 7017 and 389 kg/ha with Bio-seed 6488 was observed with 3 rows of mungbean at 30 cm spacing were accommodated in 135 cm space available between the paired rows. The extra expenditure Rs. 3800 for seed cost of mungbean and hand weeding charges for cultivation for mungbean as intercrop also estimated and deducted from total income of the system. The net income Rs. 65190 with MRC 7017 and Rs 65340 with Bioseed 6488 was higher in sole cotton at spacing 65.5 x 75 cm followed by paired row with 3 row mungbean Rs. 61100 with MRC 7017 and Rs. 61350 with Bioseed 6488.

4.11: High Density Planting Systems (HDPS) for Maximizing Productivity

Nagpur

Development of high density planting systems (HDPS) for maximizing productivity of rainfed cotton

Separate experiments involving 5 genotypes of *G. hirsutum* across 5 plant geometries (accommodating 55000 to 166000 plants/ha) and 5 genotypes of G. arboreum across 5 plant geometries (accommodating 111000 to 222000 plants/ha) were conducted on rainfed Vertisols of agro eco sub region (10.2) characterized by hot dry sub humid agro ecosystem. Among the 5 genotypes of G. hirsutum (Anjali, CCH 724, NISC 50, PKV 081 and CNH 120 MB) evaluated, the genotype PKV 081 was found most suitable for high density planting (1,66,000 plants/ha at 45 x 13.5 cm) in terms of yield (1921 kg/ha) morphological features, earliness, tolerance to sucking pests and boll weight. Among the 5 genotypes of G. arboreum (AKA 07, CINA 404, PA 255, PA 08, JK 5) evaluated, on the basis of yield, CINA 404 (2174 kg/ha) performed the best at

high density planting (2,22,000 plants/ha at 45 x 10 cm). However with the same spacing, other high yielding genotypes viz., JK-5 (1842 kg/ha) and AKA-07 (1815 kg/ha) were more dwarf and compact than CINA-404.

Among the spacing 60 x 30, 45 x 20, 45 x 13.5, 30 x 30 and 30 x 20 cm of *G. hirsutum* evaluated, across the genotypes a spacing of 45 x 13.5 cm (1,66,000 plants/ha) was optimum for short compact types. Among the spacing viz., 60 x 15, 45 x 13.5, 45 x 10, 30 x 20 and 30 x 15 cm evaluated, across genotypes a spacing of 45 x 10 cm (2,22,000 plants/ha) was optimum for *G. arboreum* for short compact plant types. In both *G. hirsutum* and *G. arboreum* genotypes the harvest index decreased with increasing plant density. This is turn decreased nutrient utilization efficiency. Nevertheless in all the genotypes of *G. hirsutum* and *G. arboreum*, the nutrient uptake efficiency and partial factor productivity for N increased with increase in planting density.

Standardization of nutrient requirements for cotton varieties under (HDPS)

a. *G. hirsutum*

Under HDPS *G. hirsutum*, PKV 081 produced more bolls, had higher weight and gave more seed cotton yield (1209 kg/ha) as compared to NH 615 (1050 kg/ha) and NH 452 (1049 kg/ha). Fertilizer level @ 125% RDF significantly influenced the number of bolls. Seed cotton yield (1253 kg/ha) was higher with 125% RDF compared to 100 % RDF (1082 kg/ha) and 75 % RDF (872 kg/ha). Higher nutrient uptake was observed at 125% RDF.

b. *G. arboreum*

Under HDPS higher boll weight and seed cotton yield (1981 kg/ha) was recorded with the application of 125 % RDF in the variety PA 255 as compared to 100% RDF (1607 kg/ha). NPK uptake was higher in JLA 794 compared to AKA 7 or PA 255 at all the fertilizer levels. Higher nutrient utilization of N and P was noted in PA 255. Higher dose of fertilizer at 125% RDF increased nutrient utilization efficiency in all the cultivars.

Altering cotton plant morphoframe for improving yield and resource use under HDPS

Four cotton genotypes – *G. hirsutum*- cv Anjali and PKV 081 and *G. arboreum* cv. AKA 7 and PA 255, were raised under two spacing. Eleven treatments were taken for foliar application to alter the canopy growth. Planting at narrow (30 x 30 cm) gave double the yield compared to recommended (60 x 30 cm) spacing in *G. hirsutum*. This yield enhancement was 30-40% in *G. arboreum*. Application of Maleic hydrazide (@500 ppm at 45 day) and Mepiquat chloride (@60 ppm at 45 DAS) showed promise to further enhance the yield under HDPS.

Coimbatore

High Density Planting System-*hirsutum* genotypes

Under HDPS narrow row planting at 45 x 15 cm (1, 48, 148 plant/ha) was followed for the genotypes Anjali, C-1412 and CCH-7245 and control RCH-2 Bt was planted at 90 x 60 cm (18,519 plant /ha). The genotypes were evaluated at 75,100,125 and 150 % of RDF. Light interception had been significantly influenced by genotypes and their planting methods. The highest light interception (68.9 %) recorded with CCH-7245 (planted at 45 x 15 cm) and the least one with RCH-2 Bt (17.0 %). Agronomical advantage associated with narrow row planting (45 x 15 cm) of genotypes (Anjali, CCH-7245 and C-1412) had resulted in an increase in seed cotton yield to the extent of 300-800 kg/ha over to RCH-2 Bt (Fig.15). The economic assessment indicated that narrow row planting of Anjali (45 x 15 cm) provided the highest gross return (Rs. 1,19,538/ha) and net return (Rs. 78,286/ha). Nutrient levels (75,100,125 or 150 %) did not influence the seed cotton yield significantly.

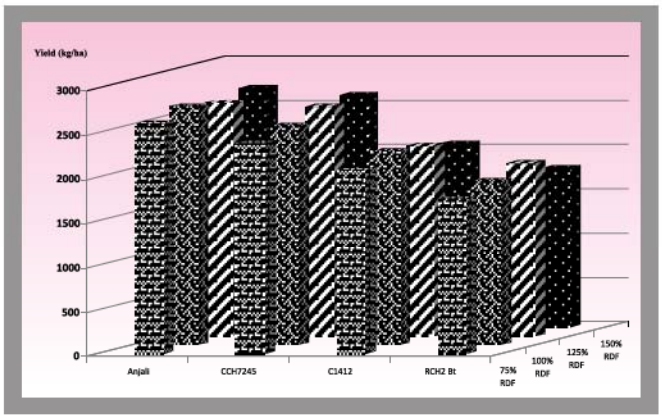

Fig.15 : Yield (kg/ha under Ultra Narrow row (Anjali, CCH7245 & C1412)

4.12: Weed Management

Nagpur

Stale Seed Bed Technique

Controlling weeds mechanically by harrowing once before sowing, or Roundup 2.5 l ha^{-1} or Roundup 2.5 l ha^{-1} + Pendimethalin 1.0 kg a.i. ha^{-1} alongwith three inter-cultures and two hand weeding produced statistically similar yields to that of farmer's practice of three inter-cultures and two hand weeding. Herbicides were effective in weed control in intercropped field bean by reducing hand weeding requirement. Stale seed bed technique, common in rainfed areas, helped Bt hybrid cotton to overcome the competition in first inter-culture by reducing 66% hand weeding requirement compared to intercrop. Cost of cultivation, net returns and FUE of Bt hybrid cotton were similar in the above treatments at par with farmers practice. The weed control efficiency was 95% compared to control due to continuous rains.

Coimbatore

Novel approach of exhausting weed seed bank before the crop emergence by Stale Seed Bed Technique (SSBT) was standardized for Bt cotton + coriander intercropping system.

SSBT and application of a mixture of glyphosate 1.0 kg + pendimethalin 1.0 kg one week after irrigation controlled the weeds effectively because the germinated weeds were killed by glyphosate and the germinating weeds were controlled by the residual action of the pendimethalin with the weed control efficiency of 86.61 % and on par seed cotton yield with SSBT and manual removal of weeds (thrice) (Table 15) .

Field experiment was conducted in RBD with nine treatment combinations to find out the suitable herbicides rotation for efficient ,economical and safe weed control method in Bt cotton RCH 20. The weed flora count recorded at 35 DAS has shown significant difference among treatments. During initial stage, the carpet weed (*Trianthema portulacastrum*) was the dominant accounting for 87% of the total weed population and application of pendimethalin as pre emergence herbicide could control the weeds effectively with weed control efficiency of up to 84.17 % while alachlor was not effective against *Trainthema*. The rotation herbicides *viz*., Phenoxy–p-ethyl 100 g and quizalofop-ethyl 50 g at 60 DAS were effective against the grassy weeds whose population increased during later part of cotton growth. None of the herbicides tried in the experiment were phytotoxic to cotton crop. The pre emergence application of pendimethalin followed by one hand weeding at 35- 40 DAS and post emergence application of either phenoxy–p- ethyl 100 g or quizalofop- ethyl 50 g on 60 DAS recorded on par seed cotton yield with hand weeding thrice (20,40 and 60 DAS).

4.13 : Soil Biology and Biochemistry

Nagpur

Impact of Bt cotton soil biological properties

Rhizosphere samples were collected at 30 days interval till harvest from Bt (Bunny, Jai and Ankur) and corresponding non Bt plots raised following normal agronomic practices. The selected soil chemical (organic carbon, pH, nitrogen, available phosphorus and available potassium) and biological parameters (soil respiration, soil urease activity, soil dehydrogenase activity (DHA), microbial biomass carbon (MBC) and soil microbial population were analysed following the standard methods. The results indicated that growing Bt cotton does not pose any ill effects on the above soil chemical and biological parameters studied, rather, interestingly, all the parameters in biological and chemical properties (except available potassium) found to increase in soil where Bt cotton were grown compared to its counterpart (non-Bt cotton) and bulk soil. There was found to be statistical significance between the Bt cotton hybrids, crop growth stages and their interactions. Most of the soil parameters studied, found to show its maximum activity between 60-90 days of crop growth which coincides with flowering period. Thus growing Bt cotton does not pose any ill effects on soil health.

Developing efficient carrier based microbial delivery system for cotton nutrition and soil health

Fifteen native bacterial isolates (*Enterobacter asburiae*-1, *Bacillus spp*., *Erwinia spp* , *Enterobacter spp*, *Acinetobacter baumannii-1*, *Pseudomonas putida-1*, *A. baumannii-2* , *E. asburiae-2* , *A. baumannii-3* , Un-cultured bacterium, *E. asburiae -3*, *A. baumannii-4* , *P. putida -2*, *Pseudomonas plecoglossicida*, *P. putida-3*) possessing good phosphorus solublizing activity, growth promotion and bio control potential has been isolated from cotton rhizosphere. The bacterial isolates were characterized biochemically and identified based on 16S rDNA. Among the isolates, higher pH reduction was recorded with *A. baumannii-2* (43.4%) followed by Un-cultured bacterium (35.5%). *A. baumannii-4* (6.7 mg/ml) followed by Un-cultured bacterium (5.3 mg/ml) showed maximum phosphorus under broth culture. Higher acid phosphatase activity was recorded with *Erwinia spp*. (127 µg PNP/ml), while higher alkaline phosphatase activity was recorded with Un-cultured bacterium (103 µg PNP/ml). High IAA production was recorded with *E. asburiae-3* (200 mg/ml) followed by *Pseudomonas putida-1* (140 mg/ml).

Table 15 : Weed control treatments on weed count, weed control efficiency and seed cotton yield

Treatments	Weeds count/m2	Weed DMP (g/m2)	WCE (%)	SCY (kg/ha)
SSBT glyphosate 1.0 kg week after irrigation	128.4 (11.32)	52.9	54.59	2339
SSBT pendimethalin1.5 kg third day after irrigation	37.6 (6.11)	19.00	83.69	3565
SSBT glyphosate 1.0 kg + pendimethalin 1.5 kg week after irrigation	26.42 (5.13)	15.6	86.61	3686
Pre emergence application of pendimethalin 1.5 kg 3 DAS	44.57 (6.66)	24.4	79.06	3402
SSBT and manual removal of weeds thrice	49.41 (7.02)	28.5	75.54	3740
Un weeded check	263.0 (16.2)	116.5	-	8.55
CD (p=0.05)	**0.55**	**4.59**		**311.2**

Figures in parenthesis are square root transformed values for statistical analysis.

Geo-referenced soil information system for land use planning and monitoring soil and land quality for agriculture

A survey was undertaken in established benchmark soil series in Black Soil Region (BSR) of India covering 6 AERs and 16 AESRs (3.0, 5.1, 5.2, 6.1, 6.2, 6.3, 6.4, 7.1, 7.2, 7.3, 8.1, 8.2, 8.3, 10.1, 10.2, 10.3) accounting for 19% (63 m ha) of total geographical area of the country to analyse the impact of management practices on selected soil biological properties (soil urease, soil dehydrogenase, microbial biomass carbon and soil microbial population) for development of land quality indicators and threshold values. From each benchmark spots, soil samples were collected from individual horizon in two pedons, one each representing farm management (FM) and high management (HM) regimes. From the analysis, high management found to recorded higher soil enzymatic and microbial activity as compared to farm management in all the BM spots studied. In general, the enzymatic and total microbial activity declines with the depth, and maximum activity (>50%) have been restricted to 50 cm.

4.14: Cotton Mechanization

Nagpur

Development, evaluation and refinement of seed bed preparation, planting, inter culture and spraying machinery for cotton production

Manually operated cotton planter

Manually operated cotton planter was developed for planting cotton seed. It is light weight, simple in operation, and delivers single seed in 30 ± 1.5 cm plant to plant spacing. The plant to plant spacing can be varied from 10 - 30 cm.

Adjustable cultivator: Adjustable cultivator was designed and developed for intercultural operation for narrow spaced cotton crop with an adjustment in the row spacing. It can be used successfully for high density planting cotton crop.

Bullock operated fertilizer attachment to bakhar: A fertilizer applicator has been modified for equal distribution of fertilizer from both tubes. A single agitator is attached above the opening for fertilizer metering. The agitator spread the fertilizer in equal proportion in both the delivery tubes.

Fertilizer Applicator

Mechanization of cotton picking operation

Testing of spindle type cotton picking machine

It was observed that geometry of crop and plant height affects the picking drum dimensions. The RPM of spindle and the linear speed of each spindle relative to the speed of cotton bolls (the latter depending on the forward speed of travel of the machine) ultimately affects the picking efficiency. The performance results of the machine having forward speed, effective field capacity, fuel consumption, total harvesting loss, mechanical picking efficiency and picker efficiency were 2.20 - 3.38 km/h, 0.278 - 0.563 ha/h, 22.0 - 24.0 l/h, 14.29 - 31.74%, 55.6 - 83.1% and 68.3 - 85.7% respectively.

Testing of commercially available manually operated small hand picking machine

Manually operated small hand picking machine was tested in CICR, farm as well as in farmer's field. It has been found that, the field efficiency of the machine was varied from 56% to 100% of the manual. It was seen that the machine efficiency was at best at par with manual picking given adequate training to the operator.

4.15: Morphoframe / Boll Load Management

Nagpur

Physiological manipulation of Bt cotton plant morphoframe for enhanced productivity

The physical nipping of plant reduced the height when compared to control. Foliar application of Maleic hydrazide (MH) also brought about the same effect by effectively inhibiting the meristem growth in both main stem and sympodial branches. The nipping or use of MH enhanced the leaf area and it was maintained higher than control on all the genotypes tested. The biomass and yield also showed a positive effect with treatments over the control. The per cent increase in seed cotton yield ranged from 6 to 25 %.

Stance, a combination of mepiquat chloride (anti- gibberellins) and cyclanilide (anti-auxin) and defoliants, Dropp Ultra (thidiazuron+diuron) and Ethrel (ethephon) were tested for their growth retarding and defoliation efficiency respectively, in 31 popular Bt Hybrids on rainfed Vertisols. Stance was sprayed at match head square stage of the hybrids @2.5 ml/5 litres of water. Stance was effective in reducing the plant height of MIST BG, RCH 314 BGII and BTH 97377and this may be attributed to the reduction in the endogenous levels of gibberellins and auxins which are responsible for apical dominance. The canopy width of Goldmine, SP 1037, MRC 6304, Platinum 144 and Brahma BGII was reduced by the application of Stance.

Defoliants, Dropp Ultra and Ethrel were sprayed @ 5 ml/12 litres of water and 60 ml/12 litres of water respectively, when 70% of the bolls were opened. Dropp Ultra performed better with 90 to 100% defoliation after 15 days of spray. Higher defoliation efficiency of Dropp Ultra can be attributed to its active ingredients *viz*., thidiazuron and diuron, with thidiazuron, inhibiting the polar transport of auxin (increasing the ethylene to auxin ratio) and diuron, blocking the electron transport chain of photosystem II, thus inhibiting photosynthesis and accelerating senescence of leaves. The decreased efficiency of Ethrel in defoliation in the present study could be because of low temperature which prevailed during the post application period. At temperatures <15.5 °C (at night), ethephon efficiency decreases, because of a temperature dependent degradation to ethylene.

Sirsa

Effect of defoliant on physiological parameters and seed cotton yield.

The effect of application of Ethrel at concentrations 1500 ppm, 2000 ppm and 2500 ppm at 145 and 160 days after sowing on Bt. hybrid RCH 134 was evaluated. The numbers of opened boll/plant were significantly higher in the crop sprayed with 2000 ppm (39.0) and with 2500 ppm (41.0) concentration of defoliant at 160 DAS than control unsprayed crop (32.7). Because of higher number of opened bolls, the yield / ha was significantly higher in crop sprayed on 160 DAS with 2000 ppm (2500 kg/ha) and with 2500 ppm (2580 kg/ha) than unsprayed crop (2147 kg/ha).

4.16: Studies on Abiotic Stress

Nagpur

Physiology of drought tolerant genotypes

Eleven *G. hirsutum* cultures were raised in pots under rainout shelter and rigorous screening of the lines for drought tolerance and yield was carried out. The drought stress was induced at the onset of flowering (75 DAS) for 15 days. The physiological parameters like water potential, osmotic potential, chlorophyll stability index and membrane stability index was studied. Among the biochemical constituents-reducing sugars, amino acid, proline and protein was studied. All the eleven lines were found to be tolerant to mid-term stress compared to the check LRA 5166.

Physiology of drought resistant transgenic cotton

Sixteen transformed plants for DREB and ZFP genes were raised in pots along with control plants of LRA 5166. The plants were grown under optimum conditions till flowering. Moisture was withheld after 75 days after sowing and plants were allowed to grow under receding moisture. The leaves of both non-transformed and transformed plant started to droop within seven days after stress induction. The transformed plants would show recovery during night and leaves were turgid in the early part of the day. This helped the plant to recover and grow normally. The leaf water potential also was maintained at higher level due to accumulation of solutes, which was not observed in case of control plants.

In the second method of screening, the leaf discs from non-stressed plants of both transformed and non-transformed were placed on PEG medium with varying degrees of stress (0, 0.4, 0.6 and 0.8 MPa). The biochemical changes induced due to stress was quantified at 0, 7 and 15 days after inoculation. The data showed that there was an inherent tolerance developed in transgenic plants due DREB and ZFP genes. The control plants showed a immediate burst in synthesis of reducing sugars, amino acids and proline, but declined by seven days. The transformed plants showed a gradual increase in solute accumulation and maintained high even after 7 days. The non-transformed discs produced very high phenolics which led to death of the tissues with stress. Of the sixteen plants, based on the biochemical and physiological factors six transgenic plants were selected for confined trails.

Leaf reddening

The project on leaf reddening was initiated during the year 2010-11 and several treatments including chemical fertilizers, hormones and insecticides. Foliar application of nutrients (viz., urea, DAP, $ZnSO_4$, $MgSO_4$, lime, potash, ascorbic acid and salicylic acid), hormones (viz., NAA, GA, mepiquat chloride, maleic hydrazide and methanol), insecticides (Monocrotophos, Chlorpyriphos, Larvin, Methomyl, Confider, Fenvalerate, Acephate and Thiomethoxam) and fungicide (copper sulphate, copper oxychloride and Bavistin) were tested. The physiological, biochemical, morphological analysis of the leaf samples were done to study the cause and effect of inputs on leaf reddening.

With the receding moisture and high light intensity the reddening of leaves was induced. Foliar application of nutrients, hormones and fungicide could not control leaf reddening, but the intensity of reddening varied. Plant applied with monocrotophos and confider showed no reddening all through the season. Foliar application of Methomyl at recommended dose showed toxicity effect and the whole plant turned red within 24-48 hours after application. The cross section of control and treated leaves showed that the insecticides were absorbed through the stomatal opening and immediately affected the guard cells. Anthocyanin was accumulated in the guard cells and with time led to the death of the cell which was very clearly visible from avacuolated cells.

A colour chart has been developed to rate the extent of leaf reddening. The chart is now being used in AICCIP for rating the extent of damage due to reddening.

Coimbatore

Alleviation of moisture stress

The effects of various combinations of nutrients were studied under moisture stress and irrigated condition in Bunny Bt cotton. Nutrient consortia spray recorded 23-25 bolls under irrigated and moisture stress condition compared to 20 bolls in control plants. *Panchakavya*, Hoagland solution and DAP 1% + KCl 0.5% could also increased the boll no significantly under irrigated condition.

Boll weight was not altered significantly by nutrient spray under moisture stress condition. Irrespective of treatments, significant differences in yield could not be recorded between irrigated and moisture stress treatment. However, a significant difference due to nutrient spray was evident on yield. For instance, spray of nutrient consortia increased the final yield significantly both under irrigated and moisture stress condition with 127.19 g and 130.50 g per plant respectively compared to 104.80 g per plant in control (Table 16). Other treatments like *Panchakavya*, Hoagland, DAP (1%) + KCl (0.5%) could also increase the final yield significantly.

Leaf reddening symptoms was comparatively less under irrigated than moisture stress condition, irrespective of treatments both at 120 days after sowing and at harvest. Among the treatments, nutrient consortia showed a distinct differences in maintaining the greenness of the leaves upto harvest followed by *Panchakavya* and DAP (1%) + KCl (0.5%). In control plants, 70-75% leaf reddening was recorded where as in treatments like nutrient consortia spray leaf reddening symptoms was to the extent of 30-35%.

Effect of heat stress on growth and development of cotton

Six Bt cotton hybrids and 3 commercial genotypes were evaluated for tolerance to heat stress in pot culture. Morphological attributes and physiological parameters were favorable under T 2 treatment (plant grown under heat stress initially for 30 days and then shifted to ambient condition). For instance, the total dry matter production at harvest was higher in T 2 suggesting that initial shock of heat stress for 30 days was beneficial to cotton for better growth and development.

Table 16 : Effect of nutrient spray on yield and yield components

	Boll number/plant		Boll weight (g)		Yield (g/plant)	
Treatment	**Irrigated**	**Stress**	**Irrigated**	**Stress**	**Irrigated**	**Stress**
Nutrient consortia *	23	25	5.53	5.22	127.19	130.50
Panchakavya (3%)	23	22	5.10	5.16	117.53	113.52
Boiled ash (5%)	21	22	5.19	5.20	108.99	114.84
Hoagland solution	24	23	5.11	5.14	122.64	118.22
Hoagland + NAA	23	22	5.22	5.03	120.06	110.66
DAP (1%) + K (0.5%)	23	22	5.22	5.24	120.06	115.28
Control	20	20	5.43	5.32	104.80	104.00
CD at 5%	2.3		NS		9.2	

* DAP 1% + KCl 0.5% + $MgSO_4$ 0.5% + $FeSO_4$ 0.25% + $ZnSO_4$ 0.25% + micronutrients

Hybrid Bt cotton appeared to be more sensitive to heat stress. Hybrids like MRC 6918 and Mallika produced less reproductive parts and dry matter under heat stress while genotypes like LRA 5166, H -777 and Anjali were more tolerant to heat stress and produced more dry matter and yield. Irrespective of Bt cotton hybrids evaluated there was a reduction of 5.5% in dry matter of reproductive parts when grown completely under heat stress condition (T 1). On the contrary there was an increase of 11.6% in cotton genotypes grown under heat stress condition. However, both Bt cotton and genotypes showed a significant increase of 27.2 and 39.7% respectively in T 2 treatments. Again, a reduction of 11.3% and 3.7% in Bt cotton and genotype was recorded for T 3 treatment (plant grown under ambient initially for 30 days an then under heat stress) indicating that genotypes could tolerate heat stress compared to Bt cotton.

The results also suggested that T 2 treatment (plant grown under heat stress initially for 30 days and then shifted to ambient condition) was beneficial for cotton.

Sirsa

Heat and salinity tolerance

With the aim to identify the heat tolerant cultivars which can improve plant stand, screening was made using 50 working collection of each *G. hirsutum* and *G. arboreum* exposing their seedlings to temperatures ranging from abiotic stress 31.0-46.6, 23.4-43.4 and 24.4-46.6 degree centigrade by sowing at different intervals. Comparatively heat tolerant lines were Stonevilla, SA 1057, SA 1078, SA 1393, SA 1427, SA 310, SA 1601 of *G. hirsutum* and CISA 361, AC 3475, AC 3134, AC 3346, AC 3026, AC 3392, AC 3065, AC 3553 of *G. arboreum*.

Similarly, with the aim to identify the tolerant genotypes for salinity which can be used for improving the plant stand under saline conditions, screening was made using 50 working collection of each *G. hirsutum* and *G. arboreum* under naturally developed saline farmers field. Out of fifty lines, only few lines could germinate and survive under saline condition. The percent plant stand in these line was very less between 10 to 25%. In *G. hirsutum* SA 1178, SA 1168, Stonevilla, SA 1393, SA 1522, SA 1101,NACA 5, RS 810, AO3N 123 and in *G. arboreum* AC 3603, AC 3194 NLL, AC 3652, AC 3736A, AC 3222, CISA 53 were comparatively tolerant.

4.17: Socio Economic Dimensions of Cotton Farming

Assessment of cotton based intercropping system

Data collected from 120 farmers of Akola in Maharashtra and Khandawa in Madhya Pradesh, indicated that all farmers in both the districts were aware about intercropping of soybean, mung, urid, cowpea with cotton. The benefits and advantages of intercropping such as additional returns, helping to suppress weeds, minimize soil erosion and increasing fertility of soil were aware by many of respondents (53.33 - 83.33 %). Knowledge assessment and adoption of cotton intercropping indicated that one third respondents (34%) were placed under full knowledge group while one fourth respondents (26%) had fully adopted various components of cotton intercropping. The overall percentage of knowledge and adoption of various aspects about intercropping was noted to the extent of 71.02 and 67.91 per cent, respectively. Medium and large holding farmers adopt more cotton based intercropping practices due to more land holding and frequent contact with extension personnel, while marginal and small farmers adopt cotton based intercropping on limited land holding and in leased area. The main constraints in adoption of intercropping were, difficulty in intercultural operations, lack of exposure and unsure about more income. The other bottlenecks were non availability of quality seed of appropriate varieties, lack of expert advice, fear of more expenditure towards intercropping. Land holding, social participation and age levels had significant impact on level of adoption of intercropping system.

Further for popularizing intercropping system through farmer to farmer's participatory learning approach, a farmer namely Sh. Vinod Raut was identified from village Weni in Hinganghat tahsil of Wardha district and trained and motivated to conduct on farm cotton + soybean and cotton + cowpea intercropping trials at his field in one acre each. Many farmers from his village and adjoining villages, as well as state agriculture department officials visited and appreciated these trials.

Agrarian distress among cotton farmers

The study conducted in two districts of Maharashtra indicated that majority of cotton farmers from distress district Yavatmal faced more sociological, economical and psychological problems and were under high level of distress as compared to progressive Jalgaon district. The sociological problems faced by the farmers were family responsibilities, family conflicts, increasing alcoholism/drug abuse. Among economical factors, the rising cost of cultivation, yield uncertainties, labour problem, inadequate irrigation facilities and increasing dependency on others in farming were important. The study also pointed out those psychological factors like worries about family responsibilities, increasing mental tension and fear of

loan repayment leads to distress. The overall contribution of psychological factors for distress among the farmers was noted to be 75.14 per cent. The other factors, include, inadequate training and exposure, lack of other earning sources, lack of perceived benefits from new technology, problems in getting crop insurance claims and lack of support systems. The study indicated that the psychological and economical factors are more severe among farmers in Yavatmal distressed district compared to progressive Jalgaon district.

Analysis of yield gap and constraints in cotton production

An attempt was made to estimate yield gap and constraints contributing those yield gaps was attempted in Maharashtra and Tamil Nadu. Jalgoan and Yavatmal districts in Maharashtra and, Coimbatore and Perambalur districts in Tamil Nadu were selected. Constraints in cotton production in these districts were identified and ranked based on the yield loss incurred due to each constraint.

Maharashtra

Results indicated that an average yield gap of 1020 kg/ha was present in the cotton production in Yavatmal district. Incidence and damage caused due to sucking pests like jassids, aphids, whiteflies, thrips, mealy bugs and mired bugs was the major constraint in cotton production which ranked first based on the yield loss. The problem of weeds ranked second among the constraints while leaf reddening ranked third. Delayed sowing due to late onset of monsoon and water logging ranked fourth and fifth positions. Other important constraints includes non availability/high cost of human labour, non availability of good quality seed, shortage/high cost as well as inferior quality of fertilizers, lack of knowledge about correct crop production practices, low price/price fluctuations of farm produce at the time of harvesting, dry spell during later stages of crop growth, deficiency of micronutrients , low temperatures during last stage of crop, reduced use of organic manures and incidence of diseases.

In Jalgoan district yield gap was estimated to be 1302 kg/ha. Incidence of sucking pests raked first followed by dry spells during later periods of crop growth and leaf reddening. Delayed sowing due to late onset of monsoon and non availability of human labour ranked fourth and fifth positions. Other important constraints includes low fertilizer usage , weed infestation, higher degree of use of non-certified seeds, deficiency of micronutrients, low price of farm produce at the time of harvesting, lack of knowledge about recommended package of practices, incidence of diseases, reduced use of organic manures and non availability of suitable machinery.

Tamil Nadu

Yield gap was estimated to be 7160 kg/h in Coimbatore district of Tamil Nadu. Weed problem was the main constraint followed by non availability of labour and untimely interculture due to shortage of labour. Damage due to sucking pests and scarcity of irrigation facilities ranked fourth and fifth positions. Other important constraints includes lack of knowledge about recommended practices, low price of farm produce at the time of harvesting, non availability of quality seeds, delayed sowing due to late onset of monsoon, dry spell during later stages of crop growth, low fertilizer usage, poor soil conditions, deficiency of micro-nutrients, lack of support systems and reduced use of organic and farmyard manures.

In Perambalur district yield gap was estimated to be 6170 kg/ha. In this district also Incidence of sucking pests ranked first followed by non availability of human labour and weed infestation. Delayed sowing due to late onset of monsoon and lack of irrigation facilities ranked fourth and fifth positions. Other important constraints include lack of irrigation facilities, untimely interculture, lack of knowledge about recommended package of practices, low price of farm produce at the time of harvesting, dry spell during flowering / boll development, lack of support systems, sub optimal use of inputs, deficiency of micro-nutrients and use of non certified seed, and reduced use of organic and farmyard manures.

Impact of Bt cotton cultivation on farm economy in India

Data was collected from 75 farmers from Dharwad, Belgaum and Raichur districts of Karnataka. Bt cotton area increased from 10.42 per cent in 2003-04 to 92.41 per cent in 2008-09. On an average, Bt cotton growers are incurring an expenditure of Rs. 37,582.62 per ha towards the cultivation expenses. Human labour is the major cost item in cotton cultivation accounting for 50.01 per cent of working expenses. Fertilizers and manures occupy second and third place accounting for 16.19 per cent and 11.09 per cent respectively of working cost. On an average cotton farmers are producing 1800 to 2200 kg of seed cotton per ha. Gross returns obtained from cultivation of cotton in one ha amounted to Rs. 52410. B:C ratio was worked out to be 1.39. B:C ratio was highest in medium farm category with 1.67 followed by large (1.55), small (1.52) and marginal farms (1.46) respectively. A reduction of 68 per cent was observed in plant protection cost in Bt cotton cultivation. Seed cotton yield in Bt cotton was 2300 kg per ha and non Bt cotton was 2100 kg per ha. An increase of 26 per cent in net returns was observed in Bt cotton cultivation when compared with non Bt cotton.

Majority of the respondents opinioned that profit increased from cotton cultivation increased, economic position improved and indebtedness decreased after taking of Bt cotton. As per the opinion employment in cotton cultivation, demand for labour, fertilizers and requirement of cash increased while demand for pesticides decreased due to Bt cotton. Similarly majority of the respondents opinioned that availability of seed, fertilizers and pesticides improved, sale price of cotton increased.

Economic implications of trade openness on Indian cotton economy

With the implementation of the agreement on agriculture in 1994, the international trade opportunities are expected to change as trade barriers are reduced and freer trade takes place. To study the implications of these changes on cotton production, the year 1994-95 was bench marked. The period 1980-81 to 1994-95 were grouped as pre-WTO period and 1994-95 to 2009-10 were grouped as post-WTO period. The post WTO period was further bifurcated into Pre Bt era (1995-96 to 2001-02) and post Bt era (2002-03 to 2009-10).

During the pre WTO period, the area of cotton was almost stagnant around 7.8 m ha. But, there was an increase in production and yield of cotton at a rate of 3.83 and 4.07 per cent respectively during the same period. The performance of cotton was quite impressive in the post WTO period. The area, production and yield had grown at 0.85, 7.35 and 6.45 per cent respectively. During the pre Bt period, cotton area decreased to 8.73 m ha from 9.04 m ha showing a negative significant growth rate of 0.86 per cent. The production and yield showed a positive growth rate of 3.44 and 4.37 per cent respectively.

Unlike pre Bt era, the post Bt era experienced an increase in area, production and yield to the tune of 4.37, 9.72 and 5.12 per cent respectively. The area increased from 7.67 m ha to 11 m ha, threefold increase in production from 13 to 33 m bales and yield from 300 kg/ha to 502 kg/ha. The influx of Bt technology has been one of the factors in the phenomenal performance of cotton in India. Though there were fluctuations, the cotton area, production and yield showed a positive trend of during overall period of analysis.

India has enjoyed a surplus of production over consumption since 2003-04, contributing to its emergence as one of the world's top exporters of raw cotton. Most important destinations for Indian cotton exports (based on value) are China (46.7%), Pakistan (20.5%), and Bangladesh (12.1%). During the post WTO period, the quantity of imports almost remained stagnant at 13 lakh tonnes and gradually reduced during post Bt era from 3.74 lakh tonnes to 0.85 lakh tonnes. The export increased from 2.89 lakh tonnes during 1999-00 to almost 14.11 lakh tonnes during 2009-10.

The trading in cotton, both domestic and international, is subject to several government interventions. The changing pattern of raw cotton exports were estimated by obtaining the transitional probability matrices for the annual export data of raw cotton (in terms of volume and value). The major cotton importers from India, i.e. Bangladesh, China, Japan, Korea, Thailand and the UK were considered for analysis. The cotton trade with the remaining countries was pooled under 'other countries'.

The analysis indicated that in pre WTO period Italy and Thailand remained, stable importers with a probability retention of 0.67 and 0.54 respectively. During the post WTO period, China and Japan remained, stable importers during pre Bt era. But after post Bt era only China remained as a stable importer of Indian cotton. Interestingly, minor importers of raw cotton, the other countries also remained importers with a probability of retention of 0.29 and 0.21 during pre and post Bt era respectively.

Comparative analysis of conventional, biotech and organic cotton production systems in India

The livelihood changes created by three different production systems in cotton farming was carried out to determine the additional benefits of each system in the social and economical arena, using the Sustainable Livelihoods (SL) concept with five identified capitals viz. natural, social, human, physical and financial capital. The study was conducted among 120 cotton growers, of them, 50% were Bt cotton farmers, 25% were non-Bt farmers and 25% were organic growers. The analysis on financial and physical capitals revealed that the Bt cotton production system was perceived by the participants to have become more economically resilient than other systems when faced with adversity. With regard to natural capital, organic production system has the perceived benefits of living in a cleaner environment as a result of reduced pesticide use. The organic farmers felt that their human and social capitals increased due to the knowledge and skills acquired through their involvement in organic farmers' associations while Bt and conventional farmers perceived no change. The analysis on sustainability level of these production systems were done using thirteen major sustainability indicators. Majority of the Bt cotton farms were found to be high with the indicators viz., production efficiency, net return, cultivated land utilization index and technology use level. Most of the organic farms were found to be significantly high with the indicators viz., low cost technology use level, employment generation capacity, farm family employment level, self reliant level, cultivated land utilization index, eco-friendly technology use level, organic recycling level, low external input use level, soil health and self sufficiency level. The cultivated land utilization index and technology use level were observed to be high with conventional cotton farms.

4.18 : Cotton Information System

Coimbatore

Indian Cotton Portal

The main purpose of the cotton portal is to bring cotton information especially Indian cotton scenario under single window system. In the present emerging trend and advancement in Information and Communication Technology especially dissemination of information, the only mass media which catch large population without any boundaries is the internet. CICR has identified the importance of this useful tool well in advance and made significant contribution for the dissemination of timely, systematic and reliable cotton production and protection technologies to the stake holders.

CICR website has been in the web of internet from 2001 onwards. In the initial phase it has some 40-50 pages site now in the year 2010-11, the cotton portal has more than 1000 pages and as much number of images covering cotton cultivation on various aspects. The cotton portal has two main sites and two sub-domains to cater the need of different stake holders. The main site www.cicr.org.in has information pertaining to National Cotton scenario, which has two sub domains viz., a)www.tmc.cicr.org.in b) www.aiccip.cicr.org.in.Recently,we have floated an exclusive sitewww.kvknagpur.org.in for the cotton farmers the contents exclusively supplied by KVK, Nagpur - the unit under CICR, Nagpur. All the sites under Indian Cotton Portal have been periodically updated with latest information and the obsolete information has been periodically reviewed and removed from the portal.

Decision support system for cotton cultivars selection

Many cotton cultivars were released over the years based on field trials but successful only in some locations or agro-climatic conditions and not so in all locations. Though the genotype underwent rigorous test procedures, recommendation/decision made for release of genotype for commercial cultivation is based on few attributes. Many a times the judgment for selection of particular genotype for specific agro climatic condition is cumbersome with complex attribute datasets. An ideal statistical tool, "Multi Criteria Decision Analysis" usually involves selection of a number of alternatives to achieve an overall result based on the suitability of those alternatives against a set of criteria. The criteria will normally be weighted in terms of their importance to the decision maker, since criteria are rarely of equal importance. With the use of this tool an attempt has been made to develop Decision Support System for selection of suitable genotype for the specific agro climatic conditions.