CONTENTS

SOIL AND WATER CONSERVATION

WEED MANAGEMENT

WATER MANAGEMENT

On-line soil fertility maps of different states and fertilizer recommendation system for targeted yields of crops

Salient features

The soil fertility data on N, P and K index values at district level for the states of Andhra Pradesh, Maharashtra, Chhattisgarh, West Bengal, Haryana, Odisha, Himachal Pradesh, Karnataka, Punjab, Tamil Nadu and Bihar have been developed in MS-Access. From the attribute database, the different thematic layers have been reclassified to generate various thematic maps on N, P and K index values (IVs). The calculated soil-test values were incorporated into the developed fertility maps to prescribe nutrients for targeted yields. This application software was developed to recommend fertilizer doses for the targeted yield at the district level. This system has the facility to input actual soil test values at the farmers' fields to obtain optimum doses of fertilizers. The application is a user-friendly tool. It will aid to the farmer in improving the efficiency (appropriate dose) of fertilizer use to achieve a specific crop yield. The system is explained with the example of Tamil Nadu. The system works as a ready reckonner to give prescription in the form of fertilizer available (eg. Urea, SSP, MOP etc).

Performance results

This decision support system provides real use of fertility maps to the users. It can be used up to field level, if the farmer has the knowledge of his field fertility status and the yield target. It can be further narrowed down to block/village level depending on the availability of information. The experiments conducted at different locations in the states suggest that a considerable amount of fertilizer can be saved, if the fertilizers are prescribed using soil-test values.

Cost of technology

Technology available in public domain (www.iiss.nic.in)

Impact and benefits

- Ensure site specific balanced fertilizers
- Facilitate distribution of fertilizer in the country
- Monitoring soil fertility status

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PUSA Soil-Test Fertilizer Recommendation (STFR) meter

Salient features

Pusa STFR Meter is a low cost, user friendly digital embedded system instrument which is programmed according to type of soil, type of crop and yield based on ICAR research data base. The unique features of this instrument are:

- It can quantitatively estimate as many as five important soil parameters viz.,pH, Electrical conductivity, organic carbon, phosphorus, potassium (sulphur, zinc and boron in pipeline).
- It gives quantitative values, thus is more accurate than other soil-test kits available in the market, which are based on visual colour comparison.
- It is portable, and can be operated both by electricity and battery.
- It is user-friendly and easy to operate with minimum training.
- Unlike other soil test kits, it gives fertilizer recommendations for selected crops using the in-built program.

Performance results

Tested and validated over one year with different soils with minimum 80 % accuracy.

Cost of technology

Maximum ₹30,000 with complete package of soil-testing.

Impact and benefits

In view of the ever-expanding multi-nutrient deficiencies in soils, site specific nutrient management, which is considered as Fertilizer Best Management Practice, needs to be promoted to improve soil health and crop productivity. Inadequate and unreliable soil-testing facilities, poor awareness of farmers about balanced plant nutrition and lack of appropriate policy are the major constraints in adoption of Fertilizer Best Management Practices. It is realized that the soil-testing service has not made the desired impact and farmers have not yet been able to adopt it in large numbers. On the other hand, on-station and on-farm experiments conducted under diverse agro-ecologies across the country established the significance of soil-test based balanced fertilizer use in improving crop yields and nutrient use efficiency. Compared with farmers' fertilizer practice, 20-25% yield gain could be easily obtained with the adoption of soil-test based recommendations, although much greater advantages are also reported depending on soil conditions and crops/cropping systems. The Pusa STFR Meter would increase farmers' access to soil testing, and thus help them to achieve higher yields owing to soil test based fertilizer application.

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Iron (Fe) enrichment in rice, maize and pulses

Salient features

- About 15% Indian soils are deficient in Fe and it is the most common nutritional disorder in human beings affecting at least half of the India's population.
- The fertilization strategies physiological interventions have been developed to enrich the grains with Fe.
- In rice and maize, two sprays of ferrous sulphate @ 0.5% solution at the time of pre- and post-anthesis are sufficient along with basal application of ferrous sulphate @ 50 kg ha^{-1} at planting. In Fe rich soils, only two foliar sprays are enough to enrich the grains with Fe.
- In pulse crops (chick pea and pigeon pea), 25% defoliation or nipping at bud before flowering along with one spray either at flowering or pod formation stage has proved to be effective in enhancing grain Fe concentration.

Performance results

- One foliar spray along with 25% defoliation is best strategy for enhancing Fe content in chick pea (17-25%) while nipping is the best strategy to enhance Fe content in pigeon pea grain (24-32.8%).
- Fe concentration in grains of rice and maize can be increased by 9-23% with the application of ferrous sulphate @ 50 kg ha^{-1} along with two foliar sprays at pre- and post- anthesis.

Cost of technology

- Cost of Fe enrichment varies with crop, the soil types, amount of fertilizer used and method of fertilizer application.
- Manual nipping and defoliation enhances the cost but new machinery may be useful in minimizing labour cost on such intervention. On an average, cost of Fe enrichment varies between ₹1,500 and 3,500/ha.
- Output also varies with crop response to fertilization. On average, output range between ₹7,000 and 20,000/ha.

Impact and benefits

This strategy is considered as a relatively low cost, highly efficient and safer than diet supplementation approaches in prevention of nutritional deficiencies to combat dietary mineral inadequacies in rural areas. Fe bio-fortified products appear to be better sources of potentially bioavailable Fe in comparison with the non-fortified analogues.

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Techniques for correcting zinc (Zn) deficiency

Salient features

- Wide spread Zn deficiency in soils of India (45%) not only causes loss in crops yield but also overlaps with malnutrition in animal and human. It is further hampered by low use efficiency of Zn carriers/ fertilizers (seldom exceeds 5%).
- Zinc, which is associated with many metallo-enzymes in plant can be supplemented in crops through different sources *viz.* zinc sulphate hepta hydrate ($ZnSO_4.7H_2O$), Zn chelates, Zincated urea/ super phosphate, Zinc oxide, Zinc phosphate and Zn enriched organic manures. Among these sources, $ZnSO_4$ is cheapest, easily available and most effective source of Zn in crops.
- Zinc can be supplemented to different crops at different time through any of the following methods (as suitable to the crop).
  Seed Coating: zinc oxide/ Teprosyn-Zn/ zinc phosphate slurry
  Root dipping: zinc oxide/ zinc phosphate
  Basal application : zinc sulphate @ 5.0 kg Zn ha^{-1}
  sufficient for 2-3 crop cycles (rate varied with crops and soils)

or 4-5t FYM+2.5 kg Zn ha^{-1}

or Top dressing : zinc sulphate (if not applied as basal)
Foliar application : 0.5 to 2.0% zinc sulphate (supplement to basal application)

Performance results

- Use of Zn in balanced fertilization improved yield of different crops to a tune of 10-35% depending upon soil types, severity of deficiency, crops etc.
- Application of Zn alone contributes about 25 million tonne of total food grain production. It sustained the productivity over the years.
- The National Food Security Mission has adopted the Zn in fertilization package and provides a subsidy of ₹500 ha^{-1} for Zn fertilizer to each crop.

Cost of technology

Cost of Zn application varies with amount of Zn fertilizer used and labour required. On an average, cost of Zn fertilizer use varies between ₹500 and 2,000 ha^{-1}. Output also varied with crop response to fertilization. On average, output range between ₹1,000 and 20,000ha^{-1}.

Impact and benefits

Application of zinc enchances crop yield and profit by 10-35% and can has the potential to contribute 25 million tonnes of food grain production. Besides, the package has become a part of National Food Security Mission (NFSM).

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Balanced fertilization through sulphur application

Salient features

- About 40% of Indian soils are deficient in S which causes great economic loss in several crops especially, oilseeds and pulses.
- Inclusion of sulphur in balanced NPK fertilization schedule in S deficient soil is based on large number of experiments conducted at farmers' fields at varying S status with different sources, rates and methods of application.
- Sulphur uptake by crops ranged from 5 kg to more than 50 kg S ha^{-1} $year^{-1}$ depending on type of crop, available S at the crops' disposal, availability of other nutrients, growth conditions and cropping intensity.
- Among different sources, single super phosphate, gypsum, phospho-gypsum, ammonium sulphate, bentonite S pastilles were better for rectification of S deficiency. Pyrite, a good source of S should be applied in moist soil through surface broadcast before one month of planting to meet S requirement of the crops.
- Basal application of S sources is beneficial, however, it can be used at 25-30 days crop growth stages in case of oilseeds.
- The recommendations/technology options developed for correction of S deficiency for different crops/ cropping systems are:
- Rice-wheat cropping system : 30 kg S ha^{-1} in each crop
  45 kg S ha^{-1} to rice
- Other cereal based cropping system(s) : 30- 45 kg S ha^{-1}
- Pulse-based cropping system(s) : 35-45 kg S ha^{-1}
- Oilseeds-based cropping system(s) : 45-60 kg S ha^{-1}
- Sugarcane : 80 kg ha^{-1}
- Green gram/Black gram/Lentil : 30 kg S ha^{-1}

Performance results

- More than 40 crops responded to S application in S deficient soils in more than 140 districts of the country.
- The yield advantage due to S application over NPK recorded from 10 to 30% in cereals, 15-40% in pulses and 15-45% in oilseeds. The additional net profit obtained with S application varied from ₹5,000 to ₹39,000 per hectare.
- Long-term experiments showed sustainable yield trend with NPKS fertilization schedule and utilization efficiency of NPK increased with inclusion of S in fertilization schedule.

Cost of technology

Cost of S fertilization varies from ₹700 to 1,500 ha^{-1}.

Impact and benefits

The technology has the scope of improving yield (10-40%) of various crops and enhancing oil content in oil seed crops. It has vast scope of application in more than 140 districts of the country.

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Ameliorating deficiency of Manganese (Mn) in field crops

Salient features

- Manganese deficiency is increasing in rice-wheat systems grown in Indo-gangetic plains having highly permeable coarse textured alkaline soils with low organic matter.
- The principle of any micronutrient including Mn recommendations for different crops and cropping systems is based on its available status in soil, requirements to meet the crops/cropping system and fixation in soil complex and other losses.
- Durum wheat genotypes are more susceptible to Mn deficiency than *aestivum* wheat.
- Manganese (Mn) can be supplied through the sulphate salt of Mn i.e. $MnSO_4$ either through soil or foliar.
- Three to four foliar spray of 0.5-1.0% $MnSO_4$ solution is more efficient and economical for enhancing wheat yield in sandy soils.
- Foliar spray of $MnSO_4$ solution one before and two after first irrigation is effective in mitigating Mn deficiency in crops in Mn-deficient soils.

Performance results

- Different crops and cropping systems, especially wheat performed tremendously with application of Mn in deficient soils.
- Application of Mn enhances the farmers profit by 10-35% depending upon crop type and crop response to Mn fertilization.
- Replenishment of Mn improves the fertility and soil health, and also increases the utilization of other macronutrients, reducing leaching losses and thus helpful in saving environment.

Cost of technology

Cost of Mn application varies with amount of fertilizer used and labour required. Foliar spray enhances labour cost. On average, cost of micronutrient fertilizer use varied between ₹700 and 2,000 ha^{-1}. Output also varies with crop response to fertilization. On average, output ranges between ₹2,500 and 15,000 ha^{-1}.

Impact and benefits

Application of Mn enhances the farmer profit and improve the soil health.

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Bio-enriched compost

Salient features

Bi-enriched Compost

Normal farm compost could be converted into a superior bio-enriched compost by amending with 1% P as rock phosphate along with inoculating *Azospirillum/Azotobacter* and Phosphate Solubilizing Bacteria (PSB) (10^8-10^9 cfu/g) each and subsequently curing for about 20 to 25 days in shade at 25% moisture level. To maintain the moisture, curing materials should be covered with a polythene sheet/gunny bags. Quality improvement of the final product results because of the change of following characteristics over normal farm compost:-

- Stabilization of C:N ratio around 10.0 to12:1
- pH stabilizes around neutral (7 to 7.5)
- CEC of final product increases above 25%
- Microbial carbon increases more than 100 times.
- Viable population of *Azospirillum*/ *Azotobacter* and PSB increases 300-400 times and six times, respectively.

Performance results

- Use of bio-enriched compost @ 1 tonne/ha could minimize the recommended nitrogenous and phosphatic fertilizer to 50% without any yield loss of crops grown in rice- *toria* and rice- wheat sequence.
- Biofertilizers with increased dose of compost @ 2 tonne/ha, more specifically enriched compost could reduce recommended N, P fertilizer up to 75% in subsequent year due to cumulative effects of INM package.

Cost of technology

Preparation of Bio-enriched compost involves modest additional cost of the price of low grade Rock Phosphate and biofertilizer over that of normal compost. Every tonne of Bio-enriched compost requires around 170 kg rock phosphate and 10 kg of *Azospirillum*/ *Azotobacter* and Phosphate Solubilizing Bacteria (PSB) biofertilizer. Considering the cost of Rock Phosphate ₹3/ kg and biofertilizer ₹75/ kg, additional cost for each tonne of Bio-enriched compost preparation is about ₹2,000/ only.

Impact and benefits

Incorporation of enriched compost with subsequent reduction of fertilizers (N, P) showed improved soil health. Huge amount of foreign exchange can be saved for importing chemical fertilzers.

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Technology for preparation of enriched compost

Salient features

- A new technology has been developed to prepare enriched compost using low-grade rock phosphate, waste mica and crop residues.
- For this purpose, a trench or pit is filled layer-wise (5-6 layers).
- Biodegradable organic materials like crop residues, farm wastes, animal feed wastes and tree leaves are spread on the floor of the trench (about 20-cm thick layer).
- A layer of rock phosphate (RP), followed by waste mica is then spread over biodegradable organic material.
- Cattle-dung is made into slurry by adding water, and this is sprinkled over RP and waste-mica layer.
- Layering is repeated till whole compostable materials are added.
- Moisture content is maintained throughout the composting period at 60% of water-holding capacity.
- Periodic turning (monthly interval) is done to provide aeration.
- Composting is continued for 4 months.
- For the preparation of 1 t enriched compost, 1 t biomass (crop residues/ biodegradable wastes, 200 kg low-grade rock phosphate (18-20% P_2O_5), 200 kg waste mica (9-10% K_2O), and 100 kg fresh cattle dung are required.

Performance results

- The enriched compost contains 1.4-1.5% total N, 5.0–6.0% total P_2O_5 and 2.5-3.0% K_2O, respectively. Therefore, addition of one tonne (1,000 kg) of enriched compost will substitute about 14-15 kg of N, 50-60 kg of P_2O_5 and 25-30 kg of K_2O, respectively.

Cost of technology

₹2,00,000

Impact and benefits

Enriched compost would reduce dependence on costly phosphorus and potassium fertilizers. Hence, it will reduce cost of cultivation in one hand and increase income of the farmers on the other. Large quantities of crop residues may be recycled back to the field after converting them into quality manure. Substantial amounts of rock phosphate and waste mica may be recycled in agriculture as a source of phosphorus and potassium and thus lead to the utilization of indigenous mineral resources. Huge amount of foreign exchange can be saved partly or wholly on import of costly P and K fertilizers.

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Phosphate solubilizers
(*Trichoderma* sp. and *Penicillium* sp.)

Salient features

- Phosphorus is considered to be one of the major nutrient elements limiting agricultural production in acidic soils. Phosphate solubilizing fungi (PSF) play an important role in supplementing phosphorus from insoluble phosphate source to the plants.
- Easy multiplication of PSF for application in phosphate deficient soils. It also increases plant growth, induces resistance and control soil borne phytopathogens like *Fusarium*, *Rhizoctonia*, *Sclerotium* and *Sclerotinia*.
- The *Trichoderma* and *Penicillium* based formulations, respectively, have 50-67 and 40-45% phosphate solubilising potential on inorganic insoluble source of phosphate like ferric phosphate and tricalcium phosphate.

Performance results

The technology is cost effective and easy to apply in the acidic soils.

Cost of technology

₹400.0 per ha (or) ₹100 per kg.

Impact and benefits

Adoption of technology leads to enhanced (i) phosphorus availability, (ii) growth promotion and (iii) biological disease management in acidic soils.

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Vermicomposting technology for recycling of organic wastes

Salient features

Vermicomposting is a very effective method of converting wastes into useful manure with the help of earthworms. For vermicomposting, open permanent pits of 102 ft × 32 ft × 22 ft dimensions are made under the shade of a tree at an elevated place, about 2 feet above the ground to avoid entry of rainwater into the pits. Brick walls are constructed above the floor of the pits leaving 5-6 gaps in the pit wall of 10 cm dia to facilitate aeration. These holes are blocked with nylon screen (100 mesh) to prevent escape of earthworms from the pits. 3-4 cm thick layer of partially decomposed dung (about 2-month-old) is spread on the bottom of the pits. A layer of litter/residue and dung in the ratio of 1:1 (w/w) is then added. A second layer of dung is then applied followed by another layer of litter/crop residue in the same ratio up to a height of 2 feet. Two species of epigeic earthworms *viz., Eisenia foetida* and *Perionyx excavatus* are inoculated in the pits or heaps. Watering by sprinkler is done intermittently. Moisture content is maintained at 60-70% throughout the composting period. Jute bags (gunny bags) are spread uniformly on the surface to facilitate maintenance of suitable moisture regime and temperature. The material is allowed to decompose for 15-20 days to stabilize the temperature after the initial thermophilic stage. Earthworms were then inoculated in the pit @ 10 adult earthworms per kg of waste material and a total of 5,000 worms were added to each pit or heap. The materials were allowed to decompose for 110 days. The forest litter decomposes faster (75 to 85 days) than farm residues (110-115 days). In the heap method the waste materials and partially decomposed dung (1:1 w/w) are made out into heaps of 10 feet length × 3 feet width × 2 feet high and during inoculation, channels are made by hand and earthworm @ 1 kg per quintal of waste are inoculated and then watering is done by sprinkling. Pieces of jute cloth are used as covering material.

Performance results

Under organic farming systems, combined application of cattle dung manure (2 t/ha) + Vermicompost (1.5 tonne/ha) and poultry manure (1.5 tonne/ha) + biofertilizer @5kg/ha sustained the productivity of soybean, chick pea and mustard and *isabgol* crops as well as biological health of soil.

Cost of technology

About 3 tonnes of vermicompost can be produced from 10 beds of 10 ft × 3 ft × 2 ft each. The cost of earthworms is ₹400-500 per kg. A 50-kg bag of vermicompost can be sold for ₹150 (₹3,000/tonne). Basically, vermicompost is used like any other manure: ₹5,000 kg/ha in cropping and 1-10 kg/ tree in plantations, depending on the size of tree.

Impact and benefits

This technology is better in terms of faster decomposition of the waste over conventional method. Secondly the nutrient composition of the vermicompost is superior over conventional compost.

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Microbial based bio-nutrient package for rice

Salient features

- Biofertilization in community /consortium mode targeting different niches of rice ecosystem *viz.* enriched mycostraw for rhizosphere, *Azospirillum* for rhizoplane / inside root and cyanobacterial inoculants for surface soil. The component of package include *Pseudomonas* enriched mycostraw, *Azospirillum* and cyanobacteria for different niches.

Content

- Enriched mycostraw (Mycostraw +*Pseudomonas*) - Solid - 2 tonne/ha
- *Azospirillum* inoculant (liquid) 1.0 litre/ha
- Cyanobacteria inoculant (dry mix, tobacco waste based) -1 kg/ha
- New techniques for enrichment of mycostraw with *Pseudomonas* (PGPR)
- Generation of revenue during the raw material /paddy straw processing through mushroom as a byproduct
- A new carrier for cyanobacterial biofertilizers for cyanobacterial grazers (snails) infested fields
- Liquid formulation of *Azospirillum* and new mode of application for transplanted rice plant
- Multi nutrient delivery system through different niche of rice plant
- High titer value of inocula and round the year production
- Indoor production in mushroom hut for mycostraw
- Indoor production in fermentor (*Azospirillum, Pseudomonas*)
- Indoor production in multiplication units in glasshouse / polyhouse in a well defined media (*Cyanobacteria*)
- Revenue generation during processing of raw materials itself
- Quality assurance due to indoor production
- Feasibility of commercialization

Performance results

- Increase in grain yield : 17% (average)
- Increase in fertilizer use deficiency : 5-10%
- Increase in organic carbon : 14-16 %
- Increase in soil total nitrogen : 4-5%
- Increase in soil total phosphorous : 0.7 to 1%

Cost of technology

₹ 450 – 500 ₹/ha

Impact and benefits

- Farmers would save 40 kg nitrogenous fertilizer and 20 kg potash fertilizers from enriched mycostraw/*Azospirillum*/Cyanobacteria
- Enriching and sustaining soil fertility with respect to organic carbon, micronutrient and major nutrients
- Farmers can generate a revenue of ₹1,000.00 from 0.1 acre paddy straw produce in the form of mushroom

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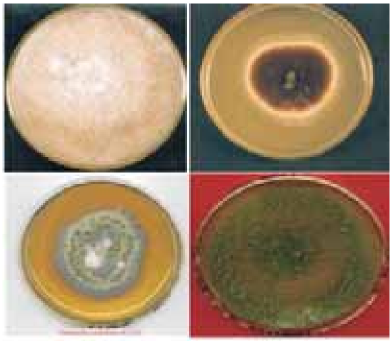
Compost inoculant

Salient features



- Agricultural residues available in India are estimated to be 600 million tones which can be converted into good quality compost through the use of ligno-cellulolytic microorganisms.
- The degraded material can be incorporated in the soil for plant growth promotion as well as to maintain sustainability by improving soil health.
- A consortium of four fungi was developed for composting of crop residues.
- The inoculant titled 'IARI Compost Inoculum' is being commercialized. A packet of 300 g is enough to decompose one ton of organic matter within 90 days.
- Various crop residues may be composted by this inoculant in perforated brick-tanks.
- The crop residues may be supplemented with poultry droppings (8:1) or urea at 0.5% to bring down C: N ratio of the composting mixture.
- Rock phosphate (1%) along with inoculum containing four fungi may be applied at 0.3 kg/tonne of moistened crop residues.

Performance results

By this technique, compost with C: N ratio of 15:1 can be prepared within three months. The use of microbial consortia for bioconversion of biomass into compost reduces the time for decomposition.

Cost of technology

₹2,00,000

Impact and benefits

This compost when applied to soil improves the soil structure and organic carbon content to the soil. It is an important component of integrated nutrient management as well as organic farming.

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Liquid inoculants technology of biofertilizer organisms

Salient features

Influence of liquid Biofertilizers on Redgram crop

- High titre value after the expiry date that will be >10^8 CFU/ml.
- Shlef-life will be >360 days (Carrier based formulations stay only 180 days)
- Less quantity of application 250 ml/acre
- Low levels of contaminants than solid formulations
- Greater colonization in crop rhizosphere
- Wide adoptability across different soil stress conditions (or) agroclimatic conditions because of presence of cell protectants.
- Easy to apply: Directly through spray nozzles to root zone or mixing with organic manure.
- Can be stored under normal room temperature conditions

Liquid biofertilizers inoculum in bottles

Performance results

In case of pulses, this technology could save 50% of fertilizers (RDF). In case of maize, this technology gave 12% higher yields than 100% RDF.

Cost of technology

₹625-750 ₹/ha.

Impact and benefits

It is economical to use liquid inoculant technology as it is a cheap source for mobilizing nutrients compared to chemical fertilizers. It has vast potential for use as farmers are benefited in terms of increased income from the agricultural produce.

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Bacterial inoculant for quality seedling production of apple

Salient features

Multifunctional Plant Growth Promoting Rhizobaceria (PGPR) isolate (*Bacillus licheniformis* CKA1) for Apple

- Bio-fertilizer- Enhances NPK availability in soil and increased uptake of these nutrients in plant.
- Bio-stimulant- IAA production.
- Bio-protectant-Bio-control against *Dematophora necatrix*.

Nursery treatment

Nursery treated seedlings

Performance results

There is 20-25% increase in apple seedling biomass, significant improvement in plant root and shoot parameters, bio-control against white root rot disease.

Cost of technology

For charcoal based seed treatment (200 g of charcoal based culture per kg of seed) followed by seedling dip in liquid biofertilizer(@1 litre/500 seedlings), the total cost of biofertilizer treated seedlings = ₹1,000 per kg of seed

Impact and benefits

PGPR inoculums are eco-friendly inputs and improve soil health.

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Bacterial inoculant for rejuvenation of white root rot infested apple orchard

Salient features

Multifunctional Plant Growth Promoting Rhizobacteria (PGPR) isolate for Apple *Bacillus licheniformis* CKA1.

Biofertilizer- Enhances NPK availability in soil and uptake of these nutrients in plant.

- **Bio-stimulant-**IAA production.
- **Bio-protectant-** Bio-control against *Dematophora necatrix.*

Rejuvenating apple tree in white root rot infested apple orchard

Bacillus licheniformis CKA1 20-35% increase in apple fruit yields

Performance results

There is significant 20-35% increase in apple fruit yields, significant improvement in plant parameters, bio-control against white root rot disease.

Cost of technology

₹80-90/plant (No. of plants in hectare = 1,200 and the inoculums will be applied @1 litre /plant twice (February/March at the end of senescence and July/August at the time of proliferation of fungus) and the cost of 1 litre liquid Bio-fertilizers is ₹40-45/litre)

Impact and benefits

PGPR inoculums are eco-friendly inputs and enhance beneficial soil micro-flora and help control plant diseases.

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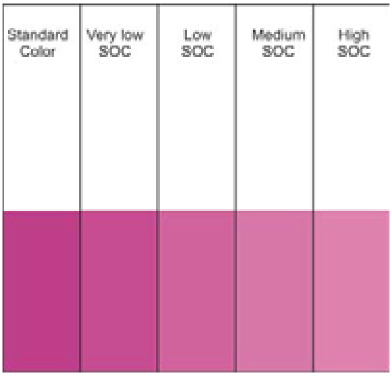
Kit for assessing soil organic-carbon

Salient features

Soil organic carbon (SOC) is a broad indicator of soil fertility. A simple kit has been developed for assessing SOC. The principle of kit is based on colour intensity of $KMnO_4$.



Kit components

- Chemical 'A' Potassium permanganate ($KMnO_4$) 5mM solution in distilled water Liquid 'B' Distilled water, standard colour chart
- Soil is shaken with solution of $KMnO_4$
- Based on decrease in colour intensity of $KMnO_4$ status of soil organic carbon (SOC) is approximated on the basis of standard colour chart

Performance results

Satisfactory distinction between different soil fertility level

Cost of technology

Estimated cost is ₹5 per sample

Impact and benefits

Adoption of technology would lead to resource conservation

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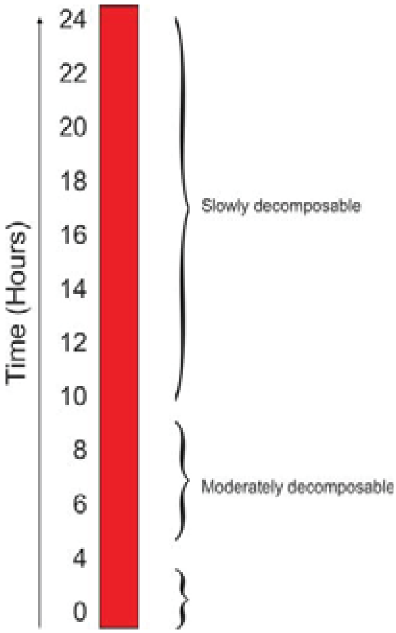
Kit for assessing compostability of farm waste



Salient features

Crop residue that decompose faster can be composted in a shorter period. A simple kit for assessing compostability of farm waste has been developed.

Components of kit

- Reagent "A" Distilled water
- Reagent "B" 2,3,5-Tetrazolium chloride 3% w/v in alcohol
- Reagent B is added in the finely powdered form
- Time taken for development of red colour indicate decomposability of waste
- Early production of more intense red colour indicate easier decomposability

Performance results

Satisfactory distinction between different light-coloured crop residues

Cost of technology

Estimated cost: ₹5 per sample

Impact and benefits

Adoption of technology would lead to resource conservation and resource use optimization

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Integration of reduced tillage and BBF land configuration for better productivity of rainfed cotton

Salient features

The technology is the package of the reduced tillage (one harrowing and intercultural operation with pre-emergence herbicide), followed by Broad Bed and Furrow (BBF) planting of rainfed cotton. The BBF are formed by BBF maker that makes one meter wide bed followed by 50 cm wide furrow of about 15 cm depth. The cotton crop is supplied with recommended dose of fertilizers along with location specific deficient micronutrients.

Performance results

The reduced tillage (one harrowing and intercultural operation with pre-emergence herbicide) followed by Broad Bed and Furrow planting of rainfed cotton applied with recommended dose of fertilizers, provided the rainfed cotton farmers with 32.6 % higher yields of seed cotton when compared to farmers' practice (rainfed cotton cultivation on flat beds with conventional tillage involving one summer ploughing followed by 2-3 harrowing with intercultural operations and application of about 70 % of recommended fertilizer dose).

Cost of technology

The cost of technology is ₹10,933/ha (Kovilpatti, Tamil Nadu) to ₹11,933/ha (Khargone, Madhya Pradesh). The net returns/ benefits to the farmers from the adoption of the technological package were in the range of ₹4,955/ha (Kovilpatti, Tamil Nadu) to ₹18,936/ha (Khargone, Madhya Pradesh) per hectare.

Impact and benefits

The new technology will add to the income of the farmers. The net returns from the package varied from around ₹5,000 (Kovilpatti, Tamil Nadu) to 19,000 per hectare (Khargone, Madhya Pradesh). In addition to it, the technology provided the intangible benefits of improvement in soil health, reduction in the runoff and soil losses, better drainage of excess runoff water from the fields. The reduced tillage in combination with residue incorporation and proper nutrition has yielded equal or higher than intensive tillage, which has reduced the energy requirements on one hand and good economic returns to the farmers on the other.

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Income maximization through participatory INM for soybean-wheat system

Salient features

Nutrient management is a crucial issue with resource poor small farmers. More often there exists a mismatch between the farmers' resources and farmers' practices. Therefore a need was felt for participatory nutrient management at farmers' fields. Seven Integrated nutrient management modules were tested for two years at the institute for their effectiveness *vis a vis* farmers resources. Two best modules are very suitable for upscaling. These are: i) Balanced Fertilization (BF) i.e. 100% Recommended rate of N, P, K, S, Zn to soybean and 100% recommended rate of NPKS to wheat; ii) Integrated Nutrient Management (INM) ie. 50% Recommended rate of NPKS + 5 t FYM/ha +*Rhizobium* to soybean and 75% of Recommended rate of NPKS + PSB to wheat.

Performance results

The INM technology i.e. 50% NPKS+5t FYM+ *Rhizobium* to soybean and 75%NPKS+PSB to wheat produced 24-60% higher soybean – wheat productivity. Similarly balanced fertilization also improved the soybean and wheat yield by 23-30 per cent. The choice between the two technologies depended upon the availability of FYM with the farmers.

Cost of technology

Total cost of INM and balanced fertilizer application was ₹21,621 and ₹ 22,668/ha. However, the net returns were ₹61,240 and ₹60,342/ha respectively. The BC ratio was the highest (2.83) with INM intervention.

Impact and benefits

The technology ensure maximum income to the farmers along with favourable improvements in soil properties.

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Modified System of Rice Intensification (SRI)

Salient features

To maximize grain yield and water saving in rice cultivation, SRI method was modified to make it suitable for eastern India. Optimum spacing, water management practice and N-requirements for SRI method were standardized.

Performance results

The System of Rice Intensification (SRI) with 20 cm x 20 cm saved about 22-35% of water, 14% labour inputs and gave 36-49% higher yield (about 6 t/ha) than conventional transplanted crop.

Cost of the technology

₹25,000 /ha

Impact and benefits

It has potential to enhance rice yield upto 49% with less water than conventional transplanting method. In SRI, only 1,571 litres water was required to produce 1 kg seed, but with conventional method 2,801 litres water was needed for 1 kg seed production. The SRI method also showed reduction in labour inputs by 14% than the conventional transplanting method for various cultural practices.

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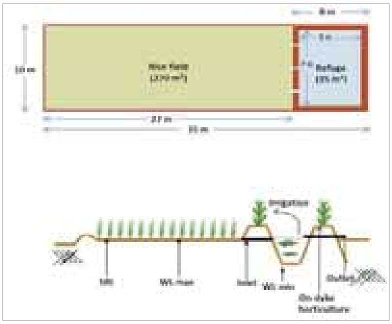
Integrated System of Rice Intensification (SRI)

Salient features

To maximize land and water productivity of rainfed paddy land, 10% of the total rice field was converted into small dugout ponds (refuge) at downstream to harvest rainwater from the field. The stored water in the pond is used for short-duration aquaculture during monsoon and its embankment is used for growing horticultural crops. The conserved rainwater in the pond is used for giving supplemental irrigations to *kharif* paddy and irrigating horticultural crops. To enhance rice productivity, rice was grown by SRI method and rice field was kept without any stagnant water during vegetative stage of crop growth. This technology referred to here as Integrated SRI (ISRI) includes combining SRI methods of rice cultivation and pond/refuge to conserve rainwater for multiple use.



Layout design of integrated system of rice intensification

Performance results

The *kharif* paddy yield increased from 2.89 tonne/ha to 6.16 t/ha with fish yield of 2.6 tonne/ha. The Integrated SRI system has potential to generate net profit of ₹268,600 ha^{-1} in the two years. The net water productivity (NWP) in the Integrated SRI system was enhanced from ₹ 0.31/ m^3 (Conventional rainfed rice) to ₹18.91/ m^3 in economic gain per volume of water.

Cost of the technology

₹136,000/ha

Impact and benefits

This technology has potential to enhance both land and water productivity in rainfed medium lands. The Output Value: Cost of Cultivation ratio indicates that in the Integrated SRI system for an investment of ₹1, one can get a return of ₹2.97, almost three times back, however, in conventional rice system this ratio is 1:1.13.

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Technology of Direct Seeded Rice (DSR)

Salient features

Sowing of rice seeds done directly into field though multi-crop planters or zero till seed –cum-fertilizer drill in dry or optimum moisture conditions. If sown dry, it has to be followed by irrigation.

Seed rate: 20-25 kg per ha

Nutrient management: Basal @200 kg NPK (12:32:16) should be drilled at sowing + 50 kg MOP ha^{-1}. 25 kg zinc sulphate ha^{-1} to be applied at 7–10 days after sowing (DAS). Urea topdressing: 300 kg urea ha^{-1} to be applied in three splits at 50 kg ha^{-1} at early establishment (15-20 DAS) and at 125 kg ha^{-1} each at active tillering (25-30 DAS) and panicle initiation (45-55 DAS).

Water management: Soil moisture should be kept approximately at field capacity for first 20 days followed by irrigation at 7-10 days interval depending upon rainfall, upto around 80-85 days growth. Later on, again the soil moisture should be kept at field capacity up to maturity. Irrigation should be stopped 7-10 days prior to harvest.

Weed management: Pre-emergence application of weedicide viz. Oxadirgyl 90 g ai ha^{-1} or Stomp/ pendimethalin at 1000 g ai ha^{-1} at 2–3 DAS followed by azimsulfuron at 35 g ai ha^{-1} or fenoxaprop with safener + ethoxysulfuron 90 + 18 g ai ha^{-1} as POST at 20–25 DAS. One hand weeding should be done to avoid weed competition.

Performance results

Almost comparable yield can be achieved with puddled transplanted rice particularly in Basmati type fine grain varieties. In case of coarse grain high yielding varieties also, comparable yields can be achieved with proper agronomic management.

Cost of the technology

Savings of around ₹5,000 per hectare can be achieved compared to puddled transplanted conventional methods of cultivation.

Impact and benefits

It eliminates puddling, saves on water (approximately 30%), labour and also improves soil health and system productivity along with financial benefits on account of reduced tillage, savings in labour, water and energy. This method of cultivation is also environment friendly and can be a cushion against impending climatic changes.

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Redgram as contingency crop for delayed onset of monsoon in black cotton soils

Salient features

Generally redgram is grown in *kharif* (June and July) with the onset of monsoon. However, even if the monsoon is delayed redgram can be successfully grown till the end of August without any reduction in the yield in heavy black soils. Majority of soils in Kurnool districts are black cotton soil (70%). Hence, this technology is best suited under such situation.

Performance results

Redgram is the most remunerative (₹59,310 per ha.) crop under delayed sowing conditions in black cotton soil under delayed onset of monsoon.

Cost of technology

Adjustment of sowing and selection of crop is not monetary input. Hence, no additional cost is involved in this intervention.

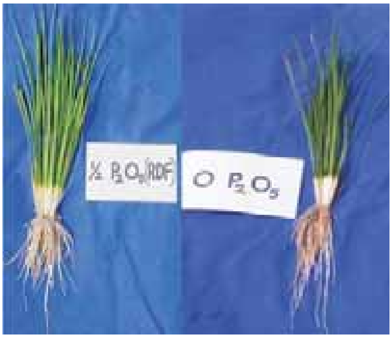
Impact and benefits

Farmer can choose more remunerative crop out of several dryland crops under delayed onset of monsoon.

Withhold phosphorus application for paddy in P rich vertisols

Salient features

Repeated application of P to rice crop in vertisols under K.C. Canal ayacut resulted in the build up of P in the soil leading to imbalance of nutrients and causing Zn deficiency . Without phosphorus, the cost of inputs will be reduced.



Performance results

Grain yield of rice was not influenced by different doses of P where the soil available P is high.

Cost of technology

Amount saved without "P" application is ₹2,784/ha (Recommended dose is 80 kg P_2O_5/ha).

Impact and benefits

There is build up of P in rice growing vertisols due to indiscriminate use of P fertilizers, especially di ammonium phosphate (DAP). Growing of paddy without phosphorus doesnot reduce yield in such soils.

Intercropping of foxtail millet and redgram (5:1)

Salient features

Foxtail millet intercropped with redgram in 5:1 ratio is most profitable and feasible cropping systems. This result was taken to the farmers' fields through Front Line Demonstrations (FLDs) and the farmers are convinced to adopt the system because of substantial increase of the returns with inter cropping system compared to sole crop of foxtail millet.

Performance results

Higher Setaria grain equivalent yields were obtained with foxtail millet + redgram intercropping system (3,384 kg/ha) than sole crop of foxtail millet (2,046 kg/ha).

Cost of technology

₹2500/- per ha

Impact and benefits

Additional cost on inter crop: ₹2,500 per ha. Additional benefit (7 q/ha @ ₹35/kg): ₹24,500. Therefore, net benefit due to intervention is (₹22,000/ha) in addition to returns from sole crop of foxtail millet: ₹24,000/-(Av.20q/ha @ ₹1,200/q).

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Intercropping of autumn sugarcane and potato

Salient features

Sugarcane widely spaced (0.90 to 1.20 m) grow slow initially, long duration and one time income generating crop, provides ample scope for intercropping with potato to generate mid-season income for household nutrition and economic security.

Performance results

Two rows of potato grown between the rows of sugarcane with recommended dose of fertilizers ensures higher productivity and profitability when compared with the farmers' practices (full dose of fertilizers to sugarcane + only nitrogen to the potato). Intercropping of sugarcane + potato (1:2) ensured higher monetary return than farmers' practice. The magnitude of increase in cane yield over farmers' practices was 69 %. The yield of potato under the system was 15 tonne/ha, besides reduces the cost of cultivation by inhibiting the growth of weeds.

Cost of technology

Total cost of cultivation of treatment was ₹30,050 and 24,400/ha under improved and farmers practices, respectively. Total values of product was ₹1,05,680 and 74,720/ha respectively under demonstration and farmers' practices. Net return, from the system was ₹75,630 and ₹5,320/ha, respectively under improved and farmers' practices at prevailing price of input and output at that point of time.

Impact and benefits

Intercropping plays important role in economizing the total cost of cultivation through saving in the cost of preparatory cultivation, irrigation, weed management and interculturing operation. Besides generating mid season income and reduces the risk of total crop failure.

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In-situ green manuring for sustainable productivity in Western Ghat

Salient features

Technology is applicable for rice- rice system in Western Ghat. In this zone, in between two rice crops, space and moisture is available and no other crop can be grown due to excess moisture. After harvesting of *rabi* rice, green manure crop (*Sesbenia*) can be sown and incorporated in the soil after 40-45 days. Technology not only enhanced the productivity but also increased soil organic carbon and physical and biological properties as intangible benefits which help in sustaining productivity. This also helps in supplying additional nitrogen (N).

Performance results

Economics of technology demonstrated at farmers' fields at Pattambi (Kerala)

Items	100% NPK	100% NPK+ 5 mt FYM	50% NPK+ 5mt FYM	100% NPK + *in situ* green manuring	50% NPK + *in situ* green manuring
Cost of the technology in ₹	2,400	12,400	11,200	6,000	4,800
Grain yield kg/ha	3,300	4,200	3,880	4,050	3,750
Return in ₹	39,600	50,400	46,560	48,600	45,000
Net return in ₹	37,200	38,200	35,360	42,600	40,200
Economic advantage over 100% NPK in ₹	-	1,000	1,840	5,400	3,000

Cost of technology

₹3,600 (Green manure seed cost + operation cost for incorporation).

Impact and benefits

The technology has vast scope of replication in rice-rice cropping system of Western Ghat. Besides improving productivity of rice, it also enhance bio-availability of nutrients and saves fertilizers.

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Bio-intensive complementary cropping systems for higher productivity and profitability

Salient features

Bio-intensive system of raising maize for cobs + vegetable cow pea (1:1 ratio) on tractor made broad beds (BB) and *Sesbania* in furrows (F) during *kharif* and mustard in furrows and zero till sown 3 rows of lentil on broad beds in *rabi* while zero till sown 3 rows of green gram on beds in summer (for grain and residue incorporation) is suitable for marginal- and small- farm holders.

Performance results

The system produces the yield of 18.32 t ha^{-1} as rice equivalent with productivity of 50.2 kg grain $ha^{-1}day^{-1}$ and profitability of ₹363 $ha^{-1}day^{-1}$. The complimentary effects could be reflected in the system as in broad bed and furrow (BBF) system, the furrows served as drainage channels during heavy rains in *kharif* which were utilized for *in-situ* green manuring with 35 t ha^{-1} green foliage incorporated after 35 days of sowing and timely sown mustard crop in these furrows resulted a good harvest 1.94 t ha^{-1} and a bonus yield of lentil (1.44 t ha^{-1}) can be harvested. In the summer, green gram could yield 1.05 t ha^{-1} grains while incorporation of green foliage of about 4 t ha^{-1} in the soil further helps the system favourably.

Cost of technology

The cost of cultivation of bio-intensive complementary cropping system ranged from ₹48,000 to 64,500 per ha. The output in terms of rice equivalent yield jumped from 6.7 to 18.3 tonne ha^{-1}.

Impact and benefits

In overall 40% water, 10-20% energy, 30-40% nutrients and 50% pesticide use could be saved on one hand while productivity could be doubled on the other when compared to existing rice-wheat system.

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Integrated farming system model for western plain zone of Uttar Pradesh

Salient features

Integrated Farming System (IFS) approach is an appropriate strategy to improve the livelihood of marginal- and small- holders. IFS model for 1.5 ha comprising of crops (1.04 ha) + dairy animals (2 buffaloes + 1 cow) + horticulture crops (fruits, vegetables and flowers in 0.20 ha) + fishery (composite fish culture in 0.10 ha) + apiary (10 bee boxes) + vermicompost (0.01 ha) + boundary plantations all along the farm boundaries is found to be viable for 7 member family size. All the farm- and animal- wastes and crop residues were recycled in such a way that output of one enterprise was used as input for other and *vice-versa*.

Performance results

The IFS approach enabled to fulfil most of the household needs, sustained production through recycling of farm- wastes and crop residues, provided green fodders and feed concentrates to the dairy animals and green biomass. The bees collected nectar from the flowers of field crops and helped in cross pollination. More than 36% of total annual NPK requirements of crops can be met by recycling/addition of farm and animal wastes, crop residues and intercropping of dual purpose legumes etc. within the system itself. In addition to this, the silt of fish pond can be mixed in to soil once in three years. A total amount of 18.56 kg N, 6.21 kg P and 74.24 kg K was added by excavation of 15 cm deep ground soil surface of 800 m^2 pond area saving an amount of about ₹950. The OC of the soil was as high as 1.20 % with an average value of 0.95. Total manpower requirement for the model is 684 mandays /ha/year. The relative share of different component enterprises included in the IFS model were from Crop (41 %), Dairy (48 %), Horticulture (6 %) followed by Fishery (3.0 %) and Apiary (2 %) respectively.

Cost of technology

Annual Cost ₹197,883; Annual Gross Return ₹362,775; Net returns ₹164,892

Impact and benefits

IFS approach enables to get round the year income and nutritious food (cereals, pulses, oilseeds, sugar, vegetables, fruits, meat and milk) and feed & fodder (round the year green fodders, grains etc.) for human and animals. In addition, an average amount of rupees ranging from ₹46,663 in first four year and ₹77,932 in fifth year can be expected to meet other liabilities of the family. More than 57 per cent of the total cost of production of different farm commodities (₹188,574 per annum) could be met from the inputs (out- put of other enterprise/enterprises) generated within the system itself.

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Nutrient management for organic maize-potato-onion system

Salient features

In India many crop rotations involving maize are feasible. Maize-potato- onion is one of the important cropping systems under assured irrigation. The organic nutrient management packages for the system on holistic approach includes combinations of bulky organic manures like farmyard manure, the non-edible oilcake like neemcake, enriched organic manures like vermicompost and biofertilizers in various combinations. Application of one-third of FYM, one-third of vermicompost and one- third of neem oil cake along with rock phosphate and PSB can result into 32.2 t ha^{-1} maize equivalent yield besides increasing soil organic carbon, available N and P to the tune of 37.5, 92.7 and 203.6 % respectively over initial status.

Performance results

Maize equivalent yield of 32.2 tonne ha^{-1} can be obtained with organic package consisting of 33 % N application through FYM, 33 % N application through vermicompost and 33 % N application through neem- oilcake plus rock phosphate plus phosphatic biofertilizers.

Cost of technology

Organic nutrient management packages is based on the practice of the recycling on farm produced organic resources like crop residue, animal waste, green manuring.

Impact and benefits

Organically grown maize, potato and onion fetch higher profit to the farmers besides improving the soil- health in the long run. Soil organic carbon, available N and P increased by 37.5, 92.7 and 203.6 % respectively over initial status. Organic nutrient management package also improved the soil microbial diversity and also quality of the produce.

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Package of practices for organic production of crops in cropping system

Salient features

Package of practices for organic production of cropping systems have been developed under Network Project on Organic Farming. The systems which was giving consistently (6 years) higher net returns (>20 %) over inorganic farming are identified for the following five agro climatic zones.

View of Organic Farming Experiments

Cropping systems for organic production

(i) Western Himalayan zone : Cauliflower-radish-tomato and cabbage-radish- capsicum for Himachal Pradesh, rice-wheat-*Sesbania* and rice-pea (vegetable)- *Sesbania* for Uttarakhand

(ii) Eastern Himalayan zone: Rice-carrot for Meghalaya

(iii) Transgangetic Plains zone: Maize-gram, maize –potato- summer moong, rice-wheat- summer moong and maize-berseem – maize+cowpea in Punjab

(iv) Central Plateau and Hills zone: Rice-wheat-berseem for Madhya Pradesh

(v) Southern Plateau and Hills zone: Chilli- onion and turmeric +onion for Tamil Nadu and groundnut-sorghum for Karnataka

Salient technical features

(i) Western Himalayan zone: 50 % of recommended dose of N through reinforced farmyard manure + 50 % of recommended dose of N through vermicompost + spray of aqueous leaf extract of *bhang* (*Cannabis sativa*) for pest management in Himachal Pradesh, 25 % of recommended dose of N each of through enriched compost + vermicompost + non- edible oilcakes + farmyard manure + stale seed bed + 2 hand hoeing at 20 and 40 days after sowing for weed management in Uttarakhand.

(ii) Eastern Himalayan zone: 33 % of recommended dose of N through farmyard manure + 33 % of recommended dose of N through vermicompost + 33 % of recommended dose of N through local compost + spray of *karanji* @ 3 ml / lit for pest and disease management + mulching with fresh eupatorium/ ambrosia alone or with one hand weeding for weed management in Meghalaya.

(iii) Transgangetic Plains zone: 33 % of recommended dose of N through green manure + 33 % of recommended dose of N through farmyard manure + 33 % of recommended dose of N through vermicompost during *kharif* and 33 % of recommended dose of N through farmyard manure + 33 % of recommended dose of N through vermicompost + 33 % of recommended dose of N through crop residue during *rabi* + seed treatment with neem-cake + 2 sprays of *Trichoderma harzianum* for pest management in Punjab.

(iv) Central Plateau and Hills zone: 50 % of recommended dose of N through farmyard manure + 50 % of recommended dose of N through neemcake in cereals and 33 % of recommended dose of N through farmyard manure + 33 % of recommended dose of N through neem-cake + 33 % of recommended dose of N through vermicompost to berseem + soil application of *Pseudomonas fluorescence* + two sprays of neem extract for pest management + combination of two hand weeding along with mechanical weeding for weed control in Madhya Pradesh.

(v) Southern Plateau and Hills zone: 50 % of recommended dose of N through farmyard manure + 50 % of recommended dose of N through non edible oilcakes + neem + *mahua* cake + *Trichogramma* + neem spray + bird perches for pest and disease management + using of mechanical weeder + one hand weeding for weed management in Tamil Nadu and 33 % of recommended dose of N through enriched compost + 33 % of recommended dose of N through vermicompost + 33 % of recommended dose of N through green leaf manure + *Verticillium lecani* + eco-neem + neem seed kernal extract + botanicals for pest management in Karnataka.

Principles of successful adoption, recommendation to different agro climatic regions and improvement over existing systems

The package for organic production of crops has been evolved over the period of six years of experimentation under various agro-climatic conditions. The cropping systems and packages recommended are specific to the particular agro-climatic zone. New packages of input identified for organic production of systems are found to enhance net returns by more than 20 % and organic carbon by 10-15 % over the conventional practice of chemical farming.

Eco-friendliness of the technology

Organic farming package identified for different regions does not include any chemical input for management of pest and diseases. Hence, these packages are highly suitable to environment.

Performance results

All the practices recommended for the different agro climatic regions have recorded more than 20 % increase in net returns and 10-15 % increase in organic carbon over conventional practice. Net returns ranged from ₹25,888 to as high as ₹64,310 ha^{-1} in various agro-climatic regions according to the cropping systems and their premium price received by the organic products.

Cost of technology

ACZ	Cost of Package (₹/ha)	Output (₹/ha) (Gross returns)	Net returns (₹/ha)
Himachal Pradesh	102,117	179,657	77,540
Uttarakhand	35,158	45,413	10,255
Punjab	60,144	149,667	89,523
Madhya Pradesh	48,478	151,290	102,812
Tamil Nadu	44,924	79,384	34,460
Karnataka	15,804	41,590	25,786

Impact and benefits

The new package identified for each agro-climatic zone are expected increase the net returns of the farmers by at least 20 % by way of reducing the cost of production. Moreover, the timely availability of adequate chemical fertilizer is a national issue which can be addressed through the newly developed packages of organic farming in the cropping system mode. The packages of organic production in all the zones identified are relying on the natural process of pest and disease management, thus reducing the cost on account of pesticides and herbicides. In addition, the package is having the innumerable benefits on environment in general and society in particular as production of organic products is having its own advantages.

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Conservation agriculture for improving productivity and profitability of wheat in rice-wheat cropping system

Salient features

Conservation agriculture aims to produce with minimum disturbance to soil and environment. The machineries such as bed planter, zero-till drill, strip-till drill and rotary-till drill can be used in wheat for resource conservation in terms of better benefit: cost ratio, energy output: input ratio, water use and management of *Phalaris minor*.

Performance results

Zero, strip and rotary till drills and bed planter provided higher wheat yields (2-12%), net returns (7-18%), cost effectiveness (9-14%) and energy efficiency (20-29%); required lower specific energy (16-21%) and specific cost (4-6%); and reduced *Phalaris minor* (56-79%), other weeds (66-79%), when compared with conventional sowing of wheat.

Cost of technology

The cost of sowing by these machines ranged from ₹1,200 to 1,800/- than ₹6,000 in conventional sowing.

Impact and benefits

The rotary, strip and zero till drilling and bed planting were time saving (78, 77, 83 and 75%), labour saving (76, 73, 78 and 70%), diesel saving (65, 84, 86 and 86%), cost saving (71, 78, 82 and 77%), energy saving (65, 84, 87 and 86%) and also irrigation water saving (10, 10, 11.0 and 35%) when compared with conventional sowing of wheat. Also, there was saving of about 20-25% in seed and fertilizer inputs in bed planting compared to conventional sowing. Net saving of ₹4,200-4,800 on account of wheat sowing.

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Broad Bed and Furrow (BBF) land management with maize+pigeon pea in maize–chick pea cropping systems in Vertisols

Salient features


Luxurious growth of maize crop on BBF

The BBF system consists of semi-permanent broad beds of approximately 100 cm wide, separated by furrow of about 50 cm wide. The BBFs are to be made along a key line keeping a rolling slope of 0.4-0.7% for safe drainage of excess water. BBF are made with a tractor drawn BBF former. On BBF, sole maize or intercropping of pigeon pea with maize crop in rainy season and chick pea in the winter can be grown with application of recommended doses of fertilizer and farmyard manure @ 5 tonne/ha. Two rows of maize at 60 cm interval or two rows of maize intercropped with one row of pigeon pea could be sown on a bed and four rows of chickpea at an interval of 30 cm could be grown on a bed in winter. The BBF system is particularly suitable for the Vertisols. The technique works best on deep black soils in areas with intense rainfall averaging 750 mm or more per annum.

Performance results

The BBF system reduced the runoff (20-24%) and consequent soil losses (30-45%) from the Vertisols. It increased the amount of water that infiltrates in the profile by increasing the opportunity time of water to infiltrate and also increases storage of water in the profile for their use by crops during the dry spell. When rainfall is very heavy, the furrows safely carry runoff water away without causing excess soil loss and drain the excess water to the water harvesting ponds which is used for irrigating chickpea during the winter season. BBF also makes heavy soils more workable by improving drainage and extending the opportunity time for infiltration. The package gave a yield advantage of 20-25% on soybean-equivalent weight basis over soybean-chickpea system grown on traditional flat on grade system.

Cost of technology

Only the additional cost of the BBF maker and tropiculter (in lieu of seed drill) each costing ₹50,000 is involved for adoption of this technology, which is a one-time investment for a span of around 10 years.

Impact and benefits

The technological package gives a yield advantage of 20-25% over traditional flat on grade system. This will add to the income of a farmer proportionally. Other intangible benefits of the technology include the reduction in the runoff (20-24%) and reduction of soil loss by 30-35% in comparisons to conventional system of flat on grade sowing of *kharif* crops in Vertisols of central India.

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Mechanical harvest borne residue management

Salient features

Mechanical harvesting of wheat by using combine harvester leaves behind almost all the crop residue *in-situ*. The residue so left in the field cannot be utilized for any of the traditional uses, the common practice in vogue is to burn the residues in the field itself to facilitate easy land preparation for the succeeding *kharif* crop. The field burning of crop residues is undoubtedly a wasteful practice as it results in loss of valuable organic matter, and associated nutrients. Soil microbial population in surface layer may also get affected. A suitable alternative residue management strategy has been developed at the Indian Institute of Soil Science, Bhopal through years of experimentation. The technology of crop residue management involves soil incorporation of wheat residue plus N supplementation through FYM@ 28 kg N ha^{-1} (approx. 4 t FYM ha^{-1}) along with 25 kg P ha^{-1} for rainfed soybean and 68 kg N + 30 kg P ha^{-1} for irrigated (1+ 2 irrigations) wheat is more effective and profitable.

Performance results

- Wheat residue incorporation or retention coupled with application of 28 kg N ha^{-1} through fertilizer or organic manures is more beneficial than burning in terms of enhanced crop productivity and soil fertility.
- Wheat residue incorporation resulted in 20–22% higher yields in soybean and 15-25% in wheat as compared to residue burning.
- Compared to residue burning, the residue incorporation or surface retention caused a marked improvement in the soil organic carbon content. Irrespective of residue management option, the N supply through organic sources led to an appreciable increase in soil organic carbon.
- Available P and K status of soil improved with residue incorporation and residue surface retention. Further, the residue incorporation/ retention improved soil physical health in terms of a decrease in soil bulk density and an increase in the percentage water-stable aggregates and mean weight diameter.

Cost of technology

Residue Management Option	Additional cost over burning — (₹ha^{-1}) —
Burning	-
Incorporation	340
Surface Retention	1,320

Impact and benefits

The technology generated resulted an additional advantage of ₹4,992 per hectare over the residue burning. Apart from it there is incorporation of organic carbon to soil that helps restore the soil health.

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Makhana (Euryale ferox) cultivation in cropping system mode

Salient features

- *Makhana* is generally cultivated in stagnant waterbodies. However, it could be successfully grown in the agricultural fields at a shallow water depth of 40-45 cm. Besides *makhana*, main food crops like paddy and wheat and forage crop-Barseem could be cultivated in the same field during the year.
- On average, 4-5 months are sufficient for *makhana* cultivation and other crops could be cultivated during rest of the months.

Performance results

- In general, *makhana* is transplanted in the second week of April and harvested by the second week of August. Thereafter, short duration varieties of rice are cultivated in the same field. Wheat is sown by mid December and harvested by the second week of April, and the field is prepared for the subsequent crop of *makhana*. Hence, cultivation of three crops per year is possible from the same field.
- *Makhana* based different cropping system include: *makhana*-Water chestnut; *makhana*-barseem; *makhana*-rice; and *makhana*-rice-wheat.

Cost of technology

- *Makhana,* followed by water chestnut- ₹56,000 per ha; *makhana,* followed by barseem- ₹47,500 per ha, and *makhana,* followed by rice and wheat ₹77,000 per ha.

Impact and benefits

- The technology is suitable for replication in 1.1 million ha of waterlogged areas.
- The net monetary gain in case of *makhana*, followed by water chestnut is estimated to be ₹88,790 per ha. *makhana*, followed by barseem could result in the monetary gain of ₹98,465 per ha. In case of *makhana,* followed by rice and wheat cultivation, the net monetary gain could be ₹122,570 per ha.
- *Makhana* is commercially cultivated mainly in north Bihar, however, with assured irrigation, its cultivation in possible in other areas as well.

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Integration of *makhana (Euryale ferox)* with fish and water chestnut *(Trapa bispinosha)* for higher productivity

Salient feature

- Water productivity is low when *makhana* alone is grown in stagnant waterbodies.
- *Makhana* + fish + water chestnut can be integrated in the ponds for generating the additional revenue and maximizing the profit.

Performance results

- Transplanting and gap filling of *makhana* to maintain the plant population of 10,000 per ha of waterbody.
- Making of refuge area (10% of the total waterbody) at the centre for fish rearing.
- Integration of fish fingerlings (5,000 nos. per ha) of different carp species (Rohu, Catla, Common carp and Mrigal) in the ratio of 40 : 20 : 20 : 20, respectively in March-April and again in September.
- Harvesting of fishes in December-January before the emergence of *makhana* crop and in September after the harvest of *makhana*· Cultivation of water chestnut (10,000 plants per ha) as tertiary crop during the months of October-November.

Cost of technology

₹16,500 per ha excluding the cost of waterbodies.

Impact and benefits

- The integration of fish and water chestnut with *makhana* can exhibit fish yield of 0.18 to 0.4 tonne/ha, *makhana* seed yield as 1.06 to 2.06 tonne/ha and water chestnut yield of 3.08 to 8.8 tonne/ha, respectively.
- *Makhana* as a primary crop provide a net profit of ₹20,000 per ha with an employment generation of 240 mandays/ha/yr. Fish, a secondary crop, could result into additional net income of ₹11,800 per ha with an employment generation of 24 mandays/ha/yr. Likewise, water chestnut as tertiary crop generate net income of ₹13,400/ha with an employment generation of 83 man-days/ha/yr.

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Integrated Farming System (IFS) Model for irrigated midland/uplands (one acre model)

Silent feature

- More than 80% farmers in the Eastern region have small and scattered landholdings. To address the issue of food and nutritional security of marginal farmers IFS mode of food production model has been developed integrating goat, poultry, mushroom, and vermicompost with food crops like rice-wheat, rice-maize, rice-lentil and rice-mustard, and vegetables like cowpea-okra-tomato, okra-pea-cabbage and cucurbits-cauliflower-onion.

Performance results

- An additional employment of 60 mandays over traditional farming could be generated.
- Through recycling of within farm renewable resources, 2.20 tonnes of vermicompost could also be produced. Integration of goat (22 nos.) provide 4.5 tonnes of manure. Similarly, poultry farming (700 birds) contribute 2.0 tonnes of manure. All these sources of nutrients are equivalent to 224.6 kg of urea, 481.3 kg of SSP and 106.3 kg of MoP application.

Cost of technology

- Establishment Cost: ₹96,000 per acre
- Recurring expenditure/year: ₹170,500 per acre

Impact and benefits

The net monetary return for ₹142,000 per acre of land could be achieved in IFS mode of food production system.

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Multi-tier horticulture land use model for rainfed upland ecosystem of Eastern Hills and Plateau Region

Salient feature

Long gestation period (5-6 years) and low productivity (5-6 tonne/ha paddy equivalent yield) of traditional fruit orchards is the major constraint in Eastern Hills and Plateau region. Hence the technology of multi-tier horticulture comprises of planting of fruit trees with large canopies (mango, litchi, aonla, jackfruit) at a spacing of 10 m × 10 m as main crop, planting of precocious bearing fruit species with dwarf canopy (guava, custard apple, lime, lemon) at a spacing of 5 m × 5 m between rows and between plants in the same field as filler crop, and growing of intercrops in the interspace.

Performance results

- The system accommodates 100 large-sized trees and 300 small-sized trees per ha. During the initial years, even the light demanding species could be grown. However, once the main crop attains full canopy size, the filler plants can be removed and only shade tolerant inter-crops like turmeric, ginger, elephant foot yam are cultivated.
- A productivity level of 12.0 tonne/ha of paddy equivalent yield can be obtained following multi-tier system compared to 4.0 tonne/ha under traditional orchard.

Cost of technology

- Mango-based multi-tier model would need ₹420,000 per ha till 12 years of age.
- In case of litchi, the establishment and maintenance cost till 12 years would be ₹575,000.
- For *aonla*-based multitier model, the establishment and aftercare cost would be ₹290,000 for 12 years.

Impact and benefits

- Suitable for upland ecosystem of Jharkhand, Chhattisgarh, Odisha and Bihar.

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Bench terracing for soil and water conservation measures in the Nilgiris

Salient features

Inward sloping bench terracing is recommended for cultivation on lands with slopes ranging from 10 to 33%. The specifications include 2.5% inward slope and 1% longitudinal gradient for the benches and 0.5:1 or 1:1 slope for the risers.

Inward sloping terraces are very suitable for high rainfall areas with deep permeable soils of the Nilgiris. It can also be applied in similar areas of the Western Ghats in Kerala, Karnataka, Goa and Maharashtra where high rainfall and steep slopes prevail and crops requiring proper drainage are cultivated.

When inward sloping bench terraces are adopted, excess runoff is kept towards the hill rather than on valley side and therefore it can be safely disposed with minimum soil loss.

Improper bench terraces

Inward sloping bench terraces

Performance results

Bench terracing with inward sloping resulted in reduction in soil loss and runoff ranged from 44.3 to 71.2 %, and from 21.3 to 63.8 %, respectively. Increase in the yield of potato ranged between 57.1 and 103 % where terrace renovation (to inward sloping terraces) was carried out. Increase in the yield of crops like potato, carrot and broccoli ranged from 66.0 to 84 % on new inward sloping terraces when compared with that obtained on sloping land.

Cost of technology

Cost will vary with the original land slope (10 to 33 %), vertical interval adopted (1.0 to 2.0 m) and riser slope adopted (0.5:1 or 1:1). For a land slope of 20% and vertical interval of 1.6 m and riser slope of 0.5:1, the cost of terracing per ha works out to ₹90,405 at the earthwork rate of ₹45/m^3.

Impact and benefits

Due to the reduction in runoff and soil loss and better conservation of moisture, soil health is maintained. Under such conditions higher crop yield can be realized with subsequent increase in the income of farmers who opt for this technology.

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Bio-fencing technology for the Vertisols of semi-arid region

Salient features

Methodology of bio-fencing

During summer the bunds may be cleaned and kept free of weeds with a trench (20 cm × 30 cm) on outer side. If field bunds do not exist, the soil excavated from the trench may be used to form ridge or bund. Immediately after the onset of monsoon rains either during June or September, planting of bio-fence species is to be taken up. Holes of 6 inches (15 cm) on the ridge or field bunds may be made at a spacing of 50 cm × 50 cm in two staggered rows for planting/seeding of the bio-fence material. *Agave sisilana* and *Euphorbia tirucalli* are the most suitable bio-fence species that may be used as planting materials in arid to semi-arid regions in black and red soils.

Glyricidia maculata may also be used as a bio-fence species as it protects crops from animal and human interference, reduces runoff and soil loss and it is also used as green manure to improve soil properties. Application of 1 kg FYM and 200 g of DAP per running meter is recommended for the bio-fence plants at the time of establishment.

Bio-fencing in the semi-arid regions has a scope for preventing the trespass of human and animals, soil and water conservation.

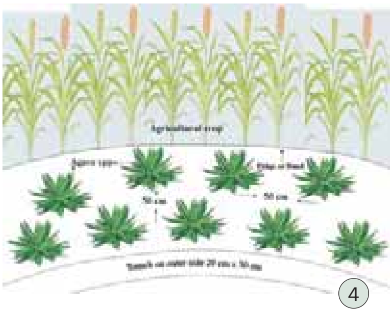
1. *Agave* spp. with winter sorghum 2. *Euphorbia tirucalli*

Agave spp. in farmers' fields

Performance results

Production/Output

Yield and bio-products of live-fence can be used directly by the farmers and has a market value. Pruning of *Euphorbia tirucalli* and *Gliricidia maculata* at 1.5 m height and incorporation of pruned biomass improved the soil fertility. The fibre that is extracted from leaves of *Agave sisilana* is used for making ropes. The yield of fibre is 5 kg per running metre that fetches an additional annual income of ₹20 per metre.



Planting technique in Bio-Fence

Crop yield improvements with bio-fencing in Vertisols of Karnataka

Grain yield of sorghum (2- 4 m away from bio-fence) was higher by 6%, i.e., 11.5 q ha^{-1} as compared to near the bio-fence (< 2m) species (10.9 q ha^{-1}) indicating that bio-fence and crop compete for water and nutrients. The yield of winter sorghum was higher by 26% and 20% when planted with *Agave sisilana* and *Euphorbia tirucalli,* respectively over control (without bio-fence), while bengal gram grain yield was higher by 27% and 20% when planted with *Agave sisilana* and *Euphorbia tirucalli,* respectively over control.

Runoff and soil loss

Ridge planting reduced runoff by 57% and soil loss by 87% over flat planting. Planting *Agave sisilana* and *Euphorbia tirucalli* reduced the runoff by 56% and 58%, soil loss by 73% and 75%, respectively over control.

Cost of technology

The highest cost of bio-fencing is for *Agave sisilana* (₹20.00 per running meter) while the least cost of bio-fencing is for *Euphorbia tirucalli* ₹14.00 per running meter; Table 1.

The rate of bio-fencing is based on the rate of March 2008.

The economics of all the 4 species of bio-fence along with NPV, (benefit cost ratio) BCR and pay back period (PCB) are presented in Table 2.

The rates of bio-fencing is based on the rate of March 2008.

Table 1. Cost of bio-fencing (₹/running meter)

Species	Cost of establish-ment	Cost of mainte-nance	Total
Agave sisilana	15.50	4.50	20.00
Euphorbia tirucalli	10.50	3.50	14.00
Ipomoea cornea	10.80	3.70	14.50
Glricidia maculata	11.00	3.80	14.80
Cassia siamea	10.80	3.80	14.60
Jatropha curcas	11.00	3.90	14.90

Table 2. Economic analysis of bio-fence species (per ha)

Particulars	*Agave sisilana*	*Euphorbia tirucalli*	*Gliricidia maculata*	*Cassia siamea*
NPV (₹)	34,662	9,779	11,295	17,521
BCR	2.38	1.26	1.61	1.96
PBP (Yrs.)	5	9	6	6

Impact and benefits

The technology of bio-fencing with ridge planting established the bio-fence species quickly and reduced runoff and soil loss over flat planting with prevention of trespass by human beings and animals. *Agave sisilana* and *Euphorbia tirucalli* are the best bio-fence species under Bellary conditions with *Agave sisilana* being more promising. Thus, bio-fencing has a vast scope for preventing trespassing and measure of soil and water conservation in semi-arid regions.

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Conservation ditching for efficient resource conservation and enhanced productivity of semi-arid Vertisols

Salient features

Vertisols in the semi-arid region receive low rainfall (<750 mm/year) but storms of high intensity are common (32 to 120 mm/ha) leading to sheet erosion and high runoff. Conservation ditches can store runoff water at field level. Conservation ditch is a shallow trapezoidal dugout, laid on contour with vertical interval 0.6 to 1.0m.

Field slope (%)	Horizontal spacing (m)
0.5 – 1.5	50-60
1.5 – 2.5	40-50
2.5 – 3.0	35-40

a. ***Design depth***: 0.6 to 0.9 m based on the storage volume and soil depth (d)
   Bottom width: 0.6 to 0.9 m. 0.6 m is convenient for construction

b. ***Side slopes***: Upstream slope is 5:1 and downstream is 1.5:1

c. ***Common size and C/S***=0.5 × (Top width + bottom width) × Depth
   1.= 0.5 × (4.57+0.6) × 0.6= 1.57 m^2

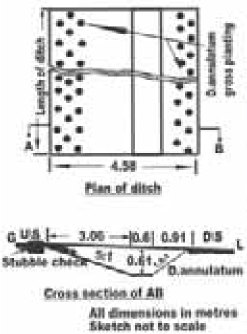
d. ***Design capacity :*** 1.57 m^3 per running meter of ditch

e. ***Length of ditch:*** 30 to 300 m long ditch is constructed in length segments of 100 m with 4 to 5 m length left unditched in between for free passage. In case of series of ditches, the unditched stretches (4 to 5 m) should be staggered for effective erosion control

(i) ***Bottom level (bed slope):*** The bed slope of the ditch must be maintained at constant level throughout. In valley portions, a small embankment is to be raised suitably to maintain the depth of storage constant

(j) ***Dimensions and a view of conservation ditch***

It reduces the runoff velocity and reduces soil erosion on the downstream of



the ditch. Sufficient volume of rainwater is harvested in the ditch, could be manually lifted and applied to the downstream area to augment the soil profile moisture and stabilize yields of dryland crops. Suitable in deep black soils with low infiltration rates (<1 mm hr^{-1}) receiving low annual rainfall (< 750 mm).

Performance results

After every ditch-filling rainfall, the water stays for about a week to 10 days. Traditional low-lift and low-cost hand operated lifting devices; swing basket and Archimedean screw can be used for lifting the water. The water is available for irrigation at different stages of crop growth and also for pre-sowing irrigation. Horticulture or agro-horticulture system is to be preferred in the downstream area as more area (about 40% of catchment area) could be irrigated from ditch. Shrubby frint plants like lemon and custard apple can be planted in the downstream portion of ditch. The system is sustainable with low-cost operation and maintenance along with additional benefits.

Cost of technology

The cost of technology is ₹4,914/- for 37 m running length (2012 prices)

Impact and benefits

Supplemental irrigation facilitates additional yields of 650 to 850 kg ha^{-1} in sorghum and 298 kg ha^{-1} in safflower, which is 35-48% higher over unirrigated condition. Yields of about 6 q ha^{-1} of *moong* grain can be realized in *kharif* which otherwise is left as fallow and is additional income to farmer. It provides additional net income of ₹7,346/ha. The benefit cost ratio (B:C) works out to 2.3 at 10% interest rate considering a life span of 15 years.

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Contour furrows for medium deep black soils of south-eastern Rajasthan

Salient features

Contour furrow (CF) is a suitable conservation measure for facilitating *in-situ* rainwater conservation as well as drainage during consecutive rainfall events. Contour furrows are small ditches laid out on the contour at pre specified spacing across the natural slope of the land.

Spacing: The 6-15 m horizontal spacing based on the land slope and spacing of cropping systems.

Design specifications of Contour Furrows (CF)

i. Shape of ditch: Trapezoidal

ii. Depth: 20-30cm

iii. Bottom width: 20-30cm

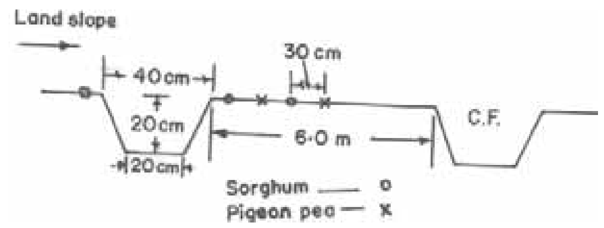
iv. Top width: 40-50cm

v. Cross sectional area: 0.06-0.12m^2

vi. Runoff storage capacity/m: 0.06-0.12m^3

vii. Length: Depend on width of land across the slope and spacing of the ditch. For 6 m horizontal spacing, the total length of the CF would be 1,600 m in one hectare area.

Construction



A cross section of contour furrow for sorghum and pigeon pea intercropping (1:1)

1. Immediately after sowing of crop 40-50 cm wide and 20-30 cm deep furrow is constructed with a single-blade furrow plough or similar equipment. The excavated soil is pushed towards both sides of furrow to avoid any stagnation of water above the furrows.
2. The contours furrows are reopened every year after *kharif* sowing and ploughed after crop harvest.

Technical features

- For sorghum and pigeon pea intercropping(1:1), crops are sown in alternate lines, 30 cm apart, so that distance between 2 sorghum and 2 pigeon pea lines remains 60 cm.
- After every five rows of sorghum, pigeon pea row is skipped to accommodate a contour furrow between two rows of sorghum.

Performance results

- The furrows create additional surface storage capacity of 11.25 mm/ha for promoting in-situ moisture conservation.
- Runoff reduced by about 22% and soil loss by 1.4 tonne/ha/yr.
- Contour furrows improved crop yield by about 30% when compared with to without contour furrow field in sorghum + pigeon pea intercropping system.

Cost of technology

Total cost of cultivation of sorghum + pigeon pea (2:1) intercropping with contour furrows at 6 m spacing comes to ₹16,750/ha.

Impact and benefits

Gross and net returns under contour furrows are ₹24,977 and 8,227 per ha respectively. The net returns under contour furrow is 129% higher than the local practice. The technology of contour furrow has good scope for reducing soil and runoff losses from field. It facilitates better soil water conservation and thus improve yield in medium, deep black soils of south east Rajasthan and adjoining region.

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Improved tillage and mulching practices for resource conservation in red soils

Salient features

Technology of improved tillage and mulch practices is suitable for red soils which occupies almost half of the area of the Bundelkhand region. It often experience moisture stress after cessation of monsoon consequently yield is affected adversely.

Improved tillage

Field is ploughed up to a depth of 20 cm by mould board plough after harvest of *rabi* crops in April – May on contours which augments conservation of rainwater into soil.

Sorghum

Sowing of hybrid sorghum varieties (CSH 14, CSH 16, CSH 18, CSH 21 or CSH 23) should be done in first week of July on contours using 8 kg seed/ha in rows spaced at 60 cm. Apply 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha. Half dose of N and full dose of P and K should be applied at the sowing and the remaining dose of N should be top dressed after 30-35 days after sowing.

In-situ surface mulching of sunnhemp

In between two rows of sorghum, one row of sunnhemp spaced at 30 cm should be sown using seed @ 20 kg /ha. After 25 days of sowing, rows of sunnhemp should be cut from ground level and green bio-mass should be spread uniformly on soil surface in between two rows of sorghum as mulch.

Performance results

Improved tillage (20 cm depth) with mould board plough combined with *in-situ* surface mulching of sun hemp increased the grain yield of sorghum by 47% and stover by 36% over conventional tillage. The technology also helped in conserving 34% higher rain water conservation over conventional tillage.

Cost of technology

An additional cost of about ₹1,500/ha is required for adopting the technology over conventional practice.

Impact and benefits

Additional net return of ₹7,437/ha is obtained with application of improved tillage plus *in-situ* surface mulching of sunnhemp over traditional tillage practice. The technology has the potential of outscaling in red soils of Bundelkhand region for better water conservation and higher yield.

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Jhola Kundi: a low cost water harvesting technique suitable for Eastern Ghat high lands

Salient features

Jhola Kundi is a low cost water harvesting device of circular shape dug manually with depth varying from 2 to 4 m and diameter of about 3 m. The water stored in it is lifted through traditional water lifting devices i.e, Tenda or pump for irrigating the field. By using a Jhola Kundi, a farmer can irrigate 0.5 to 1 ha area in *rabi* and 0.2 to 0.4 ha area in summer. Yield increased from 48.5 q/ ha to 172 q/ ha and net returns had been achieved to the tune of ₹52, 178/- per ha/year. Net income from important cash crops improved from ₹23,027/- to ₹64, 700 per hectare.

Krishak Bandhu pump

Performance results

Introduction of Jhola Kundi technology facilitate the farmers to grow vegetable crops during lean periods and their incomes had increased manifolds. The technology is widely accepted by farmers as it is affordable and cost effective.

Cost of technology

Cost of excavation for a Jhola Kundi (30 m^3capacity) is about ₹3,000. Traditional water lifting device can be fabricated by the farmer himself or he can opt for pedal operated *Krishak Bandhu* Pump which costs ₹3,000. For cultivation of vegetables in 1 ha, total cost is about ₹15,000 including excavation of Jhola Kundi, *Krishak Bandhu* pump and inputs (seeds, fertilizer and pesticides).

Impact and benefits

- Existing non-remunerative millets or upland rice based cropping systems can be replaced by remunerative cash crops like vegetables and flower crops.
- Cropping intensity can be increased from 127 to 270 % and benefit cost ratio observed is 2.8: 1.

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Improved agri-horticultural system in the North-Western Himalayas

Salient features

The mango (cv. Mallika) and peach (Shan-e-Punjab) plantation can be established with a suitable pit filling mixtures of 70-75% imported soil + 50 kg FYM + recommended NPK for better aeration and moisture conservation on degraded riverbed lands.

The drip irrigation system is beneficial for irrigation during establishment of fruit plants and during fruiting period for sustainable and improved productivity. This system helps in conservation of vegetation, soil, nutrients and provides fruits and food grain on a sustainable basis. The degraded lands can be rehabilitated through fruit based agri-horticultural systems. The crop rotations like Black gram-*toria* and cow pea-*toria* can be practised to utilize the interspaces for getting additional benefits from the systems.

Standing stage of cowpea between two rows of mango on degraded land

Standing stage of *toria* between two rows of mango on degraded land

Standing stage of *toria* between two rows of peach on degraded land

Performance results

Mango based agri-horti system produced cowpea 1,400 to 1,500 kg ha^{-1}, *toria* 300 kg ha^{-1} and mango fruit 7,000 kg ha^{-1} resulting higher net profit. Besides this, crop residues of cow pea and *toria* added 13.6, 7.45 and 41.3 kg NPK ha^{-1}. Peach based agri-horti system produced blackgram 355 kg ha^{-1}, *toria* 358 kg ha^{-1} and peach fruits 9000 kg ha^{-1} resulting higher net profit. Besides this, crop residues of blackgram and *toria* added 10.5, 5.34 and 35.5 kg NPK ha^{-1}.

Cost of technology

The total cost of cultivation for the mango+cow pea -*toria* rotation is about ₹35,520. Output in terms of net profit per unit area is 16,850 ha^{-1} year^{-1} when compared with farmers' practice. Similarly the total cost of cultivation for peach+blackgram-*toria* rotation is about ₹40,240. Output in terms of net profit per unit area is ₹25,560 ha^{-1} year^{-1} from degraded land which is presently out of cultivation.

Impact and benefits

The overall net income per hectare per year with mango+ cowpea-*toria* raised from ₹12,340 to ₹16,850 ha^{-1} year^{-1} under rainfed condition for cowpea – *toria* and irrigated condition for mango under moisture stress situation on degraded lands. In peach based agri-horti system, net income per ha per year raised from ₹20,250 to ₹25,560 ha^{-1} year^{-1} under irrigated condition for peach and rainfed condition for intercropping of blackgram and toria. Improved agri-horticulture system has wide scope of replication in degraded lands in the north-western parts of Himalayas.

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Recharge filter : a cost effective technology for augmenting groundwater

Salient features

Installation of Type-I recharge filter unit

The recharge filter consists of a pit of 1 meter depth dug into the soil and lined with LDPE (250 μ thickness) sheet. The base is sloped towards middle. A perforated pipe covered with a wire mesh is placed in the middle leading to the recharge well (As shown in step-2 of figure). The graded filter materials are laid in 3 layers of 30 cm each. The bottom layer consists of graded stones/gravels of size 40 mm, the middle layer has graded stones/grits of 20 mm and the upper layer is coarse sand (clean) of grain size of about 2 mm. The size of graded stones laid in the bottom layer should not exceed 40 mm to avoid damage to LDPE sheet. An agro-net/geo-jute (0.25 mm opening) sheet is placed over the sand layer to stop sediments to clog the sand surface. This sheet is periodically cleaned generally after every rainfall event. For larger size filters LDPE sheet may be replaced with a 9 inch brick wall.

Performance results

The recharge filters have been installed and are performing well for last one decade. However, periodic cleaning is must for longer effective life. The technology is cost effective and easy to install in the field.

Cost of technology

₹20,000 for a 3 m × 3 m filter

Impact and benefits

Watertable decline is a major problem due to overexploitation. Direct well recharge is must to supplement natural recharge. Recharge filter aimed to remove sediments from the runoff before it enters into well. Series of recharge filters were installed in IWDP (Antisar Watershed), NWDPRA (Vejalpur-Rampura watershed) and under FPARP in hard rock areas of Central Gujarat. Subtle improvement in ground water level (22.13 m in September and 14.71 in May) as well as in quality was observed in these areas. Higher extraction period, pumping duration, increased acreage under irrigation and higher productivity by 17 to 200% were observed. Benefits from groundwater extracted in Antisar watershed (2003-2007) was estimated to be ₹11,25,837.

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Stabilization of bench terrace risers

Salient features

Economic utilization of riser with tea crop

Double row parallel planting of tea (*Thea sinensis*) on terrace risers at a spacing of 0.75 m × 0.75 m helps to overcome the problem of riser instability which is the result of not providing the slope of 0.5:1 or 1:1 to the risers by the farmers who tend to make the risers as vertical as possible for accommodating more crop rows. Crop diversification, resource conservation and higher production from annual cropped areas in the Nilgiris are other advantages of the technology. Suitable for southern hilly regions wherever tea is being grown and bench terracing is required for annual crop cultivation.

Performance results

Reduction in run off (27.46 mm) and soil loss (0.33tonne/ha/year) from the risers.

Cost of technology

₹50,000 per ha till the establishment of tea (during initial 2 years)

Impact and benefits

Additional net income that could be obtained by growing tea on the terrace riser area from one ha of terraced land is ₹22,000/year.

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Improved design of mechanical spurs for control of torrents in the lower Himalayas

Salient features

Spurs are commonly used mechanical measures to prevent flood induced damages along torrents (hilly rivers). Spurs constructed at an angle to the stream flow, to guide the stream flow along a desired alignment and to prevent bank erosion. A well designed series of spurs built along an eroding bank will firstly check the erosion and induce siltation in between the spurs. The silted bank may be put under perennial plantation subsequently.

Series of attracting Type Mechanical Spurs

Deflecting Spur with Proper Anchoring

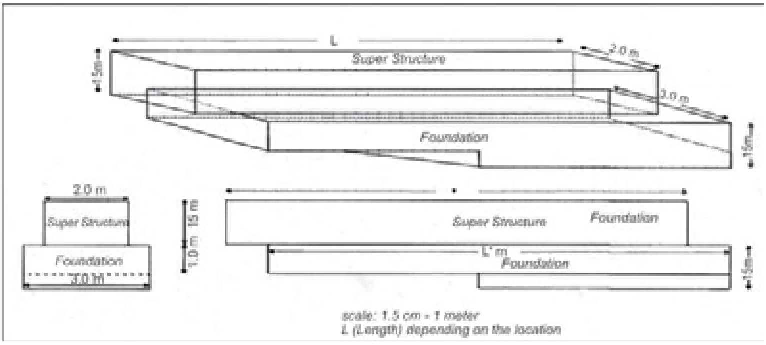
Mechanical Spurs reinforced with the Vegetation

- Attracting type of spurs having angle from 20° to 45° have proved most stable. Deflecting type (angle=90°) of spurs could be provided in long straight stretches.
- Foundation of at least 1 to 1.5 m depth should be provided to prevent damage of spur because of scouring. Generally, 2.5 to 3 m wide foundation and having 1 to 1.5 m depth is to be provided along the length of spur.
- The most vulnerable portion of the spur is its nose. Extended foundation up to 1-2 m in front of spur as apron can be provided.
- The minimum base width of the spur suggested is about 1.5 m, however, in case of stepped structure, width could be reduced up to 1 m at the top.
- Height of the spur should be sufficient to handle the peak flow expected at the desired return period above Highest Flood Level. Generally 1.5 to 2.5 m of spur height is recommended.
- Generally, blockage ratio (projected length of spur / width of torrent) should be kept between 0.20 and 0.30. The more the length there is more chance of damage to spur.
- Protection to stream bank could be increased significantly, if supportive vegetation is provided in the interspaces. The spacing between spurs can be kept as 4 to 6 times the length of the spurs.
- Anchoring the bank (0.5-1.0m length) is a must for stability of spur. Compaction of earth fill can be done at the joint of spur and the bank of torrent. If required, stone pitching of anchor is recommended.
- The minimum stone size suggested is 22.5 cm. Few (up to 10-15%) smaller stones could be used for support of irregular larger stones, if stone without dressing is used.

- Generally 10 gauge (3.15 dia) GI wire is recommended for the purpose.
- The wire net can be woven with the net opening size of 15 cm × 15 cm.
- Apron has proved to be a good solution for its protection. Reinforcing by vegetation has further improved its efficiency in control of torrent.
- The technique is suitable to control the torrents in the lower Himalayas for small and middle size torrents

Performance results

- With the improved design of the spurs and incorporating vegetative measures, about 77% savings was achieved when compared with a continuous gabion wall all along the banks in the torrent control project at Narayanpur (Haryana). Reinforcing the vegetation with the mechanical spurs improved its performance and made it a sustainable technique.
- The technique to tame the torrents emerging from the Shivalik Foothills was found economically viable with a Benefit: Cost ratio of 2.65:1 assuming the life of project as 15 years. IRR of 29% also substantiate the economic viability as well as profitability of the projects taken up in Shivaliks.



Dimensions and view of Mechanical spur

Cost of technology

- Cost of mechanical measures comes to be around ₹1,000 per m^3 of crate wire structure (gabion) including the cost of boulders, galvanized wires, making of wire net and labour charges for installation. However, this may vary at different locations as per the availability of boulders and labour cost.

Impact and benefits

- Experience in Shivalik in one of the project showed that installing mechanical spurs reinforced with the vegetation for torrent control reclaimed about 35 ha agricultural land in the vicinity by treating a torrent of length 1.7 km.
- The gross income from total torrent affected lands after the treatment increased by 263 %. Annual agricultural income on per hectare basis increased by 4-5 times.

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Technology for rehabilitation of mine wastelands in arid regions

Salient features

After mining, such lands remain barren and unproductive which can be rehabilitated for improving carrying capacity of such waste land. During rehabilitation, the land is reshaped into terraces and slopes for rainwater harvesting. Soil profile is modified by top layering of pre-mining surface soil. Planting pits (60 cm^3) at 3 m spacing in rows 9 m apart are filled up with necessary growing medium, consisting of mixture of fine sand / farm soil and farmyard manure in 2:1 ratio. Ecological suitable species of trees and shrubs matching the climax formation can be planted at 3 to 5 m in a row which should be 6 to 9 m apart. The interspaces should be utilized by growing forage grasses, perennial medicinal plants and cucurbitaceous vegetables and cereals e.g. pearl millet.

Fig. 1: Heaps of overburden at lignite Backfill in foreground before rehabilitation with high dumps behind at Giral, Barmer.

Fig. 2: Three years after planting *Parkinsonia aculeata* at back fill. *Cenchrus ciliaris* growing in the inter row space after rehabilitation.

Performance results

Within three years, area can be rehabilitated. Trees and shrubs attain 2-4m height and 1-4 m^2 canopy cover. Forage grasses, cereals and other intercrops grew successfully.

Cost of technology

₹20,000/ ha

Impact and benefits

After rehabilitation it is possible to obtain about 5-7 tons of wood per ha from mined waster lands. Cultivation of crops between the two rows of trees could also produce about 150-200 kg pearl millet per ha. Additionally, *Cenchrus ciliaris* yielding about 1.5-2 tons ha^{-1} could also be produced from inter tree space.

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Chemical weed control in wheat

Salient features

Application of mesosulfuron + iodosulfuron at 12+2.4 g/ha as post-emergence (25-30 DAS) in wheat or clodinafop+ metsulfuron-methyl at 60+4 g/ha or sulfosulfuron + metsulfuron at 32+4 g/ha as post-emergence application (25-30 DAS). This technology increases the grain production, improves quality of grain, and results in higher income.

Performance results

Grassy and broad-leaved weeds in wheat have been reported to cause 30-50% yield loss. As a result, the growth of the crop is adversely suppressed, and the crop productivity is reduced significantly. However, continuous use of the same herbicide may result in development of resistant biotypes. This calls for use of other competitive herbicides for weed management to avoid shift in the weed flora. The overall net return with the adoption of herbicides for weed control in wheat is to the tune of ₹10,000-12,000/ha.

Cost of technology

₹1,500-2,000/ha

Impact and benefits

The new technology lowers the weed competition from the beginning and saves loss of nutrients to an extent of 30-50%. The saving in weeding cost to an extent of ₹1,000/ha has been observed. The technology also helps to overcome the labour problem during weeding season. This technology relieves pressure on human labour for weeding, avoids loss of nutrients, cost effective and improves yield. Further, upscaling can be done through demonstrations, KVKs, ATMA and NGOs.

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Herbicidal control of grassy weeds in direct-seeded rice

Salient features

Timely use of newly-released effective herbicides in direct-seeded rice helps in better weed management and results in increase in yield besides increasing the profitability. Management of *Echinochloa colona* and other grassy weeds in direct-seeded rice can be accomplished using fenoxaprop (60 g/ha) as post-emergence application (25-30 DAS); chlorimuron + metsulfuron (20 g/ha) + fenoxaprop (60 g/ha) as post-emergence at 25 DAS; bispyribac-sodium (25 g/ha) as post-emergence at 25 DAS; and bensufuron + pretilachlor (10 kg/ha) as pre-emergence.

Untreated plot

Fenoxaprop treated plot

Performance results

Echinochloa colona and other grassy weeds have been reported to cause 50-60 per cent yield loss in direct-seeded rice. Due to adoption of improved weed management technologies, the weeds are effectively controlled and the yield increases by 2-3 t/ha. *Echinochloa colona* is usually not controlled by the traditional practices but it is effectively controlled by the use of fenoxaprop (60 g/ha) as post-emergence (25-30 DAS) using 500 litres of water with knapsack sprayer. Use of bispyribac-sodium at 25 g/ha as post-emergence reduces the weed pressure and results in higher yield of rice. Pre-emergence application of bensulfuron + pretilachlor at 10 kg/ha provides season-long weed control.

Cost of technology

₹1,500-2,000/ha

Impact and benefits

Improved weed management technologies result in better quality of the produce and higher grain yield. The net income of ₹27,000/ha over the traditional practice of weed management be obtained.

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Weed management in pulses

Salient Features

Application of pendimethalin at 0.75-1.0 kg/ha as a pre-emergence, quizalofop or clodinafop at 50 g/ha as post-emergence (20-25 DAS) for effective weed control in pulses. Application of metribuzin at 500 g/ha as early post-emergence (15-20 DAS) provides excellent weed control in pea. The technology increases productivity, seed quality, and net income.

Performance results

Major weeds of pulse crops, such as wild oat (*Avena ludoviciana*), *Phalaris minor* and broad-leaved weeds like *Medicago denticulata* have been reported to cause 30 to 50 per cent yield loss. As a result, the growth of pulses is adversely suppressed and consequently, the crop productivity is reduced significantly. Improved weed management technologies result in significant increase in yield by 0.5-0.6 tonne/ha over the traditional practice.

Cost of technology

₹1,500-2,000/ha

Impact and benefits

The technology can help pulse growing farmers, earning ₹8,000 to 10,000 ha besides fetching higher pulse production.

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Chemical weed control in soybean

Salient features

Soybean is infested severely with grassy weeds. Sometimes, the crop is completely damaged due to severe infestation of weeds. The farmers grow soybean in Madhya Pradesh particularly in Malwa region because it the most profitable enterprise. Application of quizalofop-p-ethyl @ 50 g/ha or fenoxaprop-p-ethyl @ 100 g/ha along with + chlorimuron at 9 g/ha as post-emergence at 20-25 DAS control the complex weed flora in soybean. Application of imazethapyr at 100 g/ha as post-emergence is also effective for control of broad-spectrum weeds in soybean.

Performance results

These technologies are found efficient for managing grassy weed flora, facilitating better crop growth, improving use-efficiency of inputs, less infestation of insect-pests and diseases, leading to higher productivity and good quality of seed.

Cost of technology

Cost of intervention: ₹1,450/ha; Benefit over existing technology: ₹8,700/ha.

Impact and benefits

This technology ensures timely weed control in soybean crop. Constraints of labour availability may be overcome.

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Soil solarization for weed control in vegetables and high-value crops

Salient features

- Soil solarization involves covering the soil with transparent polyethylene (TPE) films which trap the heat inside, resulting in raising of soil temperature to lethal level to many soil pathogens, nematodes and weed species.
- The field is irrigated and brought to fine tilth. The TPE of 50 µ thickness is laid close to the soil surface and sides are tucked into the soil to prevent any heat loss. This is best practised in summer (April-June) when sky is clear with high solar radiation. Soil solarization for a period of 3-6 weeks is sufficient.

Solarization by TPE sheets

Cost of technology

- Initial cost of material is about ₹68,000 per ha, assuming cost of TPE @ ₹120/kg.
- Same TPE sheet can be used twice in a season and re-used for two years.
- Treated field can be utilized for raising the nursery twice or thrice in a season.
- Labour cost for laying is ₹3,000/ha.
- The cost of treatment may be around ₹10,000 to 12,000/ha per annum.

Solarized nursery

Impact and benefits

- This technique controls most annual weeds and provides season-long control during both the seasons.
- Helps in reducing weed seed bank effectively.
- Controls many soil- borne pathogens responsible for causing root rot, wilt etc.
- Proves effective against parasitic weeds
- It is not effective against perennial weeds like *Cyperus rotundus*.
- Some broad-leaved weed seeds like *Melilotus* sp. and *Medicago hispida* with hard seed coat are tolerant to soil solarization.
- Using this technology, yield increases of about 100-125% in onion, 50-55% in ground nut, 70-75% in sesamum and 77% in soybean can be achieved.

Non-solarized nursery

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Weed management in zero-till wheat

Salient features

- Wheat is conventionally-grown following intensive tillage operations. This results in preparation of good seed-bed and mixing of fertilizers and weeds/stubbles of previous crop, if any, leading to good crop stand and growth as well as early weed control. However, there is greater use of energy, increased cost of cultivation, deterioration of soil physico-chemical and biological properties.
- To counter these adverse effects, zero-tillage technology has been advocated for growing wheat but there is likely to be greater infestation of weeds compared with conventional tillage.
- Weeds can be managed effectively in zero-till wheat through an integrated approach. Apply paraquat @ 0.5 kg/ha before sowing to kill the existing foliage of the weeds growing after the harvest of previous crop of rice, maize, soybean, pigeon pea, cotton, black gram etc.
- After 2-3 days, sow wheat with specially-designed zero-till seed-cum-fertilizer drill having knife type tynes at 4-5 cm depth using 120 kg seed/ha.
- Full dose of P and K along with 50% N should be placed basally after proper calibration of the machine.

  Apply any of the following herbicides depending on the infestation of the weed flora:

Herbicides	Dose (g/ha)	Time of application	Remarks
Clodinafop propargyl	60	25-30 DAS	Annual grasses, especially *Avena* spp.
Metribuzin	175-200	30-35 DAS	Annual grasses and broad-leaved weeds
Sufosulfuron	25	25-30 DAS	Annual broad-leaved weeds and grasses
Sufosulfuron + metsulfuron	30+2	25-30 DAS	Annual grasses, broad-leaved weeds and sedges
Mesosulfuron + Idosulfuron	12 + 2.4	20-25 DAS	Annual grasses and broad-leaved weeds and sedges
Isoproturon + metsulfuron	1000 + 4	20-25 DAS	Annual grasses and broad-leaved weeds

Cost of technology

Cost of production is reduced by about ₹2,500 per ha due to no use of tractor for 3-4 ploughing operations in conventional tillage.

Impact and benefits

- Results have shown that the productivity of zero-tilled wheat is almost the same as of conventionally-tilled wheat if sown at the same time.

Happy seeder for sowing of wheat under zero-till + rice residue

Good crop stand of zero-till sown wheat

Conventional-till wheat

Zero-till wheat

- The crop of zero-till wheat can be sown timely (7-10 days early) which can result in higher yield (10-20%) especially when sowing under conventional tillage gets delayed due to late harvesting of *kharif* crops. Infesation of *Phalaris minor* is also less in zero-till crop.
- There is improvement in soil physico-chemical and biological properties due to little soil disturbance.
- There may also be less use of irrigation water (5-10%) as the deep percolation losses of water are checked.
- The practice is eco-friendly, results in less emission of GHGs and thus helps in mitigating adverse effects of climate change.

Precautions

There is required greater care in sowing, crop management and precise conditions in the field for success of this technology. It is essential to ensure proper levelling of the field preferably through laser land leveler so as to place the seed and fertilizer at proper depth. Ensure the seed is properly covered with soil during sowing operation to check damage by ants, birds etc. Seed may be treated with chloropyriphos to check termite damage. There should be adequate moisture in the soil at sowing or else irrigation should be applied after sowing. It is preferable to use 15-20% more seed and fertilizer to compensate for any possible loss in crop stand and growth due to poor seed-soil contact, less germination, damage by birds etc. Recommended herbicide should be applied timely. The technology is suitable for most soil types. Happy seeder should be used for zero-till sowing when previous crop residues are retained on the soil surface.

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Integrated weed management of tiger grass

Salient features

- Summer ploughing up to 30 cm depth followed by application of glyphosate @ 2.0 kg/ha at 3-4 active leaf stage of tiger grass (*Saccharum spontaneum)* followed by sowing of *Sesbania* 20 days after herbicide spray in cropped lands.
- Sequential application of glyphosate 2.0 kg/ha followed by glyphosate 1.5 kg/ha after 2 months of first spraying in non-cropped land.
- Application of glyphosate 2.0-2.5 kg/ha 20 days before sowing at active foliage stage followed by fluazifop-butyl 0.3 kg/ha at 25 days after sowing in soybean, and quizalofop 125-150 g/ha at 20 days before sowing in mustard, chick pea and lentil.

Performance results

- Sequential application of glyphosate 2.0 kg/ha followed by glyphosate 1.5 kg/ha after 2 months of first spraying reduces the population of *Saccharum spontaneum* significantly and provides season-long control.
- Application of quizalofop@125-150 g/ha at 25-30 DAS reduces the problem of *Saccharum spontaneum* and enhances the yield of mustard.
- Appreciable control can also be achieved with the application of glyphosate at 20 DAS at active foliage stage followed by fluazifop-butyl 0.3 kg/ha at 21 DAS in soybean.
- Summer ploughing followed by application of glyphosate @ 2.0 kg/ha at 3-4 active leaf stage of tiger grass followed by sowing of *Sesbania* 20 days after herbicide spray provide effective and season-long control.

Cost of technology

- Cost of herbicides : ₹2,000-3,500/ha
- Labour cost for spraying : ₹1,000-1500/ha
- Cost of *Sesbania* seed : 40 kg/ha @ ₹30/kg = ₹1,200/ha
- Cost of summer ploughing : ₹2,000/ha

Impact and benefits

- This technology involves combination of tillage, cultural and chemical methods, and helps in better management of this perennial weed.
- Nearly 4 million ha of fertile cultivable land in Madhya Pradesh, Uttar Pradesh, Rajasthan and Maharashtra is infested with tiger grass (*Saccharum spontaneum)*, which can be brought under cultivation through this technology.

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CRIDA precision planter-cum-herbicide applicator

Salient features

Specifications

Power source for hauling: Tractor (35 hp)	
Number of rows	: 3 to 5
Row spacing	: 30-90 cm
Herbicide tank capacity	: 150 litres
Pump	: 0.125 hp,1200 lph
Nozzles	: Flat fan nozzle
Power source for herbicide pump	: Tractor battery (12 Volts) DC
Inverter (capacity)	: DC to AC (650 VA)

Salient technical features: A precision planter-cum-herbicide applicator was designed and developed to place seed and fertilizer precisely along with application of pre-emergence herbicide. This unit is designed for sowing under zero and reduced tilled conditions. The planter consists of spring loaded flexible shanks apart from individual seed and fertilizer metering boxes to meet the precision in undulated two-way slopping lands. The herbicide is sprayed in the rows through the nozzles arranged behind the planter. An electric pump draws the power from an alternator kept below the herbicide tank which is mounted on the frame to build up the pressure in the nozzles for controlled spray. The alternator is backed by the tractor battery power.

Performance results

Germination percentage: 92 %; Field capacity: 0.5 ha/hour

Cost of the technology

Operational cost: ₹650/ha; Initial investment: ₹3 lakh

Impact and benefits

- Farmers can go for sowing with fertilizer and herbicide application at one time in any type of soil with high precision and also with minimum disturbance of top soil.
- It can work well in two way sloppy lands because of individually operated spring loaded tines.
- Separate seed metering mechanism is available for each row for high precision. Separate seed metering plates are available for different crops.
- Saving on operational cost when compared to conventional: ₹1,000/ha.

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Mass multiplication of *Zygogramma bicolorata* for biological control of *Parthenium*

Salient features

Rearing methods have been developed for mass multiplication of *Zygogramma bicolorata* (Mexican beetle), a potential bioagent of *Parthenium*, in low-cost portable mosquito net house, permanent net house and in open field conditions. The mature seeds of *Parthenium* are collected from the infested area and sown by broadcasting on raised-beds. Urea @ 50 kg/ha is applied when plant are 10 cm in height. Mosquito net house may be prepared over raised *Parthenium* beds simply by fixing on the ground with the help of bamboo poles. In this mosquito net house, adult beetles of *Z. bicolorata* are released @10 beetles/m^2 having 50:50 ratio of males and females for egg laying and natural development of grubs after hatching. Lower part of the net may be embedded in the soil to prevent escape of the bioagents. New adults start to emerge after 30 days of release. The multiplication may continue for 2-3 months. Mexican beetles can also be multiplied by this method during summer and winter by providing shading through polythene cover on the bamboo frames.

Cost of technology

With this technology, bioagents can be produced throughout the year. On demand, the same maybe sold @ ₹1.0 to 1.50 per beetle depending on the terms and conditions, thus saving about ₹0.75 to 1.0 per beetle over the initial cost.

Impact and benefits

The results of mass rearing technique are extremely good when compared with conventional lab rearing. In this technology, there is no need to feed the insects daily and clean the excreta material. The bioagents reared in natural conditions on the live hosts have higher vigour of reproduction than the laboratory reared bioagents.

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Design and development of rubber dams for watersheds

Salient features

A rubber dam is an inflatable and deflatable structure used for regulating water flow and hence it is highly instrumental in watersheds. When it is inflated, it serves as an agricultural weir (low-level dam) and when it is deflated it functions as a flood mitigation device. As an innovative hydraulic structure, the rubber dam project mainly consists of four parts : (i) a rubberized fabric dam body; (ii) a concrete foundation; (iii) a control room housing mechanical and electrical equipment, such as air blower/ water pump, automatic inflation and deflation mechanism; and (iv) an inlet/ out let piping system.

Performance results

Five rubber dams were installed in watersheds at different locations of Khurda district, Odisha i.e. one unit each in Mendhasal, Baghamari, Badapokharia and two units in Chandeswar with innovative manufacturing, fabrication and installation technology. This is the first indigenous rubber dam in our country. This technology has potential to create an additional water storage capacity of about 52,000 m^3 to 80,000m^3 for irrigating about 40 ha of paddy in *kharif* and 6 ha of pulse, oilseed and vegetable crops in *rabi*. The productivity of rice in *kharif* was found to be enhanced up to 62% and productivity of vegetables in *rabi* up to 47 % due to installation of rubber dams in watersheds.

Cost of the technology

₹800,000 for 5 m width rubber dam with the height of 1.5 m.

Impact and benefits

The positive impact of rubber dam in terms of additional water storage, enhancement in irrigation command area, cropping pattern, cropping intensity and crop productivity resulted in enhancement of net returns of about 85 farmers of Baghamari and Chandeswar villages of Odisha. Farmers have shifted from pulse cultivation to vegetable cultivation due to assured water availability after installation of rubber dams. It has potential to enhance the net returns of the farmers up to ₹48,000/- per ha. The farmers of Badapokharia got benefit through additional ground water recharge due to installation of rubber dam at entry point of percolation tank.

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Farm pond technology for water harvesting

Salient features

- Recommended for black soil areas (Vertisols) without lining.
- Optimum dimension of farm ponds to retain at least 1000 m^3 of runoff. The recommended dimensions are 20 m × 20 m top and a minimum depth of 4 m while bottom will vary from 10 m × 10 m to 15 m × 15 m depending on slope.
- Fencing of these ponds with barbed wire recommended for preventing trespass of livestock and to grow cucurbits.
- Rearing of fish in ponds retaining water for more than six months with stunted fingerlings.

Performance results

- One to two supplemental irrigation can be given to arable or horticultural crops. Yield enhancement may vary from 15 to 40%.
- Use of harvested water for sowing of *rabi* crops through pre-sowing irrigation
- Growing of vegetables using harvested water for higher economic returns upto ₹40,000/ha

Cost of technology

₹1,00000 per pond inclusive of digging of pond and silt trap, stone pitching of inlet and outlet, pumpset with accessories, fencing, seeds, seedlings/fingerlings, etc.

Impact and benefits

Cropping intensity will improve due to more water valuability and thereby increasing the productivity and profitability of the farmers.

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Crop diversification with *in-situ* rainwater conservation for drought mitigation

Salient features

The technology is suitable for rainfed upland ecology where rice productivity is low (<1 t ha^{-1}). Crop diversification by adopting maize, groundnut, pigeon pea, cowpea through sole or intercropping following ridge and furrow methods of sowing will generate stable and higher income (₹20,000 to 25,000 per ha per annum).

Performance results

Rice yield equivalent of 7.5 t ha^{-1} with average net return of ₹20,000 to 25,000 per ha per annum.

Cost of technology

₹14,000/ha

Impact and benefits

Higher rice equivalent yield per annum was obtained through maize cob (8,125 kg ha^{-1}), groundnut + pigeon pea (5,550 kg ha^{-1}), sole groundnut (5,640 kg ha^{-1}), sole pigeon pea (5,550 kg ha^{-1}). The technology is helpful for mitigating dry spells, sustain soil fertility and ensuring nutritional security to poor and marginal farmers.

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Rainwater conservation for rice-fish integrated system

Salient features

In 8 to 10% of the rice fields, small dugout ponds of 2.0 to 2.5 m depth and 1:1 side slope are beneficial. It can be used for short-duration aquaculture during monsoon and the embankment is used for growing horticultural crops. The conserved rainwater will be available for supplemental irrigations to *kharif* paddy and irrigating light duty *rabi* crops.

Performance results

The *kharif* paddy yield increased from 1.8 tonne/ha to 4.9 tonne/ha with a concomitant fish yield of 1.4tonne/ha.

Cost of technology

₹67,000 per ha

Impact and benefits

The cropping intensity can be increased up to 200%.

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Raised and sunken-bed technology

Salient features

Alternate sunken and raised beds, each of 30 m length and 5 m width. The technology is suitable for medium- and low- land of eastern India for growing vegetable crops and rice or other aquatic crops like colocasia. Fish spawn can be raised up to fingerling stage in the sunken beds together with rice.

Performance results

Adoption of this technology increased *kharif* paddy and pointed- gourd yield from 4.2 tonne/ha to 5.2 tonne/ha and 4.24 tonne/ha to 4.74 tonne/ha respectively, in addition, providing a fish yield of 1tonne/ha.

Cost of technology

₹50,000/ha

Impact and benefits

Additional income per ha per year: ₹70,000.

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Sub-surface water harvesting structure for coastal areas

Salient features

Below sub-surface profile fresh water floats above the saline water in coastal water logged areas. This could be tapped through subsurface water harvesting structures to meet the irrigation demand of *rabi* crop as well as for pisciculture. To lift water from these structures, 1-2 hp pumps are recommended so as to avoid ingression of saline water in to the fresh water layer. The depth of structure should be restricted up to 5 m (i.e. within sandy zone).

Performance results

These structures act as an off-season source for increasing cropping intensity and crop productivity. The average benefit: cost ratio of sub-surface water harvesting structure (SSWHS) is 1.55 in the first year of construction. Average water productivity of SSWHS with pisciculture and *rabi* vegetables is ₹36/m^3 of water.

Cost of technology

Average unit cost for SSWHS construction is ₹14/m^3

Impact and benefits

The SSWHS technology helps in meeting the irrigation demand for *rabi* and improve the cropping intensity and crop productivity. Average total net benefit from the system is about ₹20,000/ha/year.

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Micro-level water resource development through tank-cum-well system

Salient features

The tank-cum-well system technology along the drainage line in a watershed is recommended for plateau areas having slope of 2 to 5%. The site for the technology should be selected in such a way that the area should have a well defined valley where the runoff flows either as overland flow or channel flow. The well is constructed about 100 to 300 m downstream of the tank to tap the water that is lost by seepage from the tank. The schematic diagram of tank-cum-well system and multi tank and multi well system in a watershed are shown in Figs. 1 and 2 respectively.

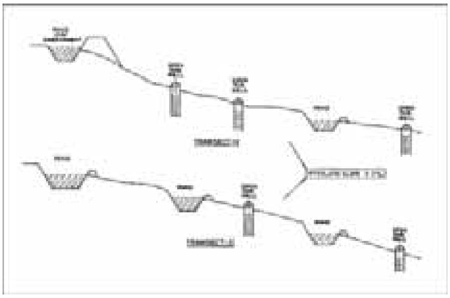

Fig. 1. Schematic diagram of tank-cum-well system

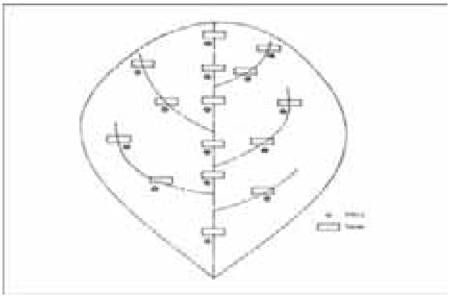

Fig. 2. Schematic sketch of multi-tank multi-well system

Performance results

₹50,000 extra gross income/year with additional employment generation of 115 mandays/ha. Increase in cropping intensity to 166%.

Cost of technology

₹80,000/ ha of net command area.

Impact and benefits

Cropping intensity will increase due to more water availability and thereby increasing the income of farmer. Farmers will have access to water for timely rice transplanting.

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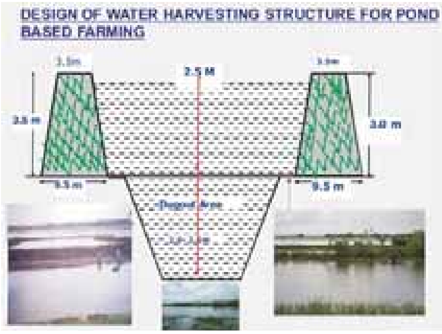
Pond-based farming system for deep waterlogged areas

Salient features

Due to poor drainage, saucer-shaped topography and high monsoon rainfall, some parts of east coast of India remain waterlogged (>1m surface water logging) and unproductive. To stabilize and enhance net income from such waterlogged ecosystem, pond-based farming technology (deep water) rice in *kharif* + salt tolerant vegetables like watermelon, ladies finger, spinach, chili in winter + on-dyke vegetables-fruits + fish inside pond) was developed and implemented in deep waterlogged areas (1-2.5 m water depth) of Puri district, Odisha.



Performance results

Additional net return: ₹25,000-30,000/ha/annum

Water Productivity from the system: ₹7.2/m^3

Cost of technology

₹65,000/ ha of net command area

Impact and benefits

Pond-based farming system in deep waterlogged area will generate higher income due to intensive cropping with harvested water along with fisheries, and on-dyke horticulture. Farmers will have also access to water for timely transplanting of rice during post flood period. Thus the non-productive waterlogged areas can be converted into a productive and profitable system.

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Farm pond-based agricultural diversification model for multiple use in rainfed areas

Salient features

Rainwater harvesting system was designed and agricultural diversification model (on-dyke horticulture, fisheries, cultivation of diversifies field crops, short-term fruits like papaya, banana, floriculture like marigold, tuberose etc.) with harvested rainwater was developed for small-and marginal-farmers through multiple uses of water.

Performance results

Additional net return: ₹30,000-35,000/ha/ annum

Cost of technology

₹70,000/ ha of net command area

Impact and benefits

Farm-pond based farming system will generate higher income due to intensive cropping with harvested rainwater along with fisheries, and on-dyke horticulture. Farmers can utilize the harvested rainwater for providing supplemental irrigations during dry spells in *kharif* and to grow second crops during *rabi*. The system will also helpful for groundwater recharging.

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Multiple use of water with trench-cum-raised bed system in waterlogged areas

Salient features

- Seasonally waterlogged lands can be productively used for increasing land and water productivity.
- Trenches in waterlogged areas with more than 1.0m stagnant water are excavated in such a way that excavated soil is filled in alternate strips to make bunds with top rising above highest flood level to cultivate vegetable or horticultural crops.
- Two types of models have been developed. First model simulates the river flow conditions, in which trenches are made in *meandering style*, and water is allowed to enter from one side with enough provision for fish culture.
- The second simulates pond type conditions in which continuous trenches are excavated with *island type* of raised bed, which may provide enough security to any high value production on the beds, and fishes have access to continuous movement around the island.

Performance results

- High value crops could be grown on the raised beds and composite fish culture in trenches.
- The fish yield of 2 tonnes/ha can be obtained from the models by stocking fries @ ₹15,000/ha.
- Fruit crops contributed 54% to the net income followed by fish (24%) and vegetables (22%), respectively.

Cost of technology

₹125,000 to 150,000 per ha

Impact and benefits

- Provision of irrigation is required to maintain water level in the trenches and irrigation on the beds during canal off periods or when depth of waterlogging is reduced.
- Most of the waterlogged areas could be rehabilitated adopting this technology.
- Net income from trenches-cum-raised bed system is ₹81,000 per ha per year.

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Low cost rainwater harvesting structure *(Doba)* for fruit orchard establishment in uplands

Salient features

- Unavailability of irrigation water is one of the major constraints for establishment of fruit plants in the Plateau region of Eastern India.
- Due to undulating topography and low water holding capacity of soil, storage of the rainwater is difficult. Hence, low-cost storage structure (*Doba*) has been standardized for storage of runoff water under upland conditions.
- The technology involves digging of pit of size 3.0 m × 1.5 m × 1.0 m in uplands and lining the pits with UV-stabilized black polythene of 250 µ thickness.
- After collection of rainwater in the *Doba*, the pit has to be covered with thatch made out of locally available material.

Performance result

- It has been estimated that one *Doba* is sufficient for storage of rainwater for providing life saving irrigation to 10 newly planted fruit saplings.
- The structure has a life span of 2 years. The structure can also be used for storage of water from seasonal streams.

Cost of technology

The cost of construction of one *Doba* is approximately ₹1,200 to 1,300.

Impact and benefits

- About 5,000 litres of water could be conserved in each *Doba*. The technology can be effectively used under rainfed upland conditions of Eastern Plateau and Hill region.
- Approximately 40 *Doba* are required to provide life-saving irrigation in 1 ha of orchard.
- *Doba* has become integral part of Wadi scheme of NABARD.

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Broad Bed and Furrow system for waterlogged areas

Salient features

Land manipulation is made in the form of raised beds and sunken furrows. Broad beds are made in the shape of inverted trapezium by digging soil from either sides of the beds and putting it in the bed area by cut and fill method. Beds of 4-5 m width and furrows of 5-6 m width with minimum 1 m depth are found suitable for Island condition. The length of beds and furrows can be according to the length of field. Thus, in one ha area of flat paddy field, 10 beds of 4 m × 100 m × 1 m and 10 furrows of 6 m × 100 m × 1 m can be made which envisages 60 % area of furrows and 40% area of beds. In the downside of the slope in the furrow, fish shelter having the size of 5 m × 3 m × 1 m can be made to shelter the fish in the event of prolonged dry spell during monsoon season. Stabilization of slopes of beds can be made by planting grasses. Vegetables are grown on the beds and rice-cum-fish in furrows. The raised beds help to prevent waterlogging and crop diversification in other wise rice monocropped area.

Performance results

BBF-based farming has sound economic impact in the lowland rice ecology in Andamans. It offers scope for growing of highly priced vegetables during the monsoon when the market price is high and depends on the arrival of vegetables from the main land. Besides this, the BBF system is expected to increase the cropping intensity from 100 to 125% in the traditional system to 300-400% in the beds and 200% in the furrows. Being an Integrated system, it provides scope for the maximum utilization of on-farm resources and family labours and thereby reduces the cost of cultivation and increases the profit and ensures the nutritional security of the farm family. Crop diversification was achieved by growing vegetables like okra, cauliflower, amaranthus, and flowers like marigold in beds of BBF system which resulted in additional net income of ₹1.05 lakhs/- with B: C ratio of 1.49 as compared to growing rice alone.

Cost of technology

- Cost of land manipulation: ₹80,000 per ha.
- Net return: ₹1.2 lakh/ha/annum

Impacts and benefits

- Additional net income of ₹1.05 lakhs with B: C ratio of 1.49 as compared to growing rice alone
- Increased food production through diversification and integration of different crops and enterprises in otherwise rice monocropped area. Ensures food and nutritional security by enabling the cultivation of various crops and fish. Helps in reclamation of coastal saline soils by promoting filtration and preventing waterlogging.
- Technology is transferred to farmers through NAIP and FPARP projects. Department of Agriculture, Government of A & N Islands is also taking up the technique to farmers through RKVY scheme by providing subsidy to the farmers.

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Three-tier system of farming in coastal valley lands

Salient features

Involves shaping of low lying land into three equal portions as pond, original or mid-land and raised land. Pond area should be at the end of slope. The dug out soil from the pond area should be taken to upper side of slope for raising the land. The pond can be used for water harvesting during rainy season and supplemental irrigation during dry season crops. Besides, fish cultivation can also be taken up which will further increase the farm income. During wet season rice is grown in the middle portion while vegetables are grown in the top or raised portion of land. As the flat area is divided into two terraces with pond at the end, it promotes good drainage and also facilitates crop diversification and integration of other enterprises like fish in otherwise waterlogged rice growing areas.

Performance results

Though the Islands receive an average annual rainfall of more than 300 cm, water scarcity is the major problem during dry season extending from December to April. This kind of land shaping results creation of 1,080m^3/ha water resource which can be utilized for providing irrigation to dry season crops like vegetables. Moreover, conversion of flat land into three terraces by excavation of pond at the lower land and filling the upper slopes with that soil helps in growing vegetables in the raised land, followed by rice cultivation at the mid-portion and integration of fresh water fisheries in the pond. Cropping intensity increases by 300 to 500% and gross return of ₹10.0 lakhs/ha/annum.

Cost of technology

- Cost of land manipulation: ₹5.0 lakh per ha.
- Gross return: ₹10.0 lakh/ha/annum.

Impact and benefits

- Gross return increases to ₹10.0 lakh/ha/annum as compared to growing rice alone due to crop diversification and integration of other components.
- Increased food production through diversification and integration of different crops and enterprises in otherwise rice monocropped area. Ensure food security and nutritional security by enabling the cultivation of various crops and fish. Helps in reclamation of coastal saline soils by promoting filtration and preventing waterlogging.
- More than 10 farmers have been given with the technology covering four clusters in South, Middle and North Andaman.

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Paddy-cum-fish system for coastal waterlogged areas

Salient features

In this system, a trench of about 3m width and 1.5m depth is dug around the field. The excavated soil is used for making raised bunds of about 1.5 m width around the field to avoid overflow of water. Vegetables are grown in these bunds through out the year. Trenches serve as a fish shelter during dry spells. In the middle portion, rice is grown during wet season and in dry season; vegetables are grown using water stored in the trenches. Because of this technique, cropping intensity is increased by 200 to 300 %, besides integration of other farm enterprises like fisheries which will enhances the farm income.

Performance results

This technique results in creation of 600m^3/ha water resource in the form of trenches. Because of improvements in drainage, dry season crops like vegetables, pulses are taken up after harvesting of rice. This increases the cropping intensity to 200 to 300%. Besides, growing fish in trenches and in rice during wet season increases the farm income to ₹8.0 lakh/ha/annum.

Cost of technology

Cost of land manipulation: ₹2.0 lakh/ha plus other input costs.

Net return: ₹3.5 lakh/ha/annum.

Impacts and benefits

- Additional net income of ₹3.5 lakh with B:C ratio of 1.86 as compared to growing rice alone. The initial establishing cost is covered in the first year itself.
- Increased food production through diversification and integration of different crops and enterprises in otherwise rice monocropped area. Ensure food security and nutritional security by enabling the cultivation of various crops and fish. Helps in reclamation of coastal saline soils by promoting filtration and preventing waterlogging.
- The technology has been demonstrated at more than 10 farmers' field.

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Buch as alternate crop for waterlogged areas

Salient features

Suitable for Chhattisgarh agro-climatic plain zone.

Performance results

Buch (*Acorus calamus*) a high value medicinal crop can be grown with spacing of 30 cm × 20 cm with a amount equal to 48 irrigations, each of 6 cm depth after 1 DADPW produced maximum yield of 89.1 q/ha with net return of ₹1.72 lakh/ha. Buch can be well adopted in water logged areas.

Cost of technology

Cost of planting material

Impact and benefits

Buch (*Acorus calamus*) a high value medicinal crop can be grown with net return of ₹1.72 lakh/ha in waterlogged area of Chhattisgarh.

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Software for evaluation of water delivery system in canal commands of irrigation project

Salient features

SPI_Canal software was developed for estimation of performance indicators of canal system to avoid manual calculations. V.N NET programming language was used to develop software. The software was designed in Graphical User Interface (GUI) to interact with users which can run on window operating systems.

Recommendation: SPI_Canal (Ver.1.0) software is recommended for easy and fast evaluation of canal water delivery system of irrigation project.

Performance results

Software is used by various scientists and students for research work. State irrigation departments are using software for evaluation of canal water delivering system to find out the area/location requring maintenance.

Cost of technology

Open source

Impact and benefits

This software can be used to find out the leakages in canal water delivering sytem to increase the system performance of canal network. This evaluation can help to increase area under irrigation and ultimately increases the revenue and production per unit of available water.

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Equation for determination of acid injection rate and constant for acid treatment through drip irrigation system

Salient features

The chemical clogging is a major problem for drip irrigation system users. In India, most of water used for irrigation contains calcium and magnesium. Calcium carbonate is common in arid region. Hydrogen sulphite with calcium carbonate greater than 40 mg/litre promotes formation of precipitation in drippers which adversely affect the water application efficiency and hence crop yield. Specific ion concentration, water pH and temperature play an important role in chemical clogging. Acidification is only alternative to remove such clogging. The use of hydrochloric acid- HCl (36%), sulphuric acid – H_2SO_4 (98%) and nitric acid – HNO_3 (60%) as per schedule through drip irrigation system can solve the salt clogging problem. Algae and fungi are the major contributors of biological clogging restricting the path of emitters. Chlorination is a main remedy to control the biological clogging. Generally calcium hypochlorite or sodium hypochlorite or chlorine gas can be used for chlorination treatment. Hence the acidification and chlorination is very much important for uniform application of water to each and every plant and at every corner of the field. The information regarding acidification as per water quality for drip irrigation is not available .Farmers were not well aware about the acid injection rate as per existing quality of water source.

Recommendation: Following equation is recommended for calculation of acid injection rate and constant for acid treatment through drip irrigation system. The equation applicable for pH of water 7.3 to 8.5

$$\text{I.R.} = Y \times Qs$$

where I.R., Acid injection rate through drip irrigation system (lph); Y, Acid Injection Constant (using HCL 36 %); Qs, Water flow of system (litre/sec)

$$Y = -28.314 + 4.368 \times [\text{pH of water}]$$

Performance results

Farmers of Parbhani region are adopting the technology for acidification of drip irrigation system.

Impact and benefits

Regular acidification of drip system will help to extend life of drip system, improve the uniformity in water application and enhance the water productivity per unit area.

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Tensiometer -based irrigation scheduling to rice

Salient features

A cheap, simple and user-friendly tensiometer for measuring soil moisture status, consisting of polyacrylic transparent tube connected to porous ceramic cup at the lower end for insertion into the soil and encapsulated in an outer polyacrylic transparent tube of bigger diameter is fixed with a silicon cork at the upper end to form a sealed water-filled (de-aerated distilled water) system. The specific water level in the inner (smaller diameter) tube has been calibrated to schedule irrigation to rice. This technique helps in saving 25-30% irrigation water in rice crop, compared to existing 2-day fixed interval technique.

Performance results

Tensiometer-based irrigation scheduling in rice in saving 25-30% water and energy besides improve water productivity of rice.

Cost of technology

This equipment costs ₹300 per piece.

Impact and benefits

The use of this technology saves 30% of the energy costs in terms of electricity, diesel and at the same time helps in saving of precious resource of water.

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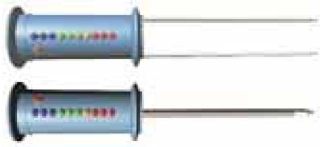
Soil moisture indicator

Salient features



- Soil moisture indicator (SMI) is a simple and farmer-friendly electronic soil moisture-indicating gadget useful for scheduling irrigation.
- It comprises a sensor-rod and a casing.
- There are either two metal sensor-rods.
- The casing houses an electronic printed circuit board with an integrated circuit, electronic components, ten LEDs, a provision for two AA batteries and a control switch.
- To assess the soil moisture the sensor rods are to be inserted into the soil.
- The resistance between the sensor rods depends on the moisture content in the soil between the rods.
- The electronic circuit is designed in such a way to display moisture levels by glowing any one-coloured LED / lamp out of the 10.
- Blue colour glow indicates ample moisture available in the soil, while green for sufficient, orange for caution (indication meant for irrigation) and red for low moisture.
- A provision is given in the devise for fine-tuning the device to suit different soil conditions.

Performance results

- Sugarcane Breeding Institute, Coimbatore has tested SMI under field conditions. Further it is being tested under field conditions by the farmers themselves for scheduling irrigation in sugarcane. The results indicated that using SMI and scheduling irrigation has considerably reduced the number of irrigations (5 to 10 irrigations) required for sugarcane without affecting yield.

Cost

₹500 per piece

Impact and benefits

- SMI will be useful in scheduling irrigation based on soil moisture. This will help in reducing 5 to 10 irrigations for sugarcane crop per year which will result in considerable saving in terms of water, power and labour. Save irrigation water.
- Protects soil from excess irrigation water.

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Pusa Hydrogel, a novel superabsorbent hydrogel and its use in agriculture

Salient features

- Pusa Hydrogel is a product for increasing agricultural productivity primarily through improvement in use efficiency of water.
- The technology includes bench scale process for its production along with the concomitant use package under diverse agricultural situations.
- The product is based on cellulosic backbone (natural polymer).
- Exhibits maximum absorbency at high temperatures (40-50^{0}C), suitable for semi-arid and arid regions. Absorbs a minimum of 350 times of its dry weight in water and gradually releases it.
- Low rate of application (2.5-3.5 kg/ha); effective in soil for a minimum period of one crop season. Improves physical properties of soils and the soil less media, Improves seed germination and the rate of seedling emergence.
- Helps plants withstand extended moisture stress. Reduces nursery establishment period. Reduces irrigation and fertigation requirements of crops.

Performance results

- Application of Pusa Hydrogel has resulted in water saving (30-50%), increased yield (15-30%) and improved quality of produce.

Cost of technology

The cost of hydrogel is ₹1,000-1,400 kg

Impact and benefits

Pusa Hydrogel is an innovative product suitable for semi-arid and arid region for imoproving water used efficiency.

The product has been licensed through NRDC to six companies of Indian origin and is currently being manufactured by two of them under the brand name of 'Kauvery' and 'Vaaridhar G1' is available in the market.

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Reclamation and management of alkali soils

Salient features

Gypsum-based technology is developed for reclamation of alkali soils. The process includes land leveling and bunding of field, application of gypsum @ 10 to 15 tonne per hectare in 10 cm surface soil, ponding water for 1-2 weeks before transplanting of rice and adopting proper agronomic practices.

Performance results

This technology has helped in reclamation of about 1.8 million ha sodic land of the country. The reclaimed area contributes more than 12 million tonne of food grains to the national pool annually.

Cost of technology

₹45,000 per ha

Impact and benefits

Farmers obtained 4 tonne/ha rice and 2 tonne/ha wheat yield from reclaimed alkali land right from the first year of the reclamation, which increased to 5 and 3 tonne/ha during 3rd year onwards, respectively with 135 mandays of employment per ha. Its net present worth estimated to be ₹56,000/ha, benefit cost ratio 1.52 and internal rate of return 21.4%.

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Sub-surface drainage technology for saline soil reclamation

Salient features

The subsurface drainage system consists of perforated corrugated PVC pipes, covered with synthetic filter, installed mechanically at a designed spacing and depth below soil surface to control water table depth and drain excess water and salts out of the area by gravity or pumping from an open well called sump. The depth and spacing of drainage system are governed by rainfall, irrigation, hydro-geology, texture and salinity of soil and outfall conditions in the affected area.

Performance results

The sub-surface drainage technology has resulted in 25 to 100 % improvement in cropping intensity and significant enhancement in crop yields (up to 45 % in paddy, 111 % in wheat and 215 % in cotton) in different parts of India. The technology is suitable for Haryana, Rajasthan, Gujarat, Punjab, Andhra Pradesh, Maharashtra and Karnataka. During the last two decades, this technology has been implemented in 7,000 ha waterlogged saline area by Department of Agriculture in Haryana where annual loss due to waterlogging and soil salinity has been estimated more than ₹200 crore. About 50,000 ha waterlogged saline soils have been reclaimed in different states of India through subsurface drainage technology.

Cost of technology

The cost of sub-surface drainage system is about ₹60,000/ha in alluvial soils of North-West India and ₹75,000/ha for heavy textured soils of Maharashtra and Karnataka. Both the material and installation costs cover about half of the total cost.

Impact and benefits

Due to notable increase in crop yield, the technology results in 3-fold increase in farmers' income. The technology also generates around 128 mandays additional employment per ha per annum. Its net percent worth estimated to be ₹45,000/ha, B-C Ratio 1.46 and internal rate or return 13%.

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Collector well technology for coastal sands (Improved Doruvu Technology)

Salient features

Dug out conical pits locally called *Doruvu* is used to skim fresh water floating on saline water. It is used to draw water manually and is applied on crops like vegetables, flowers groundnut, nurseries of paddy, tobacco and chillies using pitchers. Each *Doruvu* will occupy an area of about 200 m^2 and the water collected will be sufficient to irrigate 800 m^2 requiring 10-12 *Doruvu* per ha. This will, however, result in about 20% loss of cultivable area and adoption of modern irrigation equipment will not be possible. As an alternative to traditional *Doruvu,* AICRP Saline Water Scheme, Bapatla developed an improved *Doruvu*. In this, flow of water from 1.8 to 2.4 m below the ground to collectors sump is accomplished. The water is pumped and used to irrigate crops using sprinklers/ drip and specially designed hand held jerry.

Traditional *Doruvu*

Skimming well with Collector lines

Performance results

AICRP on Saline Water Scheme, Bapatla installed, 94 skimming wells in coastal farmer's fields for drinking purposes under the Rural Water Scheme of the Government of Andhra Pradesh.

Cost of technology

₹85,000 per well and suitable for irrigation of 2 ha area with low duty crops during *rabi*.

Impact and benefits

Minimization of irrigation cost, savings in land wastes (15 to 20%) under traditional *Doruvus* and improvement in crop yields.

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Sub-surface drainage system for reclamation of waterlogged saline soils in coastal region

Salient features

In order to reclaim waterlogged saline soil in coastal region, pipe drainage system has been standardized at Appikatla. The pipe drainage system installed at 30 m spacing at a depth of 1 m with stoneware pipe material leached the soluble salts effectively and reduced the ECe from 16.2 to 3.5 dS/m and increased the paddy yields. The system leached the salts to a tune of 19.8 t/ha over 5 years. The drainage system with spacing of 30 m was found better than 60 m spacing in the initial years but from third year onwards, both the systems performed similar with stoneware pipe drains as well as PVC pipe drains.

Details of technology

Area covered	:	7.5 ha
Hydraulic conductivity	:	0.265 m/d
Rainfall	:	900-1300 mm
Drainage coefficient	:	2 mm/d
Hydraulic head above the drains	:	0.4 m
Depth of observation wells	:	2.5 m
Depth of water table (June, 2002)	:	1.35 m
Drain Depth	:	0.85-1.1 m
Depth to impervious layer from drain level	:	4.8 m
Equivalent depth	:	2.33 m
Drain spacing	:	30 m (computed) 60 m (Sensitivity analysis)
Lateral pipe line Depth	:	0.85-1.1 m
Total length	:	1640 m

Installation of CPVC collector line with Nylon mesh

Stoneware pipe collector line packing with sand envelope at coir filled joints

Lateral drain discharge collection into main sump

Type of envelope material	:	Nylon 60 mesh socks for CPVC pipe Sand/Gravel pack for SW pipes with coir jointing
Collector pipe line	:	Depth: 1.2-1.5 m Slope: 0.2% Dia.: 0.15 Total length: 255 m
Inspection chambers	:	No. of IC: 9 Depth of IC:1.8-2.1m Dia. of IC: 0.75m
Main sump	:	Depth of main sum p: 4.2 m, Dia.: 1.5

Performance results

Reduced the ECe of saline soils from 16.2 to 3.0 dS m^{-1} and leached the salts to a tune of 19.8 tonnes/ha over 5 years, crop yield increased by 15 to 30% in different seasons over the surrounding fields.

Cost of technology

₹50,000/- per ha and benefits are additional yields during *kharif* and *rabi* and to a tune of ₹15,500/- per ha.

Impact and benefits

The immediate gains are increased agricultural production, cropping intensity, asset values and employment generation. In the pilot study, paddy crop yields increased by 15 to 30% during different seasons. Sunnhemp crop was established as second crop during 1st year after instillation of subsurface drainage. In the subsequent years, farmers started growing black gram, green gram, *jowar,* pillipesara and sunnhemp after paddy. At present the installation of pipe drains at a depth of 1 m and a spacing of 50 m costs around ₹50,000/-. The BC ratio estimated for 30 years life of the system is 1.82.

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Soil sodicity kit

Soil sodicity kit determines the level of soil sodicity in the soil which can be reclaimed by adopting recommended practices. These tests are applicable for those sodic soils having EC<4dSm^{-1}. This developed laboratory neutral field kit for the sodic soils of Uttar Pradesh to determine the degree of sodicity and quantum of amendments at farmers' field level by following the instructions given in the kit and observing the changes in the soil and comparing them with the charts provided in the kit.

Salient features

Turbidity test: Take 100 g of surface or sub-surface soils into a clear 600 ml glass jar or beaker. Gently pour 500 ml rainwater or distilled water to give a 1:5 ratio of soil to water without disturbing the soil at the bottom. Invert the jar slowly and gently once and then return to its original position. Avoid any shaking. Allow it to stand for 4 hrs.. Check the suspension above the sediment at the bottom of jar and score the amount of cloudiness as shown in Fig. 1.

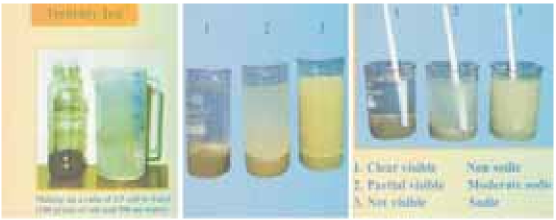

Fig. 1. Turbidity Test

Dispersion test: From each sample, select three aggregates or fragments about the size of a bean and place them carefully in the beaker or glass jar as shown in Fig. 2.

Carefully add enough rain or distilled water from the side to cover the aggregates. Do not move the container. Leave the container undisturbed for 20 hrs and carefully acess dispersion (milkyness in the water). Group it as clear water (no dispersion), partly cloudy (partial dispersion) and very cloudy (complete dispersion) as shown in Fig. 3.

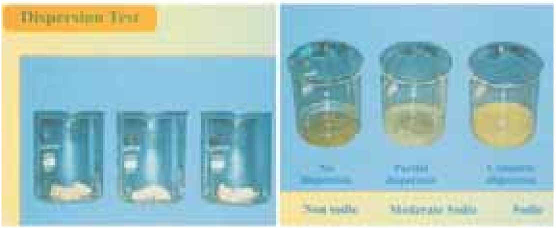

Fig. 2. Dispersion Test

Swelling test: Free swell index (FSI) indicates per cent increase in the soil volume in the distilled water system as compared to in a non-polar

Fig. 3. Swelling Test

system. This index was used to devise a colour chart to qualitatively determine the sodicity level of soil.

Take two graduated testtubes as shown or glasstubes marked in colour pencil at each centimeter interval. Fill both the tubes with the ground and sieved soil up to 1/3rd level.

Add rain-distilled-water slowly into one testtube and kerosene oil to other, give turn by putting thumb on the top, thoroughly mix the content and finally make the soil and water/kerosene oil ratio 1:1.

Keep it as such without any disturbance up to 24 hrs. Compare the gel thickness in the testtube with water to that of kerosene as shown in the figure and categorize the sodic soil as follow:

- No swelling/sight swelling-Non sodic
- 1.5 times swelling of soil in water as compared to kerosene oil-Moderate sodic

More than 1.5 times swelling of soil in water as compared to kerosene oil-sodic.

Performance results

The field kit was developed on the basis of soil's swelling, slaking and dispersion behaviour and qualitative determination of sodicity could be judged from the colour chart provided in the kit.

Cost of the technology

₹500/-

Impact and benefits

It is helpful in identifying the sodicity in the field condition by applying these test to the soil. Farmer can himself perform these test to confirm whether soils of his/her field is sodic or not using these simple test through this simple soil sodicity kit.

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Zinc, Iron, Boron and Suphur doses for rice-wheat cropping system in calcareous soils

Salient features

Wheat crop, left plot treated with zinc and sulphur and right control (only NPK) in calcareous soils of Muzaffarpur district

Rice crop, right plot treated with zinc and sulphur and left control (only NPK) in calcareous soils of Muzaffarpur district

Nutrients to be applied when below critical limit

(i) Zinc (critical limit in soil 0.78 mg/kg) - @ 5 kg Zn or 2.5 kg Zn with 5 t FYM per ha in rice only.

(ii) Iron (critical limit in soil 7.0 mg/kg) - Foliar spray with 1% Ferrous sulphate + 0.2 % citric acid solution 2-3 times at 7-10 days intervals to each crop. Lime juice can be used instead of citric acid.

(iii) Boron (critical limit in soil 0.5 mg/kg) - 16 kg Borax along with 5 t of organic manure per hectare as basal dose once in rice only.

(iv) Sulphur (critical limit in soil 13.0 mg/kg) - 60 kg S per ha as basal dose in rice only

Performance results

Depending upon the extent of deficiency, the average response in yield varied from 10 to 50%.

Cost of technology

At an average intervention cost of ₹1,000/- tonne, the farmers will get an additional net profit of approx. ₹9,000/- per ha.

Impact and benefits

(i) Average benefit of 6.0 and 4.0 q/ha in rice and wheat yield, respectively.

(ii) Improvement in nutrient content in crops.

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Furrow application of lime for amelioration of acid soils

Salient features

The broadcast method of lime application required large quantity of lime (3-4 tones ha^{-1}) which proved to be uneconomical. Application of lime @ 2-4 q/ha along with recommended dose of fertilizer in furrows at time of sowing proved highly cost effective.

Performance results

The technology tested in acid soil regions has increased the yield of various crops by 50-109% over conventional practices. In case of oilseed and pulses, 50% saving of N,P, K fertilizers has been recorded.

Cost of technology

₹500/- per hectare

Impact and benefits

The technology has the potential to raise the productivity by 1 tone ha^{-1} which may result into 12 million tonnes additional agricultural production per annum.

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Amelioration of acidic soils through headgerow intercropping

Salient feature

- Land degradation, soil fertility and acute shortage of fodder are some of the factors responsible for poor agricultural productivity in rainfed upland ecosystems.
- Acidic soils in Hills and Plateau regions limits the crop yield to a great extent. To address the problem, various nitrogen fixing hedgerow species were screened and *Tephrosia candida* has been found most suitable species for cultivation in Hill and Plateau regions of the Eastern states.

Performance results

- Thick rows of *Tephrosia* could be planted across the slope at a distance of 10 to 15 m, depending on the topography. The plants are pruned at knee height after six month of plantation.
- The pruned biomass could be used as a green mulch and also fodder to the livestock. The pruned biomass productivity range from 6.46 to 10.86 t/ha/yr (Fresh weight basis).
- The N, P and K concentration in the foliage of *Tephrosia* was estimated to be 3.67, 0.67 and 1.51%, respectively, and it could add 54.62 kg of nitrogen, 4.90 kg of phosphorus and 25.55 kg of potassium into the soils besides 40% increase in organic carbon content.
- The soil pH also increased to 5.16 from the initial value of 4.67.
- The species could be propagated successfully through seeds and the seeds are easy to germinate. However, prior to sowing, seeds are soaked in cold water for 24 hr so as to obtain the homogenous germination.

Cost of technology

₹5,000 per ha of land

Impact and benefits

- Liming is the common practice for amelioration of acidic soils. The $CaCO_3$ required to raise topsoil pH by 1.0 unit is 5 t/ha/yr of lime, which need to be repeated every 5 years. On average, pruned biomass of *Tephrosia* provides 84 kg of Ca/ha/yr, which is equivalent to 210 kg of $CaCO_3$. It is almost 1/5 of the lime requirement. Hence, hedgerow intercropping of *Tephrosia* could successfully replace the application of the lime to counter soil acidity.
- On average, one kg of seed is sufficient to rehabilitate 15-20 ha of land.
- The species is suitable for rehabilitation of the acidic soils of eastern and north eastern states.

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Bench grafting in *Aonla*

Salient features

This is an easy technique for propogation of desired varieties of *Aonla* plants with high success. Grafted plants are prepared within a short span of time. They can be easily transported to long distances with negligible cost and damage.

Performance results

The 150-250 grafts can be prepared per day/person. Field establishment is >90%. It takes hardly one year to produce grafted plants in polythene bags. About 25 kg aonla fruits per plant can be harvested from 7th year, 80-100 kg/plant from 10th year onwards in addition to returns from field crops. During the past few years, 85 farmers have planted aonla in 110 ha in Uttar Pradesh and Madhya Pradesh states from planting material supplied from the Centre.

Cost of technology

₹30 per plant.

Impact and benefits

Aonla, a minor fruit plant has been found highly successful under agroforestry system particularly under rainfed situations. The species is common throughout India in the frost-free regions and known for its prolific and regular bearing, hardy nonperishable nature and medicinal property. Plants of known variety ('Krishna', 'Kanchan', 'NA-7') may be planted at 12 m × 8 m spacing in croplands. Deep ploughing once in 3 years in interspaces has been found quite effective for moisture conservation under rainfed condition and thereby improving survival, growth and productivity of tree as well as comparison crop. Vegetative propagation technique of *aonla* through soft wood cleft grafting with capping technique and bench grafting technique ensures true to the type production of quality planting material in polythene bags. This gives by and large 100% field establishment on account of intact earth balls and undisturbed root system. Bench grafting technique ensures timely availability of potted plant in shortest span. They are transport friendly. NRC for Agroforestry, Jhansi also imparts training in vegetative propagation of fruit plants.

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Eucalyptus-based agri-silviculture system

Salient features

Plants of improved clones of *E. treticornis* (C- 3, C-6, C-7 and C-10) under block plantation, boundary plantation and agrisilviculture system at 10 m × 2 m spacing in 5 year rotation enhanced the overall productivity on sustained basis.

Performance results

System yields timber, poles, paper pulp and fuelwood from harvesting /lopping of eucalyptus trees within short span (5-10 yrs). Total dry biomass (including above and below ground both) ranged from 92.97 to 294.30 kg/tree with an average value of 165 kg/tree. It is compatible with crops of Bundelkhand region.

Cost of technology

Improved clonal plant of eucalyptus cost ₹10 to 20 per plant

Impact and benefits

Eucalyptus wood is widely used as minor timber, poles, paper pulp and fuel wood and can be grown on short rotation basis. Boundary plantation: (2 m × 2 m in chess board pattern in 2-3 rows), block plantation (3 m × 3 m) or as agri-silviculture landuse with wheat (*rabi*) and blackgram (*kharif*) (10 m × 2 m) and the trees can be harvested at an age of 5-10 year depending upon need and market demand. The species is highly suited for boundary plantation under agroforestry system in rainfed areas. In view of rising demand for wood, the system will be remunerative to the farmers.

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Vegetative propagation of *Pongamia pinnata* through stem cuttings

Salient features

Stem cuttings (15 to 20 cm length) taken from selected mature mother trees (10 to 12-yr-old) during February and treated with IBA 400 ppm for 12 hrs. The stem cutting tips, covered with wax, are immediately placed in polythene bags (10 cm × 20 cm) filled with soil+FYM, watered and placed under partial shade or mist chamber at 25^{0}C and relative humidity 60–70 %. Sprouting takes place within 10–15 days and rooting within a month with more than 70 % success. The stem cuttings are ready for plantation in the ensuring monsoon.

Performance results

The vegetative propagated plants can be successfully out planted.

Cost of technology

Stem cutting plants cost ₹20.

Impact and benefits

Mother plant, IBA, mist chamber/partial shade, assured watering are the minimum input required. Depending upon size of nursery about 750 plants in 10m × 1 m nursery beds can be multiplied.

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Vegetative propagation of *neem* through air-layering for quick evaluation of germplasm

Salient features

One-year-old semi-hard terminal shoots of *neem* plant were air layered using 200 ppm IBA wrapped with wet moss grasses in July, which gave above 70% rooting in layers.

Performance results

Air-layered plants are true to the type.

Cost of technology

Air-layered plant cost ₹20.

Mother plants, IBA are the minimum requirement and depending upon size of mother plant about 750 plants in a year can be produced.

Impact and benefits

Such plants gives fruiting in ensuring summer and facilitate quick evaluation of germplasm for oil content and azadirectin, the active ingredient for insecticidal property.

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Agri-silvi model of poplar and sugarcane

Salient features

This is highly remunerative and very popular farming system among the farmers in the foot-hills and *tarai* region of Punjab, Haryana, Uttarakhand and Uttar Pradesh. Poplar plantations under agriculture have 20m^3 ha^{-1} mean annual increment in timber. Poplar grown at a spacing of 8 m × 3 m is inter-cultured with sugarcane planted at distance of 45 cm between rows. It is suitable for subtropical and tropical areas. This technology gives enhanced remuneration of ₹1.4 lakhs per hectare per year over a rotation of eight years.

Agri-silvi models

Performance results

- Sugarcane yield 45-50 tonne/ha/year when grown alone
- Poplar yield 15-20 m^3/ha/year when grown alone
- Sugarcane yield varies from 35-45 tonne/ha and poplar yield varies from 12-18 m^3/ha/year when grown in association.

Cost of technology

₹0.5 lakh input cost one time and ₹1.4 lakh output on 8 year rotation from one ha area

Impact and benefits

The technology yields quite high returns per unit of land as compared to mono-cropping of either crop. C:B ratio is 1:2.8.

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Agri-horticulture system
peach grown under wheat-soybean cropping system

Salient features

Peach *(Peach persica)* as a tree crop and wheat- soybean cropping system. The fruit trees of peach are planted at the spacing of 9 m × 4 m in the pit size of 90 cm^3. The wheat crop should be supplemented with 25% more nitrogen above the recommended dose (80 kg ha^{-1}).

Performance results

The net returns from this system can realized to the extent of 1,88,800 per ha per year.

Cost of technology

Peach plant costing ₹25 per plant.

Impact and benefits

Peach-based system are quite popular in the sub-temperate ecosystem in the Sirmour district of Himachal Pradesh, which has got subtemperate to temperate climatic conditions.

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Superior subabul (*Leucaena leucocephala*) variety (K-636) for pulpwood industry

Salient features

- Variety K-636 of *Leucaena* recommended for pulpwood in regions receiving an annual rainfall of 700-1300 mm for all type of soils except waterlogged situations.
- K-636 cultivar of *Leucaena* produces less seeds, fewer branches and has straight bole.
- Suitable for intercropping with short duration pulses during the initial two years.
- The spacing recommended is 3 m × 0.75 m.

Performance results

- *Leucaena* biomass production ranges from 50-75 tonne/ ha / 3 years, yielding a net return of ₹40,000 to 60,000/ ha/ 3 years.
- Farmers can get an additional return from the intercrop.
- Tree leaves can also be used as fodder

Cost of technology

The cost of seed is about ₹500/ha
Seed rate: 2.5 kg/ha

Impact and benefits

The species is well suited for agroforestry plantation. Looking into future demand of pulpwood, the system will be remunerative to the farmers.

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Sunken bed technology for nursery production

Salient features

- The technology is especially developed for production of summer vegetables nursery under foggy conditions in winter. Germination process of seeds is enhanced in sunken beds when compared with raised beds/poly tunnels/ NV polyhouses sowing.
- Prepare a trench of any length, 1.2 m wide and 45 cm deep. Essentially new trench should be excavated every time.
- Prepare a raised bed of 5-10 cm height at the bottom of the trench. The soil should not be imported from outside the trench. Albeit, FYM (25kg) and inorganic fertilizer mixture (100 g) may be added as recommended for raised beds.

Performance results

The chilli seeds germinated within 20 days under foggy conditions in sunken bed as compared to 26 days in raised beds covered with white polythene, 30 days in natural, ventilated polyhouses and 58 days in raised beds covered with grass.

Cost of technology

Cost is incurred only for the purchase of transparent polythene sheet, which may cost around ₹100 for 6 m × 3 m length.

Impact and benefits

The seedlings produced under sunken bed shall be ready for transplanting early in February/March depending upon the farmers requirement. The early transplanting will also protect the crop from scorching heat.

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Gum inducer technology for production of gum-Arabic from *Acacia senegal*

Salient features

- A simple process of administration of gum inducing (ethephon) solution (4 ml) of specific concentration into the main stem of the tree through a small hole.
- Gum exudation starts within 5 to 10 days and lasts up to 1-2 months.
- Generally, in western Rajasthan treatment time starts from February and extends up to May.
- The physico-chemical characteristics of the exuded gum conform to Indian Pharmacopoeia .
- Gum production on application of the Technology – 500 g (average) per tree.

Performance results

The technology is well perfected and time tested. It has more than 90% efficiency at farmer fields in arid zone. The capacity of operation is 50 trees/ person/day during the period of gum exudation. The operational losses are to the tune of 10%.

Cost of technology

- Cost of treatment : ₹10 per tree
- Gum production : 500 g per tree
- Current sale price of gum : ₹500-700 per kg

Impact and benefits

Normally the farmers make a blaze in the tree trunk for obtaining gum Arabic. This is a conventional method and by this procedure farmers get 15-25 g of gum arabic/ tree. By using gum inducer technology, the exudation of gum/ tree ranged between 300 and 800 g/ tree, with an average of 500 g/ tree. The rate of pure gum Arabic in the market is ₹500-700/kg. In gum belt of arid region of western Rajasthan, on an average farmers have 20-25 trees/ ha on agricultural fields in different parts. Treating half of the trees in alternate years, a farmer can earn ₹11,500-13,000/ha. By using this technology, the farmers of target villages in Barmer, Jodhpur and Nagaur district have earned a revenue of about ₹194 lakhs between 2009-10 to 2011-12.

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Neem pellets for the control of termites

Salient features

Under dry and warm growing conditions of arid and semi-arid regions, crops are highly prone to attack of termites which may cause losses to the extent of 35-40%. Use of neem products (neem pellets) have been found effective in minimizing termite infestation.

- Process: Collection of neem fruits (June-August)
- The fruits are depulped, dried and processed after 2-3 months fortified with 1% *Eucalyptus* oil
- Contents: 20-30% Neem oil, 65-75% Neem Cake, 0.1-0.2% *Azadirachtin*, 0.01% Nibin, 0.01-0.02% Nimbidin, 0.01% Nimbinin
- Neem pellets contain 5.2% Nitrogen, 1% P_2O_5, 1.4% K_2O.

Performance results

Processing capacity: 40-60 kg/hr

Cost of technology

Cottage industry set up for farmers: ₹1,20,000/-; Pay back period: 1 year; ₹3/kg operating cost

Impact and benefits

The farmers can have own cottage industry for extra income to minimize the use of pesticides by using these pellets for managing termite in their farm.

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Bio-formulations for managing soil-borne plant pathogens

Salient features

Soil-borne plant pathogens cause enormous losses to the valuable crops like cumin and legumes grown in arid regions of the country. Use of native bio-control agents have been found effective in reducing these losses. Bio-formulated products of these bio-control agents have been prepared and having shelf-life of more than 90 days.

- Maru Sena 1: *Trichoderma harzianum* based formulation effective against wilt of cumin (40% loss) and dry root rot of legumes (60-65% loss). Used as seed treatment (4 g/kg seed) or soil application@1 kg/ha mixed with farmyard manure.

- Maru Sena 2: *Aspergillus versicolor* (survives at >65°C in dry soils), antagonistic to *Fusarium oxysporum* (wilt of cumin) to be used @1kg ha^{-1} mixed with farm yard manure
- Maru Sena 3: *Bacillus firmus*, specific to *Macrophomina phaseolina* (causative agent of root rot in legumes) used for seed coating @ 400 g for 16 kg seed.

Performance results

Bio-formulated products were found effective in managing wilt of cumin and dry root rot of legumes.

Cost of technology

Estimated cost/unit: ₹3300/-; ₹20/- per packet (100 g)

Impact and benefits

Reduced wilt and dry root rot incidence of cumin and legumes, respectively. This will in turn will enhance seed yield at farmers' field.

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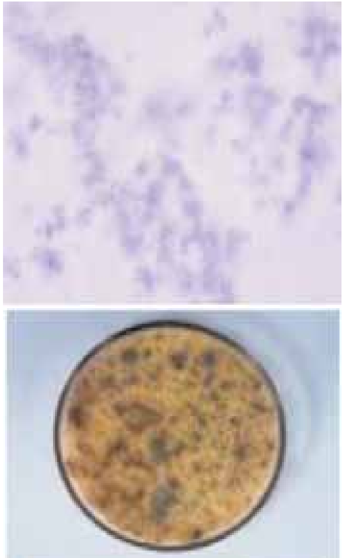
Bio-Phos–a native phosphorus mobilizing organism

Salient features

The biological phosphorus fertilizer (Bio-Phos) has been developed which is very effective for use in crops.

- The organism is capable of solubilizing both unavailable inorganic (mineral) and organic P.
- Components: Pure spores of *Chaetomium globosum* (viable cell count CFU 10^7-10^9 cell/g at 35°C, moisture content 30-40%); Sticking solution ; Absorbent material.
- Recommended for all soil types.
- Used as seed innoculant approximate dose 500g/ha depending upon seed size.



Chaetomium globosum

Performance results

- Expected yield increase: 16-25% (which is equivalent to 45-60 kg SSP ha^{-1})
- Biomass production increase: 15-22%
- Increase in seed P concentration: 32-35%

Cost of technology

Estimated cost : ₹50 per kg

Impact and benefits

P fertilizer is very costly as compared to Bio-Phos; B:C ratio 16:1

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Biodegradable plastics from poly-hydroxy butyrate production by eco-friendly *Rhizobia*

Salient features

- The bio-plastic developed under the process can be used in packaging, medicine and agriculture for a wide range of applications
- Maximization of poly-α-hydroxybutyrate (PHB) production using commonly available agri-byproducts has been standardized. *Rhizobium* spp. mutants with improved polyhydroxy butyrate formation from agribyproducts have been generated and as much as 59.5 % of total biomass produced has been found to be extractable as PHB.

Performance results

- A cost effective and total eco-friendly protocol has also been developed for the production of fully bio-degradable plastics from this mutant rhizobia using economical and abundantly available agri-byproducts like mustard and cotton cakes.

Cost of technology

- ₹12 lacs for technology licensing (non-exclusive and non refundable).
- The CCSHAU has all the rights to revise the licensing fee as and when required.

Impact and benefits

Recently potato-peel, a kitchen waste, and potato industry refuse has been successfully utilized in growth media formulation towards value addition in the form of low cost PHB production.

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Integrated rodent pest management using environment friendly plant-based products

Salient features

Potential of plant essential oils as repellents against rodent pests and other plant products as reproductive inhibitors of predominant rodent species is being studied for use in integration with chemical control. This will lead to reduced usage of rodenticides as well as a method effective in long term and ecofriendly in nature.

Performance results

Castor oil (5%) has shown both repellent and antifeeding effects against *Rattus rattus* and *Tatera indica* with sustainability up to 2-3 weeks, whereas, triptolide (0.2% in bait) obtained from plant *Tripterygium wilfordii,* has shown effectiveness in reducing resiliency in population of *R. rattus* in poultry farms upto 60 days of treatment.

Cost of technology

Field-scale testing and determination of cost and output per unit area yet to be conducted.

Impact and benefits

Continuous use of rodenticides leads to the development of bait shyness and resistance among rodent species besides causing non-target toxicity hazards. The integration of above environmentally safe technologies will lead to the development of long-term management of rodent pests thus reducing the direct and indirect damages caused to foodgrains both at pre-and post-harvest stages ultimately leading to economic benefit to the farmers.

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ISBN 817164155-5

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