Maintenance breeding

The selected progenies (5 female and 5 male) of hybrid Om Shankar and their 25 crosses, and the newly released hybrids CSHH 198 and CISAA 2 were evaluated based on desirable gca effects and per se performance for yield, boll number, boll weight, 2.5% span length, uniformity ratio, fibre maturity and fibre strength in three replications. During first year several female and male parent progenies of these hybrids were selected based on morphological parameters from large plant population. Data on yield, boll number, boll weight, seed index and GOT was recorded from each progeny.

Breeder seed production

Breeder seed production of the following varieties has been taken up and would be commercially sold to the Seed Producers as per the Government of India allotment.

No.	Name of Variety/ Parent of Hybrid	2004-05	
		Indent (q)	Production (q)
1.	Savita T 7	0.22	0.09
	M 12	0.01	0.12
2.	LRA 5166	0.74	1.99
3.	Surabhi	1.02	2.50
4.	MCU 5VT	1.12	1.50
5.	Anjali	0.47	1.50
6.	Supriya	1.02	1.50
7.	Sumangala	0.15	0.50
8.	LRK 516	-	0.30

Nucleus seed production

Twenty kilogram seeds each of CNH 120 MB (Pratima) and CNH 36 were produced.

4.8 Integrated Water Management

Nagpur

Significant mean maximum (23.30 q ha^{-1}) seed cotton yield was recorded with two irrigations @ 4 ha cm of water, first at flowering and second at boll development stage closely followed by (22.64 q ha^{-1}) three irrigation at the same rate first at flowering, second at early boll development and third at peak boll development stage. One protective irrigation @ 4 ha cm of water at peak boll development stage enhanced seed cotton yield > 1 q and found superior over *in-situ* moisture conservation.

Seed cotton yield due to moisture conservation practices increased from 0.61 – 2.4 q ha^{-1} over control. Ridge and furrow system was best over others adopted in different topo-sequences.

The influence of intercrops on moisture conservation and seed cotton yield showed that one row of green gram with cotton has given maximum (15.91 q ha^{-1}) seed cotton yield followed by (15.52 q ha^{-1}) cotton + blackgram. Seed cotton yield under one protective irrigation at peak boll development stage has also produced almost similar (15.50 q ha^{-1}) quantity of seed cotton and found economical.

Water use efficiency

The influence of protective irrigations in relation to water use efficiency (WUE) on seed cotton yield was maximum (3.20 q ha^{-1} mm^{-1}) when applied one irrigation at peak boll development stage and the minimum (2.20 kg ha^{-1} mm^{-1}) under control.

While evaluating the impact of intercrops on seed cotton yield maximum (2.46 kg ha^{-1} mm^{-1}) WUE was recorded in the treatments where green gram was intercropped with cotton closely followed by (2.40 kg ha^{-1} mm^{-1}) cotton intercropped with black gram and the minimum (2.01 kg $ha^{-1}mm^{-1}$) under control.

Rain water management in cotton

Ridge and furrow system across the slope at the end of August was best and effective in reducing maximum runoff, increasing percolation, conserving

maximum rainwater and improving the recharge capacity of irrigation wells.

Recycling of harvested rain water enhanced seed cotton yield by 3-5 q ha^{-1} due to application of life saving irrigation while *in-situ* moisture conservation was able to improve seed cotton yield by 2-3 q ha^{-1} in upper to lower topo-sequences.

Coimbatore

Integrated water management system for quality fibre production

Highest seed cotton yield (1210 kg/ha) was recorded with protective irrigation at par with soil moisture conservation treatments of opening of the furrow at each row (1025 kg/ha) and alternate row (1015 kg/ha) after last interculture and compartmental bunding combined with straw mulching along with spraying of anti-transpirant (Kaolin 1%) at 30 days after rain (971 kg/ha). The highest seed cotton equivalent yield (1421 kg/ha) and highest rainfall use efficiency (4.54 kg/ha mm) were with intercropping of one row black gram between cotton rows which was closely followed by cotton + green gram intercropping system.

Response of different critical growth stages of cotton to protective irrigation

Significantly higher seed cotton yield (1950 kg/ha) was obtained with the application of irrigation scheduled at 0.8 IW/CPE ratio and was at par with other protective irrigation treatments, including application of irrigation at flowering and boll development and single irrigation at boll development and flowering stage. None of the irrigation treatments significantly influenced the quality parameters. Application of irrigation at boll development stage gave the highest irrigation water use efficiency (36.5 kg/ha mm).

Developing and testing of economical method of drip irrigation system in cotton

Linear Low Density Polyethylene lateral with dripper, with microtube and different thicknesses (200, 300 and 600 gauge) were compared with control (ridges and furrow method of irrigation) showed no significant improvement in seed cotton yield and ginning percentage of RCH 2. Seed index (10.9) and lint index (5.9) were significantly higher and net return (Rs. 17,151/ha) and cost benefit ratio (1: 1.56) were seen maximum in drip system.

4.9 Integrated Nutrient Management

Nagpur

Sorghum straw and grain yield are greater in the plots where FYM was applied with NPK. Least yield of sorghum was recorded in control plot and single nutrient applied plots. The results indicate beneficial effects of long-term FYM application persist.

A long term study was initiated to understand the effects of fertilizer and manure on the cotton + pigeon pea strip intercropping system. Results of the first year indicated that higher seed cotton yield was obtained with treatment $N_{60} P_{30} K_{30}$ + 2 t FYM + 2 t green manure (15.7 q/ha) followed by RDF treatment (14.1 q/ha) and farmers' practice (13.29 q/ha). Significant higher boll numbers were recorded with combined application of inorganic and organic fertilizer treatments over control.

A significant effect of nutrient management practices was observed in a field experiment conducted for the second consecutive year. Response to Zn and B was not observed. Yield in the plots with partial supplementation through organics (25 % and 50 %) was at par with the NPK plots. On the other hand, site specific nutrient management for a targetted yield was found to be the best treatment. None of the treatments affected the fibre quality parameters.

Response of both G. *arboreum* (cv. AKA 8401) and *G. hirsutum* (cv. Rajat) was noticed to foliar application of potassium at early and peak boll formation stages compared to K applied basally as soil application. Furthermore, soil applied K resulted in significant yield increase over the NP plots. However, K application did not impact any of the fibre quality traits. GOT of *G. arboreum* was significantly better in the + K compared to (-) K plots.

Cotton crop on ridges and furrows

Inter cropping in cotton with radish and amaranthus

Poly mulched cotton crop

In an organic farming and INM demonstration trial, results indicated that there was no significant difference in seed cotton yields obtained in organic manure treated plots and inorganic fertilizer applied plots. Higher root length and low dry matter accumulation was recorded in organic farming plots as compared to inorganic nutrients fertilized plots.

Under the NATP project, 40 on-farm trials on INM technology were laid out in two villages each in Yavatmal and Wardha districts. Data on soil moisture content indicated that soil moisture conservation treatment (ridges and furrow) with INM treatment had higher moisture contents as compared to flat bed system, and in an increased seed cotton yield by 2 to 3 q/ha more over farmers' practice.

The influence of major and micronutrients under protective irrigation on the yield of hybrid (Ankur 651) was evaluated. Results showed that the significant maximum (8.49 q ha^{-1}) seed cotton yield was recorded with 120 kg N + 60 kg P_2O_5 + 60 kg K_2O ha^{-1} + micronutrient (10 kg $ZnSO_4$ ha^{-1}) + growth retardant pix @ 50 ppm at 60 and 120 DAS followed by 120 kg N + 60 kg P_2O_5 + 60 kg K_2O ha^{-1} + 1.5 t ha^{-1} FYM every year and the minimum (4.48 q ha^{-1}) under control.

Response of Bt. cotton to application of micronutrients through soil and foliar at different growth stages studied showed improvement in seed cotton yield and staple length of Bt. hybrids *viz.* MECH 184 and MECH 162 as compared to recommended dose of fertilizer alone (N_{90} P_{45} K_{45}). Increase in Zn and Mn contents in soil (surface soil) was observed in the plots where micronutrients were given as compared to RDF plot. Higher incidence of bollworm was noticed on NHH 44.

Three years studies confirmed the benefit of supplemental irrigations from harvested rain water at peak flowering and early boll development stage of intra G. *hirsutum* hybrid NHH 44 in medium deep soils. This supplemental irrigations significantly improved the seed cotton yield by 24% i.e. 264 kg ha^{-1} over rainfed cotton. Pooled analysis of 2002-2004 results confirmed the need for micro nutrients application under supplemental irrigations to meet the higher nutrients demand at seed cotton yield levels of more than one ton per hectare. Application of micronutrients with supplemental irrigations such as B 3 kg ha^{-1} and Mn 10 kg ha^{-1} singly or together at soil + foliar application in 3:1 together Zn, Mn and Boron @ 10, 10 and 3 kg ha^{-1} every year significantly improved the seed cotton yield by 25, 20 and 18% or 372, 335 and 332 kg ha^{-1} over rainfed conditions.

Coimbatore

Testing of promising bio inoculants for potential utilization in cotton

Cotton crop responded significantly to fertilizers, bio inoculants and their interaction. Crop response was observed up to 100% N (60 kg/ha) and P (30 kg/ha) under uninoculated condition in the low N and medium P Vertisol. Fertilizer x bioinoculants interaction, revealed that highest (3327 kg/ha) seed cotton yield could be achieved with Azospirillum (HAU) + PSB + PPFM at 75% N and P level, which was 412 kg higher than 100% NP without bioinoculants. Seed index and lint index were influenced significantly due to level of N and P numerically due to bionoculants.

The yield level with either HAU or Surat culture of Azospirillum + PSB + PPFM at 50% NP is on par with 100% NP without bio inoculants, thereby a saving of 50% NP could be seen due to combined inoculation of Azospirillum + PSB + PPFM.

Individual effect of bio inoculants

Combined application of Azospirillum + PSB + PPFM at 75% N and P level produced an additional seed cotton yield of 642 and 496 kg/ha respectively than at 75% and 100% NP alone without bioinoculants resulting in 25% saving of N and P fertilizers is addition to increased yield of 496 kg/ha.

PPFM and Pesticide interaction

The phyllosphere population of PPFM, in the fully expanded third leaf of cotton on 45 DAS reveal that application of chemical fertilizers alone without

bioinoculants recorded significant reduction in PPFM colonies/cm2 of leaf. The phyllosphere population of PPFM recorded immediately after foliar spraying of PPFM has shown an increase of 57.3 to 94.7% population of PPFM in the treated plants over uninoculated check. However, pesticidal spray drastically reduced the PPFM colonies in the leaf. The reduction was only about 16.5% in the native PPFM (recorded in uninoculated plants), while the reduction in population of inoculated plants ranged from 27.6 to 59.6 % indicating that introduced PPFM is more susceptible to pesticides than native strain.

Assessment of organic residues along with *in situ* incorporation of green manure on soil fertility dynamics and cotton productivity

An integration of organics *viz.*, combined application of FYM @ 5 t/ha (15 days before sowing, DBS), cotton whole residues @ 2.5 t/ha (60 DBS) and sun hemp seeded @ 15 kg/ha simultaneously in inter-rows of cotton as GM and buried at 45 DAS produced significantly higher SCY (1904 kg/ha) over both control i.e., no NPK and RD-NPK.

Higher net return with less cost of cultivation was realized following application of crop residues/ GM over that in control.

The most revealing aspect of the present study is that application of cost effective organics available locally may act as an effective substitute for inorganic fertilization in sustaining the yield and restoring soil fertility.

Studies on changes in the soil physico-chemical properties and crop productivity under various soil cover/incorporation of *ex-situ* plant wastes in a freshly/ under-reclaimed sodic soil

Trianthema or *Parthenium* weed residues were equally effective in influencing seed cotton yield (with yields of 1791 and 1675 kg/ha) with that in FYM (1728 kg/ha); and all the above led to significantly higher seed cotton yield (over the treatments *viz.*, absolute control (no NPK & no residues), cotton crop residues, leaf litter and neem twigs etc.

Studies on the long term effect of continuous application of nutrients in fixed cotton based crop rotation on the productivity, nutrient balance and sustainability of the cropping system

Significantly higher seed cotton yield (1047 kg/ha) under cotton-jowar rotation compared to cotton-fallow (732 kg/ha) at the end of two years with additional jowar grain and straw yield to the tune of 6.5 and 17.5 t/ha, respectively because of higher crop growth and development. Application of FYM alone @ 15 t/ha, FYM @ 5 t/ha + RD-NPK or RD-NPK + crop residues had a beneficial effect on the cotton productivity in both the years.

4.10 Conservation Tillage

Nagpur

Effects of tillage management practices on *G. arboreum* and *G. hirsutum* were assessed for the third year. Tillage x genotype interaction was significant. Yield of the *G. arboreum* did not differ significantly between tillage systems. On the other hand, yield of the *G. hirsutum* was significantly better in the reduced tillage systems compared to the conventional tillage system (Table 8).

Table 8 : Effect of tillage systems on yield of *G. arboreum* and *G. hirsutum*

	G. arboreum	*G. hirsutum*	Mean
Conventional tillage	1089	1006	1047
Reduced tillage-1	1066	1163	1114
Reduced tillage-2	1136	1243	1189
LSD (0.05)	102		

A tillage x N or genotype x N interactions were not significant. Regardless of tillage systems, yield was significantly greater in the plots supplied with 75 kg N ha^{-1} compared to plots supplied with recommended N rate (60 kg ha^{-1}).

None of the fibre properties (staple length, strength, micronnaire and uniformity), 100 seed weight and GOT were affected by the tillage systems.

Expectedly, differences between genotypes were highly significant. Fibre length and strength were greater in the *G. arboreum* (cv. AKA 8401) than *G. hirsutum* (cv. Rajat). The fibre of the *G. arboreum* was coarser (mic. 5.0) as compared to *G. hirsutum* (4.5).

Coimbatore

Polyethylene mulch for Cotton-Maize cropping system

All the poly films, irrespective of the thickness and colour, promoted growth and enhanced the seed cotton yield ranging from 2769 to 3473 kg/ha as compared to 1846 kg/ha under non-mulching. The white coloured polymulch, out yielded all other colours with the highest seed cotton yield of 3473 kg/ha. The sucking pest incidence was very less in white colour (due to reflective action) and higher under yellow films (attractive action). In general, the stem weevil damage was very less under poly mulching and the infected plants produced galls but did not break due to higher stem girth and sturdy plants due to poly mulching.

The rate of mineralization was very high under poly mulching as evidenced from 1.33 and 2.18 fold enhancement in ammonical nitrogen (112 kg/ha) and nitrate nitrogen (244.3 kg/ha) respectively under poly mulching as compared to 84 kg/ha and 112 kg/ha recorded under non mulched soil. Due to favourable microclimate, the poly mulched cotton fixed higher CO_2 of 90.25 μ mol/cm^2/sec. as compared to 79μ mol/cm^2/sec recorded under non mulching and thus, the ploy mulched plants could assimilate higher biomass and resulted in better partitioning of assimilates. The rate of growth as measured by crop growth rate (CGR) revealed that poly mulched cotton grew faster.

Water use efficiency was heighest with 42.72 to 53.59 kg seed cotton/ha cm of water applied as against 23.12 kg seed cotton / ha cm under non mulching. Poly mulched plant could accumulate higher biomass and resulted in better partitioning of assimilates as evidenced from higher (38) number of heavier bolls (4.04 g) as compared to 22 bolls and 3.58 g/boll under non mulching. The ginning percent (34.9), lint index (3.99) and seed index (9.3) were favourably influenced by poly mulching as compared to 32%, 3.67 and 8.2, respectively for non mulching.

The intercrop also produced better nodulation and growth and recorded on an average 490 kg/ha grains as compared to 258 kg/ha under non mulching.

After harvest of cotton, fresh punching were made at 5 cm away from cotton holes and maize hybrid CORH M 4 was sown under zero tilled condition. The maize crop also benefited favourably due to poly mulching and the white coloured poly mulch recorded the highest grain yield of 8229 kg/ha, followed by yellow mulch (8044 kg/ha) as against 2864 kg/ha recorded under non mulching.

4.11 Cotton based Cropping Systems

Nagpur

Improving the efficiency of cotton+pigeon pea strip cropping in Vertisols

The studies on the competition and production efficiencies as influenced by 12, 8, 6 rows of cotton showed statistically non significant differences and reduced the seed cotton yield of adjacent cotton row by 36, 31 and 33% compared to middle rows. The single pigeon pea row produced 95 kg ha^{-1} more grain yield over two rows in *desi* cotton AKA 8401 + pigeon pea strip cropping. Hybrid cotton NHH 44 with single row of pigeon pea produced 42, 60 and 93% higher yields at 8, 6 and 12 rows of cotton respectively over two rows of pigeon pea and no significant differences were observed for 12, 8 and 6 rows of cotton or 1 or 2 rows of pigeon pea. Strip cropping with 1 row pigeon pea was economical at 6 and 12 rows of cotton whereas 2 rows of pigeon pea had at 8 rows marginal advantage. The pooled results of three years showed that year to year variations are significantly influencing both types of cotton and pigeon pea crop performance.

The seed treatment with bio-fertilisers in *desi* cotton AKA 8401 improved seed cotton yield by 42 kg ha^{-1} and alongwith 2% foliar application of urea improved the pigeon pea grain yields by 81 kg ha^{-1}

which is economical over farmers' practice (FP). The yield reductions were compensated by bio-fertilisers and 2% urea foliar spray by 10% over FP. In NHH 44 hybrid strip cropping with pigeon pea in 8:2 ratio, bio-fertilisers in hybrid cotton improved seed cotton yields by 153 (10%) and 93 kg ha^{-1} (7%) at 50% and 100 % recommended fertilizers respectively in 2/3 years. Two foliar sprays of 2% urea did produce 104 kg ha^{-1} (7%) improvement in seed cotton yield in 2/3 years. The pigeon pea grain yields were improved by 157 kg ha^{-1} at 50% recommended fertilizers with hybrid cotton strip cropping. The bio-fertilisers seed treatment in pigeon pea improved grain yields by 40% and RDF by 76% showing nutritional demand of legumes which needs attention. The application of recommended dose of fertilizers responded in all three years by 294 kg ha^{-1} (14%) over farmers practice. In hybrid cotton strip cropping system over all bio-fertilisers improved seed cotton yields by 166 (10%), foliar spray of urea 2% by 104 (9%) and 100% RDF by 192 kg ha^{-1} (19%) and bio-fertilisers over 100% RDF by 64 kg ha^{-1} (6%) respectively. The B:C ratio were improved from 2.78 to 3.66 by bio-fertilsers followed by RDF + bio-fertilisers 3.47 and bio-fertilisers with 2% urea as foliar spray by 3.18 in hybrid cotton +pigeon pea strip cropping.

Coimbatore

Evaluation of cotton based multi-tier vegetables intercropping system under irrigated condition

Growth characters and yield recorded in different multitier intercropping systems did not vary significantly. The highest seed cotton equivalent yield (4350 kg/ha) was registered with the multi-tier cropping of cotton with radish and amaranthus planted between cotton rows followed by cotton + radish + coriander + cotton (3806 kg/ha) as against sole cotton (2190 kg/ha).

Ginning percentage, seed index and lint index of cotton were not affected by the multi-tier intercropping systems. Radish and amaranthus planted between cotton rows registered the highest gross return (Rs.84908/ha.) and net return (Rs.55832/ha.) and cost : benefit ratio (2.9).

4.12 Organic Cotton Production

The survey conducted with organic farmers showed 50% yield reductions in 28-32 mm staple hybrids with no reduction in soybean- gram rotational crops. Farmers used *Jivamrut* (cow dung+urine, ghee and honey or jaggery paste) as seed treatment followed by 3-4 times application of *Amrutpani* (fermented liquid cow dung manure) + cow urine spray as vitalizer and NSKE 5% as insecticide. Insect management is crucial in years of heavy pest incidence under mono cropping of cotton.

One year study with extra long staple genotypes found Bunny, Abadhita, Sahana and Swati as superior to NHH 44 under organic managements. N fixing, P solubilising bacteria, *Trichoderma viride* and *Pseudomonas* application as seed treatment improved seed cotton yield by 21% over farmers' organic practice in long staple Surabhi cotton . Vermi compost improved seed cotton yield by 11%, Neem seed Kernel Powder (after spray) @ 2 kg ha^{-1} improved by 28% and EM application by 12% over organic farmers' practice.

4.13 Ergonomically Efficient Implements for Cotton Production

BCN single, Hollow cone and NMDS nozzeles were tested at 10, 20, and 30 PSI with Knapsack sprayer with single boom on dwarf compact genotype CNH 120 MB. NMDS nozzle found to deliver finer spray followed by hollow cone and BCN single nozzle with minimum ground loss of pesticide and giving maximum deposition on the site of egg laying on the top. The pressure range of 30 PSI is sufficient with backpack knapsack sprayer for NMDS nozzle and BCN nozzle provided the uniform pressure. Maximum spray was deposited at bottom leaves (36 %) followed by middle (36 %) and top leaves (23 %).

Adoption and Refinement of Cotton Picker and Cleaning Systems

Six varieties namely CNH 120 MB, CNH 911, CNH 123, CNH 2713, CNH 4736 and GSH 2 were planted at 100 x 45 cm spacing and tested in 2004

season with two row mechanical cotton picker to identify the suitable genotypes for mechanical picking. These varieties produced seed cotton yields under similar spacings as 881, 1506, 1590, 1285, 1529 and 1769 kg ha^{-1} in CNH 120 MB, CNH 911, CNH 123, CNH 2713, CNH 4736 and GSH-2 respectively. CNH 120 MB and CNH 2713 are most compact genotypes from height and spread basis. CNH 123 MB produced maximum bolls with 10-20 from main stem. CNH 911, CNH 2713 and CNH 4736 had all the bolls concentrated within 40 cm radially from the plant.

4.14 Production Physiology

Nagpur

Effect of plant growth regulators and nutrients on growth and yield of cotton

Three cotton cultivars *viz.*, LRA 5166, Bunny and AKH 8401 were grown in a replicated field experiment under rainfed condition. During flowering NAA and nutrients were sprayed singly and in combination to study the effect on growth, development and yield. The results indicated that the cultivar response remained significant, whereas the treatment differences were mostly non-significant.

Bunny hybrid was grown in pots and during flowering the treatments - Ethanol, methanol 1ml/l, Zinc 0.5 %, GA, IAA, IBA and Kinetin 100 ppm (single spray) and ethanol and methanol in combination with other nutrients and PGRs were given as foliar sprays. The results were significant with regard to plant height; inter node length, number of leaves, squares and total fruiting parts. The seed-cotton yield however, was non significant.

Foliar spray of GA 200 ppm and Ethanol 5 and 10 ml/l as single and in combination at flowering to Bunny hybrid grown in pots indicated that the treatment effects on growth and yield were non-significant.

Growth and Development of *Arboreum* in Shallow Soil

Arboreum genotypes viz CINA series 345, 346,347,348,349, AKA 8401 and AKA 7 grown in shallow and deep soil conditions were studied for growth and development during 90 to 120 days after planting. The study indicated that among the genotypes grown under shallow soil condition, CINA 348 has recorded better performance with regard to biomass production.

Yield modelling

A generic model INFOCROP has been calibrated and validated using crop, weather, soil, genotype, date of sowing, nitrogen level as basic inputs. The model has simulated the phenology more accurately and the accuracy of simulated yield was 92% and biomass 89% across the centers.

The integrated approach for yield predicting production at regional level (including RS generated data base, GIS and crop model) was further fine tuned with the use of refined model and was tested for Nagpur, Bharuch and Dharwad districts during the year. The model based integrated approach predicted the values of production and productivity lower than those reported by the Govt. in respect of Nagpur district. The productivity values were higher for Dharwad district as compared to Nagpur.

Source-Sink Relationship in Cotton

Nagpur

Under rainfed condition the contribution of early-formed squares to the yield is minimal. Mechanical removal of early-formed squares for either 10 or 20 days led to sudden spurt in fruiting activity. Some of the action specific chemicals such as ethrel at low concentration could delay the production of squares. This resulted in increased sympodial nodes on the plant and higher fruiting activity subsequently. However, increased yield could not be realized in these plants under rainfed condition mainly because the duration got extended and the late formed bolls were subjected to soil moisture depletion. Nevertheless, this technique can be made use of in effective control of insect pests.

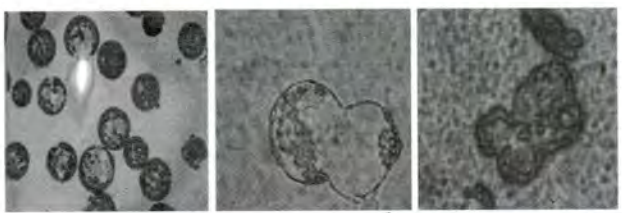
Coimbatore

Ethrel was used as foliar spray at three concentrations viz., 30, 45 and 60 ppm on 35th and 45th DAS in cotton cv. LRA 5166. At 60 ppm, there was total shedding of squares and also the vegetative growth was suppressed. The splitting of stem was observed when two sprays of ethrel were given. Two foliar sprays of ethrel at 35 and 45 DAS irrespective of the concentration brought about total change in the plant biology leaving the plants highly susceptible for sucking pests. There was synchronous flowering and boll development due to 30 and 45 ppm ethrel spray- leading to uniform boll bursting and picking could be completed in 1-2 pickings. The application of Ethrel at 45 ppm showed an increase in yield of around 40% (2340 kg/ha in LRA 5166 and 2400 kg/ha in Sumangala) over the control (1620 kg/ha).

Maleic hydrazide was applied at 90 and 100 DAS @ 500 and 1000 ppm in cotton cv. LRA 5166 and Sumangala. There was no perceptible change in the reproductive activity. The leaf area duration was prolonged by about 15-20 days. The boll size showed a marked reduction, while the boll number was enhanced by 25-30%.

Isolation and regeneration of cotton protoplasts

Hypocotyl and cotyledonary explants of cotton cv. Sumangala were exposed to three different sources of cellulolytic enzymes *viz.*, Cellulase and Macerozyme (from Yakult Biochem, Japan)- Onozuka enzymes; Celluloclast and Pectinex (Nova, Denmark); Cellulase and Pectinase (Genetix, USA), at varying levels of osmoticum and the digestion efficiency was studied. Mannitol at 9% was found optimum for maintaining the spherical shape of the protoplasts. The enzyme combination of cellulase (2%), macerozyme (0.25%) from Onozuka was found effective in release of good viable protoplasts after 12-14 hours digestion. The yield from hypocotyl explant was very low (2 x 102 protoplasts /g tissue) and released protoplasts were very fragile and could not sustain the purification process. Cotyledonary explants yielded healthy protoplasts (2 x 106 protoplasts /g tissues). MS basal medium with phytohormone combination of NAA (0.5 mgL^{-1}) + Kinetin (0.5 mgL^{-1}) and 2,4-D (1.5 mgL^{-1}) + Kinetin (0.5 mgL^{-1}) and plating density of 2 x 104 protoplasts/ml led to first cell division after three days in culture and subsequently showed quadruplet formation. The divided cells continued to survive for 15-20 days. The plating efficiency was 10-15%.



a b c

a. Freshly isolated protoplasts, b. First division
c. Quadruplet formation

Response of elevated carbon dioxide on physiology and productivity attributes of cotton genotypes

The desired level of 650 ± 50 ppm was maintained throughout the crop growth of cv. Suvin (*G. barbadense*). Right from the initial stages, the growth and vigour of the plant was significantly higher under elevated CO_2 atmosphere in terms of plant height, number of leaves and leaf size. The plant height recorded on 30th day after sowing was 9.5 cm compared to 5.2 cm in control plants under ambient condition. Leaf number was marginally more at 30 days after sowing. The leaf expansion rate was significantly faster under elevated CO_2 atmosphere with 30-40% more leaf area than the control plants. Photosynthetic activity and nitrate reductase activity in 70 days old crop was significantly higher than observed in plants grown under elevated CO_2 atmosphere. It was also seen that both photosynthetic and nitrate reductase activity got inducted earlier in the morning hours than control plants.

Sympodia number was significantly more in plants grown under elevated CO_2 atmosphere. Consequently, the boll number was also more and the boll development process was also faster. However, seed filling took 10 days more for the physiological maturity of the seeds to be attained in plants grown

under elevated CO_2 atmosphere than normal ambient grown plants. Significant increase in boll number and boll weight was recorded in plants grown under elevated CO_2 atmosphere. Consequently, the seed cotton yield was significantly more under elevated CO_2 atmosphere leading to significantly higher yield.

Nitrate reductase activity recorded 30% higher activity under elevated CO_2 atmosphere than ambient grown plants. Until 8.00 AM, the enzyme activity was at very slow rate as the leaves were quite wet on both adaxial and abaxial surface. However, this set back was compensated during the later part of the day.

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

The physiological and biochemical characterization of linted (cv. MCU 5) and lintless (cv. MCU 5LL) mutants of cotton was monitored from flowering to boll bursting. The protein content was high and ranged around 55 to 65 mg.g-1 till 15 DAA and thereafter lesser accumulation of protein was observed in both fibre (0.5-2.0 $mg.g^{-1}$) and ovules (20-50 $mg.g^{-1}$). Characteristic accumulation of reducing sugars and total free amino acids was noticed in developing seeds of lintless mutant as compared to linted MCU 5. However, such a trend could not be seen with respect to soluble proteins as it accumulated in both the genotypes. Peroxidase activity was found increasing till boll bursting in the seeds of both genotypes with a range of 40-175 units in MCU 5 and 40-200 units in MCU 5LL.

The physiological and biochemical characterization of fuzzy and fuzzless mutants (cv. AKA 98-8-1) was monitored from flowering to boll bursting. The biochemical constituents estimated are reducing sugars, proline, total soluble protein, total phenols, IAA oxidase and peroxidase. The peroxidase activity was slightly high in fuzzless (76 - 12 units in fibres and 87 - 196 units in ovules) during progressive boll development stage as compared to fuzzy genotype (68 - 10 units in fibre and 74 - 170 units in ovules).

4.15 Physiological Disorders

Nagpur

Effect of 2,4-D on plant growth

5 ppm of 2,4-D as foliar spray to Bunny hybrid during flowering indicated that appearance of typical symptoms was delayed under low temperature. The flowers showed malformation leading to reduction in size of flowers, petals and length of filaments bearing the pollen sac. Unlike in normal flowers, the petals of malformed flowers were mostly non-overlapping and stiff in texture. The pollen column has become conspicuously denser with reduction in the length of filaments. Due to the dense nature of pollen, the style appears protruded. The pollens were more brownish as compared to the normal flowers.

4.16 Stress Physiology

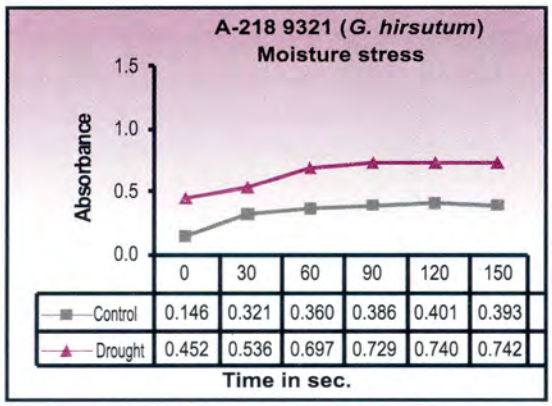
Nagpur

Screening of genotypes for drought tolerance

Nineteen genotypes *viz.* A 218, AC 19 GF, AP 18-2-1, Bunny, CAT 2107, CAT 2121, CPH 1835, LRA 5166, CAT 3260, Y 23, CAT 3656, CAT 710 , CAT 3289, CAT 1319, CAT 1934 (*G.hirsutum*) and AC 40, AS 49, CAT 6527 and CAT 3533 (*G. arboreum*) were grown in pot culture and during flowering drought stress was inducted. Leaf relative water content and leaf water potential were more prominent in *hirsutum* genotypes. On the other hand, solute concentration and root-shoot ratio were found to be relatively higher in *arboreum* lines.

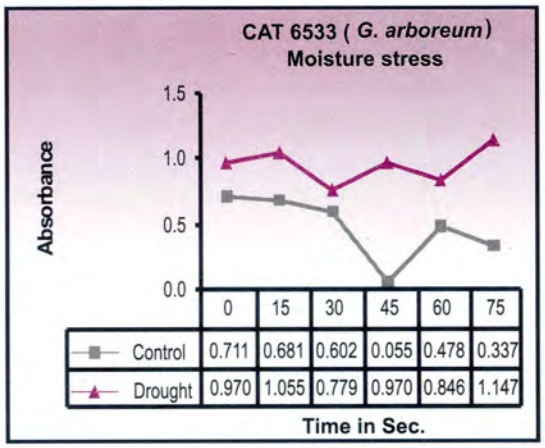
Nitrate reductase activity remained higher in eleven *hirsutum* and two *arboreum* genotypes under stress condition as compared to control. For *G.hirsutum* germplasm lines, initial catalase and peroxidase activity were found to be more under stress and after recovery phase, the difference between control and recovered set narrowed down. With time the catalase activity decreased more in stress samples than in control. In case of *G.arboreum* germplasm lines, catalase activity was found to be more in stressed leaves, but contrary to *hirsutum* lines, the catalase activity did not show decrease over a definite time period.

In case of peroxidase activity, the trend was found to be the reverse. (Figs.5 & 6).



	0	30	60	90	120	150
Control	0.146	0.321	0.360	0.386	0.401	0.393
Drought	0.452	0.536	0.697	0.729	0.740	0.742

Fig.5: Peroxidase activity in *G.hirsutum* lines



	0	15	30	45	60	75
Control	0.711	0.681	0.602	0.055	0.478	0.337
Drought	0.970	1.055	0.779	0.970	0.846	1.147

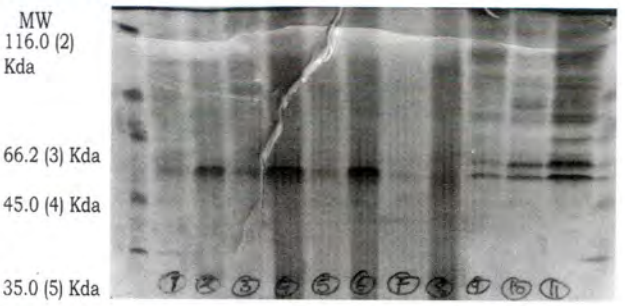
Fig.6: Catalase activity in *G.arboreum* lines

In an attempt to find out the response of cotton plants to stress proteins, leaf protein profile was determined through PAGE (Poly Acrylamide Gel Electrophoresis) for control and stress samples. Accumulation of proteins was observed under moisture stress conditions (Fig.7).

These proteins may be Heat shock proteins (HSPs), but needs further investigation.

Y 23, CAT 2107 and AC 40 had relatively higher drought tolerance.

Fig. 7 : PAGE showing bands in *G. hirsutum* and *G. arboreum* leaf samples under control and moisture stress



Genetical and anatomical studies for drought tolerance

Twenty four advance lines grown in control and moisture stress conditions were screened for leaf relative water content during flowering. The lines with higher leaf relative water content identified were - SPS 7 UR. SPS 20, SPS 28, SPS 30, SPS 39.

Salinity tolerance

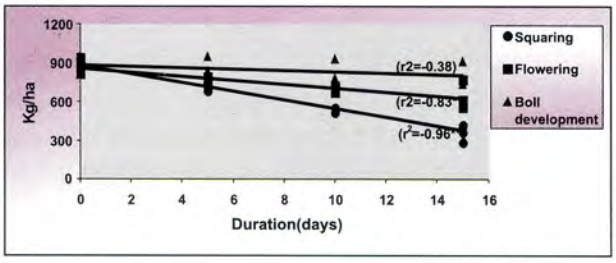
Cotton genotypes showed decline in growth and yield beyond 7 dS m^{-1}. Yield showed 10 to 20 % decline at 5 dS m^{-1} and at higher salinity, yield decreased at an increasing rate. The yield decline per unit increase in salinity was less in *G. arboreum* and *G. herbaceum* compared to *G. hirsutum* germplasm lines, hybrids and derivatives of wild species. The rate of yield decline was highest in hybrids. *G. arboreum* and *G. herbaceum* genotypes showed better tolerance for salinity. Leaf area production was very sensitive to salinity compared to decline in photosynthesis. Tolerant genotypes possessed higher accumulation of

proline and higher K/Na ratio. In cotton, the Na accumulation and K depletion was seen in roots, stems and leaves except the fruiting parts. Even at high salinity level fruiting parts maintained high K content. Decline of yield was more marked in G. *hirsutum* genotypes.

Water logging tolerance

The effect of water logging on growth, development and yield of cotton varieties and hybrids across the species was quantified in pot culture and field experiments. Depending upon the stage and duration of water logging treatment, plants response to water logging varied. Water logging for a period of 5 and 15 days at early seedling stage reduced the yield by 21% and 52% and at flowering by 11% and 37% respectively while, at later stages water logging did not show significant effect on growth and yield (Fig.8). Cotton plants at flowering and thereafter developed lenticels as an acclimatization phenomenon to withstand water logging. Wide variability was seen amongst species as well as varieties for water logging tolerance. *Hirsutum* and hybrids showed better tolerance compared to Asiatic cottons. However, prevailing weather conditions again found to influence the plants' response to water logging. Unlike yellowing, senescence, shedding of leaves and fruiting parts observed with water logging under cloudy weather, under bright light and high temperature water logging elicited wilting in cotton known as parawilt. These plants have been found to have insensitive stomata under adverse conditions.

Fig. 8. Effect of water logging duration on yield at squaring, flowering and boll development stages



Coimbatore

Identification and utilization of adaptive responses to abiotic stress in cultivated species of Cotton

Plants under water stress treatment showed significantly low rate of photosynthesis by 20 – 25% than control irrigated plants. Tolerant genotypes appeared to have better photosynthesizing capacity even under water stressed condition. Nitrate reductase activity also followed the same trend to that of photosynthetic rate. The crop maturity was delayed by 10 –12 days in plants grown under irrigated condition.

The moisture level of the soil under water stress treatment was 8-10% compared to 17 – 18% under irrigated condition as recorded on 130 days after sowing. Detopping of cotton plants at 10 cm from the tip at 90 days after sowing had a favourable impact on productivity.

Application of 2% *Kamadhenu* (cow's urine based organic fertilizer cum natural pesticide) as foliar spray brought usual change of dark green colour in the leaf. The photosynthetic rate and nitrate reductase activity was significantly higher compared to control plants. However, with repeated spray at weekly intervals, the effect of Kamadhenu on these parameters was not significant. Fresh *Komium* at the rate of 2% as foliar spray too showed the same trend.

4.17 Social Dynamics of Cotton Production

Nagpur

The panel data collected from 107 cotton growers from Mangli, Mohgaon, Kawdas and Adegaon villages in Hingna Taluka of Nagpur district during the year 2000-2005 revealed that the cotton growers whose total income is just enough to get barely on has been reduced from 35% in the year 2000 to 19% in 2005 and current financial condition of a family has become a serious problem for 46% of farmers which is increased from 26% during last five years. To supplement the income from farming, 16% more farmers have started doing off-farm jobs and womenfolk have increased their number of hours for

work on farm. Seventy per cent cotton growers are concerned about returning the loan they have taken for agriculture, which was only 9% during the year 2000.

The regression model for explanation of technology adoption behaviour of 127 cotton growers in Hingana Taluka of Nagpur district revealed that 53% of the variance in technology adoption behaviour related to adoption of hybrid cotton is explained by the variables like spatial distribution, availability of technology, marketing strategy, pricing, and promotional communications.

Impact of Technology Transfer

Analysis of the 95 FLD sample farmers from Nagpur and Coimbatore centers for showed awareness and adoption of intercropping with cotton shows that 67% respondents were aware about intercropping of cotton + soybean (1:1), cotton + Moong/Urd (1:1), cotton + cow pea (1:1). The analysis revealed that intercropping soybean, moong/urd and cowpea was adopted fully only by 7.37, 23.16 and 11.58% farmers respectively. Most of the farmers do not adopt the intercropping technology because majority of them fear that intercropping in cotton is not profitable. The other reasons for low or partial adoption of intercropping in cotton were, reduction in seed cotton yield, problems in interculture operations, fear of more pest incidence. In adoption of intercropping of cow pea with cotton, most of then expressed reasons such as them unawareness of technology, crop a competitor/ delayed growth of cotton crop. The common practice of cotton + pigeaon pea strip intercropping was adopted by more than 44% farmers.

Accessibility to Mass Media and Information Technology

Interview schedule proforma for collection of data was devised separately for extension functionaries and farmers. The sampling framework with respect of access to and use of modern mass media i.e. electronic media (radio & television), print media (newspaper and magazines) and information technologies (internet, cellular/mobile phones), etc. was finalized. Nagpur and Wardha districts in Vidarbha region of Maharashtra were identified for data collection from the respondents comprising both extension functionaries and farmers.

Coimbatore

Evaluation of cotton production technologies for yield, fibre quality and economic viability

Seven technological interventions *viz.*, Popularization of varieties (Surabhi and Sumangala), date of sowing, paired row technique (Intercropping with onion and beet root), fertilizer application based on Soil Test – Plant response correlations (INM), Integrated Weed Management (IWM), Integrated Pest Management (IPM) and Integrated Disease Management (IDM) were implemented during the year. Due to the interventions, 18 - 20 % yield increase was reported.

The farmers were motivated to take up commercial vegetables like beetroot / onion along with cowpea / blackgram under paired row technique. Water requirement was reduced by 15 per cent as compared to single row technique. The added return was appreciable to a tune of Rs. 5000/- per acre due to the intercrop.

Technology assessment and refinement of irrigated agro-eco system for coimbatore region tamil nadu through institute village linkage programme -

Various technological interventions were implemented as per the technical programme.

Sumangala was introduced to the farmers of Senthampalayam village, Coimbatore district wherein cotton is one of the major crop grown in 200 acres. In general, continuous heavy rainfall during the bursting stage of the crop coupled with low price of cotton has affected the overall profitability of the cotton crop during the present season. 'Field Day' was organized on 9th December, 2004 at the village, Allapalayam.

4.18 Cotton Economics and Marketing

Nagpur

Cotton outlook

Data were collected from 250 farm households on cotton performance during the year from Maharashtra, Andhra Pradesh, Gujarat and Madhya Pradesh. Year 2004-05 had been one of the best years from yield point of view but prices have fallen denying the accrual of benefits to the cultivator. The risk in farm income generated from prices, as the production world over has increased. Price fall also has not been production driven but by the subsidy support given by some major cotton countries.

Total factor productivity in cotton

Increase in crop production can be acreage/ input/ price or technology driven. Technology driven production is termed as total factor productivity (TFP) and measured as increase in rate of growth of output due to technical progress over rate of growth of input. The growth rates worked out over decades revealed declining productivity during 1990s in Sirsa, where as Yavatmal indicated productivity gains in post hybrid era. Time series data on agricultural inputs use since 1970-71 have been collected for Sirsa and Yavatmal districts. The information included crop acreages, production, yield, fertilizer consumption, irrigation, electricity, farm machinery, agricultural labour, animal power, prices, etc. Difficulties were encountered in collecting district-wise pesticides consumption and dis-aggregation of input use.

Bt cotton performance, constraints and risks

Data on Bt cotton performance and constraints have been collected from 300 households in the above states. This season (2004-05) too had witnessed less of the targeted pest (*Helicoverpa armigera*) menace, but there had been severe incidence of pink boll worm (*Pectinophora gossypiella*) and considerable incidence of Spodoptera (*Earias vittella*) particularly in Andhra Pradesh. Bt cotton had shown better resistance to pink bollworm and recorded higher yields with positive benefits ranging from Rs. 2200 to 20000/ ha. The partial budgeting revealed a net benefit of Rs.2200/ha in Maharashtra, Rs.4600/ha in M.P, Rs.5800/ha in Gujarat and Rs.9000-20000/ha in A.P.

The data collected from 60 cultivators in Surendranagar district (Gujarat) indicated that Bt hybrids recorded a yield of 20.46 q/ha against 16.34 q/ha in conventional hybrids. If the RCH-2 Bt alone was considered, the yields were still superior at 22.87 q/ha. The flip side of the technology was that many other non-descript and unapproved Bt hybrids too are in cultivation (few of them developed by farmers themselves) and seem to be popular among farmers.

The Andhra Pradesh survey covered 76 cultivators of Bt and conventional cotton hybrids in the intensive cotton district of Guntur. The average area under Bt was 1.58 ha against 1.53 under non-Bt cotton. Surprisingly 79 % of the sample farms Bt cotton area was totally rainfed indicating the risk capacity of the cultivators. While the 29% of the Bt cotton area was distributed between the officially approved Bt hybrids (MECH – 15% and RCH 2 – 14%), the rest 71 % of the area was under many non-descript Bt hybrids referred commonly by cultivators as Kurnool Bt (Kurnool district in A.P. is known for its cotton seed industry). The average yield performance was in the order – Kurnool Bt (33.68 q/ ha) followed by RCH-2 (30.12 q/ha) and MECH-12 (26.87 q/ha) as shown in table 9.

In cases of non-descript Bt, the seed price ranged between Rs.700 to Rs.900/packet against Rs.1600/ packet of official Bt and the concept of refuge seed supply itself was practically absent, while the adoption of the same in case of official Bt was less than 10%.

Besides there were clear benefits in terms of timely operation, crop termination, savings in yield loss and plant protection expenditure. Overcoming labour shortage ;minimizing exposure to chemicals, early termination of the crop, reduced plant protection expenditure, rejuvenating capacity of the Bt, are some of the reasons cited for preferring them. Besides, Bt particularly RCH 2 has shown resistance to pink boll-worm in Andhra Pradesh though the disadvantages

Table 9 : Performance of Bt Cotton in Guntur-2004-05

Particulars	Bt Hybrids			Conventional
	MECH -12	RCH -2	Kunrool Bt	Hybrid
Number of sprays	9.4	7.8	6.9	12.8
Cost of Plant Protection (Rs./ha)	9477.5	7936	7548	12125
Cost of cultivation (Rs./ha)	28975	26694	25185	30987
Yield (q/ha)	26.87	30.12	33.68	25.25
Gross returns (Rs/ha)	45486	51581	58064	41031
Net returns (Rs./ha)	16511	24886	32879	10044

were susceptibility to sucking pests and excessive vegetative growth.

The low seed prices of unofficial Bt ranged between Rs.700-900 per packet against the conventional hybrid seed of Rs.400-500 per packet has set off intensive competition in the industry. While the pink bollworm resistance facilitated reduction in picking cost, the relatively poorer fiber quality in case of Bt cotton fetched lesser prices compared to their non-Bt counterpart. The indiscriminate growth in unapproved Bt cotton area is courting twin dangers of hampering the monitoring of resistance break down and yield overiding quality, especially when quality cotton is the need of the hour under WTO.

Marketing of Cotton

Data on marketing were collected from 200 farmers. The information collected from these farmers who have sold to the trader, federation and CCI and were compared for price and quality relationship. Price and staple length had positive relation matching up to 70% in on farm sales and CCI procurement. But federation pricing had more element of arbitrariness. Besides, the criterion of price determination by traders were collected and analysed and was found to be bearing some relationship with HVI recorded fibre parameters and the corresponding prices. The results show the need for changing the basis of price fixation on fiber quality than mere cost of cultivation alone on the basis of varieties as is being practiced by CACP currently.

Coimbatore

Present status, constraints and future strategies of cottonseed production in Tamil Nadu

Data were collected in respect of straight variety from two seed companies, 30 growers and 20 dealers in and around Coimbatore district. The average cost of cultivation per acre was around Rs.5935/. The B:C ratio worked to 1.30.

In case of hybrid seed production, five dealers each from three districts *viz.*, Coimbatore, Erode and Salem and seventy five seed growers were selected. Cost of cultivation in Salem was greater than in Erode but cost of production was very less because average yield in Salem was to the tune of 13.12 q as compared to 11.42 q in Erode.

Marketing channel was of three types : i) Seed growers – Seed organizers – Seed firms – Distributors – Dealers – Consumers; ii) Seed growers – Seed firms – Dealers – Consumers; or iii) Seed growers – Seed firms – Consumers. Channel III was more remunerative than other channels.

Information system on cotton

All the data collected so far have been digitized and an appropriate database was created. Beta version of the Information system on cotton was developed

using Visual Basic. NET as front-end and Microsoft Access as back-end.

Information System on Cotton Cultivars (InsCOT- ver 1.1) will provide information on all the cultivars released by various agencies so far in India. The CD was created with Visual Basic. NET as front-end and Microsoft Access as back-end. Digital Cotton Photo Library (DigiCOT – ver 1.1) contains collection of around 1000 photographs with thumb view as well as full view on various features of cotton including production, protection, wild species collection, cotton disease, biotechnology, post harvest, extension activities, etc.

Package of practice for cotton production system and ITKs related to cotton production system were documented.

4.19 Pest Scenario

Nagpur

During 2004-05, jassids, thrips and mirids (*Ragmus spp.)* attained pest status during mid-August, 1st week of September and mid-September, respectively. Aphid incidence was very low. Three peaks of fruit damage during mid-September, October last and November-December caused mainly by *H. armigera* to squares, *E. vitella* and *P. gossypiella* to bolls, respectively were observed. Damage peaks in respect of bollworms occurred with the simultaneous presence of all larval instars. With the occurrence of all fruiting structures simultaneously preference by *H. armigera* to squares followed by bolls and *vice-versa* by *E. vittella* was observed. Emerging pest status of thrips and mirids among sucking pests, and pink bollworm attaining the status of key pest in cotton were established. Considering larval diapause and off season moth emergence patterns in pink bollworm it is highly essential to focus on off-season pink bollworm management.

Aphidophagous coccinellids and syrphids were meager on account of low aphid abundance. Chrysopid oviposition coincided with both the peaks of *H. armigera* oviposition. Spiders and predatory mirids were regular in occurrence between September and November. Estimated egg mortality of *H. armigera* was 47.2 %. Seasonal mean parasitisation of *Earias* by *Rogas aligarhensis* and *H. armigera* by *Campoletis chlorideae* was 16.3 and 13.9 %, respectively.

A population of reniform nematode (*Rotylenchulus reniformis*) ranged from 20-150 nematodes per 250 cc soil at the time of sowing CICR experimental farm. At mid cropping season, the population varied from 200-360 nematodes/ 250 cc soil. Reniform nematode population dipped to 10-30 nematodes/ 250 cc soil with onset of winter. Soil solarisation reduced the population of root-knot nematode (Meloidaogyne incognita significantly.

Three plant species viz. marigold, custard apple and bitter gourd were found to repel phyto-nematodes from their rhizosphere up to one meter. There was reduction in nematode population involving crops as Sorghum while in cropping systems with Soybean, there was four fold increase in population of reniform nematode.

Soil with different nutrient status was surveyed to explore the possibility of use of nematodes as indicators of soil health. It was observed that free living nematodes as Cephalobids and Rhabditids were associated with high organic matter soil. Soil with high incidence of root-rot was found to have corresponding high presence of fungal feeding nematodes as *Aphelenchus spp.* and *Aphelenchoides spp*. High population levels of plant parasitic nematodes were associated with low population levels of free living nematodes and *vice versa.*

Coimbatore

During the year 2004-05, the pest infestation was low. Aphids appeared in the month of September and persisted all through peaking during October and January. Leafhopper incidence started in the month of September and the peak activity was in the month of December and the hopper population was 5-8 per plant during this period. Infestation of white fly and spotted bollworm was very low. Incidence of