Institute Technology Management Unit

ICAR-Indian Institute of Soil Science, Bhopal

Date: 27 September, 2018

Sub: RTI query IIOSS/R/2018/50005 of Milton David

Ref: ICAR-IISS Note Application No. 151-09/IISS/RTI/2018 dated 06.09.2018

1. As per the record available in ITMU there is one technology filed for patent in India from IISS, Bhopal.
   Technology: Mridaparikshak mini lab

   a. Relevant document attached (sheet 1)
   b. Information available at IISS website (www.iiss.nic.in)
   c. Information not available in our record
   d. Sheet 1 attached
   e. Dr. Sanjay Srivastava
   f. Information not available in our record
2. International patent under PCT is filed. However not applied in any specific foreign country so far. Sheet 2 attached.

   a. As in sheet 2 read along-with sheet 1
   b. As in 1b
   c. As in 1c
   d. Sheet 2 attached read along-with sheet 1
   e. As in 1e
   f. As in 1f
3.

a. Information obtained from ICAR-IISS library is enclosed. This includes relevant pages from
   - IISS: Two Decades of Soil Research (Pages 76-84 enclosed)
   - Glimpses of IISS Contribution in Technology Generation and Dissemination (2014), Compiled and Edited by A. Subba Rao, A.B. Singh, R.H. Wanjari, K Ramesh, M. Vassanda Coumar, K.|C. Shinogi (Pages 5-83 and 119-123 enclosed).
   - ICAR-IISS Annual Report 2014-15 (pages 65-83 enclosed)
   - ICAR-IISS Annual Report (2015-16, pages 63-73, enclosed)
   - ICAR-IISS Annual Report (2016-17) (Pages 67-87) available at www.iiss.nic.in
   - The list of institute technologies is also available at http://www.iiss.nic.in/Institute%20Technology.html

b. The information is available in the answer of 3a.

Sanjay Srivastava
I/c, ITMU

To,
Dr. R. Elanchezhian
PS & Nodal Officer cum CPIO RTI (Scientific)

Sheet 1

Sum

Appendix II

PATENT OFFICE
INTELLECTUAL PROPERTY BUILDING
Plot No. 32, Sector 14, Dwarka, New Delhi-110075
Tel No. (091)(011) 28034304-06 Fax No. 011 28034301,02
E-mail: delhi-patent@nic.in
Web Site: www.ipindia.gov.in

सत्यमेव जयते

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

G.A.R.6
[See Rule 22(1)]
RECEIPT

Docket No 26356

Date/Time 14/08/2015 17:33:57

UserId: userid0401

To
TARUN KHURANA

S/19-22, IFAIA Center, Greater Noida
Shopping Plaza, Site IV, Kasna Road, Plot
7/2

CBR Detail:

Sr. No.	Ref. No./Application No.	App. Number	Amount Paid	C.B.R. No.	Form Name	Remarks
1	2522/DEL/2015		9600	17469	FORM 1	DEVICE AND METHOD FOR MEASUREMENT OF SOIL HEALTH PARAMETERS AND FERTILIZER RECOMMENDATION

TransactionID	Payment Mode	Challan Identification Number	Amount Paid	Head of A/C No
N-0000123837	Online Bank Transfer	0280634140820155O428	9600.00	1475001020000001

Total Amount : ₹ 9600

Amount In Words: Rupees Nine Thousand Six Hundred Only

Received from TARUN KHURANA the sum of ₹ 9600 on account of Payment of fee for above mentioned Application/Forms.

* This is a computer generated receipt, hecnce no signature required.

Sheet 2

FORM 3
THE PATENT ACT, 1970
(39 OF 1970)
&
The Patents Rules, 2003
STATEMENT AND UNDERTAKING UNDER SECTION 8
(See section 8, rule 12)

We, **INDIAN COUNCIL OF AGRICULTURAL RESEARCH** hereby declares,

(i) that we who have made this Application No. **2522/DEL/2015** Dated **14/08/2015** alone, made for the same/substantially same invention, applications for patent in the other countries, the particulars of which are given below :

Name Of The Country	Date Of Application	Application No.	Status Of The Application	Date Of Pub./ Pub. Number	Date Of Grant/Grant Number
PCT	12-08-2016	PCT/IB2016/054853	Application Published	23-02-2017 [WO/2017/029592]	-

(iii) That the rights in the application(s) have been assigned to **INDIAN COUNCIL OF AGRICULTURAL RESEARCH**, and that I undertake that up to the date of grant of the patent, by the Controller, We would keep him informed in writing the details regarding corresponding applications for patents filed outside India within three months from the date of filing of such application.

Dated: 11th day of Aug, 2018

Signature:

Name:
Tarun Khurana (INPA-1325)
Khurana & Khurana, Advocates and IP Attorneys

To,
The Controller of Patent
The Patent Office, Delhi

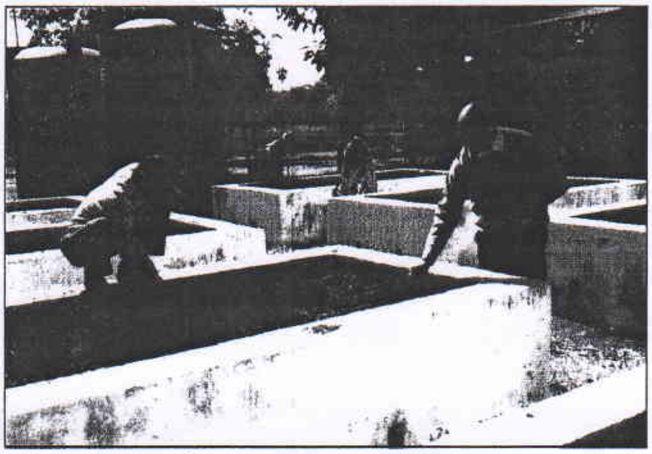
XII. DEVELOPMENT OF TECHNOLOGIES

1. Technologies

1.1 Production of microbial enriched Phospho-Sulpho-Nitro compost by pit method

Different crop residues (soybean, wheat and mustard) and city garbage can be recycled through this technique. For the preparation of microbial enriched compost the following steps were followed:

- First, bright sunlit place was selected, and cemented pits of size 1m x 1m x 1m was prepared
- The crop residues were mixed with fresh cow dung in the ratio of 5:1 (w/w) on material dry matter basis and placed in the cemented pits
- Low cost mineral amendments such as rock phosphate (Mussouri phosphate, 100 mesh), pyrite and urea-N were added @ 5 % P_2O_5, 10 % (w/w) and 0.5 % urea-N, respectively to the mixture. The contents were mixed thoroughly with fresh cow dung slurry (60-70 % moisture)
- Fungal culture was added @ 500 g mycelial mat per tonne of materials, whereas bacterial culture was added @ 50 ml kg^{-1} of material having 10^8 viable cell/ml. Initially for 1-3 days, bioinoculum was added twice in the mixture owing to a high initial temperature (55 to 70°C) and thereafter, the frequency of addition of inoculums decreased gradually



Pit method of composting

- The materials were allowed to decompose in the pits
- Polyvinyl chloride tubes were inserted vertically as well as horizontally, for sufficient aeration throughout the decomposition period
- The filled pits were covered with polythene sheets to prevent entry of rain water and insects etc.
- The compost was ready for field application after 110±15 days

1.2 Preparation of Phospho-Sulfo-Nitro compost by heap method

- For heap method, a cemented floor was selected so that nutrients do not percolate in to the soil
- The ingredients required for the preparation of compost by heap method are given in Table 1
- In this method, in a heap of dimensions 7.5 ft x 6 ft and 3 ft depth, about 500 kg of wastes was added
- The residue was spread in 16 layers and in each layer the following proportion of organic and inorganic ingredients were added:
  - 15 kg of wastes spread on the floor followed by 15 kg of fresh cow dung (dry weight basis)
  - 330 g urea (0.5 %-N basis) dissolved in 1-litre water
  - 10-litre water
  - 8.6 kg Mussori rock phosphate (5 % P_2O_5 basis from Mussori rock phosphate containing 17.5 % P_2O_5)
  - 3 kg Pyrites (22 % S content and added @ 10 % on materials dry weight basis)
  - Soil @ 5% on materials dry weight basis.
- To protect from rain, wind, and to maintain the moisture and temperature a polythene sheet was used to cover the heap

- After 3-4 weeks of decomposition, the first turning of heap was done.
- The moisture was maintained at 60-70% of materials on dry weight basis
- The compost was ready after 3 months and about 250-300 kg of enriched phospho-sulfo-nitro-compost was recovered from this method.

Stages of compost by heap method

Table 1. Ingredients required for preparation of 500 kg of Phospho-Sulpho-Nitro compost by heap method 250+250+143+50+5.5+25

Waste (kg)	Fresh cow dung (kg)	Rock phosphate (kg)	Pyrites (kg)	Urea (kg)	Soil (kg)
250	250	143	50	5.5	25

1.3 Use of spent wash in compost preparation

Spent wash has vast potential for its practical application in agriculture as a source of plant nutrients and organic matter and as an amendment for sodic soils. However, high transportation and labour costs for loading and unloading restrict their wider use beyond the sugar factory and the distillery zone. Hence, there is a need for transforming the liquid effluent into solid form to make its transportation easier and cheaper. Moreover, on the face of scarcity of water in semi-arid tropics of India, there is a need for looking for the alternate source of water for compost preparation , and spent wash being an organic carbon rich wastewater can be utilized perfectly. In view of this, a new process of composting has been developed at IISS, Bhopal by replacing water with distillery effluent. The compost was prepared by heap method using the standard procedure developed at the Institute for enriched compost preparations except that water was replaced with spent wash. This has not only saved precious little water but also enriched the compost with useful nutrients like N, P, K, S and enzyme activity, apart from other growth promoting substances available in the effluent (Table 2). Crop performance of this compost was tested in maize-chickpea system in a black soil and results indicated that it was as good as or even better than FYM and conventional compost.

Table 2 : Composition of spent wash amended compost at different sampling period

Sampling Details	Ash (%)	Total N (%)	Total P (%)	Total K (%)	C:N
Ist Sampling					
Control	54.55	1.13	1.22	1.05	23.33
Before SW addition	61.80	1.03	1.22	1.13	20.95
After SW addition (400L)	60.73	1.09	1.49	1.66	20.89
2nd Sampling					
Control	60.07	1.37	1.08	1.23	16.90
Before SW addition	70.37	0.89	1.24	1.26	19.31
After SW addition (200 L)	70.83	0.99	1.25	1.52	17.45
3rd Sampling					
Control	66.88	1.31	1.08	1.03	17.00
Before SW addition	64.74	1.16	1.28	1.57	17.60
After SW addition (200L)	66.33	1.37	1.31	1.82	14.25

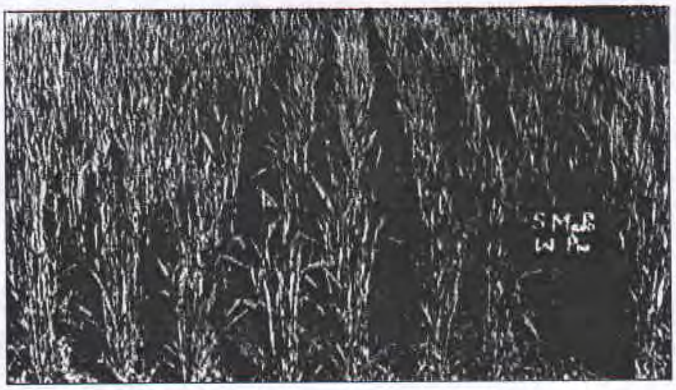
1.4 Integrated nutrient management technology for soybean-wheat system

Integrated Nutrient Management Technology for soybean-wheat has been developed at the Institute. A series of field experiments on soybean-wheat system on Typic Haplusterts (Vertisols low in N, P, S, and Zn) indicated that application of FYM in conjunction with fertilizer N, P, S and Zn was better in improving the externally applied nutrient use efficiency, productivity of soybean-wheat system as well as soil fertility than the application of fertilizer or manure alone. The technology provides different option to the farmers depending upon the availability of FYM and fertilizer resources with them for achieving soybean seed yield of 2 t ha^{-1} or more and that of grain yield of irrigated wheat grain yield of 3.5 t ha^{-1} or more in deep black soil of the agro-ecological zone 10 with the application of the following combination of FYM and fertilizer N, P, S and Zn (Table 3).

This technology of integrated nutrient management is recommended for adoption to the farmers of the Agro-Ecological Region 10 and for forming a part of package of practices of the universities/Institutes of the region as well as of the soil testing laboratories/extension agencies for enhancing the efficiency of the fertilizer nutrient and the productivity of soybean-wheat system as well as improving soil health.

Table 3 : Integrated nutrient management technology for in soybean-wheat system

Rate of FYM Application (t ha^{-1})	Application rate of fertilizer nutrient (kg ha^{-1}) to achieve							
	Target yield of 2 t ha^{-1} or more of soybean seed				Target yield of 3.5 t ha^{-1} or more of wheat grain			
	N	P	S	Zn	N	P	S	Zn
0	35	39	40	12	135	40	40	0
4	25	24	20	6	120	32	20	0
8	12.5	15.5	0	3	90	22	0	0
16	0	0	0	0	90	10	0	0



1.5 Integrated N management in rice-wheat on Vertisol

Integrated use of FYM (5 t) or green manure (6 t) in conjunction with 90 kg (two splits) fertilizer N in rice and 110 kg N/ha in subsequent wheat sustained 4.5 t ha^{-1} yield of rice and 4 t ha^{-1} yield of wheat in rice-wheat system. The technology developed not only sustained the productivity of rice-wheat in Vertisol but also improved the physico-chemical health of the soil. Significant improvement in soil organic C content and availability of P, K and S ensured the safeguard of the natural resources of soil. Adoption of the technology also saved 65-70 kg N ha^{-1} yr^{-1} without reduction in productivity in addition to improvement in N use efficiency by 3-4 per cent.

1.6 Irrigation optimization vis-a-vis nutrient management in Indian mustard and wheat

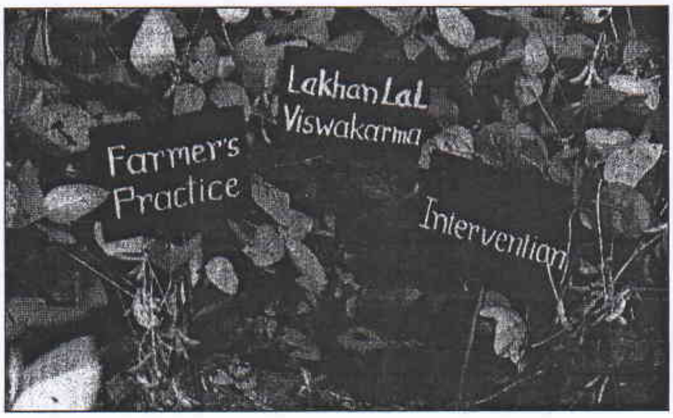
Results of a three years experiment on soybean-mustard rotation under different irrigation levels and nutrient management treatments showed that application of 100% recommended dose of NPK with 10 t FYM/ha applied to the previous soybean crop and one irrigation applied to mustard at flowering stage produced seed yield of mustard at par with 100% NPK dose with two irrigations i.e., one at rosette and flowering stage. Organic matter application through the FYM improved the physical properties of the surface soil particularly MWD, hydraulic conductivity and water retention characteristics.

In Soybean-wheat rotation, wheat under 100% recommended dose of NPK with residual FYM @10t/ha and two post sowing irrigations (at CRI and flowering) yielded at par with the treatment where 100% recommended NPK dose with three irrigations were applied (at CRI, maximum tillering and flowering). In FYM treated plots along with two irrigations to wheat, the water use efficiency was also higher than the treatment where three irrigations were applied to wheat.

2. Participatory Technologies

2.1 Farmers' resource based integrated plant nutrient supply system for soybean-wheat on Vertisols

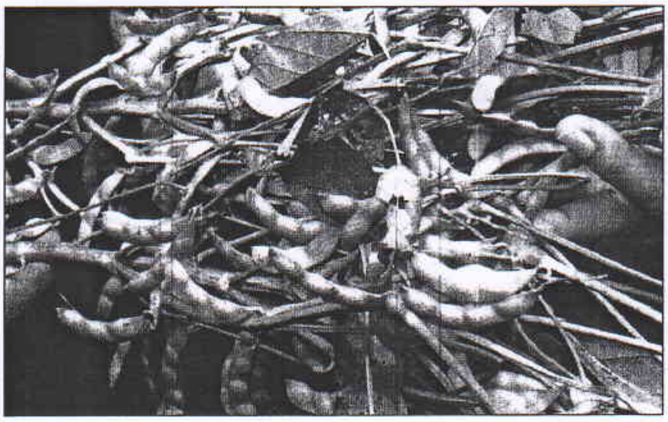
Integrated plant nutrient supply (IPNS) system is a proven nutrient management strategy for sustaining agricultural productivity and soil health. In most cases, however, the IPNS research has been confined to research stations without considering the availability of organic sources and their competitive uses, and the technological options specific to farming situation are scarce. Farmers' resources based integrated nutrient management technology has been developed for soybean-wheat system for Malwa region and further refined by assessing the farmers' resource base with regard to organic manures and water availability through Participatory Diagnosis of Constraints and Opportunities (PDCO) survey. Results of the field trials showed that in soybean-wheat system, balanced fertilization based on soil tests with 4 t FYM ha^{-1} to soybean crop was the best in terms of system productivity. Farmers' resource-based IPNS intervention as calculated from targeted yield equation based on soil test crop response produced 8-49% more soybean yield and 11-39% more wheat yield as compared to farmers' practice.



2.2 Low-cost integrated nutrient management (INM) technology for soybean-wheat system

On-farm trials conducted in different villages of Rajgarh, Vidisha and Bhopal districts of Madhya Pradesh to evaluate the efficiency of different integrated nutrient management

(INM) modules for sustaining higher productivity of soybean-wheat system vis-à-vis farmers' practice showed that the INM Module, comprising 50%NPKS + 5tFYM/ha + *Rhizobium* to soybean and 75%NPKS + phosphate solubilizing bacteria (PSB) to wheat proved to be an economically viable technology for higher yields. In *kharif* season, integrated use of 50%NPKS + 5t FYM/ha + *Rhizobium* to soybean increased the seed yield by 11% and 25% over the chemical treatment (100%NPKSZn) and Farmers' Practice, respectively (Table 4). *Rhizobium* inoculation with 50%NPK + 5t FYM/ha produced 6% higher yield over 50%NPK + 5t FYM/ha without *rhizobium*. In *rabi* season, this INM Module which comprises 50%NPKS+5tFYM/ha+*Rhizobium* to soybean and 75%NPKS+phosphate solubilzing bacteria (PSB) to wheat produced 16.3% higher wheat grain yield over the farmers' practice (FP). This INM module produced not only the higher yields of soybean and wheat but also saved 42 kg N, 45 kg P_2O_5, 15 kg K_2O, 15 kg S and 5 kg Zn/ha/year in a soybean-wheat system. When soybean and wheat crops were considered together as a soybean-wheat system, this INM module gave the highest net returns (Rs. 61,240/ha), which was 24% higher as compared to the farmers' practice (Rs. 49,264/ha). The benefit: cost ratio of this INM module in the soybean-wheat system was also higher (2.83: 1) among all the options tested.



Pod bearing under INM

Project scientists discussing about the pod bearing with the farmers

Table 4. Economics of INM in Soybean-Wheat System

INM Modules	Details of the INM modules	Mean grain yield (kg/ha)		Gross income (Rs/ha)	Total cost (Rs/ha)	Net returns (Rs/ha)	B: C ratio
		Soybean	Wheat				
INM Module 1	100% NPKSZn to soybean and 100%NPKS to wheat	2099	5001	83010	22668	60342	2.66
INM Module 2	50%NPKS+5t FYM/ha to soybean and 75%NPKS to wheat	2198	4783	81362	21567	59795	2.77
INM Module 3	50%NPKS+5t FYM/ha+*Rhizobium* to soybean and 75%NPKS+PSB* to wheat	2325	4792	82861	21621	61240	2.83
FP	Farmer's Practice	1864	4121	69699	20435	49264	2.40

Table contd...

Note :

100% NPKSZn	Soybean : 25 kg N, 60 kg P_2O_5, 20 kg K_2O, 20 kg S and 5 kg Zn/ha
	Wheat : 120 kg N, 60 kg P_2O_5, 20 kg K_2O and 20 kg S
Farmers' practice	Soybean : 12.5 kg N and 30 kg P_2O_5/ha
	Wheat : 80 kg N and 50 kg P_2O_5/ha
*PSB - Phosphate Solubilizing Bacteria	

2.3 Balanced fertilization technology for improving the productivity of wheat

The average productivity of wheat in Madhya Pradesh (M. P.) state is lower than the national average. A survey conducted in selected villages of M. P. indicated the emerging multi-nutrient (N, P, S, Zn) deficiencies. This was coupled with the application of only N and P by farmers that too at lower rates. On-farm trials conducted in Geelakhedi (Rajgarh district), Mugaliahat (Bhopal district) and Rangai (Vidisha district) villages revealed that the balanced application of N, P, K, S and Zn at recommended rates (120 kg N, 60 kg P_2O_5, 20 kg K_2O, 20 kg S and 5 kg Zn/ha) increased the wheat grain yield by 15-24% as compared to framers' practice. The results of these trials clearly indicated that higher wheat grain yields could be sustained by encouraging farmers to correct N, P, S and Zn deficiencies by adopting appropriate nutrient management practices. There is a great scope for transfer of this technology in the three districts - Bhopal, Vidisha, and Rajgarh for increasing and sustaining higher productivity of wheat.

2.4 Balanced fertilization technology for improving the productivity of soybean

The balanced application of N, P, K, S and Zn at 25 kg N, 60 kg P_2O_5, 20 kg K_2O, 20 kg S and 5 kg Zn/ha, respectively increased the soybean grain yield by 20-25% as compared to farmers' practice in field trials conducted in different villages Rajgarh, Bhopal and Vidisha districts.

2.5 Nutrient input, output and balance of farmyard manure production by farmers through conventional method

Under the ACIAR project, simple mass balance studies have been conducted by selecting a FYM pit of Mr. Hukum Singh, Geelakhedi village, Rajgarh district in Madhya Pradesh. The depth of this pit was about 1.2 m. In each month the dried samples of each type of organic materials that put into the FYM pit were pooled together to obtain a composite sample and were processed and analyzed for total N, P, K, and C. At the end of the 9th month, based on the nutrient concentrations of different types of materials, total amount of each nutrient input into the FYM pit and the nutrient content in the FYM at the end were computed to work out the nutrient recovery in FYM and apparent loss. The results revealed that the cattle dung was the main component of the FYM (66.9%) followed by cattle shed wastes (20.4%). About 40% of N, 23% of P and 36% of K put into the FYM pit through different organic materials was lost during the FYM production through conventional method by farmers. There is a scope to improve the quality of FYM by reducing the losses from FYM pits by introducing simple and farmers' friendly modifications such as hybrid pit (between heap and deep pit) , thatched roofs etc in the Farmers' Practice of FYM production.

2.6 Integration of broad bed furrow (BBF) and balanced fertilization: An efficient management practice for successful cultivation of soybean on waterlogged fields

About 20-25% of cultivable land in Vidisha district is left uncultivated by farmers during *kharif* season due to waterlogging. Even though farmers sow some waterlogged fields with soybean, the yields are very low due to poor establishment of soybean. Most of the fields in this district were also deficient in N, P, S, and Zn. Therefore, three field trials were conducted in Rangai village, Vidisha district to demonstrate the beneficial effect of integration of farmer friendly drainage techniques and farmers practice of land configuration with balanced fertilization on soybean. These soils were low in available N, P, S and Zn but high in available K. The beneficial effect of integration of Broad Bed Furrow (BBF) with balanced fertilization (100% NPKSZn) on soybean seed yield was compared with that of farmers' practice of land configuration (1 furrow after every 11-12 rows of soybean) with balanced fertilization on waterlogged fields which could not be cultivated in most of the years. The results of these trials showed that the integration of BBF with balanced fertilization produced 38% higher soybean yield at site 1, 46% higher yield at site 2 and 48% higher yield at site 3 as compared to integration of farmers' practice with balanced fertilization (Fig. 1). The pooled data of three sites indicated that the integration of BBF with balanced fertilization produced 44% higher soybean yield over the integration of farmers' practice of land configuration with balanced fertilization.

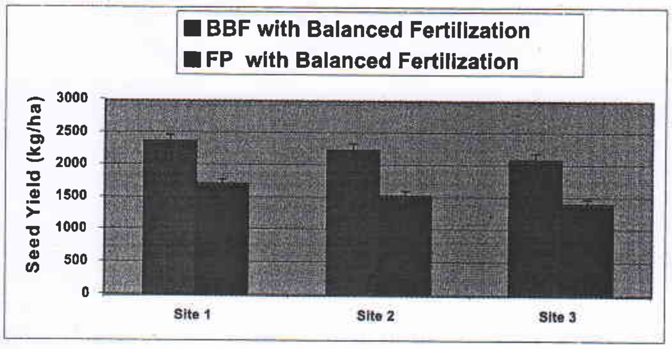
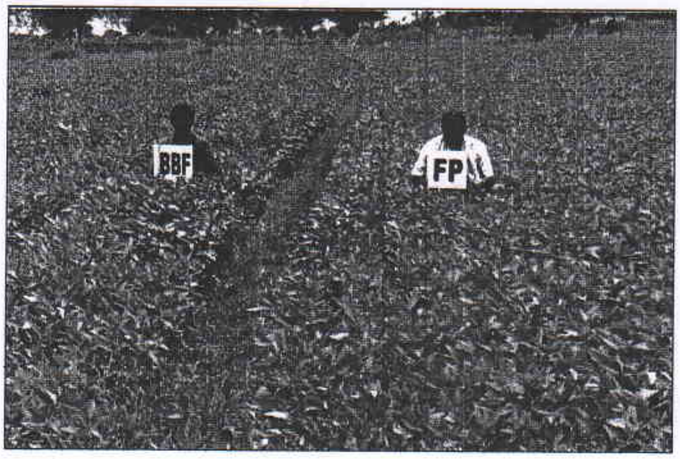


Fig. 1. Effect of integration of BBF and balanced fertilization on soybean seed yield on waterlogged fields.

Fig 4.68 Soybean crop stand at 60 DAS on broad beds and flats



Soybean crop stand at 35 DAS on broad beds and flats

Soybean crop stand at 20 DAS on broad beds and excess water flowing through furrows into the nearby pond

2.7 Safe prescription limits for direct application of distillery effluents in agriculture

The disposal of spent wash, a distillery waste has long been a problem of the industry. On the other hand, it is reported to have good manurialvalue and a very rich source of organic matter. But it is presumed that although the effluent may facilitate better yields at the beginning due to its richness in nutrients, its continuous and indiscriminate use and abuse may cause accumulation of salts endangering the soil productivity and sustainability. Based on the crop performances and long-term implications of use of different distillery wastes on soil physical, chemical and biochemical parameters, suitable management prescriptions have been devised for efficient utilization of these waste products in soybean-wheat, maize-chickpea and groundnut-wheat systems in deep black soils (Table 5). On-farm demonstration is going on at the institute with the following prescriptions.

Table 5. Options safe use of distillery effluents

Sl. No	Soybean (rainfed)	Wheat (one pre-sowing plus two post-sown irrigations)
1	2.5 cm SW	N & P Fertilizers only
2	2.5 cm SW	1.25 cm SW + two top-dressings of N (1/4N +1/4N)
3	2.5 cm PME	N & P Fertilizers only
4	2.5 cm PME	1.25cm PME + two top-dressings of N (1/4N +1/4N)
5	5 t ha^{-1} LS	N & P Fertilizers only
6	5 t ha^{-1} LS	10 t ha^{-1} LS + two top-dressings of N(1/4N +1/4N)

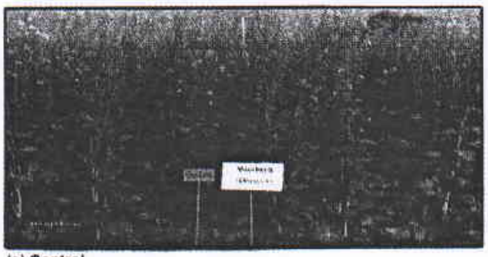
SW = Spent Wash, PME = Post-Methenation Effluents, LS = Lagoon Sludges (RSW, PME and LS to be applied 7-15 days before sowing).
P-1, P2, P3, P4, P5, P6

The contribution made on this aspect has lead to the development of a technology for safe disposal of otherwise polluting distillery effluents onto the agricultural lands for crop production, and also advanced our knowledge on the risk assessment and environmental impact of long-term use of the effluents in soil in terms of changes in quality parameters of the soil and water.

2.8 Novel fertilizers: Bentonite sulphur pastilles as a source of sulphur

Generally the response of crops to elemental S application increases with decreasing particle size. However, finely divided S particles are difficult to handle, can't be applied through seed-cum fertilizer drill and can cause skin irritations. In contrast, large particles (1 mm to 3.7 mm) can be easily handled and blended with other granular fertilizers. But, S particles in this size range oxidize slowly, thus, they are not an effective source of plant nutrient S during the year of application. The challenge, therefore, was to develop a product that can be easily handled, while providing crops with available S during the year of application. To meet this challenge, a new granular fertilizer, Bentonite Sulphur Pastilles (BSP) which contains 90% S and 10% clay has been developed. In a two-year study the direct and residual effects of Bentonite sulphur pastilles on soybean-wheat system on a Vertisol deficient in S has been evaluated.

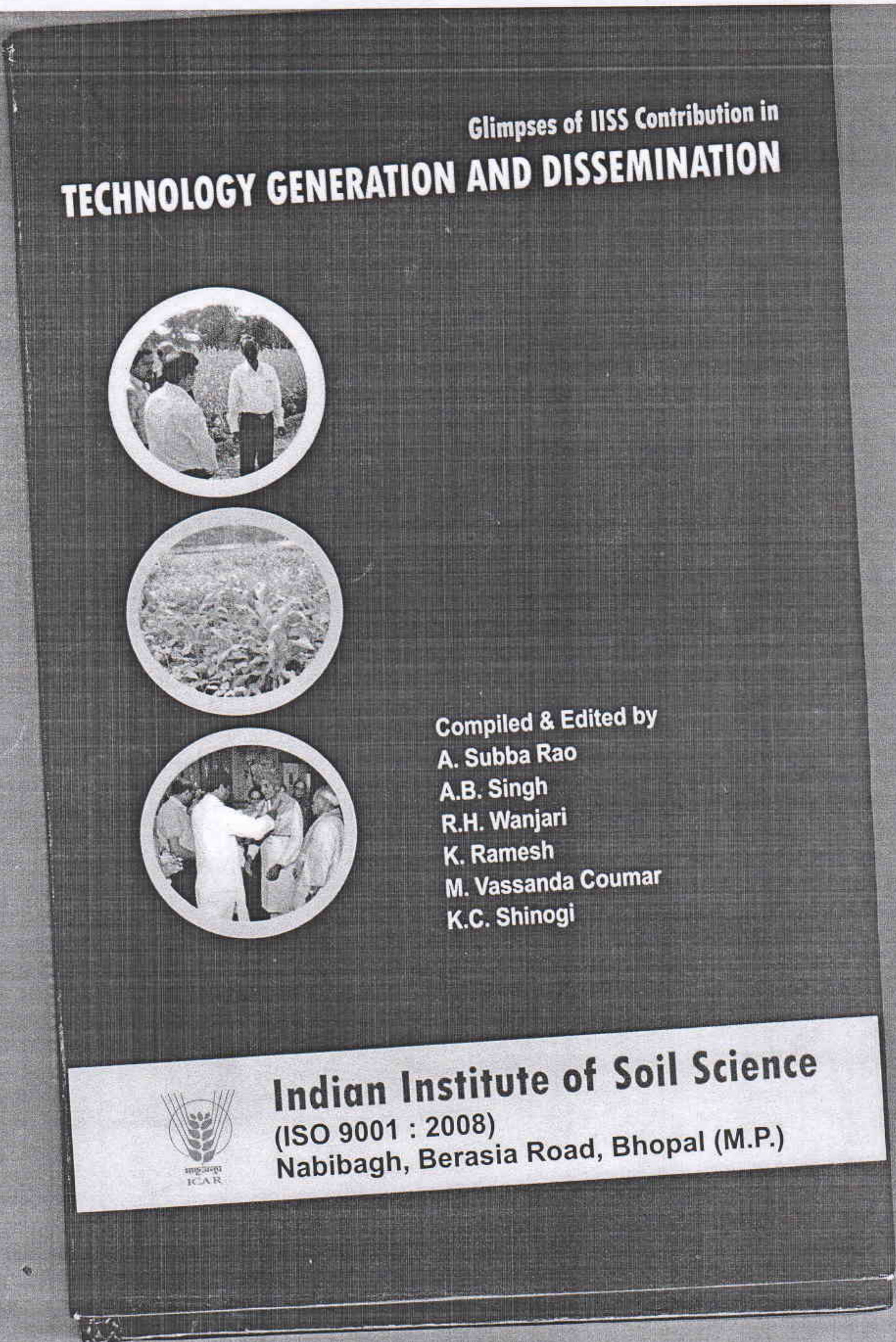
Application of bentonite S pastilles with NPK @ 20 kg S/ha to soybean produced 17-19% higher soybean and wheat yields as compared to NPK without S. The efficiency of the Bentonite S pastilles in affecting soybean and wheat yields was comparable to the standard S source i.e. gypsum. Bentonite S pastilles were also found better source of sulphur for mustard.



(a) Control

(b) Bentonite - S 20 kg/ha

(c) Bentonite - S 40 kg/ha


Glimpses of IISS Contribution in
TECHNOLOGY GENERATION AND DISSEMINATION
Compiled & Edited by
A. Subba Rao
A.B. Singh
R.H. Wanjari
K. Ramesh
M. Vassanda Coumar
K.C. Shinogi
Indian Institute of Soil Science
(ISO 9001 : 2008)
Nabibagh, Berasia Road, Bhopal (M.P.)
ICAR

dehydrogenase and phosphatase activity. In general, increase in microbial biomass carbon in organic manure amended soils was due to increased availability of substrate-C that stimulates microbial growth, but a direct effect from microorganisms added through the compost is also possible. In organically managed soils, both macro (N, P and K) and micro nutrients (Zn, Cu, Fe, Mn) were available in larger quantities compared to the conventional soils. It is well documented that there is a significant positive correlation between organic matter and micronutrient cation availability.

10. PRINT MEDIA AND ELECTRONIC GADGETS DEVELOPED FOR THE FARMERS

RESEARCH INFORMATION/TECHNOLOY GENERATED AND DISSEMINATED by the institute has been published in the form of research bulletins, technical/extension bulletins, folder / leaflets, electronic gadgets (Video Films), decision support system etc.

Research Bulletin

1. Sulphur Management for Oilseeds and Pulses (1999)
2. Soil Quality, Crop Productivity and Sustainability : Experiences under Long Term Finger Millet-Maize Cropping in Alfisol (2004)
3. Soil Quality, Crop Productivity and Sustainability: Experiences under Long Term Maize-Wheat Cropping in Inceptisol (2004)
4. Nutrient Dynamics, Crop Productivity and Sustainability under long term fertilizer Experiments in India (2004)
5. Long term Effect of Fertilizer, Manure and lime Application on Changes in Soil Quality, Crop Productivity and Sustainability of Maize-Wheat System in Alfisol of North Himalayas (2005)
6. Soil Quality. Crop Productivity and Sustainability as Influenced by Long term Fertilizer Application and continuous Cropping of Finger millet-Maize-Cowpea Sequence in Swell-Shrink Soil (2005)
7. Lessons Learnt from Long Term Fertilizer Experiments and Measures to Sustain Production in Alfisols (2007)
8. Lessons From Long Term Fertility Experiments (2007)
9. Impact of Fertilizer and Manure Use for Three Decades on Crop Productivity and Sustainability and Soil Quality under Soybean - Wheat System on Vertisol in Central India (2007)
10. मध्यप्रदेश की काली मिट्टी पर संतुलीत और समन्वित पोषक प्रबंध द्वारा सोयाबीन– गेहूं प्राणाली उत्पादकता को बढ़ाना (2007)
11. Enhancing Productivity of Soybean-Wheat System by Balanced and Integrated Nutrient Management on Black Soils of Madhya Pradesh (2007)
12. Soybean Rhizobial Inoculants Survey in Madhya Pradesh (2008)
13. Organic Farming Status and Research Achievements (2009)

14. Safe Use of Distillery Effluents in Agriculture (2011)
15. Micro and Secondary- Nutrients and Polluted Elements Research in India (2011)
16. Nitrate Contamination of Ground Water in some Heavily Fertilized and Intensively Cultivated Districts of India (2010)
17. Soil Organic Carbon in Different Agro-Climatic Regions of India under Varying Land Use, Cropping Systems and Management (2013)
18. Crop Growth Simulation Modelling (2013)
19. Predicting Nitrogen Mineralized from Crop Residues, Growth Manures and Organic Manures in Relation to their Quality Using APSIM Model (2013)
20. IISS Contribution in Frontier Areas of Soil Research (2013)

Technical/Extension Bulletin

1. मिट्टी परिक्षण : क्यों, कब और कैसे (1999)
2. फास्फो कम्पोस्ट : एक सम्पूर्ण प्राकृतिक खाद (2000)
3. अत्यधिक पारगम्य मृदाओं में अधिक उत्पादन हेतु गहरी जुताई तकनीक (2001)
4. मृदा तथा पौधों में गंधक का समुचित प्रबंध (2001)
5. उप सतह भौतिक अवरोध वाली मिट्टीयों में अधिक उत्पादन हेतु गहरी जुताई तकनीक (2001)
6. Raised -Sunken Bed Technology for Rainfed Vertisol of High Rainfall Areas (2002)
7. जैविक सोयाबीन का उत्पादन (2003)
8. Methodologies and Package of Practices on Improved Fertilizer Use Efficiency Under Various Agro-Climatic Regions for Different Crops/Cropping Systems and Soil Conditions (2003)
9. Technology at a Glance (English & Hindi) (2003)
10. Consultancy Services in Soil Quality, Nutrient and Water Management Technologies and Experts (2005)
11. Impact of the use of Polluted Irrigation Water on Soil Quality and crop Productivity near Ratlam and Nagda Industrial Area (2006)

12. Organic Soybean Production (2006)
13. Nutrient Competition and Nutrient Requirement in Intercropping System (2006)
14. A Study of Organic Farms in Central Madhya Pradesh (2006)
15. Prescription of Optimum Doses of Fertilizers for Targeted Yield of Crops through Soil Fertility Maps in different States of India (2007)
16. Phospho -Nitro-Compost Production & Use (English & Hindi) (2007)
17. Phospho - Sulpho -Nitro- Compost: Production and Evaluation (English & Hindi) (2007)
18. Soil and Water Pollution in India : Some Case Studies (2010)
19. Nano-Science and Nanotechnology in Soil Fertility and Plant Nutrition (2010)
20. Soil Testing for Fertility Improvement (2010)
21. Heavy Metal Pollution in Soil - Plant System and its Remediation (2012)
22. Grading of Municipal Solid Waste Compost for Safe and Maximum Recycling in Agriculture (2011)
23. A Manual on Soil Carbon Analysis (2013)

Folders/Leaflets

1. Understanding the Mechanism of Variation in Status of a Few Nutritionally Important Food Crops and the Mechanism of Micronutrient Enrichment in Plant Parts (2012)
2. Microbial Enriched Compost Production from Municipal Solid Waste (2011)
3. Phosphorus, Potassium and Sulphur Enriched Organo-Mineral Compost Production Technology (2012)
4. Vermicomposting (English & Hindi) (2012)
5. Farmer Friendly Technological Options for Sustainable Soil Health and Enhanced Crop Production (2013)
6. Rapid Composting Methods (English & Hindi) (2013)
7. Beneficial Soil Microbes for Crop Production (2013)
8. AICRP Long-Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability - At a Glance (2000)

9. Division of Soil Chemistry and Fertility at a Glance (2013)
10. STCR at a Glance (2011)
11. Soil Biology at a Glance (2011)
12. Pine Oleoresin Coated Slow Release Urea (2012)
13. Nano-Rock Phosphate a Potential Phosphorus Fertilizer for Crops (2012)
14. Biofertilizer Based Nutrient Management for Tribal Areas of Madhya Pradesh (2007)
15. IISS at a Glance (English & Hindi) (2008)
16. सोयाबीन की जैविक खेती (2012)
17. ईसबगोल की जैविक खेती (2012)
18. ड्यूरम गेहूँ की जैविक खेती (2012)
19. कृषि में जैविक उर्वरकों का महत्व (2013)
20. जैविक पद्यति द्वारा अनार की खेती (2012)
21. सरसों की जैविक खेती (2012)
22. अरहर की जैविक खेती (2012)
23. चना की जैविक खेती (2012)
24. फसल सुरक्षा हेतु जैविक विधियां (2012)
25. एकीकृत मृदा स्वास्थ्य आंकलन दिग्दर्शिका (2012)
26. फास्फो सल्फो नाइट्रो खाद का उत्पादन एवं फसलों में प्रयोग (2013)

Electronic Gadgets

1. A documentary video film on 'Organic Farming for Profitability and Sustainability' has been made in English, Hindi and Telugu languages of 15 minute duration each and submitted to ICAR, New Delhi for telecast on Doordarshan's Krishi Channel.
2. A documentary video film on 'Vermicomposting for Bio-fertilization' has been made in English, Hindi and Telugu languages of 15 minute duration each and submitted to ICAR, New Delhi for telecast on Doordarshan's Krishi Channel.

Decision Support Systems

2. Decision Support Systems for making soil test based recommendations to the farmers by using the web enabled software programme have been developed for the states like Maharashtra, Punjab, Chhattisgarh, Orissa, Kerala and Himachal Pradesh in collaboration with NIC, Pune softwares, for other states like Bihar, West Bengal, Karnataka and Haryana are under process.

2. Prepared GIS based soil fertility maps of India using soil test data of 21 states. In case of N 283 (57%), 182 (36%), and 33 (7%), in case of phosphorus 257 (49%) 200 (45%) and 40(6%) and in case of K 47 (9%) 212 (39%) and 239 (52%) districts are found to be of low, medium and high respectively with respect to each nutrient out of 500 districts of the country.

Table 1.2 Chronology of shifting of AICRPs to IISS, Bhopal and subsequent phasing out

Name of AICRP	Place from where Shifted	Year of Shift	Year of Phasing Out
Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (MN)	PAU Ludhiana	1988	On going
Soil Test Crop Response Correlation (STCR)	CRIDA Hyderabad	1996	On going
Microbiological Decomposition and Waste Recycling (MD)	HPKV Palampur	1997	2002
Long Term Fertilizer Experiments (LTFE)	IARI New Delhi	1997	On going
Biological Nitrogen Fixation (BNF)	IARI New Delhi	1997	Reframed as Network Project on Biodiversity and Biofertilizers
Soil Physical Constraints and their Amelioration for Sustainable Crop Production (SPC)	IARI New Delhi	1997	2002

The Mandate of the Institute is...

"TO PROVIDE SCIENTIFIC BASIS FOR ENHANCING AND SUSTAINING PRODUCTIVITY OF SOIL RESOURCES WITH MINIMAL ENVIRONMENTAL DEGRADATION"

...with the following specific objectives:

- To carry out basic and strategic research on soils especially physical, chemical and biological processes related to management of nutrients, water and energy.
- To develop advanced technology for sustainable systems of input management that is most efficient and least environmental polluting.
- To develop database repository of information on soils in relation to quality and productivity.
- To develop expertise and backstop other organizations engaged in research on agriculture, forestry, fishery and various environmental concerns.
- To exchange information with scientists engaged in similar pursuits through group discussions, symposia, conferences and publications.
- To collaborate with State Agricultural Universities, National, International and other Research Organizations in the fulfillment of the above objectives.

2. TECHNOLOGIES DEVELOPED

THE INDIAN INSTITUTE OF SOIL SCIENCE since its inception has developed an array of technologies for the farmers, extension personnel and also in the interest of the country. The valuable technologies are illustrated and elaborated sequentially.

Technology 1

Broad Bed and Furrow System for High Productivity, Improved Drainage and *in-situ* Moisture Conservation

Excessive loss of rainwater through runoff, loss of fertile topsoil through sediment loss and problem of water congestion during the heavy rainfall period are the major constraints for low productivity in Vertisols of central India under rolling topography. An improved land management system viz. broad bed and furrow tested on Vertisols has showed promising results to address these constraints. 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. BBFs are made with a tractor drawn BBF former. Bullock drawn BBF formers are also available. On BBF, sole maize or intercropping of pigeon pea with maize crop in rainy season (Plate 2.1) and chickpea in the winter season is grown with application of recommended doses of fertilizers and farm-yard manure @ 5 t ha^{-1}. 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 season. 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.

The BBF system reduces the runoff (20-24%) and consequent soil losses (30-45%) from the Vertisols. 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 pond 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 technological package gave a yield advantage of 20-25% on soybean-equivalent yield basis over soybean-chickpea system grown on 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. The increased income of the farmers will improve their quality of life and social status. This technology reduces the runoff and soil losses from the field which otherwise would have contributed to the siltation and eutrophication of water bodies and degradation of the arable land. The extra runoff water safely passed through grassed waterways was stored in farm pond which was utilized as life saving irrigation to the winter season crop.

Plate 2.1 Maize and maize-pigeonpea intercrop grown on BBF system in Vertisols

Technology 2

Conservation Tillage for Soybean-Wheat Cropping System on Vertisols of Central India

Removal or burning of wheat residues and excessive tillage operations results in loss of carbon and nutrients from the soil system, pollution of atmosphere, degradation of soil through runoff and soil loss and decline in soil quality. From the long-term tillage management experiment, suitable conservation tillage management options for soybean-wheat

cropping system have been developed for Vertisols which reduce loss of carbon from the system and also improve the energy utilization efficiency of the system. Conservation tillage practices tested for soybean-wheat system includes no tillage and reduced tillage systems. In no tillage system during the kharif season soybean crop was sown directly with a no-till seed drill while wheat residues were kept on the surface. Under reduced tillage system soybean was sown using a no-till seed drill in wheat residue retained field after one pass ploughing by duck-foot sweep cultivator. Reduced tillage system was found more efficient in controlling weeds and ease of sowing operation. Weeds in both the conservation tillage systems were controlled by herbicide Glyphosate as pre-emergence herbicide and Imazethapyr as post-emergence herbicide. One hand weeding is required in some heavy rainfall years for controlling weeds. Similarly wheat in rabi season was sown directly with no-till seed drill in no tillage system while in reduced tillage wheat was to be sown after one-pass of tillage operation by duck-foot tyne sweep cultivator. Recommended dose of NPK fertilizer was applied to both the crops.

Long-term tillage management studies on soybean-wheat cropping system showed that the yield of soybean under conservation tillage practices like no tillage and reduced tillage was on par with the conventional tillage (residue removed + 1 summer tillage by sweep + 2 tillages by sweep) treatment. Wheat crop under conservation tillage systems also produced grain yield similar to the yield under conventional tillage system (Plate 2.2). Average seed yield of soybean was around

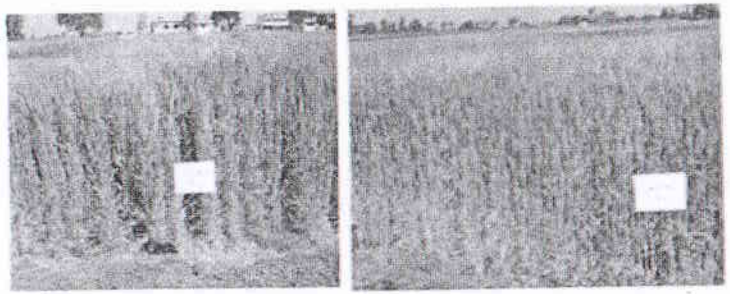


Plate 2.2 Wheat crop grown under conventional and no tillage system in Vertisols

1250 kg ha^{-1} while average grain yield of wheat was about 3800 kg ha^{-1} in no and reduced tillage systems. The conservation tillage saved energy and time during field operation and improved soil physical health and organic carbon compared to conventional tillage system.

The cost would be normal cost of cultivation of soybean-wheat with some reduction on tillage operational cost but with double the cost of herbicide application.

Technology 3

Irrigation Optimization vis-a-vis Nutrient Management in Indian Mustard and Wheat

Results of a three years experiment on soybean-mustard rotation under different irrigation levels and nutrient management treatments showed that application of 100% recommended dose of NPK with 10t/ha FYM applied to the previous soybean crop and one irrigation applied to mustard at flowering stage produced seed yield of mustard at par with 100% NPK dose with two irrigations at rosette and flowering stage. Organic matter through the application of FYM improved the physical properties of the surface soil particularly MWD, hydraulic conductivity and water retention characteristics.

In soybean-wheat rotation, wheat under 100% recommended dose of NPK with residual FYM @ 10 t ha^{-1} and two post sowing irrigations (at CRI and flowering) yielded at par with the treatment where 100% recommended NPK dose with three irrigations were applied (at CRI, maximum tillering and flowering). In FYM treated plots along with two irrigations to wheat, the water use efficiency was also higher than the treatment where three irrigations were applied to wheat.

Technology 4

Soybean-based Intercropping Systems for Sustainable Productivity on deep Vertisols of Madhya Pradesh

Soybean + maize intercropping (2:1 ratio) in kharif followed by wheat in rabi was highly productive (3546 kg ha^{-1} of SEY) and economical (2.37

B: C ratio) with the application of FYM @ 5 t ha^{-1} without nitrogen application.

Sole maize - wheat cropping system was more productive (5195 kg ha^{-1} of SEY) and economical (3.01 B:C ratio) at the recommended fertilizer dose (100% N).

Intercropping systems were more sustainable as they resulted in lower runoff and soil losses compared to the sole crops of sorghum and maize.

Table 2.1 Effect of cropping system on soil loss and run off on deep Vertisols of Madhya Pradesh

Cropping System	Total productivity* (kg ha^{-1})		Benefit: Cost Ratio		Runoff (mm)	Soil loss (t ha^{-1})
	N_0	100% N	N_0	100% N		
Soybean - Wheat	3339	3972	2.27	2.64	27.4	1.007
Sorghum – Wheat	2846	4502	1.90	2.82	60.2	4.823
Maize – Wheat	3216	5195	2.08	3.01	62.4	5.817
Soybean + Sorghum - Wheat	3278	4095	2.16	2.70	40.1	2.001
Soybean + Maize – Wheat	3546	4640	2.37	2.91	40.2	1.991
CD (P= 0.05)	320		0.22			

** Expressed in terms of soybean equivalent yield (SEY)*

Technology 5

Balanced Use of Nutrients: Key to Sustainable Productivity

Fertilizer is one of the key inputs of green revolution in India. Long-term fertilizer experiments provide an opportunity for precise monitoring the changes in soil fertility and productivity. Continuous use of chemical fertilizers with major plant nutrients and introduction of irrigation under intensive agriculture accelerated the mining of nutrients from soil. To monitor the crop yield and soil nutrient status under different soil and cropping systems, a long term fertilizer experiment was initiated in early seventies. The results of long-term fertilizer experiments revealed that in first few years there was no adverse effect on crop yields. But after few years a drastic reduction in yield was noticed at several places in the plots, which received nutrients in imbalanced form. Soil analysis revealed that inadequacy of some of the plant nutrients and hidden hunger of micronutrient were found to be yield limiting factors. Some classic examples are given below for substantiating the yield limiting factors.

- Continuous use of N alone and imbalanced supply of nutrients (N and NP) in several long term experiments have resulted in low yield or failure of crop especially in Alfisols. For instance, at Bangalore, Ranchi and Palampur continuous application of N alone resulted in almost failure of crop which was even poorer than absolute control.
- Due to continuous harvesting of high yield of rice and wheat at Pantnagar and Ludhiana, Zn became the limiting factor. The zinc availability has gone down from 2.7 mg kg^{-1} soil to 0.8 mg kg^{-1}. Inclusion of Zn in fertilizer schedule resulted in significant increase in yield of rice and wheat (Table 2.2). FYM met out the requirement of zinc of both the crops.

Table 2.2 Effect of addition of Zn and FYM along with NPK on rice and wheat yield at Pantnagar

Treatment	Rice (t ha^{-1})				Wheat (t ha^{-1})		
	1998	1999	2000	Mean	1998-99	1999-2000	Mean
100% NPK	4.06	3.94	3.84	3.95	3.68	3.61	3.45
100% NPK+Zn	4.72	4.58	4.44	4.58	4.15	4.20	4.17
100% NPK+FYM	4.88	4.76	4.67	4.77	4.65	4.71	4.68

Zn was applied @ 50 kg Zn SO_4 ha^{-1} in soils in kharif of 1993 and 1997 and FYM @ 15 t ha^{-1} once in a year before transplanting of rice

- Similarly, K was found to be a yield limiting factor in Alfisols. Because, the amount of K removed by the crop was much larger than the applied. Spectacular increase in yield of finger millet and maize was noted on application of K (Table 2.3). Further increase in yield on application of FYM indicates inadequacy of other nutrients.

Table 2.3 Effect of potassium application and crop yield (t ha^{-1}) at different centres of LTFE

Treatments	Bangalore		Palampur		Udaipur	
	F. millet	Maize	Maize	Wheat	Maize	Wheat
NP	0.59	0.25	2.79	0.47	2.88	3.54
NPK	4.35	2.03	4.35	1.73	3.06	3.85
NPK+ FYM	4.74	2.40	5.80	2.48	3.45	4.33

At some of the sites of LTFE more than one nutrient were found as yield limiting factor. Thus, the results of LTFE clearly demonstrated that balanced supply of nutrients either through inorganic or organics or conjunctively is the only solution for sustainable productivity.

Technology 6

Integrated Nutrient Management in Rice-Wheat on Vertisol

Eight years results of field experiment on IPNS demonstrated that integrated use of FYM (5 t) or green manure (6 t) in conjunction with 90 kg (two splits) fertilizer N in rice and 110 kg N ha^{-1} in subsequent wheat sustained 4.5 t ha^{-1} yield of rice and 4 t ha^{-1} yield of wheat in rice-wheat system. The technology developed not only sustained the productivity of rice-wheat in Vertisol but also improved the physico-chemical health of the soil. Significant improvement in soil organic C content and availability of P, K and S ensured the safeguard of the natural resources. Adoption of the technology also saves 65-70 kg N ha^{-1} yr^{-1} without reduction in productivity in addition to improvement in N use efficiency by 3-4 per cent.

Technology 7

Integrated Plant Nutrient Supply System for Soybean-Wheat System

Soybean-wheat system is commonly practiced in the semi-arid to sub-humid tropical Malwa and Vindhya plateau regions of Madhya Pradesh state in 2.30 m ha. This belt contributes nearly 80% of the total soybean produced in the India. The average productivity of soybean (1.2 t ha^{-1}) and wheat (1.7 t ha^{-1}) in this cropping system is very low, owing to low soil fertility. Earlier studies showed the deficiencies of nitrogen, phosphorus, sulphur and zinc in swell-shrink soils of this area. The Institute has developed an Integrate Plant Nutrient Supply (IPNS) Technology for enhancing and sustaining crop productivity and soil health in soybean-wheat system in Vindhyan and Malwa regions. The technology has got the flexibility of using different proportions of fertilizer and FYM depending on the availability of farmyard manure (FYM) with the farmer.

Based on the resources, for a yield target of 2 t soybean and 3.5 to 4.0 t wheat per ha the choices are:

- If a farmer has 4 t FYM, he needs to apply 130 kg N, 56 kg P, 40 kg S and 6 kg Zn annually to the cropping system. Thus, he can save about 30 kg N (65 kg urea), 23 kg P, 40 kg S (83 kg SSP) and 6 kg Zn (25 kg Zn SO_4), which are approximately worth Rs.1197/- (Table 2.4).
- If a farmer has access to more FYM, say 8 t, he can save 65 kg N, 30 kg P and 9 kg Zn and does not need to apply any S.
- If 16 t FYM can be applied to soybean, the farmer needs no fertilizer to be applied to soybean, he needs to apply only 60 kg N and 10 kg P to wheat, thus saving Rs. 2566/-.

Table 2.4 Ready reckoner of nutrients for soybean-wheat system and economics

Farmer No.	Yield advantage ($q\ ha^{-1}$)		Additional profit (Rs.)		Total profit	Value/ cost ratio (Rs. Per Re)	
	Soybean	Wheat	Soybean	Wheat	(Rs.)	Soybean	Wheat
1	1.8 (7.7)	1.0 (3.1)	1834 (13.9)	2999 (17.0)	4833	3.9	4.4
2	5.2 (29.5)	11.0 (35.5)	3912 (47.5)	8300 (34.9)	12212	3.0	4.4
3	7.1 (40.1)	6.0 (17.1)	7348 (109)	5163 (26.0)	12511	3.5	4.0
4	8.6 (55.5)	3.0 (9.7)	9565 (22.1)	4475 (27.6)	14040	3.6	4.2
5	3.5 (16.7)	7.0 (14.6)	4212 (44.4)	5250 (14.1)	9462	3.3	4.6

Data in parenthesis indicates increase in percentage

Technology 8

Integrated Nutrient Management for Pulses

Since time immemorial, pulses and oilseeds have been cultivated on marginal and sub-marginal lands, which are characterized by poor soil fertility and moisture stress, and consequently their yield potentials have not been realized. Further, more than 90 per cent area under pulses and more than 75 per cent area under oilseed are rainfed. Therefore, there is a great scope of increasing the production in rainfed areas through nutrient management.

- On-farm trials on integrated nutrient management (INM) for pulses (chickpea and lentil) conducted at 60 farmers' fields in Raisen, Bhopal, Rewa and Satna districts of Madhya Pradesh not only resulted in higher yields but also saved fertilizer cost.
- Application of 75% NPK + 2.5 t FYM + seed inoculation through rhizobium + soil application of 3 kg PSB ha^{-1} to the soybean during kharif season and 50-75% of the recommended NPK dose to rabi crop (chickpea/lentil) (based on residual moisture availability) harvested 12-25% more chickpea and 15-28% more lentil as compared to traditional practice (Table 2.5).

Table 2.5 Yield advantage of pulse crops over farmer's practice in some selected districts of Madhya Pradesh.

Treatment	Bhopal & Raisen	Rewa & Satna	
	Chickpea	Lentil	Chickpea
Integrated Nutrient Management	1.3 (13.5)	1.1 (20.7)	3.3 (31.0)
Integrated Nutrient Management + Moisture Conservation	2.4 (25.0)	1.3 (28.3)	4.6 (42.7)

Data in parenthesis indicates percentage increase in seed yield

The average profit to the farmers with improved nutrient and soil moisture management practices from three cropping systems is given below:

Economic gains* (Rs. $ha^{-1}\ yr^{-1}$)		
Soybean-chickpea	Soybean-lentil	Paddy-chickpea
4000-14000	2500-7500	10000-15000

**Average of 150 on-farm field trials tested for three years (2001-03) in five districts*

Technology 9

Integrated Nutrient Management for Oilseeds

Results of more than 300 on-farm trials in 9 target districts across 7 states of the country on different rainfed oilseed based cropping systems at different agro-ecosystems, conducted over 3 years, clearly showed that:

- Introducing soil moisture conservation treatments resulted significant increase in yield and net return, particularly in sunflower in Latur, safflower in Parbhani and castor in Palem.

- Integrated nutrient management involving different sources of organic manure has been found to maximize yield as well as income in different oilseed based cropping systems (Table 2.6). Application of FYM in soybean-chickpea system and in fallow-sunflower system; lime along with FYM in groundnut + pigeonpea intercropping system; green manuring in safflower, castor and mustard has been found beneficial in increasing yield as well as income over farmers' practice as well as RDF.

Table 2.6 The most beneficial INM recommendation for the cropping systems indicating additional return due to best INM over farmers' practice (Rs.)

Cropping Systems	Most Beneficial INM Treatment	Additional Return (Rs)
Soybean – chickpea	100% RDF + 2 t ha^{-1} FYM to soybean and 50% RDF to chickpea RDF of soybean: 20 kg N, 25 kg P through Urea and SSP; RDF of chickpea: 30 kg N, 25 kg P ha^{-1} through Urea and SSP	6121
Green gram-safflower	Incorporation of greengram stalk before sowing of safflower along with 75% RDF of safflower + soil moisture conservation measure (Summer ploughing and inter- culture with blade hoe) RDF of safflower = 40 kg N : 20 kg P ha^{-1}	3066
Fallow – sunflower (at Latur)	100% RDF+FYM @ 2 t ha^{-1} + Soil moisture conservation measure (Opening furrow after every 6 rows) RDF = 60 kg N: 40 kg P: 40 kg K ha^{-1}.	2395
Fallow – sunflower (at Raichur)	100% RDF + FYM @ 2 t ha^{-1} + Soil moisture conservation measure (Opening furrow after every 2 rows) RDF = 60 kg N: 40 kg P: 40 kg K ha^{-1}.	3269
Castor monocropping	Cowpea incorporation after first picking and 75% RDF of castor RDF = 60 kg N: 40 kg P: 30 kg K: 20 kg S ha^{-1}	1450
Groundnut – pigeonpea intercropping	100% RDF + lime @ 2 t ha^{-1} + FYM @ 2 t ha^{-1} + Soil-water conservation measure (furrows between groundnut and pigeonpea rows) RDF = 10 kg N: 20 kg P: 15 kg K ha^{-1} for both the crops.	16669
Fallow-mustard system	Green manuring with Sesbania and FYM @ 2 t ha^{-1} + 75% RDF RDF = 80 kg N: 40 kg P: 20 kg S ha^{-1}	4283
Maize – raya system	100% RDF + S @ 20 kg ha^{-1} + Soil moisture conservation measures (summer ploughing + maize residue application on surface) RDF = 80:40:0 kg N:P:K ha^{-1} (maize); 37:20:0 kg N:P:K ha^{-1} (raya)	2594

- Application of recommended doses of fertilizers can significantly boost up the yield of oilseed crops as well as net return over the existing practice of farmers on nutrient management. The yield increase varied from 0.48 q ha^{-1} in case of sunflower in Latur to 2.80 q ha^{-1} in case of groundnut in Ranchi (Table 2.7).

Table 2.7 Economics of the cropping system

Cropping system	Additional return over farmers' practice	
	Recommended Dose of Fertilizer (RDF)	INM
Soybean - chickpea	3832	6121
Greengram - safflower	601	3066
Fallow - sunflower		
At Latur	403	2395
At Raichur	1993	3269
Groundnut + pigeonpea	11446	16669
Castor monocropping	954	1450
Fallow-mustard	2543	4283
Maize-raya	764	2594

Technology 10

Sulphur Management for Oilseed and Pulse Crops

Sulphur (S) deficiency is widespread in areas under oilseeds and pulses. Visible symptoms of S deficiency in most of the oilseed and pulse crops appear on young foliage in the form of pale chlorotic leaves, thin slender stem, stunted growth, poor branching, and bushy appearance. On an average, 41 per cent Indian soils are deficient in S and it is widespread in coarse textured alluvial, red and laterite, leached acidic and hill soils and black clayey soils.

- Regular use of 40 kg S ha^{-1} to soybean, groundnut, mustard, gobi sarson, raya, safflower, castor, and 20 kg S ha^{-1} to sesame, linseed, niger was found optimum.
- Among pulses, chickpea, field pea and pigeon pea require 40 kg S ha^{-1}, while lentil, green gram, black gram and cluster bean needs 20 kg S ha^{-1} to produce optimum crop yield.
- Application of 20-40 kg S ha^{-1} gave economic seed response of 204 to 640 kg ha^{-1} in oilseed crops, and 176 to 592 kg ha^{-1} in pulse crops amounting to Rs. 9 to 82 benefit for each rupee spent on sulphur.

Bio-inoculants

Mixed Consortium Biofertilization: Use of mixed biofertilizers (BIOMIX) containing a consortium of N fixers, P solubilisers and PGPR (plant growth promoting rhizobacteria), had been found to promote the growth of cereals, legumes and oilseeds better than their individual application. For example, in Tamilnadu inoculation of consortia of Azospirillum, PSB and PGPR on rice variety `whiteponni' in the presence of 75% N and P, recorded 13% higher grain yield than with 100% NP, besides saving 25% NP. Rhizobium, RBG 314 and P solubilizer, AMT 1001, the promising and compatible combination developed in Andhra Pradesh gave 15% increase in yield of blackgram variety LBG 20. Chilli is an important crop in Andhra Pradesh of great commercial value. Azospirillum strains were developed and inoculated on chillis which yielded 25% yield increase over 100% RDF (recommended dose of fertilizers) and 30% over 75% RDF. In vertisols of Maharashtra, inoculation of Azotobacter and PSB on blackgram, soybean and pigeonpea increased the seed yields significantly by 150-250 kg ha^{-1} over control even at 100% RDF.

Integrated Application of Biofertilizers with FYM: Organics have been found to boost the proliferation of Rhizobium and enhance nodulation, nitrogen fixation, N and P uptake in legumes and oilseeds. In Vertisols of Maharashtra, Rhizobium inoculation of groundnut increased the pod yield by 3.9 q ha^{-1} while FYM alone @ 5 t ha^{-1} increased it by 1.5 q ha^{-1}, combined application of FYM and Rhizobium increased it by 7.3 q ha^{-1}. Similarly in greengram use of Rhizobium along with FYM gave an additional grain yield of 2.8 q ha^{-1} over unmanured and uninoculated control. These and similar results in pigeonpea led to the recommendation released by AICRP on BNF at Parbhani. Apply Rhizobium inoculants along with FYM @ 5 t ha^{-1}.

Nitrogen Savings due to Microbial Inoculation in Oilseed-Cereal Rotation: In soybean-wheat rotation in Vertisols wheat yields at Jabalpur following soybean are higher (+11%) than those following sorghum.

Wheat yield at 90 kg with biofertilizers (Rhizobium in soybean and Azotobacter in wheat) were comparable to 120 kg N, thus saving 30 kg N ha^{-1}.

Inoculation along with Micronutrients Application in Acid Soils: In acid soils (of Orissa), application of micronutrients (molybdenum and cobalt) boosts nodulation, BNF and yield of legumes. In green gram Rhizobium inoculation increased the grain yield (26 %). Application of micronutrients along with inoculation further enhanced the grain yield dramatically (+78 %) over uninoculated control resulting in additional BNF of 24 kg ha^{-1}.

Biofertilizers Improve Fertilizer Use Efficiency: Research leads by the AINP on Biofertilizers-Bhubaneswar center on improving fertilizer use efficiency (FUE), were tested in three farmers' fields in Dhenkanal district of Orissa in acidic sandy loams (pH 5.2-5.6). Bioinoculants (Azotobacter + Azospirillum) improved the yield of Okra, tomato and brinjal by .13.5-20.0 % over farmers' practice and 8.5-14.3% over recommended dose of fertilizers (RDF). Most significantly the apparent FUE increased by 6-15% for nitrogen, 10-22 % for phosphorus, 13-28% for potassium and 2.7-5.0% for sulphur. Averaged together they represent an increase in the yield of 16.6 % over farmers' practices and 11.3% over RDF due to the use of bioinoculants. Average increase in FUE due to inoculants was 11.3% in the case of N, 14.2 % in the case of P, 20 % in the case of K and 3.6% in the case of S.

Biofertilization in Drylands: Crops in dryland areas suffer due to moisture stress and low native soil organic matter and nutrient status. Use of integrated nutrient management practices in loamy sand soils in Haryana showed that inoculation of bacterial biofertilizers like Azospirillum and Pseudomonas on pearlmillet, wheat and mustard gave 10-22% increase in yield in grain yield when applied alongwith 75% recommended dose of nitrogen. Fifty two demonstration trials on mixed biofertilizer inoculation in pearlmillet in farmers' fields (District of Hisar, Bhiwani, Jajjhar, Mahendergarh and Rewari) resulted in an average increase of 5% increase in grain yield and 6% increase in fodder yield at 75% RDN, giving an additional monetary return to the farmers of Rs. 780/ha (net return).

Biofertilizer Technology : In efforts at improving the shelf life of inoculants, survival of *Azotobacter*, *Azospirillum* and PSB was found to be better (~10 fold) in charcoal based inoculants than lignite based ones at the end of 90 days at HAU, Hisar. For improving the shelf life of *Rhizobium*, *Bradyrhizobium*, and phosphate solubilizing bacteria - Bacillus sp., addition of 2% humic acid to lignite and vermiculite carrier based cultures enhanced the survival of all the bacteria upto 150 days of storage. A new medium for co-culturing *Azospirillum lipoferum*, *Bacillus* and *Pseudomonas fluorescens* was formulated at TNAU, Coimbatore and staggered inoculation was used to get high titre. In lignite carrier this co-culture had a population of 107-108 cells /g at 6 months in contrast to individual inoculant count of 108-109/g. Liquid inoculant of co-culture prepared by addition of 2% PVP supported titre of 109 cfu/ml upto six months. Similarly at ANGRAU, Amaravathi, liquid formulations LM2 and LM4 retained maximum population of Azospirillum i.e., 10.7 and 10.64 log CFU/ml after one year.

Demonstration of Bacterial Inoculants: Seed inoculation of leguminous oilseeds-groundnut and soybean with *Rhizobium* were successfully demonstrated in farmers' fields in 'Front Line Demonstrations' in the states of Tamil Nadu, Maharashtra and Madhya Pradesh. Inoculation of vegetable crops in Orissa in acid soils in farmers' fields led to significant benefits as follows:

- Better adoption of technology
- Better seed yields
  - Additional groundnut pod yields 14-23% in Tamil Nadu and 23-28% in Maharashtra
  - Additional soybean seed yields of 9-16% in Madhya Pradesh
- Reducing the dependence on costly chemical fertilizers
  - Saving of 20-30 kg fertilizer- N per hectare, as starter dose, was achieved
- Better vegetable yields

  - 9-14% increase in yield of tomato, brinjal, okra upon bioinoculation (BI) of Azotobacter, Azospirillum and PSB over and above the recommended nutrient management practices.

These efforts have contributed to other on-going efforts in increasing the production of microbial inoculants by the states and diffusion of BNF technology among the farmers.

Economic Benefits: From the average values of BNF in legumes, cereals, oilseed, fibre, horticultural and fodder crops in India cultivated over 190 million ha; A conservative estimate for BNF inputs in India amount to 4.20 million tonnes of nitrogen per year which at the current prices of urea works out to Rs. 4410 crores every year. Considering that BNF efficiencies are at least twice that of fertiliser urea nitrogen, the corresponding monetary benefits would also be twice as much. Extrapolation of the benefits of biofertilizer consumption of 13,000 t per yr (taking into consideration the average yield, N and P saving benefits observed in AICRP-BNF centres all over India in last 20 years) show that inoculation benefits amount to about N and P inputs of 0.32 and 0.13 million tonnes respectively equivalent to a monetary equivalent of Rs 600.2 crore per annum.

Technology 12

Production of Microbial Enriched Phospho-Sulpho-Nitro Compost by Pit Method

Different crop residues (soybean, wheat and mustard) and city garbage can be recycled through this technique. For the preparation of microbial enriched compost the following steps were followed:

- First, a place with bright sunshine is selected

- Each residue was mixed with fresh cow dung in the ratio of 5:1 (w/w) on material dry matter basis and placed in cemented pits of size 1m x 1m x 1m
- Low-cost mineral amendments such as rock phosphate (Mussouri phosphate, 100 mesh), pyrite and urea-N were added @ 5% P_2O_5, 10% (w/w) and 0.5% urea-N, respectively to the mixture. The contents were mixed thoroughly with fresh cow dung slurry (60-70 % moisture)
- Fungal culture was added @ 500 g mycelial mat per tonne of materials where as bacterial culture was added @ 50 ml kg^{-1} of material having 108 viable cell/ml. Initially for 1-3 days, bioinoculum was added twice in the mixture owing to a high initial temperature (55 to 70°C) and thereafter, the frequency of addition of inoculums decreased gradually
- The materials were allowed to decompose in the cemented pits (1 m x 1 m x 1 m)
- Poly vinyl chloride tubes were inserted vertically as well as horizontally, for sufficient aeration throughout the decomposition period
- The filled pits were covered with polythene sheets to prevent entry of rain water and insects etc.
- The compost get ready for field application after 110-115 days (Plate 2.3)

Heaping Covering

ʳphospho-sulpho-nitro compost (Heap method)

Technology 13

Preparation of Phospho-Sulfo-Nitro Compost: Heap Method

- Select cemented floor to avoid nutrient percolation in to the soil
- The ingredients required for the preparation of compost by heap method are given in Table 2.8
- In this method, in a pit of dimensions 7.5 ft length x 6 ft width and 3 ft depth, about 500 kg of waste was added
- The residue was spread in 16 layers and in each layer the following proportion of organic and inorganic ingredients were added:
- 15 kg of waste spread on the floor followed by 15 kg of fresh cow dung (dry weight basis)
- 330 g urea (0.5%-N basis) dissolved in 1-litre water
- 10-litre water
- 8.6 kg Mussori rock phosphate (5% P_2O_5 basis from Mussoori rock phosphate containing 17.5 % P_2O_5)
- 3 kg Pyrites (22% S content and added at the rate of 10% on materials dry weight basis)
- Soil @ 5% on materials dry weight basis.
- To protect from rain, wind, and to maintain the moisture and temperature a polythene sheet was used to cover on the heap
- After 3-4 weeks of decomposition, the first turning of heap was done
- The moisture was maintained at 60-70% of materials on dry weight basis
- The compost was ready after 3 months and about 250-300 kg of enriched phospho-sulfo-nitro-compost was recovered from this method.

Table 2.8 Ingredients required for preparation of 500 kg of phospho-sulpho-nitro compost by heap method

Waste (kg)	Fresh cow dung (kg)	Rock phosphate (kg)	Pyrites (kg)	Urea (kg)	Soil (kg)
250	250	143	50	5.5	25

Technology 14

Vermicomposting Methods for Recycling of Organic Wastes

A) Vermicomposting under Field Conditions : In general, there are two methods of vermicomposting under field conditions (i) Vermicomposting of wastes in field pits and (ii) Vermicomposting of wastes on ground heaps.

a) Vermicomposting of wastes in field pits

It is preferable to go for optimum sized ground pits of 20 feet length 3 feet width 2 feet deep for effective vermicomposting bed. Series of such beds are to be prepared at one place.

b) Vermicomposting of wastes on ground heaps

Instead of open pits, vermicomposting can be taken up in ground heaps. Dome shaped beds (with organic wastes) are prepared and vermicomposting is taken up. Optimum size of ground heaps may be 10 feet length x 3 feet width x 2 feet high.

Materials Required for Vermicomposting

- Farm wastes: straw from wheat, soybean, chickpea, mustard etc.
- Fresh dung
- Rock phosphate (Jhabua Rock phosphate 30-32% P_2O_5). (Note: In the case when vermicompost is to be prepared by P-enrichment technique)
- Wastes: dung ratio (1:1 on dry weight basis).
- Earthworm: 1000-1200 adult worms (about 1 kg per quintal of waste material).
- Water: 3-5 liters every week per heap or pit.

B) Vermicompost Preparation under Tree Shade by Pit and Methods

Open permanent pits of 10 feet length x 3 feet width x 2 feet deep constructed under the tree shade, which was about 2 feet above grou avoid entry of rainwater into the pits. Brick walls were constructed a the pit floor and perforated into 10 cm diameter 5-6 holes in the pi for aeration. The holes in the wall were blocked with nylon screen mesh) so that earthworms may not escape from the pits. Par decomposed dung (dung about 2 months old) was spread on the b of the pits to a thickness of about 3-4 cm. This was followed by ad of layer of litter/residue and dung in the ratio of 1:1 (w/w). A se layer of dung was then applied followed by another layer of litter residue in the same ratio up to a height of 2 feet. Two species of ep earthworms viz., Eisenia foetida and Perionyx excavatus inoculated in the pit. Moisture content was maintained at 60 throughout the decomposition period. Jute bags (gunny bags) spread uniformly on the surface of the materials to facilitate mainter of suitable moisture regime and temperature conditions. Waterir sprinkler was often done. The material was allowed to decompo 15-20 days to stabilize the temperature because to reach the meso stage, the process has to pass the thermophilic stage, which com about 3 weeks. Earthworms were inoculated in the pit or heap wi adult earthworms per kg of waste material and a total of 500 worms added to each pit or heap. The materials were allowed to decompo 110 days. The forest litter was decomposed much earlier (75 to 85 than farm residue (110-115 days).

In the heap method the waste materials and partially decomposed (1:1 w/w) are made in heaps of dimension; 10 feet length x 3 feet wi 2 feet high and during inoculation channels are made by hanc earthworm @ 1 kg per quintal of waste are inoculated and then wat is done by sprinkler method. Jute cloth pieces are used as cov material.

C) Phosphorus-Enriched Vermicompost by Pit and Heap Metho

In the case of phosphorus-enriched vermicompost, Jhabua rock phate (30-32% P_2O_5) is used @ 2.5% P_2O_5 of waste material with the same dimension of pit or heap as mentioned earlier. The chemical and biochemical characteristics of vermicompost and P-enriched vermicompost are presented in Table 2.9 and 2.10.

Table 2.9 Chemical composition of vermicompost and P-enriched vermicompost prepared from soybean straw

Parameters	Vermicompost	P-enriched vermicompost
Ash (%)	51.0	52.5
TOC (%)	27.2	26.5
C/N ratio	14.3	13.6
N (%)	1.90	1.95
P_2O_5 (%)	2.05	4.00
K_2O (%)	0.80	0.86
WSC (%)	0.94	0.88
Mn (ppm)	500	540
Zn (ppm)	100	100
Cu (ppm)	44	46

Table 2.10 Biochemical characteristics of vermicompost and P-enriched vermicompost prepared from soybean straw

Parameters	Vermicompost	P-enriched vermicompost
Total phenol (mg kg^{-1} compost)	98	100
Dehydrogenase (mg TPF kg^{-1} compost hr^{-1})	40	39
Alkaline phosphatase (mg p-nitrohenol kg^{-1} compost hr^{-1})	490	562
Acid phosphatase (mg p-nitrophenol kg^{-1} compost hr^{-1})	398	421

Technology 15

On-line Soil Fertility Maps of Different States and Fertilizer Recommendation System for Targeted Yields of Crops

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, Orissa, Himachal Pradesh, Karnataka, Punjab, Tamil Nadu and Bihar has been developed in MS-Access. The state boundary maps, which consist of districts were scanned in .tiff format and imported to Arc GIS system ver 9.0. The polyconic projection system with modified Everest Datum was followed for each state during the georeferencing. The state and district boundaries were digitized. The individual district ids were assigned in the layer to assign the attribute database. Through arc catalog the columns for N, P and K were added in the layer to enter the attribute data. As far as the attribute database is concern, the N, P, K index values of each district in state were imported from MS-Access and assigned to polygon attribute table (PAT) in the layer. From the attribute database, the different thematic layers have been reclassified to generate various thematic maps on N, P, K index values.

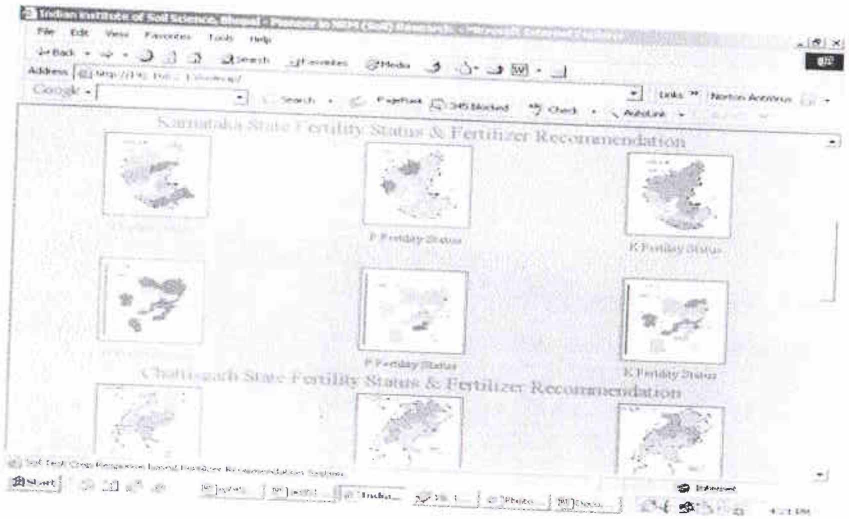
These index values (IVs) were classified into three categories viz., (Low 1- 1.5, Medium 1.5-2.5 and High >2.5). The STCR approach has been used to prescribe optimum doses of nutrients, based on available soil nutrients.

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. 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 state.

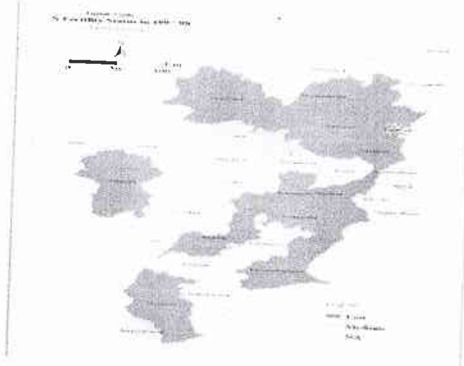
The system works as a ready reckonner to give prescription in the form of fertilizer available (eg. Urea, SSP, MOP etc.). In case of known fertility status one can give the known values for N, P and K and submit for calculation. This system provides real use of fertility maps to the users. It can be used up to field level also, if the farmer has the knowledge of his field fertility status and the 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 under STCR scheme suggest that a considerable amount of money can be saved if the fertilizers are prescribed using soil test values.

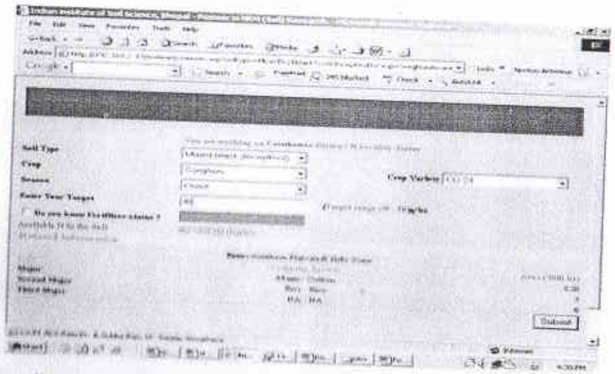
Prescription of Optimum Doses

On running the application with an Internet browser the page shown below will be displayed. All three images are clickable thumbnail to the corresponding larger images of N, P and K status. On clicking any of the links, the corresponding larger image will be displayed on the screen as shown below (for Nitrogen of Tamil Nadu)

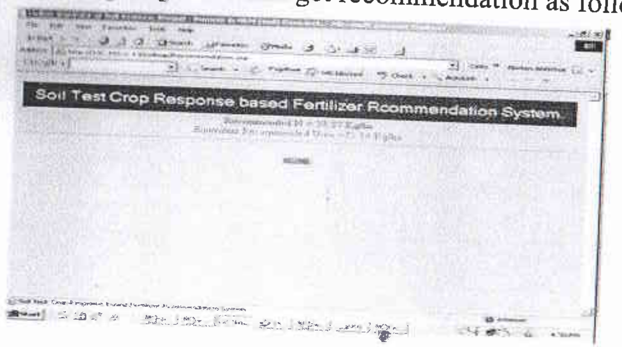


Each district on the maps is uniquely identifiable and upon clicking any district the relevant page for that district will be displayed. On clicking Coimbatore district in the N status map and proving data (sequentially in order soil type, crop, crop variety, season and target (say 40 q/ha)) the page displayed is:



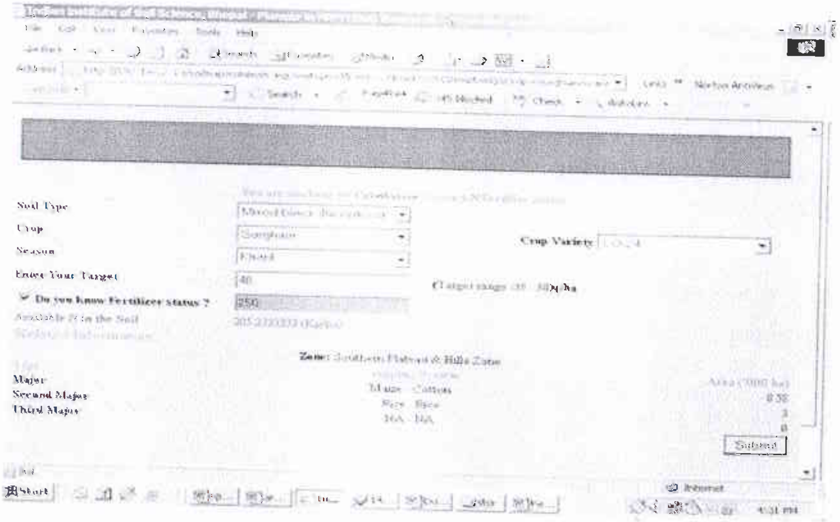


After submitting target we will get recommendation as follows:

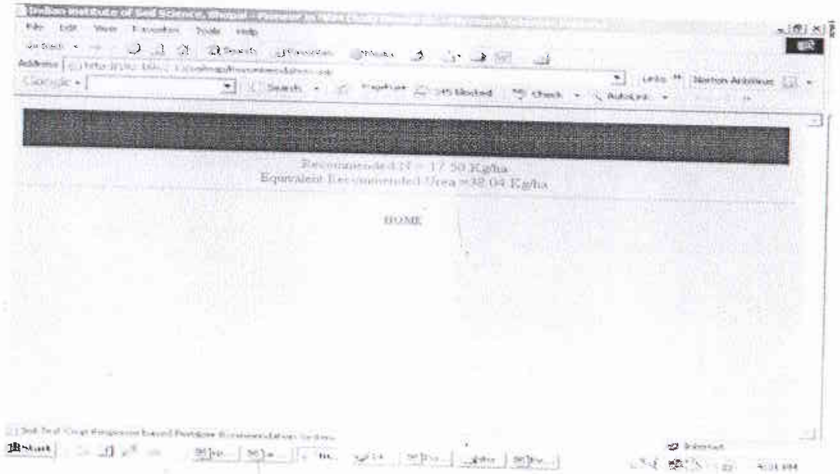


We see that the system suggests that for obtaining 40 q ha^{-1} yield of sorghum in the district Coimbatore 33.37 kg N is required (equivalent to 72.54 kg Urea).

In case a farmer in the district is having actual knowledge of his field fertility status we will see how the recommendations are changed. Now, suppose the available N is 250 kg ha^{-1} in the field and other parameters are taken exactly as above (see below)



After submitting the target of 40 q ha^{-1}, we will get recommendation as follows:



We see that recommendation has changed with change in available soil nitrogen. Similarly one can obtain the recommendations for P and K.

Technology 16

Technologies Developed by AICRP Micronutrients

Micronutrients play a crucial role in enhancing food/crop production. Widespread micronutrient deficiencies in crops, have been recorded all over the country, which has resulted in severe losses in yield and nutritional quality. It is estimated that nearly half of the soils on which food crops are grown, are deficient in zinc (Zn). Next to Zn, boron (B) (33%) and iron (Fe) (15%) deficiencies are also limiting the crop production to a large extent. Extensive manganese (Mn) (6%) deficiency is now being manifested in the most wide spread 'rice-wheat' cropping system in northern India, particularly in Punjab (18%) and Haryana (12%). Intensive agriculture in north India and soils rich in organic matter in southern part of the country also exhibited copper (Cu) (8%) deficiency. Extensive micronutrient deficiencies lead to decline in factor productivity even with balanced NPK fertilization. Although the crop response to micronutrients application varies with soil type, crops and genotype, agro-climatic conditions and severity of deficiency, an enormous response to micronutrient fertilization has been reported in a wide variety of crops including horticultural crops across the country. Large number of technologies and Best Management Practices (BMPs) have been generated by conducting thousands of micronutrients response trials in deficient soils. Some of the technologies and BMPs are given below.

Zinc (Zn)

Zinc deficiency is the most widespread problem affecting more than 45% of the soil. Studies carried out at thousands of farmers' fields with a large number of crops and cropping systems across the country revealed that application of Zn had variable response on crop productivity and profitability. The response was considered economic when increase was more than 200 kg ha^{-1}. Basal application of 2.5 to 5 kg Zn ha^{-1} increased the economic yield by <200, 200-500, 500-1000 and >1000 kg ha^{-1} representing <6%, 6-15%, 15-30% and >30% increase over no Zn (control) in high, marginal low and very low fertility Zn status of the soils, respectively. Based on the above criteria, 4,144 trials conducted on farmers' fields during 1967-84, on average 42, 32, 17 and 9 per cent trials showed high, marginal, low and very low fertility status of Indian soils, respectively. It is inferred from the data that about 58% trials showed response to Zn fertilization, while 5,807 trials conducted during 1985-2001 revealed a decline in micronutrient status, which resulted in increase in responsive trials to an extent of 63%. Zn fertility status continued to decline and as a result number of responsive trials reached 72% during 2001-2010 (Fig. 2.1).

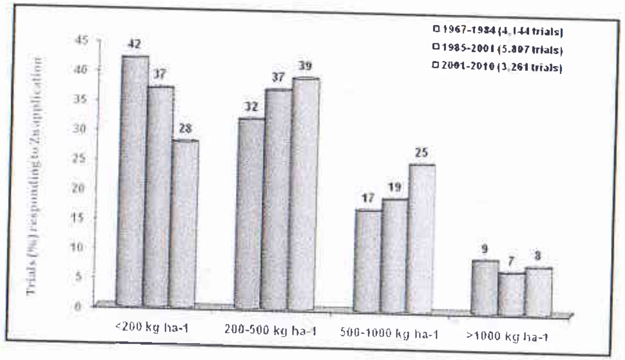


Fig. 2.1 Changes in crop responses to Zn application during 1967-1984, 1985-2001 and 2001-2010 (based on trials conducted at cultivator's field).

Zn rates vary with the crops, type of soil, severity of deficiency, method, time and frequency of application. The large variation in rate of Zn application has emanated from the sensitivity of crops to soil type and deficiency status, soil environment, Zn sources and their residual effects and method of application. Many aspects have been taken into consideration while making recommendations for Zn applications. Zn recommendations for some of the important cropping systems are given below (Table 2.11).

Table 2.11 Zn recommendations for important cropping systems

Cropping systems	Critical limit (mg kg^{-1})	Doses and method of application	Remarks (including soil type, area and any other special feature if any)
Rice-wheat system	In general, 0.6 mg kg-1 and 0.5 mg kg^{-1} for Gujarat, 1.2 mg DTPA Zn kg^{-1} soil in Tamilnadu and Uttarakhand	➤ Application of 2.5, 5/5.5 or 10/11 kg Zn ha^{-1} as basal to rice crop.	➤ In rice wheat system, fertilizer Zn is preferably used in rice crop. In general, 5/5.5 kg Zn for two crop cycle and 10/11 kg Zn for three crop to four crop cycles depending upon soil type, cultivars and climate in Northern states of the country. In calcareous soils, application of 10/11 kg Zn ha^{-1} is sufficient to meet requirement of two crop cycles.
		➤ 10 ml slurry/1 kg seed treatment.	
		➤ Zn Enriched cow dung/FYM (12.5 kg Zn sulphate (20-21% Zn) ha^{-1} + 200 kg).	➤ In Gujarat, application 8 kg $ZnSO_4$ per ha every year or 1.0% foliar of Zn at 30, 40 and 50 days after sowing in light textured soils of middle and north Gujarat regions.
		➤ Mixture of 1.5-t- wheat straw + urea + 25 kg Zn sulphate (20 -21% Zn)/ha	➤ Treated wheat seed with 10 ml of ZnO (30% Zn) slurry for 1 kg seed before sowing in loamy sand soil of middle Gujarat region. Zn enriched mixture with FYM/cow dung/crop residue/biogas slurry should be incorporated at least 30 d before rice transplanting/ sowing of wheat.
		➤ Application of 50 kg Zn sulphate (20-21% Zn)/ha to I year Hybrid rice	➤ In direct seeded rice based system foliar spray of 0.5% $ZnSO_4$ and 1% $FeSO_4$ thrice at 15, 25 and 35 days after sowing is beneficial.

		crop and 25 kg Zn sulphate (20 - 21% Zn)/ha to II year Hybrid rice crop	
Rice – Rice system	In general 0.6 mg kg^{-1} and 1.20 mg kg^{-1} for Tamilnadu and Uttarakhand	➢ In Tamilnadu, 5.5 kg ha^{-1} for every crop as basal ➢ In Andhra Pradesh 25, 50 and 75 kg^{-1} as basal ➢ In Orissa, 2.5, 5.5 and11 kg Zn ha^{-1} as basal.	➢ Zn deficient wet land soils of Tamilnadu 25 kg $ZnSO_4$ one crop cycle and 50-100 kg $ZnSO_4$ once in 6 crops. ➢ For Alluvial Soils of Godavari Zone in A.P for two rice crops 50 kg Zinc sulphate ha^{-1}. ➢ In Red Soil, 75 kg Zinc Sulphate ha^{-1} as basal for two crop cycles with hybrid rice. ➢ In Orissa, 25 kg $ZnSO_4$ once for two crop cycles in acid soils. Soil application of Zn@2.5kg /ha as basal with green manure crop to rice is recommended for alluvial soil.10 kg Zn ha^{-1} to Fe toxic soils every year.
Pearlmillet-Wheat	0.5 mg kg^{-1} in Gujarat and Haryana and 1.0 mg kg^{-1} in Uttarakhand	➢ 2.5 kg Zn /ha + 200kg FYM + Biogas slurry (2kg)	➢ Apply Zn @ 2.5 kg ha^{-1} through enriched FYM (200 kg /ha) to both pearlmillet and wheat in light textured soils. ➢ Application of 50 kg Zn sulphate (20-21% Zn)/ha to I and II year Pearl millet crop or Application of 12.5 kg Zn sulphate (20-21% Zn) + 5 t FYM/ha to I and III year Pearl millet crop.
Rice-Maize	0.6 to 1.20 mg kg^{-1}	➢ 25 kg $ZnSO_4$ ha^{-1} as basal for variety. ➢ 37.5 kg $ZnSO_4$ ha^{-1} as basal for Hybrid ➢ 18.75 kg $ZnSO_4$ ha^{-1} as Zn enriched poultry manure / sago waste as basal	➢ In Zn déficient red soils (Inceptisol) and Typic Ustropept soils. ➢ In Bihar, 25 kg ha^{-1} Zinc sulphate in calcareous soils with two foliar sprays of 0.5%.
Groundnut - Wheat	0.5 mg kg^{-1}	➢ 25 kg $ZnSO_4$ ha^{-1} as basal to first crop	➢ It is recommended to apply Zn $SO_4.7H_2O$ @ 25 kg in groundnut on light textured soils. ➢ Application of 55 kg Zn $SO_4.7H_2O$ to first groundnut crop can meet the Zn requirement of 10 crops grown in sucession. ➢ Apply 25 kg Zn sulphate (20-21% Zn)/ha before planting or Seed treatment with 8 ml Teprosyn -Zn kg^{-1} seed. ➢ Foliar spray of 0.5% Zn sulphate + 0.25% lime at 30 and 45 days after emergence.

Maize-wheat	0.60 mg kg^{-1} 0.70 mg kg^{-1}	➢ 50 kg Zn Sulphate ha^{-1} as basal ➢ 5 kg soil or 0.6% $ZnSO_4.7H_2O$ + 0.3 % $Ca(OH)_2$ spray	➢ For irrigated conditions in state followed by any other crop ➢ In shallow black soil in mixed red and black soil of MP. ➢ When the symptoms are observed late in the season and intercultural is not possible, spray crop with 0.6% Zn neutralized with lime.
Pulses (Chickpea, Pigeonpea, black gram)	0.6 mg kg^{-1}	➢ 2.5 kg Zn ha^{-1} as basal to each crop	➢ For rainfed / irrigated conditions in state (for one crop)
Sugarcane-ratoon	0.6 to 1.0 mg kg^{-1}mg	➢ 25 to 50 kg zinc sulphate ha^{-1}	➢ Apply 50 kg Zn sulphate (20-21% Zn)/ha before planting in light textured soils and apply 25 kg Zn sulphate (20-21% Zn) + 2.5 t press mud compost/ha before planting in calcareous soils.
Soybean-wheat Soybean-chickpea	0.6 to 1.0 mg kg^{-1}mg	➢ 25 kg Zn sulphate + 200 kg FYM	➢ 5 kg Zn + 200 kg FYM (Zn incubated with FYM for 30 days) for medium black soil and alluvial soil

Agronomic biofortification techniques for Zn enrichment in edible plant parts and its bioassimilation

The fertilizer Zn management/ application strategies have been developed to enrich the grains with Zn by breaking the barriers in Zn accumulation in grains of cereals and pulses. Since, this practice enhances the micronutrient loading at field itself; hence, it may be useful for common man (mostly poor people who live in villages and cannot afford physically fortified meals). The efficiency of different cultivars of a crop in accumulating grain Zn also varies greatly. Zn efficient cultivars should be grown in Zn deficient soils while Zn inefficient cultivars are agronomically highly responsive and should be supplied with external application of Zn. Enhancing Zn content in grains also increases its bioavailability in human due to different physiological mechanisms for example; enhanced Zn absorption has been noticed by reducing the phytate: zinc molar ratio in grains/meals. Application of Zn also enhances the nitrogen assimilation and thereby the protein content in grains. Application of Zn either through soil, foliar or both at specific growth stages depending upon crop, type of soils and native Zn content of soil had significant effect on enhancing Zn density in grains. Strategies of Zn application for Zn enrichment vary with the crop. In soils with deficient Zn status, basal + foliar application of Zn was found to be the best strategy to enhance the Zn load in grains of pigeon pea, wheat, rice and maize (Plate 2.4 & 2.5) . However, in Zn sufficient soils, 1-2 foliar applications of $ZnSO_4$ are useful in enriching the grains with Zn. The technology adoption may result in enhanced Zn concentration in grains about 15-45% and grain yield by 10-20%. Feeding with Zn

Plate 2.4 Effect of Zn application on Rice crop

enriched food will leads to the solution of Zn malnutrition and it would be helpful in curtailing the medical expenses incurred on human health.

Plate 2.5 Zn enrichment trials in different crops

Iron (Fe)

Iron is important for several metabolic and enzymatic activities, synthesis of chlorophyll and for redox reactions in plants. Iron deficiency has been commonly observed in horticultural and vegetable crops as well as in pulses. In upland crops, especially rice, sorghum, groundnut, sugarcane, chick pea etc. grown in highly calcareous soils showed spectacular Fe deficiency resulting in leaf chlorosis (Plate 2.6). Application of Fe either as soil or foliar application is useful in mitigating the Fe deficiency in crops. However, in problem soils foliar applications at 10-15 days intervals is best option for correcting the Fe deficiency.

BMPs for Fe Management

- Foliar sprays of 1-2% un-neutralized ferrous sulphate solution three to four times efficiently correct the iron chlorosis. Soil application of Fe is inferior and less profitable than foliar sprays.
- Iron chelets are more efficient than inorganic sources in combating Fe deficiency but farmers do not prefer to use chelates due to high cost except in cash crops.
- Iron deficiency in rice seedlings can be effectively controlled by raising them under puddled nursery beds supplemented with requisite dose of FYM or compost. Ponding of water in nursery beds during dry spell is essential to mitigate Fe chlorosis.

- Iron deficiency in rice is encountered in upland soils or highly permeable coarse textured soils because of less mobilization of Fe^{2+} as the desired degree of reduction does not occur. So puddling markedly reduces the extent of Fe deficiency in rice.
- Green manuring, use of FYM and compost helped in mobilization of native soil iron during its decomposition. Combination of green manure (GM) or organic manures with foliar spray of un-neutralized 1% $FeSO_4.7H_2O$ solution is more effective in increasing crop yield than either GM or spray of iron sulphate solution alone.

Techniques for Fe enrichment in rice, maize and pulses to combat Fe malnutrition

Biofortification strategies (Fe enrichment) 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. The following techniques are useful in enhancing the Fe loads in grains.

- 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. 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.
- In pulse crops (chickpea 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. One foliar spray along with 25% defoliation was best strategy for enhancing Fe content in inefficient cultivars of chickpea (17-25%) while nipping was the best strategy to enhance Fe content in pigeon pea grain (24-32.8%).

- Feeding with Fe enriched food leads to the enhanced haemoglobin in rat under bioassimilation studies which proved an important proposition to fight against Fe malnutrition in rural areas.

Plate 2.6 Fe deficiency in different crops

Manganese (Mn)

Mn deficiency is a fast emerging problem in areas under oilseeds and pulses due to higher removal of manganese by these crops. Deficiency symptoms first appear on young foliage in the form of chlorotic area and strips and leads to poor branching and stunted growth. Mn deficiency has been emerged as a major problem in states of Punjab, Haryana and western Uttar Pradesh where rice-wheat system is practiced on highly permeable coarse textured soils. During rice cultivation, solubility of Mn increases due to reduction under sub-merged condition and leaches down to lower soil layers in four to seven years of cultivation. The subsequent wheat and berseem crops also suffer due to Mn deficiency. Studies conducted in Punjab revealed that adoption of deep tillage practices can ameliorate Mn deficiency in coarse textured soils and enhance wheat yield and Mn uptake. 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, reduces

leaching losses and thus helpful in saving environment.

Development of amelioration measures for Mn deficiency

Manganese (Mn) can be supplied through the sulphate salt of Mn i.e. $MnSO_4$ either through soil or foliar. Soil application of Mn sulphate @ 50 kg/ha is recommended for getting the optimum crop response. However, in case of wheat, oat and berseem, foliar spray of 0.5% Mn sulphate solution is more economical than soil application. Generally 3-4 sprays of Mn sulphate solution are required to correct Mn deficiency in wheat (Plate 2.7) and oat. Foliar spray of $MnSO_4$ solution one before and two after first irrigation effective in mitigating Mn deficiency in crops in Mn-deficient soils.

Plate 2.7 Management of Mn deficiency in wheat

Sulphur (S)

Sulphur is required in amino acid and protein synthesis, enzymatic and metabolic activities of plants. About 40% of Indian soils are deficient in S which causes great economic loss in several crops especially; oilseeds and pulses. Visible symptoms of sulphur deficiency in most of the crops appear on young foliage in the form of pale chlorotic leaves, thin slender stem, stunted growth, poor branching, and bushy appearance. 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, yield and cropping intensity. In general, sulphur uptake of oilseeds> pulses > cereals/millets. Application of S to S-deficient soil resulted in increased yield as well as enhanced qualities of the agricultural produce such as (a) increased oil content of seeds, (b) increased protein percentage in plants and harvested produce, (c) improved nutritional quality of forages by providing balance N:S ratio and increasing crude protein content, (d) improved starch content of tubers, (e) improved baking quality of wheat, (f) increases sugar recovery in sugarcane, (g) enhanced marketability of copra (coconut kernel) and (h) increased fibre strength of cotton and jute etc.

BMPs for Sulphur Management

- Among different sources, single super phosphate, gypsum, phospho-gypsum, pyrites, ammonium sulphate, bentonite S pastilles were found better for S fertilization.
- Basal application of S was found beneficial but in oilseed its application can be made in at 25-30 days of crop growth.
- Pyrite should be applied in moist soil through surface broadcast. Application of 8-10 t ha^{-1} organic manure efficiently correct sulphur deficiency and gives equal yield as that of inorganic sources.
- Sulphur should be preferably applied to oilseed and pulses to achieve higher benefits in oilseed/pulse based cropping systems.
- Among pulses, chickpea, field pea, pigeon pea require 40 kg S ha^{-1}, while lentil, green gram, black gram and cluster bean need 20 kg S ha^{-1} to produce optimum crop yields (Plate 2.8).
- Crops irrigated with high sulphate containing waters generally do not respond to external supply of sulphur.

Balanced fertilization schedule of sulphur (S) for different crops a cropping system

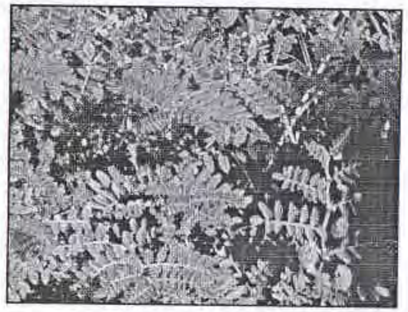
The recommendations/ technology options developed for correction S deficiency for different crops/ cropping systems are:

- Rice-wheat cropping system : 30 kg S ha^{-1} in each crop (45 kg S ha^{-1} to rice
- 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}

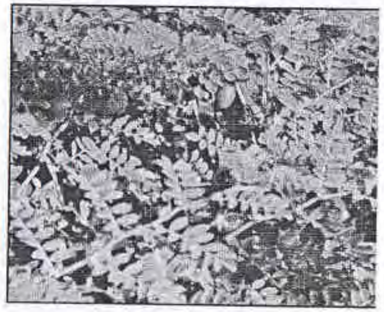
(# For detail information please see the bulletin on State-wise Micro- and Secondary nutri recommendations for different crops and cropping systems)

No sulphur

Sulphur @ 40 kg ha^{-1}



No sulphur



Sulphur @ 40 kg ha^{-1}

Plate 2.8 Effect of sulphur application on soybean and gram

Technology 17

Use of Spent Wash in Compost Making

Spent wash has vast potential for its practical application in agriculture as a source of plant nutrients and organic matter and as an amendment for sodic soils. However, high transportation and labour costs for loading and unloading restrict their wider use beyond the sugar factory and the distillery zone. Hence, there is a need for transforming the liquid effluent into solid form to make its transportation easier and cheaper. Moreover, on the face of scarcity of water in semi-arid tropics of India, there is a need for looking alternate source of water for compost making, and spent wash being an organic carbon rich wastewater can be utilized perfectly. In view of this, a new process of composting has been developed at IISS, Bhopal by replacing water with distillery effluent. The compost was prepared by heap method using the standard procedure developed at the Institute for enriched compost preparations except that water was

Table 2.12 Composition of spent wash amended compost at different sampling periods

Sampling Details	Ash (%)	Total N (%)	Total P (mg kg^{-1})	Total K (mg kg^{-1})	C:N
1st Sampling					
Control	54.55	1.13	12200	10500	23.33
Before SW addition	61.80	1.03	12275	11300	20.95
After SW addition (400L)	60.73	1.09	14900	16600	20.89
2nd Sampling					
Control	60.07	1.37	10875	12300	16.90
Before SW addition	70.37	0.89	12450	12600	19.31
After SW addition (200 L)	70.83	0.99	12550	15200	17.45
3rd Sampling					
Control	66.88	1.31	10800	10300	17.00
Before SW addition	64.74	1.16	12850	15700	17.60
After SW addition (200L)	66.33	1.37	13060	18200	14.25

replaced with spent wash. This has not only saved precious little water but also enriched the compost with useful nutrients like N, P, K, S and enzyme activity, apart from other growth promoting substances available in the effluent (Table 2.12). Crop performance of this compost was tested in maize-chickpea system in a black soil and results indicated that it was as good as or even better than FYM and conventional compost.

Technology 18

Safe Prescription Limits for Direct Application of Distillery Effluents in Agriculture

The disposal of spent wash, a distillery waste has long been a problem of the industry (Plate 2.9). On the other hand, it is reported to have good fertilizer value and a very rich source of organic matter. But it is presumed that although the effluent may facilitate better yields at the beginning due to its richness in nutrients, its continuous and indiscriminate use and abuse may cause accumulation of salts endangering the soil productivity and sustainability. Based on the crop performances and long-term implications of use of different distillery wastes on soil physical, chemical and biochemical parameters, suitable management prescriptions have been devised for harmless utilization of these waste products in soybean-wheat, maize-chickpea and groundnut-wheat systems. On-farm demonstration is going on at the institute with the following prescriptions.

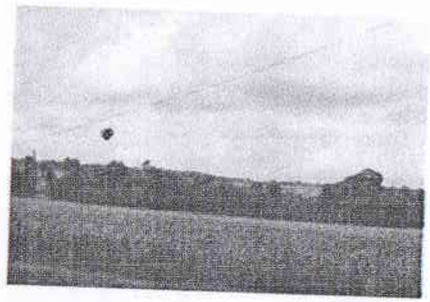



Plate 2.9 The distillery effluents dumping site: Before and after

The contribution made on this aspect will not only lead to the development of a technology for safe disposal of otherwise polluting distillery effluents onto the agricultural lands for crop production, but also advance our knowledge on the risk assessment and environmental impact of long-term use of the effluents in soil in terms of changes in quality parameters of the soil and water.

Based on five years of experimentation under field, pot-culture and laboratory conditions on application of distillery effluents on soybean-wheat productivity and consequent effects on soil physical, chemical and biological properties of soil, the following prescription has been formulated for soybean-wheat sequence in deep black soils of Madhya Pradesh.

Sl. No.	Soybean (rainfed)	Wheat (one pre -sowing plus two post -sown irrigations)
P-1	2.5 cm SW	N & P Fertilizers only
P-2	2.5 cm SW	1.25 cm SW + two top-dressings of N (1/4N +1/4N)
P-3	2.5 cm PME	N & P Fertilizers only
P-4	2.5 cm PME	1.25cm PME + two top-dressings of N (1/4N +1/4N)
P-5	5 t ha^{-1} LS	N & P Fertilizers only
P-6	5 t ha^{-1} LS	10 t ha^{-1} LS + two top-dressings of N(1/4N +1/4N)

SW = Spent Wash, PME = Post-Methenation Effluents, LS = Lagoon Sludges (RSW, PME and LS to be applied 7-15 days before sowing).

Technology 19

Potassium Management Strategies for Finger millet in Alfisol

Results of long term fertilizer trials indicated that all the crops grown on Alfisol type of soils showed significant response to K application. On going long term experiment in Alfisols at Bangalore has clearly established the core role of potassium application in enhancing yield of finger millet. Yield of finger millet was drastically reduced due to imbalanced nutrient application as compared to balanced and integrated nutrient management. Critical perusal of yield data generated over the years

further revealed that there is continuous decline in yield of finger millet due to imbalanced nutrient application viz. control, 100% N, 100% NP, and 50% NPK. On the contrary, 100% NPK, 150% NPK, 100% NPK+lime and 100% NPK+FYM gave significantly higher yield of finger millet. Decline in productivity is due to inadequate supply of K and compaction of soil due to decline in SOC. Thus a strategy was developed to enhance the productivity by managing K and bulk density of soil.

Potassium Nutrition Management Technology

Field experimentation data (2009-11) indicated that soil inversion (0-30 cm) resulted in increase in yields of finger millet compared to 100% NP and 100% NPK without soil inversion (Table 2.13). The recommended dose of N, P and K in finger millet was 100: 22: 42 kg ha^{-1} while in nutrient application in farmers' practice was 54: 23: 0 kg N, P, K ha^{-1}, respectively. Soil inversion resulted in decrease of average soil bulk density from 1.5 to 1.3 Mg m^{-3}. Bulk density was significantly reduced due to soil inversion as compared to other treatments. Thus, enhanced yield with soil inversion could be an integrated effect of easily available K and aeration to plant's roots. Split application of 100% K (42 kg K) also resulted increase in yield significantly over single application of K. Though increase in K dose to double (100% NP + 200% K) has given maximum finger millet yield but it was on par with split application of K and soil inversion (along with 100% NP). Inversion of soil also led to exploration of K which moved down to lower layer. Thus, results proved that less K availability and compactness of soil are two factors for low yield of Finger millet.

Agronomic efficiency for K has improved with application of lime (20 kg grain / kg K) and split application of K (28 kg grain / kg K) compared to 100% NPK (8 kg grain / kg K) and 100% NP + 200% K (16 kg grain / kg K). Sustainable yield index (SYI), is a relative measure of sustainability and was influenced significantly with different potassium nutrient management options. The maximum SYI of 0.64 was recorded with

100% NP + 2 split of K. Thus, it is advisable to split K dose to enhance K use efficiency as well as finger millet productivity under such acid soils (Plate 2.10).

Table 2.13 Average yield of finger millet (kg ha^{-1}), agronomic efficiency (potassium) and sustainable yield index of finger millet at Bangalore

Treatments	Finger Millet (kg ha^{-1})	AE (kg grain/ kg K)	SYI
Control	1909	-	0.25
100% NP	3180	-	0.34
100% NP + Lime @ 1 t ha^{-1}	3340	-	0.36
100% NP (adjusted) + FYM @ 10 t ha^{-1}	2403	-	0.37
100% NP + 100% K + Lime @ 1 t ha^{-1}	4028	20	0.55
100% NP + 100% K	3891	8	0.53
100% NP + 200% K	4493	16	0.57
100% NP + 2 Splits of 100% K (50% K at basal & 50% K at 30 DAS)	4354	28	0.64
100% NP + Soil inversion (0-30 cm depth)	4279	-	0.42
Farmers' practice (54 kg N and 23 kg P_2O_5)	3037	-	0.33
LSD (0.05)	269		0.07

Control **100% NP + K (2 Splits)** **100% NP + Soil Inversion**

Plate 2.10 Effect of potassium management treatments on growth of finger millet at Bangalore

Recommendation

Split application of K in two equal doses is advisable to harness the highest yield and potassium efficiency in finger millet. Inversion of soil once in two-three years would further help in maximizing the soil productivity. Finger millet is well adapted to acidic condition hence lime is not essential for this crop.

Technology 20

Pine Oleoresin Coated Slow Release Urea

Urea is an important source of N for crop production. Slowing down the diffusion of urea by coating, reducing the urea hydrolysis rate by inhibiting urease activity and reducing the microsite pH with acidifying materials are options of tonning up the N use efficiency of urea N. The crude pine oleoresin has all these three properties which can successfully be utilized for making coated urea for increasing efficiency of urea N. Pine oleoresin is a gum like substances extracted from pine trees *(Pinus roxburghii)* which is commercially used for the production of turpentine oil and other products. Hence an attempt was made to coat urea with pine oleoresin with the underlying three principle mechanisms by which N use efficiency of urea can be enhanced. It provides a physical barrier (coating film) for slow release of N from coated urea; inhibits urease activity through antibacterial properties of oleoresin; and inhibiting volatilization loss by reducing alkaline microsites due to acidic nature of the pine oleoresin.

Protocol for preparation of Oleoresin coated Urea

A protocol has been developed to coat urea with oleoresin to have a slow release urea fertilizer. The crude oleoresin was dried in the oven at 50°C for three days to remove water and turpentine, as a result of which it becomes semi-solid gum like substances. About 12 gm of this crude resin was dissolved in 100 ml hexane in a wide mouth bottle and to it 220 gm urea and 10 drops of methyl red indicator was added. After shaking for 5 minutes, the whole content was transferred to a plastic tray fitted snugly on a horizontal shaker and shaking operation with maximum speed was continued for around one hour till the hexane gets evaporated. Thereafter the whole material was kept in hot air oven at 50°C for 15 minutes for hardening of the material and to get oleoresin coated urea (Plate 2.11). Based on the several estimates, it was found that coated urea contained 3.82 – 4.36% pine oleoresin on the final product and the N content varied from 44.31 to 44.07% N.

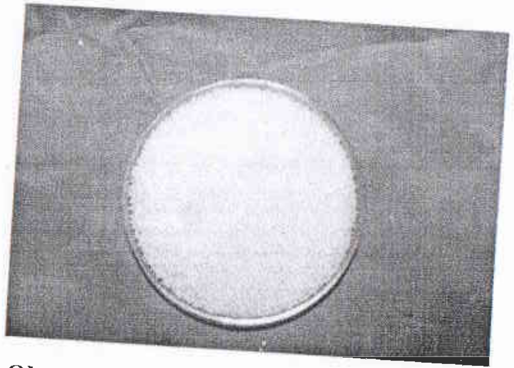


Plate 2.11 Oleoresin Coated Urea Fortified with Nano-particles

Technology 21

Protocol for Nanoparticle Coating

A protocol was developed to fortify the Urea granules with a consortium of nano-particles of Zn, Cu, Fe and Si using oleoresin. For easy dispersion of nano particle in water, ethyl alcohol was used instead of hexane to dissolve oleoresin for coating urea and then fortified with nano particles. This protocol can successfully be used to deliver nano-particles of micronutrients along with urea. About 12 g of crude oleoresin was dissolved in 100 ml ethyl alcohol in a wide mouth bottle and to it 220 g urea was mixed and shaken for 5 minutes. After that whole content was transferred to plastic tray fitted snugly on a horizontal shaker and shaking operation was continued with maximum speed to evaporate the alcohol. When 80% of the alcohol evaporated, mixtures of nano-particles were uniformly sprayed over the tray using a 53 µm sieve. The mixture of nano-particles contained 1 g Zn as ZnO (<100 nm), 0.5g Fe as Fe_3O_4 (50 nm) 0.3 g Cu as CuO (50 nm) and 1 g Si as SiO_2 (<20 nm). Before spraying these nano-particles on the pine oleoresin coated urea, they were mechanically mixed well. After the addition of nano-particles, the shaking operation continued for 10 minutes and thereafter kept in oven at 50°C for hardening to get free flowing urea fortified with the consortium of nano-particles (Plate 2.12) Out of the total amount of nano-particles added, 48.42% of the nano-particles got adsorbed on the surface of

oleoresin coated urea. The nano-particles coated urea, thus produced, contained 43.84% N, 2.20 mg Zn/g Urea, 1.10 mg Fe /g Urea, 0.66 mg Cu / g Urea and 1.06 mg Si / g Urea. Application of such urea @ 200 Kg/ha will supply , 440 g Zn, 220 g Fe, 132 g Cu and 212 g Si along with 87.68 kg N/ha to the crops.

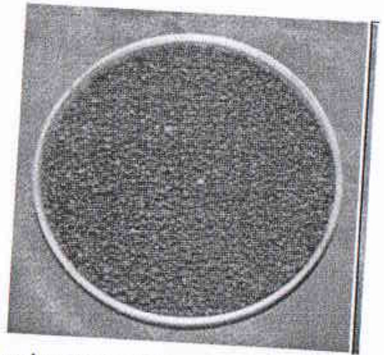


Plate 2.12 Oleoresin Coated Urea Fortified with Nano-particles

Technology 22

Mechanical Harvest Borne Residue Management

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 evolved at the Indian Institute of Soil Science Bhopal through years of experimentation. Wheat residue incorporation or retention coupled with application of 20 [illegible] N ha through fertilizer or organic manures is more beneficial than [illegible] in terms of enhanced crop productivity and soil fertility.

Wheat residue incorporation resulted in 20 [illegible] soybean and 15-25% in wheat as compared to residue burning. Soil incorporation of wheat residue plus N supplementation through FYM at the rate of 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 was more effective and profitable. 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 has 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.

The technology generated have resulted an additional advantage of Rs. 4992 per hectare over the residue burning (Table 2.13). Besides, incorporation of organic carbon to soil helps restore the soil health.

Table 2.13 Economic analysis of wheat residue management options (RMO) for soybean (based on 5 years mean data)

Residue Management Option	Cost of RMO	Additional cost over burning	Mean crop yields ($kg\ ha^{-1}$)		Value of produce	Additional value over burning	Profit over burning
	--- (Rs. ha^{-1}) ---		Soybean	Wheat	--------- (Rs. ha^{-1}) --------		
Burning	2640	-	1128	2601	29142	-	-
Incorporation	2980	340	1307	3075	34134	4992	4652
Surface Retention	3960	1320	1252	3026	33180	4038	2718

Note : *Calculation of costs includes only those operations that are uncommon among the RMOs*

3. RESULT DEMONSTRATIONS

BEST PROVEN TECHNOLOGIES WERE TESTED and demonstrated on the farmers' fields. These technologies have emerged from the institute projects and All India Coordinated Research Projects located at the Institute. The result demonstration teaches why a practice or input should be adopted by physically showing how a new or different practices compares with a commonly - used one in crop production. The purpose of using the result demonstration is to prove that the new practice is superior to the one currently being used, to persuade the farmer to try the new practice, and to set up a long-term teaching situation.

3.1 Broad Bed and Furrow (BBF)

The performance of maize, sorghum, pigeonpea and pearl millet genotypes grown as sole and intercropping systems on broad bed and furrow was demonstrated on institute farm to participating farmers in the three-day Kisan Mela during 24-26 September, 2002 organized by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, alongwith IISS.

3.2 Broad Bed and Furrow and Integrated Nutrient Management

Demonstration trials conducted at Rangai village, Vidisha district showed increase of 92% in soybean seed yield with integration of BBF with INM on waterlogged fields over that of integration of land with INM alone. On plots those had BBF in kharif season, INM and balanced fertilization produced 18% and 24% higher rabi wheat yield respectively over the farmers' practice. If soybean-wheat system grown on water-logged fields considered as a unit, a farmer can get a net income of Rs 68121/- and B:C ratio of 3:1 with the adoption of BBF and INM in soybean and INM in wheat. These results clearly brought out the fact that farmers can cultivate soybean in water-logged fields with BBF and INM in kharif and wheat with INM in rabi.

3.3 Balanced Fertilization Technology

3.3.1 On-farm demonstration for cotton

A balanced fertilization technology (BF) for cotton (80-40-20 kg N-P_2O_5- K_2O kg ha^{-1} + Zn @ 25 kg $ZnSO_4$ ha^{-1} +B @ 1 kg ha^{-1} as 0.1% B foliar spray twice), developed in the Technology Mission on Cotton project, was demonstrated on 10 farmers' fields in Balwada village of Khargoan district (M.P.). The balanced fertilization consistently resulted in better crop performance and distinctly higher cotton yields over farmers' practice. The yield gains due to balanced fertilization ranged from 13 to 41% with the mean yield increase across all farmers being 28%. Both participating and some non-participating farmers of village are now convinced about the benefits accruing from balanced fertilization and expressed their willingness to adopt it.

3.3.2 On-farm demonstration on soybean – wheat system

Field trials on farmers' fields in Rangai (Vidisha district), Geelakhedi (Rajgarh district) and Mugaliahat (Bhopal district) villages were conducted to identify nutritional constraints for soybean-wheat system production on Vertisols through nutrient omission approach and to demonstrate the effect of balanced fertilization in enhancing the productivity to farmers. The field experiment was laid with seven treatments, namely NPKSZn, NPSZn, NPKZn, NPKS, farmers' practice (FP) and modified farmers' practice (FP+S+Zn) with 3 replications. In case of farmers' practice treatment only N and P were applied as per the farmers' rates of application of N and P to soybean in the region (12 kg N and 30 kg P_2O_5 ha^{-1}). In other treatment N, P, K, S and Zn were applied at recommended rates (25 kg N, 60 kg P_2O_5, 20 kg K_2O, 20 kg S and 5 kg Zn ha^{-1}). Results revealed that balanced fertilization through application of NPKSZn at recommended rates produced higher soybean seed yield by 30-35% over farmers' practice (FP) (12 kg N and 30 kg P_2O_5 ha^{-1}). It indicates that farmers in this region are not able to realize the full yield potential of soybean by applying lower rates of N and P. Skipping of application of P (NKSZn treatment) and S (NPKZn treatment) had

resulted in reduction in soybean seed yield as compared to NPKSZ treatment. Similarly, the soybean yield was reduced significantly whe Zn was not applied. Application of S and Zn along with modifie farmers' practice (FP+S+Zn) produced 19% more soybean yield ove farmers' practice (FP). Balanced fertilization through application c NPKSZn at recommended rates produced higher soybean seed yield b 15% over modified farmers practice. Apparent recovery of P (22%), I (68%) and S (30 %) by soybean was also higher under balance fertilization. The results of experiments clearly indicated that highe soybean seed yield could be sustained by encouraging farmers to correc N, P, S and Zn deficiencies by adopting appropriate nutrien management practices. Chemical analysis of post-harvest soil sample showed the lower concentrations of available P, K and S in plots wher their respective application was omitted. There was a sligh improvement in their concentrations in plots where those nutrients wer applied.

3.4 Integrated Nutrient Management

Integrated Nutrient Management (INM) packages for pulse production systems were demonstrated on farmers' fields during 2002-03 in districts of Bhopal, Raisen, Rewa and Satna. Nutrient management practices for oilseeds were demonstrated in on-farm trials in farmers' fields in 7 states (Bhopal, Bharatpur, Raichur, Latur, Parbhani, Palem, Ranchi and Ballowal) under NATP project. The management of FYM was demonstrated to farmers, in Vidisha as a part of ICAR-ACIAR project.

3.4.1 Integrated plant nutrient supply technology for improving the productivity of soybean – wheat system

ICAR-ACIAR collaborative project entitled "survey of potential of manure for meeting crop nutrient needs with integrated nutrient management in Madhya Pradesh" was carried out with the objectives (i) to assess district level nutrient balance and trends of FYM use for the dominant cropping systems in M.P. using district level secondary data, and (ii) to survey the trends in alternative uses of cattle dung, including for FYM and use quantitative and qualitative methodologies to reveal other factors, including socio-economics and crop responses to FYM, likely to affect their use in two key districts.

Four on- farm trials were conducted in two villages of Rajgarh and Bhopal districts of Madhya Pradesh to evaluate different IPNS modules *vis-a-vis* farmers' practice. The details of different IPNS modules are presented in Table 3.1. The experimental soils at all sites were low in organic C, available N, P, S and Zn but high in available K. Soybean *cv* JS 335 was sown at sites 1, 3 and 4 where as soybean cv JS 9305 was sown at site 2. In *kharif* season, integrated use of 50% NPK + 5 t FYM ha^{-1} + *Rhizobium* increased the soybean seed yield by 11% and 25% over the 100% NPKSZn and farmers' practice, respectively. In *rabi* season, the IPNS module consisting of 50% NPK + 5 t FYM ha^{-1}+*Rhizobium* to soybean and 75% NPKS + PSB to wheat increased the wheat yield by 25-30% over farmers' practice. This IPNS module not only produced the wheat yield at par with that of 100% NPKSZn applied to both soybean and wheat but also saved 42 kg N, 45 kg P_2O_5, 20 kg K_2O, 15 kg S and 5 kg

Table 3.1 The details of different IPNS modules

Treatment	Soybean	Wheat
T_1	100% Recommended dose of NPKSZn*	100% Recommended dose of NPKS**
T_2	50% Recommended dose of NPKS + 5 t FYM ha^{-1}	75% Recommended dose of NPKS
T_3	50% Recommended dose of NPKS + 5 t FYM ha^{-1} + Rhizobium	75% Recommended dose of NPKS + Azotobacter
T_4	Farmers' practice (FP) (12 kg N + 30 kg P_2O_5 + 2 t FYM ha^{-1})	Farmers' practice (FP) (80 kg N + 50 kg P_2O_5 + 2 t FYM ha^{-1})
T_5	100% Recommended dose of KSZn + 50% of N + 75% of P + Rhizobium + PSB ***	100% Recommended dose of KS + 75% of N P + Azotobacter + PSB
T_6	5 t FYM ha^{-1} + Rhizobium + PSB	8 t FYM ha^{-1} + Azotobacter + PSB
T_7	5 t FYM ha^{-1}	8 t FYM ha^{-1}

** Recommended dose to soybean : 25 kg N + 60 kg P_2O_5 + 20 kg K_2O +20 kg S + 5 kg Zn ha^{-1}*
***Recommended dose to wheat: 120 kg N + 60 kg P_2O_5 + 20 kg K_2O +20 kg S ha^{-1}*
**** PSB – phosphate solubilizing bacteria*

Zn ha^{-1} and produced 6% higher yield over 50% of NPK + 5 t FYM/ha. Irrespective of the INM modules, soybean *cv* JS 9305 produced 5.5% more yield as compared to JS 335.

3.4.2 Demonstration of balanced and integrated nutrient management technology on farmers' fields : ACIAR-IISS Project

During the year 2009-10, 98 field demonstrations on farmers' fields in 6 villages of Raisen, Vidisha and Rajgarh districts of M.P have been conducted to demonstrate and popularize the INM technology in MP. In these trials, 2 nutrient management options viz., balanced fertilization (BF) through inorganic fertilizers alone (100% NPKSZn to soybean and 100% NPKS to wheat) and INM module (50% NPKS + 5 t FYM ha^{-1} + Rhizobium to soybean and 75% NPKS+PSB to wheat) were compared with the farmers' practice (FP). Soybean cv JS 335 and wheat var GW 366 were grown in *kharif* and *rabi* seasons, respectively. The initial soil fertility status of 98 trial sites showed that all sites were low in available N. About 47% sites were low in available P and 52% were low in available sulphur. Available Zn was low in 60% of the sites whereas 50% of sites were low in organic carbon.

About 32% field sites were deficient in four nutrients namely; N, P, S and Zn. In *kharif* (monsoon) season, the pooled data of soybean seed yield from 98 sites revealed that the balanced fertilization through inorganic fertilizers produced 32% higher seed yield over the farmers' practice. The INM module (50% NPKS + 5 t FYM ha^{-1}+ *Rhizobium* to soybean) produced about 52% higher soybean seed yield as compared to farmers' practice. This INM module produced about 15% higher soybean seed yield as compared to balanced fertilization through inorganic fertilizers alone. The soybean seed yield ranged from 875 kg to 1663 kg ha^{-1} in farmers' practice, from 1375 kg to 2125 kg ha^{-1} in balanced fertilization and 1500 kg to 2750 kg ha^{-1} under integrated nutrient management.

During the Farmers' Day, farmers attributed the higher soybean yield under INM to the higher pod bearing as compared to balanced fertilization. The mean number of pods/plant under INM varied fro[illegible] to 90. In *rabi* (winter) season, wheat crop (cv GW 366) was grow same plots with required amounts of nutrients in farmers' practice, balanced fertilization and integrated nutrient management. The pooled data of 98 trials indicated that the wheat grain yield ranged from 2500-4750 kg ha^{-1} under farmers' practice, 3375-6000 kg ha under balanced fertilization and from 2875-5375 kg ha^{-1} under integrated nutrient management. The mean wheat grain yield of 98 trials showed that the integrated nutrient management produced higher grain yield by 28% over farmers' practice. Balanced fertilization (fertilizers alone) increased the wheat grain yield by 42% over the farmers' practice.

3.4.2 Demonstration of LTFE technology through satellite experiments (AICRP on LTFE)

To evaluate technologies generated by LTFE centers and to develop strategies for enhancing the productivity of the region by intervening the management practices, few centers (Bangalore, Ludhiana and Akola) conducted satellite experiments on farmer's fields during 2005-06 (Table 3.2).

The purpose of conducting the demonstration experiments was to educate the farmers about judicious and balance use of nutrients. Survey conducted by the centers revealed that majority of the farmers are using N alone and some of the farmers are using N and P through external source of nutrients. Due to continuous use of phosphatic fertilizer there has been built up in soil P as observed in LTFE plots. To exploit the higher built up of P in soil, experiments were conducted.

Bangalore

The results of the experiment conducted with maize at Verammanahally village revealed that reduction of P doses to half did not have adverse effect on yield, whereas increase in K dose to double resulted in increased yield of maize from 37.9 q ha^{-1} (100% NPK) to 48.6 q ha^{-1} (Table 3.2). Incorporation of lime increased the productivity of maize but could not show any improvement in productivity of finger millet. FYM increased maize as well as finger millet yield significantly. This suggested that phosphorus dose can be reduced safely and the diversion

of the money saved equivalent to half dose of P to the K and lime would fetch more benefit to farmers.

Table 3.2 Evaluation of alternate nutrient management strategies of fertilizer use to sustain productivity of maize and finger millet

Treatment	Maize		Finger millet	
	Yield (q ha^{-1})	FRR	Yield (q ha^{-1})	FRR
Control NPK	37.92	6.84	34.00	6.13
N ½ PK	37.44	9.86	34.60	9.74
N ½ P 2 K	48.61	7.54	35.00	8.22
N ½ P K + lime	48.61	6.23	36.00	11.18
N ½ P K + 5 t FYM	51.33	10.67	39.80	10.14

FRR= Fertilizer response ratio (yield kg^{-1} fertilizer)

To evaluate the nutrient response ratio (NRR) in most sustainable nutrient management options of LTFE and to compare with the farmers' practices, field experiments were conducted on farmers' fields in Kolar, Tumkur and Madenahalli districts of Karnataka. The results obtained (Table 3.3) revealed that through the maximum yield of maize (45.2 q ha^{-1}) was recorded with the application of 150% NPK but the response ratio was least. The highest nutrient response ratio (kg grain kg^{-1} nutrient) was obtained on application of 100% NPK + 15 t FYM in both the crops. The yield of maize and response ratio of nutrients under farmers' practice is comparable with intervention but both yield and nutrient ratio were low in case of finger millet. The maximum yield in 150% NPK further supports the findings that to sustain the productivity at higher level, K should be added in sufficient quantity.

Thus, results at farmers' field clearly indicated that the P dose can be reduced to half safely without any reduction in yield. But to enhance the productivity, K is needed in more quantity and part of that could be supplemented through FYM. To harness greater nutrient utilization

Table 3.3 Evaluation of most sustainable fertilizer use practices

Treatment	Maize		Finger millet	
	Yield (q ha^{-1})	FRR	Yield (q ha^{-1})	FRR
150% NPK	45.20	14.08	34.00	15.04
100% NPK + FYM @ 5 t ha^{-1}	42.10	19.67	27.50	16.77
Package of practice	37.72	17.46	25.50	15.55
Farmers' practice	40.83	18.77	22.00	8.76
Control (100% NPK)	37.92	17.72	26.00	15.85

Package of practice =100% NPK +10 t FYM, Farmer's practice =64 kg N + 46 kg P, FYM (15-20 t ha^{-1}); FRR= Fertilizer response ratio (yield kg^{-1} fertilizer)

efficiency, integrated use of chemical fertilizer with FYM is a better option.

Ludhiana

To assess the soil fertility status of farmers' fields of nearby districts and also to compare and simulate with the management options of LTFE, soil samples from Ludhiana, Bathiada and Gurdaspur districts of Punjab were collected and analyzed for their fertility status. Field experiments were conducted with 6 treatments (Table 3.4) with maize-wheat system in three villages. The results obtained indicated that reduction in P dose to half resulted decline in yield significantly at some of the sites compared to 100% P. However, application of Zn resulted in increased yield of both maize and wheat at all the sites. Critical evaluation of data further indicated that conjunctive use of chemical fertilizer and FYM resulted in the highest productivity at all the sites. The yield obtained was at par with the yields obtained with application of nutrients on soil test basis; nutrient application was in similar quantity. Decline in yield (may not be statistically significant) of maize and wheat on reduction in dose of P indicated that still the P built up was not sufficient enough to curtail the P dose at farmers' fields.

Thus, results clearly indicated that application of P and Zn is essential to

harness the potential productivity of crops. But to sustain the productivity at higher level with conjunctive use of chemical fertilizer and FYM is the only option. This supports the strategies developed out of LTFE results.

Table 3.4 Effect of organic and inorganic fertilizer on grain yield (q ha^{-1}) in maize-wheat cropping system in different zones

Treatment	Jhaloa		Ramgarh		Rajewal	
	Maize	Wheat	Maize	Wheat	Maize	Wheat
100% N + 50% PK	36.5	47.0	38.3	40.7	36.7	44.2
100% NPK + 50% Zn	40.6	52.8	44.7	45.3	46.3	47.3
100% NPK	40.0	55.0	44.0	45.5	43.6	49.5
100% NPK + FYM	45.3	59.7	50.0	51.1	53.3	54.1
Farmers' practice	37.2	50.5	41.3	41.1	41.0	44.1
Soil test basis	41.2	53.0	44.3	46.9	45.7	48.0
CD 5%	3.9	4.2	4.7	4.5	4.2	4.4

Farmer's practice = 150 kg N + 45 kg P_2O_5 + 0 kg K_2O to Maize and 150 kg N + 60 kg P_2O_5 + 0 kg K_2O to wheat

Akola

To evaluate the strategies developed out of the results of LTFE, field experiments were conducted at six farmers' fields in five villages using soybean-wheat as test cropping system. The result recorded revealed that Zn and S are essential to harness the potential yield in addition to N, P and K. Application of Zn + S over and above NPK resulted in increased soybean yield from 11.17 q ha^{-1} to 14.12 q ha^{-1} and wheat yield from 27.6 q ha^{-1} to 33.1 q ha^{-1} (Table 3.5). The result further revealed that the conjunctive use of NPK + FYM resulted in the highest productivity of both soybean and wheat. The decline in yield under farmer's practices was due to imbalanced use of nutrients and P application in less quantity in both soybean and wheat.

From the field experiments it was concluded that to sustain the productivity of soybean-wheat system Zn and S are essential in Akola region of Maharashtra. To sustain the productivity at the highest level

Table 3.5 Yield soybean and wheat at Akola as influenced by various treatments (Average of 6 experiments)

Treatment	Grain (q ha^{-1})	
	Soybean	Wheat
RD NP	11.17	27.69
RD NPK + Zn	12.19	29.66
RD NPK + S + Zn	14.12	33.15
RD NPK + 10 t FYM ha^{-1} + Zn	16.79	37.61
Farmers' practice	9.35	24.49
CD at 5 %	0.67	2.06

RD for soybean N-30, P-75, K-0, Wheat N-120, P-60, K-60, Zn 2.5 kg ha^{-1}, S-40 Farmer's practice: soybean N-25 kg, P-50 kg, wheat - 100 kg N

and sustain over a long period of time integrated use of fertilizers and FYM is essential.

3.5 Benefits of STCR Based Prescriptions

3.5.1 Follow-up trials on validation of fertilizer prescription equations and front line demonstrations on farmers' fields

Demonstrations at the farmers' fields are effective approaches for motivating farmers for adopting STCR technology by showing its benefits. To create awareness amongst the farmers, STCR frontline demonstration on soil test based fertilizer was launched in 10 states by 12 co-operating centres of AICRP STCR and state soil testing laboratories with a grant from the Department of Agriculture and Cooperation, Government of India. The demonstrations carried out in the states of Himachal Pradesh, Punjab, Haryana, Delhi, Maharashtra, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Bihar, and West Bengal shown high response ratios and benefit:cost ratios in important crops when fertilizers were applied on soil test basis for pre-targeted yields. In the demonstrations carried out in Punjab, Tamil Nadu and Andhra Pradesh,

the soils in many districts were adequate or high in available phosphorus in these soils and applications of very small amounts of P helped to obtain high response ratios and benefit:cost ratios. In Gurdaspur, Sangpur, Ropar and Kapurthala districts of Punjab the soils had high available P status but low N and K. Application of balanced rates of N and K helped to obtain high benefit:cost ratio and response ratios. Similarly, in Andhra Pradesh soils having adequate P and K, small rates of P and small to moderate rates of K helped to obtain high profits thus saving the cost of fertilizers (1998-99)

During 2000-2001, eco-regional balanced and IPNS demonstrations on soil test based fertilizer application were conducted by cooperating centres of AICRP (STCR) and state soil testing laboratories with assistance from the Department of Agriculture and Cooperation, Government of India. The demonstration carried out at Palampur (Himachal Pradesh), Coimbatore (Tamil Nadu) and Nellore (Andhra Pradesh) showed high response ratios and benefit: cost ratios in important crops when fertilizers were applied on soil test basis for pre-targeted yields. STCR frontline demonstrations carried out at farmer's fields in 11 districts of Punjab revealed that the application of fertilizers based on soil tests resulted in more benefits to the farmars compared to fixed recommended doses as well as farmers practice.

Frontline demonstrations (FLDs) on STCR during 2002-03 were carried out by various centres of AICRP-STCR in various states. Similarly, FLDs on sulphur response were carried out by AICRP on Micro and Secondary Nutrients in various states,

The STCR equations were tested in the follow-up and FLD trials. In general, there were higher net returns and higher B/C ratios in STCR based treatments than general recommendations (GRD) or farmers' practice. At Hyderabad, higher response and higher benefit: cost ratios were observed in STCR recommended treatment than GRD and farmer's practice. Similarly at PAU, Ludhiana, results of follow-up trial on rice and wheat for validation of prescriptions equations revealed that yield targets were achieved within variation of less than 10%. The economic analysis revealed that net profit was higher in STCR treatment than GRD and farmer's practice. At New Delhi, similar observation has been made in wheat and pearl millet. The follow-up verification trials conducted at Pantnagar, Rahuri and Raipur on garlic, onion, wheat, cauliflower, chilli, rice, soybean, chickpea, brinjal and okra showed that adoption of STCR recommendations under IPNS resulted in 90% of target yield achievements. In addition to the observation, net profits were higher in STCR treatment compared to other practices. The front line demonstrations carried out on farmers' fields at Jabalpur under IPNS on wheat, paddy and urd bean revealed that the benefit:cost ratio was better with the STCR recommendations than the farmers practice and general recommendations. Similarly demonstration on groundnut and sunflower showed that soil test crop response treatment exhibited superiority over farmer's practice and general recommendations.

During 2006-07 at Raipur, the demonstrations carried out on farmers' fields with rice and soybean to test the validity of fertilizer recommendation indicated that higher economic returns together with higher yield can be achieved with STCR based fertilizer use as compared to farmers' practice and general recommendation. The average response ratios were 10.76 in farmers' practice and 12.8 in target yield of 50 q ha^{-1}. At Jabalpur, higher response and response ratios were obtained in FLD's on gram, wheat and paddy which indicated the superiority of soil test based dose over blanket fertilizer application.

3.5.2 Front Line Demonstration on oil seed crops

The STCR centres have conducted about sixty (60) front line demonstrations in oilseed crops (2009-10) on farmers' fields to demonstrate the beneficial value of the STCR technology based on soil test values to the farmers and thereby balanced use of fertilizer application in conjunction with organic manure, biofertilizers, green manuring etc. for achieving the targeted yields (Table 3.6).

3.6 Micronutrients

3.6.1 Frontline Demonstrations of AICRP Micronutrients

The FLDs (20) under AICRP (Micronutrients) were carried out to demonstrate the benefits accrued from the balanced use of micro and secondary nutrients in oilseeds and pulse crops in farmers' fields with the financial assistance from Technology Mission on Oilseeds, Application of 5.5 kg Zn ha^{-1} to oilseeds and pulse crops was found beneficial. Hence its basal application through broadcast is recommended in zinc deficient soils. In boron deficient calcareous soils, application of 0.8 kg B ha^{-1} to each crop or 1.6 kg B ha^{-1} annually through borax was found optimum for rice-wheat, maize-lentil-mustard, and maize-lentil-gram based cropping systems. Balanced application of 5.5 kg Zn ha^{-1} with 40 kg S ha^{-1} gave the maximum yield in zinc and sulphur deficient soils.

Table 3.6 Front line demonstrations conducted using STCR technology in different oilseed crops (2009-10)

Centre	Crop	No. of demonstrations conducted			Total
		Kharif	Rabi	Summer	
New Delhi	Mustard (1)	--	Rabi	--	1
Bikaner, Rajasthan	Mustard (10)	--	Rabi	--	10
Coimbatore, Tamilnadu	Groundnut (2)	Kharif	--	--	4
	Sunflower (2)	Kharif			
Bengaluru, Karnataka	Groundnut (10)	Kharif	--	--	14
	Sesame (2)	Kharif			
	Safflower (2)		Rabi		
Hyderabad, AP	Sesame (3)	Kharif	--	--	6
	Sunflower (3)	Kharif			
Palampur, Himachal Pradesh	Soybean (4)	Kharif		--	10
	Toria (6)	--	Rabi		
Jabalpur, MP	Mustard (2)	--	Rabi	--	4
	Soybean (2)	Kharif			
Raipur, Chhattisgarh	Soybean (5)	Kharif		--	10
	Safflower (5)	--	Rabi		
Hisar, Haryana	Raya (3 irrigation.)	--	Rabi	--	5
	Raya (2 unirrigated.)	--	Rabi		
Bhubaneswar, Orissa	Groundnut	Kharif	--	--	6
				TOTAL	70

3.7 Biofertilisers

3.7.1 Network Project on BNF

Soybean rhizobial and PGPR strains developed and identified by IISS were supplied for mass production to JNKVV Biofertilization production centre. Around 2.13 lakh inoculants packets were prepared with these strains and supplied all over Madhya Pradesh. These inoculants packets were also used in 1000 demonstrations on farmers' fields in a TATA-ICRISAT livelihood project in various districts of Madhya Pradesh and 100 demonstrations were conducted by IISS, Bhopal.

Nine frontline demonstrations were conducted during the year 2008-09 on farmers' field on efficacy of mixed inoculation of *Bradyrhizobium* and PSB in Soybean.

3.7.2 Bio-nutrient package demonstrations

Efficacy of a bionutrient package consisting of 50% NPK (Urea, SSP, MOP) FYM 5 t ha^{-1} and biofertilizers (*Azotobacter, Azospirillum* and PSB) was demonstrated on soybean, maize, kodo, kutki and niger in 5 farmers' fields in Tehsil Kurai, Seoni district (M.P.) and compared with Farmers practice (FP – 50% N P through DAP). The yield increase was 17, 25, 40, 20 and 18% in soybean, maize, kodo, kutki and niger respectively. The absolute increment for the crops (kg ha^{-1}) was 240, 550, 175, 50 and 80 kg ha^{-1} (JNKVV, Jabalpur).

Biofertilizer costing Rs 3,70,000/- were produced and sold to the farmers from university counter at Parbhani, Nine frontline demonstrations were conducted during the year 2008-09 on farmer's field on efficacy of mixed inoculation of *Bradyrhizobium* and PSB in soybean. Soybean seed yield in farmers' fields varied from 1420 to 2642 kg ha^{-1}. There was an average increase of 24% in yield due to inoculation (MAU, Parbhani).

3.7.3 Bio-nutrient package demonstrations

Evaluation of the package in eight farmers of Samastipur, Muzaffarpur

and Vishali districts showed 32% increase in grain yield in resource poor farmers and 11-14% increase in grain yield in resource rich farmers who also applied chemical fertilizers. There was an increase of 20% in grain yield of broad bean (11 q ha^{-1} in farmer's practice and 13.2 q ha^{-1} in biofertilizer treated plot).

3.7.4 Impact of Biofertilizers

Demonstrations were carried out at Kandhamal and Kalahandi (tribal districts) of Orissa on *Rhizobium* inoculation of pulse crops along with acid soils amelioration with paper mill sludge (PMS @ 5 q ha^{-1}) and soil test based nutrient application. There was 75, 63 and 74% increase over farmers' yield of 37.1q ha^{-1} of cowpea pods; 4.5 q ha^{-1} of green gram and 4.2 q ha^{-1} of black gram grain respectively. Bioinoculation of potato, ginger and turmeric crops with *Azotobacter, Azospirillum* and PSB integrated with soil test based fertilizer dose showed 22, 24 and 21% yield increase (OUAT, Bhubaneshwar).

Impact analysis of biofertilizers studied in different KVK's of Assam as components of INM showed average yield range of 4.0-5.0 t ha^{-1} in *sali rice* and 6.5 t ha^{-1} in *boro rice* with B:C ratio of 1.6-4.0 and 1.7 respectively. *Azotobacter* and PSB increased `*toria'* yield by 26% with average of 1.6 t ha^{-1} against 1.3 t ha^{-1} obtained under farmers' practice. *Azospirillum* and PSB as seed treatment enhanced fibre yield of Jute by 20.4% with B:C ratio of 1.9 (AAU, Jorhat).

The FLDs conducted on farmers' fields showed 13-31% yield increase due to rhizobial inoculation in groundnut and 13% increase in rice due to Azophos application (TNAU, Coimbatore). Biofertilizer sale in Maharashtra increased from Rs.70000/- (2003-04) to Rs.5,00,550/- (2010-11) showing increased awareness and the impact created (MAU, Parbhani).

3.7.5 Front line demonstrations of BNF

Demontrations in Maharashtra

Ten front line demonstrations were conducted on farmers' fields on mixed inoculation of *Bradyrhizobium* and PSB in soybean in Vertisols. Large scale commercial production of biofertilizers was undertaken and sold to the farmers. Good response in the use of *Rhizobium, Azotobacter,* phosphate solubilizing bacteria and *Azospirillum Biofertilizer* was observed by the farmers of the area (MAU, Parbhani).

Bionutrient package for Rice in Bihar

Application of enriched mycostraw (spent residue or semi decomposed straw + *Pseudomonas* spp) alongwith *Azospirillum* sps. and cyanobacteria to ten farmers' fields increased yield from 4-32% depending upon the doses of fertilizer applied by the farmers. All the farmers used the mycostraw developed by them during the cultivation of oyster mushroom. Addition of *Aeschyomene* in bionutrient package further enhanced the saving of nitrogen and phosphorus upto 65-75 per cent of recommended dose. Application of *Azospirillum* and PGPR in six farmers' fields in rabi maize augmented the yield by 12-15 per cent. (RAU, Bihar).

Demonstrations in Tamilnadu

In Front Line Demonstration trials on groundnut in Tamilnadu, 13-16% increase in pod yield per ha was observed in farmers' fields (TNAU, Coimbatore)

Demonstrations in north east region (Azolla application in rice)

Azollla application for rice in North-East: Azolla is grown in polythene lined pits round the year; it multiplies in 15-20 days. For continuous harvest of *Azolla,* 10-15 pits are required. Maximum cost of each pit is approximately Rs. 80-90 and can be used for 2 years. After 3-4 weeks of growth and formation of mat, *Azolla* is incorporated in soil. Again after 7-

8 weeks, the *Azolla* covers the field and requires a second incorporation. About 2-3 tonnes of *Azolla* can be supplied in each bigha of rice field with a supplementation of 4-8 kg N per crop per season (20-40 kg N ha^{-1}). The technology was generated for round the year homestead cultivation and extended to villages around Jorhat.

3.8 AICRP on Microbial Decomposition

Under AICRP on microbial decomposition and recycling of farm and city wastes the technology for preparation of phosphocompost production using phosphate ore and bio solids as a substitute for phosphatic fertilizers was disseminated to the Department of Agriculture, Govt. of Madhya Pradesh during 2000-2001. This technology has been recommended by ICAR for wider publicity and adoption by the farmers and is being popularized through field level demonstration (FLDs) under Technology Mission on Oilseed programme.

4. METHOD DEMONSTRATION

THE TECHNOLOGIES ORIENTED TO METHOI DEMONSTRATION (MD) at research farm of Indian Institute c Soil Science and farmers' fields are elaborated and described hereunder.

Method demonstrations, oldest form of teaching basically show farmer how to follow a particular methodology. The method demonstratio shows a group or class how methodology is done step-by-step for th purpose of teaching new techniques and practices to the farmer. Ideally each individual attending the demonstration would have an opportunit to practice the new skill during the lesson or session. The effectiveness c the demonstration depends, to a great extent, on the amount of prepara tion and planning. The researcher will probably be dealing with farmer who have already accepted the particular practice being demonstratec but who now want to know how to do it themselves. They are participa tory and enable farmers to learn by doing.

The purpose of method demonstration are to teach basic skills involve in agriculture to small groups of people and to teach how to do certai things (rather than why they should be done, as in a result demonstration

4.1 Broad Bed Furrow and Balanced Fertilization

Demonstration of effect of integration of broad bed and furrow (BBF and balanced fertilization on growth and productivity of soybean-whea system on waterlogged fields in Vidisha district

About 20-25% of cultivable land in Vidisha district is left uncultivated b farmers during kharif season due to prolonged waterlogging conditior Even though farmers sow some waterlogged fields with soybean, th yields are negligible due to poor establishment of crop. Most of the field in this district were also deficient in available N, P, S and Zn but high i available K. Therefore, three demonstration field trials were conducte in Rangai village, Vidisha district to demonstrate the beneficial effect o integration of Broad Bed and Furrow (BBF) with balanced fertilizatio or integrated nutrient management (INM) on soybean-wheat systen

The beneficial effect of integration of BBF with balanced fertilization (100% NPKSZn) or INM on soybean seed yield was compared with that of flat-on grade (normal) with balanced fertilizer or INM on waterlogged fields which could not be cultivated in most of the years.

During kharif season, the results of demonstration trials showed that the integration of BBF with INM produced higher soybean yield by 83%, 78% and 96% at site 1, site 2 and site 3, respectively over the integration of flat land (normal) with INM. Whereas, the integration of BBF with balanced fertilization with inorganic fertilizers produced 73%, 82% and 75% higher soybean yield over the integration of flat land (normal) with balanced fertilization at site 1, site 2 and site 3, respectively. The pooled data of 3 sites showed an increase of about 92% in soybean seed yield with integration of BBF with INM on waterlogged fields over that of integration of flat land with INM (Table 4.1).

Table 4.1 Soybean grain yield (kg ha^{-1}) as affected by the integration of nutrient management and land treatment (LT) on waterlogged fields (Mean of 3 sites)

Land treatment	Nutrient management options			Mean
	FP	BF	INM	
Flat (Normal)	1017	1246	1246	1141
BBF	1585	2322	2322	1985
Mean	1301	1784	184	
LSD (5%)	LT	NM	LTx NM	
	481	309	487	

FP : Farmer's practice; BF : Balanced fertilization; INM: Integrated nutrient management

During *rabi* season, wheat was grown on flat land with INM, balanced fertilization and farmer's practice of nutrient management. On plots those had BBF in kharif season, INM and balanced fertilization produced 18% and 24% higher wheat yield, respectively over the farmer's practice (Table 4.2).

Table 4.2 Economics of nutrient management in wheat grown on plots those had BBF in kharif season (Mean of 3 sites)

Treatment	Mean yield (kg ha^{-1})	Gross income (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
FP	3977 (± 184)	56424	10173	46251	4.55
BF	4931 (± 272)	70178	11180	58998	5.28
INM	4690 (± 284)	66620	10507	56113	5.34

Figures in parentheses are standard deviations

Economics of BBF and nutrient management in soybean-wheat system grown on waterlogged fields has been computed. The economics evaluation in soybean showed that a farmer can get a net income of about Rs. 12000/- and a B:C ration of 0.96:1 with the integration of BBF with INM on water-logged fields (Table 4.2). During rabi season, cultivation of wheat on plots those had BBF in kharif produced a net income of about Rs. 59000/- with balance fertilization through inorganic fertilizers and a net income of Rs 56000/- with integrated nutrient management (Table 4.2). If soybean-wheat system grown on water-logged fields considered as a unit, a farmer can get a net income of Rs. 68121/- and B:C ratio of 3:1 with the adoption of BBF and INM in soybean and INM in wheat. These results have clearly indicated fact that the farmers can cultivate water-logged field with soybean with BBF and INM in kharif and wheat with INM in rabi which facilitate higher cropping intensity and net income to the farmers in Madhya Pradesh.

4.2 Vermicomposting

There is a growing realization for the adoption of ecologically sustainable farming practices that can only reverse the declining trend in the global productivity and environment protection. Compost is one of the nature's best mulches and soil amendments. Compost improves soil structure, aeration and water-holding capacity. The quality and quantity of organic manures play a vital role in the maintenance of soil quality in sustainable agriculture production. The organic wastes available in India are estimated to supply about 7.1, 3.0 and 7.6 million tonnes of nitrogen, phosphorus and potassium, respectively. In this, crop residues alone can supply about 1.13, 1.41 and 3.54 million tonnes of nitrogen, phosphorus and potassium, respectively.

Epigeic earthworms remain active all throughout the year under favourable conditions. Moisture levels, temperature, food and space are essential for their survival and biomass production. A technology for vermicomposting of different organic wastes by earthworms was developed. Addition of earthworms accelerates the breakdown of organic wastes by providing the right environment for the organisms in the compost pile and it is possible to produce excellent compost in the shortest possible time within 3 - 3½ months. In earthworm composting technology, the beneficial soil microflora destroy soil pathogens and convert organic wastes into enzymes, antibiotics, growth hormones and protein rich products. In this technology, methods have been standardized to decompose agro-based wastes by worm alone or P- enriched earthworm compost (vermicompost) using rock phosphate. Methods have been standardized to obtain good matured compost having narrow C/N ratio, less total organic C, water soluble C, higher ash content and cation exchange capacity.

4.3 Enriched Compost Production Technology

A method for compost making enriched with N, P and S was perfected by amending the wastes with chemical amendment, *viz.*, rock-phosphate, pyrite and nitrogen through urea and bioinoculum. This method reduced the period of decomposition from 180 to 110±5 days. In the aerobic decomposition process mineral enriched nitro-phospho-sulfo-compost was prepared by adding an aqueous slurry of 1:1 ratio straw and fresh dung charged with chemical amendments (rock phosphate @ 2.5% P_2O_5, pyrite @ 5%, nitrogen through urea @ 0.5%) and then inoculated with N-fixers *(Azotobacter chroococcum)* P-solubilizing organisms *(Aspergillus awamori*), cellulose decomposer *(Paecilomyces fusisporus),* and fungal inoculum (*Pseudomonas striata).* The microbial inoculation was done after 35 days when temperature reduced from 70°C to 30°C. Evaluation of manurial quality of the phospho-sulfo-nitro-compost showed that the compost should be good substitute for super phosphate containing

equivalent amount of P_2O_5 The maturity values in terms of total organic carbon (24-33), water soluble carbon (0.1-0.3), cation exchange capacity (77-86) and C/N ratio (10-15:1) with bio-degradability index between 2.0-3.0 depicted that the compost is in complete mineralized form.

5. PARTICIPATORY TECHNOLOGY DEVELOPMENT

THE TECHNOLOGIES DEVELOPED BY THE INSTITUTE were tested and several field trials were conducted in participatory mode with farmers. It includes the technologies compatible to farmers' situation based on feasibility, resources availability, low cost, farmer-friendly methods, economical profitability etc.

5.1 Collaboration with FAO & IFFCO

One FAO-ICAR-IFFCO collaborative project on 'Developing eco-regional integrated plant nutrient management systems for sustainable crop production' involving Indian of soil science, Bhopal has been started on January, 1999 with the objectives of generating data on field applicability of IPNS approach, to evaluate the performance and to refine the of different technologies for sustaining high yields and fertility maintenance and refine the IPNS based recommendations for extension and transferring to similar areas elsewhere in the country . A group of farmers following soybean - wheat-cropping system on black and red soils were selected based on PDCO (Participatory Diagnosis of Constraints and Opportunities) survey in an adoptive village Mugaliahat. Experiments were conducted on those farmer's fields with treatment comprising of different nutrient management systems *viz*., farmer's practice, soil test based fertilizer dose, established IPNS dose and new interventions based on PDCO.

5.2 Conservation Tillage in Soybean-Wheat Cropping System

Demonstration (Plate 5.1) was carried out in farmers' field in village Bagroda, district Bhopal (Madhya Pradesh) on conservation tillage and manure application under soybean-wheat cropping system. The selected farmers followed two major practices for crop residue management after harvest of wheat crop *viz*., crop residue burning or removal. These are the two common practices of crop residue management commonly followed by farmers of Madhya Pradesh. The predominant cropping system followed by both farmers is soybean-wheat. A comparative study was done in farmer's field to compare the effect of three tillage systems and manure application on crop yield and soil productivity. The treatment details at farmers' fields were as follow,

Tillage	Soybean	Wheat
Conventional tillage/farmer's practice	Three ploughing + sowing by seed drill + NPK recommended dose	Two ploughings + sowing by seed drill+ NPK recommended dose
Reduced tillage	One pass cultivator/rotavator + sowing by seed cum fertilizer drill + Vermicompost @ 1.5 t/ha	One pass cultivator/rotavator + sowing by seed cum fertilizer drill + NPK recommended dose
No tillage	Direct sowing by no till seed cum fertilizer drill + Vermicompost @ 1.5 t/ha	Direct sowing by no till seed cum fertilizer drill + NPK recommended dose

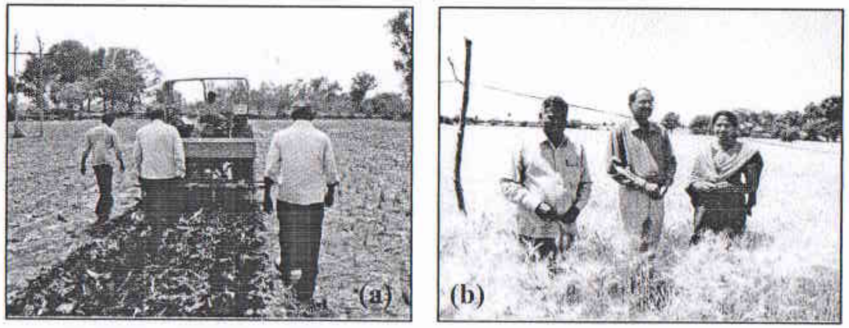


Plate 5.1 A view of (a) Soybean sowing with no till drill (b) wheat crop with reduced tillage after soybean under farmer's field *(Shri Prem Narayan Patel, village Bagroda)*

Benefits of the Technology

- Energy requirement was 4.68 and 2.32 times more in conventional tillage sowing as compared to no tillage and reduced tillage sowing system.
- Cost of production of wheat was 40.62% and 21.12% more in conventional cultivation as compared to zero and reduced tillage

cultivation system.

- The zero and reduced tillage saved Rs 7800 and Rs 4725 ha^{-1} $year^{-1}$ in wheat production system over conventional tillage in vertisol condition.
- No and reduced tillage offers an opportunity for C sequestration and reduce C emissions.
- Crop residue retention and conservation tillage propagated in farmer's field

5.3 Integrated Nutrient Management

Low-cost integrated nutrient management (INM) technology for soybean-wheat system in black soils of Madhya Pradesh was developed through participatory method by conducting several field trials in different villages of Rajgarh, Vidisha and Bhopal districts.

5.3.1 Farmers' resource-based integrated plant nutrient supply system for soybean-wheat on Vertisols

Integrated plant nutrient supply (IPNS) system is a proven nutrient management strategy for sustaining agricultural productivity and soil health. In most cases, however, the IPNS research has been confined to research stations without considering the availability of organic sources and their competitive uses, and the technological options specific to farming situation are scarce. Farmers' resources based integrated nutrient management technology has been developed for soybean-wheat system for Malwa and vindhyan plateau region and further refined by assessing the farmer's resource base with regard to organic manures and water availability through participatory diagnosis of constraints and opportunities (PDCO) survey. Results of the field trials showed that in soybean-wheat system, balanced fertilization based on soil tests with 4 t FYM ha^{-1} to soybean crop was the best in terms of system productivity. Farmer's resource-based IPNS intervention as calculated from targeted yield equation based on soil-test-crop-response produced 8-49% more soybean and 11-39% more wheat as compared to farmer's practice.

5.3.2 Low-cost Integrated Nutrient Management (INM) Technology for Soybean-Wheat System

On-farm trials conducted in different villages of Rajgarh, Vidisha and Bhopal districts of Madhya Pradesh to evaluate the efficiency of different integrated nutrient management (INM) modules for sustaining higher productivity of soybean-wheat system vis-à-vis farmers' practice showed that the INM Module, comprising 50% NPKS + 5 t FYM /ha+Rhizobium to soybean and 75% NPKS + phosphate solubilizing bacteria (PSB) to wheat proved economically viable technology for higher yields. In kharif season, integrated use of 50% NPKS + 5 t FYM/ha + Rhizobium to soybean increased the seed yield by 11% and 25% over the chemical treatment (100% NPKSZn) and Farmers' Practice, respectively (Table 5.1). Rhizobium inoculation with 50% NPK + 5 t FYM/ha produced 6% higher yield over 50% NPK + 5 t FYM/ha without rhizobium. In rabi season, this INM Module which comprises 50% NPKS + 5 t FYM/ha + Rhizobium to soybean and 75% NPKS + phosphate solublizing bacteria (PSB) to wheat produced 16.3% higher wheat grain yield over the farmers' practice (FP). This INM module produced not only the higher yields of soybean and wheat but also saved 42 kg N, 45 kg P_2O_5, 20 kg K_2O, 15 kg S and 5 kg Zn/ha/year in a soybean-wheat system. When soybean and wheat crops considered together as a soybean-wheat system, this INM module gave the highest net returns (Rs. 61240/ha), which was 24% higher as compared to the farmers' practice (Rs. 49264/ha). The benefit: cost ratio of this INM module in the soybean-wheat system was also higher (2.83: 1) among all the options tested.

5.3.3 Nutrient input, output and balance of farmyard manure production by farmers through conventional method

Under the ACIAR project, simple mass balance studies were conducted by selecting a FYM pit at Geelakhedi village, Rajgarh district (M.P.). The depth of this pit was about 1.2 m. In each month dried samples of each type of organic materials that put into the FYM pit were pooled together to obtain a composite sample and were processed and analyzed

Table 5.1 Economics of INM in soybean-wheat system

INM Modules	Details of the INM module	Mean grain yield (kg/ha) Soybean	Wheat	Gross Income (Rs/ha)	Total cost (Rs/ha)	Net returns (Rs/ha)	B: C Ratio
Module 1	100% NPKSZn to soybean and 100% NPKS to wheat	2099	5001	83010	22668	60342	2.66
Module 2	50% NPKS+5t FYM/ha to soybean and 75% NPKS to wheat	2198	4783	81362	21567	59795	2.77
Module 3	50% NPKS + 5t FYM/ha +*Rhizobium* to soybean and 75% NPKS+PSB* to wheat	2325	4792	82861	21621	61240	2.83
FP	Farmers' Practice	1864	4121	69699	20435	49264	2.40

Note

100% NPKSZn — Soybean – 25 kg N, 60 kg P_2O_5, 20 kg K_2O, 20 kg S and 5 kg Zn/ha; Wheat - 120 kg N, 60 kg P_2O_5, 20 kg K_2O, and 20 kg S

Farmers' Practice — Soybean – 12.5 kg N and 30 kg P_2O_5/ha; Wheat – 80 kg N and 50 kg P_2O_5/ha

*PSB - Phosphate Solublizing Bacteria

for total N, P, K, and C. At the end of the 9th month, based on the nutrient concentrations of different types of materials, total amount of each nutrient input into the FYM pit and the nutrient content in the FYM at the end were computed to workout the nutrient recovery in FYM and apparent loss. Results revealed that the cattle dung was the main component of the FYM (66.9%) followed by cattle shed wastes (20.4%). About 40% of N, 23% of P and 36% of K put into the FYM pit through different organic materials was lost during the FYM production through conventional method by farmers. There is a scope to improve the quality of FYM by reducing the losses from FYM pits by introducing simple and farmers' friendly modifications such as hybrid pit (between heap and deep pit), thatched roofs etc in the Farmers' Practice of FYM production.

5.4 AICRP on Soil Test Crop Response Correlation (STCR)

The Raipur center has conducted Participatory Diagnosis of Constraints and opportunities (PDCO) survey and laid out experiments in the farmers' fields based on their manurial and other resources. The treatments for the 2 categories of farmers are given below.

Category 1- Poor resource farmer

No.	Treatment
T_1	Farmers' practice – dose of chemical fertilizer ($N:P_2O_5:K_2O$) (45:20:0) 2 yield target of 35 q ha^{-1} based on STCR recommendation – chemical fertilizer (65:30:40)
T_2	Yield target of 35 q ha^{-1} (IPNS using FYM based on farmers resources) i.e.3 t ha^{-1} FYM + 60-25-30 chemical fertilizer ($N:P_2O_5:K_2O$).
T_3	Yield target of 35 q ha^{-1} (IPNS using FYM and BGA) i.e.3 t ha^{-1} FYM +10 kg BGA+ 40-25-30 - chemical fertilizer ($N:P_2O_5:K_2O$)
T_4	Yield target of 35 q ha^{-1} (IPNS using green manure generated by STCR Raipur center (i.e. GM +20-30-40)

Category 2 – Medium resource farmer

No.	Treatment
T_1	Farmers' practice - dose of chemical fertilizer ($N:P_2O_5:K_2O$) (65-45-15)
T_2	Yield target of 45 q ha^{-1} based on STCR recommendation–chemical fertilizers (99-40-0).
T_3	Yield target of 45 q ha^{-1} (IPNS using FYM based on farmers resources) i.e.5 t ha^{-1} FYM + 90-28-0 chemical fertilizer ($N:P_2O_5:K_2O$).
T_4	Yield target of 45 q ha^{-1} (IPSN using FYM and BGA) i.e.5 t ha^{-1} FYM +10 kg BGA+ 70-28-0 chemical fertilizer ($N:P_2O_5:K_2O$)
T_5	Yield target of 45 q ha^{-1} (IPNS approach using green manure generated by STCR Raipur center (i.e. GM +60-40-0- chemical fertilizer)

Soil test calibration equations used for prescribing fertilizer doses for different yield of rice in Vertisols are given below.

$$FN = 4.95\ Y - 0.62\ SN$$

$$FN = 8.05\ Y - 2.56\ SN \text{ (with green manure)}$$

$$FP_2O_5 = 130\text{-}2.56\ SP - SQRT\ (16819 - 260Y)$$

$$FK_2O = \text{zero if } SK > 250 \text{ kg ha}^{-1} \text{ and } 40 \text{ kg } K_2O \text{ and kg } K_2O \text{ ha}^{-1} \text{ if } SK < 250 \text{ kg ha}^{-1}$$

Where FN, FP_2O_5, FK_2O are fertilizer N, P_2O_5 K_2O and required for yield target (Y) of price in q ha^{-1}, SN, SP and SK are soil test values in kg ha^{-1}.

Results for rice (Table 5.2) show that targeted yields in different treatments could be more or less achieved though the deviations were on the negative side. The full benefit of the technology could not be realized due to poor seed germination and dry spell.

Table 5.2 Grain yield of rice during *kharif* season

Treatment	Poor resource farmers	Medium resource farmers
T_1	20.2	28.1
T_2	33.5	42.6
T_3	36.9	43.4
T_4	32.2	43.0
T_5	31.7	38.2

After harvest of rice crop, soil samples of field plots were taken for nutrient analysis and then. Fields were prepared for wheat crop during *rabi* season under medium resource farmer's category who had irrigation facility. Under poor resource farmer's category, *lathyrus* crop was taken as relay cropping without addition of any nutrient. In this system, *lathyrus* seed @ 30 kg ha^{-1} was broadcasted over the field 20 days before harvesting of rice, *lathyrus* seed germinated with residual moisture and crop established at the time of rice crop harvesting. Similarly for wheat crop, under medium resource category, the yield target of 25 q ha^{-1} was fixed and fertilizer were applied based on the nutrient status of each field plot. The targeted and observed yields of wheat (Table 5.3) were very close which confirm the superiority of soil test based fertilizer recommendation. The nutrients build up after first crop season reflected in soil test values and varied maximum with FYM application. The grain yield of *lathyrus* did not vary with different treatments.

Barrackpore : Experiments to generate soil test crop response for jute and rice were taken up in the farmers' fields. Frontline demonstrations on jute and wheat were also undertaken at different locations of North 24 Paraganas. Follow-up trails with jute in farmers' fields at Koirapur have shown that the targeted yields were achieved with the supplementation of FYM 5 t ha^{-1} as the yield deviations were within ±10%.

Kalyani : The center has started several experiments and established fertilizer gradients at three different sites. The center also conducted

Table 5.3 Grain yield (q ha^{-1}) of *Lathyrus* and wheat during *Rabi* season

Treatment	Poor resource farmers Lathyrus	Medium resource farmers Wheat
T_1	4.35	17.85
T_2	4.90	27.60
T_3	4.95	25.45
T_4	5.20	24.25
T_5	4.80	25.85

follow – up trails with rape (rabi 1998) in farmer's fields. The results (Table 5.4) revealed that the maximum fertilizer use efficiency in both the trials was obtained in T_3 i.e.soil test based fertilizer dose for targeted yield of 12 q ha^{-1}, although the yield targeted was not achieved in trial 2. As compared to the treatments of N 104, P_2O_5 45, K_2O 59 and N 91, P_2O_5

Table 5.4 Fertilizer use efficiency and additional profits in follow-up trial with rape during *rabi*

Trial Treatment	Fertilizer dose (kg ha^{-1})			Yield (kg ha^{-1})	Response ratio	Price of produce (Rs.)	Cost of fertilizer (Rs.)	Profit over farmers' Practice
	N	P_2O_5	K_2O					
Trial 1								
T_1	76	36	36	1108	7.5	13296	1555	-
T_2	80	40	40	1237	7.7	14844	1690	+1413
T_3	71	29	45	1211	8.4	14532	1450	+1341
T_4	104	45	59	1407	6.8	16844	2120	+2983
Trial 2								
T_1	85	42	42	1207	7.1	14484	1783	-
T_2	80	40	40	1211	7.6	14532	1690	+0141
T_3	58	24	45	1162	9.1	13944	1249	-0006
T_4	91	40	59	1425	7.5	17100	1920	+2479

Cost of 1 kg N = Rs. 8.48; 1 kg P_2O_5 = Rs.18:12; 1 kg K_2O = Rs. 7.17
Cost of 1 kg rape grain = Rs. 12.00

40, K_2O 59 (T_2) in trial 1 and 2, respectively, for targeted yield of 14 q ha^{-1}. Treatments for trials were T_1 = Framers' practice; T_2 = General recommended dose (GRD) ; T_3 = Soil test based for 12 q ha^{-1} target ; T_4 = Soil test based for 14 q ha^{-1} target

5.5 On Farm Production and Evaluation of Vermicompost and Enriched Compost

To assess the various methods of preparation of vermicompost and enriched compost and its quality using local resources, field experiment on the farmers' fields of Misrod and Parwalia villages near Bhopal were initiated during *kharif* – 2009. Two farmers's each from Misrod and Parwalia village were selected for the experimentation. Before start of experiment initial soil samples have been collected. Based on the phosphate contents in the vermicompost and enriched compost, treatments were taken in soybean crop. Soybean crop was grown during July to October. Soil samples were collected after harvest of the crop for further chemical analysis. Seed yield of soybean at different farmers' field varied significantly among various treatments (Table 5.5). The highest seed yield of soybean was recorded with vermicompost treatment followed by enriched compost, farmers' practice and the lowest with 100% NPK treatments at all the farmers' fields. Wheat was grown on the same plots after harvest of soybean with 100% recommended dose of fertilizers. Seed yield of wheat (Table 5.6) did not vary significantly between vermicompost and enriched compost treatments but varied significantly between farmers' practice and 100% NPK treatment. The lowest seed yield of wheat was recorded with 100% NPK treatment compared to all other treatments.

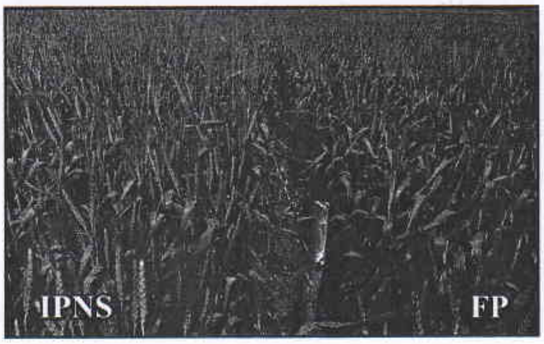
4. TRANSFER OF TECHNOLOGY

4.1 Frontline Demonstrations

A. Main Institute

Farmers' field demonstration in Berasia, Bhopal district

Four technologies developed by IISS viz., Integrated Plant nutrient supply system, Phospo-sulpho-nitro compost, biofertilizers (powder and liquid formulations) and Soil test based fertilizer recommendation for targeted crop yield were demonstrated in the farmers' fields to show the superiority of these technologies over farmers' practice in giving a good yield and better income to farmers with the optimum use of resources available at the farm. These technologies were demonstrated in nine farmers' fields of Berasia Tahsil of Bhopal district (Plate 4.1.1). The technologies performed differently in different field conditions but gave superior results compared to farmers' practice in terms of resource use and net profit to the farm family.



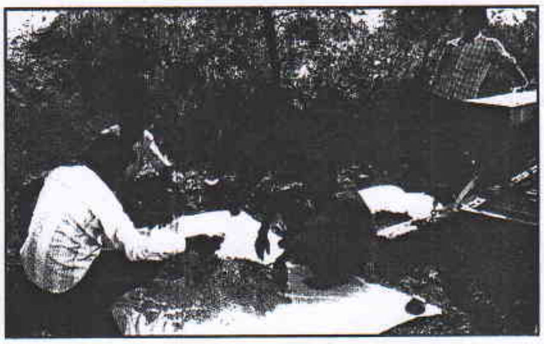


Plate 4.1.1(a) Performance of wheat crop (b) Seed treatment with biofertilizers

Farmers' field demonstration in the tribal dominated Alirajpur and Jhabua district

Demonstration trials on integrated plant nutrient supply (IPNS) and soil test based nutrient recommendation (STNR) were conducted in ten farmers' fields (soybean-6 fields and maize-4 fields) in the Alirajpur and Jhabua district of Madhya Pradesh during *kharif* season (Plate 4.1.2).

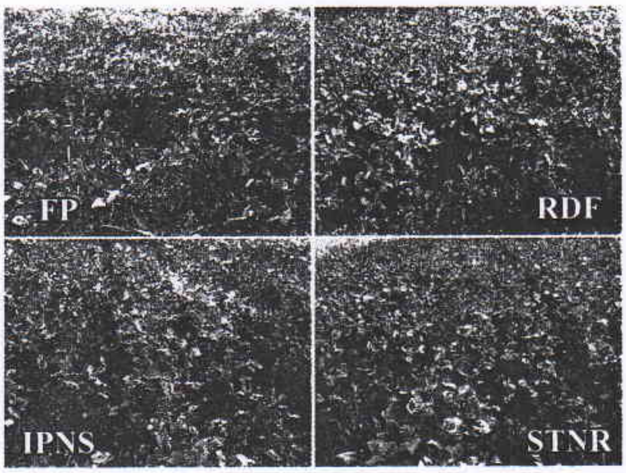


Plate 4.1.2 Soybean demonstration in Bawdikurd village, Alirajpur district

B. All India Coordinated Research/Network Projects

AICRP on STCR

Rice in Assam

Frontline demonstration trials on rice cv. Ranjit were conducted in 12 farmers' fields in five villages of Dergaon area, Golaghat district, Assam. The range and mean values of available soil nutrients is given in Table 4.1.1 and the results are given in Table 4.1.2. The targeted yield of 50 and 60 q ha^{-1} under T3 and T4 where chemical fertilizers were applied alone has very little negative deviations (-0.4% and -3.7%, respectively). On the other hand, targeted yield of 50 and 60 q ha^{-1} could easily be attainable when integrated application of chemical fertilizers are applied with a B:C ratio of 2.2.

Table 4.1.1 Range, mean and standard deviation of soil properties of FLDs

Properties	Minimum	Maximum	Mean	Stdv
Available N (kg ha^{-1})	178.8	314.8	245.9	46.6
Available P (kg ha^{-1})	4.1	7.3	6.1	1.1
Available K (kg ha^{-1})	108.0	278.6	194.8	62.3
OC (%)	0.6	1.1	0.8	0.2

Table 4.1.2 Results of verification trials/FLDs of *sali* rice (mean of 12 trials, and 2 years)

Treatments	Grain yield (q ha^{-1}) Year 1	Grain yield (q ha^{-1}) Year 2	Deviations from the targeted yield (%)	Average grain yield (q ha^{-1})	B : C
T1- Control	23.2	27.2	-	25.2	1.3
T2- State recommendation	33.5	38.4	-	36.0	1.5
T3- Yield target 50 q ha^{-1}	50.4	48.8	-0.4	49.6	2.0
T4- Yield target 60 q ha^{-1}	57.3	57.8	-3.7	57.6	1.9
T5- FYM 5 t ha^{-1} Yield target 50 q ha^{-1}	53.1	50.9	+4.2	52.0	2.2
T6- FYM 5 t ha^{-1} Yield target 60 q ha^{-1}	58.6	61.6	+ 0.2	60.1	2.2

Summer green gram in Assam

Frontline demonstration trials on summer green gram cv. Pratap were conducted in 8 farmers' fields in four villages of Dergaon area, Golaghat district, Assam (Plate 4.1.3). The range and mean values of available soil nutrients is given in Table 4.1.3 and the results on productivity are given in Table 4.1.4. The results revealed that the yield target of 12 q ha^{-1} with inorganic treatments could not be obtained showing 1.7 % negative deviations while that could be attained with IPNS treatment with 2% positive deviations. On the other hand, 14 q ha^{-1} target could not be attained with either of the treatments mainly due to moisture shortage during crop growth. However, the B:C ratio was comparatively higher in treatments T4 and T6 with IPNS components. Noteworthy increase in yield was observed in targeted yield treatments over the farmers' practice.

Table 4.1.3 Range, mean and standard deviation of soil properties of FLDs

Properties	Min	Max	Mean	Stdv	CV(%)
Available N (kg ha^{-1})	197.7	304.8	274.4	23.0	8.4
Available P (kg ha^{-1})	6.9	10.6	8.9	1.5	16.8
Available K (kg ha^{-1})	114.7	249.5	191.5	36.0	18.8
OC (%)	0.8	1.3	1.0	0.1	10.3

Table 4.1.4 Results of verification trials/FLDs of summer green gram (mean of 8 trials)

Treatment	Seed yield (q ha^{-1})	% Increase/ decrease over target	B : C
T1- Control (farmers' practice)	9.3	-	2.9
T2- State recommendation	11.1	-	3.0
T3- Yield target 12 q ha^{-1} (Inorganic)	11.8	-1.7	3.1
T4- Yield target 14 q ha^{-1} (Inorganic)	12.8	- 8.6	3.4
T5- FYM 5 t ha^{-1} yield target 12 q ha^{-1} (IPNS)	12.2	2.0	3.1
T6- FYM 5 t ha^{-1} yield target 14 q ha^{-1} (IPNS)	13.3	-5.0	3.3

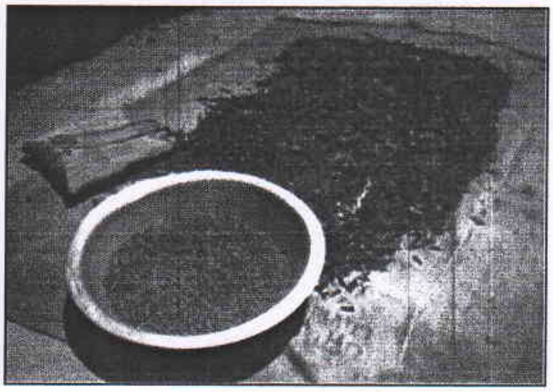


Plate 4.1.3 Summer Moong - Golaghat district, Assam

Tomato in Odisha

FLDs were conducted on tomato cv. BT-10 in Balibandh village of Jhumpura block of Keonjhar district during rabi 2013-14. The soil fertility status and fertilizer nutrient rates are given in Table 4.1.5. Maximum yield of tomato was achieved where fertilizers were applied as per the fertilizer adjustment equations (Table 4.1.6). Although 12.68% more yield of tomato was achieved in case of Soil Test Based (STB) fertilizer recommendation (L-M-H basis) and 27.71% more yield was achieved in case of STCR plots compared to the farmers' practice. Besides, 13.36% more yield in

STCR over STB treated plot indicate the superiority of Fertilizer Prescription equation in site specific nutrient management (Plate 4.1.4). These demonstrations have motivated the tribal farmers to convert hitherto fallow lands into cultivated land. Similarly, frontline demonstrations on tomato cv. BT-10 were also conducted in Sadhupalli billage, Reamal block, of Deogarh district which indicated the similar trend in the yields of tomato.

Table 4.1.5 Front line demonstration on tomato at Balibandh village, Keonjhar district

Sl. No.	Name of Farmers	pH (1:2)	E.C. (dSm^{-1})	OC (%)	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})
1.	Arjun Munda	6.60	0.18	0.61	73.8	4.8	140.0
2.	Pradip Munda	6.24	0.28	0.02	65.0	6.4	110.9
3.	Sankar Munda	6.22	0.69	0.54	102.5	5.6	131.1
4.	Trilochan Munda	5.75	0.67	0.57	137.5	4.8	96.3
5.	Akshay Munda	5.64	0.26	0.54	108.8	6.4	245.3
6.	Rabi Munda	5.66	0.69	0.46	225.0	5.0	84.0

Field Visit of Project Coordinator

STCR based fertilizer recommendation

Negligible amount of fertilizer applied in farmers' practice

Pesticide solution is being prepared for tomato seedling treatment at Sadhupalli village of Deogarh district

Tomato seedlings being transplanted in the experimental field

Plate 4.1.4 Tomato - Keonjhar, Odisha

Table 4.1.6: Yield of tomato

Sl. No.	Name of Farmer	Fruit yield (q ha^{-1}) Farmer's practice	Fruit yield (q ha^{-1}) Soil Test Based	Fruit yield (q ha^{-1}) STCR recommendation (Target - 225 q ha^{-1})	% increase or decrease over targeted yield
1.	Arjun Munda	167.7	187.5	201.7	(-)10.4
2.	Pradip Munda	172.3	192.9	237.1	(+) 5.4
3.	Sankar Munda	176.4	196.6	236.1	(+) 4.9
4.	Trilochan	165.7	188.9	203.3	(-) 9.6
5.	Ak shay Munda	159.8	183.7	205.4	(-) 8.7
6.	Rabi Munda	171.3	191.8	211.3	(-) 6.1

Mustard in Odisha

FLDs were conducted on Mustard (cv. Sushree) in Bangalimunda village of Teleibani block of Deogarh district during rabi 2013-14. The soil fertility status with respect to available N was low, available P low-medium and available K medium to high. The fertilizer nutrient rates are given in Table 4.1.7. Maximum yield of mustard was achieved where fertilizers were applied as per the fertilizer adjustment equation. Although 30.18% more yield of Mustard was achieved in case of soil test Based fertilizer recommendation (L-M-H basis) and 47.92% more yield was achieved in case of STCR plots compared to the farmers' practice plots. Beside this, 13.63% more yield in STCR over STB treated plot indicate the superiority of fertilizer prescription equation in site specific nutrient management.

Table 4.1.7 Soil Test (STB) and STCR targeted yield based fertilizer doses

Sl. No	Name of Farmer	Soil Test Based N (kg ha^{-1})	Soil Test Based P_2O_5 (kg ha^{-1})	Soil Test Based K_2O (kg ha^{-1})	STCR N (kg ha^{-1})	STCR P_2O_5 (kg ha^{-1})	STCR K_2O (kg ha^{-1})
1.	Poulus Ekka	75	37.5	10	61	31	10
2.	Peter Minj	75	37.5	10	54	31	10
3.	Tito Kindo	75	37.5	10	62	32	10
4.	Joseph Toppo	75	37.5	10	57	32	10
5.	Vincent Minj	75	37.5	10	55	35	10
6.	Rosalia Lakra	75	37.5	10	60	33	10
7.	Anil Tirkey	75	37.5	10	69	33	10
8.	Sushama Tirkey	75	37.5	10	62	34	10
9.	Augustin Tirkey	75	37.5	10	64	35	10
10	Lily Tirkey	75	37.5	10	70	33	10
11.	Nicholas Kullu	75	37.5	10	68	33	10

Raya in Punjab

Five frontline demonstrations on raya crop were conducted in different agro-ecological regions of Punjab. Results indicate that except in one case, applying fertilizers on the basis of target yield approach proved superior to the general recommended Dose (GRD) and the farmers' practice (Table 4.1.8).

Table 4.1.8 Results of FLDs on raya in various districts of Punjab during *Rabi*

Treatment	Fertilizer nutrient applied(kg ha^{-1})			Grain yield (q ha^{-1}) (Value cost ratio)
	N	P_2O_5	K_2O	
1. Name and address: Sital Singh, V. Jaffarpur, Distt. Gurdaspur				
Soil test values: OC (%) = 0.45, SN=116.5 kg ha^{-1}, SP=22.5 kg ha^{-1}, and SK=67.2 kg ha^{-1}				
GRD	100	30	15	16.5 (8.79)
Target 20q ha^{-1}	118	0	74	13.3 (3.97)
Target 22q ha^{-1}	135	0	83	14.5 (4.45)
Farmers' practice	140	55	30	11.3 (1.74)
Control	0	0	0	8.8
2. Ramesh Lal , V. Pachowal, Distt. Gurdaspur				
Soil test values: OC (%) = 0.75, SN=161 kg ha^{-1}, SP=19.5 kg ha^{-1}, and SK=376 kg ha^{-1}				
GRD	100	30	15	16.9 (10.1)
Target 20 q ha^{-1}	97	0	0	15.6 (17.0)
Target 22 q ha^{-1}	114	0	0	16.8 (16.6)
Farmers' practice	150	50	30	11.3 (2.32)
Control	0	0	0	8.0
3. Rakesh Kumar, V. Rasoolpur, Distt. Gurdaspur				
Soil test values: OC (%) = 0.79, SN=170 kg ha^{-1}, SP=30.8 kg ha^{-1}, and SK=141.1 kg ha^{-1}				
GRD	100	30	15	15.0 (8.17)
Target 20 q ha^{-1}	93	0	49	16.8 (9.75)
Target 22 q ha^{-1}	110	0	58	17.3 (11.1)
Farmers' practice	120	55	30	10.5 (2.03)
Control	0	0	0	7.8
4. Amarjeet Singh, V. Sham Chak, Distt. Gurdaspur				
Soil test values: OC (%) = 0.90, SN=206 kg ha^{-1}, SP=30.8 kg ha^{-1}, and SK=141 kg ha^{-1}				
GRD	100	30	15	14.8 (8.05)
Target 20 q ha^{-1}	76	0	48	15.2 (10.1)
Target 22 q ha^{-1}	93	0	58	17.0 (10.4)
Farmers' practice	120	55	30	10.3 (1.88)
Control	0	0	0	7.7
5. Ranjodh Singh V. Chugga, Distt. Moga				
Soil test values: OC (%) = 0.48, SN=180 kg ha^{-1}, SP=27.2 kg ha^{-1}, and SK=234 kg ha^{-1}				
GRD	100	30	15	16.3 (7.83)
Target 20 q ha^{-1}	88	0	17	14.4 (18.6)
Target 22 q ha^{-1}	106	0	27	19.5 (17.1)
Farmers' practice	100	55	0	21.4 (4.94)
Control	0	0	0	9.4

Soybean and toria in Himachal Pradesh

In order to popularize the prescription based fertilizer application, fourteen frontline demonstrations, seven each on soybean (*kharif*) and *toria* (*zaid*) were conducted. All of the FLDs on *toria* were conducted in district Una in low hills sub-montane zone of Himachal Pradesh, whereas four FLDs on soybean were laid out in Kangra and three were carried out in Hamirpur district of the state. Five treatments were tested in both the crops. In soybean, the treatments were control, farmers' practice, general recommended dose, two pre- fixed yield targets of 20 and 25 q ha^{-1}. In case of *toria*, the treatments consisted of control, farmers' practice, GRD and two pre-fixed yield targets of 10 and 15 q ha^{-1}. The average data with respect to fertilizer nutrients applied, seed yields recorded, per cent deviations and economic aspects for soybean and toria are given in Tables 4.1.9 and 4.1.10. In case of soybean, as anticipated, the lowest yield was obtained under farmers' practice (9.1 q ha^{-1}) followed by farmers' practice (10.7 q ha^{-1}). By applying the same dose of N and less doses of P_2O_5 and K_2O higher yield was recorded under pre- fixed target of 20 q ha^{-1} in comparison to GRD. The close agreement between targeted and observed yields was achieved in case of both the pre- fixed targets of 20 and 25 q ha^{-1}, as the percent deviations in both the cases were within the permissible limit (±10%) *i.e.* -6.0 and -8.5 per cent, respectively. The net returns in targeted treatments over farmers' practice and GRD were higher justifying the usefulness of targeted yield concept based fertilizer application. The benefit cost ratio was highest (3.55) in the treatment comprising of target 25 q ha^{-1} followed by target 20 q ha^{-1} (3.27) as against the farmers' practice where it was comparatively low (1.78). So, the cultivation of soybean based on targeted concept may be recommended to harvest better yields thereby getting more returns in low hills sub-montane zone of Himachal Pradesh in Hamirpur and Kangra districts. Similar to soybean, in case of toria, application of fertilizers as per target yield approach, in general, resulted in higher yield of toria in comparison to farmers' practice and general recommended dose. Similarly, few more demonstrations were conducted in Bilaspur, hamirpur, and Una district with soybean (cv. PK 472) and toria (cv. Bhawani). In case of soybean, as anticipated, the lowest yield was obtained under control (8.7 q ha^{-1}) followed by farmers' practice (10.4 q ha^{-1}). The treatments based on STCR concept out yielded all

Table 4.1.9: Fertilizer demonstrations on soybean in Kangra and Hamirpur districts of H.P.

Treatments	Nutrient doses applied (kg ha^{-1})			Yield (q ha^{-1})	Deviation (%)	Cost of yield (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs.ha^{-1})	B:C ratio
	N	P_2O_5	K_2O						
Control	0	0	0	9.1		23543	12200	11343	1.93
FP	20	0	0	10.7		27553	15436	12117	1.78
GRD	20	60	40	17.2		44400	16377	28024	2.71
Target 20 q ha^{-1}	20	38	28	18.8	-6.0	48410	14786	33624	3.27
Target 25 q ha^{-1}	20	67	49	22.9	-8.5	58894	16578	42316	3.55

In FP, FYM was applied @ 3t ha^{-1} on fresh weight basis;
Fertilizer rate: N=11.8 Rs. kg^{-1}, P_2O_5=48.1 Rs. kg^{-1}, K_2O=18.8 Rs. kg^{-1}, price of soybean grains: Rs. 2500 q^{-1}

other treatments (control, farmers' practice as well as GRD). In case of toria, application of fertilizers as per target yield approach, in general, resulted in higher yield of toria in comparison to farmers' practice and general recommended dose.

Table 4.1.10: Fertilizer demonstrations on *toria* in low hills sub-montane zone of H.P

Treatment	Nutrient doses applied (kg ha^{-1})			Yield (q ha^{-1})	Deviation	Price of yield (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
	N	P_2O_5	K_2O						
Control	0	0	0	4.2	-	10607	7500	3107	1.41
FP	20	0	0	7.0	-	17607	9836	7771	1.79
GRD	60	40	40	11.0	-	27393	10885	16508	2.52
Target 10	47	28	41	10.8	7.57	26893	10185	16708	2.64
Target 15	73	47	70	16.0	6.95	40107	11912	28195	3.37

In FP, FYM was applied @ 3t ha^{-1} on fresh weight basis, sale price of toria seed = Rs.25.00 kg^{-1}, Cost of fertilizers (Rs. kg^{-1}): N=11.8, P_2O_5=48.1, K_2O=18.8

Tribal sub plan programme in Chhattisgarh

A number of field demonstrations on various crops were conducted in tribal districts of Chhattisgarh (Table 4.1.11, Plate 4.1.5). Twenty six tribal farmers from 7 hadi's (hamlet's) at Kakanakote forest area of H.D. Kote taluk were identified based on the land available with them. The soil samples were

Table 4.1.11 Field demonstrations in the tribal districts of Chhattisgarh

Name of tribal district	Village	Crop/No of FLD's	No of beneficiaries	% Yield increased over FP
Kanker	Dhaneli	chick pea = 4	20	1.85-2.72
	Kanhar, Siltara,	wheat = 7		0.4-2.72
	Babudabena	maize = 9		0.6-1.0
Dantewada	Binjam, Nagul,	chick pea = 12	20	7-24
	Ronge	wheat = 8		26-52
Kondagaon	Bhagdewa, Bolbola	wheat = 10	20	32-42
		maize = 10		24-37
Jagdalpur	Tekameta, Tandpal	wheat = 20	20	24-54
Surajpur	Sambalpur	wheat = 20	20	28-47
Balrampur	Chirkoma	wheat = 20	20	40-50
Korba	Dongri	chick pea = 20	20	9-31
Koreya	Bakira	wheat = 20	20	18-38
Narayanpur	Karalakha, Palaki,	chick pea = 10	20	8-37
	Devgaon	wheat = 10		24-33
Ambikapur	Beldagi, Kunwarpur	wheat = 20	20	26-44

FP - Farmers' practice

collected with geographical positioning system (GPS) depicting latitude and longitude of each soil sample. These samples were analyzed for available N, P and K. Based on the soil test values and yield target fixed, fertilizers were distributed to these farmers for chickpea crop by using the chickpea targeted yield equation developed at Acharya N.G. Ranga Agricultural University (ANGRAU), Andhra Pradesh.

Bumper crop of toria in Bilaspur

Field Day at Una

Plate 4.1.5 Field demonstrations in Chhattisgarh

Maize (Hybrid Hema)

A follow up trial on hybrid maize at ZARS, GKVK under dry land condition was undertaken to evaluate the targeted yield equation developed at the STCR centre. Under dryland condition, significantly higher grain yield of 47.35 q ha^{-1} in STCR (173-94-98) 90 q ha^{-1} target was obtained, as compared to package of practice (150-75-40) treatment (39.6 q ha^{-1}). However, all these values were far below the target fixed because the crop was not irrigated and the rainfall received during crop growth were very less.

Equations used:

FN $= 3.84\,T - 0.42\,SN$ ($KMnO_4$-N)

$FP_2O_5 = 1.57\,T - 1.18\,SP_2O_5$ (Bray's-P)

$FK_2O = 1.15\,T - 0.11\,SK_2O$ (Am. Ac.-K)

Ragi (GPU-28)

A follow up trial on *ragi* was conducted at ZARS, Hiriyur to evaluate the targeted equation developed at ZARS, Mandya. Highest grain yield of 37.0 q ha^{-1} was recorded in STCR (60 q ha^{-1}) targeted treatment with the fertilizer nutrient dose of 163-100-0 followed by an yield of 36.2 q ha^{-1} in STCR target of 50 q ha^{-1} with fertilizer nutrients 135-83.2-0 (N- P_2O_5- K_2O). However, all these yields were far below the target fixed. Highest VCR of 8.68 was recorded in STCR target of 60 q ha^{-1} with integrated approach (81.7-50-0 (N- P_2O_5- K_2O) + FYM). Lowest VCR of 3.66 was recorded in package of practice (100-50-45) treatment.

Equations used:

$FN = 3.29 T - 71.17 SN\ (\%OC) - 0.00281 OM$

$FP_2O_5 = 1.789 T - 0.189 SP_2O_5 (Olsen's\text{-}P) - 0.00173 OM$

$FK_2O = 1.775 T - 0.15 SK_2O (Am. Ac.\text{-}K) - 0.0015 OM$

Ragi (GPU-28)

A follow-up trial on ragi was taken to verify the targeted yield equation of dryland ragi at ZARS, GKVK. Significantly highest grain yield of 41.4 q ha^{-1} was recorded in STCR (30q ha^{-1}) integrated treatment which was on par with package of practice (40.4 q ha^{-1}). These yields were far above the target fixed due to sufficient rains during the crop growth period even though it is grown under dryland condition. The yield response worked out was higher (12.30q ha^{-1}) in STCR (30 q ha^{-1}) integrated treatment followed by package of practice and VCR was highest (29.71) in STCR (20 q ha^{-1}) with only inorganics followed by STCR (30 q ha^{-1}) with only inorganics (8.68) as compared to package of practice (POP) and STL approaches. Even though STCR integrated approaches haven given higher yields, yet lower VCR were recorded mainly due to very high cost of FYM added.

Potato (Kufri Jyoti 2)

In order to verify the newly developed IPNS equation for potato, five multi-location follow up experiments were conducted during *rabi* on natural soil fertility conditions at farmers' fields. All the experimental sites fall under wet temperate zone of Himachal Pradesh. The treatments comprised control, farmers' practice, general recommended dose and two pre-fixed yield targets with and without the use of FYM in case of potato.

The targets evaluated were 150 and 200 q ha^{-1} of potato tubers. In farmers' practice, FYM was applied @ 25 t ha^{-1}. Initial soil test values with respect to available N varied from 209 to 285 kg ha^{-1} with a mean value of 247 kg ha^{-1}, that of available P from 23 to 44 kg ha^{-1} with a mean value of 33 kg ha^{-1}, and available K varied between 179 and 194 kg ha^{-1} with an average of 184 kg ha^{-1}. The target yield equations used for applying fertilizers in potato were as given below (Table 4.1.12).

Table 4.1.12 Fertilizer adjustment equations used for potato crop

Crop	Equations		
	FN	FP_2O_5	FK_2O
Potato	3.37T-0.90SN-0.22ON	0.71T-0.95SP-0.18OP	1.47T-0.62SK-0.10OK

SN, SP, SK, T etc. above have their usual meanings. ON, OP, OK stand for amounts of N, P & K in kg added from organic manure as per dosage involved.

The lowest yield (84 q ha^{-1}) of potato (Table 4.1.13) was recorded in control followed by farmers' practice (120 q ha^{-1}). As far as the pre-fixed yield targets vis-à-vis yields obtained are concerned, deviation was within 10 per cent between the actual yield obtained and the pre-fixed targets under both the situations *i.e.* with and without the use of FYM. The net returns were highest (Rs. 132457 ha^{-1}) in 200 q ha^{-1} target without FYM followed by the same target with FYM (Rs. 122951 ha^{-1}) and lowest was in control (Rs. 29167 ha^{-1}). The benefit cost ratio was highest (2.92) in 200 q ha^{-1} target without FYM followed by the same target with FYM (2.47). The benefit cost ratio for the yield target of 150 q ha^{-1} with and without FYM were 2.07 and 2.45, respectively.

Table 4.1.13: Target yield experiment (involving IPNS based equations) on potato

Treatment	N	P_2O_5	K_2O	FYM ($t\ ha^{-1}$)	Tuber yield ($q\ ha^{-1}$)	Deviation (%)	Gross returns (Rs. ha^{-1})	Cost of inputs (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
	(kg ha^{-1})									
Control	0	0	0	-	84	-	84167	55000	29167	1.53
FP	30	0	0	25	120	-	120000	80354	39646	1.49
GRD	120	80	60	-	141	-	141333	61394	79940	2.30
Nutrients as per Targets (q ha^{-1})										
150	279	77	105	-	157	4.4	156667	63963	92704	2.45
200	448	112	179	-	202	0.8	201500	69043	132457	2.92
150 (IPNS)	269	68	99	15	162	7.9	161833	78302	83531	2.07
200 (IPNS)	437	103	172	15	206	3.2	206333	83382	122951	2.47

Besides 30 kg N, farmers apply FYM @ 25 t ha^{-1}, FYM was applied @ 15 t ha^{-1} in 150 and 200 q ha^{-1} target with IPNS, Sale price of potato = Rs. 10 kg^{-1}. Fertilizer: N=11.8 Rs. kg^{-1}, P_2O_5=48.1 Rs. kg^{-1}, K_2O=18.8 Rs. kg^{-1}

Maize (PG 2474)

A long term yield target experiment was started from *kharif* five years ago with maize and wheat as test crops with the objectives to verify fertilizer adjustment equations for maize and wheat grown in a sequence and simultaneously to study the impact on soil quality over the years. The IPNS based fertilizer adjustment equations were used to calculate nutrient doses for various targets which were kept as treatments for maize and wheat (Table 4.1.14, Plate 4.1.6).

Table 4.1.14 Fertilizer adjustment equations (IPNS based) used in long term target yield experiment in maize-wheat sequence

Maize

FN = 5.88 T - 0.23 SN - 0.93 ON

FP_2O_5 = 4.87 T - 1.22 SP - 0.81 OP

FK_2O = 3.66 T - 0.49 SK - 0.51 OK

Wheat

FN = 5.27 T - 0.25 SN - 1.06 ON

FP_2O_5 = 4.13 T - 0.38 SP - 0.98 OP

FK_2O = 2.87 T - 0.15 SK - 0.55 OK

The lowest grain yield of 19.3 q ha^{-1} in maize was recorded under control (No fertilizers) whereas, farmers' practice (40-0-0) and application of fertilizers based on soil test (STB) (150-45-40) and general recommended dose (GRD) (120-60-40) recorded yield levels of 23.3, 26.2 and 25.7 q ha^{-1}, respectively. A close agreement between the yield targeted and the actual yield obtained was observed in the four pre-fixed targets of 30 and 40 q ha^{-1} with and without FYM. FYM involving two yield targets recorded higher yields than their non-FYM counterparts. However, the net returns and benefit cost ratio were higher in case of non FYM treatments because of additional cost of FYM. The highest net returns were obtained in treatment corresponding to yield target of 40 q ha^{-1} without FYM. The benefit cost ratio was also highest (2.57) in targeted yield level of 40 q ha^{-1} without FYM followed by targeted yield level of 30 q ha^{-1} without FYM (2.38) and least was in farmers' practice (1.07).

Almost, similar yield trends were also observed in case of wheat. The lowest grain yield of 13.2 q ha^{-1} was recorded in control followed by farmers' practice (16.3 q ha^{-1}). Application of fertilizers based on soil test (STB) and general recommended dose resulted in 18.6 and 18.0 q ha^{-1} grain yield of wheat, respectively. The pre- fixed targets (25 and 35 q ha^{-1}), where FYM was applied consumed less nutrients but produced more grain yield.

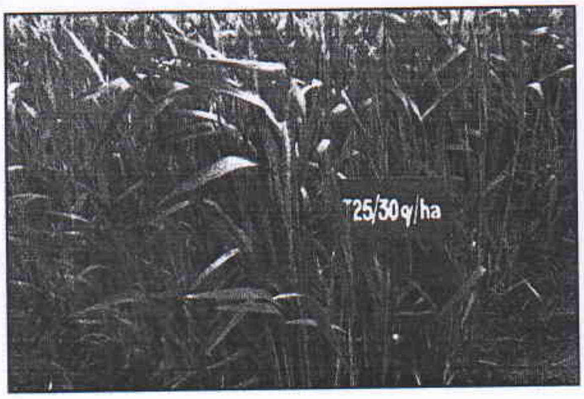


Plate 4.1.6 Long term experiment on wheat

Target yield concept based fertilizer application excelled all other approaches in terms of yield and net returns.

AICRP on MSN

Micro and secondary nutrients

Technologies generated in AICRP- Micronutrients for micronutrient management were demonstrated in more than 500 farmers' fields through cooperating centres (Plate 4.1.7). Micronutrient kits and soil health card were distributed to more than 500 tribal farmers (Table 4.1.15, Plate 4.1.8). Number of Farmers day / Field day / On spot advice / *Krishi melas* conducted in tribal areas to increase the awareness regarding the use of micro and secondary nutrients for enhancing crop productivity and animal/ human health




Plate 4.1.7 Front line demonstrations in different crops

Table 4.1.15 Distribution of soil health card, micronutrient kit and extension materials in tribal areas

State/Centre	No. of beneficiaries		
	Soil health card	Micronutrients kit	Extension materials
Maharashtra (Akola)	61	61	320
Tamil Nadu (Coimbatore)	50	50	450
Gujarat (Anand)	164	45	1250
Jharkhand (Ranchi)	80	80	-
Andhra Pradesh (Hyderabad)	20	20	240
Madhya Pradesh (Jabalpur)	76	18	300
Assam (Jorhat)	50	50	250
West Bengal (Kalyani)	20	20	150
Odisha (Bhubaneswar)	500	125	500
Uttarakhand (Pantnagar)	50	50	-
Himachal Pradesh	130	130	-
Bihar	16	100	100




Plate 4.1.8 Distribution of micronutreint kit and extension materials

AINP on BF

PGPR for apple, cauliflower, pea

The demonstrations of PGPR on apple (5 nos.), cauliflower (3 nos.) and pea (3 nos.) resulted in about 38 %, 22% and 26 % increase in yield over recommended package of practices in mid and high hills of Himachal Pradesh (YSPUHF, Solan).

Biofertilizers and upland rice in eastern India

Demonstrations (wet season 2014) on biofertilizer application in direct seeded upland rice variety

'CR Dhan 40' showed that application of AMF inoculum (soil application) and *Azotobacter* (seed application) resulted in 29 % and 13 % increase in grain yield, respectively in Jharkhand. Similar trends of results obtained during last three seasons (wet seasons of 2011-12, 2012-13 and 2013-14 confirmed better performance of AMF inoculum over *Azotobacter* in acidic upland soils of Jharkhand (CRURRS, Hazaribagh).

Biofertilizer technology intervention in tribal / non-tribal farmers in eastern India

Biofertilizer technology intervention was introduced in rice and pulse (lentil and urdbean) crop of tribal & non-tribal farmers of West Champaran East champaran, Samastipur, Muzaffarpur, Vaishali, Katihar and Bhagalpur district in Bihar. Intervention in rice crop at ten farmer's site resulted 7-16 % increase in grain yield. Increase in lentil (13 -24%) and urdbean (4-8%) yield was recorded due to *Rhizobium* inoculation. There was poor response to inoculation in *Diara* land of Katihar and Bhagalpur district on urdbean owing to good soil fertility and adequate rhizobial populations or both (RAU, Pusa).

Tribal demonstrations

In three villages of Kalahandi district, 64 on-farm (tribal area) trials were conducted with nine crops: namely tomato (15 nos.), cauliflower (13 nos.), cabbage (3 nos.), brinjal (4 nos.), cowpea (3 nos.), french bean (1 nos.), maize-cowpea (8 nos.), sole maize (8 nos.) and cotton (9 nos.). For vegetable crops on an average 400 m^2 area per farmer, for maize/ maize-cowpea 1000 m^2 per farmer and for cotton 2000 m^2/ farmer were allowed to grow their desired crops and were supplied with critical inputs like seed, fertilizers, BFs and pesticides. The BFs used were *Azotobacter, Azospirillum*, PSM and *Rhizobium*. The response to BFs inoculation ranged from 10.6- 22.0 %, lowest with maize and highest with cowpea. On an average bioinoculation of crop increased the economic yields by 17.6 % (OUAT, Bhubaneswar).

Fourteen demonstrations were carried out in tribal villages of Mandla and Chhindwara districts with farmer practice (imbalanced fertilization without biofertilizer) and recommended doses of fertilizers with biofertilizers on soybean (var. JS-9752). An increase of 21.5% was demonstrated with RDF+BF (average 1730 kg ha^{-1}) over F.P. (average 1424 kg ha^{-1}). Six demonstrations were carried out on maize (var. JM-216) in tribal villages of Chhindwara district with farmers practice and RDF+ BF. An increase of 75% was demonstrated with RDF+BF (average 768 kg ha^{-1}) over F.P. (average 1343 kg ha^{-1}) (JNKVV, Jabalpur).

Production and supply of biofertilizers

Biofertilizer packets- 60323, 24842, 16481, 1504, 40096 and 3187 pkts of PSB, *Trichoderma Azotobacter, Azospirillum, Rhizobium*, and soil based BGA respectively were produced and supplied to farmers amounting to sale of Rs. 35.50 lakhs (JNKVV, Jabalpur). Biofertilizer sale during 2014-15 was of Rs. 6.50 lakhs, which was lesser compared to 2013-14 (Rs. 7.95 lakhs) owing to drought situation in Maharashtra (MAU, Parbhani). Using the strains of AINP on Soil Biodiversity and Biofertilizers, 170 MTs of solid carrier based biofertilizers and 20 MTs of liquid biofertilizers worth Rs. 121.20 lakhs were produced during 2014-15 (ANGRAU, Amaravathi). More than 3000 packets (200g each) of *Azotobacter*, *Rhizobium*, *Azospirillum* and PSB were prepared and supplied to farmers. In addition 1000 packets of BGA inoculant and 300 packets (1 and 5 kg) of AM inoculant were prepared and supplied (IARI, New Delhi). Training was given to different farming groups on the usage of liquid biofertilizers as well as solid biofertilizers (IISS, Bhopal and all centers).

4.2 On-Farm Demonstrations

On-farm demonstration of resource conservation technology

To popularize the resource conservation technology among farmers of Central India, Division of Soil Physics, IISS, Bhopal has been demonstrating following packages of treatments to the farmers since last five years in the institutes research farm (Plate 4.2.1). Details of treatments and yield (Table 4.2.1) are given below:

a. Two tillage practices viz. (a) No-Till and (b) Reduced Tillage were demonstrated. In both tillage practices Broad Bed and Furrow system is being followed. In No-tillage, sowing was done by slit-drill whereas; in reduced tillage sowing was done with tropi-culter after one ploughing by duck foot cultivator.

b. Three cropping systems selected for this purpose were: (a) maize - chick-pea, (b) soybean – wheat, and (c) soybean + pigeon pea (inter-cropping ratio is 3:2). In all the treatments recommended fertilizer doses with 8 t FYM ha^{-1} yr^{-1} were applied and standard pest management and weed management (manual + chemical) practices were followed.

Table: 4.2.1 Crop yield observed during *Rabi* season of 2014-2015

	Wheat (q ha^{-1})	Chickpea (q ha^{-1})
BBF+No Tillage	43	20
BBF+Reduced Tillage	42	22

Plate 4.2.1 Demostration of resource conservation technologies

Demonstration of STCR based nutrient recommendations

Institute is maintaining eight demonstration plots on nutrient recommendations for the soybean-wheat cropping system since 2003. Different treatments in the demonstration trial are given in Table 4.2.2. The soil analysis of the samples taken in 2013-14 revealed that available K was 287 kg ha^{-1} in STCR (-K) treatment as compared to 414 in STCR (full) treatment. The values for organic C were

0.58% and 0.72% in -N and STCR (full) treatment, respectively. The most prominent reduction was observed in available P status which was only 2.2 kg ha^{-1} in STCR (-P) treatment as compared to 18.7 kg ha^{-1} in STCR (full) treatment.

Table 4.2.2 Treatments in the trial

S. No.	Treatment	S. No.	Treatment
1	STCR based (-N)	5	STCR based (Full)
2	STCR based (-P)	6	IPNS
3	STCR based (-K)	7	STCR based (Limited irrigation)
4	State recommended dose (NPK)	8	IPNS (Limited irrigation)

In STCR based (-N) treatment, P and K rates were applied as per STCR equations, N was not applied

Demonstration of enriched composting

Institute is doing on-farm demonstrations on preparation of different enriched composts (Plate 4.2.2). Different compost preparations are vermicompost, phosphocompost, microbial enriched compost, poultry compost and parthenium compost.

DDG (NRM) Dr. A.K. Sikka's visit to composting unit

Farmers' visit to the composting unit

Plate 4.2.2. Composting unit of IISS

4.3 Method Demonstrations

In connection with demonstration of IISS technologies in Mengra Kalan village of Bhopal step-by-step procedure of biofertilizer treatment of soybean and wheat seeds, and preparation of phospho-sulpho-nitro compost in portable plastic pits were shown to a group of 30 farmers under the supervision of the scientists of the Institute, during soybean-wheat, 2014-15 (Plate 4.3.1).

Demonstration of soil nutrients analysis using *Mridaparikshak* was done on the following occasion

- 86th AGM meeting, NASC, New Delhi, February 02, 2015
- Pusa *Krsihi Vigyan Mela*, IARI, New Delhi, March 09-12, 2015
- Demostration at *Krishi Bhawan*, New Delhi, March 25, 2015

Plate 4.3.1 : Method demonstration on use of bio-fertilizers and compost preparation

4.4 Technology/Product Developed

A Main Institute

Mridaparikshak

A new mini lab named *Mridaparikshak*, a mini soil lab has been developed at ICAR-IISS, Bhopal. This can estimate 10 parameters viz., pH, EC, Organic carbon, available N, P, K, S, Fe, Zn, and B. Fertilizer recommendations for specified targets for selected crop and soil can be generated which can be transmitted to farmers mobile. This is compatible with soil health card. This technology was, demonstrated during annual general body meeting of ICAR (Plate 4.4.1).

Mridaparikshak development team

Demonstration before Hon'ble Union Minister of Agriculture Shri Radha Mohan Singh

Plate 4.4.1 Demonstration of Mridaparikshak

Rapo-compost technique

A survey of farmers' fields has revealed that 'Rapid Composting' technique which can reduce the time required for obtaining good quality compost, is the need of the hour. Therefore, a new technology, 'Rapo-compost Technique' using consortium of Ligno-cellulolytic thermophilic organisms, has been developed by ICAR-IISS that has considerably reduced the time required for composting to1-1.5 months. This technology is especially suitable for recycling of kitchen wastes and vegetable wastes. The institute has developed this technique in collaboration with ICAR-CIAE, Bhopal and ICAR-NBAIM, Mau. As a part of this technology, lignocellulolytic thermophilic organisms, important for accelerating the decomposition, were isolated, screened and identified by ICAR-IISS. The technology has been demonstrated to farmers and trainees of winter school (Plate 4.4.2).). It has received accolades from Natural Resource Management (NRM) division of ICAR and has been identified as a key component for the recycling of biodegradable wastes and could be very useful in pursuing the "Swachh Bharat Abhiyan" of the Government.

Rapo-compost device

Demonstration of 'Rapo-compost technique' to trainees of winter school

Plate 4.4.2 Demonstration of rapid composting technology

Bioactive products from Jatropha curcas

Experiments were carried out to determine how best the biomass of *J. curcas* can be used to improve agriculture. Leaf biomass was extracted by a specific aqueous extraction method (Plate 4.4.3). Leaf extract at different concentration (0 - 1.0% v/v). was added to soil Preliminary study highlighted this product has the capacity to enhance soil methane (CH_4) uptake by about 20-40%. It can also decrease N_2O production. Product also increased microbial abundance including heterotrophs, N fixers and P solubilizers. Further tests are being undertaken to study the effect of the extract on plant growth attributes.

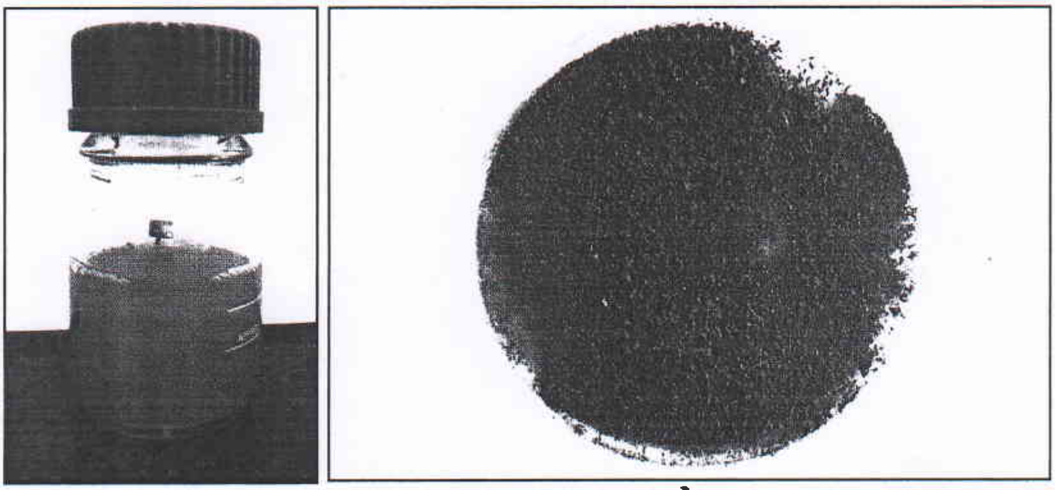


Plate 4.4.3 Leaf extract concentrate of bioenergy crop *J. curcas*

Biofilter technology

The main problem in using municipal and solid wastes (MSW) for compost making is the presence of high content of heavy metals. These heavy metals may harm the plants and in turn the animal and humans who consume these contaminated plants. The Institute has developed a bio-filter (plate 4.4.4) containing fungi which can reduce the quantity of the heavy metals in MSW compost. These MSW compost after decontamination can be safely used in agricultural fields as an amendment.

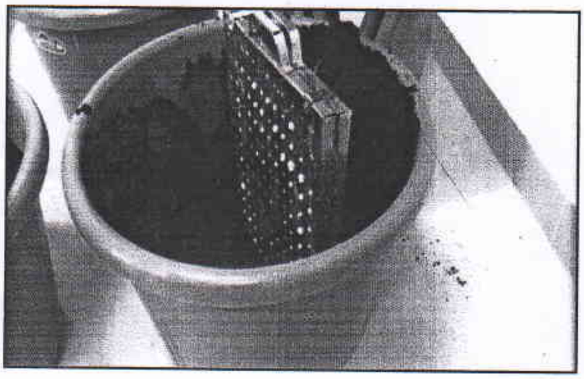



Plate 4.4.4 View of inserted bio-filter block

4.5 Participatory Technology Developed

IPNS with Phospho - Sulpho - Nitro - (PSN) compost

Considering the lack of availability of farmyard manure (5 t ha^{-1}) for adopting the IPNS recommendation of IISS, the nutrient package was modified by integrating another IISS technology viz., phospho-sulpho-nitro compost (2 t ha^{-1}). The technology was evaluated in the farmers' field for a period of two years for the soybean-wheat cropping system (Plate 4.5.1). For the soybean crop, average grain yield in the first year for IPNS with PSN compost was 12.3 q $h^{-1}a$ and that of IPNS with FYM was 11.2 q ha^{-1}. In the second year the corresponding yields were 12.3 and 11.5 q ha^{-1} respectively. For the wheat crop, average grain yield in the first year for IPNS with PSN compost was 42.7 q ha^{-1} and that of IPNS with FYM was 40.7 q ha^{-1}. In the second year the corresponding yields were 45 and 41 q ha^{-1}.


Plate 4.5.1 Preparation of PSN compost under farmers' field conditions

3. TRANSFER OF TECHNOLOGY

A. Main Institute

3.1 Mridaparikshak a Mini-Lab (Upgraded version)

Mridaparikshak, a Mini-Lab developed by ICAR-IISS in collaborative research project with M/s Nagarjuna Agrochemicals Pvt Ltd., Hyderabad has been upgraded. The upgraded version is capable of analysing 12 important soil parameters viz., pH, EC, Organic carbon, Available Nitrogen, Phosphorus, Potassium, Sulphur, Boron, Zinc, Iron, Manganese, and Copper; the last two being the additions in the original version.The upgraded Mridaparikshak Mini-Lab is also equipped to analyse three more parameters viz., Gypsum Requirement, Lime Requirement, and Calcareousness.Mridaparikshak Mini-Lab is a proprietary and patent applied product (Application No. 2522/DEL/2015 dated 14.08.2015) in the name of Indian Council of Agricultural Research.

Plate 3.1.1 Upgraded Mridaparikshak, capable to analyse 15 parameters

3.2 Frontline/ on farm Demonstration

Evaluation-cum-demonstration of IISS technologies under farmers' field conditions

Performance assessment of some of the innovative technologies developed by the ICAR-Indian Institute of Soil Science had been conducted in nine farmers' fields of Megra Kalan village located in the Berasia Tehsil (Bhopal) for the third crop season. Four technologies viz., Integrated Plant Nutrient Supply system (IPNS), phospho-sulpho-nitro (PSN) compost, soil test based fertilizer recommendation for targeted crop yields (STCR), and biofertilizers (liquid and powder formulations) were selected and evaluated as three technology packages i.e. IPNS-I, IPNS-II and STCR (Fig 3.1.1). IPNS-I recommends the use of 5t farmyard manure and 50% recommended dose of NPKS with seed treatment of biofertilizers per ha for the *kharif* soybean and 75% NPKS and seed treatment of biofertilizers per ha for the *rabi* wheat. IPNS-II replaced the 5t farmyard manure with 2t phospho-sulpho-nitro compost. In the third *kharif* season the soybean crop showed a yield advantage of 10.2 % in IPNS-I, 27.0 % in IPNS-II, and 20.8 % in STCR over farmers' practice.

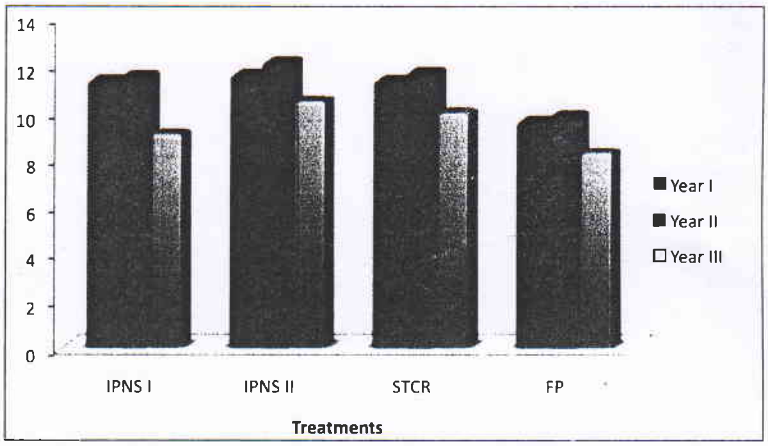


Fig 3.1.1 Performance of soybean for different treatments under Farmers' field condition

Demonstration trials in farmers' fields of Alirajpur, Jhabua and Dhar districts, M.P.

Frontline demonstration trials in the tribal farmers' fields in Alirajpur, Jhabua and Dhar districts (8 for soybean and 4 for maize during *kharif* and 10 for wheat during *rabi* 2015-2016) were conducted to disseminate the institute technologies like IPNS and STCR (Plate 3.1.1).


Plate 3.1.2 Seed and fertilizer distribution and demonstration trials in the farmers' fields

3.3 Farmers'/Field Days Organized

Kisan divas at Khamkheda to review success and promote conservation agriculture

One day Kisan divas was organized by ICAR- Indian Institute of Soil Science, Bhopal at Khamkhedha (Plate 3.1.2) on 5th March 2016 under Consortia Research Platform on Conservation Agriculture (CRP on CA). Dr. A.K. Patra, Indian Institute of Soil Science, Bhopal addressed to the farmers gathered from different villages and interacted with farmers and enquired about the problems of the villages in relation to conservation agriculture. Dr. A.K. Biswas, Lead Centre Platform Coordinator of CRP on CA and Dr. R.S. Chaudhary, Deputy Lead Centre Platform Coordinator described the benefits to farmers with respect to resource conservation and better utilization under conservation agriculture. All the scientists and farmers visited field experiments under Demonstration of Best-Bet Conservation Agriculture Practices on Farmers' Fields in Vertisols of Central India and witnessed the success of field experiments. The field visit was followed by Kisan Sangosthi for interaction between scientists and farmers to answer the questions related to the conservation agriculture. Similar to the Khamkheda program, another Kisan Divas was organized at Momanpur to promote conservation agriculture in farmer's field on 11th March 2016 under CRP on CA. A field visit of best bet CA practices under farmer's conditions was followed by scientist-farmer interaction meet.


Plate 3.1.3 Kisan Diwas at Khamkheda village

B. All India Coordinated Research /Network Projects

3.4 AICRP (LTFE)

3.4.1 Integrated nutrient management under Tribal Sub Plan

Under the tribal sub plan large scale demonstrations on finger millet (GPU – 28) and maize (Hybrid – Hema) were carried out in the tribal farmer's field in different states. In Karnataka field demonstration conducted in tribal clusters at Biligiri Rangana Hills, Yelandur Taluk, and tribal villages near Kollegal taluk of Chamarajanagar District. Representative soil samples were collected from these fields was analyzed for Soil Health Card preparation and was distributed. Before demonstration a training programme on importance of integrated nutrient management and awareness on soil sampling were imparted. The nutrient status of soils in the selected tribal beneficiaries was done in Chamarajanagar District, Karnataka state in two phases (i) TSP- I Phase (49 families of Soliga Tribes) with implementation at Purani Podu, Kalyani Podu in Biligiri Rangana Hills, and Yelandur Taluk and (ii) TSP- II Phase (53 families of Soliga Tribes) at Jeerige Gadde, Haavina Moole and Maavattur in Lokkanahalli Hobli, Kollegal Taluk.

3.4.2 Integrated nutrient management and productivity

a) GKVK, Bangalore

After imparting training, field demonstrations were carried out on tribal farmers' fields and the data revealed that average productivity of finger millet and maize is in the range of 25 to 28 q ha^{-1} and 61 to 68 q ha^{-1} respectively (Table 3.1.1). Improved practices were found to boost the productivity of finger millet and maize to the extent of 25 and 22%, respectively

Table 3.1.1 Average yield of finger millet and maize (kg ha^{-1}) in different tribal areas

Tribal cluster	Farmers practice	INM	Farmers practice	INM
	Finger millet		Hybrid maize	
Purani Podu*	2550	3350	6520	7885
Kalyani Podu*	2430	3150	6121	7706
Jeerige Gadde#	2450	3045	6712	8023
Haavina Moole#	2630	3125	6425	8156
Maavattur#	2850	3456	6852	8282
Average yield	2582	3225	6526	8010
Increase in yield (%) over FP	-	24.9%	-	22.7%

*B.R.Hills, Yelandur Tq; # Kollegal Tq Chamarajanagar: Farmers practice – Only DAP @ 50 kg /acre / and FYM @ 1 to 2 tonnes /acre

The farm inputs and soil health cards were distributed by the dignitaries including the honourable DG ICAR and Secretary DARE Dr. S. Ayyappan, who visited the tribal clusters at B.R. Hills in Chamarajanar Dt. to interact with the beneficiaries in these tribal areas (Plate 3.1.3 and Plate 3.1.4). Besides training program on 'Importance of balanced nutrition to field crops' was also conducted (Plate 3.1.5)

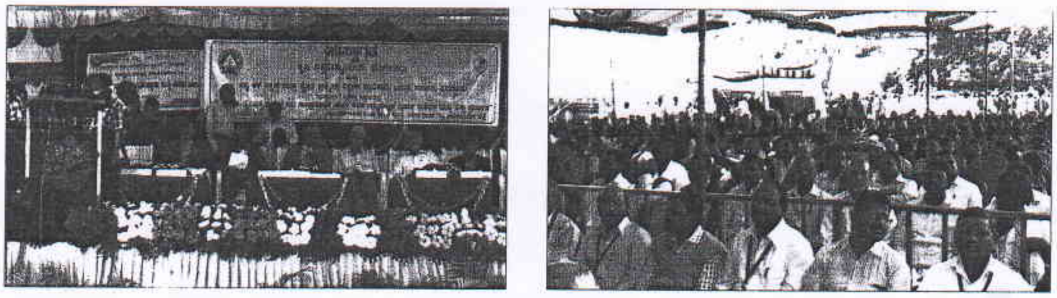


Plate 3.1.3 Visit of Dr. S. Ayyappan, Hon'ble then DG ICAR to the tribal clusters of B.R. Hills, Chamarajanar District

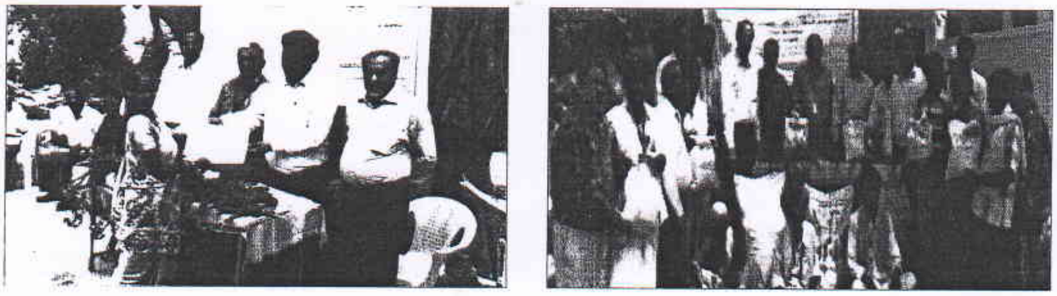


Plate 3.1.4 Distribution of soil health cards and farm inputs to the beneficiaries

Plate 3.1.5 Training programme on 'Importance of balanced nutrition to field crops'

b) OUAT Bhubaneshwar

Demonstrated the impact of balanced and integrated nutrient management in five villages viz., Banjhakusum of Dhenkanal dt, Kailash and Sadhupalli of Deogarh dt, Khariadiha village of Keonjhar dt and Penala village of Kandhamal dt. covering 60 tribal farmers under Tribal Sub-Plan (TSP) during 2015-16 (Plate 3.1.6). The average increase in grain yield was 9 and 13 q ha^{-1} due to balanced and integrated use of nutrients.

Plate 3.1.6 Farmer's field in Kandhamal and Scientist's visit to Farmers' field in Dhenkanal

c) CSKHPKV Palampur

During *Kharif 2015*, farmers (*Tribe: Gaddi)* field demonstrations (50 nos.) were laid out at village Balla of Distt Kangra on integrated nutrient management (INM) in maize. The yield data of maize (Table 3.1.2) revealed a very quantum jump in yield to the tune of 27 q ha^{-1} from improved practices. Besides, six training programmes were organized on balanced fertilization in different crops in dt Kinnaur, Chamba, Kangra and Mandi (Table 3.1.3 and Plate 3.1.7). Two field days were also organized on balanced fertilization in maize and wheat crops in district Kangra.

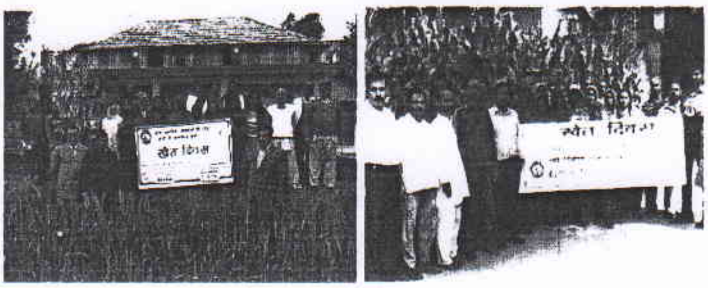
Table 3.1.2 Effect of INM on maize grain yield at farmers' fields at Palampur, HP

Treatment	Range (kg ha^{-1})	Mean (kg ha^{-1})
INM (N: 120, P: 60, K: 40 kg/ha + FYM 5 t/ha)	3750 – 6250	5030
FP (N: 60, P: 24, K: 16 kg/ha + FYM 5 t/ha)	1560 – 2810	2300

Table 3.1.3 Details of training camps organized under TSP component (2015-16)

Venue	No. of Farmers	Tribe
Lamu (Holi), District Chamba	81	Gaddi
Rakh (Nagri), District Kangra	81	Gaddi
Chaura (Bhawanagar), District Kinnaur	80	Gaddi
Gunehar (Bir), District Kangra	80	Gaddi
Tikri (Nushehra), District Mandi	80	Gujjar
Gujreda (Gopalpur), District Kangra	80	Gujjar

Demonstrations on INM in maize and wheat at Balla village (Dist Kangra)



Field day on INM in wheat and maize (Balla)

Lamu (Holi), Dist Chamba (Tribe: Gaddi)

Gunehar (Bir), Dist Kangra (Tribe: Gaddi)

Rakh (Nagri), Dist Kangra (Tribe: Gaddi)

Chaura (Bhawanagar), Dist Kinnaur (Tribe: Gaddi)

Tikri (Chauntra), Dist Mandi (Tribe: Gujjar)

Gujreda (Gopalpur), Dist Kangra(Tribe: Gujjar)

Plate 3.1.7 Training Programme for tribal people in tribal areas in Himachal Pradesh

3.5 AICRP on STCR

Tribal Sub Plan Programme

All India Coordinated Research Project on Soil Test Crop Response (AICRP on STCR) has implemented TSP across the country in various tribal belts.

3.5.1 IGKV, Raipur, Chattishgarh

STCR technology has been tested on tribal farmer's fields with wheat, mustard, maize and chickpea crops

Table 3.1.4 Details of FLD's conducted under TSP-STCR during *Rabi* season

Name of tribal districts	Village	Crop variety	No of beneficiaries	Range of % yield increased over FPD
Kanker	Aturgaon	Wheat (GW-273)	05	9.0 - 32%
		Maize (Vedanta)	05	16 – 27 %
Surajpur	Salyadih	Wheat (Lok -1)	10	23.72-36.65
Jagdalpur	Mooli	Wheat= 10	10	15.87-45.11
Balrampur	Padhi	Wheat (Vidisha)	10	19.23-34.09
Raigarh	Mahloi	Wheat (GW-273)	10	23.59-45.48
Koreya	Mahora	Wheat (MP-2923)	10	29.48-58.81
Kondagaon	Bhagdeva	Maize (Hysel, & Bioseed)	10	0%
Dhamtari	Guhan Nala	Maize	10	36.84-53.41
Korba	Litiyakhar	Wheat (Kanchan)	10	34.07-40.91
Durg	Maravi	Chickpea (JG 11)	10	6.27-25.76

during *rabi* season in Chhattisgarh state. Out of total 100 demonstrations (one acre each), 65 for wheat, 10 for chickpea and 25 FLD's for maize were taken in all ten tribal districts. The percent yields increased due to soil test based fertilizer application over farmer's practice were recorded in the range from 9.00 to 58.8 % for wheat, 6.27 to 25.76 % for chickpea, and 16 to 53 % for maize (Table 3.1.4).

STCR technology has been tested on tribal farmer's fields successfully with rice and potato crops during *kharif* season (Table 3.1.5). One hundred and seventy field demonstrations (one acre each) for tribal farmers in 14 tribal districts (Balrampur, Koriya Ambikapur, Korba, Jashpur, Bilaspur, Narayanpur, Gariyaband, Rajnandgaon, Dhamtari, Kanker, Jagdalpur, Dantewada and Bijapur) of Chhattisgarh state were selected for successful conduction of FLD's during Kharif season.

Out of total 170 demonstrations, 130 for rice and 30 for potato were taken. Overall results show that the yield targets of rice and potato fixed for a definite goal were nearly achieved with the acceptable limit of ±10% variation accept in few cases.

Table 3.1.5 Training program and field days organized at different KVK's

Name of village, Block & district	No. of tribal farmers participated (Women)	Name of tribe	Any other information
Sonbachkachhar/Pendra district Bilaspur	20	Gond	Training cum field day organized.
KVK Dhamtari District - Dhamtari	20	Netam Shori	Training programme organized.
KVK- Durg District - Durg	20	Gond	Training programme organized.
KVK - Balrampur District: Balrampur	20	Sai and Tirkey	"training programme organized.
Village: Siliyadih Block: Batoli District: Surajpur	20	Urao	"Field day–cum–training" programme organized.
KVK-Koriya District - Koriya	20	Gond	"Field day–cum–training" programme organized.
KVK- Dantewada District - Dantewada	30 (15 farmers from Bijapur and 15 from Dantewada district)	Muriya, Halbi	"Field day–cum–training" programme organized.
KVK-Kanker District - Kanker	50 (15 from Kondagaon, 15 from Narayanpur and 20 from Kanker district)	Gond Kuraiti, ShoriPotai, Salam	"Field day–cum–training" programme organized.
Village – Mahloi Block- Tamnar KVK-Raigarh District - Raigarh	20 (10 farmers from Jashpur and 10 from Raigarh district)	Kanwar,Sai, Paikra, Rathiya	"Field day–cum–training" programme organized.

3.5.2 Field demonstrations under TSP component during *Rabi* season

One hundred thirty field demonstrations (one acre each) were taken with wheat, tomato and brinjal crop under TSP component in four tribal districts (Dantewada, Ambikapur, Korea and Balrampur) during *rabi* season. A 48.92 % yield increases over FPD was noticed in wheat, 33.55 percent in Tomato and 33.96% in Brinjal.

3.5.3 ICAR Res Com NEH, Imphal

Nine frontline demonstrations were conducted at farmers' field in Chandel district of Manipur on garden pea (Arkel). Response of crop to liming (furrow application) and fertilizer application (N, P_2O_5 and K_2O at 20, 40 and 40 kg ha^{-1}, respectively) was demonstrated. Green pod yield varied from 17.90 to 18.45 q $ha^{-1}$with a mean value of 18.10 q ha^{-1} for garden pea, 14.35 q ha^{-1} for field pea, 9.51 q ha^{-1} for Rape seed (M-27), 4.44 t ha^{-1} for Rice (RC Maniphou 6) and 23.48 t ha^{-1} for Groundnut (ICGS 76)

3.5.4 CRIJAF, Barrackpore, West Bengal

Ten front line demonstrations were conducted in village-Hanumanhir, Grampanchyte-Nakaijuri, Block-Onda. The average grain yield of mustard was recorded 6.30 q ha^{-1} under soil test and targeted yield based fertilizer application (Table 3.1.6) against farmers practice 3.48 q ha^{-1}. Thirty-five front line demonstrations were conducted in Village-Saresh, Grampanchyte-Nakaijuri, Block-Onda. The grain yield of mustard varied from 4.35 to 7.13 q ha^{-1} in soil test and targeted yield based fertilizers treatment as compared to farmers practice varied from 2.50 to 4.10 q ha^{-1}. The average grain yield of mustard was recorded 5.97 q ha^{-1} under soil test and targeted yield based fertilizers application against farmers practice 3.19 q ha^{-1}. A total fifteen front line demonstrations were conducted in village-Daldali, Grampanchyte-Nakaijuri Block-Onda. The average grain yield of mustard was recorded 5.71 q ha^{-1} under soil test and targeted yield based fertilizers application against farmers practice 3.14 q ha^{-1}. Twenty-two front line demonstrations were conducted in Village - Bamundia, Grampanchyate - Lachmanpur, Block- G. Ghati, District. The average grain yield of mustard was recorded 6.27 q ha^{-1} under soil test and targeted yield based fertilizers application against farmers practice 3.83 q ha^{-1}. Similarly, in Village-Majharpara, Grampanchyate- Chingani, Block- Chhatna, District Bankura, where covering about 28 bigha (3.73 ha) and success area recorded about 24.5 bigha (3.25 ha) at fifteen locations. Grain yield of mustard ranged from 5.60 to 9.75 q ha^{-1} under soil test and targeted based treatment whereas 2.73 to 4.60 q ha^{-1} recorded in farmers practice treatments. The fixed targeted yield of mustard (10 q ha^{-1}) could achieve only in two locations within ±10% yield deviations. The average grain yield of mustard was recorded 6.58 q ha^{-1} in soil test and targeted yield based treatment as against 3.44 q ha^{-1} under farmers practice. The net return (Rs. 6055 ha^{-1}) was recorded higher over farmers practice.

Table 3.1.6 Targeted yield equations used for conduction of front line demonstration on mustard and lentil in farmer's field

Mustard (B 9)	Lentil (B 256)
FN = 16.5 T – 0.08 SN	FN = 4.76 T – 0.15 SN – 0.08 ON
FP = 4.66 T – 0.41 SP	FP = 3.76 T – 0.07 SP – 0.07 OP
FK = 5.71 T – 0.03 SK	FK = 6.87 T – 0.42 SK – 0.07 OK

3.5.5 BCKV, Kalyani, West Bengal

Field demonstrations were conducted in 21 tribal farmers fields under the scheme of Tribal Sub-Plan (TSP). The villages selected for demonstrations were Suoapara and Kannan of Hoogly and Kalanabagram of Burdwan district respectively. It was found that in most of the cases STCR technologies excel over farmers' practices.

3.5.6 TNAU, Coimbatore, Tamil Nadu

Field demonstrations on STCR technology were conducted at tribal farmers' field with maize, groundnut, onion, carrot and tomato in Western and North western zones of Tamil Nadu. At Alangandi and Gopanari, Coimbatore district, highest Maize (CO 6) yield was recorded in the STCR-IPNS treatment followed by STCR-NPK alone treatment. In Groundnut (CO 6), STCR-IPNS and STCR-NPK alone recorded relatively higher yield and response ratio when compared to blanket recommendation. Similar response was noticed in Onion (Co 4), Carrot (Hybrid Tokita), Tomato (PKM1), Turmeric (BSR1) and Tapioca (Mulluvadi), Maize (CP 808), Gingelly (TMV 3), Cotton (Surabhi), Bhendi (Kaveri 909), Rice (ADT (R) 45) etc.

ANGRAU, Hyderabad conducted frontline demonstrations on maize (7), rice (2) and groundnut (3) in Vizianagaram and Warangal district. RAU, Pusa, Bihar conducted demonstrations in wheat. MPKV, Rahuri, Maharashtra conducted demonstrations *Kharif*- Soybean, *Kharif* Sorghum, Pigeon pea, Drilled paddy, *Rabi*-Wheat, Chickpea, *rabi* sorghum and Maize.

3.6 AINP on BF

Biofertilizer Extension

Biofertilizer technology for soybean and wheat was demonstrated in nine farmers' fields of Menghra Kalan village, Berasia Tehsil, Bhopal District. *Rhizobium* and Plant growth promoting bacteria consortium (mixture of three PGPR strains) for soybean; and PGPR only for wheat. Soybean and wheat yield increased in INM mode with Biofertilizer by ~10% with FYM and ~25% with enriched compost over farmers' practice. Recommendation was released in Maharashtra for soybean-wheat: For enhanced grain yield, improved quality of the produce, soil fertility improvement and more monetary returns; seed treatment of liquid biofertilizers i.e., *Bradyrhizobium* + PSB @ 50 ml each / 10 kg seed to soybean and *Azotobacter* + PSB @ 100 ml each/10 kg seed to wheat should be used. K-solubilizing bacteria and consortia for decomposition crop residues in short period were released to farmers in A.P.

Biofertilizer technology (*Rhizobium* and *Bacillus* co-inoculation) intervention among farmers of Bhagalpur and Katihar dt. for black gram and among Vaishali and Samatipur dt. for lentil gave grain yield increase of 10-14% for lentil and 6-9% for blackgram. Microbial consortium based bionutrient package for rice in farmer's fields in Samastipur, Muzaffarpur and Vaishali dt. resulted in 5-15 % increase in grain yield over farmers' practice. Imbalance use of chemical fertilizers and higher doses of fertilizer application was common among poor farmers' due to fragmented land holdings.

In five multi-locational field trials, *Bacillus licheniformis* (i.e. soil drenching of apple plant basin with one litre of liquid formulation diluted to five liters) increased the yields of apple in H.P. by 12-86%.

In cauliflower, the application of *Bacillus pumilus* at 3 locations, saved 25% NPK and improved yield by

22%. In pea the application of *Rhizobium leguminosarum* R2 at 3 locations saved 40% NPK and improved yield by 26%. Organic farming for rice in Assam consisting of enriched compost (EC) @ 5.0t/ha with biofertilizer as organic input for rice was tested in several KVKs of Assam and found to give additional yield of 0.5-1.2 t/ha over farmers's practice.

In Tribal area sub-programme in Kalahandi and Rayagada on vegetable crops, cotton and banana (125 farmers) increase in yields ranging from 8-20% were obtained with biofertilizers, generating an additional income ranging from Rs.6000 to 12,000 ha^{-1} with the investment of Rs.1000-1500 ha^{-1} on BFs. The construction of small vermicompost units enabled farmers to save 25% cost on chemical fertilizers. In nine tribal settlements in Wayanad district, 1400 kg of biofertilizers *Azotobacter chroococcum, Azospirillum* and PGPR mix-1 were distributed to 125 farmers for application in ginger and black pepper. Two training classes were conducted at two places. In tribal settlements of Attapady, Kerala 312 kg of PGPR mix I were distributed to tribal farmers engaged in the cultivation of vegetables, pulses, banana, sorghum, groundnut, ragi etc. Training programmes on application of biofertilizers were created. 312 tribal farmers from 3 locations and 54 extension officers participated.

160 MT of solid and 23MT of liquid biofertilizers worth Rs 133 lakhs produced at ANGRAU, Amaravathi. About 3.1 lakh biofertilizer packets worth Rs. 71.7 lakhs produced at JNKVV, Jabalpur. Biofertilizer sale was Rs. 5.3 lakhs at VN MAU, Parbhani. Total BF production in project was ~210 lakhs representing 69% return on funding of Rs 305 lakhs received by the project.

3.7 Mera Gaon Mera Gaurav (MGMG) activities

An innovative initiative "Mera Gaon Mera Gaurav" has been initiated to promote the direct interface of scientists with the farmers to hasten the lab to land process. The objective of this scheme was to provide farmers with required information, knowledge and advisories on regular basis by adopting villages. Under this scheme, the team of scientists have selected villages and remain in touch with the selected villages and provide information to the farmers on technical and other related aspects in a time frame through personal visits or on telephone. Being a resource person for the village, the scientists monitor the process of adoption of agricultural technologies by the farmers with the cooperation of KVKs, ATMA, etc. (Plate 3.7.1) Besides providing information to farmers on market rates and market trends, the information on various agricultural organisations associated with agriculture are given so that the farmers can contact these organisations for finding solutions to their agriculture related problems. Scientists also created awareness among farmers about climate change, other customized services, protective measures and other issues of local and national importance. The list of scientist groups and their adopted villages are given in the Table 3.2.1.

Plate: 3.7.1 Glimpses of activities under MGMG program

Table 3.1.7 ICAR-IISS, Bhopal Adopted Villages under MGMG

S.N.	Group	Name of five adopted villages
1	Dr. A.K. Patra, Director, IISS Dr. A.B. Singh, PS, SBD & Nodal Officer Dr. Abhay Shirale, Scientist, SC&F Dr. Sudeshna Bhattacharjya, Scientist, SBD	Dobra, Khejra, Kurana, Badarkha Sadak, Mubarakpur
2	Dr. M.C. Manna, HOD, SBD Dr. K. Ramesh, PS, SC&F & Co-nodal officer Dr. N.K. Sinha, Scientist, SPD	Acharpura, Parewakheda, Arwali, Hazampura and Parewalia sahani
3	Dr. M. Singh PC, LTFE Dr. S. Kundu, PS, ESS Dr. R.H. Wanjari, SS, LTFE Dr. K. Bharti, SS, SBD	Choupdakala, Ghat Kheri, Sayyaid Semara, Emaliya Chopra and Amoni
4	Dr. J.K. Saha, HOD, ESS Dr. N.S. Bhogal, PS (STCR) Dr. M.L. Dotaniya, Scientist, ESS	Islam Nagar, Dewalkhedi, Bharonpura, Kalyanpura, Puraman Bhavan
5	Dr. D.L.N. Rao, NC, BNF Dr. Sanjay Srivastava, PS, SC &F Dr. K.M. Hati, PS, SPD Dr. K.C. Shinogi, Scientist, ITMU	Bankhedi, Baroda, Sojna, Amaravadi and Kuravadi
6	Dr. A.K. Shukla, PC, MSN Dr. R. Elanchezhian, PS, SC&F Dr. R.K. Singh, SS, SPD Dr. J.K. Thakur, Scientist, SBD	Sagoni, Munirgarh, Gudawal, Chhattarpura, Chiklod khurd
7	Dr. A. K. Biswas, HOD, SC&F Dr. Brij Lal Lakaria, PS, SC&F Dr. Asha Sahu, Scientist, SBD Dr. Bharat P. Meena, Scientist, SC&F	Golkhedi, Binapur, Kanchbavli, Khamkheda and Raslakhedi
8	Dr. R.S. Choudhary, HOD, SPD Dr. P. Jha, SS, SC&F Dr. S.R. Mohanty, SS, SBD Dr. A.K. Vishwakarma, SS, SPD	Raipur, Kanera, Momanpur, Kadhaiya and Karod Khurd
9	Dr. P. Dey, PC, STCR Dr. N.K. Lenka, PS, SC&F Dr. M. Mohanty, Scientist, SPD Dr. M. Vassanda Coumar, SS, ESS	Ratibad, Rasuliya Pathar, Mugaliahat, Ratanpur Sadak, Chandukhedi
10	Dr. A.K. Tripathi, PS, SBD Dr. S. Ramana, PS, SBD Dr. J. Somasundaram, SS, SPD Dr. A. Mandal, Scientist, SBD	Dobra Jagir, Kolua Khurd, Sagoni Kalan, Chor Sagoni, Adampur Chhawni
11	Dr. Ajay, PS, ESS Dr. Tapan Adhikari, PS, ESS Dr. S. Lenka, Scientist, ESS Dr. S. Rajendiran, Scientist, ESS	Shahpur, Devpur, Kasi Barkeda, Sagoni, and Barkedi Hajam