NATIONAL AGRICULTURAL TECHNOLOGY PROJECT

RESEARCH ACHIEVEMENT

CENTRAL INSTITUTE FOR COTTON RESEARCH
NAGPUR

Compiled by :

Dr. S. K. Banerjee
Facilitator (Cotton)

Dr. S. K. Bhalkare
Research Associate

Mr. B. R. Pathak
Research Associate

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Dr. C. D. Mayee
Director, CICR, Nagpur

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Foreword

Central Institute for Cotton Research, Nagpur is the premier Institute in the country devoted to basic, strategic and applied research on cotton production technology. The institute has generated series of useful technologies such as development of quality cottons, rainwater conservation, nutrient management, integrated pest management and insecticide resistance management, to quote a few. It has been supporting the entire cotton research system in India through the network programme and through its own regional centres at Coimbatore (Tamil Nadu) and Sirsa (Haryana). Cotton productivity in the country rose from 99 kg lint to nearly 300 kg lint per ha between 1950 to 1995. However, the changes in trades, textile demand, modernization of industries, cotton as a commodity is receiving maximum global attention.

In this changing scenario, a closer look at production technology revealed many gaps to be filled by research and development. Cotton was very fortunate that these gaps were identified and understood well in time. However, due to lack of infrastructure, manpower and financial support, they remained unattended. Thanks to the launching of National Agricultural Technology Project in India, the cotton research and development gaps received immediate attention. Germplasm conservation and evaluation, varietal verification, production technology dissemination particularly in rainwater conservation methods, integrated nutrient management, integrated pest management, location specific socioeconomic parameters for production stagnation and cotton biotechnology were identified under the National Agricultural Technology Project programmes and concentrated. Target oriented efforts were made to achieve the objectives of each. It is matter of great satisfaction that the results of these projects are highly useful both for direct implementation or for indirect utilization in furthering the science and art of cotton production in India. CICR is extremely grateful to World Bank and all authorities of National Agricultural Technology Project who have given them this opportunity to participate in the programme. This publication is an embodiment of only significant achievements of cotton research and development carried out under National Agricultural Technology Project at Central Institute For Cotton Research, Nagpur. I must put on record my sincere thanks to Dr. S.K.Banerjee, National Agricultural Technology Project Facilitator, all PI's, CCPI's and associates who have done excellent job in successfully implementing the projects in the Institute and regional centres and to National Agricultural Technology Project Cell who compiled the information in the form of a publication.

Dr. C. D. Mayee
Director, CICR, Nagpur

NATP RESEARCH ACHIEVEMENTS

In India nearly 65 percent of the total cotton area is under rainfed conditions. The crop is subjected to vagaries of monsoon. Due to wide fluctuation in rainfall patterns and unexpected prolonged dry spells at different stages; the yield realization is low and highly unstable. Biotic stresses further aggravate the situation. Although lot of technologies to increase the production has been developed it could not be adopted *in toto* replicated in farmers field condition because of variability in soil, physical and chemical parameters, pest problems and erratic rainfall. Even in 35% irrigated cotton areas, lack of precise water, pest and nutrient management tools have been responsible for unassured yield. With less resource it was not possible to transfer the technologies already available under different farmers field conditions.

With the funding from National Agricultural Technology Project several priority projects were launched with the aim to develop new technologies to fillup the gaps in areas where research issues were either inadequately addressed or not tackled at all for want of funds, infrastructure or manpower. Where technologies were available but less adopted due to insufficient technology transfer effort, NATP attempted to address the issues through 'On Farm' demonstration of technology based on location specific needs.

The projects addressed a number of thematic issues like germplasm collection, on farm varietal evaluation, watershed- based resource conservation, integrated nutrient management, integrated pest management and biotechnology.

SIGNIFICANT RESEARCH ACHIEVEMENTS

A. Germplasm Collection and Varietal Evaluation

Survey/ Exploration and collection of cotton germplasm was taken up in potential remote areas of the country. In all, 522 samples of cotton germplasm have been collected against drastic genetic erosion in tribal areas with landraces and from areas having no report of cotton existence through explorations conducted in ten (10) different States/ Regions so far. Valuable collection of *G. hirsutum, G. barbadense* (with tree & climber habit) and *desi* cotton from high altitudes as high as at 1200 m. on hilltops of Mizoram State in Northeastern India (fig. 1)was done. The collected *Gossypium* germplasm from different locations comprise of lines resistant to biotic and abiotic stresses, salt and drought tolerant, high seed cotton retaintivity and economic characters like MHL ranging from 12.3 to 35.0 mm. and GOT ranging from 31.0 to 46.0% (fig. 2 & 3). So far 254 collected samples have been characterized as per the germplasm index card.

Fig.1 *Gossypium arboreum*

Fig 2 *Gossypium hirsutum,* bushy habit (Andhra Pradesh)

Fig.3 *Gossypium barbadense,* tree habit (Andhra Pradesh)

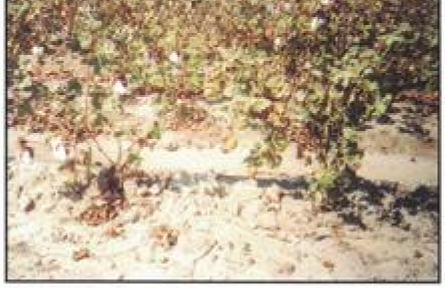

Fig 4 *Gossypium herbaceum* with Semi opened bolls in Coastal Saurashtra

Moreover, the collection of smooth stapled *G. herbaceum* with closed to semi-opened capsules and salinity tolerance from coastal area of Saurashtra has been undertaken (fig. 4). Passport data of all the collected samples have been submitted to NBPGR, New Delhi.

With an objective to upgrade net economy of the marginal farmers through increased productivity of *arboreum* (desi) cotton, the results of the on-station and on-farm testing reveal that the performance of *G. arboreum* was better and yield ranged between 1145 to 1955 kg/ha (DLSA 17) in comparison to 931 kg/ha (LRK 5166) seed cotton yield of upland Cotton. DLSA 17 also recorded the highest GOT of 38.87 % followed by PA 402 (38.78%) (fig 5).

Fig.5 DLSA 17 (*Gossypium arboreum* Genotype)

Some of the genotypes from introgressed population of *G. hirsutum* and *G. arboreum* for boll size, boll no. and fibre quality were isolated with boll weight of 2.98 gm, GOT - 40.36%, earliness index of 140-145 days.

Evaluation trial of suitable genotypes for different cropping system existing in cotton rainfed ecology reveal that red gram variety BSMR 736 was best suited for intercropping with PA 255 which gave the highest yield of 935 kg/ha indicating better performance of cotton genotypes under intercropping system than in sole cotton crop. (fig 6). Large scale 'on farm' trials of *G. arboreum* genotypes on farmer's fields proved that their performance was better than upland cotton and those could be promoted to minimize the cost of cultivation. (Fig-7)


Fig.6 PA 255 + BSMR 736 (Intercropping)


Fig.7 AKA 4801

These achievements through concentrated efforts forms the milestone in identification and evaluation of productive superior medium, fine quality *G. arboreum* genotypes suitable for rainfed ecology.

Further identification of suitable cotton variety for sustainable production under different agro-ecological situation was carried out for 2 years in a large scale evaluation trials which include genotypes of *G. hirsutum, G. arboreum, G. herbaceum* and 2 tetraploid hybrid combinations at 6 different agro-ecological situations considering rainfall and soil parameters.

Trial under high rainfall and medium soil situation having paddy as principal crop revealed that under adverse conditions of low rainfall, cotton can substitute paddy. Cultivation economics of rainfed cotton and paddy shows that cotton offers Rs. 3925/- net profit/ha whereas paddy offers Rs. 1509/- net profit/ha. Hence, cotton could provide financial backup in case paddy failure due to low rains (fig.8).

Fig.8: Cotton crop in Paddy dominated area

Project results also proved that cultivation of *G. arboreum* is beneficial not only in terms of higher production but also in cost of cultivation and cropping intensity. Cost of cultivation for *G. arboreum* varieties is Rs. 1935/- per hectare, for hybrids is Rs. 3775/- per hectare; where net profit of *arboreum* is Rs. 4065/- per hectare and that for hybrids is Rs. 225/- per hectare.

Fig.9: Farmers field view

Such tested technology on farmer's field with farmers own management consequently provides farmers an option to improve their socio economic status by adopting own tested technology (fig.9).

Adaptive trials were carried out to bring the saline alkaline lands that remain either uncultivated or sparsely cultivated into *G. herbaceum* cotton cultivation in the vast coastal agro ecosystem as this species of cotton, in general, possesses tolerance to salinity and drought. Thus, there is a potentiality to revive the coastal agriculture with impetus to grow *herbaceum* cotton in the existing cropping system, as well as in the sparsely cultivated barren and sandy loams. (Fig.10)

Fig. 10 *G. herbaceum* field in the back waters of Arabian Sea- economic yield of cotton assured

Through the concerted efforts, *G. herbaceum* cotton could be introduced in about three lakh hectares of land in the coastal agro-ecosystem in Karnataka, TN, AP, Gujarat and Union Territory of Pondicherry thereby improving the income and employment opportunities in the coastal farm holdings.

The high yielding ability of *desi* cotton hybrid G. Cot DH 7 was demonstrated in coastal areas of Gujarat (Khapat 14 q/ha & Danti 24 q/ha), Karnataka (Brahmavar 5 q/ha & Ankola 9 q/ha), Tamil Nadu (Kovilpatti 6.6 q/ha) and Andhra Pradesh (Konanki 6.4 q/ha & Uppugundur 5.4 q/ha).

G. Cot DH 9 established its high yielding ability in coastal areas of Gujarat (Khapat 14 q/ha & Danti 31 q/ha), Karnataka (Brahmavar 5.5 q/ha & Ankola 7 q/ha), Tamil Nadu (Kovilpatti 6.7 q/ha) and Andhra Pradesh (Konanki 7.0 q/ha & Uppugundur 5.8 q/ha). Both G. Cot DH 7 & G. Cot DH 9 registered very high yields (42 - 44 q/ha) in coastal areas of Karaikal (Union Territory of Pondicherry). These desi hybrids are being popularised through appropriate extension programme.

Fig. 11 *G. herbaceum* field in the saline soils of Gangavathi (Karnataka)

G. herbaceum genotype RAHS 14 was found to be saline tolerant, high yielding (8-9 q/ha) even under adverse conditions, early and well adapted in many locations. This genotype can be promoted in coastal areas of peninsular India for enhancing cotton productivity and income of farmers (fig.11)

The high yielding potential of *G. herbaceum* variety viz., DB 3-12 & G. COT 21 was demonstrated at several locations even under very adverse situations with average yield of 6 q/ha. Genotypes RAHS 14, RAHS 119, RAHS 101 & hybrids G. Cot DH 7 & G. Cot DH 9 yielded around 6-9.5 q/ha in highly saline areas of Ankola, wherein sea water intrusion was seen and crops like green gram/ black gram failed. The performance of *G. herbaceum* genotypes RAHS 132 & RAHS 14 under rainfed situation in Paramakudi (TN) was found superior with yield of 18 and 15 q/ha respectively. GBhv 198, GShv 531/92 & RAHS 131 have been identified as drought tolerant genotypes with better yielding ability at Surat. Based on physiological & biochemical evaluation at Guntur, var. Dhumad, Jayadhar, G. Cot 17 & G. Cot 21 were categorized as saline & drought tolerant genotypes.

Cotton cv. LRA 5166 was found best suited in coastal agro ecosystem of Sundarbans, West Bengal under cotton- rice system. A low cost technology for growing cotton seedlings in Pai nursery has been developed for transplanting of cotton seedlings and its survivability in coastal areas of Sundarbans.

Keeping in view the objectives such as developing improved production technologies like identification of superior genotypes, appropriate plant populations, integrated plant nutrient management and need based pest management, a trial with *G. arboreum* cotton under rainfed condition was conducted at ARS, Mudhol (AP). INM with *A. chrococcum* HT 54 (2) or

A. chrococcum Nagpur-2 or *Azospirillum* Nagpur-2 as seed treatment along with PSB + 2% urea twice as foliar spray at 60 & 80 DAS + 50% RDF, produced seed cotton yield similar to that with 100% RDF. *G. arboreum* cottons at Srikakulam (AP) were found to be distinct by fibre properties which help them to spin very high count as confirmed by scanning electronic microscope studies. These cottons favorably respond to INM and supplemental irrigations.

Ratooning is performing superior over seed cotton in continuous drought condition prevailed during past three years. Deep root system may be offering better survival and earliness of crop in drought conditions.

Development of male sterile based hybrid cotton lines and their evaluation was carried out with 198 CMS & 63 GMS hybrids. CINHH 109 a GMS based American cotton hybrid maturing in170-190 days, recorded 23% increase over the zonal check CAHH 468 (PKV Hy. 3) & having 25 mm. 2.5% span length, GOT of 34.3% and fibre strength of 22.2 g/tex at 3.2 mm. gauge. The promising GMS hybrids identified for seed cotton yield and fibre quality parameters as per the CIRCOT recommendations are as under :

Station Trial I - NGMSH 14, NGMSH 74, NGMSH 140, NGMSH 139, *LRA 5166 & NHH 44*

Station Trial II- NGMSH 15-02, NGMSH 14-02, NGMSH 23-02, NGMSH 32- 02, NGMSH 1-02, NHH 44 (cc) and PKV Hy. 4 (cc)

National Trial - CAHH 99, HHH 286, NGMSHH 89-99, CAHH 146, LMSH 102, CAHH 8

CMS hybrids NCMSH 90-02 (1009.25 kg/ha) & NCMSH 83-02 (896.08 kg/ha) were on par with the Checks NHH 44 & CAHH 8. AAH 7 GMS *desi* hybrid recorded highest yield of 1452 kg/ha followed by AKDH 32 (1281 kg/ha) in National Trial.

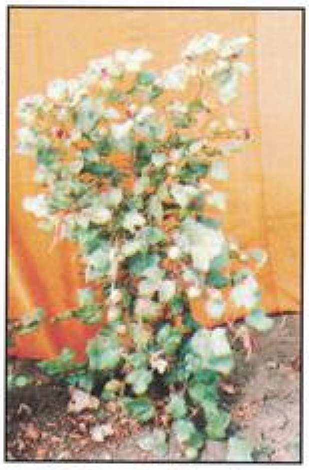

Fig.12 Cross boll setting in new converted and registered GMS line LRA 5166

Evaluation of existing & new MS lines of cotton reveal that PKV Rajat B (1597.21 kg/ha) followed by GSCMS 34 (1263.88 kg/ha) under sprayed and RCMSB 1 (1348.60 kg/ha) followed by GSCMS 15 (1189.48 kg/ha) under unsprayed condition were the best lines. Forty genotypes for CMS, 32 for R lines and 14 for GMS lines are under conversion. R line development through R X R crosses is also under progress.

LRA 5166 a newly converted GMS line has been registered with Plant Germplasm Registration Committee of ICAR, New Delhi (fig. 12).

A total of 198 CMS & 63 GMS based hybrids, A, B, R and GMS lines were field screened for their reaction to sucking pests and bollworm, while NCMSH 32 was found resistant to all the diseases. Out of 100 *hirsutum* germplasm lines evaluated, TAMCOT, CAMD-E, TAM 86- DDRK &TAM 86 E-14 were immune to all three diseases and among the *arboreum* lines screened, 30847, 1011, 6040, 8251, 30814, 30815, 30817, 30843, 30850, showed resistance to *Alternaria* leaf spot and grey mildew. Desi GMS lines GAK 20 A, GAK 09 and SGMS-2.were resistant to both grey mildew and *Alternaria*.

In order to identify various plant morphological traits suitable for mechanical harvesting, field trials were conducted at six cooperative centers in the country.

Fig 13 CNH 120 MB (Single Plant)

Based on the overall performance of all the genotypes contributed by the six co-operating centers and evaluated in three spacings of 90 x 30 cm., 90 x 20 cm. and 90 x 10 cm., high yielding and early maturing genotypes with almost synchronous boll opening (fig.13) having dwarf and compact plant structure have been identified at each location which may be suitable for mechanical harvesting. These identified genotypes are resistant / tolerant to sucking pests and recorded less bollworm damage.

Among the 42 genotypes with control check tested during the two crop seasons at Nagpur, some of the best genotypes with their yield potential are: ACCLD 163 (2016 kg/ha), GSH 8 (1955 kg/ha), CNH 155 (1900 kg/ha), HISAR 3 (1593 kg/ha), CNH 123 (1408 kg/ha), CNH 152 (1364 kg/ha). CNH 120 (2150 kg/ha) and CNH 123 (1844 kg/ha)have also performed better at UAS-Dharwad, & at RAU-Sriganganagar, respectively. One of the major impact of the project is that the closer spacing of 90 x 10 cm. was found to be best for compact genotypes irrespective of the environment / agro climatic conditions (Fig.14 & 15).


Fig.14 CNH 123 (Spacing 90 x10cm.)


Fig.15 CNH 155 (Spacing 90 x10cm)

Shedding of leaves before harvesting is a prerequisite for mechanical picker. Ethrel @ 5000 ppm. tested in large scale trial for two consecutive years indicated 85 to 95% leaf shedding after eight days of defoliant application / spray.

Complimentary to the evaluation and identification of plant type suitable for mechanical harvesting, another project was taken up for adoption and refinement of cotton picker and cleaning system. The findings pertaining to mechanical harvesting are also based on defoliant application resulting into low trash content. The distribution and the coordinates of bolls in several popular genotypes and for all the spacings have been studied and analyzed for the most compact plant type wherein most of the bolls were concentrated near the plant stem.

Genotype CNH 123 was found most compact with most of the bolls within 60 cm. from ground and 30 cm. from the row. However, there was no ground clearance as bolls were found in the 0-10 cm. region also. (fig 16) The promising genotypes identified for mechanical harvesting on the basis of boll distribution were i.e., CNH 123, CNH 152, HISAR 3, LH 1899. Although genotype CNH 152 had a shift of bolls upward upto 80 cm. from ground level, the lowermost bolls were above 10 cm. from ground and lateral spread was up to 40 cm. from the row. It was also found to be the highest yielder (fig 17).

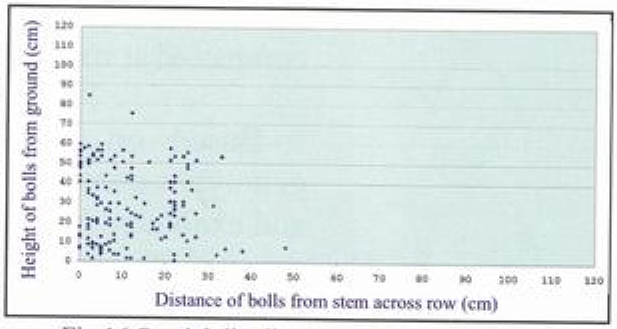

Fig.16 Spatial distribution of bolls (CNH 123)

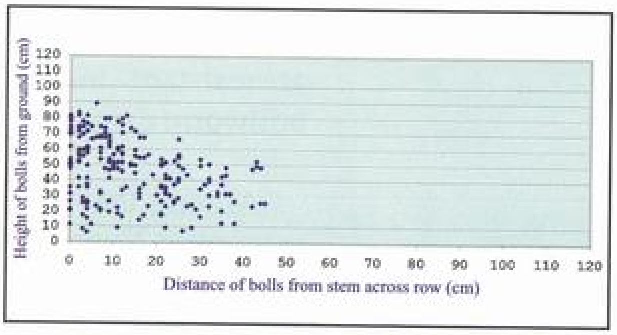

Fig.17 Spatial distribution of bolls (CNH 152)

Genotype HISAR 3 had most of the bolls concentrated in the region of 50-90 cm. from ground level with the lateral spread of about 40 cm. whereas the lowermost bolls were way above the ground at 15 cm. (fig 18).

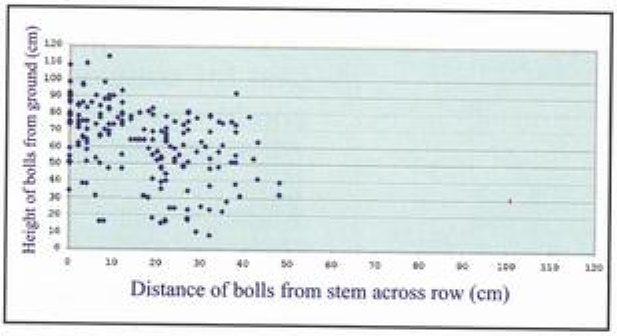

Fig.18 Spatial distribution of bolls (HISAR 3)

Gossypol content in cotton seed has been estimated for 450 working collections of *G. hirsutum, G. arboreum* and *G. herbaceum* germplasm lines where *G. arboreum* lines display comparatively more gossypol content on an average (fig.19).

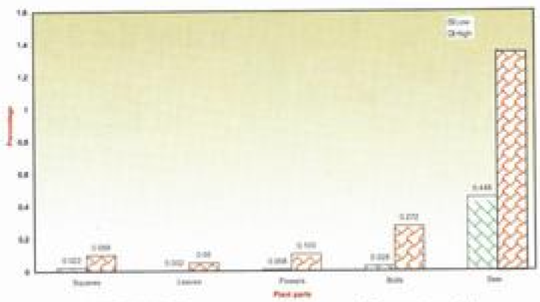

FIG.19 Percent Gossypol content in different plant parts of G. *Arboreum* lines

General observations reveal that gossypol content is considerably less in plant parts to that compared in seeds (fig. 20 & 21).

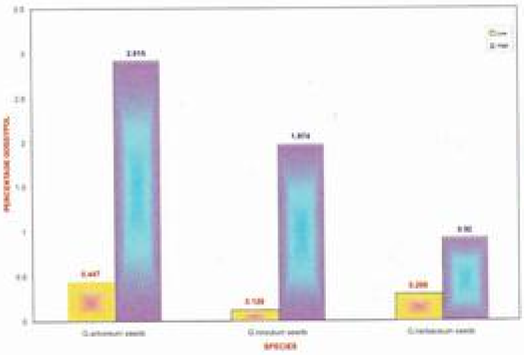

Fig. 20 Variation of Gossypol content in cotton seeds across the species

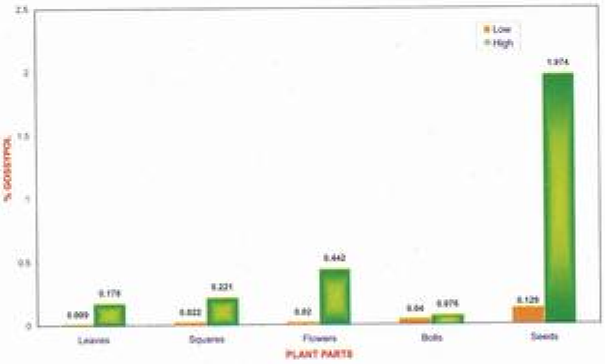

Fig. 21 Variation of Gossypol content in *G. hirsutum* plant parts

B. Biotechnology

The project on transgenic cotton was aimed to develop Bt. transgenic diploid and tetraploid cotton by standardizing regeneration protocol and incorporating Bt. gene mediated by *Agrobacterium*. Under rainfed conditions diploid cotton offers better promise from sustainability point of view where abiotic stress and poor soils are encountered.

An efficient regeneration protocol of cv AKH 4, AKA 5, RG 8 & AKA 8401 have been standardized by multiple shoot induction.

Fig. 22 Regenerated putative transformed plants *G. Arboreum* cv. RG 8

These four diploid cultivars of *G. arboreum* have enabled genetic transformation with desired genes. Medium was perfected for regeneration of complete plants, which were successfully hardened and established in the soil. (fig 22)

Transformation was carried out with *Agrobacterium* in these cultivars using the 2 gene constructs, i.e., CRY IA (c) & CRY IA (b).

In all, more than 10,000 explants were inoculated and 118 shoots were obtained (fig 23). During subsequent passages in selection medium, 6 plants were finally established in the soil and were grown in the glass house.

Fig.23 Regeneration of putative transformed plants *G. arboreum* cv. RG 8

Gene expression test was taken up using leaves samples from the putative transformed plants for detecting the presence of Bt. protein by conducting ELISA test. So far 114 leaves samples were tested out of which 61 samples were tested ELISA positive.

Further, in tetraploid cotton 150 putative transformants were developed in co- cultivated LRA 5166 ruling variety by growing them on 50 mg./lit. Kanamycin medium and subjected to rigorous screening on 100 mg./lit Kanamycin medium. Developed and survived shoots were allowed to grow on MS medium without Kanamycin and rooted with standardized efficient protocol for shoot tip & embryonic axis. (fig 24 and fig 25).

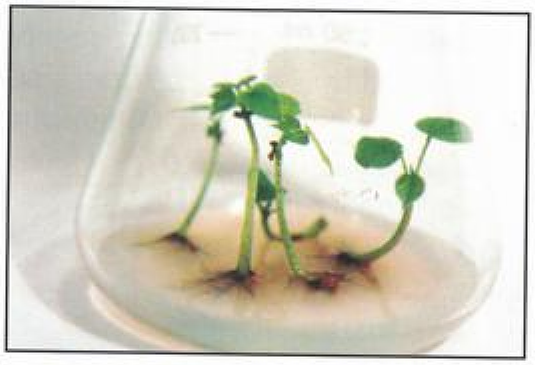

Fig.24 Embryonic axis growing on rooting medium after regeneration and Co- cultivation

Fig.25 Different stages of growth of Co- cultivated embryonic axis of cultivar LRA 5166

Developed putative transformed plants were analyzed by PCR based amplification of Cry I AC & NPT II gene and conformed the integration of fragments in the plant cell genome. The Cry I AC positive plants were tested with southern hybridization using probe of Cry I AC gene. *ELISA* test was done for satisfactory expression of CRY gene in the plants. Out of 150 putative transformed plants, 5 plants were found positive .(fig .26).

Fig.26 Fully developed and hardened plant of transgenic LRA5166

The first report on induction of para nodules in a non legume like *G. hirsutum* cotton *Rhizobium* & *Azorhizobium* strains revealed that *Rhizobia* could invade and induce the formation of nodules on cotton by certain virulent strains. The inoculation of nodules was done on seven days old seedlings of *G. hirsutum* Indian cultivars LRA 5166 & LRK 516 at in vitro condition with different growth harmones, viz., IAA, IBA, GA3, NAA & 2, 4 D. Among these growth harmones used IBA 0.4 mg/l induced more roots (avg. 53 roots/ plant).

Among the 12 cultures tested fast growing *Rhizobium fredii* (isolated from *G. max*) induced nodules after 10-15 days of inoculation. Averages of 30 nodular structures were observed all over the root system. Initiation of leaf curling and crack entry formation was noticed and recorded. Presence of *Rhizobium* (Bacteriods) was confirmed. The rRNA amplicon from root extracts and the culture extracted DNA amplicon were confirmed through ARDRA (Amplified Restriction DNA Ribosomal Analysis) pattern (fig. 27).

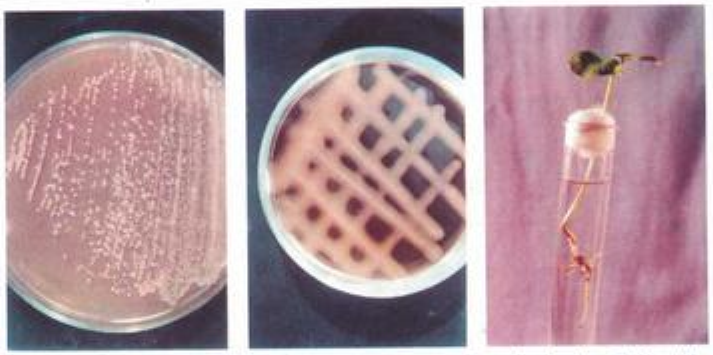

Plate 1 - *Rhizobium fredii* isolate, 2 - *Azorhizobium caulinodans* isolate, 3 - Seedling treated with *Rhizobium* isolates of root nodules induction in cv-Anjali

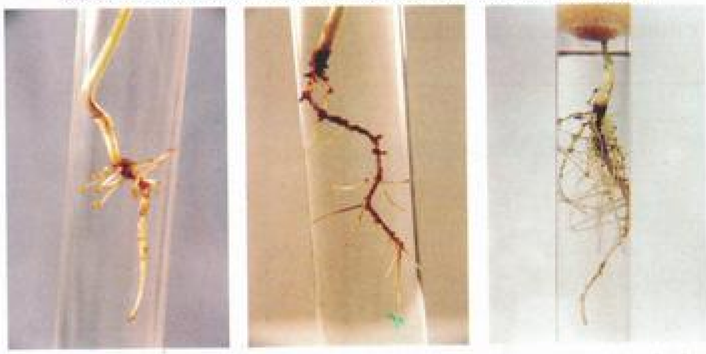

Plate 4 - Close up view of root curling, 5 - Root nodules after 3-4 weeks of incubation, 6 - Roots induced in IBA medium and nodule induction with R. *Fredii* in cv Anjali

These experimental results open up the possibility of extending effective nodulation to non legumes. Further studies to establish the nitrogen fixation abilities, symbiotic relationship and molecular analysis of surface determinants are in progress.

Fig. 27 Induction of para-nodule in cotton with nitrogen fixing bacterium

C. Integrated Nutrient Management And Rainwater Conservation /Harvesting

Characteristics of Vertisols, seed cotton yield and yield attributes supporting rainfed cotton were studied from the four participating centers of the project.

Vertisol characteristics included representative surface soil samples (0-0.15m) of Vertisol supporting rainfed cotton were collected from Nagpur, Parbhani, Dharwad & Nandyal and analyzed for their initial physical & chemical fertility characteristics.

All the soil samples were low in available N (KMnO4 oxidizable), with values varying between 72.6 & 101.2-mg kg soil. Seed cotton yield & yield attributing characteristics included fertilizer treatment for improving nutrient synchrony between demand & supply through chemical & IPNS system indicated that treatment (Cotton + intercropping with cowpea + Recommend dose NPK + Limited Micronutrient (Zn) + 2% DAP spray) gave significantly higher seed cotton yield over lower doses of NPK at all the centers.

Forty on-farm trials with INM technology were laid out in 2 districts, viz., Amraoti (low rainfall) and Yeotmal (high rainfall), with shallow and medium deep soils respectively. The soil moisture in both Amraoti and Yeotmal soil samples was low in flat bed system as compared to ridge and furrow system in all the treatments (Fig 28).

Fig.28 Cotton +Cowpea (mulching)

Increase in seed cotton yield due to green manuring in INM over farmers practice was found significant(Fig.29 and 30) . Similarly, 3-4 quintal yield of seed cotton/ha more was recorded in ridge & furrow system than in flat bed; it was due to higher utilization of nutrients & moisture by cotton at higher water requirement stage.

Fig.29 Ridges and furrows across the slope

Fig.30 Cotton +Cowpea (green manure)

The available nitrogen at 80 & 110 DAS increased marginally in INM+ green manuring as compared to farmer's practice. It indicates that green manuring with INM treatment has higher effects on increasing nitrogen availability and better utilization which consequently reflects the higher growth of cotton and seed cotton yield.

With an objective to study the impact of tillage, land treatment and organic residue management on soil health, drainage and crop productivity of rainfed cotton based system, experiment was conducted in farmers field. The data of the 'on farm' trials conducted with 4 different treatments in 12 farmer's fields indicate that the highest seed cotton yield was obtained in treatment comprising of reduced tillage (RT), broad base furrows (BBF), RDF, green manure (GM) and zinc sulphate, i. e., an integration of all improved practices.

Fig.31 Cotton crop residue considered as waste materials and disposed off by burning

Results of the present on-farm trials suggest that the yield gap in cotton is mainly due to the nonadoption of the recommended fertilizer schedule and the soil water conservation measures (BBF). Cotton crop residue can be used to increase the fertility of the soil, which otherwise, farmers disposed off by burning. (Fig.31).

The better yield in treatment with reduced tillage + BBF + RDF + *in situ* green manure was due to better weed control (fig 32 & 33) reduced competition for growth resources, improved nutrition supply and greater soil moisture.

Fig.32 High weed density in conventional tillage plots (farmers practice)

Fig. 33 a) low weed density in reduced tillage plots b) Sun hemp green manure in between cotton rows.

Evaluation of tillage residue and nutrient management practices for cotton-wheat system was taken up and the findings reveal that deep ploughing once in 2 years before cotton sowing + reduced tillage with rotavator + herbicide application at sowing for early season weed control was found beneficial and is recommended for successful cotton production under irrigated conditions.

Retaining of wheat straw in the field (instead of burning) followed by shredding and incorporation in the soil is recommended for realizing higher yield potential of cotton and wheat crops (fig 34). Recycling of cotton stalks after chopping and wheat straw incorporation was found to improve soil organic matter status (00-20 cm. depth) as compared to the plots where residue was either removed or burnt (fig. 35).

Fig.34 Wheat straw retained in the field

Fig.35 Wheat residue burnt *in situ*

Laboratory incubation studies indicated 20% of added residue C to be mineralized within 3 months. *In situ* field studies show that over 40% of applied stem C was decomposed.

Results on studies on efficacy of bioinoculants use in cotton-wheat system under irrigated conditions revealed that, *A. chrococcum* heat tolerant strain Ht 54 (i) performed superior with an improvement of 16% seed cotton yield over 65% RDF which was statistically similar to that of 100% RDF. In the trial to find out the reaction of commonly used agrochemicals in cotton-wheat system, to different microflora, *Pseudomonas* along with *A. chrococcum* could tolerate Mancozeb, Carbendazim, Imidachlorprid; *Azospirillum* could tolerate Carbendazim, Imidachlorprid, while *Acetobacter* could tolerate only Carbendazim in order to produce seed cotton yields similar to that of 100% R D F. The N P K uptake with these cultures is more than 100% RDF when supplemented with 50% RDF. In cotton mixed liquid cultures of *Azotobacter/Acetobacter, Azospirillum* and *Pseudomonas* seed immersion was superior than alone either seed immersion or seed treatment. This technique was much superior to the present 100% recommended fertilizers and was confirmed in subsequent wheat season.

To increase the productivity of cotton based cropping system farmers field experiment consisting of rainwater conservation, harvesting & recycling/recharging techniques were conducted. In situ moisture conservation and excess runoff collection, storage and recycling was found very effective in moisture conservation and increasing the yield of cotton based cropping system. Accordingly, water harvesting pond of size 20 x 20 x 3m^3 was developed and excess runoff water was collected, stored and recycled to cotton and cotton based crops resulting in 80- 100% increase in seed cotton yield.(fig 36 and fig 37).

Fig.36 Recycling of stored rain water

Fig.37 A view of water harvesting pond

Fig.38 Proper drainage and ridge and furrow improved cotton plant stand in bottom soils

Implementation of moisture conservation practices like ridge & furrow system, which was found to be the best in the situation, resulted in the increase in seed cotton yield by about 3 q/ha over flat bed and about 5 q/ha over farmer's practice in upper toposequence. Ridge and furrow, broad bed and sunken bed and the raised & sunken bed increased seed cotton yield by 4 to 6 q/ha on bottom toposequence. (fig. 38).

On lower plain, ridge and furrow + soybean as strip crop not only increased soil moisture but also increased seed cotton yield by about 9 q. over *G. hirsutum* as sole crop on flat bed. Strip-cropping of green gram increased seed cotton yield over sole cotton. Moisture conservation through ridge and furrow system and life saving irrigation increased gross monitory return as well as additional income in upper plain by Rs. 13000/- and in middle plain by about Rs. 7000/- and on lower plain by more than Rs. 25000/- due to introduction and adoption of soil and water conservation measures on different toposequences.

D. Integrated Pest Management

Weeds, insect pests and diseases being the major yield constraints in cotton based production system several pest management studies were carried out including field visits in the target districts to generate awareness in farmers on IPM.

Efforts taken for control of leaf curl viral diseases in cotton have resulted in perfection of quick detection techniques such as molecular cloning of CLCuV was done using a PCR based technique & the virus was detected in infected cotton plants (fig. 39,40,41, & 42).

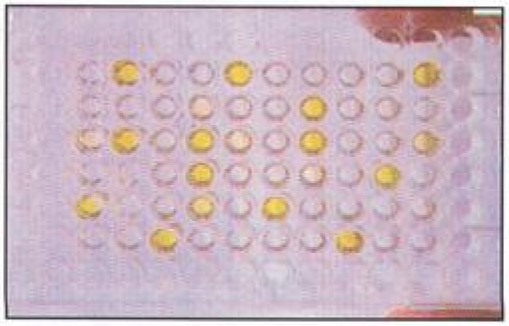

Fig39 An ELISA plate showing colored dots representing virus positive samples

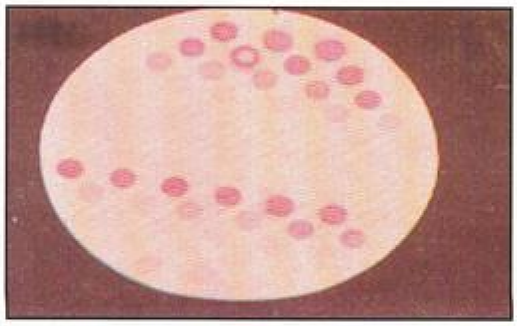

Fig.40 Dot ELISA: A membrane with colored dots representing virus positive samples

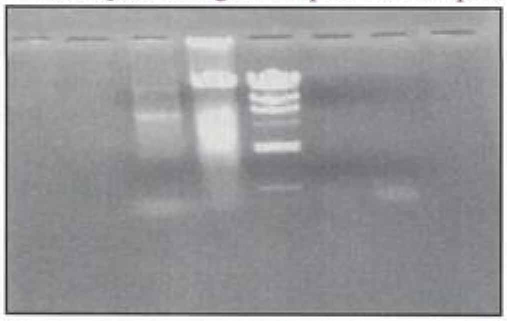

Fig.41 Lane1:Plasmid DNA; Lane 2: Genomic DNA; Lane 3 : Marker

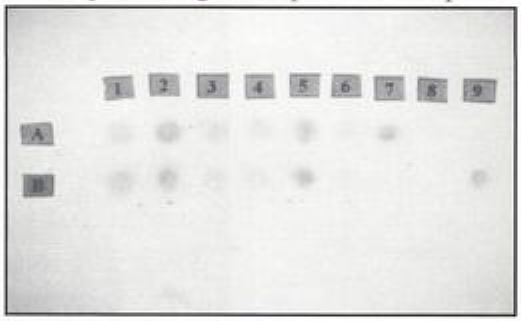

Fig.42 Detection of leaf curl virus in cotton and weeds with radio labeled fragment of DNA-A

PCR based diagnostic technique for rapid detection of leaf curl virus in cotton was also developed (fig. 43). Molecular Marker was developed to identify resistant plants in cotton germplasm & segregating population (fig. 44 & 45).

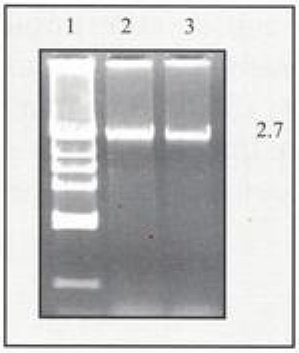

Fig.43 PCR amplification of CLCuV DNA-A genomic compound; Lane1:Healthy; Lane2:Marker; Lane 3:Infected

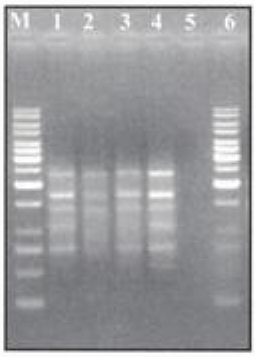

Fig.44 RAPD-PCR of cotton germplasm, Lane1; 1Kb DNA ladder; Lane2: cv.RS- 875(R); Lane3: cv. F-846 (S); Lane4: RST-9 (S); Lane5: CNH 4736 (R); Lane6:Control using Random Primer OPA-10

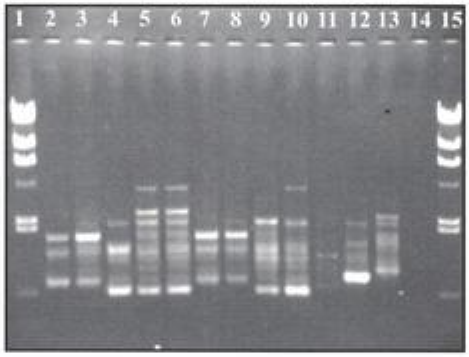

Fig.45 Lane1: Marker; Lane2: RS-875(R); Lane3: RS 810 (R); Lane4:LD327 (*arboreum*); Lane5:CNH 911(R); Lane6: CNH 4736(R); Lane7: RS 2013 (R); Lane8: PIL 8(S); Lane9:RG 8(*arboreum*); Lane10: CNH 2713(R); Lane 11: F 846(S); Lane12: HS 6(S); Lane13: RST 9(S); Lane14: Control; Lane15: Marker using OPA 16

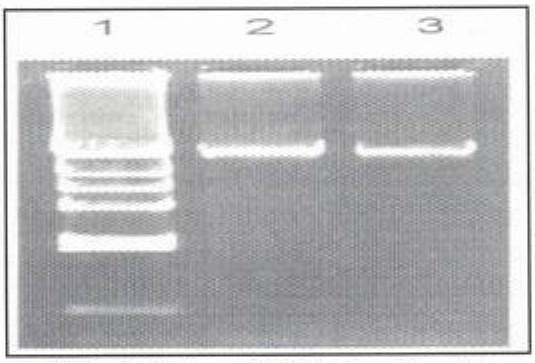

Fig.46 Isolation of DNA from *Bemisia tabaci* Lane1:Lambda Hind III Marker; Lane2&3: Whitefly DNA of whitefly

The protocol for isolation of DNA from whitefly was standardized (fig. 46). Random Amplified Polymorphic DNA (RAPD) analysis of whitefly DNA showed that OPA 5 was most suitable for amplification of whitefly DNA (fig. 47).

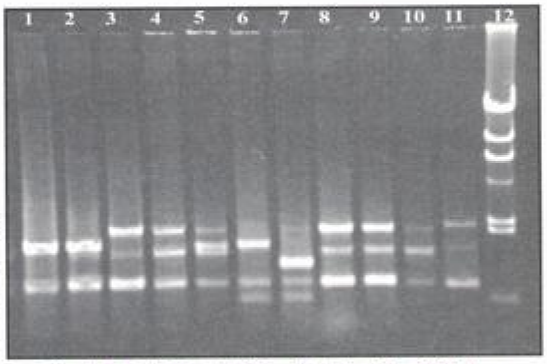

Fig.47 RAPD- PCR of whitefly DNA as molecular marker (OPA-5) to differentiate polymorphism

Under the activity of mass multiplication, protocol for *Bacillus thuriengensis* in liquid form was standardized using TYG & a few antibiotics in a bucket commonly termed as Bt. Bucket (fig. 48). Bucket culture could be ready in 14-16 hrs, for immediate use in one acre which a farmer can easily do. Two automatic mass multiplication units for production of *Corcyra cephalonica* were designed, developed, fabricated & commissioned (fig. 49 & 50).

Fig.48 *Bt.* Bucket

Fig.49. 72 trays containing sorghum diet

Fig.50 Moth collecting receptacle with light source

For forecasting of pests the historical data that have been collected from different centers on insect-pests & disease of crops and weather was compiled and digitalized so far. (table.1). The on farm data on pest and natural enemies was also collected.

Table - 1 Historical database

Data criteria	NAGPUR	SIRSA	PARBHANI	LAM, GUNTUR
Met. Data	1990-2000	1990-2000	1945-2001	1983-2000
Entomology				
Jassids	1983-2001	1990-2001	1987-2001	1989-2000
Whitefly	-	1990-2000	-	1989-2000
Helicoverpa	1983-2001	1990-2000	1987-2001	1989-2000
Earias	-	1990-2000	-	-
Pectinophora	1983-2001	1990-2000	1987-2001	1989-2000
Plant Pathology				
Bacterial blight 1983-2001		-	1990-2000	1986-2001
Alternaria	-	1990-1994	-	1983-2001

Field experiments have been conducted under various regimes of insect pest & disease control for validation purposes of the prediction equations developed through analysis of pest & weather variables. In addition to sampling for incidence of insect pests at fields, pheromone traps were also deployed during on as well as off-season to monitor male moth catches of bollworms.

Development of prediction equations has been taken up with historical data on pheromone trap catch of *Helicoverpa armigera* & *Pectinophora gossypiella* for Nagpur area and whitefly data at Sirsa center were analyzed with meteorological factors of the current week, and one & two log weeks. The equations so derived are put to test for validation with the current year's data to perfect certain thumb rules, relevant to each location in question.

E. Technology Assessment and Refinement

Under technology assessment and refinement (TAR) in irrigated agro-ecosystem at Coimbatore TN region, through IVLP the project was implemented in the villages-Kallapuram & Veerappagoundanur of Pollachi taluk of Coimbatore and Chinnaputhur, Dharapuram of Erode of TN. These villages are traditionally cotton growing besides having an intensive agriculture with horticulture, coconut plantation, and animal husbandry activities, since time immemorial. Before the actual implementation of this project a multi-disciplinary core team was formulated to identify problems to the on farm situation. The information required for this was obtained through Participatory Rural Appraisal (PRA) tools. Based on this, the technological interventions were planned and the action plan was implemented through 'On Farm Trials' (OFT) and Verification Trials (VT). These trials were monitored and evaluated by regular visits of team members.

During 2000-2001, a total of 24 technologies were assessed and during 2001-2002, 19 technologies were assessed under 8 thematic areas.

Though cotton is the principle cash crop of Coimbatore region of Tamilnadu, the productivity is very low. The major reasons for low productivity are nutritional, pests, diseases, weed menace, and water scarcity.

To cope up with such a situation, important crop management technologies for cotton and tomato have been intervened so far. Technological intervention for cotton viz., application of balanced fertilizers Urea 78.12 kg/0.4 ha, Super Phosphate 113 kg/0.4 ha, MOP 30 kg/0.4 ha, DAP- 2% spray on 20 days interval & Planofix NAA-200ppm-2 sprays at 45th and 60th DAS; IPM, IDM, IWM modules developed by CICR, RS, Coimbatore and alternate furrow irrigation system were assessed in the farmers' field and found as usable technologies with an average of 43.5% increase in yield and 1: 1.76 cost benefit ratio. (fig 51)

Fig.51 Technological interventions for Cotton

Tomato being the major source of income for the farmers in the project region next to cotton, 90% of the total tomato area were covered under hybrid tomato. Major problem faced by the farmers was poor yield caused by imbalanced nutrient application, incidence of pests, and weeds and water scarcity.

Technological interventions viz., nutrient & physiological management with Urea 86.8 kg/0.4 ha, Super phosphate-200 kg/ ac, MOP 53.8 kg/0.4 ha, Planofix 5ppm in 2 sprays & vegetable microfood 1.25 kg/0.4 ha (5 spray @ 250g/spray), IPM, IDM & IWM modules of TNAU were assessed in the farmers' fields. An average of 22% increase in yield with 1 : 2.27 cost benefit ratio was obtained in the intervention plots and technologies were found to be usable ones. (fig. 52)

Fig.52 Technological interventions for Tomato

Fig.53 Crop management practices for Turmeric

Crop management practices for turmeric were found usable with an average yield increase of 30% over farmer's practice and cost benefit ratio of 1: 1.8. (fig 53)

Farmers practice of imbalanced nutrients in maize and groundnut crops resulted in low productivity in the region. Application of Urea 117 kg/0.4 ha, Super 33.4 kg/0.4 ha, as technological intervention in Maize resulted in 15% yield increase over farmers' practice and 1:1.64 cost benefit ratio. Similarly, balanced schedule of Urea 15 kg/0.4 ha, Super 86 kg/0.4 ha, MOP 36 kg/0.4 ha resulted in 20% yield increase in groundnut over farmers' practices with 1:2.85 cost benefit ratio (fig 54 & 55.)

Fig.54 Technological interventions for Maize

Fig.55 Technological interventions for Groundnut

Live stock management technologies included PRA conducted on livestock problems revealed that the problems of foot and mouth disease, imbalanced nutrient application and problems of ecto-endo parasites have lead to low productivity of milk and meat. The technological interventions viz., control of foot and mouth disease, artificial insemination for improving the milk productivity, integrated nutritional management, deworming of endo and ecto parasites, introduction of new breeds of goats were assessed.

Few important measures were taken for conservation of natural resources. Under agri-horti system, integrated nutrients and pest management technologies were assessed in the farmers' orchards.

To empower the rural folk to protect the soil, water and environment, an eco-green club was established in the village. A soil fertility and water quality

Fig.56 Technological interventions for livestock managment

map for 500 samples of the project area was formulated (fig .56). Eighteen training programs were conducted for the project farmers to enhance the know-how of farmers.

IVLP team of CICR, Nagpur in their extensive survey identified the constraints of the rainfed farming for low productivity of major crops like cotton & citrus of Vidarbha region. (fig 57).

Technological interventions like maintaining optimal plant density with reduced plant spacing, IRM strategy developed by CICR, Nagpur (fig 58)

Fig.57 Optimal plant density in cotton Pays- off

Fig.58 Insecticide Resistance Management- Environment friendly way

and transgenic cotton (Bt. Cotton) were done in the cotton growing farmers' fields (fig 59) and found as usable technologies that gave increased seed cotton yield with additional monitory returns. It also helped to protect the rural environment.

Fig.59. *Bt.* Cotton brings the smile

Fig.60 Marigold makes inroads in Citrus based intercropping system

For citrus growers the technological interventions by growing more remunerative inter-crop of Marigold in orange orchards were done in farmers' field. This crop in drought like situation also gave high returns to the farmers.(fig 60). Marigold flowers get premium price in festival season and are in high demand.

In the field of live stock management, the technology of introducing the Osmanabadi buck to upgrade the genetic potential of local breed was assessed. By this technology the farmers not only recovered their capital invested in Osmanabadi goat unit within one and half years but also made considerable profit (fig 61).

Fig.61 Osmanabadi goat unit brings cheers

F. Agro-economic Characterization

In Maharashtra cotton is grown in nearly 30 lakh ha .that too mostly in Vidarbha and Marathwada region and under rainfed conditions. As per the survey carried out in 6 talukas of Nagpur district according to the Performa supplied, farmers of Maharashtra in general and Vidarbha in particular were found to practice age old, time tested and traditional strip cropping with pigeon pea under different row ratios even though 6: 2, 8: 2 (fig. 62 & 63) appear to be predominant.

Fig.62 Cotton + Tur strip cropping (6:2)

Fig.63 Cotton + Tur strip cropping (8:2)

The strip inter crop was found to provide monetary returns in addition to meeting the nutritional demands of the farm family without additional expenditure by way of inputs, etc. The importance of the strip inter crop in risk management is quite apparent. It was also observed that most of the farmers were found to rely on *Krishi Seva Kendras* either in the village or nearby village /Talukas / Districts for obtaining the inputs as well as technology. The literacy percentage of the surveyed farmers is quite high and almost all the farmers were found to be land owners as well.

Under economic analysis of different intercropping system, cost of cultivation was computed taking into account the average variable inputs and cultural practices across the four categories of farmers and accordingly the values for the villages were worked out. Owing to the intercropping system based on replacement series in a strip cropping mode, all the villages have reported negative net profit over base crop as sole crop, whereas, interestingly, the LER values fluctuated around 1.0. For the entire Nagpur district the gross returns in the inter- cropping system (strip cropping with pigeon pea) were 23,281 Rs./ha and net returns Rs. 13,297 Rs./ ha with the cost of cultivation at Rs. 9995 Rs./ ha.

Based on the comprehensive and intensive interaction with the farmers, several research gaps and researchable areas have been identified. Majority of farmers have indicated lack of technological interventions as the reasons for non adaptation of recommended intercropping system in the cotton based production system leading to continued reliance of strip inter cropping with pigeon pea. Amongst the technological interventions the farmers' perception is for more effective nutrient and pest management. Further the farmers have pointed out that the non-availability of inputs including seed in time is leading to stagnation in the productivity of inter cropping system. One more factor pointed out by the farmers for not implementing inter cropping system is the low and fluctuating market price in respect of strip crop and need to provide a remunerative price even though part of the strip intercrop yield is utilized by the farm family for the nutritional and domestic need.

Such perceptions of the farmers consequently expose the research gaps which have been identified with particular focus on intercropping system. Lack of better understanding regarding the complex pest management in intercropping system indicated by majority of the farmers involved in rudimentary farming practice. Moreover, the farmer's mindset for the age old, traditional strip cropping since many decades has also been a major obstacle.

As per the information provided by the farmers during the personal interaction, few important reasons have been identified for non-adaptation of recommended technology for intercropping system. Row to row inter cropping recommended by the research institutions with black gram, green gram, soybean, cowpea, etc. is not practiced due to the farmers apprehension of lack of scope for intensive interculture including cross wise hoeing. Lack of awareness about the latest work on intercropping system and the fear of increase in pest incidence due to introduction of new crop was one of the cause of non-adoption which leads to reluctance of the farmers to dispense with the traditional strip cropping with pigeon pea.

The Survey in general has brought out a clear picture of strip intercropping practice, its economic returns, farmers' mindset including their apprehensions along with all the relevant information at the farmers and field levels including information on yield and other economic parameters. This can certainly form the basis for initiating appropriate remedial action by all the concerned for improving the cotton based production system specifically in the rainfed tract of Maharashtra and also to ensure higher monetary returns and welfare of cotton farmers. Multi-disciplinary approaches involving Agronomist, Soil Scientist, Physiologist and Entomologist are the need of the hour to develop a more effective profitable and acceptable intercropping system in the cotton based production system especially in the rainfed tract along with the development of a total package.

Characterisation and constraint analysis study was conducted in relation to soil, rainfall & socio economic factors. In all, 18 tehsils and 60 villages were selected based on cotton area to net cropped area in 5 agro- ecological sub regions spread over 6 district across the two states of Maharashtra and Gujarat. Based on the study conducted in the selected area, the data indicated that the percentage of cotton area in total farm area constituted 48.17 % in Jalgoan district to 86.28 % in Surendranagar and except in the latter, in all the other district, the ratio decline with farm size. The mean monthly rainfall data for a decade indicated that June- Sept. rainfall accounted for 70-80 % of the annual rainfall in all the districts. The mean total rainfall was least (385.56 mm) in Surendranagar. The coefficient of variation of mean monthly rainfall of sample district was overall less in Maharashtra as compared to Gujarat. CV also increased progressively from June onwards and reached maximum as the monsoon receeded. in all the districts, area under the hybrid cotton decreased with the farm size, while that of *desi* & American showed a positive relation with farm size. The livestock trend revealed that bullocks have been substituted by machine power & cows by buffaloes over the decade across the districts.

The farm income to total income varied from 95% in Nanded distt. to 66.44% in Baroda. Cotton share in the crop income ranged between 72.04% in Surendranagar distt. to 15.31% in Nanded distt. & the share of cotton in the income increased with farm size. The farm structural analysis revealed that irrigation percentage increased with farm size while that of cropping intensity decreased with farm size. The number of varieties cultivated increased with farm size in Yeotmal, Nanded, Jalgaon & Surendranagar distts. & decreased with farm size in Baroda district. "Reducing Yield" was quoted as the major reason for decreasing farm cotton area. The spray intensity increased with the area under hybrids & the overall spray number was less in Gujarat distts. compared to Maharashtra counterparts. The percentage of farms not resorting to any chemical spray was highest in Baroda at 27.33% & lowest at 6% in Nanded. The spray intensity was inversely proportional to the area under *desi* cotton. The preference for technological needs by cotton farmers indicated that the demand for resistance varieties increased with farm size, while that of good quality seeds & pesticides was inversely proportional to size. This is because the area under hybrids and associated intensive cultivation calling for pest management was more in small farms. The yield realized was lowest in Baroda distt. hovering around 3.5 q/ha, because of the poor performance of the hybrids & the yield was highest in Jalgaon distt. (12 q/ha). The overall yield gap existed was more than 8 q/ha across the distts. The fixed cost in the total cost of cultivation ranged between 28-35% & the cost-benefit ratio was lowest in *desi* and american compared to hybrids yielding high but also calling for high cost of inputs.

Among the bio-physical constraints, boll shedding, insect-pest damage, rainfall deficit & moisture stress and unsuitable soils were frequently refrained by the respondents as major reasons for low productivity. *Helicoverpa* & sucking pests were treated as devastating pests, whose combined damage across size group was estimated between 30-39%. High prices of pesticides, fertilizers & human labour were rated as the major socio-economic constraints in marketing of cotton.

The production function result indicates that the farm size was negative & significant in Yeotmal indicating inverse relationship between yield & farm size and in other distts. it was non-significant irrespective of the sign of the coefficient. Plant density had positive & significant coefficient in Yeotmal, Surendranagar & Baroda distts. indicating that there is further scope to increase plant population for higher productivity. A separate function was fitted for varieties (*desi* & American) & the results indicated that plant density, nitrogen, phosphorus, & potash had positive & significant coefficients indicating that added quantities of these inputs in the production of cotton shall contribute positively to the productivity.

Socio- economic characterization and analysis under irrigated system in Northern cotton zone offers deep insight into the cotton based cropping system. This study envisages secondary data analysis of cotton and wheat system and primary data collection from 400 farm households for three seasons in five districts of three states and characterization of the system.

Major findings including composition of cotton and its trends showed a progressive decline in case of desi cotton area from 54.21 % of the farm cotton area before 10 years and 47.84 % before 5 years to the present 35.01 %. The hybrid area has increased progressively from a negligible one percent to the present 7 % (fig 64).

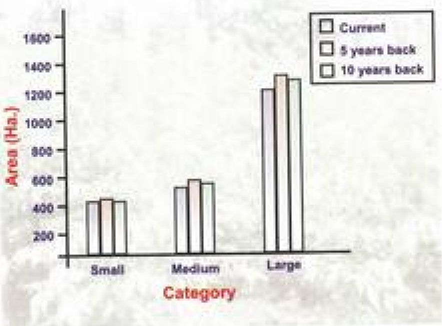

Fig.64 Cotton trend in sample farms

Livestock trends pertaining to the herd composition showed that while the bullock/ farm has decreased progressively over the decade being substituted by machinery, owned or hired, that of the camel has shown a steady increase. The average number of cows/farm has shown steady decline, while that of the buffaloes has increased. The study on varietal distribution showed that while varietal proliferation was rampant in cotton, varietal discipline was more pronounced in wheat (table - 2).

Table 2 : Varietal distribution

No of genotypes in	Cotton	Wheat
70% area	4	1
Rest area	13	3

One of the remarkable major findings is regarding the input use in sample farms. Overall, the input use of almost all items - seeds, fertilizers and pesticides in cotton was on a higher side in both the crops, viz., cotton and wheat. The fertilizer use had negative correlation with yield, with more than recommended use in case of nitrogen.

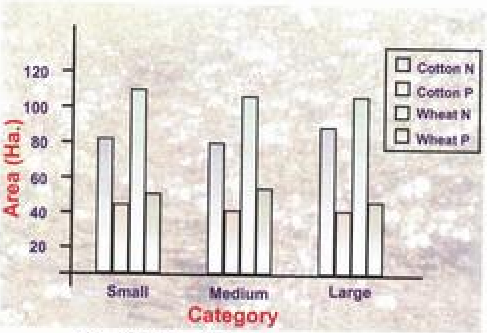

Fig.65 Fertilizer use pattern

The average number of sprays ranged between 12 and 15 with the highest of 30 in Muktasar district. Labour use was observed least in wheat compared to cotton, as most of the cultivation practices were mechanized (fig 65).

Crop wise major biotic and abiotic constraints identified & the biological constraints quantified in cotton and wheat system have been observed and studied .

Cotton	Wheat
Problem soils, rising water table, delayed sowing, multiplicity of genotypes, poor quality seeds, seedling burn, closer spacing between rows, use of high N, low P and no K, bollworm complex, sucking pests, leaf curl virus, whitefly, high temp. During Sept., boll shedding, bacterial blight, resistance to insecticides, multiple picking, etc.	Problem soils, water logging, brackish water, less turn around time, weed infestation, low population, late sowing, leaf blight, rust, zinc deficiency, cloudy weather during milky stage, smut, early summer, descicating winds, etc.

Common socio- economic constraints comprise of non- release of water on time, erratic power supply, poor quality of seed and chemicals, tied up credit, indiscriminate use of pesticides and chemicals, etc. The frontier production function fitted showed that the cultivars were highly technically efficient from output point of view but their input management leaves a lot to be desired as the quantum of input used in zeal for higher productivity accompanied by malpricing of resources by the State.

The farm technological progress index calculated as the some of the product of the ratio of the realized yield of the crops to the potential yield and weight (share of the crop in the cropping pattern) of the crops in the farm showed that the average realization of the technology is high, with a positively skewed TPI curve (Fig. 66).

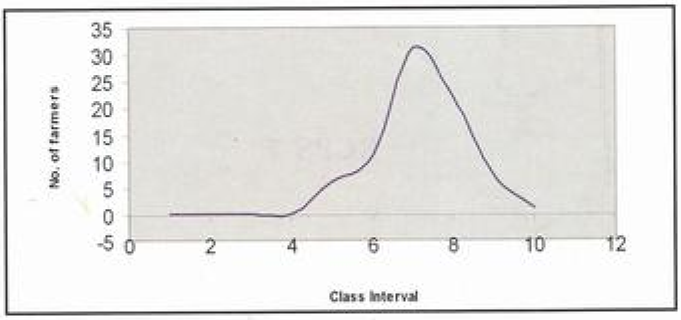

Fig. 66. TPI Frequency Distribution

Several activities were carried out with an objective of delineating the efficient productive zones for cotton production system using GIS based crop models. Characterization was accomplished whereby analysis of the time series data of cotton area, production, productivity for dominant cotton growing states and districts indicated that rainfed cotton area occupies about 70% of total cotton area with a contribution to 50% production. Together the 6 distts., namely, Akola, Amraoti, Yeotmal, Nanded, Parbhani and Buldhana cover about 32-36% of total rainfed area. In terms of area contribution, Akola has recorded higher growth rate of 130% and the same for Yeotmal and Amraoti is in the range of 60-70%. The growth rate of rainfed area to an extent of 100% was phenomenal for Guntur distt. which was not cultivating cotton during 1966-70.

Climatic parameters, viz., total rainfall, rainfall during growing season, growing season mean temp., mean max. temp., ground water depth and texture cotton growing areas were categorized into 5 classes under the delineation activity. These categories included (a) suitable without any limitation, (b) with slight limitation, (c) moderate limitation, (d) severe limitations for cultivation and (e) not suitable for cultivation.

Computer programs were developed to estimate the potential yields of cotton based on radiation and crop season, and review of the data sets is going on for their usefulness in the model validation.

List of NATP Sub-Projects on Cotton Based Cropping System

Project Code	Name of the Project	Name of the PI/CCPI
	A. *GERMPLASM COLLECTION AND VARIETAL EVALUATION*	
PB-MM	Survey/Exploration, collection, evaluation, characterization, conservation and utilization of global collection of *Gossypium* species for sustained production and productivity.	Dr. V. V. Singh (CCPI)
RCPS 7	Promotion of productive high quality *G. arboreum* cotton to meet the needs of marginal cultivators of rainfed ecosystem vis-à-vis textile industry.	Dr. V. N. Waghmare (CCPI)
RCPS 8	Characterisation and identification of productive and high quality cotton species/genotypes including *G. herbaceum* suitable for different agroecological situations through farmer's participatory programmes.	Dr. Vinita Gotmare (CCPI)
PSR 16	Exploitation of *G. herbaceum* cotton for improving agricultural output and economy of the coastal agroecosystem.	Dr. K. Venugopalan (PI)
RCPS 9	Develop and evaluate production technology for the indigenous cotton of NE Region.	Dr. A. R. Raju (CCPI)
HCP-MM	Development of hybrid crop Cotton.	Dr. C. D. Mayee (PI) & Dr. Suman Bala Singh (Co-PI)
PSR 27	Evaluation and identification of suitable pest tolerant compact cottons amenable to mechanical harvesting.	Dr. S. K. Banerjee & Dr. V.V. Singh (PI)
PSR 36	Adoption and refinement of cotton picker and cleaning system in the PSR mode.	Er. G. Majumdar (CCPI)

Project Code	Name of the Project	Name of the PI/CCPI
RCPS 3	Assessment of gossypol content in cotton germplasm control of leaf curl viral disease in cotton and development of protocol for mass multiplication of predator, parasites and insect pathogens.	Mrs. Mukta Chakrabarty (PI)

B. *BIOTECHNOLOGY*

RCPS 10	Development of Bt. transgenic diploid cotton against bollworm.	Dr. S. B. Nandeshwar (PI)
Bt. Transgenic - MM	Bt transgenic, Pigeonpea, Rice and Cotton for insect resistance.	Dr. A. B. Dongre (CCPI)
NIC -CGP 1	Induction of para-nodules in cotton with nitrogen fixing bacterium *Azorhizobium caulinodans* in CGP mode.	Dr. G. Balasubramani (PI)

C. *INTERGATED NUTRIENT MANAGEMENT AND RAINWATER CONSERVATION / HARVESTING*

RCPS 2	Optimizing nutrient supply in relation to moisture availability for enhanced productivity and stability of rainfed cotton based production system.	Dr. Jagvir Singh (PI)
RCPS 11	Impact of tillage, land treatment and organic residue management on soil health, drainage and crop productivity of rainfed cotton based system.	Dr. Blaise (CCPI)
PSR 33	Evaluation of tillage residue and nutrient management practices for cotton wheat system.	Dr. K. S. Bhaskar (PI)
PSR 4	Studies on efficacy of bioinoculants in cotton wheat based production system.	Dr. A. R. Raju (CCPI)
RCPS 5	Rainwater conservation, harvesting and recycling/recharging techniques for enhanced productivity of cotton-based cropping system.	Dr. K. S. Bhaskar (CCPI)

Project Code	Name of the Project	Name of the PI/CCPI
	D. *INTEGRATED PEST MANAGEMENT*	
PSR 26	Control of leaf curl viral disease in cotton and development of protocol for mass multiplication of predator, parasites and insect pathogens.	Dr. Sheoraj (PI)
MM III - 17	Development of weather based forewarning systems for crop pests and diseases-Cotton.	Dr. T. P. Rajendran (PI)
	E. *TECHNOLOGY ASSESSMENT AND REFINEMENT*	
IVLP- TAR 18	Technology Assessment and Refinement (TAR) of irrigated agro-ecosystem for Coimbatore region in TN.	Dr. Kumarswamy Ramamoorthy & Dr. Usha Rani (PI)
IVLP- TAR 15	Technology Assessment and Refinement of Rainfed cotton based production system in Nagpur district through Institute Village Linkage Programme under rainfed agro-ecosystem.	Dr. H. L. Gajbhiye (PI)
	F. *AGRO ECONOMIC CHARACTERIZATION*	
ROPS 10	Identification of research gaps in intercropping system under rainfed conditions in India in production system research mode under the NATP project.	Dr. M. R. K. Rao (CCPI)
RCPS 1	Agro economic characterisation and constraint analysis of rainfed cotton based production systems in relation to soil, rainfall and socio economic factors.	Dr. P. Ramasundaram (CCPI)
PSR 24	Socio economic characterisation and analysis of cotton based cropping systems.	Dr. P. Ramasundaram (PI)
RCPS 4	Delineating the efficient productive zones for cotton production system using GIS based crop models.	Dr. S. Vennila (CCPI)


FARMERS MEET