Natural Resource Management

SOIL RESOURCE INVENTORY

Model District Planning

Soil resource atlases of the following districts were brought out for sustainable land use planning: Bilaspur in Chhattisgarh, Chindwara in Madhya Pradesh and Adilabad, Anantpur, Chittoor, Cudappah, East Godavari, Guntur, Karimnagar, Khammam, Krishna, Kurnool, Medak, Mehboobnagar, Nalgonda, Nellore, Nizamabad, Prakasam, Rangareddy, Srikakulam, Vishakhapatnam, Vizayanagaram, Warangal, West Godavari in Andhra Pradesh.

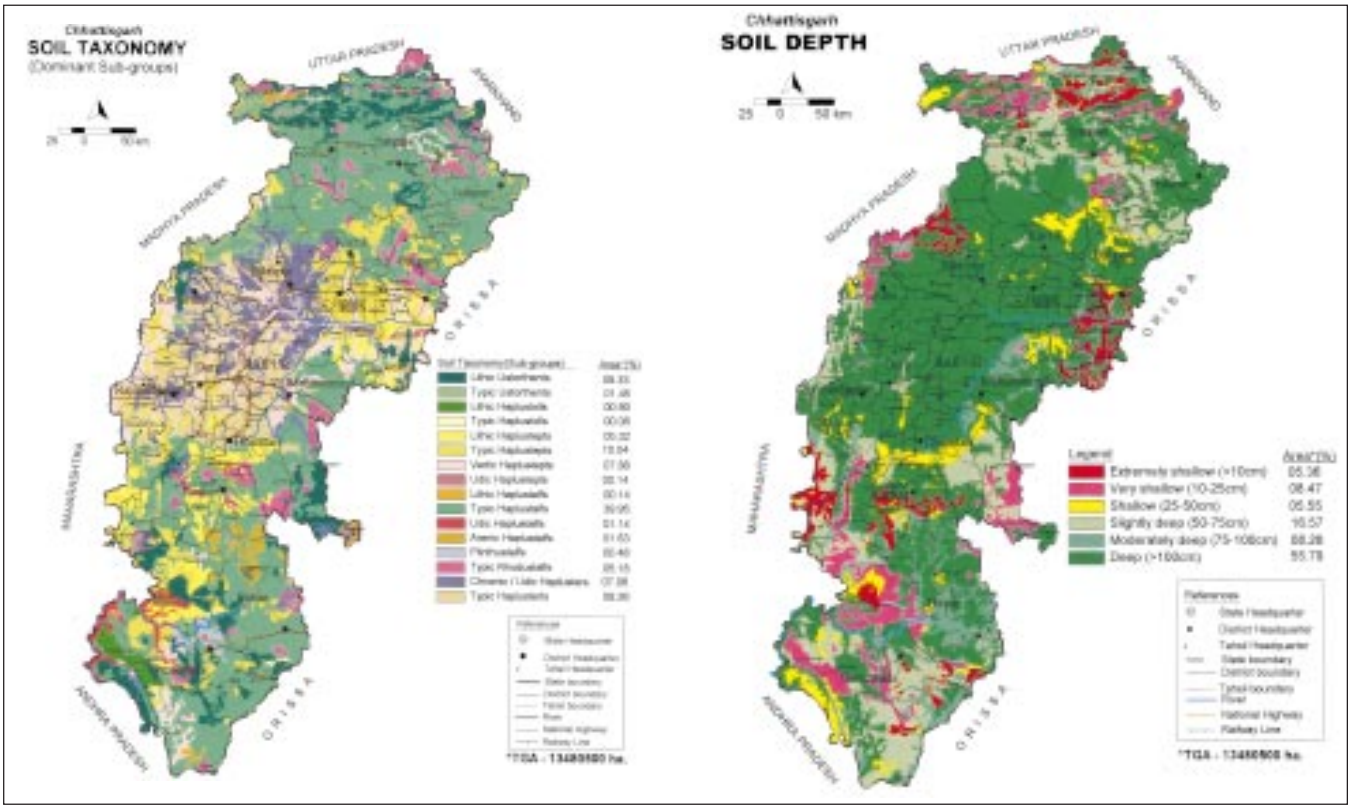
There are 40 to 45 themes pertaining to soil-site characteristics like texture, slope, depth, organic carbon, available water capacity etc. These atlases are useful for sustainable land use in the districts.

- Soil resource atlases of several districts were brought out. These atlases are useful for planning sustainable land use.
- Soil erosion maps of 3 states, viz Rajasthan, Madhya Pradesh and Chattisgarh were generated.
- Important benchmark soil series were identified in districts of Jorhat, Sibsagar, Morigaon and Kamprup of Assam. Suitability of these benchmark soils was evaluated for growing crops.

Soil Degradation

Based on the soil resource data (1:250,000 scale), the soils were assessed at each grid observation (10 km × 10 km) for their degradation status. The soil erosion maps of 3 states namely Rajasthan, Madhya Pradesh and Chhattisgarh were generated and reports were brought out.

In eastern Rajasthan, the area is affected by slight to moderate (64 per cent), severe (21 per cent), and very severe erosion (15 per cent) and is mainly due to wind erosion. Severity of water erosion in south and south east



Thematic maps showing soil taxonomy (*left*) and soil depth (*right*) of Chhattisgarh

Rajasthan is mainly due to higher slopes having more than 15 per cent area.

In Madhya Pradesh, about 2.39 m ha (17.7%) is under severe erosion which is restricted to western and hilly areas of the state.

Benchmark Soils of Assam

The important benchmark soil series were identified in districts of Jorhat, Sibsagar, Morigaon and Kamrup. The suitability of these benchmark soils was evaluated for growing crops. The major limitations of the soils were low pH, low organic matter and fertility and coarse texture.

RESOURCE CONSERVATION AND MANAGEMENT

Sustainable Cropping System for Rice Fallows of Brahmaputra Valley of Jorhat District, Assam

A study was conducted at Nagaon and Jamuguri in Jorhat district, Assam regarding performance of early maturing rice varieties under different phosphorus sources and performance of winter crops such as rapeseed, Frenchbean, pea and potato in rice fallows under recommended doses of fertilizers. The study shows that the plant population of the winter crops, particularly pea and Frenchbean, was affected due to low germination of seed in acidic soils. However, the growth yield attributes and yield of other two crops, i.e. rapeseed and potato show considerable productivity indicating thereby that successful cultivation of short duration crops can be done in rice fallows with substantial yield advantage.

- Rapeseed and potato showed considerable productivity in rice fallows of Brahmaputra valley.
- The soils of Chiratijan microwatershed in Gelabil Kakdanga watershed were evaluated for suitability of rice, potato, cabbage, tomato, Frenchbean, pea and cowpea cultivation.

SUCCESS STORY

Watershed Management

A microwatershed having an area of 532 ha in villages Bajni and Prakash Nagar in Datia district was selected. Several treatments were imposed through participatory approach on arable and non-arable lands. In most of the activities, labourers of watershed village were engaged. Tractor was used in desilting of village pond and land shaping. The contribution made by the farmers towards creation of Watershed Development Fund (WDF) ranged from 1-40% in cash.

A model of protected rocky wastelands patch of about 37 ha with conservation measures recorded forage yield of 1.97 tonnes/ha as compared to that of 0.08 tonne/ha from catchment without conservation measures. The open-grazing was controlled through the introduction of stall-feeding which increased milk production by 2-3 times in the watershed. Cropping intensity and crop yields increased from 67% to 105%. To utilize low lying waterlogged fields, paddy crop was introduced in the watershed which gave an average yield of 2 tonnes/ha. Thus, the waterlogged fields were put to profitable cultivation of paddy during *kharif* season which were otherwise kept fallow prior to the project. In addition to this, a revolving fund scheme was also launched to create employment opportunities among the rural unemployed poor by creating 10 Self Help Groups.

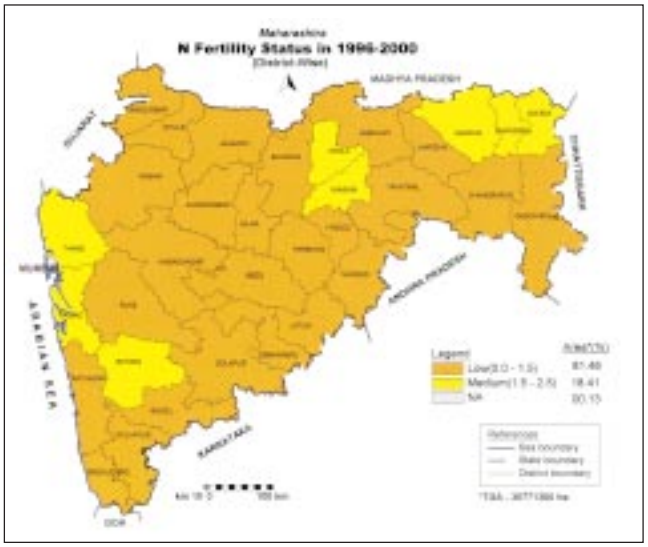
Identification of Critical Areas for Prioritised Land Treatments in Watersheds

Soil map of Gelabil Kakadanga watershed (138,655 ha) was prepared by carrying out reconnaissance survey of the area. A total of 14 microwatersheds were delineated in the watershed. The Chiratijan micro watershed was selected for detailed survey using landform map prepared from IRS-ID, LISS III and PAN merged satellite imagery at the scale of 1:12,500. Four soil series were identified in the watershed and mapped into 11 units at phase level. The soils of microwatershed were interpreted and evaluated for suitability of rice, potato, cabbage, tomato, Frenchbean, pea and cowpea. The main limitations are low pH, low organic carbon status, coarse texture and flooding. Different thematic maps such as landform, land use, soil reaction, organic carbon, surface texture, available P and available K were prepared.

SOIL FERTILITY AND NUTRIENT MANAGEMENT

Digital Soil Fertility Maps

Digitized soil fertility maps (N, P and K) at district level for Andhra Pradesh, Maharashtra, Orissa, Punjab, Chhattisgarh, Haryana and Himachal Pradesh have been prepared.



The Nitrogen fertility map of Maharashtra

Long-term Evaluation of Soil Test Based Nutrient Prescriptions

Long-term demonstrations on soil test based fertilizer and manure prescriptions for the *kharif* and *rabi* rice to

- Long-term demonstrations on soil test based fertilizer and manure prescriptions for rice to establish the possibility of achieving the targeted yield and maintaining soil fertility are in progress. Higher grain yields were recorded in the treatments where fertilizer was applied on targeted yield basis compared to the general recommendation.
- Integrated nutrient management technologies for pulse and oilseed-based cropping systems have been developed by conducting field experiments on farmers fields.
- Mixed biofertilizer formulations consisting of nitrogen-fixing organisms and phosphate-solubilizing bacteria proved superior to individual inoculants.
- In Marathwada region, groundnut pod yield was increased by 25% owing to *Rhizobium* inoculation.

find out the possibility of achieving the targeted yield and maintaining the soil fertility are in progress since 1998 in the same field (Noyyal series, Typic Haplustalf) at Coimbatore. The results of ninth and tenth crops of rice (var. CO 47) raised during 2002-2003 highlighted that higher grain yields were recorded in the treatments where fertilizer was applied on targeted yield basis compared to general recommendation by State Agriculture Department. Fertilizer prescription for targeted yield with integrated plant nutrient supply system (IPNS) recorded relatively higher yield and response ratio over the fertilizer prescription alone.

Results of the post harvest soil test values (*rabi* 2002) indicated that available nitrogen ($KMnO_4$-N) in soil after the harvest of the tenth crop of rice declined. With IPNS prescription, the $KMnO_4$-N level was maintained (280 to 272 kg/ha). Available P status was maintained in the general recommendation and increased in fertilizer alone and IPNS prescription treatments. In case of available K, a decline from the initial status was noticed and the status was maintained for the past four seasons in all the nutrient prescription treatments. In general, wherever the nutrients are added based on soil tests for specific yield targets, yield has sustained and soil fertility was maintained.

Integrated Nutrient Management Technology

Integrated nutrient management (INM) technology for pulse-based cropping systems has been developed by conducting about 150 field experiments on 60 farmers' fields in five target districts over a period of three years. The benefit of optimum nutrient managements, especially integrated nutrient management, in conjuction with soil moisture conservation measure for rainfed pulses was demonstrated to the farmers. In a year of drought farmers were able to harvest about 12-25% more chickpea and 15-28% more lentil through proper nutrient management compared to their own practices in Bhopal and Raisen districts of Madhya Pradesh. The best INM treatment was: 75% recommended NPK plus 2.5 tonnes/ha FYM (on dry weight basis) plus soil moisture conservation measure for the *kharif* crop, and 50-75% of recommended NPK depending on soil moisture stock for the *rabi* crops. In both seasons, seed inoculation with *Rhizobium* is a must.

Integrated nutrient management (INM) technology has been developed for seven rainfed oilseed based cropping systems by conducting more than 300 field experiments on about 100 farmers' fields in 9 target districts of 7 states over a period of three years. Results showed that conjunctive use of different locally available organic manures along with fertilizers increased the seed yield of safflower, mustard, castor, soybean, sunflower, raya and groundnut by 24.5, 25.7, 33.2, 35.7, 40.7, 51.7 and 67.2%, respectively over the existing nutrient management practice of farmers (which is generally 50% RDF).

Nitrogen Economy due to Rhizobial Inoculation in Soybean-wheat

Despite continuous cultivation of inoculated soybean and wheat for 3 years in Vertisols of Jabalpur, there was significant response to *Bradyrhizobium* inoculation on soybean seed yields which increased by 10.6%. Additional mineral N of 16 ppm in 0-30 cm layer was recorded after soybean growth. In case of wheat, additional yield due to *Azotobacter* inoculation was 11.6 and 10.6% under soybean-wheat and sorghum-wheat rotation, respectively, over uninoculated control. After harvest of wheat in soybean-wheat plots, there was 18.3 ppm additional mineral-N in comparison to soils under sorghum (non-fixing cereal control) -wheat rotation. The wheat yields obtained due to 120 kg N ha^{-1} without biofertilizers was close to the yield with 90 kg N ha^{-1} with biofertilizers. Thus there was saving of 30 kg N/ha due to use of biofertilizers.

Mixed Biofertilizers

Mixed Biofertilizer formulations consisting of nitrogen fixing organisms and phosphate solubilizing bacteria (PSB) proved superior to individual inoculants. In wetland rice inoculation of 'Azophos' (*Azospirillum* and PSB) and PGPR (*Pseudomonas*) along with 75% NPK gave maximum rice grain yield (6250 kg/ha), an increase of 5.8% over 100% NPK alone (5905 kg/ha) at Coimbatore. In on-farm trials on large field plots on rice at Amaravathi, Andhra Pradesh, dual inoculation of *Azospirillum* and PSB at 100% N, gave 5.35 tonnes/ha yield, whereas 100% N alone yielded 4.77 tonnes/ha. The 75% N + dual inoculation gave 5.03 tonnes/ha and, thus, saved 25% nitrogen.

In case of cotton, use of *Azotobacter* + PSB resulted in a significant increase in seed cotton yield (287 kg/ha) in the presence of chemical fertilizers (100 and 75% RDF) in a Vertisol at Parbhani. In black gram, there was highly significant improvement in nodulation, nodule mass and grain yield (122 kg/ha) over control. In sunflower, seed yield increase due to bacterization was 367 kg/ha.

For growth of diazotrophs and PSB in mixed biofertilizer formulations, a new medium-yeast extract

glucose molybdate agar (YEGMA) was developed which had glucose as carbon source instead of mannitol and 50 ppm sodium molybdate. In field trials on inoculation of mixed biofertiliser on pearlmillet, inoculation was found to save 25% of the N dose.

Shelf-life of Biofertilizers

Incorporation of 5 % glycerol and 2% PVP (polyvinyl-pyrillodone) in media maintained higher cell load than control. Even incorporation of 1% arabinose recorded higher population. In attempts to concentrate the inoculants to reduce volumes, incorporation of 10% cellulose and 2% CMC (carboxymethyl cellulose) maintained satisfactory titre even after 8 months, the population of *Rhizobium* TNAU 14 was 28×10^7 and 6×10^7 per ml with the two additives respectively.

Frontline Demonstrations on *Rhizobium* Inoculation in Groundnut

Front line demonstrations on six farmers fields on groundnut gave pod yield increases ranging form 3.5-17.6% over control. Absolute pod yield increases were from 60-265 kg/ha. In Marathwada region, groundnut (var Tag 24) pod yield was increased by an average of 25% in the presence of recommended doses of fertilizers due to inoculation of *Rhizobium* in 5 of the 6 demonstrations.

In a demonstration in Parbhani district *Rhizobium* inoculation increased groundnut pod yield to 9.13 tonnes/ha as compared to uninoculated control (7.03 tonnes/ha). The impressive effects of inoculation are apparent from the spectacular influence on root nodulation demonstrated to several farmers in farmers' fair held here.

The actual pod yields were 2.70 tonnes/ha in control and 3.38 tonnes/ha in inoculated. In the sixth demonstration conducted at village Kehal in District Parbhani by a progressive farmer (state awardee) by adopting the best package of practices along with good seeds and all precision farming techniques, very high yield of groundnut was obtained even in uninoculated control (7.03 tonnes/ha). Inoculation increased the pod yield further to 9.13 tonnes/ha. This represented the highest groundnut pod yields increase of 2.10 tonnes/ha ever recorded due to inoculation of *Rhizobium*.

WATER MANAGEMENT

Water Resource Development for Cyclone-affected Farmers of Coastal Orissa

A study was undertaken in the super cyclone affected coastal districts of Orissa (Erasama in Jagatsinghpur and Astarang in Puri district) to develop a comprehensive land and water management system that can enhance productivity and bring the farming community of the area out of perpetual poverty. At Erasama, small sub-surface water harvesting structures and at Astarang small shallow tube wells (up to 40 feet depth) were constructed to downsize the regular water resource structures like big tanks and shallow tube wells. These were constructed in participatory mode keeping in view the topography, water resources availability, saline water intrusion into coastal aquifers, poverty level of rural people, and low level of employment. The depth of subsurface water harvesting structure is limited to 3 m as the groundwater below 3 m is saline.

- A study was conducted in the super cyclone affected coastal districts of Orissa to develop a comprehensive land and water management system that can contribute enhancement in productivity.
- A study of developed watershed of the eastern region reflect that the adoption of improved technologies varied from 23% to 38% of the total interventions.
- At Madurai, 32.7 to 75.7% increase in groundnut pod yield was obtained under micro-sprinkler irrigation over surface irrigation.
- Adoption of drip irrigation in banana increased fruit yield significantly (60 tonnes/ha).
- A gross benefit of Rs 5,070/ha was found under zero tillage over conventional method of sowing.
- The feasibility of multiple uses of irrigation water for fish culture and irrigation has been experimented at ICAR-RCER, Patna.

In super cyclone affected coastal districts of Orissa land and water management system were developed. Small sub-surface water harvesting structures were constructed which can enhance productivity and bring farmers out of perpetual poverty.

The B:C ratio varied from 0.67 to 2.3 in the first year itself. The cropping intensity varied from 130% to 192%. Initially, only seven farmers constructed the structures paying 40% of the cost of construction. However, noticing the benefit, in the second year, twenty-three farmers came forward to construct the structures paying 67% of the cost. Cost of structures varied from Rs 9.51/m^3 to Rs 16.80/m^3. Adoption of integrated farming system approach, total income varied from Rs 12.93/m^3 to 47.20/m^3 capacity of pond. Water productivity varied from Rs 8.87 to Rs 31.69/m^3. Pumping test determined the replenishment rate of the subsurface water harvesting structures as 1.58 m^3/hr to 4.7 m^3/hr in sandy and 1.01 m^3/hr to 3.4 m^3/hr in clayey zone.

At Astarang, small shallow tube wells were constructed for four water user groups to a depth of 13 m with diameter of 7.5 cm as ground water below 15 meter is saline. The benefit cost ratio of these structures also worked out as 2.1. The participatory approach of implementing the above technology has improved the financial status of the rural people and increased the employment opportunity.

Scientific Resource Management in the Eastern Region

A study of developed watersheds at different locations of the eastern region reflect that on an average, percentage of irrigation to total operational area in developed watersheds during *kharif* was 33.96%, 28.02%, 17.9% and 8.76% for Keonjhar, Mahasamund, Dhenkanal, and Ranchi districts, respectively from almost zero level of irrigation in pre-intervention period. The cropping intensity in the

Intercropping of groundnut and pigeonpea for increasing cropping intensity and on farm income in developed watershed area under NATP project. These are measures of crop diversification in rainfed uplands.

developed watershed villages was 119%, 100 %, 154% and 121% for Keonjhar in Orissa, Mahasamund in Chhattisgarh, Dhenkanal in Orissa, and Ranchi in Jharkhand respectively. Cropping intensity of control villages was comparatively lower at 92%, 100 %, 139% and 106% for above districts respectively.

In developed watershed villages for Keonjhar, Mahasamund, Dhenkanal and Ranchi, the combined employment generation after development was 82, 97, 104, 294 mandays per year per farm family respectively whereas it was 73, 51, 64 and 283 man days per year in the control villages in these districts.

The study reflected that the adoption of improved technologies in developed watershed varied from 23% to 38% of the total interventions in developed watersheds. Under intervention programme in developed watersheds for scientific resource management, paddy-blackgram performed better as intercrops in unbunded uplands of Keonjhar and Dhenkanal. Intercropping of paddy with black gram gave per hectare-combined yield of 3.84 tonnes for paddy and 0.85 tonne for black gram. The per hectare combined yield was 0.9 tonnes in case of pigeonpea and 1.2 tonnes in case of groundnut in intercropping of groundnut and pigeonpea as measures of crops diversification in rainfed uplands.

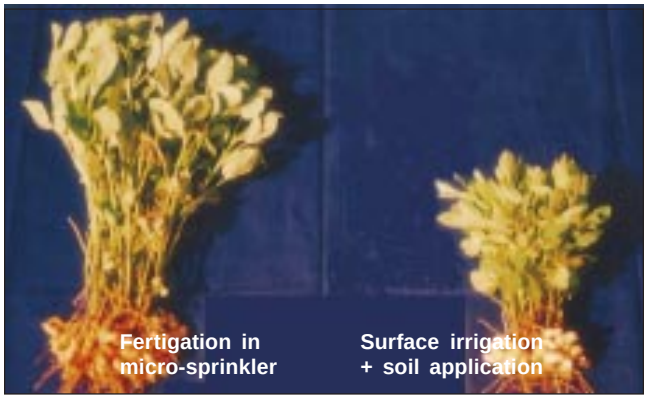
Drip Fertigation for Enhanced Productivity of *Typhonium*

Karunai kizhangu (*Typhonium trilobatum*) possessing high medicinal value is one of the long duration tuber crops grown in Tamilnadu. At Madurai, farmers' method of frequent surface irrigation (at 1.00 and 1.20 IW/CPE ratio) with soil application of 100:75:200 NPK kg/ha was compared with drip irrigation at 100, 75 and 50% pan evaporation (PE) and soil application of recommended NPK or fertigation of N and K. With drip fertigation at 100% PE, tuber yield was highest (39,450 kg/ha), which was comparable to drip fertigation at 75% PE (37,650 kg/ha) as against a yield of 23,140 to 26,600 kg/ha under surface irrigation, The water requirement with drip irrigation at 75% PE was 26% lower at 840 mm as against 1133 mm for the farmers' method of surface irrigation once in 4 days. The water productivity of 44.82 kg/ha mm through drip fertigation at 75% PE was a distinct improvement by 120 per cent over farmers' method of surface irrigation.

Drip fertigation at 100% PE gave high tuber yield (39,450 kg/ha) of *Typhonium* which was comparable with drip fertigation at 75% PE (37,650kg/ha) as against a yield of 23,140–26,600 kg/ha under surface irrigation.

Micro-sprinkler Irrigation and Fertigation to Summer Groundnut

Micro-sprinkler irrigation system enables precise control over quantity of irrigation water applied which is not possible through surface irrigation system. It also offers scope for fertigation. In an experiment on micro-sprinkler irrigation and fertigation in groundnut at Madurai in Tamilnadu over three seasons, increase in groundnut pod yield under micro-sprinkler irrigation over surface irrigation at 0.8 IW/CPE ranged from 32.7 to 75.7 per cent, higher moisture availability, higher leaf water content and greater nutrient uptake. The enhanced productivity under micro-sprinkler irrigation was more pronounced with partial or full fertigation (54.6-75.7%) than with soil application of fertilizers (32.7-54.9%) The yield improvement with micro-sprinkler irrigation was higher with irrigation regime of 100 % PE over 75% PE. Irrigation through micro-sprinklers scheduled at 75% PE saved about 34% water over surface irrigation.



At Madurai, increase in groundnut pod yield under micro-sprinkler irrigation over surface irrigation ranged from 52.7 to 75.7%.

Performance of Banana under Drip Irrigation System

The water requirement of banana under gravity flow of irrigation system is high with low water-use efficiency owing to its inherently low irrigation efficiency. Long-term experiment on the Vertisols of western Maharashtra showed that adoption of drip irrigation in banana increased fruit yield significantly (60 tonnes/ha) and saved about 38% irrigation water over gravity flow surface irrigation. Paired row planting effected 50% saving in the cost of laterals and drippers. The payback period of expenditure incurred on installation of drip system was only 1-2 years with additional annual net profit of Rs 23,400. Besides economic benefits, drip system improved the quality of banana bunches.

Water is a high energy and costly, but scarce and precious input in crop production system. Its efficient use is of utmost importance. In western Maharashtra adoption of drip irrigation in banana increased fruit yield, significantly (60 tonnes/ha) and saved about 38% irrigation water over surface irrigation.

Drip Irrigation for Vegetable Crops

Drip irrigation scheduling for brinjal, okra, tomato and cabbage and fertigation for bitter gourd with irrigation scheduled at 100, 80 and 60% ET in main plots and irrigation intervals (daily, 1 and 2 days) in sub-plots show that yield of brinjal/ okra was maximum at 80% ET and significantly higher at 100% ET. Maximum water-use efficiency was obtained at 60% ET with daily irrigation.

Irrigation and Nutrient Management in Heavy Soils of Bihar

Three recommended irrigation schedules against farmers' irrigation practice and five integrated NPK management levels were evaluated for wheat in heavy soils of south Bihar, Patna. The data reveals that there were no significant differences among the irrigation schedules for physiological parameters and growth characters like plant height, tillers/m^2. Thousand grain weight and grain yield were significantly higher under 0.9 IW/CPE irrigation schedule over farmers' practice. Fertilizer cut by 25% and use of 15 tonnes/ha FYM gave equivalent yields indicating an economy in fertilizer use by integrated nutrient management.

Tillage and Water Management in Wheat

Three methods of wheat establishment (conventional, zero tillage and raised bed planting) in combination with four depths of irrigation water (3, 5, 7 and 9 cm) were evaluated in split plot design. Adoption of zero tillage could save a total of Rs 1,650/ha under land preparation, Rs 1,200 in sowing and Rs 450 from irrigation. Under raised bed sowing, excess amount of Rs 800/ha was incurred for preparation and sowing but there was a saving of Rs 2,605/ha from irrigation water application. A gross benefit of Rs 5,070 /ha was found under zero tillage over conventional method of sowing.

Potential of *Boro* Rice in Waterlogged Area of Sone Command

The objective of this project is to find out possibility of boro rice cultivation in waterlogged lands in Sone Canal Command and to suggest a suitable method of nursery raising and optimum water regime for *boro* rice in south Bihar. To offset the adverse effect of cold, use of FYM @ 15 tonnes/ha for *boro* rice sown in November in open

field could produce 15 per cent additional seedlings for transplanting. However, by the use of polyhouse, raising of boro rice seedling was further possible in January when seed did not germinate in open field. A total of 14 irrigations with 72.0 cm depth were required for a successful crop. The crop responded upto application of 150 per cent NPK (150:75: 60).

Multiple Uses of Irrigation Water

Integrated fish farming increased water productivity with corresponding improvement of fish productivity (10 tonnes/ha against existing 2 tonnes/ha) due to increased aeration and irrigation efficiency. The feasibility of multiple uses of irrigation water has been experimented at ICAR-RCER, Patna. The study was started in July 1999 with a secondary reservoir (16.5x14.5m surface area) linked to the existing tubewell based network of irrigation channels. Out of 2.0 m of total depth, 1.5 m is kept as dead storage exclusively for fish production, while top 0.5 m was kept as line storage for providing irrigation water. The tubewell water is first fed to the reservoir, from where it is released for irrigation to the fields. This exchange of reservoir water is helpful in maintaining the water quality (dissolved oxygen, temperature, pH, turbidity etc.) for intensive fish production. Results indicated that such routing of irrigation water through the fishpond-cum-secondary reservoir effects thorough mixing of water and ill effects of quality stratification are minimized.

Improvement of Plant Genetic Resources and Improvement of Horticultural Crops

The 97 genotypes of different fruit crops were identified/collected from different region. Jackfruit selection HPJS-5/8 has been found suitable for table purpose and proposed for release.

Among the vegetable crops, brinjal variety Swarna Pratibha and tomato hybrid Swarna Baibhav and cucumber variety Swarna Poorna have been identified for release at National level. Two stable high-yielding lines of vegetable soybean, viz. GC-89009-1-1-2 and AGS-337 were identified as promising.

Production and Utilization of Horticultural Crops

Under the spacing cum planting system trials in mango cv. Amrapali, intermingling of canopy in closer spacing after 9 years was observed. Among the intercrops, *Stylosanthes* and Frenchbean have been found to improve the soil organic matter content. Phophobactrin was found to be the most effective in improving physio-chemical properties of guava fruits cv. Lucknow-49. In Studies on flushing and panicle emergence in litchi, complete cessation of shoot elongation of 2nd flush, 30 days before initiation of third flush, whereas no clear-cut cessation of growth was noticed in cv China.

Multiple cropping system with litchi cv. Swarna Roopa as base crop and guava cv. Allahabad Safeda as filler crop, cowpea intercropping proved remunerative under rainfed conditions of Chotanagpur region.

Integrated Pest Management in Horticultural Crops

A nitrogen dose of 140.5 kg and 169.5 kg /ha for rainy and winter season, respectively was most effective for minimizing infection of early blight of tomato. *Ralstonia* wilt of tomato and brinjal could be significantly managed by manipulation of hosts resistance through organic amendment of soil. Systematic fungicide were found superior over other groups when the percent disease and yield were taken into consideration for control of powdery mildew in cucumber.

Effect of Sources and Levels of Sulphur on Tobacco

Among the sources of sulphur, iron pyrite was on a par with gypsum, produced highest total cured leaf yield per hectare but they had no effect on the yield of first grade leaf. Levels of sulphur application did not influence total cured leaf but application of 40 kg S/ha had increased yield of first grade leaf. Net return was highest, i.e. Rs. 26,725/ha when iron pyrite was applied to the tobacco crop.

SOIL SALINITY AND COASTAL ECOSYSTEM

Long-term Effect of Integrated Nutrient Management in a Gypsum Amended Alkali Soil

Results of the long-term field experiment showed that rice and wheat yields could be maintained even at 50% NPK when used in conjunction with FYM or green manuring (GM). Rice and wheat yields and build up of organic carbon and available P at 100% NPK along with

Wheat yields can be maintained even at 50% NPK when used in conjunction with FYM or green manuring

- Long-term field experiment showed that rice and wheat yield could be maintained even at 50% NPK used in conjunction with FYM or green manure.
- The potential of using sewage waters for irrigation was assessed on crop production. Higher yields of paddy, wheat (4%) and cauliflower were obtained under sewage water irrigation compared to tube-well water irrigation.
- For selective extraction of fresh water overlying saline groundwater, skimming structures and their operational schedules are being designed.
- Studies on bioremediation of pulp and paper mill effluents revealed that fungal treatment for 7 days and phytoremediation for 20 days reduced the COD, BOD and solid content.
- Use of composite industrial effluent for irrigation for the past 20 years has led to contamination of groundwater.

FYM or GM equals the yields obtained with 150% NPK. In another study on gypsum amended alkali soils, one year alternate application of organic manures produced equal rice and wheat yields as with its continuous application each year.

Development of Regional Salt and Water Balance Models

In a study on the modelling of field and regional scale salt and water balance, application of Standard Groundwater Model Package (SGMP) for inverse application used to assess the seasonal groundwater recharge with seasonal groundwater table data as an input is established. The calibration and verification of the model for more sites should help in confidence building and wider application of the model.

Irrigation Potential of Sewage Water Use

The potential of using sewage waters for irrigation was assessed on crop production, in three cropping systems, viz food grain production (rice-wheat) alone or with agro-

The possibility of using sewage waters for irrigation was assessed on crop production. Here rice is seen with poplar. Higher yield of rice (14%) was obtained under sewage water irrigation than tubewell water irrigation.

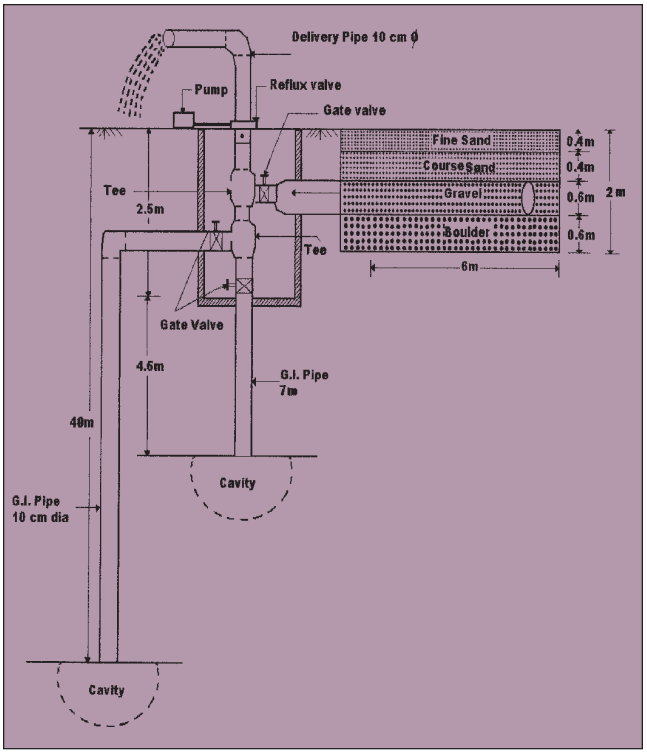
forestry (rice-wheat with poplar), vegetable production (cauliflower-okra-spinach) and fodder production (berseem-sorghum) systems. The study shows higher yields of paddy (14%), wheat (4%) and cauliflower (23%) under sewage water irrigation compared to tubewell water irrigation.

Long-term Effect of RSC Waters and Amendment Application on Soil Properties and Crop Growth

Monitoring of long term effect of irrigation with RSC waters varying in salinity (EC 2 and 4 dSm^{-1}), residual alkalinity (RSC 5 and 10 meL^{-1}) and sodicity (SARw 10, 20 and 30, adj SAR 33 and 36) on soil changes and yield of pearlmillet fodder and wheat showed that the relative yields of wheat varied from 0.88-1.03 and of pealmillet fodder from 0.55-1.0. Twelve years of continuous irrigation with these waters didn't result in increase in pH in the surface 30 cm soil layer.

Technologies for Skimming and Recharging Fresh Water in Saline Groundwater Regions

For selective extraction of fresh water overlying saline groundwater in inland areas of Haryana, skimming structures and their associated operational schedules are being designed. A skimming cum recharge structure has been designed at a downstream location at Jagsi in Safidon block of Jind District, having potential of groundwater recharge with excess rainfall during heavy rains. Two cavity tubewells installed at 7 and 40 m depth can be operated separately or together to obtain water of



A skimming-cum-recharge structure for extraction of fresh water overlaying saline ground water has been designed at down stream location at Jagsi in Jind district.

desired quality. A recharge chamber, close to these cavities facilitate recharging one or both the cavities with filtered surface runoff during rainy season which is expected to increase the availability of good quality water in upper cavity or improve the quality of water in lower cavity through dilution for possible use either directly or after treatment with gypsum.

Rapid Screening of Indian Mustard Genotypes for Salt Tolerance

Seedling emergence is a critical stage in Indian mustard when raised on salt-affected soils. Screening of different mustard genotypes in laboratory for salt tolerance during germination and seedling emergence growth had positive correlation (r=0.92) between seedling emergence at 26 dS/m in solution culture and 12.8 dS/m in soil culture.

Use of Urban and Industrial Effluents in Agriculture

- Characterisation of effluent from towns located near different centres of the project show that excessive contents (> 1ppm) of toxic ions like Cd, Ni, Cr etc and those of pathogenic bacteria (*E. coli* $2x10^6$-$4x10^9$ /100 ml) pose serious health risks.
- Use of composite industrial effluent for irrigation for the past 20 years has led to contamination of groundwaters. Pollutants like Cr could be detected to a distance of 1 km in Cauvery water from disposal point of tanneries effluent in Erode.
- Enhanced organic matter in sewage-irrigated soils reduces bio-availability and mobility of toxic ions (Xm 320-385 for Cr and 322-1489 mg/kg for sewage irrigated alluvial soils of Haryana). Due to high cation exchange capacity, organic matter and CaCO3 content in soils, toxic metal ions are retained in the surface soils only.
- Some of the case studies show that wastewater from domestic origin can also be used as source of irrigation as well as plant nutrients.

Causes and Remedial Measures for Resodification of Reclaimed Soils in Uttar Pradesh

Reports of resodification of reclaimed alkali lands in Uttar Pradesh is due to the increase in soil pH in reclaimed lands and was related to the water table condition in that particular area. It was observed that the resodification problem was found to be more severe under shallow water condition (<2m below ground level), followed by medium water table condition visible in deep water table condition (>3m bgl). The crop growth was also severely affected by resodification in 74.7% area under shallow water table condition and 15.9% under deep water table condition.

Agronomic Practices for Rice Based Cropping Systems in Saline Coastal Soils

Combined use of organic and inorganic sources of N alone are important for improving crop yield and soil health in coastal saline soils. Application of as low as 5 tonnes/ha (fresh weight basis) of locally available organic sources (*Sesbania*, *Gliricidia*, compost, locally trees) etc., contributing 10-15 kg N/ha, once in a year, was quite effective in increasing N use efficiency, soil microbial activity and fertility status of soil.

Effect of Aquaculture on Cultivated Fields in Coastal Andhra Pradesh

A survey conducted in Guntur, Prakasham and Nellore districts revealed that due to prawn culture (Aquaculture), the quality of groundwater is being rendered saline as indicated from the analysis of water samples. Paddy crop is affected severely up to a distance of 20 m unless trenches are dug around the ponds to control the seepage of saline water which affected the tree planted at the ridges.

Potentialities of Using Drip System for Saline Irrigation

Drip irrigation experiments (at 1 and 2 days interval) with saline water on vegetable crops had adverse effects as the most of the applied water was evaporated, but application of water equal to open pan evaporation resulted in optimal yield of tomato and application of 80 percent of cumulative pan evaporation in sugarcane with alkali water produced highest cane yield and saved 30% water as compared to farmers' practice. The highest water use efficiency (WUE) of 61 kg/ha-mm was achieved in case of drip irrigation in brinjal at Ganganagar at 1.2 ET while, the lowest WUE of 28.7 kg/ha-mm recorded in case of surface irrigation at 1.4 ET.

Reclamation of Alkali Vertisols Under Rainfed Conditions

Leaching of the reaction products of amendments is one of the pre-requisites for reclamation of alkali soils with assured water supplies but such water supplies are not available under this condition for which various configurations of raised and sunken bed system were tested at Barwaha farm, Indore centre for the past 8 years. Results show that cotton and paddy yields could be sustained during normal rainfall years but in case of deficit rains or long dry spells, provision for rain water harvesting ponds with water for 1-2 life saving irrigations becomes necessary. Performance of paddy crop improved with increasing ratio of sunken:raised bed ratio of 3:2 with the minimum for the ratio being 1:2.

Evaluation of Agro-potentiality of Pulp and Paper Mill Effluent for Irrigation

Studies on bioremediation of pulp and paper mill effluents revealed that fungal treatment for 7 days and phytoremediation for 20 days reduced the COD, BOD and solid content by 90, 93 and 89 percent and 91, 94 and 93 percent respectively. Thus the degradation of paper mill effluent by *P. chrysosporium* and removal of pollution by growing water hyacinth (*Eichhornia crassipes*) in effluent appear better option for safe disposal of pulp and paper mill effluent.

RAINFED RESEARCH

Resource Characterization

Information on 320 ITKs on various aspects of dryland agriculture from Zone × (AP) was collected and

- Information on 320 ITKs on various aspects of dryland agriculture were collected and documented.
- Conservation furrows plots stored 4 to 37% additional soil moisture compared to control.
- The CRIDA has signed MoUs with four entrepreneurs for mass production of 12 implements developed by it.

documented. Validation of many of these is in progress. These ITKs have been included in a publication comprising of two volumes.

- Validation of an Indigenous Rain Gauge developed by farmers in rainfed Alfisols of Rangareddy district to perform important operations like sowing, tillage and fertilizer application in sorghum+pigeonpea and castor crops is underway.

Pingali danti—an animal drawn interculture implement, has an edge over traditional blade harrow in terms of coverage, weed control, handling, cost effectiveness, durability and replicability →

Guddeli—an indigenous hand tool for uprooting ginger crop. It requires 15–20 mandays per acre for harvesting of ginger crop ←

- Validation of Pingali Danti, an indigenous animal drawn interculture implement used in tomato cultivation in Kandukur Mandal of Ranga Reddy district is also underway.
- Guddeli, an indigenous hand tool used for planting and up rooting of ginger roots (*Zinziber officinalis*) was found effective. The tool is efficient, easy to operate and reduce drudgery of farm labour. It requires 15-20 man-days per acre for harvesting of the crop, costs about Rs 30 per tool and has a life span of 2 years.

Impact of Peddagadda Watershed, Srikakulam District under NWDPRA

Implementation of watershed programme in Peddagadda watershed in Srikakulam district of Andhra Pradesh resulted in:

- Increased availability of soil moisture and rise in groundwater level by 1.5 meters.
- A substantial increase in net irrigated area (34%) and number of wells/bore wells (67%).
- Reduction in tank siltation.
- Change in cropping pattern and introduction of new crops like sugarcane, onion and maize.
- Increase in area under organic recycling by growing green manure crops like *pillipesara* and *dhaincha,*
- Overall increase in greenery, attributed mainly to plantation of casuarina and cashew,
- Ten-fold increase in the area under plantation at the cost of decline in area under coarse cereals like jowar and bajra.
- Marked improvement in participation of women in decision making process.
- BC ratio of 1.54, 1.24, 1.06 for years with good, moderate and poor rainfall, respectively after watershed treatment as against 1.08 before the implementation.

Integrated Nutrient Management

One of the major problems for low adoption of integrated nutrient management in dryland conditions is poor availability of organic residues. Long-term experiments conducted at the CRIDA, Hyderabad have revealed that it is possible to generate about 4 tonnes/ha of nitrogen rich horse gram biomass through cover cropping by utilizing the post-seasonal rains and stored soil moisture. The incorporation of this biomass has shown a positive impact on the yield of the succeeding *kharif* crops like sorghum and sunflower and also resulted in improvement of soil health.

Conservation Furrows

Conservation furrows across the slope at 3 m interval, as a measure of moisture conservation and runoff management were evaluated in ten farmers fields in five villages of Nalgonda district, Andhra Pradesh. Castor with pigeonpea (5:1) was the test intercrop. During the growing season, the study area received 290 mm rainfall in 28 rainy days (rainfall >2.5 mm/day^{-}). The results showed that conservation furrows plots stored 4 to 37% additional soil moisture compared to control throughout the growing season. This additional moisture resulted in better plant growth and 12% higher bean and grain yields of castor and pigeonpea than the control.

Crops and Cropping Systems

Tolerance of sorghum to biotic stress was enhanced through genetic manipulation

- Experiments to develop efficient regeneration protocol from sorghum shoot apices revealed that the shoot tips of cvs SPV 462, SPV 839 and M35-1 produced better regenerable calli on media containing 2,4-D and kinetin.
- Efforts were also made to produce embryogenic calli with better regeneration frequency by incorporating various amino acids, growth hormones, anti-oxidants and antibiotics in the growth and regeneration media.
- Regeneration was achieved from calli induced from shoot tip and meristem using basal MS media. About 5-8 shoots per calli were obtained. By altering the hormones and media conditions finally success was achieved in standardization of the protocol for efficient regeneration from shoot apex. The frequency of regeneration in the present protocol is about 15-20 shoots per calli.
- Histological studies of the calli were carried out and callus in regeneration media showed multiple shoot apex.
- A protocol for transformation of sorghum using biolistic approach was standardized. It was observed that GUS expression was good in shoot tip calli with the construct Pcambia1305.1.

In-situ Grafting of Fruit Plants

Establishment and survival of trees in the harsh climate prevalent in the semi-arid regions is very poor. At the CRIDA, Hyderabad, mango cv Kesar was *in situ* grafted in the field on one year old seedlings of cv Totapari. About 90% success was achieved.

Documentation of ITKs on Soil and Water Conservation Methods

Indigenous methods of *in-situ* moisture conservation and runoff management prevalent in the rainfed areas of India were collected. The findings were published in a book entitled "Indigenous Technical Knowledge on Soil and Water Conservation in Semi-Arid India". The publication describes each ITK by indicating name, purpose, location, agro-ecology, description, advantage, constraints, replicability/feasibility and researchable issues.

Alternate Land Use Systems

Field evaluation of tissue-cultured explants through participatory on-farm trials has generated much interest in the farming community. So far 50,000 neem and teak saplings have been supplied on cost basis to farmers of Andhra Pradesh, Tamil Nadu, Maharashtra and Karnataka. A production centre at Gaddipalli (SAIRD) was also established, and is producing 25,000 neem and teak explant annually.

Fruit and Vegetable Preservater

Fruit and vegetable preservation at farmers' level is a major problem in India. Though many cold storage units are available, they are restricted only to bulk produce and high value products. In order to overcome this deficiency the CRIDA has successfully fabricated a low cost and energy saving fruit and vegetable preservator.

This portable structure is made of fibre reinforced plastic and consists of two compartments with circular holes all around the periphery. They are kept offset by 1- inch thick pine grass mat. Water is dripped on to the mats continuously as per the requirement through a circular flexible pipe placed above the mats. This system keeps the basket 8-10°C cooler with 30 to 40% more humidity than the conventional method. The water requirement varies between 2-4 litres/day as per the need. The approximate cost is around Rs 2,400 for a 50 kg capacity preservator.

It has the following advantages:

- Increase shelf life by 7-12 days.
- It is portable.
- Reduces handling damages.

Castor Planter

A tractor-drawn castor planter was improvised by adding a marker to it for better maneurability of the machine. This modified version seeds around 40 acres of castor in an hour and helps farmers to sow a large area within the limited time of moisture availability, thereby reducing the cost of cultivation and helping better seed establishment.

Mechanized Weeding in Castor

A tractor-drawn 3-row weeder was developed and found very effective. Under on-farm conditions, this weeder can cover an area of 1.1 ha in an hour as compared to the traditional method which covers an area of only 0.15 ha.

A tractor drawn 4-row weeder was developed. It can cover an area of 1.1 ha/hr.

Castor Sheller

Castor shelling is a time consuming and tedious process. To make the operation easy, CRIDA Castor Sheller was modified and used during this crop season. The performance was very satisfactory and appreciated by the farmers.

CRIDA castor sheller. Its performance was very satisfactory.

Mini Dal Mill

A flour mill owner Mr Jayaprakash, Settur village, Anantapur district purchased a mini dal mill at a cost of Rs 60,000 in Kisan Expo 2000 held at Nagpur. Due to operational and mechanical problems, he could not install the machine. He attended a mini dal mill field demonstration organized at HRF (CRIDA) in March 2002. After thorough discussion and knowing the details of his mill, he was advised to replace the existing emery of the roller with rough grit, add a sieve set and a screw auger type dal polisher as extra components. The farmer spent Rs 15,000 on these works and installed the mill. Now the mini dal mill is working satisfactorily. The capacity of the mill is 100 kg redgram hr^{-1} with a recovery of 68 kg dal. The farmer is running the mill on custom hiring basis to make dal from whole redgram. He is charging Rs 60 per 100 kg grain. Mr Jayaprakash now in a normal year, gets work for about 4 months, processes 30 tonnes of redgram and earns a huge profit.

Mini Dal Mill

The conventional mini dal mill for blackgram was modified by fitting a C-type roller. A best protocol for this modified mini dal mill comprising of pitting followed by 0.3% oil application, heaping for 48 hr and 16 hr sun drying of grains was standardized. This resulted in 99% dehusking efficiency and 55% dal recovery.

AGROMETEOROLOGY

Agroclimatology

- Analysis of rainfall data of Kerala State for the period 1871 to 2001 (131 years) revealed that mean annual rainfall of the State is 2828 ± 409 mm. The rainfall in this State is highly stable and dependable with coefficient of variation of only 14.4 percent. The season-wise rainfall distribution over Kerala indicated that 68 percent of the annual rainfall is received during the southwest monsoon followed by post-monsoon (16%), summer (14%) and winter (2%) in order.
- The rainfall analysis indicated that wetland paddy could be grown under rainfed conditions during *virippu* (*kharif* season) and it could be grown during *mundakan* (winter) under assured irrigated conditions only. Many of the plantation crops mainly in north Kerala require irrigation during December to April, as the dependable rainfall (rainfall at 75% probability) is less than 100 mm.
- Agroclimatic characterization of Marathwada region of Maharashtra brought out that the chances of getting sowing rains for sowing of *kharif* crops is around 24th standard meteorological week (11-17 June) in Osmanabad and Latur districts, 25th week (18-24 June) in Parbhani, Nanded, Jalna and Aurangabad and 28th week (9-15 July) in Beed district of Marathwada. Break monsoon conditions were observed to be occurring in the month of August throughout Marathwada region. Based on the agroclimatic analysis, a short duration intercrop with a long duration sole crop or a single crop of 180-200 days duration suits best for deep black soil, while a sole crop of 110-115 days suits well in shallow soils.
- Agroclimatic analysis of Midnapur (West) district of West Bengal based on daily rainfall data of 90 years (1901-1990) showed that rainfall is most assured with probability of getting 20 mm of rainfall per week exceeding 70 percent during the southwest monsoon, i.e. 23rd to 39th standard meteorological weeks. Water balance studies of this district showed that the length of growing period (LGP) in this district varied from 203 days in sandy loam soil to 261 days in clay soil. This information can be utilized for crop planning under rainfed conditions. In sandy loam soils having LGP of 203 to 230 days, upland variety of 100 days duration followed by a second crop of mustard maturing in 100 days can be recommended and in clay loam and clay soils transplanted rice followed by mustard / lentil / gram / linseed can be grown under rainfed conditions.
- Analysis of drought years in *kharif* and *rabi* seasons in different districts of Himachal Pradesh brought out that except Kangra, Palampur and Mandi districts, all the other districts experience either moderate or severe drought during the *kharif* season in more than 20 percent of years. Similarly, except Bajaura and Chamba, all the districts experience droughts in more than 20 percent of years in *rabi* season. Drought occurs in more than 30 percent years during *kharif* season in Hamirpur, Una, Kinnaur and Sirmaur districts and during *rabi* season in Kangra, Palampur, Hamirpur, Una, Solan and Sirmaur.

- Analysis of rainfall data of Kerala during 1871-2001 revealed that mean annual rainfall of the state is 2, 828±409 mm.
- Crop-weather relationship in *rabi* crops like sorghum, sunflower and safflower at Solapur showed significant positive relationship of the yield with cumulative moisture use.
- As winter period is shorter in Raipur region, there is demand for thermal stress tolerant wheat varieties. Varieties Kanchan, Sujata and Arpan were found suitable for normal sowing, while Lok 1 for late sowing.
- Using 43 years yield data of mustard in Nadia district, scientists developed a yield prediction model for mustard crop.
- In safflower, minimum temperature and relative humidity positively influence the aphids population.
- A model for predicting groundnut leafminer based on rainfall and minimum temperature was developed at Anantapur.

Crop-weather Relationships

- Crop-weather Relationship Studies in *rabi* crops like sorghum, sunflower and safflower at Solapur centre showed significant positive relationship of the yield of respective crops with cumulative moisture use.
- In Crop-weather relationship studies in rice at Jabalpur, the moisture stress during grain filling period of rice was found to have adverse effect on yield. The results further showed that in a severe drought year like 2003, early maturing variety IR-36 could produce highest yield under all the dates of sowing when compared to late maturing varieties like Mahsuri and Madhuri, which failed to reach reproductive period under delayed sowing conditions.
- Crop-weather relationship studies in soybean at Akola centre brought out that variety JS-335 recorded higher grain yield over other varieties because of its higher thermal use efficiency and higher radiation interception ability.
- At Anand centre, weather during flowering and pod development stages of mustard have significant influence on yield. Maximum temperature (MXT) and diurnal temperature (DTR) showed positive relationship with yield while minimum temperature (MNT) showed negative relationship.
- The equations further revealed that higher maximum temperature (> 30°C), lower minimum temperature (< 14°C) and higher temperature range during flowering and grain development stage are highly beneficial for obtaining higher seed yield in mustard.
- As winter period is shorter in Raipur region of Chhattisgarh State, there is demand for thermal stress tolerant wheat varieties for *rabi* season. For this purpose, eight varieties of wheat were evaluated for their thermal tolerance using a thermal sensitivity index (TSI) at Raipur. Varieties Kanchan, Sujata and Arpan were found suitable for normal sowing while Lok-I was found suitable for late sowing, as it gives better yield under moderate thermal stress conditions.
- Crop-weather relationship studies in mango at Bangalore brought out that initiation of flowering is related to the soil moisture content during the month of November. Higher soil moisture in November due to rains in October postpones the flowering initiation to the month of January and lower soil moisture prepones the flowering initiation to December.

Crop Growth Modelling

- Yield forecasting model for coconut based on monthly index of moisture adequacy (ratio of actual and potential evapotranspiration) and humidity index (the ratio of water surplus and potential evapotranspiration) was developed by working out the water balance of Kerala for the years 1945 to 2001. The monthly moisture adequacy index (Ima) and humidity index (Ih) value for the past 42 months (time from *primordium initiation to* harvest) were used for predicting coconut yield 7 months ahead of its harvest.
- Using 43 years' yield data of mustard in Nadia district of West Bengal, scientists at Mohanpur centre developed a yield prediction model for mustard crop. The model, predicts yield based on the accumulated rainfall during different periods of crop growing season, viz 36 to 39 meteorological standard weeks 4-43 weeks 44 to 52 weeks 1 to 5 weeks and technological trend (T).
- A predictive model for predicting rice yield-using agroclimatic ARFL (Accumulated Rainfall) was developed at Jorhat. The percent variation of predicted yields from actual yields were found to be lower (< 10%) showing the efficiency of predictive models in estimating yields ahead of crop harvest under agroclimatic conditions at Jorhat.

Web Site of AICRPAM

A website named "Crop Weather Outlook" was developed by the AICRPAM.

The Website is operating from the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad where the AICRPAM is located and is linked to ICAR Website for a wider use by the planners, researchers, farming community and other public users. This Website contains links to various AICRPAM centres to view:

- Weekly report on crop-weather conditions at the respective centres of AICRPAM.
- Current weather data of the centres
- Agro advisory services based on knowledge generated at the centres and weather forecasts issued by NCMRWF, New Delhi.

Weather Effects on Pests and Diseases

- Pest and weather relationship studies in safflower indicated that minimum temperature and relative humidity positively influence the aphids population in safflower.
- The study on fortnightly mango hopper population with weather parameters at Anand centre brought out that high humidity results in lower population of mango hopper and *vice versa*. Humidity less than 50 percent was favourable conditions for outbreak of hopper population in mango.
- A model for predicting groundnut leafminer based on rainfall and minimum temperature was developed at Anantapur. The model showed that occurrence of leaf miner is negatively associated with increase in rainfall.
- At Bhubaneswar, a multiple regression model was developed with cumulative rainfall (15 days prior to prediction date), afternoon humidity (14 days prior), maximum temperature (7 days prior) and stage of the crop as independent variables to predict bacterial leaf blight incidence in rice. Similarly, leaf folder in rice was predicted based on bright sunshine hours and

average temperature accumulated over past 15 days prior to the incidence of the pest.

Pests and Diseases Forewarning

Predictive equations or thumb rules were developed for forewarning of pests/disease incidence in crops, viz. rice and groundnut using historical pest / disease collected from different Cooperating Centres of NATP Project on Development of Weather Based Forewarning Systems for Crop Pests and Diseases.

The neural network technique was applied to analyze 25 years long-term data provided by the DRR, Hyderabad on trap catches of yellow stem borer, a key pest of rice. It was observed that if rainfall is less than 8 mm and sunshine hours greater than 8 hr, the possibility of moth catch greater than 100 is 40 per cent. The neural network was tried with data of yellow stem borer from 1975-96 and subsequent years data (1997-2000) was used for validation as independent data sets. The peaks of yellow stem borer incidence were predicted one week in advance.

A prediction model was developed using five years data (1996-2000) for estimating late leaf spot incidence with weather parameters, viz. Evening RH, Morning RH, Max Temp, Rainy days and inoculum potential (current week) using data from Tirupati collected during 1996-2000. The equation could explain 65 percent variation in late leaf spot incidence due to weather parameters. Actual and predicted values of late leaf spot at Tirupati were depicted.

CROP PRODUCTION

A New Technique of Growing Mat Type Nursery for Rice Transplanters Developed

Self-propelled and manual rice transplanters have been developed and popularized to cater to the needs and requirements of farmers. These transplanters require mat type nursery that is generally grown with the help of frames. However, this process is very cumbersome. To overcome this problem, a new technique has been developed to grow the mat type nursery without the frames in open field. In this technique, the nursery beds of 5 × 1.2 m^2 area (75 m^2 per ha of transplanting) with side channels are prepared in the tilled field, polythene sheet (50/ 60 gauge being 10% perforated) is placed on the nursery bed, soil (sieved by 2 mm diameter sieve) - farmyard manure (FYM) mixture is spread over the sheet (15 mm thick) in the ratio of 3:1, sprouted seed (30-40 kg/ha depending on coarse or fine grained variety) is uniformly spread over the soil, and covered by soil- FYM mixture (5 mm thick) and by gunny bags or dry hay also (if needed). Water is sprinkled over the seedlings by rose cane for 3-4 days and then gunny bags/hay is removed and water is applied by flooding through side channels. If needed, weeding and spraying of urea and zinc sulphate is done. The seedlings become ready for transplanting in 20-22 days when height reaches 125-150 mm.

A new technique has been developepd to grow the mat type nursery without frames in field. In this technique, the nursery beds with side channels are prepared, polythene sheet is placed on the nursery bed, soil-farmyard manure mixture is spread over the sheet, sprouted seeds are uniformly spread over the soil, and covered by soil-FYM mixture. The seedling mats are rolled back over the polythene and cut according to the requirement of transplanter (about 1400 mats/ha of transplanting). This technique has been standardized which completely eliminates the requirement of farmers. The adaptive trails of this technique along with transplanting by transplanter have been carried out at farmers' fields.

- A new technique to grow the mat type nursery for rice transplanters was developed.
- In zero tillage based wheat cultivation net monetary benefit was Rs 5700/ha. It may be attributed to saving in land preparation, seed and additional grain yield.
- Cumulative effect of long-term integrated nutrient supply system on crop productivity and soil fertility under rice-rice system was studied.

Nitrogen and Phosphorus use Efficiencies Improved Through Inclusion of Forage Cowpea in Rice-Wheat System

Field experiments were conducted at the PDCSR, Modipuram, for 3 consecutive rice-wheat cycles to study the effect of forage cowpea grown in pre-rice summer season on soil organic carbon, NO_3-N leaching, N and P use efficiencies, and yields of rice-wheat system. Cowpea (forage) harvested at 50-days removed greater amounts of N and P through above ground biomass than that recycled through belowground roots and nodule. The NO_3-N in soil profile below 45-cm depth after wheat harvest was greater under fallow during summer than under cowpea, suggesting that cowpea minimized NO_3-N leaching beyond 45-cm depth. Similarly, in the treatments receiving both 120 kg N and 26 kg P ha^{-1}, NO_3-N in soil below 45-cm depth was lower as compared to those receiving N or P alone. After 3 crop cycles, incorporation of cowpea roots and their subsequent decomposition increased the soil OC content by 11.6% in 0-15 cm layer, 10.5% in 15-30 cm layer and by 6.3% in 30-45 cm soil layer. P applied at 26

kg ha^{-1} increased the available P content, which was however, invariably low under summer cowpea plots as compared to that under no cowpea ones.

This study revealed that in Upper Gangetic Plain (UGP) the 60-70 day period between wheat harvesting and rice transplanting could be successfully utilized for raising cowpea as a forage legume in rice-wheat system. Cowpea, besides providing green forage during otherwise forage-scarce summer season, may also help improving the annual productivity and nutrient use efficiency, provided both rice and wheat crops receive recommended fertilizer input.

Zero-tillage Technique in Wheat

A study on zero tillage based wheat cultivation under rice-wheat system was undertaken on farmer's field involving 71 farmers belonging to 23 villages of Meerut, Baghpat and Saharanpur districts of western Uttar Pradesh.

An overall increase in net monetary benefits due to adoption of zero tillage over conventional tillage was to the tune of Rs 5700/ha. This is attributed to saving in land preparation (45%), seed (5%) and additional grain yields (50%). In addition, saving in irrigation water at first irrigation, less weed population particularly of small canary grass (*Phalaris minor*), advancing of time of sowing by few days and early emergence of seeds by two to three days also observed.

Spatial Variability of Soil Organic Carbon Content under Different Cropping Systems

Soil organic carbon (SOC) content of fifty-three locations spread across various agro-climatic zones of India was analyzed for its relationship with climatic parameters. The combined effects of rainfall and temperature that controls the carbon turn over and its accumulation were studied. In low rainfall zones, SOC content decreased with increasing temperatures, however, in high rainfall zones, SOC content increased with increasing temperature. A significant negative relationship of SOC content with soil pH was evident. Other meteorological parameters such as relative humidity and sunshine hours further highlighted the role of rainfall and temperature in maintaining SOC content. Similar trends were observed when data were grouped according to predominant cropping systems such as rice-rice, rice-fallow, maize-wheat, pearl millet- and soybean-based systems. The locations under the rice-pulse system exhibited reverse trends in the effect of climate on SOC content.

Cumulative Effect of Long-term Integrated Nutrient Management on Crop Productivity and Soil Fertility under Rice-Rice System

Cumulative effect of long term integrated nutrient supply system on crop productivity and soil fertility under rice-rice system was studied at five locations situated at various agro-climatic zones in India. The cumulative effects of 50% recommended NPK+ 50% N as green manuring during *kharif* followed by 100% recommended NPK during *rabi* was highest at Siruguppa, Rajendranagar, Maruteru, and Bhubaneswar locations. At Chiplima and Jhorhat, 50% or 25% N substitution through FYM gave highest performance. In contrast, cumulative effects of treatments over locations were compared wherein 50% N substitution as green manuring gave best performance. Organic carbon build up was noticed irrespective of integrated plant nutrient supply system at all locations. Build up in available P was noticed at all centers. Available K status improved only at Rajendernagar, and Maruteru with integrated plant nutrient supply system where the impact of N substitution as FYM was superior at Rajendernagar and that of green manuring at Maruteru.

Enhanced Decomposition of Machine Harvested Rice Straw and its Impact on Soil Fertility and Crop Yield in Rice-Wheat System

Application of mineral salts and urea alone or in combination to the soil helped in the enhancement of decomposition of crop residues in rice-wheat system. Application of cellulolytic micro-organisms further helped in accentuating the rate of decomposition of crop residues. Substantial increase in soil organic carbon was recorded after completion of 3 crop cycles in rice-wheat system. The status of soil organic carbon after harvest of wheat was generally higher than that of rice. Soil application of ferrous sulphate, zinc sulphate and urea @ 10, 20, 20 kg/ha along with *Aspergillus awamorae* and *Trichoderma viride* was best in attaining highest crop yield, soil organic carbon and available P and K in contrast to other treatments.

ARID ECOSYSTEM

Pearl Millet Variety CZP 9802 Released for Drought-prone Arid Areas

A dual purpose pearl millet variety CZP 9802, bred and developed at the Central Arid Zone Research Institute, Jodhpur, has been released for cultivation in the scanty rainfall and drought-prone areas of Rajasthan, Haryana and Gujarat. During three years of testing at the All India Coordinated Pearl Millet Improvement Project locations, it provided a grain yield of more than 1.3 tonnes/ha under very severe drought stress conditions, the yield being 15% higher than the national check Pusa 266 (1.14 tonnes/ha) and 52% higher than the check ICTP 8203 (0.98 tonne/

- CZP 9802 pearl millet variety, developed at the CAZRI, has been released for cultivation in the scanty rainfall and drought-prone areas of Rajasthan, Haryana and Gujarat.
- A passive-cool chamber for preservation of vegetables and fruits has been developed.

ha). Under favourable growing conditions, the variety CZP 9802 has a grain yield potential of 2.0-2.2 tonnes/ha. The special feature of this variety is its ability to produce high quantity of dry stover (average 3.3 tonnes/ha, in comparison to 2.1-2.7 tonnes/ha from checks Pusa 266 and ICTP 8203), even under harsh growing conditions. The CZP 9802 adapts well to the soils of poor fertility in arid region, and responds very well to additional doses of nitrogen.

A dual-purpose pearl millet variety CZP9802 has been released for cultivation in drought prone areas of Rajasthan, Haryana and Gujarat. During three years of testing it gave yield of more than 1/3 tonnes/ha under severe drought conditions which is higher than the national check Pusa 266.

Plants of CZP 9802 are good in tillering (2-4 panicles per plant), grow 180-200 cm tall and produce compact heads (23-26 cm long) of cylindrical shape. The variety flowers within 45 days and has a maturity period of 72-75 days. Thus, it escapes terminal droughts that are very frequent in arid region. The grains are light grey in color with yellow base, and are medium-bold with 1000-grain weight of 8-9 g. This dual-purpose variety is highly resistant to downy mildew, smut and ergot diseases.

A low-cost Passive-Cool Chamber for Preservation of Vegetables and Fruits

High temperatures in the desert region, especially during the summer months, affect the keeping quality and shelf life of fresh fruits and vegetables. Conventional methods of air conditioning and refrigeration are costly and not feasible due to non-availability and erraticity of electric power in many villages. A low cost passive system based on the evaporative cooling principle has been developed by CAZRI, Jodhpur, to preserve vegetables for short duration.

The device is a double walled system (170 × 95 cm) made up of bakes, bricks and cement, filled up with coarse sand. The water, filled up between double chambers, creates sufficient humidity within the inner chamber from the sidewalls and reduces the temperature inside. Provisions are also made for water evaporation from the bottom side of the cool chamber by providing suitable drainage system, which hastens the process of

A low-cost passive cool chamber has been developed by the CAZRI, Jodhpur to preserve vegetables for short duration. Conventional methods of refrigeration are costly and not possible due to non-availability of electric power in villages. The chamber can preserve 30–50 kg vegetables.

temperature reduction and maintains high humidity in the cooling area. As compared to the ambient conditions, temperature within the inner chamber is reduced by 15°C, while humidity is maintained at >85% level. A suitable shed is also erected to protect the cool chamber from direct solar insolation.

Under normal capacity, chamber can load and preserve 30-50 kg vegetables (tomato, brinjal, cluster bean, lady fingers, chilly, lemon, bottle guard, cabbage, carrot, etc.) can be preserved for a period of 4-5 days during summer and 4-7 days in winter. The chamber requires 30-35 litres water daily in summer and 20-25 litres in winter. Approximate cost is Rs 4,000.

Chemical Differences between Khara and Meetha variety of *Aloe vera*

Indian aloe (*Aloe vera* syn *Aloe barbadensis*) has been traditionally used as an ailment and domestic medicine for gastrointestinal disturbances, burn, insect bite, minor cut, etc. It is extensively used in drug and cosmetic industries. Three commercial products: aloe, gel and the oil can be obtained from the leaves of the plant. Aloe, the bitter yellow coloured dried sap, is known for its cathartic effect and its main active principle is aloin. Aloe is also used as a bittering agent in alcoholic beverages. The gel is used as a hydrating ingredient in creams and other cosmetic products, and as a dietary supplement in several beverages. The oil is used in cosmetic industry as a carrier of pigments and soothing agent.

Two varieties of Indian aloe -Khara and Meetha, look apparently similar, and have similar colour of the sap, which oozes out after incision of leaves, making people believe that both the varieties have bitter aloin.

Thin layer chromatography (TLC), column chromatography and reversed phase HPLC of yellow sap samples of both the varieties revealed that Meetha variety were three times more concentrated than that of Khara variety. But some of the peaks present in the Khara variety were missing in the chromatogram of Meetha samples,

indicating variation in their composition.

Negligible amount of aloin (0.03 to 0.06% w/v) was detected in Meetha while in Khara it was 10.00 to 15.40 % (w/v). Aloesin, the pungent odored compound, was found in Khara variety only. Khara variety can be utilized as a rich source of aloin.

Hand Weeder

A light weight (~ 500 g), agronomically efficient, hand weeder, with a blade size of 150 mm, has been developed at CAZRI, Jodhpur. During operation, the push-pull action of the weeder helps in better utilization of kinetic energy. It collects grasses while weeding, and does not give jerk when encountering stones in the field. The hand weeder can be easily fabricated by any village blacksmith. The fabricatioin cost is about Rs 40.

A light weight hand weeder has been developed at the CAZRI, Jodhpur.

WEED MANAGEMENT

Weed Competitive Crop Cultivars

Weeds are a major problem in direct seeded rice. No single method of weed management will serve fully the purpose. Many a times no weeding is attempted as the risk of losing the crop due to adverse climatic conditions is high. Adoption of cultivars with better weed competitive traits like fast canopy closure is a potential tool in minimizing weed competitive effects and is expected to reduce costs on direct weed control methods considerably. Investigations are underway to identify crop cultivars with better weed competitive abilities and higher yield potential under sub-optimal weed management practices. The results revealed that in highly weed-infested rainfed direct seeded uplands, the short duration rice varieties of intermediate stature such as Vandana, Kalinga-III and RR 151-3 were found promising.

The other crop varieties with better weed competitive abilities and higher yield potential identified were : JG-11, JG-16 and JG-315 in case of chickpea and WH-147 and DL-803-3 in wheat.

- A light weight (500g), agronomically efficient, hand weeder has been developed at the CAZRI.
- Weed competitive crop cultivars are potential tool in minimizing weed competitive effects in rice. Vandana, Kalinga 11 and RR 151-3 varieties were found promising.
- An integrated management package has been developed by AICRPWC for successful management of lantana.

Integrated Weed Management in Wet Seeded Rice

Experiments carried out under the All India Coordinated Research Programme on Weed Control have revealed that in wet seeded rice, integrating pre-emergence application of pretilachlor with safener (Sofit) 0.45 kg/ha at 7 DAS + growing *dhaincha* as weed smoother intercrop and mechanical incorporation by cono weeder along with manual weeding on 35 DAS reduced the labour requirement and increased the yield and economics of wet-seeded rice.

SUCCESS STORY

Control of Barnyard Grass Weed in Rice

Weeds are a big constraint in direct seeded rice. Barnyard grass (*Echinochloa* sp.) is a major weed in rice system. Although, many herbicides such as butachlor, anilophos, oxadiazon etc. available for successful control of this weed under transplanted condition, the performance of these herbicides in direct seeded rice is eratic basically due to the fluctuating soil moisture status. Rice production under direct seeded rice is a virtually gamble with weeds. It requires repeated mechanical or manual removal for successful crop production, which many a times is not cost-effective particularly in areas where labour is scarce and expensive.

However, with the introduction of few post-emergence herbicides, which are specific to barnyard grass, it appears that the solution for this weed is round the corner. The demonstrations carried out by the NRCWS in farmer's fields have clearly shown the excellent control of barnyard grass (locally known as *sanwa*) with single post-emergence application of fenoxaprop (Whip Super) at 60 g/ha at 3-4 weeks after sowing. The farmers are so impressed with the performance of the herbicide that there has been a mad rush for the herbicide, which was otherwise not readily available in the local market. Farmers are pleading with the NRCWS for making this herbicide available in sufficient quantity for next year. They are prepared to deposit the money in advance with the pesticide dealers. The herbicide application involves an expenditure of Rs 1500/ha against an amount of Rs 2000-3000/ha for manual removal. According to the farmer's own submission, an estimated 60-80 man-days are required for a single manual weeding in one acre area. Due to peculiar soil type (heavy and sticky) no mechanical weeding is possible. From the response of the farmers, it is expected that there will be a huge demand for herbicide in the coming season.

Swamp morning glory (*Ipomoea carnea*) is one of the most problematic weeds spread across the length and breadth of the country. Though this weed is primarily a weed of non-cropped areas, is occasionally found to migrate rapidly to cultivated areas particularly paddy fields. This weed also causes drainage congestion in streams, rivers, and irrigation channels etc. ultimately leading to flash floods in many areas. Experiments carried out under All India Coordinated Research Programme on Weed Control have revealed that spraying of 2,4-D (2,4-D amine) 1.5 to 2.0 kg /ha, glyphosate (Round Up) at 1.5 kg /ha on actively growing plants/new shoots was very

effective in complete drying of this weed and no re-growth was recorded up to 90 days after application.

Turning waste into wealth

Huge quantity of weed biomass is available in many parts of the country which could be effectively utilized as mulching material as compost. Weeds are an excellent source of nutrients and hence serve as a very good raw material for compost making. The investigations carried out under All India Coordinated Research Programme on Weed Control has shown that the invasive weeds such as *Parthenium hysterophorus, Chromalaena odorata*), *swamp morning glory (Ipomea carnea*), lantana (*Lantana camara*), negro coffee (*Cassia occidentalis* and water hyacinth (*Eichhornia crassipes*) could be effectively used for this purpose. The compost prepared using the weed biomass has been found to be as good as FYM with regard to its nutrient composition. The response of crops has also been found to be as good as that from FYM.

Lantana camara Management in Pasture Land

Lantana (*Lantana camara*) is a noxious exotic weed and threatens the native vegetation and is a great menace in pasture and grassland. An integrated management package has been developed by AICRP-WC center at CSKHPKV, Palampur for its successful management This involves cutting of lantana bushes 5-7 cm above ground in September, spray of glyphosate 0.41 per cent on regenerated bushes in October followed by planting of bamboo, mulberry and improved grasses. The original ecosystem was restored and could be used for grazing by cattle and other livestock. Consequently the milk production increased in the adopted area and also reduced the animals toxicity cases. The productivity of grasses and other useful vegetation increased by 90 per cent. The danger of wild animals in the vicinity of the village was also reduced considerably.

Herbicide Residue Monitoring

Herbicides have come as a useful alternative in weed management. They save labour and enhance productivity. Investigations carried out under All India Coordinated Research Programme on Weed Control for the last several years have revealed that the herbicides applied at recommended doses have not been found in edible parts of many crop plants. Neither it has remained in soil to influence the soil microflora nor the crops grown in rotation. This is because of the fact that herbicides are by and large (compared to insecticides) less toxic in nature (with higher LD_{50} values) and are applied during the very early stages of the crop growth. Due to the longer interval between application and harvesting of the crop, the herbicides get degraded in the plant system with little chance of being accumulated in food, feed, fodder, soil or water.

AGROFORESTRY

Agrisilviculture

Tree crop interaction of *safed siris* (*Albizia procera*) studies indicated that moisture stress causes 30 % reduction in crop yield while canopy caused 4-5% and root competition caused 1.8% reduction in crop yield during *rabi* (mustard) crop. While in *kharif* (blackgram) crop, moisture stress caused 10% effect, share 4% and root invasion 2%.

White silk cotton tree (*Ceiba pentandra*) based agri-silviculture system at Raipur showed that tree height was highest in narrow tree spacing (4x4 m) at the age of seven years. Whereas it gradually decreased with an increase in tree spacing. The maximum height of 8.67 m was recorded in unpruned tree in 4x4 m spacing. While a lowest of 7.24 m height was observed in pruned trees in 4x8 m spacing. DBH was highest in unpruned stands (19.51 cm) and lowest in pruned stands (14.61 cm) at 4x8m spacing. Four varieties of wheat, viz Sujata, Lok-1, Kanchan and GW-173 were intercropped with white silk cotton tree. The grain yield performance due to variety was found in the order to GW-173 (26.97 tonnes/ha) >Sujata (22.42 tonnes/ha) >Kanchan (18.57 tonnes/ha) >Lok-1 (16.42 tonnes/ha).

Effect of pruning of neem trees raised on bunds on biomass yield of sorghum fodder in agrisilviculture system

- Tree-crop interaction of *Alibizia procera* and mustard crop indicated that moisture stress caused 30% reduction in crop yield while canopy 4-5% and root competition 1.8%.
- In chronjee veneer grafting and chip budding were done on plants with more than 2 or 3 year age. Veneer grafting recorded 80.0% success in August and September. While chip budding showed maximum (25%) success in August.
- Growth and biomass production of three species (*Acacia nilotica* var *Cupressiformis, Dalbergia sissoo* and *Hardwickia binata*) revealed that in 11th year *D. sissoo* showed significantly higher survival (95.1%), height (9.2%), dbh (14.9 cm). canopy diameter (5.3m) and pruned biomass (0.79 tonnes/ha).
- Genetic improvement work in progress in neem, sisham and *Anogeissus* spp.
- In plus tree progenies trial of sisham, progenies PT-2 and PT-6 proved their superiority to check for growth characters as well as straightness.
- The investigation are being carried out to develop a comprehensive online database on agroforestry entitled Agroforestry Base containing information on various aspects of agroforestry under four independent modules, namely MPTS, research projects, economic analysis and agroforestry intervention/innovations.
- At Raipur, height of white silk cotton tree was highest under narrow tree spacing.
- In sisham and Indian gooseberry agri-silvi-horti system developed at Faizabad, grain yield of mustard increased with 120, 60 and 40 kg/ha of NPK application.

at Kattupakkam revealed that the protein content was reduced marginally to the extent of 2.8% in the sorghum fodder raised 2 m away from the bole of the neem trees, however, 4 m onwards there was no reduction in the crude protein content. The total ash, which represents the mineral status in the fodder, was highest when the sorghum fodder was raised under the canopy. The fibre quality of the fodder was also not significantly affected under canopy. In the salt-affected soil, the survival percentage of different jojoba clones varies from 45.8 (C-64) to 72.6 (Local) at Hissar. After six months of plantation, maximum height (39.4 cm) was recorded in local clone and diameter was highest in clone 102 (5.47 mm). The yield of barley varied from 0.21 to 0.23 tonne/ha).

Agrihorticulture

- In chironjee in situ veneer grafting and chip budding were done on plants with more than 2 or 3 years age. During the year, 80.0% success was recorded with veneer grafting in the month of August and September. Chip budding showed maximum 25% success in August.
- Studies with four live-fence species/species combinations, viz. (i) two rows of *karaunda* (*Carissa carandas*) (ii) two rows of lantana (*Lantana camara*) (iii) one row of rambas/sisal (*Agave sisilana*) + century plant (*A. americana*) and one row of mehandi (*Lawsonia inermis)* under two method of planting (flat and ridge) were continued during third year. Results showed that the ridge method of planting was found better than flat for survival and growth. The maximum survival of 95.7% was recorded in mehandi followed by agave (92.9%) and *karaunda* (92.8%).

Silvipasture

- Growth and biomass production of three species (*Acacia nilotica* var. *cuppressiformis*, *Dalbergia sissoo* and *Hardwickia binata*) with and without pasture and with and without pruning revealed that in 11th year *D. sissoo* gave significantly higher survival (95.1%), height (9.2 m), dbh (14.9cm), canopy diameter (5.3 m) and pruned biomass (0.79 tonne/ha) but lower understorey forage yield than others. Fifty per cent trees harvested at 10 years age revealed that *Dalbergia sissoo* gave significantly higher dry biomass

Online Computerized Database for Agroforestry System

The present investigations are being carried out with the idea of developing a comprehensive on line database on agroforestry entitled Agroforestry Base containing information on various aspects of agroforestry under four independent modules namely MPTS, research projects, economic analysis and agroforestry intervention/innovations. The database are designed in MS-Acess-2000 and SQL (Standard Query Language), ADP (Active Server Pages), HTML, DHTML have been used for creating the dynamic pages of the database. The software runs on a HTTP Server and serves the request of a client on any computer connected with Internet and having a graphic web browser. The databases has been equipped with interactive web pages to browse information on on-going/complete agroforestry research projects in India, detailed information on multipurpose tree species being used for agroforestry, economic analysis of agroforestry case studies and agroforestry interventions/innovations for specific regions of India. Agroforestry Base has been designed with objective of dissemination of scientific information on agroforestry in India and the major constraint faced during its development was the current lack of information on AF technologies suitable for specific soil and climatic conditions.

Data base of the Indigenous/traditional Agroforestry systems of Kangra and Mandi districts of HP, revealed that in the in foot hills the farmers preference was mainly to grow sisham (*Dalbergia sissoo*), followed by nettle weed (*Celtis australis*), biul (*Grewia optiva*) and *Salix sp*. In midhill, the complete dominance of *Grewia optiva* was clealry seen and other additional tree species were *Ficus sp.*, white mulberry (*Morus alba*) and kachnar (*Bauhinia variegata*). In low mid hills, farmers preference was biul, *Salix* sp and *Albizia chinensis* in descending order of the adoption.

Growth performance of mehandi in the live fence of one row of sisal and one row of mehandi

Sheeps and goats grazing on silvipasture system

of 59.3 tonnes/ha than other two tree species. On the basis of ten years rotation revealed that *Dalbergia* based silvipastoral system produced more than 11 tonnes/ha/year total dry biomass (forage+leaf fodder+fuel wood+timber).

- Studies on growth and biomass production in 3 *Albizia* species (*Albizia amara, A. lebbek and A. procera*) with four pruning intensities (0,25,50 and 75% height from the ground level) during 7th year in natural grassland revealed that *A. procera* gave significantly higher survival (89.1%), tree height (6.2m), dbh (11.1 cm), canopy diameter (3.8 m), dry leaf fodder (1.12 t ha^{-1}) and fuel wood (0.87 t ha^{-1}) than other two tree species. Pruning of trees up to 75% height gave higher forage than other pruning intensities.

Tree Improvement and Silviculture

- Genetic improvement work is being carried out in neem (*Azadirachta indica*), sisham (*Dalbergia sissoo*) and *Anogeissus* spp. In neem Centre has collected 276 accessions from eight states (Uttar Pradesh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Orissa, Rajasthan, Haryana, West Bengal and Gujarat). In these collections, a wide range of variability was observed for 10-seed weight (11.00-33.04g), seed length (0.80-1.90cm), seed width (0.58-0.83 cm), 100-kernel weight (4.43-18.73g), oil content (36.39-52.40%) on kernel basis, seed-kernel ratio, seed colours, seed shape, tree height, tree diameter, fruit ripening period and crown shape. Ten selections were identified in provenances and plus tree progeny trial based on fast growth and high fruit yield. Out of these, Sel-2 and Sel-3 had more azadirachtin A.

Ten selections were identified in provenances and plus tree progeny trial based on fast growth and high fruit yield. Out of these Sel-2 and Sel-3 had more azadirachtin A.

- In plus tree progenies trial of sisham (*Dalbergia sissoo*), progenies PT-2 and PT-6 proved their superiority over check both in cultivated and degraded lands for growth characters as well as for straightness. *Anogeissus latifolia* was considered as a fast growing species as compared to dhawa *A. pendula*. It was also more straight than *A.pendula*. In *A. pendula*, five trees have been identified which have mean annual increment more than 90 cm for tree height and more than 1.50 cm for collar diameter at the age of 7.5 years.
- Study on reproductive biology of *Acacia nilotica* ssp. *indica* revealed that flowering remains from first week of June to the December with peak in July and October. Inflorescence is globose head and each head contain 22 to 40 flowers with mean of 32.2. Majority of flowers are hermaphrodite. Carpel is found absent in 2-3 flowers. Anthesis occurs during night between 00.30-1.30 hrs and all the buds open synchronously. Anther dehiscence occurs in the morning of same day (between 5.00-9.00 hrs). Pollen grains are in the form of compound grain, each containing 12 or 16 pollen grains in multiple of four. Pollen viability is more than 90 per cent.

Variability in pods of *Acacia nilotica* ssp *indica*

- Ten districts of Maharashtra were surveyed to identify genetically improved material of Pongamia. Among 216 collection, 13 tree have been identified as plus trees at Rahuri. The oil content in the selections varied from 27 to 49.8 percent.

Agri-silvi-horti System

In sisham (*Dalbergia sissoo*) and Indian gooseberry (*Emblica officinalis*) agri-silvi-horti system developed at Faizabad, grain yield of three mustard varieties (Kranti-53, NDYR-10, NDYR-4) in rabi increased up to T_3 level of fertilizer application [120 (N) : 60 (P) : 40 (K) kg h^{-1}]. Mustard variety Kranti-53 had maximum seed yield across treatments in open field condition (0.67 tonne/ha) followed by agri-silvi-horti system (0.62 tonne/ha). Mean tree height for sisham and Indian gooseberry in agri-silvi-horti system across treatments for mustard varieties was 8.6 –10.4 m and 4.1-4.3 m, respectively. Similarly, mean values for dbh in case of D.sissoo and E. officinalis were 15.2-19.5 cm and 10.2-11.6 cm, respectively.

Studies on the effect of different treatments of filling material in trenches of CCTs at Rahuri showed the treatment, 5 kg wheat trash + 25 kg FYM as filling material recorded maximum plant height while collar girth was highest in 10 kg wheat trash + 20 kg FYM treatment after 4 years of establishment of different tree species.

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