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Research Achievements of AICRPs on Natural Resource Management

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All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture

1. Title of the Project : All India Coordinated Research Project on Management of Salt Affected Soils & Use of Saline Water in Agriculture

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3. Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):

Gypsum bed technology:

- To treat the sodic water to neutralize part of residual sodium carbonate, this technology has been perfected using gypsum, pyrite and distillery spent wash. The technology is being adopted in Haryana, M.P. and Tamil Nadu.

- Agronomic practices for use of saline water for medicinal plants such as isabgol and aromatic plants such as lemon grass has been perfected.

- For skimming fresh water floating on the saline water, improved Dorouv technology has been perfected for coastal sandy soils.

- Raised and sunken beds technology has been perfected to reclaim sodic vertisols under rainfed or with limited irrigation water.

- Technologies to minimize the entry of bacterial contaminants entering human/animal chain while using domestic wastewaters have been perfected.

- Rice-wheat cropping sequences suited best for alkali soil followed by sorghum-mustard. Soil application of gypsum (50% GR) along with green manuring (Sesbania acculata) found to be most economical and profitable.

- Conjunctive use of canal water for rice and alkali water for green gram is recommended for New Kattalai Canal of Cauvery Irrigation Command area. Conjunctive use of canal and soid water in 1:1 ratio can also be practiced for rice. Gypsum bed treatment of alkali water reduced its RSC from 6.35 to 2.12.

- Crops and varieties screened for their sodicity tolerance at Tiruchirapalli (Tamil Nadu) are coarse grained rice (TRY 1); fine grained rice (ADT 35); Green gram (Pusa Bold); pearl millet (UCC 17); maize (COH M4); sunflower (CO 4); sesame (CO 1); okra (Parbhani Kranti); cluster bean (Pusa Naubahar).

- Soil application of gypsum @ 50% GR + green manuring with daincha gave perceptible results in ameliorating saline – sodic soils in Jaipur district.

- Secondary salinization of soil in IGNP command area can be prevented if water table is maintained below 125 cm.

- Application of gypsum @ 50% GR every third year has been recommended for using high RSC waters in Jaipur. Mustard should be preferred over wheat.

- Subsurface drainage decreased the EC from an average of 16.2 to 3.96 dS/m after fifth year in Krishna Western Delta in Andhra Pradesh. Salt removed during 2006-07 was 14.9t. Establishment of rabi crop was good with sorghum 25.6t/ha, Pillipesara 16.5 t/ha, sunhemp 18.7t/ha. Earlier, it has been shown that the technology worked well for heavy soils (vertisol) and alluvial soils of Haryana.

- The agronomic practices finalized through on-station trials have been transferred to farmer's fields under an Operational Research Project resulting in higher yield and income to the farmer's under saline environment.

- In high SAR saline water irrigated lands, surface drainage is very essential to minimize rain/irrigation water stagnation. Gypsum and farmyard manure could also help in getting higher yields.

- Interceptor drainage with nala cleaning has been found most useful to reclaim waterlogged saline lands in Tungbhadra Command in Karnataka. The rice yield improved by 3-4 times than before the intervention.

All India Coordinated Research Project on Soil Test Crop Response Correlation

1. Title of the Project : **All India Coordinated Research Project on Soil Test Crop Response Correlation**

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3. Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years) (2002-2007):

IMPLEMENTATION OF STCR TECHNOLOGY WHICH HAS BEEN DEVELOPED BY AICRP ON STCR IN DIFFERENT STATES AND BEING PRACTICED BY THE FARMERS.

1. 4 regional workshops on Soil testing and balanced fertilizer use have been organized of soil testing laboratory personnel of above regions every year for last five years in different regions of the country.

2. About 200 FLD's have been organized on farmer's fields to demonstrate the value of STCR technology to the farmers at different STCR centres.

3. Soil test prescription equations developed in particular state are being followed by farmers in major parts of the state since last 5 years are given below:

a) The online soil testing fertilizers recommendations developed with a help of NIC centre at Pune and have been handed over to different soil testing laboratory of Maharashtra state by the farmers since last 2 years.

(b) In the state of Orissa the STCR fertilizer recommendations are being followed for Paddy and Groundnut crops in the many parts of the Orissa state (11 Soil testing laboratory).

(c) In the state of Punjab the fertilizer recommendations developed by STCR for crops like Rice and Wheat have been included in the university of package of practices

(d) In the state of Haryana the fertilizer recommendations developed by the centre for crops like Bajra and Wheat have been included in the university package of practices and are being followed by the farmers of the state.

(e) In the state of Andhra Pradesh, STCR recommendations have been developed for about 20 crops and have been handed over to Dept. of Agril. for implementations. Efforts are being made by the

Department to transfer the technology to the farmers of the state through STLs. The STCR recommendations are also being followed by the farmers of different zones for crops like Paddy, Groundnut, Sorghum, Maize and Sugarcane in coastal areas.

(f) In the state of Tamil Nadu, DESSIFER has been developed by the STCR centre and has been distributed over to all the STL's. The Dept. of Agril. agreed to implement the technology wherever the technology is available to different crops.

4. On line fertilizer recommendations have been developed. District level soil fertility maps for about 10 different states have been prepared. However block level soil fertility data of NPK have been procured for about 10 states for preparations of on line soil fertility recommendations using GIS software which is in progress.

5. Target yield equations and IPNS equations have been developed by all the centres for different crops and cropping system of the state. For example in the state of Tamil Nadu, Karnataka, Maharashtra, Andhra Pradesh, the equations of fertilizer prescription along with ready reckoners for more than 20 crops have been developed for use by the farmers.

6. States like Punjab, Haryana, Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, Himachal Pradesh, Kerala have published technology bulletins for the benefits of the farmers and the soil testing laboratories.

AICRP STCR Transfer of Technology validated and developed under farmers fields (2001-03)

During the year 2001-03 large number of demonstrations conducted at different centres who demonstrate the value of soil test based fertilizer and manure experiments in different states. In these demonstrations farmers could obtain high returns to apply nutrients through the application of manures fertilizer based target yield equations. Long term demonstrations trial are in progress at Coimbatore and Palampur centres to demonstrate the value of soil test based recommendations in terms of yield sustainability and soil fertility maps.

The following centres have carried out FLD's in different parts of the respective states for transfer of technology purpose.

(i) Frontline Demonstrations on Farmers' Fields (2001-03)

Frontline demonstrations were conducted on farmers' fields to demonstrate the value of soil test based fertilizer and manure recommendations in different states. In these demonstrations farmers could obtain high returns to applied nutrients through the fertilizers and manures application based on targeted yield equations. Long term demonstration trials are in progressed at Coimbatore and Palampur centers to demonstrate the values of soil test based recommendations in terms of yield sustainability and soil fertility maintenance. Rahuri, Coimbatore, Jabalpur and Raipur centers have conducted frontline demonstrations in different parts of the respective state.

New Delhi: Mustard and Wheat, Bharthal, New Delhi

Rahuri: Rice (var. Indrayani) and Finger millet/Nagli (var. RAU-8), A.R.S, Igatpuri and farmers' fields on Entisol and Inceptisol.

Bangalore: Ragi (var. G. P. U. 28), Paddy (var. JR 30864) and Maize (var. Pioneer).

Hisar: Paddy (var. PR- 106) and Wheat (var. WH- 542)

Coimbatore: Continues experiment on Kharif Rice (var. ADT 36) and Rabi rice (var. ADT 38) on Noyyal soil series, Alfisol, TNAU Farm followed by Kharif Rice (var. CO 47) and Rahi rice (var.CO 47).

Jabalpur: Paddy, Wheat, Pigeonpea and Chickpea in villages in Narsingpur and Jabalpur districts.

Pantnagar: Paddy and Wheat

Palampur: Long term demonstration trial on Maize and Wheat.

Raipur: Mustard (var. Pusa bold) Higana, Dist.: Durg on Vertilsol; Soybean (var. Js-335 and Arhar (var. Asha), Hingana Dist.: Durg; Rice (var. Swarna), village Hingana, Kumhi; Rice (Var. Swarna), Pahanda; Rice (var. Swarna), Matiya; Wheat (var. Sujata), Achhoti; Wheat (var. Sujata), Dhour; Wheat (var. Sujata) Koshpatar; Wheat (var. Sujata), Ingana; Chickpea (var. JG-74 Berala, Dist.: Durg on Vertisols.

(ii) Frontline Demonstration of STCR technology on Oliseed crops.

Frontline demonstrations were carried out on farmers' fields to demonstrate the STCR Technology on Oilseeds. Most of the demonstration were successful and the farmers obtained high response and benefit: cost ratios when they used the soil test based nutrient applications. Coimbatore and Bangalore centers have carried out demonstrations in different parts of the respective

Coimbatore: Groundnut (var. VRI2), Kakapalayam, Irugur soil series; Groundnut (var. CO4), Vadivelamplayam, Irugur Soil series; Sunflower (var. SH 3322), Kurukapuram, Rasipuram, Inceptisol.

Rahuri: Soybean (var. iS 335), Guha, Rahuri, Dist.: Ahmednagar.

Bangalore: Groundnut (var. TMV-2), Ammana Ghatta, Distt.: Tumkur; Safflower (var. A-1) GKVK, Bangalore on Black soil, Sandy clay loam; Groundnut (var. TMV-2), GKVK Bangalore on Red sandy loam; Sunflower (var. KBSH—42), GKVK, Bangalore: on Red soil, Gravelly sandy loam.

Hisar: Raya (vat. RH- 8113) and Raya (var. Luxmi).

Ludhiana: Rape seed (B.napus var. GSL-l)

Palampur: Toria (var. Bhawani), Soybean (var. PK-472) and Soybean (var. Harit).

Jabalpur: Soybean, Linseed and Mustard.

AICRP STCR Transfer of Technology validated and developed under farmers fields

Front line demonstrations in farmers fields (2003-04)

RAHURI

Rice (var. lndrayani) & Finger millet/ Nagli (var. RAU-8)

Location: A.R.S, lgatpuri and farmers' fields, Soil: Entisol and Inceptisol

Five yield targeting demonstration trials on rice were conducted on farmers' fields during Kharif season. The results of the trials showed that the yield targets of 30 and 40 q/ha were achieved through balanced fertilization based on fertilizer prescription equations. Five yield targeting demonstration trials on nagli were conducted on farmers' fields during Kharif season 2002. The results of the trials showed that the yield targets of 12 and 18 q/ha were achieved through balanced fertilization based on fertilizer prescription equations.

COIMBTORE

Demonstrations were conducted during Kharif and Rabi in wetlands of TNAU Farm, Coimbatore. The yield data indicated that higher rice grain yields were recorded in STCR treatments when compared to blanket dose. The STCR- IPNS treatments recorded relatively higher yields per cent achievement and response ratio over STCR-fertilizers alone.

JABALPUR

Paddy, wheat and chickpea

Four frontline demonstrations (one on paddy, two on wheat and one on chickpea) were conducted on the farmers' fields during Kharif and Rabi. The data revealed that the profits in all the crops were higher at the targeted yield levels as compared to the profit attained by using general recommended doses. Profits were further enhanced due to inclusion of farm yard manure @ 5 t/ha. Paddy provided high profits with the inclusion of 5t FYM/ha as compared to the target and GAD. Amongst the two wheat varieties tested, Lok 1 with fixed target level of 5 tlha gave the maximum profit of As 16426/ha as compared to GW 190 which with 4 t/ha target level gave a profit of Rs 10565/ha. Benefit cost ratios, both in case of Lok 1 (5.34 to 5.63) and GW 190 (4.34 to 4.88) were higher as compared to BCR of GRD. Yard stick values were also high at the fixed target levels either with or without inclusion of FYM when compared with the YSV of GAD. High profit in case of chickpea was recorded (Asi 6439/- with the use of 5 1 FYM, of As 13189/- with no FYM. High benefit cost ratios and YSV were also noticed at target levels fixed with either or no inclusion of FYM.

RAIPUR

Rice, soybean and pigeon pea, wheat and gram

The demonstrations were carried out on farmers' fields with rice, soybean and pigeon pea. The yield targets were achieved within 10% deviation. The results indicated that high economic returns together with higher yield can be achieved with soil test based fertilizer use as compared to general recommendations. The importance of soil test was highlighted in case of pigeon pea, where all the P & K fertilizers could be saved in view of their high soil nutrient status without reduction in yield levels.

Work accomplished by some cooperating centres of AICRP on STCR during the period under report for transfer of technology (2004-05)

Centre	TYE*	FVT**	FD***	Remarks
Vellanikara	Banana Sweet potato, Ash gourd, Coleus, Groundnut	Ginger		
Hyderabad	Tomato under IPNS Safflower on vertisols	Sugarcane, Coriander		
Palampur	Wheat	Soybean, maize and wheat	Soybean, toria	High total returns and B/C ratio in STCR based than the general recommendation or farmers' practice.
Hisar	Pearl millet, Raya, barley			
Bikaner	Barley under IPNS			
Raipur	Scented rice in Inceptisols and vertisols, wheat on vertisols	Rice, wheat, gram		P and K fertilizers could be saved when the fertilizers were applied based on soil tests in the follow up experiments with rice.
Pantnagar	Gram	Paddy		
Pusa	Wheat inder IPNS (Poultry manure)	Rice on calcareous soils.Wheat, winter maize, sesamum, rape seed, Lentil	Cauliflower in farmers' field. The B/C ratio(12.3 to 13.9) were higher than GRD (12.1) and FP (10.6) at all yield targets	STCR based fertilizer application is more profitable for rice in calcareous soils. In wheat the net profit in the STCR calibrated dose ranged from Rs. 13700 to Rs. 18300 ha^{-1}.
Rahuri	Rainfed chilli	Soybean: Fertilizer application		

		based on fertilizer prescription equation with FYM has recorded the highest grain yield (33 q ha^{-1}) over the rest of the treatments.		
Kalyani	Potato, wheat, sunflower, boro rice, rape seed, sesamum			
Jabalpur	Pea under IPNS	Paddy-chickpea system, soybean-wheat	Paddy, wheat, chickpea	In demonstration trials the B/C ratio in case of paddy varied from 2.9 to 4.2 when fertilizer was applied for target of 5 t ha^{-1} alongwith FYM @ 5 t ha^{-1}. In general high B/C ratio was applied in STCR doses than general recommendation.

*TYE=Targeted yield equation

**FVT=Field verification trial

***FD=Frontline demonstration

Work accomplished by some cooperating centres of AICRP on STCR during the period under report for transfer of technology (2005-06)

Table 4.10.1.1. Summary of work done by some cooperating centers of AICRP on STCR during 2005-05

Centre	TYE*	FVT**	FD***	Remarks
Hyderabad	Chickpea Safflower Mustard Cabbage Turmeric Ragi	Tomato Chickpea Groundnut Sunflower		
Jabalpur	Sesame		Gram (3) Wheat (2) Paddy (1)	Higher response and higher response ratios were noticed with STCR based dose than with GRD dose
Pantnagar	Wheat Garlic Onion			
Vellanikkara	Cucumber Amaranthus Bhindi Rice		Banana	It is planned to demonstrate the achievements to the farmers on the University farm on the field day.
Bhubaneswar				
Barrackpore				
Bangalore	Paddy Maize Onion	Ragi		Targeted yield equations developed for zone 6 was found to be suitable for zone 5 after testing the validity.
Ludhiana	Rice Wheat	Rice Wheat		Multiple regression analysis of the data showed that soil organic carbon is most important in influencing response of wheat.
New Delhi	Wheat Pearlmillet			In demonstrations, grain yield of wheat was 48.7 q/ha with profit of Rs.14380/- in STCR based treatment as compared to 42.2 q/ha with net profit of Rs.12380/- on GRD and 37.4 q/ha with net profit of Rs.9365/- in farmer's practice.

Centre	TYE*	FVT**	FD***	Remarks
Samastipur	Rice Potato Maize Garlic	Rice (5) Wheat (6) Maize (2) Sesame (5) Rapeseed (1) Linseed (2) Lentil (1) Brinjal (6) Lady's Finger (1)		
Raipur		Rice (3)	Rice (11)	
Hisar	Barley Wheat	Paddy (3) Pearlmillet (3) Barley (2) Wheat (2)	Raya (3)	
Rahuri	Tomato Onion Soybean Wheat	Potato		
Coimbatore	Carrot Cauliflower Cabbage	Potato Carrot Cabbage Cauliflower		
Palampur	Soybean Toria Maize Wheat	Okra Soybean Maize Wheat	Soybean (8) Toria (8)	Benefit cost ratios were high in soybean implying the usefulness of target yield concept based fertilization.
Bikaner				

TYE* = Target Yield Equation
FVT** = Field Verification Trial
FD*** = Frontline Demonstrations

Summary of work done by some cooperating centres of AICRP on STCR during 2006-07 under AICRP (STCR) project for transfer of technology

Centre	TYE*	IPNS	FVT**	FD***	Remarks
Hyderabad	Chickpea Turmeric Red gram Ragi Rice Mesta	Colocassia at Hyderabad	Tomato Ragi Chickpea Groundnut	--	Higher response and cost benefit ratios have been noticed in field verification trials
Ludhiana	Rice Wheat	Rice Wheat	Rice Wheat	--	Economic analysis revealed that the net profits were higher STCR treatment
New Delhi	Wheat Pearl millet	Wheat Pearl millet	Wheat Chhawla	--	Economic analysis of the trials on farmer's fields reveled that STCR treatments resulted in higher net profits than others.
Pantnagar	--	Garlic Onion Potato Mustard Rice	Wheat at Rudrapur Onion and Garlic	--	Cost benefit ratio was found to be high in the Onion crop
Rahuri	Sugarcane Brinjal Chilli	Tomato Potato Cauliflower Cabbage	Cauliflower Chilli	--	Net profits were higher in Cauliflower and Chilli crops
Raipur	--	Brinjal Sugarcane	Rice (4) Soybean(4) Chickpea (4) Brinjal (4) Okra (4)	--	Net profits are better in Wheat Chickpea
Jabalpur	Maize	Pea Lentil	Pea Lentil Wheat (IPNs) Gram	Wheat Pannagar block paddy (2) IPNS Urad Dal (1)	BCR was high in Wheat and Paddy
Bikaner	Cotton	Isabgol Cumin	Clusterbean	--	STCR treatments were found be better than other practices like GRD, farmers practice

Bhubaneswar	Rice	Rice Pumpkin Lady's finger	--	--	--

Vellanikkara	--	Amarantus Snakeguard Bittergourd	--	Banana (4)	Net profit were high in Bananas in STCR treatments
Hisar	---	--	--	--	--
Pusa		Soump (omam) Azvai Fenugreek	Sesamum Rice Wheat Rapeseed Brinjal Winter Maize		Vegetables crops have exhibited better performance
Kalyani	--	Boro rice Cabbage Groundnut Cauliflower Radish	--	--	--
Barrackpore	--	Jute	Jute	--	--
Bangalore	--	Sugarcane Maize Carrot	Paddy sugarcane	Groundnut Sunflower	In follow up trials STCR treatments found to be better in paddy, sugarcane

TYE*= Target Yield Equation
FVT**= Field Verification Trial
FD**= Front line Demonstrations

STCR Technology developed at different centres for transfer of technology in Tamil Nadu
Tamil Nadu

State	Crop	Target	Fertilizer nutrient applied (kg/ha)			FYM applied (t/ha)	Additional yield (kg/ha)	Net Profit (Rs/ha)	BC ratio
			N	P	K				
Tamilnadu	Groundnut	2.5 t/ha	52	55	71		980	--	**5.5**
		2.5 t/ha	17	37	31	12.5t/ha	1055	--	**5.95**
2003-04	Gingelly (SVPR-I)	1 t/ha	50	38	45		395	--	**2.97**
		1 t/ha	15	20	5	12.5 t/ha	435	--	**3.27**
2002	Sunflower (SH-3322)	2 t/ha	87	63	13		1150	--	**7.05**

		2 t/ha	52	45	0	12.5 t/ha	1235	-	**7.57**
2001	Paddy (Kharif)	7 t/ha	185	51	19		4330	--	**17.0**
		7 t/ha	150	67	10	G.M.@25 t/ha+ Azo. 2 kg/ha^{-1}	4460	--	**19.7**
2001	Paddy Rabi	7 t/ha	193	84	19		2050	--	**13.3**
		7 t/ha	141	60	10	G.M.@25 t/ha + Azo 2 kg/ha^{-1}	2140	--	**19.2**
Rabi 2002	Sunflower (SH-3322) Western zone	2 t/ha	87	63	13	--	1150	7.05	--
		2 t/ha	52	45	0	12.5 t/ha	1235	7.60	--
Summer 2003 Irugur Series	Groundnut Western zone (Co-4)	2.5 t/ha	52	55	71		980	5.5	--
		2.5t/ha	17	37	31	12.5t/ha	1055	5.92	--
2004	Gingelly (SVPR-1)	1t/ha	50	38	45		395	2.97	--
		1t/ha	**15**	**20**	**5**	**12.5 t/ha**	**435**	**3.27**	--

STCR Technology developed at different STCR centres for transfer of technology in Madhya Pradesh

Madhya Pradesh

State	**Crop**	**Target**	**Fertilizer nutrient applied (kg/ha)**			**FYM applied (t/ha)**	**Additional yield (kg/ha)**	**Net Profit (Rs/ha)**	**BC ratio**
			N	**P**	**K**				
Jabalpur Dist.	Paddy (Kranti)	5 t/ha	138	112	9		3280	14,784	**3.77**
		5 t/ha	138	112	9	5 t/ha	3700	15,178	**3.08**
Jabalpur Dist.	Wheat (GW 273)	4 t/ha	109	65	28		2025	10,397	**3.76**
		4 t/ha	109	65	28	5 t/ha			

Jabalpur Dist.	Soybean (JS 093-05)	2.5 t/ha	0	50	0		611	7,516	**7.24**
		2.5 t/ha	44	102	31	5 t/ha	1619	18,826	**4.9**
	Soybean (JS 093-05)	2.5 t/ha	15	75	0		1625	20,156	**7.77**
		2.5 t/ha	42	80	0	5 t/ha	1850	22,306	**8.59**
	Chickpea (JS-315)	2 t/ha	42	80	0		127	17,003	**3.01**
		2.5 t/ha	**42**	**80**	**0**	**5 t/ha**	**1400**	**18,878**	6.0

STCR Technology developed at different STCR centres for transfer of technology in Maharashtra and Punjab states

Maharashtra

State	**Crop**	**Target**	**Fertilizer nutrient applied (kg/ha)**			**FYM applied (t/ha)**	**Additional yield (kg/ ha)**	**Net Profit (Rs/ha)**	**BC ratio**
			N	**P**	**K**				
Maharashtra	Adsali Sugarcane	150 mg/ha	327	156	142		66.0 mg/ha	29,700	**4.73**
Mean of 6 trials 1993		175 Mg/ha	439	188	160		84.2	37,890	**4.92**
	Seasonal Sugarcane	80 Mg/ha	140	76	90		28.9	13,005	**4.11**
Mean of 5 trials		100 Mg/ha	235	101	144		38.0	17,100	**5.26**
Mean of 5 trials	Groundnut	20 q/ha	25	45	0		5.9	8,850	**8.93**
		25 q/ha	46	70	0		8.3	12,450	**7.82**
	Upland Paddy (5 trials Mean)	30 q/ha	63	57	53		11.3	7,910	**3.38**
(2003-04)		30 q/ha	63	57	53	10 t/ha	12.4	8,680	**1.04**
(2002)	Trans-planted	30 q/ha	95	50	22		2.48	2,480	**1.83**

	Paddy Mean of (10 trials)								
(2003-04)	Chilli (Two trials)	6 Mg/ha	202	115	87.5		4.35	34,800	**7.03**
		6 Mg/ha	116	90	73	10 t/ha	4.50	36,000	**3.80**
(2004-05)	Potato	150 q/ha	153	46	131		95.2	38,000	**11.06**
		150 q/ha	**110**	**38**	**108**	**10 t/ha**	**106.8**	**42,720**	**4.92**

Punjab

State	**Crop**	**Target**	**Fertilizer nutrient applied (kg/ha)**			**Additional yield (kg/ha)**	**Net Profit (Rs/ha)**	**Response ratio**
			N	**P**	**K**			
Punjab	Rice	70 q/ha	151	11	12	2.8 q/ha	2386	**96**
		80 q/ha	179	15	29	8.5 q/ha	2821	**48**
	Wheat	50 q/ha	171	58	0	4.8 q/ha	2553	**8.5**
		60 q/ha	**211**	**83**	**0**	**11.3 q/ha**	**5737**	**6.3**

STCR Technology developed at different STCR centres for transfer of technology in Karnataka, Himachal Pradesh and Haryana states

Karnataka

State	**Crop**	**Target**	**Fertilizer nutrient applied (kg/ha)**			**FYM applied (t/ha)**	**Additional yield (kg/ha)**	**Net Profit (Rs/ha)**	**BC ratio**
			N	**P**	**K**				
Karnataka 2006	Groundnut (TMV-2)	20 q/ha	60	210	65		941	15,903	**6.8**
2006 Summer	Sunflower (KBSH-42)	30 q/ha	107	160	105		1420	23,785	**4.6**
2004	Ragi	40 q/ha	100	64	52		1154		**2.5**
		40 q/ha	50	33	24	17.8t/ha	1182		**0.7**
2004	Paddy	50 q/ha	0	46	51		900		**8.3**
2003	Sugarcane	150 t/ha	154	0	60		89 t/ha		**33.8**
		150 t/ha	**77**	**0**	**0**	**15.5t/ha**	**81.4 t/ha**		**7.6**

Himachal Pradesh

State	Crop	Target	Fertilizer nutrient applied (kg/ha) N	P	K	Additional yield (kg/ha)	BC ratio
Himachal Pradesh	Toria	10 q/ha	41	32	04	600	**19.1**
	Raya	15 q/ha	178	50	52	737	**14.3**
	Soybean	**20 q/ha**	**20**	**20**	**43**	**600**	**21.3**

Haryana

State	Crop	Target	Fertilizer nutrient applied (kg/ha) N	P	K	FYM applied (t/ha)	Additional yield (kg/ha)	Net Profit (Rs/ha)	BC ratio
Haryana	Wheat	45 q/ha	104	50	-		2240	-	**6.56**
		45 q/ha	84	36	-	15 t/ha	2305	--	**4.78**
2004-05	Raya Var. Laxmi	18 q/ha	85	40	-		938	14,070	**7.0**
		18 q/ha	67	37	-	15 t/ha	957	14,357	**7.1**
	Bajra	25 q ha	100	45	-		832	--	**3.5**
		25 q/ha	80	31	-	15 t/ha	880	--	**2.6**
	Paddy	70 q/ha	136	57			4112	--	**10.6**
		70 q/ha	**112**	**45**	**-**	**15 t/ha**	**4160**	**--**	**6.98**

STCR Technology developed at different STCR centres for transfer of technology in Andhra Pradesh and New Delhi states

Andhra Pradesh

State	Crop	Target	Additional yield (kg/ha)	BC ratio
Andhra Pradesh	Sugarcane (Mean of 6 trials)	100 t/ha	9 t/ha	**9.64**
	Sorghum (2 trials)	20 q/ha	10.8	**2.50**
	Groundnut (40)	25 q/ha	2.3	**39.4**
	Cotton	5 q/ha	4.13	**14.4**
	Rice (75 trials)	**55 q/ha**	**5.50**	**16.0**

New Delhi

State	Crop	Target	Fertilizer nutrient applied (kg/ha) N	P	K	Additional yield (kg/ha)	Net Profit (Rs/ha)	BC ratio
New Delhi Mean of 5 trials	Wheat	50 q/ha	138	44	33	32.6	22,834	**15.8**
Mean of 2 trials	**Mustard**	**50 q/ha**	**106**	**35**	**0**	**15.6**	**18,660**	**11.5**

Kerala

State	Crop	Target	Additional yield (kg/ha)	Net Profit (Rs/ha)
Kerala	**Banana**	**30 t/ha**	**4.18 t/ha**	**60,688**

Following is the IPNS technology developed validated at different centres of the states which is being followed partly under AICRP STCR.

State wise IPNS Technology to the Farmers

State	Fertilizer Applied			FYM	Increase in Yield (kg/ha)	Area (000 Ha)	Increase in Production (MT)*
	N (kg/ha)	P (kg/ha)	K (kg/ha)				
Tamil Nadu							
Groundnut	17	37	31	12.5t/ha	1055	591	0.16
Paddy	150	67	10	G.M.@25 t/ha + Azo. 2 kg/ha	4460	1396	1.56
Madhya Pradesh							
Paddy	138	112	9	5 t/ha	3700	1674	1.55
Wheat	109	65	28	5 t/ha	2275	4045	2.30
Soybean	44	102	31	5 t/ha	1619	4165	1.69
Chickpea	42	80	0	5 t/ha	1400	2862	1.00
Maharashtra							
Paddy (5 trials)	63	57	53	10 t/ha	1240	1535	0.48
Karnataka							
Ragi	50	33	24	17.8t/ha	1182	987	0.29
Haryana							
Wheat	84	36		15 t/ha	2305	2303	1.33
Raya	67	37		15 t/ha	957	640	0.15
Bajra	80	31		15 t/ha	880	625	0.14
Paddy	112	45		15 t/ha	4160	1016	1.06
						Total	**11.71**

* Under the assumption that 25% of total cultivable land under each crop will be cultivated using STCR recommendations

All India Coordinated Research Project on Agrometeorology

1. **Title of the Project** : **All India Coordinated Research Project on Agrometeorology**

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3. **Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):**

Climatic Characterization

- Large database on weather parameters collected by various Research Centres of the Project was analyzed to work out the climatic resources of the region for better agricultural planning.

- Climatic variability and the trends of different weather parameters were studied by almost all the centres. The rainfall trend analysis of the stations of rainfed districts indicated that 73 percent of stations shows about short-term fluctuations in rainfall.

- Based on the crop statistics and related weather parameters, crop-growing environments for mustard, pearlmillet, chickpea, cashew, cardamom and groundnut has been delineated.

- Observations on UVB radiation which has been found to be harmful for both the plants and human has been initiated at few locations and data is being collected.

- The hotspot areas of tea mosquito bug across the cashew track of the country have been demarcated considering the optimum night temperatures during the flushing and flowering stages.

- Crop calendars have been developed for Ludhiana and Kovilpatti regions for improving the crop planning strategies.

Crop Weather Relationships:

- Several field experiments during *kharif* and *rabi* season for all major crops were conducted and specific crop-weather relationships have been developed by all Research Centres.

- A multiple regression model for prediction of rice yields using rainfall, number of rainy days and technological trend as independent variables have been developed for pre-harvest forecast of rice for Musheerabad district in West Bengal.

Crop Weather Modelling:

- CERES Wheat Model was tested and validated at Anand. The results indicate that the simulated wheat yield was very close to be observed value.

- A multi-linear regression equation was developed using the monthly agroclimatic indices (IMA and IH) for predicting the coconut production in Kerala.

- Quantification of the impacts of per unit increase in minimum temperature during the reproductive stage of wheat crop by Ludhiana centre was of great help in pre-forecast of wheat yields.

Weather Effects on Pests/Diseases:

- Using long-term experimental data, regression models for forecasting powdery mildew disease incidence in *Ber* plants has been developed.

- A multiple regression model for advance monitoring bacterial leaf spot disease in grapes was developed by Bijapur centre using temperature as a variable.

- Thumb rules were developed for prediction of incidence of *alternaria* leaf blight in mustard crop at various crop growth stages in eastern Uttar Pradesh.

- Kovilpatti centre has identified the periods of outbreak of bacterial blight disease in cotton from the historical data of disease and weather and suggested contingency plans for spraying of chemicals.

Agromet Advisories:

- All the centres of the Project have participated in providing the weather-based agro-advisories to the farmers wherein the transformation of research findings crop-weather relations and weather-pest relationships developed by the individual centre are finding a place in agro-advisories. Also value addition of the agrometeorological information through agroclimatic analysis studies carried out by individual centre has improved the reliability of agro-advisories to a great extent.

Databank:

- Agromet Databank Facility was created at AICRPAM Coordinating Unit of CRIDA wherein meteorological data from 120 stations are being updated regularly.

- In addition to above, the rainfall data at block level collected under NATP Programs and by AICRPAM Centres has also been digitized. All the data is being maintained in the ORACLE Database.
- The Website www.cropweatheroutlook.org providing information on the weekly crop and weather conditions, agro-advisories and the current weather information of all the 25 centres of AICRPAM is in operation since 2003. It is also providing the weekly Contingency Crops Plans at the National level based on the information supplied by the AICRPAM Centres.

All India Coordinated Research Project on Agroforestry

1. Title of the Project : All India Coordinated Research Project on Agroforestry

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3. Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):

- The All India Coordinated Research Project on Agroforestry (AICRPAF) was initiated in 1983 at 20 centres with coordinating unit at the ICAR, Krishi Bhawan, New Delhi. Later on more coordinating centres were added and presently there are 36 coordinating centres with 11 centres in ICAR Institutes and 25 centres located in SAUs, covering all the major agro-ecological zones of the country. The Coordinating unit of AICRPAF was shifted from New Delhi to National Research Centre for Agroforestry, Jhansi w.e.f. 1st April, 1997 under the administrative control of Director, NRCAF.

The salient research achievements of the Project for last year are :

- More than 370 germplasm of *Jatropha* and 104 seed sources of *Karanj* species have been collected and evaluation is in progress at six centres of AICRP and NRCAF. Besides, the evaluation work on 27 plus trees and 10 crosses are also in progress. About 4-5 elite material developed by different centres is undergoing multi-location trails. Five major diseases namely root rot/collar rot, stem canker/ stem rot, Alternaria leaf spots, powdery mildew and Anthronox are reported in the species and mortality ranges from 8% to as high as 50% in some location. Blitox, Bavastine and Captan are found to be very effective for controlling these diseases.

- At Srinagar centre under bioeconomic productivity study of agrisilvipasture system recorded maximum profit of Rs 26,948 $ha^{-1} yr^{-1}$ at 2 m spacing. In silvipasture studies with poplar and catalpa, the total biomass was observed 90.4 and 38.4 % more under agroforestry systems compared to sole plots of poplar and catalpa. Under tree improvement programme a total of 66 Salix selections and 24 seed sources of *Ulmus* have been collected and are under evaluation.
- The results of AAU, Kahikuchi showed that the net return were maximum when coconut was inter cropped with rice. The biochemical analysis of bamboo shoot showed increased moisture content, total acid and TSS after fermentation while pH and crude fibre were reduced. *Bambusa balcooa* is most preferred edible bamboo in this region.

- At Palampur, A*lbizia chinensis*, an important component of tea garden was studied alongwith tea bushes for density and growth dynamics in tea orchards of Kangra Valley and ecologically most successful prototypes have been identified.
- Studies at Solan revealed that the bio-economic appraisal of Hortisilvi medicinal system integrating Peach, *Grewia* and *Morus* with Tulsi and Mucuna showed that Peach + *Grewia* + Tulsi is highly economic combination followed by Peach + *Morus* + Tulsi. The centre also conducted structural analysis of agroforestry system for their carbon sequestration potential in different zones.
- The centres located in the Indo-gangetic zone have conducted extensive studies on poplar based system. At Ludhiana it was found that amongst different spacing of poplar plantation of 5 years age, the addition of litter fall was significantly higher in close spacing (5.62 and 5.48 t/ha, respectively) than 11x3 m (paired) spacing (4.91 t/ha). Zn deficiency reported in poplar in Punjab can be ameliorated by soil application of the fertilizer to poplar plantation (20-25 g/plant Zn in one year old plants, 30-40 g/plant Zn in two years old plants and 15-20 kg/ha Zn in nurseries) or spray of fertilizer (5-6 sprays of 0.5 % $ZnSO_4.7H_2O$ at weekly intervals).
- At Faizabad, wheat and paddy varieties compatible for intercropping with poplar were identified. Grain yield reduction for wheat and paddy under agroforestry system in comparison to open area ranged from 32% to 38%. Similar observations were recorded with wheat at Pantnagar, where heavy pruning (75% of tree height) increased crop yield but adversely affected tree growth.
- At Bhubaneshwar, four field crops (Ragi, groundnut, sesamum and black gram) were grown in the alleys (8 m wide) of two fast growing timber trees (*Acacia mangium* and *Gmelina arborea* at 625 trees/ha). Crop yield in terms of ragi-equivalent yield was highest in groundnut followed by sesamum. The lowest equivalent yield was produced from black gram (0.50 t/ha).
- At Ranchi, maximum yield of turmeric and Colocacia was recorded under the canopy of *Gmelina arborea* i.e. 2.7 t ha^{-1} and 3.0 t ha^{-1}, respectively. It shows positive of tree shading on yield of turmeric and colocacia.
- At Jabalpur, in guava and paddy based system significantly higher rice grain yield (1.93 t ha^{-1}) was recorded in 25 % higher seed rate and fertilizer dose whereas lowest yield (1.1 t ha^{-1}) was recorded in normal dose of seed rate and fertilizer. Growing of rice with Guava (at the age of 7 years) produced higher monetary return (Rs.8958 ha^{-1}) than growing of arable crop i.e. paddy alone (Rs.4281 ha^{-1}) and fruit crop i.e. Guava alone (Rs.7100 ha^{-1}) under rainfed condition.
- At Hyderabad in Agri-silvi-Horti system, among several combinations of Tamarind based system with custard apple and curry leaf as filler trees, it was noted that Tamarind + curry leaf + intercrops (such as Redgram, Jowar, Cluster bean and cowpea) were highly profitable rather than with combination of Tamarind + custard apple + crop, probably due to slightly long gestation period of custard apple than the curry leaf.
- At Fatehpur – Shekhawati studies on evaluation of MPTs in systematic field design (parallel) revealed that growth performance of *Azadirachta indica* and *Ailanthus excelsa* increased with the increase in effective area per plant.
- Studies conducted at Hisar centre showed that all the test crops of wheat, barley, lentil and berseem showed poor performance in association with 6 years old eucalyptus (6x2m). Wheat intercropped with eucalyptus (6x2m) required 6 irrigations compared to two

irrigations in sole wheat thereby showing severe moisture competition of eucalyptus with wheat crop.

- At Rahuri, among the different methods of filling of trenches of CCTs on soil water conservation and growth of Neem trees, the refilled CCT treatment, gave more plant height, collar diameter and bole height than no refilling (open trench only) trench method throughout the period of experiment. Similarly it was resulted in heighest timber volume and monitory returns.
- In order to develop a sustainable agroforestry model for the high rainfall /assured rainfall areas of Karnataka state, a multicomponent agroforestry system involving sapota as a base crop (10m x 10m), five trees species *viz*., *Eucalyptus tereticornis, Lagerstroemia lanceolata, Casuarina equisetifolia, Tectona grandis, Dalbergia sissoo* were planted in sapota line at a distance of 3 m, 2m, 2m and 3m between two sapota trees at Dharwad. Guinea grass was planted along the tree line in a strip of one metre and the interspace was used for raising arable crops (11 years). In one of the longest trial (28 years), the economic evaluation was worked out by estimation of standing trees (timber, fuelwood etc,), income from fruit yield of sapota, receipt from felled trees at the end of 17 years and income from grass and crop yield. The result revealed that net returns (12% discounted interest) was higher in sapota+teak+field crop and benefit cost ratio in this treatment was 3.23:1 with a net average income of Rs. 38,977/ha/yr.
- At Dapoli, the average reduction in grain yield of rice due to 14 years old tree species viz., *A.auriculiformis, Eucalyptus* and *C. equisetifolia* were 16, 17 and 28% respectively. The effect of pruning of branches of *Terminalia tomentosa* indicated that 100% pruning and lopping of branches which is a local practice recorded more height (6.3 m) and dbh (8.9 cm) as compared to control (5.5 m height and 7.9 cm dbh).
- At Kerala, root activity patterns in two year old *Acacia mangium* as affected by planting density and pruning were evaluated using ^{32}P tracer soil injection method. Higher root activity was observed at 25 cm lateral distance and 30 cm soil depth for trees planted at 2x1 m spacing while widely spaced trees (1250 trees ha^{-1}) showed extensive root spread beyond 75 cm lateral distance.
- At Bangalore, the yield traits of *Simarouba* were recorded from randomly selected 10 plants from two varieties. The variety Gowri has recorded higher number of 46 bunches per tree, number of clusters per bunch (7.8) compared to Kaali variety.
- At Kattupakkam centre, in one acre of farmer field, turmeric was raised as mono crop and in another field of same area turmeric was integrated with Sesbania sesban as agrisilvi system. After 4 months of establishment, goat was integrated by feeding Sesbania sesban leaves at 40-50% of its requirement. Due to frequent pruning of Sesbania leaves for fodder purposes, there was no reduction in the light intensity and also due to the nitrogen fixing ability of the sesbania it could enable to retain the nitrogen content of the soil. Turmeric - Sesbania sesban agrisilvi system yielded 5.447 t fresh fodder and hold 50-60 young growing goat or sheep per hectare and was able to support 101g daily weight gain without any concentrate feed supplementation. Additional income through animal integration and sale of sesbania pole was Rs. 36,900 ha-1.

All India Coordinated Research Project on Cropping Systems

1. **Title of the Project** : **All India Coordinated Research Project on Cropping Systems**

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3. **Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):**

Research achievements of AICRP on Cropping Systems

2003-2004

System based production technologies for improving resource use efficiencies:

- At Ludhiana, new emerging maize-potato-onion system followed by maize-potato-moong was identified in place of predominant rice-wheat system. At Pantnagar, rice-vegetable pea-greengram emerged out to be new cropping system in place of rice-wheat. At Faizabad, potato-greengram proved to be must remunerative one. Zero tillage advanced the saving time of wheat. At Jorhat, winter rice-potato-autumn rice turned out to be most profitable cropping system. At Kota, the highest-wheat equivalent yield was obtained in soybean-wheat when soybean was cross planted with pigeonpea. At Hyderabad, Rajendranagar maize-green chilli was the profitable sequence. At Palampur, rice-radish-potato proved to be the most remunerative and gave Rs 72,709/ha net return during 2002-03. At Pusa, rice-potato+ onion gave maximum net return. At S.K.Nagar, pearlmillet-wheat was observed to be the shortest duration (238 days) cropping system. At Karjat, rice-maize grown for green fodder was the most productive cropping system with a net return of Rs 34,500/ha with B:C ratio of 2.09. At Raipur wheat equivalent yield with rice-tomato was 6.79/ha. At Jabalpur, green manuring-rice cv Kranti-wheat – cv Kanchan gave maximum grain production. At Indore, soybean-potato-wheat led to register the highest net return of Rs 41,568/ha with B.C. ratio of 2.16. At Bikaner, the energy production (K calorie) was the highest in clusterbean-onion and pearlmillet-mustard system. At Kanpur, the highest rice equivalent yield of 7.6 t/ha was recorded with maize-potato-sunflower crop rotation. At Chiplima, rice-radish-cowpea and rice-radish-greengram weremost remunerative cropping system sequences. At Bichpuri, maximum gross return was observed under dhaincha (GM)-potato-sunflower cropping system. At Durgapura, chusterbean-rabi onion and groundnut what gave significantly higher gross return. At Kathalgere, maximum net return was obstained in maize-sunhemp-sunflower cropping system.

Long term studies on the relative efficiency of legume cereal or cereal-legume rotations over cereal-cereal rotations:

- At Kota legume blackgram-cereal wheat recorded the highest sorghum equivalent yield of 4819 kg/ha with the highest not return of 43,594/ha and B:C ratio of 4.78. At Kathalgere, the maximum net return was in maize-ragi-snhemp with maximum B:C ratio of 3.59. At Raipur, cereal-legume over cereal-cereal, the green manuring has yielded better results alongwith the net return of Rs 41,545/ha under rice-wheat-green manuring sequence. At Raipur, rice-wheat green manuring followed by transplanting produced the significantly higher yield of 6.3 q/ha.

Permanent plot experiment on integrated nutrient supply in cereal-cereal cropping system:

- At Rajendranagar, 100% NPK gave the best performance and at Siruguppa, farmer's practice gave best performance. In rice wheat system, the performance of integrated nutrient package during kharif was superior, while the performance of the IPNS was superior in Kalyani and Navsari. In pearlmillet-wheat and sorghum-wheat sequence integrated nutrient supply system proved superior irrespective of season and also in terms of total system productivity. 100% NPK was better over all performance at Hisar and Rahuri.

Conservation of organic in soil to improve soil conditions:

- The maximum yield of rice was recorded with recommended dose of N-cellulose decomposing enzyme at chiplima during kharif. At Bhubaneswar, maximum yield of rice was recorded with recommended dose of N+20 kg/ha during both kharif and rabi.

Resource characterization and constraint analysis including policy related issues, socio-economic aspects, and agro inputs:

- The resource use at various location use at various location in different cropping systems was not optimal. The expenditure towards labour charges was highest in most of the cropping systems which indicated the need for mechanization. Diseases, insects and weeds resulted in a loss to the tune of 15-20%. In the NPK nutrient response experiment, the response (kg grain/kg nutrient) of NPK varied from situation to situation and from system to system viz N-20 kg, P5-10 kg and K 5-10 kg. The response in high rainfall situation was more in rabi season.

On-farm testing verification and refinement of system based production technologies:

- The predominant cropping such as rice-rice may be intensified or diversified as Rice-Rice, Rice-vegetables and rice-wheat systems for more remuneration. Need based diversification and/or intensification was found to be more profitable in various agro-ecosystems.

2003-2004

- System based production technologies for improving resource use efficiencies in different farming situations:

- Under Arid-ecosystem, in Hisar, pearlmillet-potato-greengram sequence gave higher net returns with better yield. Diversification of clusterbean-wheat was observed to be most remunerative. In S.K.Nagar, cowpea-mustard-pearlmillet, rice-onion/cowpea and pearlmillet-wheat were predominant cropping systems. At Durgapura, clusterbean-onion turned out to be the most profitable system. At Ludhiana, maize-potato-onion cropping system enhanced the productivity double than the rice-wheat major predominant cropping system. At Kanpur, maize-potato-sunflower crop sequence turned out to be most profitable system. At Akola, two years crop rotation of sorghum-chickpea, maize-wheat, soybean-wheat and soybean-sunflower was profitable. At Coimbatore, conventional method of maize sowing +pre-emergence application of herbicide alongwith one hand weeding was the best, whereas in Karnataka at Kathalgere, maize-sunhemp-sunflower registered the highest productivity. In sub-humid ecosystem at Pantnagar, rice-vegetable pea-greengram, rice-vegetable pea-mentha was better than rice-wheat system. At Varanasi, rice-potato-greengram sequence was observed better than other crops sequence. At Jabalpur and Rewa rice based vegetable crops system was found to be most appropriate. IN Ilumid Ecosystem at Kalyani, rice potato-jute recorded maximum yield and net returns. At Jorhat, rice-potato-rice was observed to be best for net returns and total calories. In coastal ecosystem, at Karmana vegetable and cassava gave the high returns. In nutshell, the integrated nutrient management substitution of 50% RDF though organics and 100% RDF in rabi recorded higher productivity in all the ecosystem.

Long term studies on relative efficiency of legume cereal rotations:

- At Durgapura, green manuring during summer had beneficial effect on succeeding crop of pearlmillet. At Kathalgere, rice-sunhemp was beneficial to hybrid maize. At Raipur, rice-wheat-greengram was more economical whereas at Kota, sorghum-wheat-green manure was better than other crop sequences.

System based maximum yield research:

- In rice-rice crop sequence, the additional dose of 50 percent fertilizer and 7.5 t of FYM/t recorded maximum yield (8.3 t/ha). In case of pearlmillet-wheat at S.K.Nagar, Gujarat, higher yield of 6.0 t/ha was observed with 15% recommended dose of fertilizer. Under rice-wheat crop sequence at Sabour, additional dose of by fertilizer by under rice-sunflower crop sequence, the highest productivity. At Raipur, under rice-sunflower crop sequence, the highest productivity. At Raipur, under rice-sunflower crop sequence, the highest system productivity (11.7 t/ha) was recorded by application of fertilizer to the tune of 150% of recommended one and 10 to FYM/ha.

Resource characterization and constraint analysis including policy related issues, socio-economic aspects and agro inputs:

- Rice-wheat was the major cropping system in Haryana, Punjab, Bihar and Jammu. The percent area to cultivated area occupied by rice-wheat system ranged from 22.5 percent in Begusarai in Bihar to 89.3 percent in Sudhar in Punjab state. In Hisar district of Haryana, cotton-wheat cropping system occupied about 50 percent of total cultivated area. In Punjab rice-potato cropping system was also identified as major cropping system which occupied about 18% of total cultivated area. In J&K, maize-wheat cultivated area found to be major cropping system which occupied about 90 percent area in Rajouri and Udhampur district and about 43 percent in Jammu. Maize-wheat cropping system was also a major cropping system occupying about 35 percent areas in Begusari of Bihar state. Arhar-fallow was found major cropping system in Gulberga district of Karnataka while green-gram-jowar was identified as major cropping system in Gulberga and Raichur districts which occupied 22-68 percent area to total cultivated area respectively.

On-farm testing, verification and refinement of system based production technologies.

- The factor responsible for lowering down and stagnating the production potential of different crop sequences were identified so as to increase the yield. In rice-rice-rice crop sequence at Ernakulam (Kerala) imbalance use of fertilizer was identified as the main constraint, Recommended fertilizer application (90:45:45 kg N,P&K/ha) increased yield significantly over farmers practice (40:30:18 kg N,P&K/ha). In rice-rice crop sequence at Mandya (Karnataka), deficiency of Zn was the most felt constraint. The application of Zn SO4 @ 40 kg/ha enhanced the grain yield by 15.9 and 22.1% over farmer's practice(without Zn) during kharif and summer seasons respectively. At Samastipur (Bihar) in rice-wheat crop sequence, sub-optimal plant population was the major constraint in both rice and wheat and therefore by maintaining the proper plant population of rice (15x15 cm2) and wheat (23 cm apart) enhanced the yield upto 44.2 and 20.01% respectively over farmer's practice.

- Application of recommended dose of NPK (100:60:40) in rice and wheat recorded improvement in the yield upto 91.5 and 79.9% respectively over farmer's practice (imbalance use of fertilizer) at Ambikapur (Chhatisgarh). Sub-optimal plant population and weed infestation were the major productivity constraints at Ambala(Haryana). Weed control measures i.e. application of butachlor @ 3 1/ha in rice and leader @32.5 g/ha in wheat resulted in 7.4% higher yield advantage in rice and wheat respectively over farmers practice. Application of carbofuran 3 g during both the seasons resulted an increase of 9.42 and 3.56% in maize yield over farmer's practices. Sub-optimal-plant population deteriorated yields level of maize-wheat system considerably at Samastipur(Bihar). Maintaining 60x20 cm2 spacing in maize and 23 cm row spacing in wheat recorded 27.0 and 29.9% increase in yield of respective crops over farmer's practices.

- At Lohardaga (Jharkhand), use of improper variety was identified as the major constraints to limit the productivity of maize-wheat system. Application of 100:50:40 kg NPK in maize (50% through FYM) and 10:50:30 kg NPK n wheat resulted in higher yields to the tune of 34.2 and 20.9 percent respectively over farmer's practice at Chhindwara (MP). At Sirohi (Rajasthan), sowing of improved varieties i.e. PEHM-2 (maize) and Raj. 1482 (wheat) with 60:30:30 and 90:35:30 kg NPK/ha respectively enhanced the yields up to level of 34.2 and 20.9 percent respectively over farmer's practice. Chemical weed control through application of Lasso and isoproturon enhanced the crop yields upto 31 and 22.8% over farmer's practice at Morena (M.P.) Maintaining 60x30 cm2 spacing in system and 20 cm row apart in wheat increased yield to the tune of 25 and 6.43% over farmer's practice. However, weed control through applying Triflame @ 2/ha in soybean and 2,4-D @ 2.5 1/ha +isoproturon @ 0.75 1/ha (mixed) in wheat increased yield to the tune of 29.9 and 24.6% respectively over farmer's practice.

2004-2005

Long term studies on the relative efficiency of Legume rotations over cereal-cereal rotations:

- The change in soil properties, weed flora, soil fertility, additions and crop removal of NPK with special reference to nitrogen budgeting as influenced by various rotations are recorded at Raipur, Durgapura and Kota. The incorporation of legumes in cropping sequence resulted in built up of available pool of average N and P content and it synchronized with the level of its fertilizer application.

Comparative performance of different period bound rotations:

- The experiment on sorghum based crop sequence at Parbhani and Indore in semi-arid ecosystem and rice based crop sequence at Jabalpur and Sabour in sub-humid ecosystem were studied. The yield of rice and wheat increased after lentil. The soil gained favourably in terms of pH, organic carbon, and available P2O5 at Sabour.

Permanent plot experiment on integrated nutrient supply in cereal-cereal cropping system:

- Under rice-wheat system, after continuation of 15-20 years of experimentation the pH and EC values of soil did not deviate much from its initial values, though at few centers like Jabalpur, indicated some increasing trends in EC values. The organic carbon and P status tended to increase at most of the centers with 50% N substitution either through FYM/wheat cutstraw/green manure and better than 100% NPK fertilizers. The organic carbon and P status tended to increase in fertilizer treatments. At various centers, bulk density of soil declined with application of organic nutrient sources to substitute 50% N in rice and was significantly less than control. Practically, there was not much variation in K status of the soil, though at sub-optimum level of NPK through fertilizers and declining trend was observed in control plots. The depleting trend was observed in micro-nutrients (Cu, Mn, Zn and Fe) in organic and control plots as compared to organic sources combinations at Kalyani. In rice-rice system, the pH and EC values of the soil have sown a declining trend as compared to their initial values, whereas, there was increasing trend in organic carbon of the soil. At Jorhat, after 15 years of the experiment, increase in organic carbon, pH and available P in all the treatment over initial status of the soil were noticed, whereas available K decreased in control, GM and farmers practice gtreatments. At Rajendranagar, the green manuring enhanced the organic carbon values, followed by crop residues and FYM.

Long term effect of continuous cropping on soil fertility and yield stability:

- Under rice-rice system at Bhub the soil reaction is neutral. The total soluble salt is within limits of salinity. The organic carbon content is medium to high. Available 'I' and 'K' remained in medium range. At Karmana, the uptake of N was significantly increased by enhancing the levels of either N or P. The significant interaction of NXK and PXK over the uptake of N and increasing P levels had significant effect on the uptake of P by the plants. However, the levels of N or K did not significantly influence the K-uptake.

Characterization of bio-physical and socio-economic constraints in various agro-eco zones:

- Site characterization of the zone based on secondary data was carried-out. Besides, through production constraint analysis, identified the bio-physical and socio-economic factors responsible for constraints faced by the farmers.

2005-2006

Long term studies on the relative efficiency of Legume rotations over cereal-cereal rotations:

- The study at Raipur and Durgapura revealed that in addition to the recommended doses of nutrients, raising of green manure crop during summer is desirable and helpful in improving the system yield and also improves soil health.

Comparative performance of different period bound rotations:

- The yield of rice ranged between 5 to 5.4 t/ha in interruptive system during kharif in comparison to continuous rice with treatment yield of 4.75 t/ha at Sabour in sub-humid ecosystem.

Permanent plot experiment on integrated nutrient supply in cereal-cereal cropping system:

- In rice-maize experiment, the application of organic recorded higher soil organic carbon, available phosphorus and potash as compared to initial soil status and farmers practice of rice cultivation. In case of maize-wheat experiment at Ranchi continuation of experiments over 20 years, showed a decreasing trend of pH from its initial value. In case of pearlmillet-wheat system, the available nitrogen and organic carbon content were higher in treatments receiving 50% N through organic sources at S.K.Nagar, whereas the potassium content reduced drastically in almost all the treatments. The content values of available phosphorus were higher in treatment was less where integrated nutrient management practices were adopted. In pearlmillet-wheat cropping system, the uptake of nutrients was higher in FYM treated plots as compated to green manure and wheat straw treated plots. Under rice-rice system, the pH and EC were reducing marginally over years, whereas, there was increasing trend in OC in the soil. At Bhubaneswar and Chiplima, the P and K reduced from the initial values due to continuous cropping over years together. However, the available N increased. In rice-wheat system, the continuous application of organic manure in conjunction with inorganic fertilizers improved/maintained organic carbon and available nitrogen in the soil. Soil pH did not deviate from initial values after 15-20 years of experimentation. However, EC showed rising trend over initial values.

Long term effect of continuous cropping on soil fertility and yield stability:

- At Siruguppa in rice-rice system there was a trend of increase in pH, EC, OC and available of major nutrients as compared to control with increment of fertilizer doses. Further, increase in N,P and K levels resulted in significant increase in yields over without replication. In rice-wheat crop sequence due to continuation of experiment over 25 years at Rewa, soil parameters, viz soil pH, EC, OC, N, P and K slightly declined under control over the initial status under different treatments, whereas P and K contents of soil drastically reduced under all treatments over their parental status but rate of reduction of these nutrients were less, where these nutrients were less, where these nutrients were applied continuously at their maximum rates. At Ranchi in maize-wheat crop sequence, there was decline in productivity of maize and wheat with continuous ertilization and cropping due to decrease in soil pII from its initial value. Further, 80 kg N/ha gave significantly more maize yield than higher and lower doses of nitrogen in maize. Increasing doses of P and K gave higher yield of maize than lower levels, whereas in wheat, effect of N and K was not significant.

Identification of need based cropping system for different agro-ecosystems:

- Under Arid ecosystem at S.K.Nagar, maximum agro-energy (K Cal) was recorded in clusterbean-wheat-sorghum (F) crop sequence with maximum net returns. At Siruguppa, rice-tomato gave maximum B:C ratio to the tune of 3.85. In semi-arid ecosystem, the highest groundnut equivalent yield was recorded with pre sowing groundnut-onion-greengram sequence followed by soybean-onion-groundnut. At Indore, soybean-potato-wheat sequence led to register the highest net return with B:C ratio of 2.87. In sub-humid ecosystem, the experiment conducted at Pantnagar revealed highest net return under direct seeded rice-vegetable-pea summer-rice. At Jabalpur, green manuring-rice-wheat cv. Kanchan fetched maximum net return with the highest B:C ratio of 2.25. However, the production efficiency was maximum in rice-wheat cv. Kanchan sequence. Under humid ecosystem, at R.S.Pura, rice-cauliflower-french bean sequence was most profitable with B:C of 2.76 among all short duration rice based crop sequence. In case of medium duration rice based crop sequence, rice –green peas maize (cobs) system was identified to be distinctly better with the highest rice equivalent yield. In case of long duration rice based crop sequence, rice radish-lady's finger gave maximum rice equivalent yield. Under coastal ecosystem at Bhubaneswar center, rice-maize-greengram recorded the highest rice equivalent yield with B:C ratio to be 2.13. At Chiplima, rice-radish-greengram fetched maximum net return with the highest B:C ratio of 2.19. At Navsari, paddy-fenugreek (green)-okra(Veg) sequence recorded the highest paddy equivalent yield followed by paddy-onion-cowpea(veg.).

Characterization of bio-physical and socio-economic constraints in various agro-eco zones:

- Site characterization of the zone based on secondary data was carried-out. Besides, through production constraint analysis, identified the bio-physical and socio-economic factors for the constraints faced by the farmers.

Site specific nutrient management experiments:

- The site specific nutrient management experiments were initiated to maximize the productivities of rice-wheat, rice-rice and soybean-wheat system.

Development of organic farming package in system based high value crops:

- The different integrated and inorganic nutrient management practices were tested in different systems. In maize-potato-onion system, experiments were conducted at Ludhiana, Indore, Kanpur, Faizabad, Akola, Kathalgere and Modipuram. The rice based cropping system was investigated at Bhubaneswar, Jorhat, Karjat, Navsari, Sabour, Chiplima, Kalyani and Jabalpur.

Resource conservation Technology:

- Under resource conservation technology programme, the effect of different tillages and planting management practices in rice-wheat at Kanpur, Pantnagar, Varanasi, Sabour, Raipur and R.S.Pura were studied so as to improve crop productivity and soil health. Under rice groundnut cropping system conducted at Rajendranagar, 3 methods of seeding of rice, i.e. dry seeding, transplanting after normal paddling and transplanting after summer green manure crop, and 3 methods of ploughing & harrowing in groundnut i.e., ploughing once and harrowing twice, ploughing twice and harrowing thrice, and ploughing twice and rotavator twice were applied.

Farming system Research:

- Under farming system research programme, the resource characterization of different farming systems in the area of all 32 ECF sites have been undertaken. The study on cropping pattern, dairy and other enterprises, land use pattern, resource characterization, farming systems and constraints analysis have been undertaken. Identified the bio-physical and socio-economic factors responsible for constraints under different farming systems.

All India Coordinated Research Project on Dryland Agriculture

1. Title of the Project : **All India Coordinated Research Project for Dryland Agriculture**

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3. Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):

- Rainfed Agriculture in India extends over 97 million ha across diverse agro climates, ecological situations and socio economic settings. In order to address the location specific problems, All India Coordinated Research Project on Dryland Agriculture (AICRPDA) initiated research on rainfed agriculture with 22 network centers and 8 Operational Research Projects (ORPs) for the last three decades. This project is continuing the efforts to generate site specific technologies in the areas of rainwater management, soil and water conservation, cropping systems, drought tolerant varieties, integrated nutrient, pest and energy management strategies, alternate land use options and farming systems for stabilized productivity and income. In addition, the ORPs located in different environs, are involved in participatory development and evaluation of the rainfed technologies for wider adoption.

3.1 Resource characterization

- Analysis of historical rainfall data (1901-2000) pertaining to 21 AICRPDA centers indicate that spatial trends in annual rainfall exhibited two distinct trends (a) decreasing annual rainfall with stable variability and (b) increasing rainfall with increasing variability. Trend (a) is more prevalent in Central India and South India covering Andhra Pradesh and parts of Tamilnadu. Trend (b) is more prevalent in Karnataka, Kerala, Western Ghats of Tamilnadu, major parts of Maharashtra, Gujarat, and Rajasthan, Haryana, Punjab and Jammu & Kashmir. At present, this analysis is more pertinent to arid, semi arid and dry sub-humid regions where rainfed agricultural land use is more in practice. These changes effect future orientation in cropping system requirements.
- For undertaking a second crop, the social constraints like open grazing and aberrant weather hinder farmer's initiative. An exercise had been done to identify potential regions of low cropping intensity, potential for an inter/sequence cropping system based on rainfall in *kharif* irrigated-*rabi* fallows and *kharif* unirrigated *rabi* fallows for a *rabi* crop. There is about 64 m ha of potential area with about 12 to 17 ma ha as paddy fallows. The *rabi* fallows have a promise of the potential of annual production 32.5 m t @ 0.5 t/ha, annual employment of 2.6 billion mandays 40 days/ha and nitrogen addition of 0.65 m t 10 kg/ha.

- First effort was made to identify regions with uniform pattern in relation to drought vulne*rabi*lity, climatic region, soil orders and rainfed crop based production systems. In India, the drought regions can be classified in to six regions based on frequency of drought, climate and rainfall season, soil quality and soil orders. These are chronic drought region of arid marginal season-Aridsol, chronic drought regions of arid sub marginal rainy season - Vertisols/Alfisols, chronic drought regions in semi-arid delayed rainy season-Vertisols/Alfisols, chronic drought regions in dry semi-arid post rainy season- Vertic/ Vertisols, ephemeral drought in wet semi-arid rainy season Vertisols/Alfisols during early, mid or terminal seasons and apparanent drought in dry sub-humid Alfisols/ Oxisols on upland, mid and low lands.
- Identified regions of low cropping intensity and assessed their potential for inter/sequence cropping systems based on rainfall during *kharif* and *rabi*.
- Studied drought vulne*rabi*lity of different regions based on climatic region, soil orders and production systems.
- Yield gap analysis was carried out for about 170 districts for predominant rainfed crops. The runoff surplus index was also calculated. Based on the matrix of yield gap and runoff surplus index, district-based recommendations for oilseed, pulses were made and published.
- The measurement index known as Sustainability Yield Index (SYI) was developed for rating and selection of treatment interventions in rainfed areas. The SYI for a treatment to be related highly sustainable was worked out to be > 0.67, moderately sustainable (0.33 - 0.67) and low sustainable (SYI < 0.33).
- A rainfed district-wise yield gap analysis was carried out for about 170 districts for the predominant rainfed crops. The run-off surplus index was also calculated. Based on the matrix of yield gap and run off surplus index, district based recommendations for rainfed rice, oilseed, pulses and cotton were recommended.
- Contingency crop planning was websited based on drought types and soil orders.
- Under NATP-MM- Project on Land Use Planning for Management of Agricultural Resources, soils were characterized at cadastral level in 16 micro watersheds across an operational area of 5258 ha. Micro-level land use modules on a soil-landscape continuum for 16 micro-watersheds were developed. Based on the information available for soil physical and chemical properties at cadastral level in the 16 micro watersheds, thematic maps were generated first and then two composite maps viz., Soil Conservation Unit (SCU) and Soil Quality Unit (SQU) and Land Management Unit (LMU) were prepared.

3.2 Crops and Cropping Systems

- Varieties of different crops have been identified matching decreasing length of crop growing period in aberrant weather situations
- Efficient cropping systems have been identified from various intercropping and sequential cropping studies of different centers

3.3 Crop Improvement

- Horsegram AK-42 (Central release-Arjia): 85 days duration; seed 9-11 q/ha; fodder 27 q/ha; useful for arid and semi-arid regions.
- Lentil HUL-57 (Central release-Varanasi): 112-130 days duration; seed 14 q/ha; suitable for humid areas.

- Castor DCH-7 (Line registered at Hisar): Early flowering – 38 days; Seed yield 28 q/ha; Low incidence of pests; Suitable for arid and semi-arid regions

3.4 Integrated Nutrient Management

- A number of sustainable practices from on-station research in integrated management have been worked out by various centers. Farmers at variable levels have adopted these recommendations.
- Nutritional Constraints identified at different AICRPDA Centers (0-15 cm) N, Zn, B in Varanasi; N Faizabad; N, Ca, Mg, Zn, B in Phulbani; Mg, B in Ranchi; N, P, S, Zn, Fe, B in Rajkot; N, K, Mg, Zn, B in Anantapur; N, Zn in Rewa; N, P, S, Zn, B in Akola; N, P in Rajkot; N, P, Zn, Fe in Bellary; N, Zn, Fe in Bijapur; N in Jhansi; N, P, Zn in Solapur; N, K, Mg, Zn, B in Agra; N, Mg, B Hisar; N, K, S, Ca, Mg in SK. Nagar; N, K, Ca, Mg, Zn, B in Bangalore; N, Mg, Zn, B Arjia; N, K, S, Mg, Zn in Hoshiarpur and N, K, Ca, Mg, Zn, B in Rakh Dhiansar.
- The permanent manorial trials were started at 19 centres varying duration from 25 to 14 years. The organic + inorganic nutrient application was in general found beneficial.
- Application of micronutrients along with recommended fertilizers improved the seed germination and vigor index.

3.5 Rain water management

- Estimated Annual Runoff was determined using the FAO method for potential water harvesting and projective for possible sites of farm ponds in GIC environment
- Components of watershed and prioritization based on rainfall. The components were prioritized for rainfall based agro climatic zones.
- Prioritized rainfall based Soil & Water Conservation measures Soil & water conservation measures have been prioritized for various rainfall and land capability classes.
- Impact assessment of some successful Soil and Water Conservation interventions at various centers has been carried out.

3.6 Energy Management

- Developed hand operated weeder, twin wheel hoe at Arjia, cycle hoe, 6 row animal drawn gorru at Anantapur, two-bowl ferti-cum-seed drill, two row seed drill at Arjia, Arjia Power weeder, modification of ridger seeder at Hisar, crop collection unit attached to ANGRAU-blade guntaka at Anantapur, Tractor mounted Reaper for Fingemillet harvesting at Bangalore, Tractor Drawn Intercultural Operation at Bangalore, Tractor drawn Digger for harvesting Groundnut at Bangalore, Cage Wheels at Anantapur, Rotavator in Arjia, Reduced Tillage in Drylands is more adoptable in low or high rainfall regions etc. were developed.

3.7 Diversified farming systems

- 43 diversified farming systems developed by various centers have been described
- A nomogram was prepared for identification of a productive farming system based on rainfall, soil and land capability. Rainfed Farming Systems Modules-for location specific assessment and refinement in various agro-eco-sub regions in various crop based production systems were developed.

3.8 Technologies validated and practiced

Varieties

- Curcumin rich high yielding turmeric varieties 'Sudersan' (200 days), 'Suguna' (200 days) and 'Subarna' (200 days) were for prosperous tribal life in Kandhamal district of Orissa. A total of 709 ha were brought under quality turmeric involving 61 Spices Development Societies and 12000 farmers in 5 blocks of the district.
- With the replacement of Safflower variety Bhima**,** earlier local strains were totally replaced by variety Bhima from Western, Central and Vidharbha region of Maharashtra. The production potential of safflower is increased from < 4 q/ha to 10 q/ha.
- **'**ZHU 11-26' rainfed rice variety has become popular in North Eastern Ghat Zone and Western Undulating Zone of Orissa. During drought year of 2002, the variety withstood early season drought successfully and gave grain yield of 36.11q/ha.
- JS-335 variety of soybean replaced the existing old varieties and this has occupied 60% area in Indore region.
- Introduction of improved varieties/ hybrids have increased the production level up to 200 % in pearlmillet and the adoption level increased up to 95 % while for production level up to raya 300 % in and 80-100 % and was adopted in 90 % raya in South-Western Haryana.

Cropping Systems

- Intercropping of groundnut + pigeonpea (11: 1) for insurance against risk in arid alfisols of Anantapur spread to more than 50% in this groundnut predominant district. This additionally generated almost Rs.31.5 crores in this region. In a limited area of 100 ha, pigeonpea was taken as sole crop during 2002-03, which was not a practice hitherto.
- Contingent crop plans for in arid shallow alfisols of Anantapur prompted district administration and Department of Agriculture to play a prominent role in procuring and supplying seed of sorghum, pearlmillet and horsegram based on the indents of the farmers. This was especially handy in 2002-03 *Kharif*. It was evident from the supply of seed of 14.7 t of sorghum and 8.8 t of horsegram as compared to 0.13 tons of sorghum and 0.25 tons of horsegram supplied in *Kharif* 2001-02. The area covered with this contingent crop planning during *Kharif* 2002-03 was 2000 ha under sorghum and 500 ha under horsegram, in addition to the unaccounted area sown by the farmers on their own
- A saving of around Rs.150 crore on cost of groundnut seed in area of 18 lakh ha of Gujarat state by advocating use of small /wrinkled seeds of groundnut for sowing in Gujarat State
- About 20 – 25 % of the farmers in Rakh Dhainsar region shifted from maize – wheat to oilseed/pulses cropping system when advocated cultivation of oilseeds and pulses as a replacement for maize/wheat.
- Contingent crop planning for pearlmillet based production system in semi-arid inceptisols of Agra was spread to an extent of 15-20% of net-cropped area of Agra region.
- Castor + cowpea (1:2) intercropping was adopted in 15-20 % in North Gujarat Region.
- Wider row spacing of sorghum with frequent deep intercultivation in Karnataka was adopted in an area of 9 to10 thousand ha in Bijapur, Bagalkot and Koppal districts of Karnataka.

- Dry seeding in black soils was adopted in 18,000 ha of *rabi* sorghum and 20,000 ha of sunflower in Bagalkot and Bijapur districts of Karnataka.
- Introduction of Castor as Sole Crop under Dryland Condition increased productivity from 4 q/ha to 10 q/ha.
- Intercropping of Pearlmillet + Pigeonpea (2: 1) and Sunflower + pigeonpea was adopted by 62.5% and 65.27% farmers in Scarcity Zone of Maharashtra.
- About 60% farmers adopted mustard through front line demonstrations in South-Western Haryana.
- As a sole contingent crop and intercrop in maize, cowpea as a promising contingent crop 'SGL-1' for rainfed uplands of Orissa has become popular in North Eastern Ghat Zone of Orissa.

Nutrient Management

- In cotton growing black soils about 3000 ha were reclaimed Mg deficient calcareous vertisols of Southern Tamil Nadu
- With soil testing in groundnut in the arid shallow alfisols of Anantapur district, a saving of around Rs.1.00 crores was worked to the farmers on cost of fertilizer with a yield advantage of 525 tones in the last triennium. Thus overall benefit was Rs.1.63 crores in this region**.**
- A saving of Rs.427/ha on cost of fertilizer with a yield advantage of 47.4% was accrued with the inclusion of legume as green manure in mustard in semi-arid soils of Agra region.
- Farmers have adopted using azotobactor as seed inoculation in about 10 % area of pearlmillet in the Hisar region.
- 25% of soybean cultivators adopted using gypsum in soybean in Indore region.

Rain Water Management

- Around 5 % farmers of the Agra region adopted deep tillage and compartmental bunding in semi-arid inceptisols.
- About 20 % of the area of Rakh Dhiansar region adopted the technology of efficient utilization of residual moisture.
- Zingg Conservation bench terraces in deep black soils spread to an extent of 2.1 to 2.6 lakh ha (25 to 30 % of net crop area) of Bijapur and Bagalkot districts in Karnataka.
- Compartment bunding in black soils was adopted in around 800 ha of area in Bijapur, Bagalkot and Raichur districts of Karnataka.
- Gravel Sand Mulching in Sodic soils spread over an area of 25 to 30 thousand hectares in Koppal and Gadag districts in sodic soils of Karnataka
- Pebble mulching in black soils was adopted in 1000 ha in Bijapur district, 600 ha in Ramdurg taluka of Belgaum district of Karnataka.
- Recommendation of bunding was adopted by Govt. of Maharashtra and implemented with Government cost on wide scale in dryland area. Bunding program is still going on under Employment Guarantee Scheme hence there is 90 – 95 % adoption in *rabi* sorghum growing area. Recently, Govt. of Maharashtra also issued Government Resolution for *in-situ* moisture conservation by compartment bunding on farmers field with Government cost under Employment Guarantee Scheme.
- Straightening of gully and utilization of wastelands in Indore region brought about 0.88 ha area under cultivation, which allowed the farmers to grow crops on it.

- A masonry check dam across Banganala waterway at village Khuj of Banganala watershed in Rewa region, the yield of soybean has risen from 8 to 12 q/ha. The yield of rice has also been raised from 6.5 to 10 q/ha. Underground water table raised in surrounding wells.
- Conservation tillage (summer ploughing) for *in-situ* moisture conservation in inceptisols of Eastern Uttar Pradesh was adopted in 80% of the area.

Farm Machinery

- Use of seed-cum-fertilizer drill (Rakh Dhiansar): Adopted in 35 to 40 % of the area under rainfed wheat Jammu and Kathua districts.
- Two bowl seed drill was widely adopted in 9-10 thousand ha area of Solapur, Ahmednagar and Pune districts.
- Cycle hoe as a new economic implement for hoeing was adopted in Sarole, Pokharapur, Konheri of Mohol tahasil, Dist. Solapur.
- Mechanization of seeding operation for desired stand and enhanced system productivity for rainfed area of the Varanasi region and adopted in 25% cultivated area. With promotion of custom hiring service use of mechanical system is found to make its impact in the region.
- Suitability of (Indore): Modified NRCS seed drill for increasing productivity in soybean was given on custom hiring to large number of farmers and used in more than 45 ha area for planting of bold seeded kabuli chickpea.
- An improved tillage implement for better moisture conservation and higher productivity of Chickpea was adopted in 75-80% area in Hisar region.

Alternate Land Use Systems

- About 10–15 percent of farmers in Kandi areas of Jammu region have adopted agri-horti and agro-forestry systems.
- Adoption of technologies in ORP and diffused in surrounding villages
- *Anantapur (170 farmers in 2 villages)*: Intercropping with groundnut and pigeonpea (11: 1/15:1; Use of small and shriveled seeds for sowing groundnut; Improved variety *Vemana* groundnut; Soil test-based fertilizer application in groundnut; Tractor drawn mechanical seed drill.
- *Arjia (130 farmers in one village)*: Summer tillage in Maize; Ridging after 30 DAS in maize; Maize (Navjot), groundnut (JL-24, TAG-24), Sesame (RT-46), blackgram (RPU-38), greengram (K-851), horsegram (AK-42; Maize + blackgram (2:2;Grounnut + sesame (6:2;Maize-black gram rotation for 2 years; Chickpea + mustard (sowing mustard 4 m apart across gram rows.
- *Ballowal Saunkhri (70 farming families in one village)*: *In-situ* rainwater management through cultivation across the slope; Wheat/chickpea + raya intercropping 10:1;Groundnut (M-522, M-548, SG-99; Green gram (SML-668; Chickpea (PBG-1);Raya (RLM-619;80-40 NP in maize.
- *Bangalore (300 farmers in two villages)*: Finger millet MR-1, GPU 28 and 26,HR9-11; Pigeonpea TTB-7, Hyd 3-C, BRG-1 and 2;Fodder crops: African tall, Giant Bajra; Horse gram PHG-9; Fingermillet + pigeonpea 10:2;Maize + cowpea 3:1 for fodder Pigeonpea + cowpea (1:1); Sowing across the slope; Finger millet + Redgram (8:2or 10:2) + mango; Drumstick on field bunds.

- *Hisar (523 farmers in 2 villages)*: Pearlmillet hybrid (HHB-67 and HHB-94); Mustard RH-30; Barley BH-393; Yellow mosaic resistant Mungbean Asha and Muskan; Short duration Cluster bean HG-365; wheel hand hoe in pearlmillet and mustard; and Anola and ber (8 x 8 m) with mung bean and clusterbean (15 rows) as intercrops.
- *Indore (310 farmers in two villages)*: Recycling of harvested water through farm ponds (dug out as well as surface ponds); Soybean (JS-335, JS-9355) Pigeonpea (JIA-3); Gabion structure for outlet for water harvest tank and Floriculture-marigold, chrysanthemum.
- *Ranchi (170 farming families in 3 villages):* Improved varieties of up land rice (Vandana, Birsa Gora) mustard (Sivani), pigeonpea (BR-65), linseed (Subra and T-397), peas (Arkel).
- *Solapur (135 farm families in 1 village)*: Ridges and furrows; Improved genotypes (Pigeon pea (BDN-2, BSMR-736, BSMR-853), Pearlmillet hybrids (Shardha, Saburi), Sunflower (SS-56, MSFH-17); Protective irrigation to *rabi* sorghum and chickpea; Use of Cycle hoe: Use of two bowl ferti seed drill; Fertilizer application to *rabi* sorghum (50 kg N & 25 Kg P_2O_5) per ha.

AICRP on Long Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability

1. Title of the Project : **All India Coordinated Research Project on Long Term Fertilizer Experiments to study Changes in Soil Quality, Crop Productivity and Sustainability**

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3. Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):

Lessons Learnt from Long Term Fertilizer Experiments and Measures to Sustain Productivity in Alfisols

- Alfisols are highly leached soils with poor buffering capacity occurring under high rainfall area. Out of 17 sites of LTFE, four sites belong to Alfisols viz. Palampur, Ranchi Bangalore and Pattambi. Experiment at Pattambi is laid out in second phase during 1996-97. In last three decades, enormous information was generated from LTFE. In this publications, attempts are made to highlight the important findings emerged out of the experiments of Alfisols, which could be used to develop the strategies to tackle the sustainability issue in Alfisols. The experiments are continued since 1971 with the following treatments in Alfisols. The details of treatments and nutrient doses and cropping sequence and soil type are described in Tables 1 and 2, respectively.

Table 1. The details of LTFE treatments in Alfisols

Code	Details	Code	Details
T_1	50% optimal NPK	T_6	100% optimal NP
T_2	100% optimal NPK dose	T_7	100% optimal N
T_3	150% optimal NPK dose	T_8	100% optimal NPK + FYM
T_4	100% optimal NPK dose + hand weeding	T_9	100% optimal NPK (Sulphur free)
T_5	100% optimal NPK dose + lime	T_{10}	Unmanured (Control)

Table 2. Optimum Fertilizer nutrients rates (100%) used for different crops in Alfisols

Location	Taxonomic Classification	Cropping system	Nutrients rates at 100% NPK (kg ha^{-1})			FYM added
			N	P	K	(t ha^{-1})
Bangalore	Kandic Paleustalf	Finger millet	100	15	42	15
		Maize	100	-	82	-
Ranchi	Typic Haplustalf	Soybean	25	10	33	10
		Wheat	80	-	33	-
Palampur	Typic Haplustalf	Maize	120	10	75	10
		Wheat	90	-	38	-
Pattambi	Typic Haplustalf	Rice	90	5	38	5
		Rice	90	-	38	-

Note: At Ranchi and Palampur, potato/toria was third crop which was discontinued since 1979 and 1986, respectively. At Bangalore cowpea was discontinued since 1992-93.

PRODUCTIVITY OF CROPS

- Crops yield data of all the Alfisols sites revealed that continuous application of N alone over a long period resulted, reduction in yield. Below control treatment (nothing was applied). At Palampur, the productivity of maize and wheat in the N alone plot is badly affected and in the recent years there is no crop in this particular plot (Table 3 and Plate 1). Thus, the results clearly brought out that application of N alone in Alfisols is detrimental.

Table 3. Grain yield of crops (kg ha^{-1}) of latest year and average (34 years) in long term experiments on yield stability and productivity

Centre/ Cropping System	Control	N	NP	NPK	NPK+ FYM	NPK+ Lime	NPK * -S
Ranchi							
Soybean (2005)	232	064	222	1741	2121	1915	136
Average	617	296	861	1496	1832	1766	650
Wheat (2004-05)	279	109	2570	2343	3651	3523	458
Average	665	344	2444	2807	3366	3207	16001
Bangalore							
Finger millet (2005)	426	392	432	4009	4416	3688	4067
Average	591	761	978	4313	4855	4127	4135
Maize (2004-05)	118	75	175	2020	2453	2242	1367
Average	280	396	635	2113	2530	2292	1762
Palampur							
Maize (2003)	580	0	3020	4390	6020	4310	2080

Average	261	463	1953	3175	4588	3209	3184
Wheat (2003-04)	370	0	1120	1730	2330	1680	1170
Average	365	425	1642	2289	3029	2217	1660
Pattambi							
Kharif Rice (2003)	1708	2630	2415	2560	2940	2117	**2900**
Average (7 years)	1577	2303	2218	2434	2795	2188	**2632**
Rabi Rice (2004)	2340	3025	3022	3250	3722	3260	**3630**
Average (7 years)	2158	3078	2816	2995	3490	3012	**3304**

* At Pattambi the treatment is 100% NPK+ in situ green manuring before kharif rice.

- Contrary to upland situation, the effect of lime of yield of submerged rice-rice system at Pattambi was not observed (Table 3) due to attainment of soil pH near neutrality under submergence. However, incorporation of FYM and *in-situ* green manuring resulted appreciable increase in yield of both kharif and rabi rice.

100% NPK+FYM PLATE-1

100% N PLATE-2

***Plate 1*. Integrated application of NPK+FYM sustained maize productivity compared to N-alone in Alfisols at Palampur (HP)**

Control 100% N 100% NPK+FYM

Plate 2. **Integrated application of NPK+FYM sustained soybean productivity compared to control and N-alone in Alfisols at Ranchi**

- Data depicted in Fig. 2 on soil organic carbon (SOC) revealed that fertilization balance maintained SOC whereas incorporation of FYM resulted in build-up in SOC in Alfisols of Bangalore and Palampur. At Ranchi, except NPK + FYM treatment decline in SOC is recorded. The results indicate that under high rainfall incorporation of FYM is essential to sustain soil productivity.

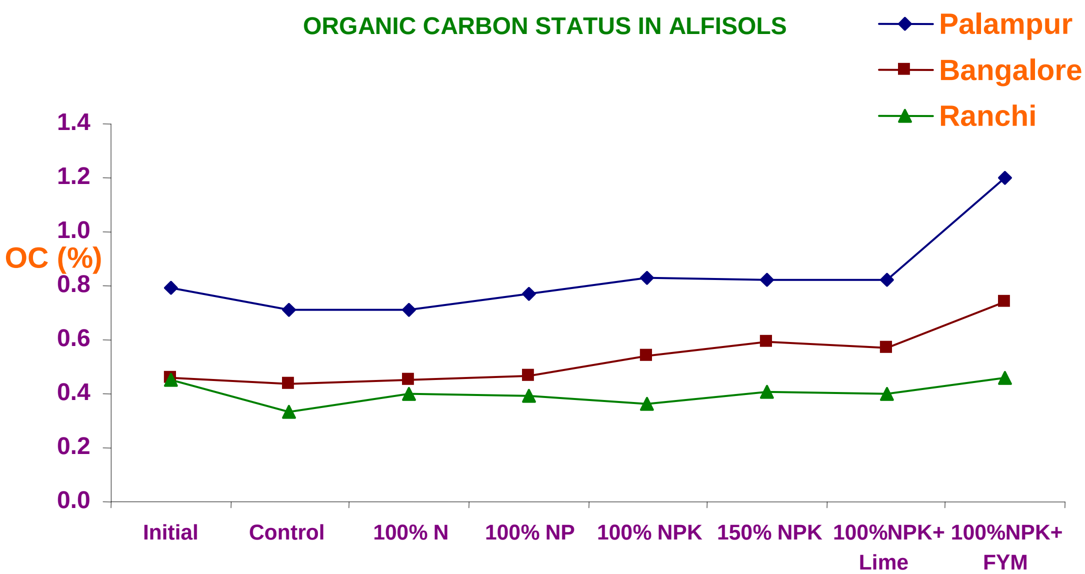
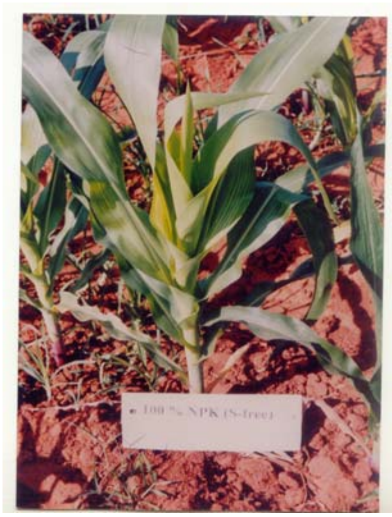


Fig. 2. **Organic C status after 34 years in different treatments under long-term fertilizer in Alfisols**

- Continuous absence of K and S from nutrient schedule resulted decline in yield of finger millet-maize at Bangalore (Plate 3), maize-wheat at Palampur and soybean-wheat at Ranch (Table 4) due to sharp decline in available K and S in soils . For example, absence of K since last 34 years at Bangalore resulted in decline in yield by 33.8 q ha^{-1} in finger millet and 14.7 q ha^{-1} in maize. At Palampur also, absence of K declined maize yield to the extent of 12.2 q ha^{-1} and wheat yield by 6.4 q ha^{-1}.

Plate 3. **Potassium : A growth limiting nutrient which adversely affected the productivity in Alfisols at Bangalore**

Sulphur is another growth limiting nutrients which adversely affect the productivity. At Bangalore absence of S from fertilizer schedule resulted in yield decline by nearly 2 q ha^{-1} in finger millet and 3.5 q ha^{-1} in maize (Plate 4).



100% NPK(-S)
Maize at Bangalore

100% NP
Soybean at Ranchi

Plate 4. **Sulphur : A growth limiting nutrient which adversely affected the productivity in Alfisols at Bangalore and Ranchi**

At Palampur, 6.2 q ha^{-1} decline in wheat yield was recorded due to S. Among the three Alfisols maximum decline in yield due to S was recorded at Ranchi.

Through application of all the three nutrients (NPK) the crop productivity sustained at a respectable level but application of FYM or lime resulted in appreciable increase in yield particularly at Ranchi and Banglore. The findings suggest that to sustain the productivity in Alfisols year after year, application of either FYM or lime is essential.

Table 4. Available Potassium and Sulfur status (kg ha^{-1}) in Alfisols after 34 years.

LTFE Site	Initial	Control	N	NP	NPK	NPK+ FYM	NPK+ Lime	NPK-S
Available K								
Ranchi	157.7	38.0	34.5	30.0	45.5	64.5	48.5	47.0
Palampur	194.0	128.8	148.4	111.5	155.7	170.8	142.8	170.0
Bangalore	123.0	70.0	59.0	58.0	143.0	182.0	162.0	137.0
Available S								
Palampur	12.8	8.5	14.8	15.2	18.1	20.1	21.3	9.0
Bangalore	20.3	15.2	16.8	59.1	47.7	60.3	50.9	7.5

INTRODUCING SUPERIMPOSITION OF TREATMENTS

Continuous use of nutrient either singly or in combination or integration with FYM resulted in either very high build of P and Zn fertility or accentuated the deficiencies of sulfur and micronutrients, high soil acidity, excessive depletion of P or K. The build-up of P may cause environmental problem and the deficiency of nutrients adversely affect the sustainability of the system. To sustain the productivity and to avoid the wasteful expenditure on excessive P, interventions were required, therefore in few selected treatments superimpositions were implemented using nested plot design in one of the replications preserving the original.

Table 5. Three years (2002-03 to 2004-05) average grain yield (q ha^{-1}) of finger millet (*Kharif*) and Maize (*Rabi*) in superimposed treatments at Bangalore

Treatments	Finger millet	Hybrid maize
100% NP (Original)	5.22	1.94
100%N, 50%P, 100%K, FYM	33.57	18.04
100%N, 50%P, 100%K, FYM + lime$^{\$}$	32.46	18.98
100%N(original)	5.00	0.82
100%NPK+FYM	31.06	16.08
100%NPK+FYM*+ lime$^{\$}$	31.06	17.24

*FYM @ 15 t ha^{-1}, $ as per lime requirement.

Response of crops to nutrients

Average responses of crops to nutrients and amendments presented in table 7 revealed that the response of all the crops to N in majority of cases is negative except in maize at Palampur. The positive response of N in maize is due to very good response of N in first 10 years of experimentation (Table 8). The negative response of crop to N suggests that application of N instead of improving the yield, it has rather deteriorated. Contrary to this, crops response to P, K, and S is conspicuous. The response of crops to S at Ranchi is, however, negative. Phosphorus response in wheat at Ranchi is as high as 21 q ha^{-1}, and the maximum K response in finger millet recorded is 33 q ha^{-1}at Bangalore, whereas S registered maximum response to extent of 13.9 q ha^{-1} in maize at Palampur. The response of crop to lime ranged from 1.2 to 8.95 q ha^{-1} with exception of negative response of lime in finger millet at Bangalore. The negative response of finger millet to lime is due to acid environment loving nature of the crop. The Response of crops to FYM ranged from 3.66 to 14.27 q ha^{-1} in Alfisols under LTFE. Thus, LTFE results clearly brought out that to sustain productivity of Alfisol balanced use of nutrients is a primary requirement.

Table 7. Average response (kg ha^{-1}) of crops to nutrients and soil amendments in different in Alfisols

Treatment	Palampur (31 years)		Bangalore (16 years)		Ranchi (34 years)	
	Maize	**Wheat**	**F. millet**	**Maize**	**Soybean**	Wheat
N	188	- 017	- 198	- 136	- 354	- 321
P	1504	1330	237	255	565	2100
K	1209	640	3301	1430	636	363
S	1398	1106	27	310	-840	-1206
Lime	895	492	- 188	128	270	400
FYM	1427	737	503	416	366	559

Response of crops to nutrient with time

At several places, under LTFE crops started showing response after few years but in Alfisols response of crop to nutrients was visible from the inception of the experiments. Decline in response of both finger millet and maize with time at Bangalore to N and P and increase in response of crops to K with time was observed (Table 8). The decline in response of crop to P with time is due to N as yield limiting factor. The negative response of finger millet to S and better performance of finger millet on DAP application compared to SSP as source of P indicates that finger millet is not a S loving crop and the little requirement is met through native S.

Table 8 Average response (kg ha^{-1}) of finger millet and maize to nutrients at Bangalore

Nutrient	Response of Finger millet (kg ha^{-1})		
	1987-91*	**1993-97**	**1998-2002**
N: (N-C)	546	84	71
P: (NP-N)	624	35	47
K: (NPK-NP)	1218	4217	3828
S:{NPK-(NPK-S)}	-299	239	-225
Response of Maize (kg ha^{-1})			
N: (N-C)	412	21	- 76
P: (NP-N)	414	127	178
K: (NPK-NP)	1101	1358	1710
S:{NPK-(NPK-S)}	45	125	585

*Mean of 4 years

Appreciable response of crop to N was recorded in initial years only which went on decline in both maize and wheat with time at Palampur (Table 9). Whereas, an inclining trends in response of crops to P, K and S with few exceptions were noted, which is due to either exceptionally very good or low yield level during the block of five years. Consistent and sufficiently large response of crops to lime and FYM till date both kharif and rabi seasons at Palampur suggests that both the amendments are essential inputs to sustain the yield in Alfisols.

Table 9 Mean total response of maize and wheat to nutrients and amendments (mean of 5 yrs) at Palampur

Nutrient	Response of Maize (kg ha^{-1})					
	1973-77	**1978-82**	**1983-87**	**1988-92**	**1993-97**	**1998-2002**
N: (N-C)	1855	254	-101	-138	-196	-262
P: (NP-N)	1114	1976	1629	938	1144	1828
K: (NPK-NP)	131	731	1444	2606	1304	1126
S:{NPK-(NPK-S)}	000	086	350	1150	830	819
Lime: {NPK+L-NPK}	618	1084	827	1023	596	1098
FYM:{NPK+FYM-NPK}	1423	1123	1885	1479	1170	1386
Response of Wheat (kg ha^{-1})						
N: (N-C)	688	168	-072	-166	-286	-320

P: (NP-N)	1412	1292	1554	1554	1264	880
K: (NPK-NP)	188	324	1090	1114	620	640
S:{NPK-(NPK-S)}	2992	058	412	1102	440	580
Lime: {NPK+L-NPK}	326	596	528	492	666	480
FYM:{NPK+FYM-NPK}	742	380	938	776	1012	610

Negative response of both soybean and wheat to N since beginning of the experiments at Ranchi suggests that application of N alone had adverse effect on crop growth (Table 10). Unlike Alfisols of Bangalore and Palampur, crop response to S was found to be negative which clearly indicates that S is not liming nutrient at Ranchi and S can be kept away from fertilizer schedule. Since beginning of the experimentation sufficiently larger response of K indicates that K is most growth limiting nutrient. Growing of crop without K may be a dream which volatilizes on awakening. The crop response to both soil amendments is consistent throughout experimentation with little variation in absolute values. In all the three Alfisols, the response of kharif crop was relatively less compared to subsequent rabi crop.

Table 10. Response of soybean and wheat to nutrients and soil amendments with time at Ranchi

Nutrient	**Soybean (kg ha^{-1})**					
	1972-80	**1981-85**	**1986-90**	**1991-95**	**1996-2000**	**2001-05**
N: (N-C)	353	-598	-357	-203	-258	-148
P: (NP-N)	282	802	496	663	540	405
K: (NPK-NP)	253	386	914	798	789	884
S:(NPK(S)-NPK)	-130	899	-1255	-1178	-992	-961
Lime: {NPK+L-NPK}	400	368	143	289	246	150
FYM:{NPK+FYM-NPK}	231	308	513	334	397	249
Wheat (kg ha^{-1})						
N: (N-C)	634	-397	-201	-85	-210	-274
P: (NP-N)	1525	1049	2958	2303	1976	2853
K: (NPK-NP)	188	278	483	753	606	62
S: (NPK(S)-NPK)	-110	-505	-1750	-1412	-1791	2018
Lime: {NPK+L-NPK}	32	186	318	240	754	1041
FYM:{NPK+FYM-NPK}	146	155	523	676	900	1101

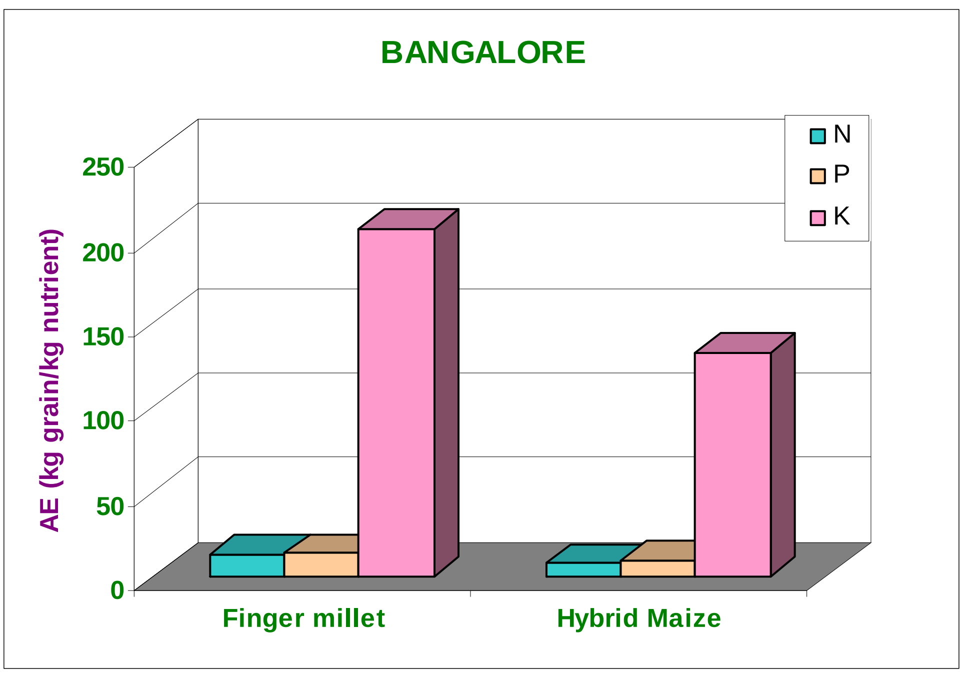
*Average of 5 years

Decline or negative response of crops to N and inclining trend in response of crops to P and K, with time suggests that one can't harness the potential yield of crops in Alfisols without ruling out the hidden hunger of all the expected deficient nutrients (N, P, K, S ...). Therefore, integrated nutrient management coupled with soil amendments (FYM/lime) is the only option to sustain the productivity in Alfisols.

Table 11 Average Agronomic Efficiency (kg grain/kg nutrients) of N, P, and K in soybean and wheat at Ranchi

Treatment	N (N-C)	P (NP-N)	K (NPK-NP)
Soybean			
N	-12.85	-	-
NP	9.76	21.73	-
NPK	35.18	46.16	19.26
NPK+FYM	48.60	59.08	29.43
Wheat			
N	-4.01	-	-
NP	22.24	80.76	-
NPK	26.77	94.71	10.99
NPK+FYM	33.76	116.21	27.93

The negative agronomic efficiency (AE) of N in both soybean and wheat indicates that N had adverse effect on plant growth. Whereas positive AE of P and K suggests that application P and K even alone also resulted in increase in yield of the crops (Fig.11). The data further revealed that inclusion of other nutrients increase the AE efficiency of nutrients. For instances, in soybean AE of P recorded in NP treatment is 21.7 kg grain/kg P which increased to 46.1 and 59.0 kg seed of soybean on application K and FYM, respectively. While in wheat AE of P recorded in NP treatment is 80.7 kg grain/kg P which increased to 94.7 and 116.2 kg seed on application of K and FYM, respectively. Thus, the results suggest that to harness the potential yield of crop in Alfisols application of nutrients in right proportion along with organic manure is essential.



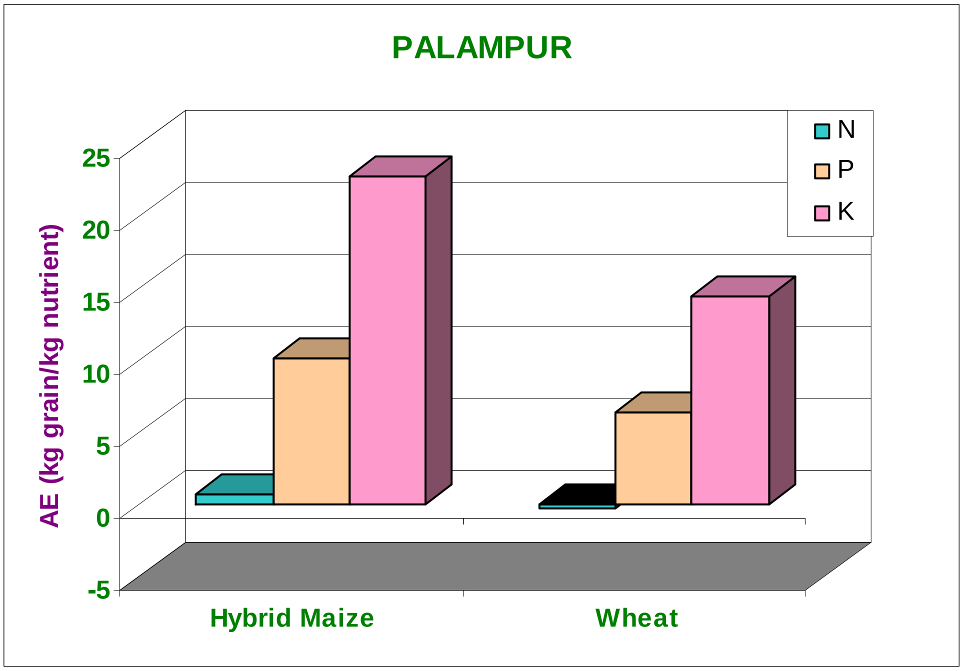


Fig. 3 **Average Agronomic Efficiency (kg grain/kg nutrients) of N, P, and K for different crops at Bangalore and Ranchi**

YIELD SUSTAINABILITY

As discussed earlier, a sharp decline in crop productivity has been observed since few years after the inception of the experiment in Alfisol due to continuous imbalance nutrient use, either N alone or NP. The superimposition of P, K and FYM in 100% N treatment (original) resulted in quantum jump in yield from 5 to 31.06 q ha^{-1} in finger millet and 0.8 to 16.8 q ha^{-1} in maize at Bangalore (Table 5). However, application of lime over and above 100% NPK + FYM did not have any additional beneficial effect on yield of both the crops. Similarly, in 100% NP treatment, reduction in P dose and addition of K and FYM also increased the productivity of both the crops. Here, in this treatment also application of lime over and above 100% NK + 50% P + FYM did not show any beneficial effect on yield. Thus, results of superimposed treatment clearly brought out that for sustaining the productivity application of K, P, S and FYM is must. An eye on P status must be kept to avoid unnecessary built up of P. This would not only curtail expenditure on P but also minimize water pollution.

The grater sustainability yield index (SYI) of all the crops (Table 6) in NPK+FYM/lime treatment is again supports the finding that to enhance and to sustain the productivity application of FYM/lime is essential along with balanced nutrition. FYM not only act as ameliorating agent but also rule out the possibility of hidden hunger of micro- and secondary nutrients. Whereas, application of lime also acts as an amendment and creates a conducive environment in root zone which facilitate plant root growth and availability of nutrients by controlling the soil pH.

Table 6. Sustainable Yield Index (SYI) for various treatments in Alfisols of Bangalore and Ranchi in long-term experiments

Location/ Crops	Control	N	NP	NPK	NPK+FYM	NPK+ Lime
Bangalore						
Fingermillet	0.06	0.07	0.09	0.53	0.62	0.53
Maize	0.00	0.00	0.00	0.41	0.55	0.51
Ranchi						
Soybean	0.14	0.02	0.21	0.47	0.62	0.61
Wheat	0.05	0.02	0.21	0.31	0.37	0.35

RECOMMENDATIONS FOR ENHANCING AND SUSTAINING THE PRODUCTIVITY OF ALFISOLS

- The results of LTFE under Alfisols brought out very valuable information which could be used by researchers for advancing in the science and for planners to take measure for increasing the productivity of Alfisols constituting an area of approximately 90 millions hectare with 25 millions hectare of cultivated lands having pH less than 5.5 in India.

- Application of fertilizer nutrients is essential to enhance the productivity. Continuous use of either N or NP or NPK without S is dangerous. To sustain the productivity balanced fertlization as per the need of crop is essential.

- Addition of FYM not only met out hidden hunger of micro and secondary nutrient but also acted as ameliorating agent which improved the nutrient use efficiency by crops and also improved the soil health.

- Excess application of P may be avoided to curtail wasteful expenditure.

- In Alfisols, application of lime is essential to maintain soil pH, which in turn maintain the supply of nutrient to crop. Application of FYM is also equally effective in sustaining the yield in Alfisols.

AICRP on Micro & Secondary Nutrients & Pollutant Elements in Soil & Plants

1. Title of the Project : **All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant elements in Soil and Plants**

2. Name and Address of the Project Coordinator :
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3. Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):

3. Major achievements of research

Delineation of Micro and Secondary Nutrients deficient areas

- With the advent of Green Revolution first, micronutrient deficiencies became one of the serious constraint in achieving maximum crop yields. So systematic surveys were carried out to delineate micro and secondary nutrient deficient areas in various talukas, district, states and country as whole. Accordingly, based on 2.50 lakh soil samples , micronutrient status has been evaluated and deficiency of micronutrients is assessed. Delineation of micronutrient deficient area and soil fertility mapping for zinc, copper, iron and manganese has been prepared using percent deficiency, nutrient index and response of crops to micronutrients use.

- In collaboration with NBSSLUP Nagpur, total 55 GIS based soil fertility maps has been prepared at taluka/ district, state level/ national level and agro ecological zone wise. These have been given the Secretary (Fertilizer), Ministry of Chemicals and Fertilizer for developing strategies for micronutrient manufacturing and supply under Prime minister mission on agricultural. Development (Plate 11-20). These maps are given to ICAR and Agriculture commissioner for developing suitable strategies for correction of micronutrient deficiencies.

- Average deficiency of zinc, iron, copper, manganese was found in 48. 12. 5, and 4 percent soils of India. The deficiency of zinc was more in soils having low organic carbon, high soil pH, High calcium carbonate etc. Zinc deficiency is most wide spared. Its deficiency was recorded less than 40% in AEZ 1, 2, 5, 15, 16, 18, 19; 40-50% in AEZ 9, II, 12; 50-55% in AEZ 4, 7, 13 and> 55% in remaining zones of country.

- Analysis of nearly 90000 surface soil samples from AEZ 4, 9, 13, 16 mainly *for* Indo-Gangetic alluvial plain (IGAP) showed 55, 47 and 36% deficiency of zinc in Trans-northern, Central and Eastern parts of IGAP respectively. Reverse trend was found *for* boron deficiency showing 8, 37, 68% deficient soils, respectively.

- Most of soils have tested to be adequate in available iron; but its deficiency in all AEZ as well as toxicity in some coastal, submontane and red lateritic soils is quite common. Studies summarize the occurrence of micronutrient deficiencies amongst and within Agro-ecological zones and magnitude of crop response for formulating suitable micronutrient management strategies for specific AEZ, soil types and cropping systems for maximizing crop production. Deficiency of boron was found in 33% soil samples tested all over the country.

- Deficiency of boron is reported in several areas, Its deficiency is found wide spread in acidic soil and highly calcareous soils of Bihar, Saurashtra, parts of central India too. Boron deficiency varied from 2% in AER 2; 24-48% in highly calcareous soils of AEZ 2, 9 and 14 but most widespread (39-68%) in red and lateritic soils of AEZ 6, 13, 16, 17, 19. Over all 33% soil samples out of 50,000 soil samples..

- Deficiencies of Cu and Mn are not widespread and response of crops was found sporadic. Iron deficiency accounts 12% soils of the country which needs attention. Deficiency of Mn has been found wide spread in sandy alkaline soils having low organic matter under rice-wheat cropping system in Punjab. So wheat crop suffer badly from manganese malnutrition.

Micronutrient recommendations under National Food Security Mission :

The information on deficiency of micronutrients and sulphur is being disseminated to various states as follows.

Table 2.1 Detail of micronutrient and sulphur deficiency status in soils in Madhya Pradesh

S.No	District	Sulphur	Zinc	iron	Manganese	Copper
1	Jhabua	Deficient	Marginal	Adequate	Adequate	Adequate
2	Ujjain	Deficient	Marginal	Adequate	Adequate	Adequate
3	Vidisha	Deficient	Deficient	Adequate	Adequate	Adequate
4	Balaghat	Deficient	Deficient	Adequate	Adequate	Adequate
5	Dhar	Deficient	Deficient	Adequate	Adequate	Adequate
6	Dindori	Deficient	Marginal	Adequate	Adequate	Adequate
7	Mandala	Deficient	Marginal	Adequate	Adequate	Adequate

8	**Shahdol**	**Deficient**	**Highly Deficient**	**Adequate**	**Adequate**	**Adequate**
9	**Betul**	**Marginal**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
10	**Bhind**	**Deficient**	**Highly Deficient**	**Adequate**	**Adequate**	**Adequate**
11	**Chhattarp ur**	**Marginal**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
12	**Damoh**	**Marginal**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
13.	**East Nimad**	**Deficient**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
14	**Guna**	**Marginal**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
15	**Harda**	**Marginal**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
16	**Indore**	**Deficient**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
17	**Jabalpur**	**Marginal**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
18	**Katni**	**Marginal (**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
19	**Raisen**	**Deficient (**	**Deficient**	**Adequate**	**Adequate**	**Adequate**
20	**Rajagarh**	**Deficient**	**Deficient**	**Adequate**	**Adequate**	**Adequate**
21	**Rewa**	**Deficient**	**Marginal**	**Adequate**	**Adequate**	**Adequate**
22	**Sagar**	**Deficie**	**Deficient**	**Adequate**	**Adequate**	**Adequate**
23	**Satna**	**Deficient**	**Deficient**	**Adequate**	**Adequate**	**Adequate**
24	**Sehore**	**Deficient**	**Deficient**	**Adequate**	**Adequate**	**Adequate**

3.2. Amelioration practices recommended under National food Security Mission

3.2.1 Micronutrients

- In zinc deficient soils, zinc deficiency can be corrected by application of zinc sulphate hepta hydrate (21% Zn), mono hydrate (33% Zn), zinc chelate (Zinc EDTA) and zinc phosphate. Zinc sulphate hepta hydrate is the most cheap, common, easily available and efficient source of zinc for correcting zinc deficiency in soils and crops. Zinc chelate are very costly hence less cost effective when applied in soil.

- Application of zinc sulphate at the rate of 25 kg ha^{-1} equivalent to 5.5 kg Zn ha^{-1} is found optimum for correcting zinc deficiency in marginal soils and 50 kg zinc sulpahte ha^{-1} for highly deficient soil. If deficiency is severe rate of application of zinc sulphate /ha may be increased to 50kg/ha which increases the yield and benefits significantly (2.60- 10.0 q/ha over no zinc application).

- Basal soil application through broadcast is good, but if soil application is missed, the same may be top dressed within 30-45 days after sowing at the time of first irrigation.

- If soil application is missed, sprays of 5 g per litre zinc sulphate solution neutralized with 2.5 g 2.5 per litre lime or 2 g per litre zinc chelate solution two to three times in 300-500 litres per hectare at 7-10 days interval between 20-45 days of germination also corrects zinc deficiency quite efficiently. So about 3-4 kg zinc chelate/ha or 7.5-10 kg zinc sulphate /ha is required for three to four foliar sprays.

- Foliar application of 0.5% ferrous sulphate un neutralized two to four times on standing crops or horticultural plants is found beneficial in correcting iron deficiency. Crops suffering from iron and zinc deficiency needs mixed foliar spray of 0.25% zinc sulphate and ferrous sulphate twice to thrice for correcting such nutritional disorders in plants.

3.2.2 Sulphur

- Sulphur deficiency can be corrected by applying 20-40 kg S/ha, through basal application of either of the sulphur sources like single super phosphate, gypsum/phosphogypsum , gromor sulphur, ammonium sulphate.

- All sulphur sources are equally efficient and enhance the crop yield and improve the quality of produce. Commonly sulphur content was found 12% S in single super phosphate, 13-18% S in gypsum or phosphogypsum , 24% S in ammonium sulphate and 90% S in gromor sulphur and all are the good sulphur source so actual fertilizer material doses can be decided accordingly to crop requirements. Oilseeds and pulses require more sulphur than cereal crops. Cereal crops yield also significantly increases with sulphur application in sulphur deficient soils.

- For 40 kg S /ha single super phosphate at the rate of 330 kg/ha, gypsum/ phosphor-gypsum at 250 kg/ha, gromor at 45 kg/ha and ammonium sulphate at 160 kg/ha should be applied as basal or top dressing through broad cast.

3.2.3 Integrated nutrient management

- Regular use of farm yard manures at 10-15 ton/ha in sulphur and zinc deficient soils is found beneficial. Farmers may be advised to apply 10-15 tonnes/ha farm yard manure regularly so that deficiencies of micronutrients could be corrected automatically to a good extent. If amount of available manure is less say 4-5 tonnes/ha the zinc sulphate or sulphur doses can be reduced to half of the recommended dose and thus saving of input without loosing crop yields.

3. Molybdenum and sulphur deficient areas

- Molybdenum deficiency is found sporadic and as such 13% soils are suffering with molybdenum deficiency.

- With continuous use of sulphur free high analysis fertilizer and lesser use of organic manure sulphur deficiency has appeared in many Indian soils (Fig. 3). As such 41 percent soils are suffering with low sulphur status in the country. Oilseed and pulses growing areas in different states are more prone to its deficiency. Map showing sulphur deficiency has been prepared and published for the benefit of various user agencies.

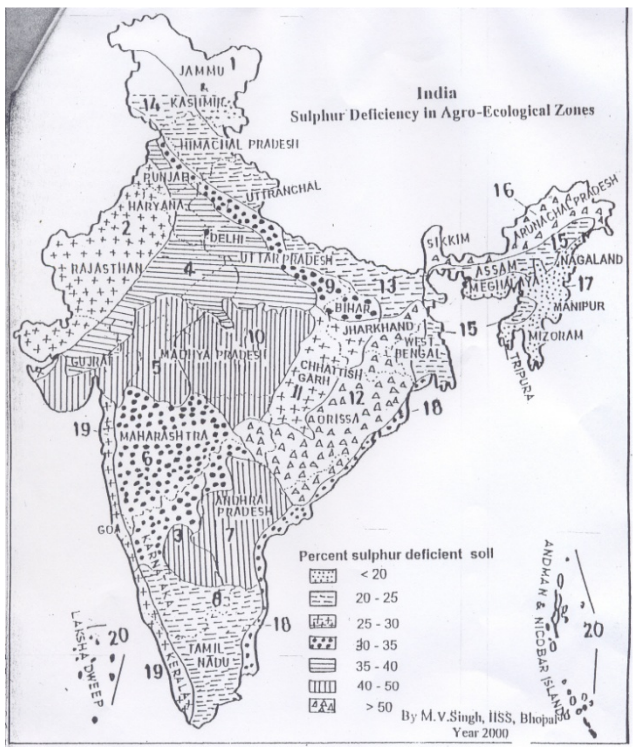


Plate 3: Sulphur deficiency in different agro- ecological zones

Nutrient indexing for forecasting emerging micronutrient deficiencies in soils and crops

- The knowledge about micronutrient deficiencies and its impact on crop yields was well visualized by the farmers so in several state use of micronutrients, mainly zinc sulphate , became a common practice. With the results status of zinc is improving and deficiency of zinc is declining in several soil-crop-management systems. On the other hand, deficiency of multi micronutrients surfaced in several areas due to continuous of depletion of micronutrient reserve of the soils.

- Initially in sixties the deficiency of iron deficiency was reported in orchards and nursery crops. But with the introduction of new high yielding varieties, zinc deficiency became a serious problem in rice, wheat and maize productivity. In early eighties, sulphur deficiency was observed and later manganese deficiency was recorded in several area of Punjab where rice –wheat sequence was introduced in place of maize-wheat sequence in sandy alkaline soils. With the introduction of rice in Indo Gangatic alluvial plains, iron chlorosis in rice caused low yield, but subsequently after 5-7 years, iron deficiency got reduced due to increased availability of iron under submergence. However. Mn deficiency became apperant which caused lower productivity of wheat. Currently about 5 lakh hs is suffering with its deficiency and needs regular foliar sprays to sustain high yield.

- In mid nineties, deficiency of boron and its responses to crops were recorded in several areas. Deficiency is found more in acid and alkaline soils. In recent years, copper deficiencies is recorded in few location but it may emerge as important micronutrient in several areas of Punjab, North Uttar Pradesh , Tamil Nadu etc. Molybdenum deficiencies is recorded in few acidic soils but response is found more to pulse and few vegetable crops. Deficiency of magnesium is recorded in certain specific crops like cotton, tea etc.

- Nutrient indexing for micro- and secondary- nutrients in low and high productivity areas of different AER has been initiated in different soil-crop-management system. The programme has been initiated at all 11 centres with respect to monitoring of 20 bench mark sites for emerging micronutrient deficiencies at 2-3 sites representing different soil-crop-management systems.. Data of periodic survey is in initial years revealed that more and more area is suffering with multi nutrient deficiencies.

Reassessment of multi micronutrient deficiencies and developing digitized maps using GIS

- Geo referenced based micronutrient fertility mapping has been initiated to forecast emerging deficiencies of various micronutrients in different soils periodically. All the centres have been provided GPS system and priorities are fixed to go GPS based soil sampling in future.

- Studies initiated by Ludhiana centre to collect surface (0-15 cm) samples and GIS based mapping on 1:50,000 scale , total 480, 690 and 408 sites were sampled in Muktsar, Patiala and Hosiarpur districts, in collaboration with Remote Sensing Agency, Punjab. Maps for various nutrient elements were generated and digitized using Arc info GIS.

- Average micronutrient status, percent deficiency and total areas affected with different micronutrient deficiencies have been worked out. The deficiency of zinc was 37% in Muktsar comared 12% in Patiala but Patiala has maximum deficiency of B (36%). Hosiarpur soils has maximum deficiency of Mn 24% and that of Fe 10% ..

- In Muktsar district, 42 per cent of (total cultivable area) in the district (1.1 lac ha) represented by category SSSS (all the micronutrients (Fe, Cu, Mn, Zn) are above the critical limit), followed by category SSSD which spreads over an area of 46002 ha (17.5 % of TGA) and in this category all micronutrients except Zn are available to plants in sufficient amount. Also categories SD (36675 ha) and DSSS (34949 ha) covers 14 and 13.2 per cent of TGA of the district respectively where Zn+Fe and Fe were found deficient. (Table 4.1 Map 4.1)

Table 4.1 :Area under various multi micronutrient deficiency categories in Muktsar district

Category FeCu Mn Zn	Muktsar		Patiala		Hosiarpur	
	Area(ha)	Percent Area	Area(ha)	Percent Area	Area(ha)	Percent Area
D D D D	5	0.01	-	-	844.8	0.25
D D D S	528	0.20	-	-	733.6	0.22
D D S D	5203	1.98	585. 27	0.16	-	-
D D S S	2796	1.06	5884.03	1.60	230.6	0.06
D S D D	3442	1.32	-	-	2168.6	0.64
D S D S	2045	0.78	357.73	0.10	7137.2	3.67
D S S D	36675	13.94	-	-	8594.5	2.54
D S S S	34949	13.28	32573.79	8.85	45634.5	13.52
S D D D	1518	0.58	-	-	2461.5	0.73
S D D S	467	0.18	349.76	0.10	2833.9	0.84
S D S D	4199	1.60	641.78	0.17	-	-
S D S S	1387	0.53	10647.16	2.89	769.9	0.22
S S D D	5225	1.99	-	-	12405.1	3.67
S S D S	7609	2.90	12049.66	3.27	72102.6	21.36
S S S D	46002	17.48	1007.18	0.27	11932.6	3.53
S S S S	110604	42.03	303903.63	82.58	169670.6	50.27
Total	263121	100	368000	100	337520	100

- Similarly, in soils of Hosiarpur district more than 50% of the negligible portion of total geographical area was not affected by the deficiencies of either of all the four micronutrients (Zn, Cu, Fe, Mn) or deficiencies of more than two micronutrients elements, like Cu+Fe+Mn, Zn+Fe+Mn. The Fe deficiency was more prevalent followed by Zn, Mn and Cu deficiency, respectively. Only 0.25 per cent (844.8 ha) (Table 4.1) of the total geographical area of the district was represented by category DDDD which indicated represented the deficiencies of all the four micronutrients (Zn, Cu, Fe, Mn). Similarly, Patiala and other districts such information is being generated (Fig.4.1) .

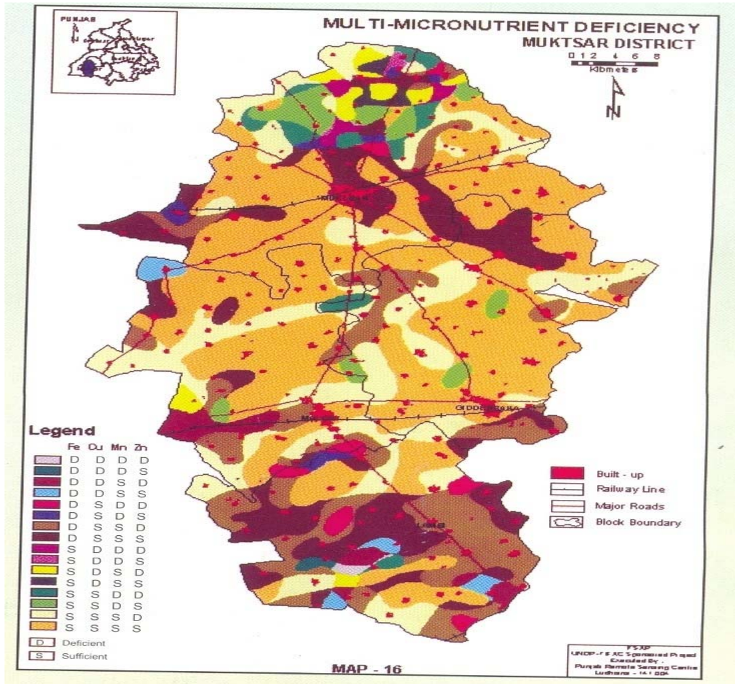


Fig. 4.1 Digitized map of micronutrient deficient areas in Muktsar district in Punjab

Relation between soil properties and micronutrient deficiencies

- Relation between soil properties and micronutrient status and percent deficiencies has been worked out so as to forecast and suggest suitable amelioration measures.

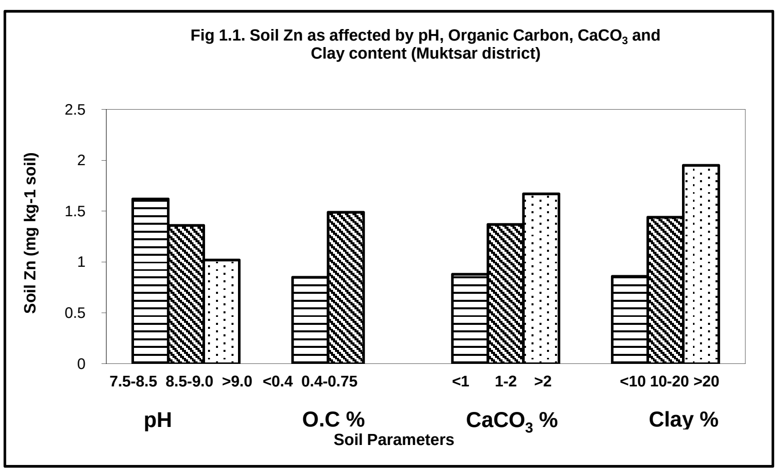


Fig. 4.2 Relationship in soil properties and micronutrient deficiencies

5. Amelioration of micronutrient deficiencies in cropping system

- Several field experiments were conducted to evaluate optimum rate, better source and method of application so as to enhance nutrient use efficiency. New products like Teprosyn zinc phosphate, Granubor II and Gromor sulphur bentonite were tested and found useful in correcting their deficiencies more efficiently. Integrated nutrient management and zinc enrichment to organic manure was tested . Zinc enrichment found better in enhancing zinc use efficiency by 25-50% over inorganic zinc application alone. Details of these experiments are given below.

5.1 Efficiency of Granubor II as new source of boron

- World over boron deficiency is found widespread . In order to reduce the import cost, borax penta hydrate in its granular form (known as "Granubor II"), was developed and tested as one of the boron sources for soil application in crop production under contractual research project Network Sponsored by M/S Rallis Research Centre, Bangalore. Total 26 field trials were conducted in eight states through state agricultural universities/ ICAR institute Treatment at 75, 100 and 125% of the optimum dose to respective crops were applied through soil application by Granubor II and crystalline borax decahydrate. Crops were raised by adopting all standard agronomic practices.

Boron control **0.75 kg B /ha**

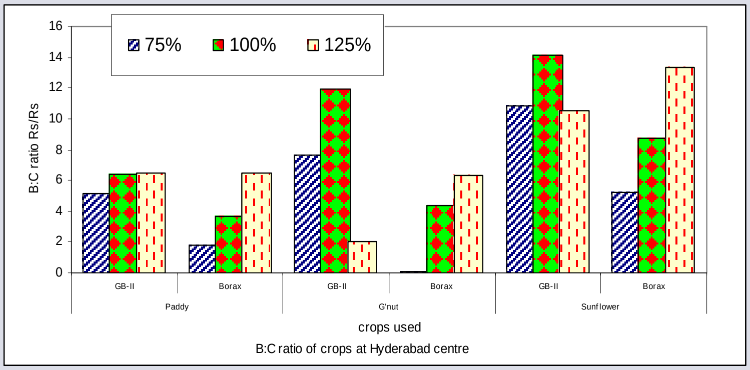
Fig. 5.1 Effect of boron fertilization on cauliflower in alfisols of Himachal Pradesh

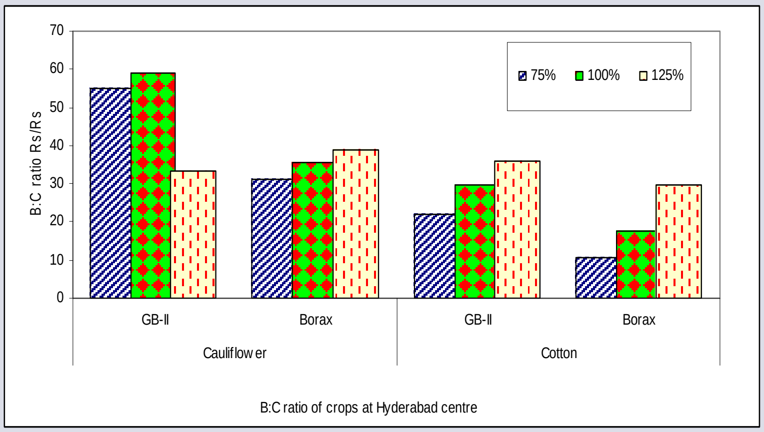
- In 80-85% experiments, crops showed response to added boron. Optimum response of crops to boron rates found limited either to 75% or 100% of the recommended dose in most of the field trials . Thus, crops need 0.50 to 1.00 kg boron $ha^{-1.}$ Soil application of 125% boron generally caused deleterious effect. Thus, considering residual effect of B it is advisable not to apply higher doses of boron and only judicious use of 0.5-0.75 kg B ha^{-1} annually will be beneficial in sustaining higher crop productivity (Table 5.1).

Table 5.1 Optimum rate of boron and relative efficiency of two sources viz. Granubor II and borax decahydrate for correcting boron deficiency in crops in different states

Crop	Efficiency of Granubor Vs Borax	Optimum rate of boron recommended , kg ha^{-1}								
		A.P.	Bihar	T.N.	Gujarat		HP	Punjab	MP	Jhar khand
					Cal-soil	Non cal –soil				
Cauliflower	At par	1 kg	1.25	1.15	-	-	1.25	-	-	1.00
Paddy	At par	0.00	-	0.00	-	-	-	-	-	-
Groundnut	At par	1.00	-	1.25	0.75	0.00	-	0.5	-	
Cotton	At par	0.75	-	-	-	-	-	-	0.75	
Mustard	At par	-	1.00	-	-	-	-	-	0.5	-
Sunflower	At par	0.50	0.75	0.75	-	-	-	-	-	-
Lentil	At par	-	-	-	-	-	-	0.75	-	-

Gram	At par	-	-	-	-	-	-	0.75	-	-
Soybean	At par	-	-	-	-	-	-	0.75	-	-
Wheat	At par	-	-	-	0.5	0.00	-		-	-





Response (B: C ratio) due to levels and sources or boron to cauliflower and cotton

- Efficiency of both boron sources was found similar in correcting its deficiency in different soils, crops and regions. Thus considering the benefits accrued from above sources borax penta hydrate has been notified in the Fertilizer (Control) Order (FCO) 1985 vide amendment order notification under section 3 of the Essential Commodity Act, 1955 of Govt. of India for agricultural use .

4.2 Seed treatment as an option for enhancing NUE and correcting micronutrient deficiencies

- Amelioration of micronutrient is becoming a costly affair. The use efficiency of micronutrient is very low. So seed treatment is one of the promising techniques to enhance use efficiency of micronutrient. Total 22 field experiments were conducted at various centres Micronutrient Teprosyn formulations having composition of Teprosyn F-2498 (600 g ZnL^{-1}), Teprosyn ZnP F-3090 (300 g Zn + 200 g P_20_5 L^{-1}) , Teprosyn Mn F-2157 (500 g Mn L^{-1}) and Teprosyn Mo F-1837 (250 g Mo L^{-1}). Were tested. High quantity of micronutrients is partially dissolved in acid and slurry is prepared to get desired concentration level of micronutrients such as Zn 300-600 g L^{-1}, Mn 500 g L^{-1} and Mo 250 g L^{-1} for seed coating .Result showed that seed treatment with Teprosyn Zn+P at the recommended level (8ml/ kg seed) increased the yields of several crops having bigger seed size and found beneficial. It is not suitable for small seed crops.

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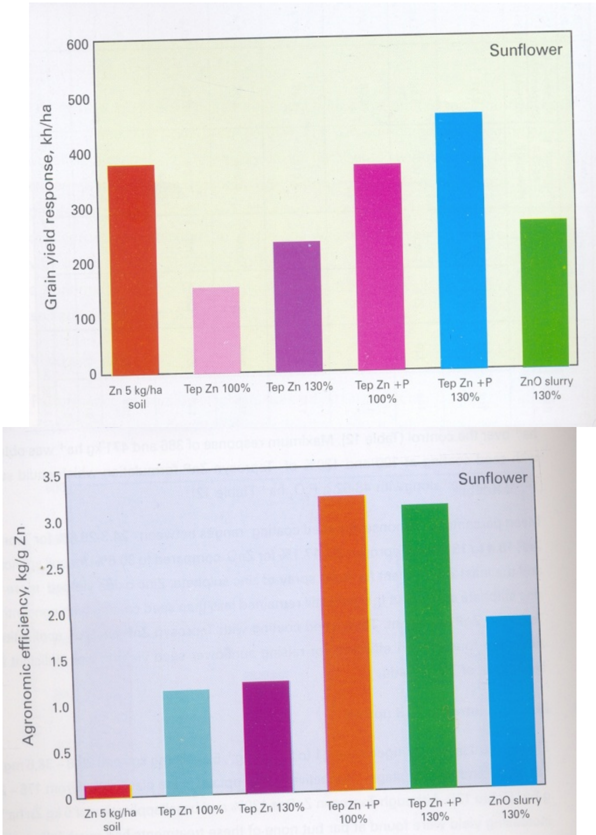

Fig. 5.2 Effect of seed treatment with various zinc products on seed yield of sunflower

- Thus, considering the benefits accrued from seed coating treatments with above micronutrient formulations, the zinc phosphate (suspension) has been notified in the Fertilizer (Control) Order (FCO) 1985 vide amendment order notification under section 3 of the Essential Commodity Act, 1955 of Govt. of India with following specifications in respect to provisional fertilizer mentioned at sl.no. 3 in the FCO order dated New Delhi 12th May, 2003 with specification as zincated phosphate (suspension), specification under FCO for agricultural use:

Total phosphate as P_2O_5) percent by weight, minimum	300 g Zn L^{-1}
Total zinc (as Zn) percent by weight, minimum	200 g P_20_5 L^{-1}
Neutral Ammonium citrate sulphate phosphate	3.9 % as P_2O
Lead (as Pb) percent by weight, maximum	0.0038 +- 1.0

5.3 Efficiency of Gromor sulphur bentonite as new fertilizer product of sulphur

- Sulphur deficiency is more commonly is corrected though gypsum, SSP or ammonium sulphate. There is no sulphur fertilizer to correct its deficiency. A research net work was therefore initiated to study the efficiency of new source as Gromor sulphur bentonite having 90% S in elemental form. Field studies showed that direct use of S bentonite to improve the grain yield of crops. The effect was significantly superior or at par to SSP and gypsum but better over S control. Among the levels, all the three levels of Bentonite – S significantly increased the yield over S control and response was at par to gypsum and SSP. Highest grain yield was found under the treatment of 40-60 kg S ha^{-1} applied through Bentonite-S. In case of residual effect of S in maize-mustard sequence, application of S through different sources increased mustard seed yield over the S control and superior over 20 kg S/ha. Application of gypsum gave low residual effect than SSP and bentonite.

5.4 Molybdenum requirement of maize- niger sequence

- Information is limited on Mo deficiency and its correction. So field experiment was initiated at RARS, Chintapalli in a Mo deficient acid soil to know the direct and residual effects of Mo in maize-niger cropping system at high altitude zone. Results indicated that foliar spray of 0.1 per cent sodium molybdate after applying lime to soil initially proved to be better in increasing in the yields of maize (37%), while in rabi soil application of 0.25 kg ha^{-1} sodium molybdate to maize and niger after liming the soil was found beneficial in niger and showed a yield response of 40 percent. Significant difference in Mo content and built up of Mo in the soils was recorded with Mo levels .

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5.5 Integrated nutrient management for different cropping systems and effect on quality

- In Ustipsamment of Badaun, the optimum dose of Zn fertilizer rice (cv. PD-10) was found 5.83 kg Zn/ha. Application of Zn improved yield attributes, seed yield and oil content in following mustard (cv. Kranti). Application of Zn increased the grain yield of rice and also increased protein and amylose content of milled rice. In Pearlmillet - wheat rotation, application of 2.5 kg Zn +5 tonnes FYM ha^{-1} gave highest yields. Applications of zinc (2.5 kg Zn ha^{-1}) together with 5 tonnes FYM ha^{-1} were much effective in increasing grain yields in Pearl millet-wheat system. Under rice-wheat rotation,. application of 2.5 kg Zn + 5 t FYM ha^{-1} after two crop cycles was found optimum.

- In a 3 yrs study, fertilizer use efficiency of Zn-using low doses of organics in rice-wheat rotation in Mollisol of Tarai indicated that application of Zn @ 1.25, 2.5 and 5.0 kg Zn enriched to 200 kg cow dung ha^{-l} increased the pooled grain yield of rice significantly by 17.62, 26.06 and 24.32 per cent over NPK control, respectively. No significant response of Zn application was recorded on the subsequent wheat crop**.**

- Field studies to develop IPNS technology for ameliorating zinc deficiency in sugarcane ratoon system at Bareilly showed that total millable cane yield of both main and ratoon crop was significantly higher on application of 2.5 tonnes PMC along with 5.5 kg Zn ha^{-1} . The yield was statistically at par with the highest millable cane yield recorded for treatment receiving 10 tonnes PMC + 11 kg Zn ha^{-1} .

- Soil application of borax at 0.25 to 1.0 kg B ha^{-1} to maize significantly increased the grain yield in over NPK. Application of 1.0 kg B ha^{-1} to each of maize and groundnut crops gave significantly higher yield and showed higher buildup in the available boron in the soil.

- Ludhiana center observed a significant seed yield increase of Holea sarson from 140-220 kg ha-I (10.9 15.6%) to the application of 20-40 kg S ha^{-1}. Lentil also showed significant response to sulphur in sandy loam soils and gave 92 to 119 kg ha^{-1} (11-15%) extra grain yield with the application of 20-40 kg S ha^{-1}. Similarly in Haryana chickpea showed response to S application, in Hisar and gave 147 to 197 kg ha^{-1} (10-14%) extra grain yield. In medium black soils of Kheda districts chickpea gave 80-458 kg ha^{-1} (11-26) extra grain yield with the application of 20-40 kg S ha^{-1}.

- In Coimbatore application of FYM @ 12.5 t ha^{-1} recorded the highest grain yield of 5483 kg ha^{-1} and it was on par with the addition of sewage sludge @ 2.5 t ha-1+ FYM @ 12.5 t ha^{-1} and sewage sludge @ 2.5 t ha^{-1} + raw coirpith @ 12.5 t ha^{-1}. The micro nutrient availability ranged in the order of Mn > Fe > Cu > Zn. Deficiency of Zn was noticed in all the treatments. The heavy metal availability in the post harvest soil showed non-toxic level irrespective of metals analyzed**.**

Optimizing Zinc Requirement of Medicinal plants

- Root and seed yield of Ashwagandha increased from 363 kg ha^{-1} in control to 595 and 517 kg ha^{-1} respectively with soil application of 5.5 kg Zn ha^{-1}. Minimum seed yield of 232 kg ha^{-1} was recorded in the control plots. Root yield increased significantly with the application of zinc either through soil or foliar sprays over the control. Increase in yield was recorded up to 63.9 % with the soil application and 23.69 % with foliar spray of zinc. Foliar application of 0.2% $ZnSO_4$ had increased the root yield but it was on par with the soil application of zinc by 10 kg ha^{-1}. Soil application of zinc resulted in higher seed yield compared to foliar application of zinc.

- Mentha (Tagetes minuta) is an important medicinal plant. Application of B and Zn significantly increased the dry matter yield of mentha but effect of S application alone was statistically not significant. The conjoint application of two nutrients together or all three nutrients also resulted a significant increase in the dry matter yield over the control..

- Zinc application (5 kg Zn ha^{-1}) increased the oil yield of Tagetes minuta significantly by 45.0 and 41.6 per cent over control. Oil yield was highest (78.7 to 84.8 kg ha^{-1}) in treatment receiving or Zn + B. Oil yield is related to Zn./B ratio in plant tissue but no significant relationship was noted with either Zn/S or B/S. This indicated that the balance of Zn and B in the plant tissue of Tagetes minuta played a determining role in governing oil yield and Zn/B value around 1.09 to 1.23 resulted in the highest oil yield.

5.8. Front line demonstration

- More than 120 FLDs were conducted to show responses of zinc, iron, boron, manganese on oilseeds, pulses and major cereal crops in different agro-ecological zones. Application of 5-10 kg zinc/ha, 1.0-1.5 kg boron /ha and 20-40 kg sulphur/ha was found optimum and is widely recommended to the farmers.

Table 5.2 Crop response to boron fertilization in field trials conducted on different soils.

Crop	No. of trials	kg grain /kg B added	Per cent response over NPK
Rice	107	384	16.6
Wheat	35	468	15.1
Maize	5	684	32.5
Chickpea	7	420	44.1
Lentil	4	298	18.6
Groundnut	11	144	9.9
Sesame	5	108	23.9
Mustard	15	320	32.8
Sunflower	3	660	35.2
Cotton	2	312	11.6
Average	194	380	24

- Spectacular response of cereals, pulses, oilseeds and cash crops to B application (0.5-2.5 kg/ha) have largely been observed on B-deficient soils of Bihar, Orissa, West Bengal, Assam and Punjab. The rates of B application for achieving optimum yield varied with crops, season, type of soil. Mustard, maize, sunflower, onion and lentil gave optimum yields at 1.5 kg/ha. of B application and that of kharif (summer) crops groundnut, maize, onion, yam bean and blackgram gave the best yield at 2.0-2.5 kg B/ha. Application of 2.5 kg B/ha causes reduction in yield due to boron injury

Screening crop cultivars to tolerance of manganese deficiency

- Deficiency of manganese in wheat is rapidly spreading in coarse textured alkaline soil having low organic matter content. Soil application of 20-50 kg Mn/ha is the optimum, but is highly uneconomical as compared to 2-3 foliar sprays of 0.5-1.0% manganese sulphate solution at weekly interval.. The response of wheat and other crops to foliar sprays ranges from 200-3000 kg/ha over NPK. Most often manganese application decided entire failure or success of crop production in about 1.5 lakh hectares area Data in Table 6.3 showed that tolerant cultivars need less number of foliar sprays of manganese as compared to susceptible cultivars of wheat..

Table 6.3 . Relative tolerance of wheat cultivars to foliar sprays of manganese sulphate

Cultivars	**No. of sprays**	**Grain yield, t /ha**				
		0	**1**	**2**	**3**	**Mean**
PBW 34	Susceptible	1.28	1.96	2.39	3.15	2.19
HDS 2285	Susceptible	1.87	2.95	3.61	4.30	3.43
Mean	Susceptible	1.58	2.46 (57)	3.00 (90)	3.73 (136)	2.81
WL 2265	Tolerant	4.12	4.29	4.75	4.79	4.49
HD 2329	Tolerant	4.15	4.78	4.98	5.11	4.73
Mean	Tolerant	4.14	4.54 (10)	4.87 (18)	4.95 (20)	4.56

Nutrient Interactions

- Cultivation of medicinal plants is increasing due to high profit in foot hill tarai soil. Studies showed that Zn and S fertilization significantly influence the yield quality of produce menthol. The highest content of menthol but the lowest level of menthane and menthyl acetate was recorded under the treatment combination of 10 kg Zn+ 20 kg S ha^{-1}. The response of green gram to multi micronutrient application indicated that the highest grain yield of mustard (1357 kg ha^{-1}) was recorded by use of 5 kg Zn + 40 kg S ha^{-1} in mollisol.

Efficacy of Multi Micronutrient Mixture in Improving Crop Production

- Multi micronutrient mixture grades for foliar and soil application were prepared in the laboratory equivalent to Govt. recognized grades for their testing in important crops under different agro-climatic situation of the Gujarat. Network studies in general indicated the superiority of different grades in increasing crop yields. Amongst the foliar grades, Grade – II (for Fe deficient soils) and Grade – IV (For Zn and Fe deficient soils) were found more effective in most of the crops of various groups viz., cereals (maize, sorghum, bajri and wheat), vegetables (potato, cabbage okra) and pulse like pigeon pea. The soil application Grade–V was also found more useful in oilseed like castor and mustard and found equally effective with foliar Grades–II and IV to cereals crops (Table 7,1). Further, the general foliar grade (Grade – I) was also found effective in paddy and summer groundnut.

Table 7.1 recommendations on use of multi micronutrient mixture grades to farmers

Grade	Content of grade	Application time	Recommended for crops
I	A. Foliar grade (Application @ 1 %)General for all soils **(Fe – 2.0, Mn – 0.5, Zn – 4.0, Cu – 0.3, B – 0.5)**	15,30, 45 DAS	Summer groundnut
		15,30,45,60 DAT	Paddy
		20,30,40 DAS	Forage maize &Forage sorghum
		40,50,60 DAS	Potato
IV	For Zn & Fe deficient soils (Fe – 4.0, Mn – 1.0, Zn – 6.0, Cu – 0.5, B – 0.5)	15,30,45 DAT	Cabbage
		20,30,40 DAS	Bajri
		30,40,50 DAS	Okra & Wheat
		60,90,120 DAS	Pigeon pea
B. Soil application grade (Basal Application @ 20 kg ha^{-1})			
V	(Fe – 2.0, Mn – 0.5, Zn – 5.0, Cu – 0.2, B – 0.5)	Basal	Kharif Maize, Forage Maize, Okra, Castor, Mustard Paddy, Bajri

DAT – Foliar sprays days after transplanting, DAS – days after sowing

- Amongst the cereals, the maximum improvement in *kharif* paddy grain was recorded up to 766 kg ha^{-1} over control due to general foliar grade–I. In case of vegetables, potato tuber yield was increased by 8190 kg ha^{-1} equivalent to 22.6 % increase over control (362.5 q ha^{-1}) due to foliar grade–III .The multi micronutrient grades have also been found beneficial in increasing yield of oilseeds. The maximum increase was due to soil application of grade- V to the tune of 579 kg ha^{-1} over control (2091kg ha^{-1}) in castor .The increase in pigeon pea grain yield was by 436 kg ha^{-1} due to grade – IV over control (1250 kg ha^{-1}). These grades were also found effective in fodder crops viz. maize and sorghum .Thus, the use of multi micronutrient mixture foliar grade-IV at the rate of 1 % and soil application Grade–V @ 20 kg ha^{-1} have shown their usefulness in increasing yield of different crops in soils of Gujarat.

8.3 . Phytoremediation and Critical toxic concentrations in soil and plant tissues

- Studies to evaluate efficacy of different crop species for phytoremediation of cadmium contaminated soil indicated that spinach and marigold showed higher tolerance to Cd accumulation as compared to fenugreek and ladyfinger. Among the crop species tested, spinach appears to be the best for remediation of Cd contaminated soils although marigold merits attention because of its non-consumable nature. Considering 25% dry matter yield decrement was encountered, approximately around 15, 16, 14 and 13 mg kg^{-1} DTPA-extractable cadmium level was found critical for fenugreek, spinach, marigold and ladyfinger, respectively. A decrease of 25% in dry matter yield was recorded approximately around 20.41, 63.62, 72.09 and 24.82 mg kg^{-1} Cd content in plant tissue for fenugreek, spinach, marigold and lady finger, respectively (Table 8.1, 8.2). Response of French bean to multi level heavy metal contamination is shown in Fig 8.2.

Fig 8.2 Effect of heavy metal Pb, Pb+Cd, Pb+CD+Ni, Pb+Cd+NI+Zn on French bean growth in alfisol.

Table 8.1 Phytoremedation efficiency and upper toxic limits for cadmium at which biomass yield reduced by 25 percent in Mollisols of Pantnagar

Critical level	Element	Upper toxic limit at levels of FYM added, t/ha		
	Fenu greek	Lady finger	Spinach	Mari-gold
DTPA-Cd in Soil, ppm	15	13	16	14
Cd in Plant, ppm	20.41	24.82	63.61	72.09
Phytoremediation Efficiency : Marigold> Spinach> Lady finger> Fenugreek				

Table 8.2 Upper toxic limits of heavy metals (ppm) in French bean as influenced by addition of organic manure levels in mollisols of Pantnagar

Critical level	Element	Upper toxic limit at levels of FYM added, t/ha		
		0	5	10
Soil	Cd	6.7	8.0	3.4
Plants	Cd	6.4	10.3	3.0
Soil	Ni	6.3	7.8	4.5
Plants	Ni	24.0	16.0	13.0

9. Technology generated:

- Visual symptoms of micronutrients in cereals, oilseeds and pulses and vegetable crops have been characterized .
- Critical limits of zinc, sulphur boron, manganese and copper have been established for efficient diagnosis of nutritional disorders in plants.
- Delineated micronutrient deficient areas in different districts, states and agro-ecological zones of India and published soil fertility maps.
- More than 50 Maps of zinc, iron, manganese was published for the use of various agencies.
- Nutrient indexing revealed that deficiency of zinc is declining in soils of Punjab, Haryana, Gujarat, Part of Uttar Pradesh, Andhra Pradesh and Tamil Nadu while the deficiencies of boron, iron, manganese, multi- nutrients are emerging in some soils and crops.
- Technology for optimizing the use of zinc , boron, iron, manganese, sulphur deficiencies have been developed for rice- wheat, maize- mustard/wheat cotton- wheat, maize-raya, sesame- chick pea, soybean-wheat, bajri-mustard, sorghum-wheat, rice-rice, oilseed based cropping systems for different soils.
- Micronutrient Seed treatment technology has been developed for enhancing fertilizer- use-efficiency (FUE) and reducing input cost and rate of fertilizer zinc application in important crops like maize, soybean, groundnut, wheat, rice, moong grown in marginally deficient soils.
- Foliar feeding for iron and manganese for important crops has proved efficient and economical than their soil application.
- Sulphur deficiency in oilseed, pulses, cereals crops has been characterized and critical levels were established for diagnosing nutritional disorders in plants.
- Technology for correcting sulphur deficiency in several crops and cropping systems using fertilizers, mine minerals, industrial by-products, organic manures and crop residues has been developed and is being widely adopted.
- IPNS technology comprising 8-10 t/ha farm yard manure, green manure, crop residues, 3-5 t/ha poultry manure, 1.5 – 2.5 t/ha piggary manure has been found efficient as that of 5.5 kg zinc/ha alone. IPNS approach enhances the fertilizer use efficiency by 10-25% of zinc,

manganese, iron to different cropping systems and helps in mobilizing nutrient from native soil pools.

- Organic manure enrichment with micronutrient is found good for reducing input cost and correcting zinc deficiency in soils and environment.
- More than 120 FLDs were conducted to show responses of zinc, iron, boron, manganese on oilseeds, pulses and major cereal crops in different agro-ecological zones. Application of 5-10 kg zinc /ha, 1.0-1.5 kg boron /ha and 20-40 kg sulphur/ha is found optimum and is widely practiced by the farmers.
- Durum wheat cultivars were found more susceptible to manganese deficiency and needs 3 spray of 0.5-1.0 % manganese sulphate solution compared to aestivum wheat which needs one spray in manganese deficient soils.
- Monitored heavy metal pollution through sewage, industrial effluents in peri urban areas. Mixed sewage with industrial effluent is found more polluting soils than sewage or treated industrial effluents. Technologies are being generated for efficient use of city solid and sewage wastes and industrial effluents in agriculture with minimal environmental pollution .
- Estimated the micronutrient supply needs, efficiency and policy issue, future requirements by 2020 for Indian soils and crops. Published Report of Task Force on Micronutrient in collaboration with Ministry of Chemicals and Fertilizers for its implementation .

AICRP on Optimizing Groundwater Utilization Through Wells and Pumps

1. Title of the Project : All India Coordinated Research Project on Optimizing Groundwater Utilization through Wells and pumps

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3. Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):

Theme-I: Regional groundwater assessment and modeling

- Groundwater simulation models for various tracts of Punjab state were developed for simulating the groundwater behaviour using Prickett Lonnquist Aquifer Simulation Model (PLASM). The effect of shifting 5,10,20 and 30 per cent of paddy area with cotton, maize and groundnut in the ratio of 3:1:1 was found to be effective. It was found that after reducing paddy area, the decline of water table is arrested. The area under depth range of 10-15 m diminished from 48.38 to 47.42, 46.43, 44.11 and 41.62 per cent when paddy was shifted by 5,10,20 and 30 per cent respectively.

- The study in Bareilly district showed that the water table during pre-monsoon season in Majhagawan and Faridpur blocks was found to be declining, while in Richha and Shergarh it was on rising trend during the period 1991 to 2001. The water table remained almost constant in alampur, Ramnagar, Baheri, Bhutah, Bhadpura, Bithrichainpur, Nawabganj, Fatheganj, Kiyara, Meerganj and Bhujipura blocks during the same period.

- The groundwater study conducted in Budaun District of Uttar Pradesh revealed that the water table is rapidly declining about 25 cm per year. Out of 18 blocks of the district, 12 blocks were identified as the main problematic areas where the condition of groundwater mining is prevailing. On the basis of the prevailing soil and water conditions areas, water conservation measures were suggested to overcome the problem.

- A correlation was developed between spring discharges and storm occurrence through dynamic modeling for the prediction of spring discharge during different months of the year for two pernnial natural springs of Uttarakhand, the Hill Campus and Fakua springs. The time variant linear dynamic models for monsoon season were found to be more suitable models than annual models.

- A mathematical model namely Rational and Power was developed on the basis of best fit regression analysis for estimating present day spring discharge from previous day observed discharge in Tehri Garwal Region of Uttarakhand and was tested with Kolmogorov Smirnov test. These models recommended to be used for planning and designing of water harvesting structure for irrigation purpose.

- Groundwater survey in Ramganga-Behgul interbasin of Uttar Pradesh revealed that 6 blocks were under safe category, 6 blocks under semi critical category, 7 blocks under critical category and as many as 6 blocks under overexploited category.

- Water resources planning and management in Bijnor district using remote sensing and GIS presented a synoptic view of the geo-morphology and identified different land forms of the district.

- Characterization of Haveli fields and estimation of Haveli areas was successfully done with the help of Remote Sensing satellite data. It has been observed that each Haveli field contribute 4 to 6 mm per day for 90-100 day in the rainy season resulting into 40 to 60 cm percolation from the entire Haveli track which is mainly responsible for rich ground water reservoir in the black soil regions of central Narmada Valley. The Haveli area has been decreasing year by year which is cause of worry for the ground water reservoir.

Theme II: Conjunctive use in canal command areas

- The study conducted in the canal command of Bhojipura distributary canal system, by Pantnagar center recommended by allocating 6586 ha under wheat, 3572.87 ha to lentil, 408 ha to potato, sugarcane (3563 ha) and mentha (369 ha) in rabi seasons and 6931 ha to paddy crop, 4005 ha to maize, in kharif season gave the net return of Rs 6084.55 lakhs which is nearly 39.06 per cent more than existing cropping pattern.

- The study conducted at Nazare Irrigation project, Maharashtra by Rahuri center revealed the potentials of Remote Sensing and GIS techniques and simulation and optimization modeling in obtaining the solution to the complex situation in water management and thereby promoting efficient use of land and water resources. More net benefits are obtained when crop area restrictions are removed; areas are allocated to few crops only; the net benefits increase with the irrigation interval; the net benefits per unit area decreases with the irrigation interval; and benefits are obtained when water is delivered according to crop, soil and location of the unit in the command area than the fixed depth approach.

- Detailed water balance study has been conducted in command area of Rani Awanti Bai Sagar Irrigation project. Pre monsoon & post monsoon water table observation were collected from 186 open wells, spreads over 1.57 lakh hectare command area situated in Jabalpur & Narsinghpur district. Data was systematized and analysed for trends of water table for last 17 years. Detailed investigations were carried out for characterizing soil, water, crop and canal water resources. It was found that canal water and well water should be used in 60:40 ratios to maintain the dynamic equilibrium of the groundwater reservoir. Groundwater model with simple water budgeting predicted that existing wells in the command should be made operative.

- The output of the model developed at Jabalpur center for conjunctive use of canal and groundwater in Bargi LBC command shows that the proposed plan arrests the water table rise (1.50 m) and if continued for three consecutive years the water table goes well beyond the root zone depth (4.5 m).

Theme III: Artificial groundwater recharge studies

- Artificial groundwater recharge studies in confined aquifer at Ludhiana Centre revealed the technique of recharging groundwater through the strainer tube well with sediment-laden water was not suitable since it resulted in the reduction of usable life of tubewell significantly. The center recommends the implication of this technology in artificial groundwater recharge.

- Studies on artificial groundwater recharge by harvesting rainwater through rooftops at Ludhiana center revealed initial sediments up to 6 ppm were found whereas pathogens were not traced in the rooftop runoff. The cost of various sizes (50 m2-400 m2) of rooftop rainwater harvesting structures was estimated. The technology is ready to be adopted by individual householders, Government agencies, Institutions etc.

- Regression models have been developed and validated for estimation of water table fluctuation, recharge, distance up to which the influence of percolation tank exists etc., at Jabalpur center for different percolation tanks in hard rock zones.

- At Rahuri center under the study of development of the model for groundwater recharge through percolation tank, DEM, Land use/land cover map, land capability map, hydrologic soil group map and hydro-geomorphologicl and groundwater potential map etc., were prepared using soil map, topographical map and IRS-IC, 1D- LISS-III and Panchromatic satellite data. Regression models have been developed and validated for the percolations tanks under study.

- The total recharge from the Shingave percolation tank was 94 percent of the total estimated inflow into the tank. The influence of the percolation tank in recharging the well was up to 888 m. Studies indicated if the resources are optimally used, 188 ha of land could be brought under irrigation generating the income of Rs 28410 per hectare.

- The influence of the percolation tank of capacity of 69.6 ha m at Pimpalgaon, Ujjaini (Maharashtra) was found up to 875 m. The estimation of groundwater recharge and draft over the period of observations indicated that the groundwater draft from the area is 15 times more than the groundwater recharge indicating the excessive mining of groundwater.

- Water balance of Karonda tank (Maharashtra) results into average percolation of 316.2 m3/day during dry season (38 SMW onwards). Out of total storage of 79,636 m3 of water in Karonda tank about 10% percolates down for recharging the groundwater.

Theme IV: Groundwater pollution

- The study at Rahuri center on assessment of distribution of groundwater pollution and soil pollution in sugar factory area it was observed that the deterioration of groundwater quality near the lagoons was due to the presence of Mg++, Na++, HCO3, CO3, and C1. The analysis of the well water and soil samples from the study area showed that as the distance from lagoon increased, the quality of groundwater and soil improved. As per the results on an average 835.20 ha area was found highly polluted in respect of EC & pH during the summer season. After monsoon the polluted area was seen reduced by 14.2%.

- From the study under taken at Jabalpur center on soil aquifer treatment (SAT), it was found that clay soils are more impaired after sewage treatment, and loamy sand soil is found to be the best as capacity of treatment is concerned. This percolates sewage water at a rate of 22.5 cm per day. Drying for 10 days and again wetting the soil for treatment gives better result than continuous wetting. It is also found that as the soil depth increases, quality of water improves further in terms of pH, EC, TDS, BOD, DO, turbidity, calcium, phosphates, chlorides, and bicarbonates.

- The model DRASTIC (Depth to water table, Recharge, Aquifer media, Soil media, Topography (slope), impact of vadose zone, hydraulic Conductivity of aquifer) was used in order to assess the groundwater pollution potential of Ludhiana district. Aquifer media, soil media thematic maps for the period from 1995 to 2002 were prepared. Thematic maps of impact of vadose zone, hydraulic conductivity parameter and Nitrate Pollution Potential Index (NPPI) were also prepared.

- Groundwater pollution study by Poondi center showed that most of the water samples of Vellore district of Tamil Nadu fall in medium salinity group that can be used for irrigation with some precautions. Reasonable water samples have magnesium toxicity that needs special attention; otherwise the groundwater of the areas is of good to marginally accepted quality from irrigation point of view.

Theme V: Water lifting devices.

- At Ludhiana center, a propeller pump has been designed for operation using 35 hp tractor at 3.5 m head. Also a split flap type valve for protection of centrifugal pump was developed. The split flap valve is to be fitted on the delivery pipe any where in between the pump (preferably near the pump) and the delivery point and was tested in farmers field.

- Performance evaluation of hydraulic ram for different lengths of drive pipe, weights of waste valve and delivery valve was taken up at Pantnagar center and suitable dimensions have been decided. Empirical relationships were developed among L/D ratio, weight of waste valve and maximum discharge, beat frequency, weight of waste value and maximum discharge for 5 cm x 2.5 cm hydram. Similarly relationship has been found among weight of waste valve, weight of delivery valve and discharge for 10 cm x 5 cm hydram.

- Field evaluation of irrigation pumping Units were taken up at Jabalpur center to make status survey of irrigation pumps for evaluation of operating efficiency; to identify deficient pumping units and analysis of causes of efficiency deterioration; rectification to improve the operating efficiency at selected sites and testing of pumping units after adopting rectification measures. It was observed that 6% of the total energy is lost due to excessive suction head and 10% due to poor maintenance and poor foundation each. It has been concluded that approximately 10% pumps are affected by each of the above problems. It is clearly depicted from the following projection that a considerable amount (2.5%) of total energy consumption in the entire state (MP) is being lost. It was also observed that discharge of pumps varied from 4.48-12.07 1ps, while the efficiency ranged between 16.10% to 56.80%. Jabalpur center has developed some fishing tools for tube wells and are working successfully.

- Although the center of AICRPs have done good technology transfer work. Documentation of research results was also satisfactory. The centers timely submitted Annual Reports and Audit Utilization Certificate. However, the quality of research work in terms of interpretation and presentation of results and relevance of the work to the emerging water management issues of the area remained major weaknesses. In order to improve the performance, these centers need to identify major issues of immediate concern in their area of jurisdiction. After identification of researchable issues, research projects may be proposed to devise short-, medium-, and long-term strategies to solve the problems. Centres should promptly submit desired information to the Coordinating Unit to smoothen the monitoring and coordination. Connecting the centers through internet will help improve the coordination and monitoring of the project. Efforts are urgently required for documenting research data in the journals of International and National repute.

All India Coordinated Research Project on Water Management

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3. **Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):**

Assessment of water availability at regional level and device interventions for matching water supply with the agricultural production systems demands.

- Assessed water demand and supply at distributary/minor/sub-minor levels in different reaches of 18 command areas of India located in different agro-ecological situations. Crop plans/cropping systems have been suggested for existing supply situations and canal rescheduling suggested for proposed cropping systems. Proposed crop plans and rescheduling of canal systems help bringing 22-28% additional cultivated area under irrigation. Proposed cropping systems have the potential to enhance farm productivity by 17-27% and net income by 20-30% in different agro-ecological situations.

- Water supply and demand scenario for entire state of Haryana with reference to existing and modified cropping patterns was assessed. Gap between water supply and demand in south-western parts of the state is much wider than North-eastern and Central Haryana. In different parts of the state it has been shown that the productivity of major crops was increased by 20-25% by adopting water-use efficient cropping systems proposed by Hisar center.

- Developed canal delivery schedules for different reaches in commands of arid, semi-arid, sub-humid and humid situations of the country to be operated by Water Resources departments. Proposed canal delivery schedules ensure crop water demand and help in equitable distribution of water in different reaches. Also moisture available for subsequent timely sown crop is ensured with modified operational schedules.

- Developed water management technologies/strategies to suit water supply situations in different command areas. Alternate crop plans for existing water supply situation are suggested in Mula, Malprabha, Jayakwadi, Chambal, Lower Bhavani, Ramnagar and Tawa command areas. Proposed alternate crop plans help enhance crop plans help enhance crop productivity by 15-20% in kharif and 21-27% in rabi season.

- The water management technologies consisting of optimum irrigation schedules, proper land-layouts, appropriate method of irrigation and judicious use of other production inputs such as quality seeds, adequate and balanced fertilizers and plant protection measures have been demonstrated through on-farm research programme of the project in 18 canal command areas in entire country, two tube-well command areas, one tank command area. Results showed that improved water management practices increase 15 to 37% crop yields and save 28 to 40% irrigation water. This water saving can help enhance irrigated area by 15 to 17%. It is estimated that the improvement water management technologies can be used on 10.3 Mha area in the country. Moreover, similar results were achieved in high rainfall and hilly areas adopting related important water management technology parameters.

Design and of evaluation of gravity and pressurized irrigation systems>

- Techno-economic feasibility of drip irrigation in fruits and vegetable crops and high water requiring cash crops such as sugarcane and banana has been established in arid and semi-arid regions of the country. Drip irrigation technologies were evolved suitably along with other inputs for old established plantation crops and orchard crops. Benefits of drip irrigation wereobtained in terms of 20 to 40% water saving, 15 to 20% yield increase.

- Drip fertigation technology has been developed refined and standardized for cash crops such as sugarcane, cotton, banana, groundnut, fruits and vegetables in different agroclimatic conditions of the country. Drip fertigation saved 20 to 40% irrigation water, 25 to 50% of N and K fertilizers and obtained 17 to 25% higher yield over surface irrigation.

- Developed drip irrigation technology to suit its adoption in intensive cropping systems without winding-up the drip irrigation system. This system is successfully demonstrated and deployed on farmers fields in Tamil Nadu and Karnataka states.

- Developed low cost drip irrigation systems which work efficiently with low energy requirements (LEPA) for adoption in plantation crops in place of micro-sprinklers. KAU micro-sprinkler developed by Chalakudy center has tremendous demand in Kerala and Tamil Nadu state. New device requires 0.3 to 1.0 kg/cm2 pressure, less than one HP pump, less clogging susceptibility, more univorm distribution and 50-60% less cost than conventional micro-sprinkler systems. This low cost micro irrigation system was proved to be highly effective in homestead farming in Kerala state.

Management of rain and other natural sources of water

- In hilly and high rainfall areas, technologies have been developed for in-situ conservation and carry-over of moisture for succeeding rabi crops. Improvement in hydrothermal regimes has been achieved by use of organic mulches. Water harvesting technology and measures to improve productivity of harvested water has been developed.

- Developed technologies for inter and intra-terrace water harvesting and enhancing the productivity of harvested water in agricultural production systems in hilly areas of Himachal Pradesh. Use of Silpauline lining the ponds has attracted the attention of planners and government departments in Himachal Pradesh, Uttarakhand, Maharashtra and Meghalaya states.

- Developed technology of micro level water harvesting (Jalkund) for inter-terrace water harvesting and its reuse for establishing high value mango and cashew orchards in Konkan region of Maharashtra. Technology is spreading at a very fast rate with the support of Maharashtra state government.

- Development technologies for conservation, harvesting and efficient use of available water through natural springs (Kuhls) in rice, maize and wheat based cropping systems; and in integrated farming systems in HP and Uttrakhand states. These technologies increase crop productivity by 15-20% ensures timely sowing of the crops. Efficient water management in integrated farming systems enhances water productivity from 3.0 to 8.6 Rs/m3.

- Developed the resource conservation technologies, which helped enhancing water, nutrient and other input-use efficiency in maize-wheat, soybean-wheat and rice-wheat systems in sub mountainous Himalayan conditions. Zero tillage in rice-wheat cropping system along with optimum irrigation schedules enhances crop yield by 10-17%, ensures timely sowing of wheat and increases water-use efficiency of the system by 25-30%.

Basic studies on Soil-water-plant-atmospheric-environment relationships

- Determined wate requirement, stage-wise crop co-efficient and critical growth stages of 15 cereals, 7 pulses and 5 oilseed crops under different agro-ecological situations using Lysimeter technique.

- In high water-table areas, contribution of ground water table towards crop evapotranspiration has been quantified and irrigation water requirement is considerably reduced. Critical water-table depths have been quantified for different crops under different agro-climatic situations. In different crops studied, 30-40%, 20-22% and 5-8% contribution of water-table towards crop ET was observed under shallow, medium and deep water-table conditions on varying textural soils, respectively.

- Leaching requirement of different soils was studied to leach out the salts from root zones. At Hisar Bathinda and Sriganganagar, leaching requirements were quantified alongwith gypsum requirement on silt loam, sandy loam, silt clay loam and sandy clay loam soils. At Chiplima, Gayeshpur and Jorhat centers drainage requirement quantified alongwith lime requirement on sandy loam and sandy clay loam soils.

- The specified techniques/agro-techniques to ameliorate irrigation induced saline and waterlogged soils were evolved in different command areas of the country. Technologies consisting preventive and ameliorative measures have been deployed on farmers fields. Green manuring by susbenia @ 20 kg seeds/ha was found to be highly effective on all textured soils. Use of sulphonated press mud for amelioration of irrigation induced saline and waterlogged soils resulted in fast reclamation of clay and clay loam, soils.

Water management in different agricultural production systems including horticultural and other high value crops

- Optimum irrigation schedules have been developed for major cereals, pulses, oilseeds, vegetables, fruits, spices, cash crops, fodder crops, aromatic and medicinal crops, and cut-flowers in relation to optimum nutrient, tillage, mulches and other input requirements. Efficient water management technologies for 14 agro-ecological regions consisting of optimum irrigation schedules, optimum depth of irrigation, proper irrigation methods, soil-specific land layouts and judicious use of associated inputs for 35 cereals, 12 pulses, 8 oilseeds, 20 vegetables, 6 plantation, 4 spices, 8 medicinal & aromatic, 5 flowers, 5 forage and 10 cash crops.

- Identified water-use efficient cropping systems and intercropping systems for different soil types in consideration with socio-economic needs and marketability of the produce. Water requirement of different intercropping systems have been evaluated under optimum, sub-optimum and sub-sub-optimum levels of water availability. Suggested best intercropping options for varying moisture availability. Suggested best intercropping options for varying moisture availability in ten agro-ecological zones of the country.

- Developed irrigation schedules for crops and cropping systems for shallow, medium and deep water-table conditions in humid and per-humid climatic situations. Water-use efficient rice-based, sugarcane-based, soybean-based, cotton-based and maize-based cropping systems suggested for optimum, sub-optimum and sub-sub-optimum water availability situations in view of their social relevance in different agro-ecological situations.

- Design specifications of various surface irrigation methods like border-strip, furrow and check basin have been standardized under varying soil and agro-climatic situations in water scarcity areas. Irrigation in alternate furrows has produced encouraging results and need to be practiced for wide-row spaced crops in Punjab. Alternate furrow irrigation in maize-chickpea cropping system saved 35% irrigation water on black clay soils at Belvatgi. Method has become highly popular in North-Karnataka. Alternately alternate method of irrigation with high SAR waters developed by Bathinda center received attention of the farmers of Central Punjab.

All India Coordinated Research Project on Weed Control

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3. **Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):**

Weed survey & surveillance

- District wise distribution of major weeds in India documented and published.
- Resistance to isoproturon in *Phalaris minor* noticed in parts of Haryana and Punjab. Clodinafop 60 g and sulfosulfuron 20 g/ha were found effective in controlling isoproturon resistant *P. minor*.
- Infestation of *Malwa pariflora, Rumex retroflexus, Poa annua, Cornopus didymus* and *Polypogon monspliensis* is increasing in rice-wheat cropping zone.
- *Ipomoea pestigridis* has become a serious weed of sugarcane in Haryana and U.P.
- *Leptochloa chinensis* in rice, *Rumex acetosella* in wheat and *Solanum* sp. in potato are spreading.
- *Parthenium* earlier a road side and wasteland weed is spreading into field and plantation crops.
  Tsunami hit shores of Kerala were surveyed to explore the surviving weeds *Cyperus javanicus, Ipomoea pes-carpe, Acanthus ilicifolius, Acrostichum aureum* were the weeds which survived the killer waves.

IWM in cropping system

- In rice-rice sequence, pretilachlor 0.75 kg or butachlor 1.25 kg/ha in *kharif* rice and butachlor 1.25 kg + almix 4.0 g/ha were effective in weed control and produced higher yields.
- In maize-groundnut system, atrazine 0.75-1.0 kg in maize and two hand weedings in groundnut was most effective.
- At Jorhat and Bangalore in rice-rice sequence application of butachlor + 2,4-D rotated with pretilachlor recorded the lowest weeds and higher yield in rice.
- Long term tillage experiment in millet-sunflower system at Bangalore revealed that adopting zero tillage continuously, zero tillage followed by conservation tillage
- Based on the four years results it was concluded that minimum tillage proved better than other tillage practices in respect of weed biomass, grain yield and economics in pearlmillet-wheat system under alluvial soil conditions.

- In maize-wheat system (Palampur) zero tillage in maize and conventional tillage in wheat in combination with atrazine in maize and clodinafop fb 2,4-D in wheat increased the yield of both the crops.
- At Jorhat in rice (DS)-blackgram system, conventional-conventional tillage system in both the crops was superior in reducing weeds and producing higher yields.
- In maize-sunflower system at Coimbatore and Hyderabad conventional-conventional tillage system reduced the weeds effectively and obtained higher crop yields.
- In rice-wheat system, at Pusa conventional and bed system was superior to zero tillage system. At Hisar minimum-zero tillage and at Raipur no significant influence of tillage treatment was noticed.
- Soil solarization in summer months was effective in reducing weed flora and obtaining higher yields in maize-groundnut, bajra-wheat, brinjal-peas, okra-tomato, okra-wheat, rice nursery, baby corn, sunflower-okra.

Long term herbicide trial

- At Anand, in the permanent herbicidal trial, potato tuber yield was not significantly influenced by different weed management practices. However, the highest potato tuber yield was recorded under application of fluchloralin (1.00 kg/ha) enriched with 10 t FYM/ha. Dry crop biomass was also higher under same treatment. Grain yield of succeeding pearlmillet crop was also not significantly influenced by continuous application of fluchloralin @ 1.00 kg/ha with or without 10 t FYM/ha.

- Pre-emergence application of butachlor 1.0 kg/ha +2, 4-D 0.5 kg/ha with addition of organic manure @ 5 t/ha in rice and application of isoproturon 1.0 kg/ha + 2,4-D 0.5 kg/ha rotated with pre-emergence application pendimethalin 1.0 kg/ha in wheat in rice-wheat cropping system, at Raipur,

- At Sriniketan, butachlor @ 1.0 kg/ha at 3 DAT fb. post-emergence application of 2, 4-D (Na) or 1 HW at 30 DAT or Pretilachlor @ 1.0 kg/ha at 3 DAT fb. post-emergence application of 2, 4-D (Na) or 1 HW at 30 DAT in rice ; rotational application 1.0 kg Pendimethalin/1.0 kg Isoproturon (pre-em) in mustard.

IWM in individual crops

Rice:

- Drum seeding of rice along with *sesbania* in alternate rows was found effective in reducing weeds at Bangalore and Coimbatore.
- In upland rice, intercropping with cowpea and application of butachlor 1.05 kg/ha was effective at Banaglore , Palampur, Jorhat, Pusa, Ranchi centres.
- Transplanted rice, almix 4 g/ha and Oxadiargyl 70 g/ha were best herbicides at Pusa, Jorhat, Raipur, Hyderabad, Banaglore.
- In direct seeded rice, intercropping of *sesbania* was effective in lowest weeds at Bangalore, Gwalior, Jorhat, Dapoli, Sriniketan, Palampur.

Maize

- In maize, intercrops like green gram, soybean, cowpea were found to reduce weeds at Anand, Palampur, Banagalore, Dharwad.

Sugarcane

- Pre-emergence application of metribuzin or Ametryn with two hoeings was effective at Pantnagar, Kanpur .

Pigeonpea

- Pigeonpea + soybean with metolachlor was the most productive system at Gwalior.

Potato

- Metribuzin 0.5 kg/ha followed by earthing up produced higher tuber yield at Gwalior, Palampur, Pantnagar, Sriniketan.

Management of parasitic weeds

- In lucerne farmers practice (weeding at 30 DAS and after each cut) and pendimethalin 0.5 kg/ha post-emergence controlled cuscuta and produced higher fodder yield at Hyderabad.
- At Parbhani, in soybean Pursit 150 g/ha controlled cuscuta and higher yields were obtained.
- In niger crop at Bhubaneswar, *cuscuta* was controlled with trifluralin 2.5 kg/ha.
- *Orobanche* weed population markedly declined with application of trifluralin 1.5 kg/ha in mustard at Gwalior.

Screening of Competitive crop cultivars

Crop	Centre	Weed competitive varieties
Rice	UAS, Bangalore	KRH-2, BR-2655 IR-30864
	AAU, Jorhat	Bahadur, Mahsuri,
	TNAU, Coimbatore	White Ponni , ADT 46,
	VB, Sriniketan	MTU-7029, Annapurna
	KAU,Thrissur	C3-2-49,
	ANGRAU, Hyderabad	RNR 23064, Satya
	CCSHAU, Hisar	Govind, HKRH 1076
	RAU, Pusa	Prabhat,
	DBSKKV, Dapoli	Pusa Sugandha –3. Masoori and Karjat – 5
	IGKVV, Raipur	R-971-2515-2-1, medium group R-741-1-35-2-1 and late group R-630-1817
Groundnut	UAS, Dharwad	GPBD-4, Dh-53, Mutant-3, Dh-86 and JL-24

Soybean	JNKVV,Gwalior	Mahamaya and Kranti
	GBPUA&T, Pantnagar	PS 1092

Studies on herbicide residues

- Isoproturon, 2,4-D, butachlor, anilophos and sulfosulfuron over the years in rice-wheat cropping system did not leave residues in soil, grain and straw at Ludhiana.
- No detectable residue of isoproturon, butachlor, observed ever after continuous use of 15 years in rice-wheat system at Pantnagar.
- Herbicide residue were below detectable limits: isoproturon in wheat at Palampur, butachlor and 2,4-D in rice at Coimbatore, butachlor in rice-wheat system at Faizabad, butachlor in rice-rice sequence at Hyderabad.

All India Network Project on Biofertilizers

1. **Title of the Project : All India Network Project on Biofertilizers**

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3. **Research Achievements (New varieties/Technologies Developed/validated and being practiced in the last five years):**

- The mandate of the project is to enhance productivity, soil and crop quality and supplement a part of the chemical fertilizer needs of crops through exploiting the soil biodiversity extant, for Biofertilizers in diverse cropping systems and agro-ecological zones in India, improve Biofertilizer technology and extend the Biofertilizer applications to disadvantaged areas.

The specific objectives of the project for the XI plan period (2007-2012) are:

- To exploit the soil biodiversity in various agro-ecologies for biofertilizer applications in diverse cropping systems.
- To study the impact of resource conservation technologies on functional diversity of microorganisms involved in key microbial functions and soil health.
- Formulation and testing of mixed biofertilizers in diverse cropping systems.
- To improve biofertilizer technology with particular reference to quality, carriers, consortia and delivery systems.
- To diversify biofertilizer research and application in drylands, mountainous regions, tribal areas and other underexplored ecosystems.
- Research-Adoption-Impact continuum analysis of Biofertilizer usage

The brief achievements of AINP on BF in various thrust areas during 2002-2007 are as follows:

Microbial Diversity

- First complete survey of Madhya Pradesh for soybean nodulation and inoculant usage completed. IPNS interventions best for nodulation and yield. Diversity of soybean assessed through molecular markers.

- Soybean rhizobia much below the threshold required for optimum nodulation; reinforces need to practice regular inoculation to build up populations.
- Microbial Diversity of `Diara' and 'Tal' lands of Bihar assessed. One new nitrogen fixing *Azospirillum* spp. from maize rhizosphere producing black pigmentation identified.
- A strain of *Pseudomonas maltophila* as biocontrol agent against root rot pathogens.
- *Rhizobium* spp. identified as endophyte of wheat.
- New Phosphorus Solubilizing bacteria *Pseudomonas* isolated from Silent valley, Kerala.
- New Rhizobial isolate SOB-1 from groundnut crop from Solabanur, Tamlinadu.
- New spore forming nitrogen fixing bacteria has been isolated from rice rhizosphere.

Mixed Biofertilizers

- Mixed biofertilizers (BIOMIX) containing a consortium of N fixers, P solubilisers and PGPR found to promote the growth of cereals, legumes and oilseeds better and save 25% NP fertilizers in rice, chilli, cotton, pulses, soybean, groundnut. A specific mixed microbial consortium developed for groundnut. The response of biofertilizers was better when used along with chemical fertilizers.
- Mixed biofertilizers able to increase grain and fodder yield by 5% of pearrlmillet in dryland areas and save 25% NP fertilizers for pearlmillet, wheat and mustard. under FLD. This resulted in 15% increase in net return to the farmers.
- In soybean-wheat, total additional nitrogen uptake of 90 kg N/ha/yr due to use of *Rhizobium* (soybean) and *Azotobacter* (wheat) inoculants; additional total soil nitrogen accretion of 60 kg/ha/yr.
- Improved Nutrient use efficiency and produce quality of vegetables by biofertilization.

Biofertilizer quality

- Addition of 1- 2% humic acid to carrier based cultures enhanced the survival of bacteria.
- A new medium for co-culturing *Azospirillum lipoferum , Bacillus and Pseudomonas fluorescens* was formulated to get high titre.
- Incorporation of CMC at 2% in the *Rhizobium* and *Pseudomonas* concentrated cell broth, increased the cell viability in the concentrated culture slurry.
- Liquid inoculants formulated for *Rhizobium, Azospirillum* and *Bacillus* enhanced the shelf life of *Azospirillum* to 12 months in liquid inoculum (10^{11} CFU/ml).

- A filter paper disc method developed for inoculant quality determination based on gene marker.

- Incorporation of glycerol (1-5%), PVP (1-2% %) and arabinose (1%) in the media maintained higher cell load than control. . The population of *Rhizobium* TNAU 14 after 240 days of storage was 6 - 28 x 10^7 $ml^{-1.}$

- Liquid inculant of co-culture prepared by addition of 2% PVP supported titre of 10^9 cfu/ml upto six months. Similarly liquid inoculants were formulated for *Rhizobium, Azospirillum* and *Bacillus s*trains isolated from vertisols of A.P by using cell protectants like arabinose, trehalose, glycerol, polyvinyl pyrrolidone (PVP) in different combinations. It enhanced the shelf life of *Azospirillum* to 12 months in liquid inoculum (10^{11} CFU/ml). Similar type of results were obtained with *Rhizobium* and *Bacillus.*

Extending BNF applications

- Bioinoculants developed for tropical vegetables (brinjal, tomato, potato, onion, bean, cowpea, okra, carrot, yam, elephant foot yam, chilli, raddish) in acid alfisols of Orissa.

- BF technologies for tribal, hill and mountains, NEH and disadvantaged areas

- Biofertilizers developed for shallow, inceptisols for minor millets and niger in tribal areas of Dt. Dindori., M.P.

- PGPR strain effective in control of white rot of apple developed.

- Biofertilizers developed for crops grown in NEH region.

Research-Adoption-Impact Continuum evaluation

- Biofertilizer mother cultures supplied to dozen companies/production units. Extended consultancy to M/ Rishita Biotech, Hyderabad for setting up biofertilizer unit.

- Biofertilizer production units (set up by AINP-BF) at Coimbatore, Jabalpur and Parbhhani produced about 24 lakh packets.

- Technology generated for round the year homestead cultivation of *Azolla caroliniana.*

- A rapid composting technique of *Azolla* and green and brown manure evolved.

- Biofertilizers for vegetables convincingly demonstrated in tribal areas of Orissa.

- FLD's at 32 locations in Tamil Nadu showed increased yields of groundnut (5 - 21% over control, mean 18%) due to `Biomix' (*Rhizobium* + PSB) inoculation.

- FLD's on *Rhizobium* inoculation of summer groundnut gave 17-24% increase in pod yield. Overall increase in soybean yield varied from 23-33 per cent with mean of 30 %.