SOIL SCIENCE

Progress Report of Soil Science Coordinated Program

(*Rabi* and *Kharif* 2016)

SOIL SCIENCE

CONTENTS

5. SOIL SCIENCE

Summary

The coordinated program in soil science addresses issues related to sustaining productivity of soil and crop systems on long-term basis, yield gap assessment and bridging the gap from soil fertility point of view, germplasm screening and nutrient management in problem soils, screening for tolerance to soil acidity related problems, nutrient use efficiency and crop productivity under late planted conditions, monitoring soil quality and productivity under emerging systems of rice production and testing of computer based nutrient management tool for site specific nutrient management, testing of slow release N fertilizer, neem coated urea for its efficiency and collaborative trials with Agronomy and Entomology in nutrient management and organic farming. A total of 9 trials were conducted during *rabi* 2015-16 and *kharif* 2016 in 17 locations representing typical soil and crop systems and important rice growing regions.

5.1. Long-term soil fertility management in rice-based cropping systems

In the 28^{th} year of study on long term soil fertility management in RBCS, the results indicated the consistent superiority of conjunctive use of RDF+5t FYM/ha at TTB and FYM alone treatment was on par to RDF in both *rabi* and *kharif* seasons. At MTU, this treatment (conjunctive use of RDF+5t FYM/ha) was on par to RDF during *rabi* and during *kharif*, RDF, RDF+FYM and FYM alone treatments were on par both at MTU and MND. Nutrient omission resulted in yield reduction to an extent of 0.84-1.17 t/ha during *rabi* and 0.12-1.88 t/ha during *kharif* and response was more to N application compared to other nutrients. In light textured soils, response to K and S was more compared to heavy soils. Soil fertility status at the end of *kharif* 2016 indicated an improvement in important soil properties in INM treatments at all three locations and maximum OC values were observed with RDF+FYM and FYM alone treatments both at MTU (1.21-1.23%) and TTB (1.59-1.60%). Whereas, at MND, INM treatments recorded higher values compared to other treatments (0.46-0.57%).

5.2. Yield gap assessment and bridging the gap through site specific integrated nutrient management in rice in farmers' fields

Yield and Technology gap is a major problem in increasing paddy production in the irrigated ecosystems of the states. This trial was conducted in farmers’ fields around few selected centres – Chinsurah, Faizabad and Titabar to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers’ fertilizer practices in some new farm sites and fine-tune the fertilizer nutrient requirement for specific target yields in a given environment and validation of fertilizer recommendations for targeted yields. Fertilizer recommendations estimated for specific yield targets in the previous years in the farmers’ fields around Titabar were validated in comparison with the current recommended and farmers’ fertilizer practices. The need was assessed to ascertain the gaps of technology and compared the yield variations under RDF, SSINM *vis a vis* farmers field yield gaps. Technology Yield Gap I was estimated based on our recommended practice of SSINM and a target yield and technology Yield Gap 2 was estimated based on our the RDF prevalent across the region as recommended by the research farm /centre. Very high yield gap 1 and 2 were noticed at Titabar. At Faizabad, Technology yield Gap 1 was manageable but technology yield Gap 2 was also very high. This means that SSINM practice is beneficial at Faizabad but it was not matched at Titabar.

5.3. Screening of Germplasm for Sodicity and Management of Sodic Soils in RBCS

The trial on "Screening of Germplasm for Sodicity and Management of Sodic Soils in RBCS" is being conducted to identify sodicity tolerant genotypes capable of higher and stable yields with ameliorative gypsum application at Kanpur. Among the 17 genotypes evaluated, grain yields were observed to improve by 59.6-94.7% due to gypsum application when compared to non amended control. The genotypes, DRR Dhan 43, DRR Dhan 42, CSR 36 and CSR 43 in addition to producing highest yields (4.22 - 4.56 t/ha) with 100% GR supplementation, also exhibited better tolerance to sodicity compared to other genotypes as was demonstrated by their significantly higher yields (2.22 - 2.32 t/ha) in treatment without gypsum amendment.

5.4. Nutrient use efficiency and soil productivity in early and late sown rice/transplanted rice

Changing climatic conditions in many vulnerable areas are likely to influence agricultural productivity by influencing crop calendar, crop growth and efficiency of inputs. This study was conducted at six locations to assess the extent of change in rice productivity and nutrient use efficiency due to changing crop calendar and identify management options to mitigate the loss in yield and nutrient use efficiency. At all the centres, the productivity was significantly influenced by the time of crop establishment with early planting in *rabi* and normal sowing in *kharif* recording highest grain yields. The nutrient management practice of 150% RDF + Zn with N in 3 splits (1/3 +1/3 +1/3 or 1/2 + 1/4 +1/4) performed better over others in terms of nutrient uptake and rice productivity. Nutrient uptake was higher under early/normal planting while delayed planting (by both 15 and 30 days) and absolute control resulted in higher nutrient use efficiencies.

5.5. Screening of Rice Genotypes for Acid Soils and Related Nutritional Constraints

The trial conducted in four locations screened 11-24 genotpypes under three different nutrient management practices. Supplementation of recommended NPK with lime and double PK resulted in grain yield increase ranging from 3.6% to 19% at these locations. The genotypes producing the highest yields due with liming treatment were Uma, DRRH 92, 27P-22, Shreyas at Moncompu, Indira Maheswari, Mahamaya, RP 5974-3-2-8-38-12, Bamleswari at Raipur, Mahamaya, Indira Maheswari, DRR 43, DRR 39 at Ranchi and Gitesh, Prafulla, DRR Dhan 42, 27P37 at Titabar. Genotypes recording superior yields in the treatment without liming were Uma, DRR Dhan 39, DRR Dhan 42, 27P37 at Moncompu, Indira

Maheswari, DRRH 92, 27P36, Mahamaya at Raipur, Mahamaya, DRR 43, MTU7029, TTB 404 at Ranchi and Gitesh, Prafulla 27P36 and Uma at Titabar and were hence regarded as possessing tolerance to native soil acidity.

5. 6. Monitoring soil quality and crop productivity under emerging rice production Systems

The fourth year of study on "Monitoring soil quality and crop productivity under emerging rice production systems" at three centres *viz*, Kanapur, Moncompu and Pusa indicated consistently superior performance of transplanted rice over DSR and aerobic rice by 14.5-19% at Kanpur; superior performance of DSR over transplanted by 6.3% at Moncompu while at Pusa, all three systems were on par. In case of nutrient management practices, maximum yields were obtained with RDF+50% NPK through organic sources at Kanapur and Pusa while, 75% RDF +25% organics recorded higher yield at Moncompu. Nutrient uptake was also higher in transplanted rice followed by DSR and soil available nutrients were high in the plots that received organic manures either alone or in combination with chemical fertilizers.

5.7. Yield maximization of rice through Site Specific Nutrient Management

It is evident from the trial that site specific nutrient management considers spatial variability in the soil supply potentials and crop requirements, to help devise a better crop nutrient management to realize the best. SSNM also meant a way for sustainability in soil nutrient supply for subsequent cropping over the time to come. Balanced plant nutrition clearly reflected the improvement in increasing important yield attributes including tiller and panicle number per m^2, which directly influence the number of grains thus ultimate rice grain yield. For instance SSNM based on NE recommendation (T_2) recorded an increase in tiller number per m^2 from 112 to 190 % over absolute control while in T_3 (SSNM based on LCC based recommendations), the percentage of increase was from 103 to 176. With regard to the other yield component, panicle per m^2, T_2 and T_3 registered an increase of 107 to 204 and 103 to 188% over absolute control. With some exceptions, the nutrient omission plots and absolute control recorded conclusively lower values of the respective soil available nutrients compared to other treatments in majority of test centers. It is clear from the experimentation at multiple locations that the SSNM takes care of local variance in growing conditions particularly with respect to soil nutrient supplies to maintain the balanced nutrition.

5. 8. Bio - Intensive Pest Management (BIPM) in rice under Organic Farming

The results from the second year of study on "Bio-intensive pest management" indicated the superiority of BIPM over FP at three (CHN, JDP and TTB) out of seven locations (CHN, IIRR, JDP, LDN, PDU, RPR and TTB) that recorded significantly higher grain yield (by 11-40%). Whereas, BIPM was on par to FP at IIRR, LDN and RPR; and inferior to FP at PDU in terms of grain yield. The observations on pest incidence indicated the beneficial effect of BIPM at most of the locations with reduced pest incidence and increased natural enemy population. Important physical, cooking and nutritional quality parameters estimated in brown rice indicated no specific trend between BIPM and FP. Except at TTB, BIPM with organics did not influence the soil properties to a larger extent.

5. 9. Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system

To evaluate the performance of NCU applied at different stages of rice and to study the yield and NUE as affected by NCU applied to rice; this trial was initiated in *kharif* 2016 at eight locations. The results of the first year indicated the superiority of 125% recommended N given in the form of NCU in 3 split applications that resulted in significantly higher grain yields at 3 locations (KNP, MCP, RPR). Whereas, it was on par with 100% recommended N as NCU in 3 splits at 2 locations (PDU, MTU). The treatment 125%-N through NCU recorded higher yield by 3-23% and 8-34% over 100% NCU and 100% Prilled urea (PU), respectively, across seven locations with an increased N recovery efficiency by 11-29%. This hike in yields with this treatment could be attributed to the increased yield parameters such as panicle number and grain number. Similar trend was observed with regard to nutrients uptake, nitrogen use efficiency and soil properties. At CHN, NCU resulted in a marginal yield increase over PU and at Pusa, all NCU treatments were on par and significantly superior to Prilled urea (PU).

DETAILED REPORT

5.1 Long term soil fertility management in rice-based cropping systems (RBCS)

Long-term studies with well-defined nutrient management treatments and cropping systems were initiated in 1989-90 at four selected locations representing major rice growing regions and cropping systems *viz*., Mandya (MND) in Karnataka (rice-cowpea, Deccan Plateau), Maruteru (MTU) in Andhra Pradesh (rice-rice, Delta system), Titabar (TTB) in Assam (rice-rice, Alluvial soils) and Faizabad (FZB) in Uttar Pradesh (rice – wheat, Indo Gangetic plains) to study the dynamics of soil and crop productivity in relation to management for identifying the constraints that affect the sustainability of a given production system. The trial at Faizabad was discontinued during 2007-08 for lack of manpower support. Hence, the results of 28th year of cropping i.e., *rabi* 2015-16 and *kharif* 2016 are presented for three centres viz., Mandya (MND), Maruteru (MTU) and Titabar (TTB) in Tables 5.1.1 to 5.1.11 and Figs. 5.1.1 to 5.1.4.

Crop productivity and soil fertility during *rabi* 2015-16

Grain and straw yields of *rabi* rice at MTU and TTB are presented in Table 5.1.2. At MTU, grain yield ranged from 2.77 (control) to 6.10 t/ha (100%NPK ZnS+5 t/ha FYM) with a mean of 4.48 t/ha. RDF and RDF+FYM treatments were at par. Omission of N,P,K,Zn and S resulted in significant yield reduction by 0.30 t/ha in -S to 3.12 t/ha in -N plots. At Titabar, grain yield ranged from 1.33 t/ha in control to 5.71 t/ha in RDF+FYM which was significantly superior to RDF (5.35 t/ha) and all other treatments while FYM alone treatment (5.10 t/ha) and RDF were at par. Here also, omission of nutrients resulted in significant grain yield reduction by 0.84 t/ha in -Zn to 1.17 t/ha in -N plots. 50% reduction in RDF resulted in 116% yield reduction in silty clay soils of TTB compared to 33% reduction in clay loam soil of MTU. The yield reduction due to omission/reduction in nutrients was more compared to previous year. Addition of organics was more beneficial in TTB soils compared to MTU.

Total nutrients (NPK) Uptake was maximum with RDF+ 5t FYM/ha at both centres, MTU and TTB (Table 5.1.3). Addition of organics increased the nutrient uptake at both locations and the effect was more positive at TTB. In general, soil organic carbon and available nutrient status after harvest at Maruteru were higher when organic manures were added either as supplementary dose (RDF+FYM) or complete substitution to inorganic fertilisers (FYM @10 t/ha) (Table 5.1.4).

Crop productivity and soil fertility status during *kharif* 2016

At MTU, grain yields were higher and on par (5.11-5.98 t/ha) with RDF, RDF+FYM and 50%NPK+25% GMN+25% FYM-N. For the second consecutive year, FYM alone treatment (4.94 t/ha) was at par to all the above treatments (Table 5.1.5). Similarly, at MND, grain yield was higher and on par (4.15-4.59 t/ha) with RDF and RDF+FYM. Whereas, FYM alone (3.37 t/ha) was on par to RDF (4.15 t/ha). Omission/reduction of nutrients resulted in an yield loss of 0.12 t/ha in –P to 1.88 t/ha in –N plots. In general, in light textured soils, response to K and S was more compared to heavy textured soils. At TTB, maximum yield was obtained with RDF+FYM (5.76 t/ha) treatment followed by FYM alone treatment (5.38 t/ha). Response to NPKZN and S was significant at TTB only while at MND and MTU, only response to N was observed. With regard to straw yield, except in control, where straw yield was very less (2.4-3.2 t/ha), other treatments recorded higher straw yield without showing any specific trend at all locations (5.1 -7.3 t/ha at MTU, 4.5-7.1 t/ha at TTB and 1.9-5.2 t/ha at MND). The total nutrients (NPK) uptake by the above ground biomass was almost similar to grain yield trend at all 3 locations (Table 5.1.6). Soil fertility status at the end of *kharif* 2016 (Table 5.1.7) indicated an improvement in important soil properties in INM treatments at all three locations and maximum OC values were observed with RDF+FYM and FYM alone treatments both at MTU (1.21-1.23%) and TTB (1.59-1.60%). Whereas, at MND, INM treatments recorded higher values compared to other treatments (0.46-0.57%). Control recorded the lowest values at all 3 locations (0.23-1.08 %).

Soil enzyme activities (Table 5.1.8)

Application of FYM @ 10 t/ha was observed to support highest phosphatase activities of 56.81 µg PNP/g soil/h, 120.63 µg PNP/g soil/h and 85.7 µg PNP/g soil/h at Mandya Maruteru and Titabar respectively followed by the NPKZnS + FYM/ PM @5t/ha treatment (42.65, 1118.30 and 77.85 81 µg PNP/g soil/h, respectively). At Mandya, NPKZnS + FYM/ PM @5t/ha, 50%NPK + 25% GM-N + 25% FYM-N and of FYM @ 10 t/ha recorded at par activity of glucosidase (37.29, 36.94 and 36.17 µg PNP/g soil/h, respectively), significantly higher than the control (28.74 µg PNP/g soil/h) and NPKZnS (32.64µg PNP/g soil/h) treatment. Significantly higher glucosidase activity was recorded in all fertilized treatments at Maruteru (29.47-31.90 µg PNP/g soil/h) and Titabar (30.52-34.15 µg PNP/g soil/h), compared to the unfertilized control treatment (22.26 and 20.88 µg PNP/g soil/h, respectively). Application of organic matter either as FYM or as green manure, singly or in combination with inorganic fertilizers resulted in increased sulfatase activities. Sulfatase activities in NPKZnS + FYM/ PM @5t/ha, 50%NPK + 25% GM-N + 25% FYM-N and of FYM @ 10 t/ha were 26.4, 30.07, 37.44 µg PNP/g soil/h, respectively at Mandya, 34.37, 30.54, 35.65 µg PNP/g soil/h, respectively at Maruteru and 41.5, 38.43 and 45.97 µg PNP/g soil/h, respectively at Titabar. The control treatment without application of fertilizer had the lowest sulfatase activity at Mandya (24.48 µg PNP/g soil/h), Maruteru (25.31 µg PNP/g soil/h) and Titabar (21.49 µg PNP/g soil/h). Dehydrogenase enzyme activity at Mandya was influenced by fertilization. Sole inorganic and organic fertilization and combinations of both improved dehydrogenase activities (40.28 - 43.63 µgTPF/g soil/24 h) over unfertilized control treatment (36.67 µgTPF/g soil/24 h). At Maruteru and Titabar, 50%NPK + 25% GM-N + 25% FYM-N (45.03 and 25.85 µgTPF/g soil/24 h) and FYM @ 10 t/ha (43.13 and 31.54µgTPF/g soil/24 h) recorded higher dehydrogenase activities at these centers compared to other treatments. Highest FDA activity occurred due to application of FYM at 10 t/ha at Mandya (6.74 µg fluorescein/g soil/0.5 h) and Maruteru (7.57 µg fluorescein/g soil/0.5 h), while application of NPKZnS along with FYM/ PM @5t/ha supported the highest FDA activity at Titabar (75.36 µg fluorescein/g soil/0.5 h).

Long term changes in crop productivity and soil fertility over a period of 28 years

The trends in mean grain yields over 28 years (1989-2016) of *kharif* and *rabi* rice at MTU and TTB by fitting to linear function using actual yields and the per cent change in important soil properties in each treatment were analysed and presented below.

Trends in crop productivity

The treatment, RDF+5 t FYM/ha recorded maximum mean yield at two locations viz., MTU (5.13 t/ha) and TTB (4.84 t/ha) with an average increase of 0.10 and 0.58 t/ha, respectively, by this treatment over RDF. Whereas, at MND, maximum mean yield (5.37 t/ha) was recorded by 50% NPK+25%GM+25% FYM. Linear trends of productivity over the years with current RDF indicated slightly positive growth in the delta soils of MTU (8.6 kg grain/ha/year) and more positive growth in the acid alluvial soils of TTB (26.6 kg/ha/year) while growth was negative in light textured soils of MND (-46 kg/ha/year). Additional dose of FYM @5t/ha along with RDF improved the growth rate substantially with 94, 70 and 87 kg/ha/year at MTU, MND and TTB, respectively (Table 5.1.9). From the figure 5.1.3, it is evident that once the treatment RDF+FYM was introduced, this treatment gave maximum yield at MTU and TTB and 50% NPK+25%GM+25%FYM was superior at MND. The control yields dropped down gradually at all three centres.

During *rabi* (Table 5.1.10) also, RDF+5t FYM recorded maximum mean yield both at MTU (6.23 t/ha) and TTB (4.29 t/ha) and this treatment recorded growth rate of 47 and 71 kg/ha/year at MTU and TTB, respectively. Compared to *rabi*, growth rate was higher in *kharif* season.

Changes in soil fertility

The per cent change in important soil fertility parameters when compared to the initial values were presented in Table 5.1.11. It was observed that there was a maximum decline in OC in control treatment at TTB (-37%) and INM treatments recorded accumulation of OC with maximum value in FYM@ 10 t/ha treatment at MTU (38%) and TTB (68%) and in 50% NPK+25%GM+25%FYM at Mandya. With regard to N, there was a decline in all treatments (-31 to - 46%) at MTU while at MND, control recorded a decline by 25%. Per cent change in P was positive in all treatments at MTU but at MND and TTB, decline was observed in control. In case of K also, change was -ve in all treatments at MTU (-9 to -11%) and in control at MND (-28%) and TTB (-39%) with a positive change in other treatments.

Summary

In the 28th year of study on long term soil fertility management in RBCS, the results indicated the consistent superiority of conjunctive use of RDF+5t FYM/ha at TTB and FYM alone treatment was on par to RDF in both *rabi* and *kharif* seasons. At MTU, this treatment (conjunctive use of RDF+5t FYM/ha) was on par to RDF during rabi and during kharif, RDF,

RDF+FYM and FYM alone treatments were on par both at MTU and MND. Nutrient omission resulted in yield reduction to an extent of 0.84-1.17 t/ha during *rabi* and 0.12-1.88 t/ha during *kharif* and response was more to N application compared to other nutrients. INM and organics alone treatments resulted in improvement of soil fertility as well as biological activities (soil enzyme activities) that was reflected positively in rice productivity at all locations.

Table 5.1.1: Long term soil fertility management in RBCS, 2016
Soil and crop characteristics

Cropping system	Mandya	Maruteru	Titabar
	Rice-Cowpea	**Rice-Rice**	**Rice-Rice**
Variety – *kharif*	Thanu	MTU-1061	Gitesh
Rabi		MTU - 1010	Lachit
Recommended Fertilizer Dose (kg NPK /ha)			
Kharif	100: 50: 50	90:60:60	40:20:20
Rabi	-	180:90:60	40:20:20
STCR (*Kharif*)		74:58:28	60:20:40
STCR (*Rabi*)	-	170:95:73	60:20:40
Crop growth: *Kharif*	Satisfactory	Satisfactory	Satisfactory
Rabi	-	Satisfactory	Satisfactory
% Clay	11.1	38	42.0
% Silt	18.00	28	28.5
% Sand	62.85	34	29.5
Texture	Clay	clay loam	Silty Clay
pH (1:2)	6.56	6.15	5.4
Organic carbon (%)	0.3	0.61	1.1
CEC (cmol (p^+)/kg)			12.5
EC (dS/m)	0.26	1.11	
Avail. N (kg/ha)	226	158	495
Avail. P_2O_5 (kg/ha)	19.9	51.7	22.4
Avail. K_2O (kg/ha)	123.2	286	112

Table 5.1.2: Long term soil fertility management in RBCS, rabi 2015-16
Grain and straw yields of rice

Treatments	Grain yield (t/ha)		Straw yield (t/ha)		Panicles/m^2
	Maruteru	Titabar	Maruteru	Titabar	Maruteru
Control	2.77	1.33	3.57	2.80	231
100% PK	2.85	4.18	3.62	5.22	273
100% NK	4.08	4.38	5.19	5.22	369
STCR recommendation	5.52	4.83	6.81	5.38	357
100% NP	4.27	4.10	5.42	6.10	354
100% NPKZnS	5.97	5.35	7.12	6.41	394
100% NPKZnS + FYM/PM @ 5t/ha	6.10	5.71	7.57	5.88	403
100% NPK –Zn	5.57	4.51	6.90	5.90	382
100% NPK – S	5.67	4.48	6.88	5.65	374
100%NPK-S+1tlime/ha	-	4.55	-	5.90	-
100% N+50% PK	5.17	3.65	6.57	5.75	362
50 % NPK	4.48	2.47	5.70	4.31	314
50 % NPK + Biofertilizer	5.25	3.76	6.67	5.71	336
50%NPK+ 50% GM-N	4.40	4.71	5.59	6.10	317
50% NPK + 50% FYM-N	3.98	4.66	5.06	5.88	283
50% NPK + 25% GM-N+25% FYM-N	3.95	4.87	5.02	5.98	311
FYM @ 10 t/ha	2.97	5.10	3.77	5.98	276
FYM @ 10 t/ha + Split application	3.27	-	4.15	-	263
Expt. Mean	4.48	4.27	5.62	5.54	329
CV (%)	**7.83**	**5.14**	**7.51**	**3.47**	**39**
CD (0.05)	**0.58**	**0.31**	**0.70**	**0.27**	**7**

Table 5.1.3: Long term soil fertility management in RBCS, *rabi* 2015-16
Total nutrient uptake (kg/ha)

Treatments	Maruteru			Titabar		
	N	P	K	N	P	K
Control	18.3	7.4	26.4	21.2	4.2	35.4
100% PK	23.7	8.6	37.6	47.3	12.1	80.7
100% NK	52.5	12.3	57.9	45.4	11.8	74.2
STCR recommendation	77.9	18.7	80.1	50.8	13.2	87.1
100% NP	58.9	14.9	63.9	49.6	12.4	89.1
100% NPKZnS	84.2	23.0	93.3	63.6	16.0	101.8
100% NPKZnS + FYM/PM @ 5t/ha	93.7	26.4	105.8	65.7	18.1	101.6
100% NPK – Zn	75.9	21.7	65.6	49.4	12.3	89.5
100% NPK – S	73.8	18.4	68.2	49.4	12.3	85.7
100%NPK-S+1tlime/ha	-	-	-	48.9	12.0	91.8
100% N+50% PK	69.3	15.8	54.4	47.1	9.1	85.6
50 % NPK	60.7	15.6	62.3	31.0	7.5	56.3
50% NPK + Biofertilizer	68.1	15.8	78.7	46.8	12.4	85.1
50% NPK+ 50% GM-N	63.3	15.2	63.5	56.2	15.1	95.5
50% NPK + 50% FYM-N	57.2	11.9	57.1	53.0	13.9	95.9
50% NPK + 25% GM-N+ 25% FYM-N	58.4	11.9	55.0	53.4	16.1	95.1
FYM @ 10 t/ha	35.7	9.0	30.3	57.2	17.8	98.1
FYM @ 10 t/ha + Split Vermi	40.5	10.0	32.3	-	-	-
Expt. Mean	**59.5**	**15.1**	**60.7**	**49.1**	**12.7**	**85.2**
CV (%)	**9.8**	**8.9**	**18.0**	**4.9**	**14.0**	**5.51**
LSD (0.05)	**9.7**	**2.2**	**18.1**	**4.0**	**2.9**	**7.75**

Table 5.1.4: Long term soil fertility management in RBCS, Rabi 2015-16
Soil fertility status at harvest

Treatments	Maruteru			
	Org. C (%)	**Avail. N (kg/ha)**	**Avail P_2O_5 (kg/ha)**	**Avail. K_2O (kg/ha)**
Control	1.04	151	32.9	195
100% PK	1.17	161	79.3	243
100% NK	1.13	200	34.3	225
STCR recommendation	1.2	215	63.8	274
100%NP	1.16	196	80.2	252
100% NPKZnS	1.17	216	85.0	282
100% NPKZnS + FYM/PM @ 5t/ha	1.3	222	88.7	289
100% NPK –Zn	1.2	180	71.3	271
100% NPK – S	1.17	182	80.3	262
100%NPK-S+ 1timelime/ha	-	-	-	-
100% N+50% PK	1.22	184	66.6	277
50 % NPK	1.2	183	48.3	268
50 % NPK + Biofertilizer	1.16	190	66.6	280
50% NPK+ 50% GM-N	1.28	170	52.8	250
50% NPK + 50% FYM-N	1.22	182	50.7	249
50% NPK + 25%GM-N+25%FYM-N	1.25	173	61.4	255
FYM @ 10 t/ha	1.31	207	58.9	240
FYM@10 t/ha +3.0 t/ha Vermicompost +200 kg/ha oil cakes	1.18	174	55.3	214
Expt. Mean	**1.2**	**187**	**63.3**	**255**
CV (%)	**0.15**	**29**	**10.1**	**47**
LSD (0.05)	**7.46**	**9**	**9.7**	**11**

Table 5.1.5: Long term soil fertility management in RBCS, *Kharif* 2016
Grain and straw yields of rice

Treatments	Grain yield (t/ha)			Straw yield (t/ha)			Panicles/m^2	
	MTU	**TTB**	**MND**	**MTU**	**TTB**	**MND**	**MTU**	**MND**
Control	2.83	1.46	2.17	3.15	3.14	2.36	243	239
100% PK	4.44	4.30	2.27	5.09	5.85	1.87	227	251
100% NK	5.16	4.42	4.03	6.20	5.99	5.20	258	244
STCR recommendation	5.30	4.86	2.75	6.37	6.49	3.11	251	252
100% NP	5.06	4.41	3.63	6.23	5.95	3.90	255	572
100% NPKZnS	5.90	5.32	4.15	7.23	6.95	4.98	266	324
100% NPKZnS + FYM/PM @ 5 t/ha	5.98	5.76	4.59	7.31	7.09	4.47	271	302
100% NPK –Zn	5.49	4.60	3.44	6.76	6.17	3.65	247	372
100% NPK – S	5.49	4.21	3.05	6.93	5.83	3.37	255	349
100%NPK-S+ 1timelime/ha	-	4.36	-	-	5.99		-	
100% N+50% P+ 50%K	5.26	2.86	2.99	6.26	4.61	2.80	265	506
50 % NPK	4.81	2.61	2.93	5.25	4.49	3.12	249	263
50 % NPK + Biofertilizer	4.97	4.20	2.62	5.27	5.79	3.29	243	236
50% NPK+ 50% GM-N	5.19	4.86	2.94	5.90	6.10	2.98	249	441
50% NPK + 50% FYM-N	5.26	5.02	2.92	6.70	6.19	2.85	252	491
50% NPK + 25% GM-N+25% FYM-N	5.11	5.18	3.35	6.18	6.13	3.00	243	482
FYM @ 10 t/ha	4.94	5.38	3.37	5.44	6.89	3.36	230	261
FYM@10 t/ha + 3.0 t/ha Vermicompost +200 kg/ha oil cakes	4.93	-	2.71	5.57	-	3.21	248	231
Expt. Mean	5.07	4.35	3.17	5.97	5.85	3.38	250.1	342
CV (%)	17	4.22	18	15.2	4.15	19	7.17	7
LSD (0.05)	1.39	0.26	1.23	1.50	0.34	1.34	29.58	48

Table 5.1.6: Long term soil fertility management in RBCS, Kharif 2016 Total nutrient uptake (kg/ha)

Treatments	Maruteru			Titabar			Mandya			
	N	P	K	N	P	K	N	P	K	Zn (mg/kg)
Control	57.8	10.4	36.4	22.6	4.35	28.6	13.5	6.0	11.9	359
100% PK	82.3	15.7	53.8	57.1	12.39	67.1	14.8	6.8	12.9	397
100% NK	108.8	21.3	87.4	59.1	12.43	73.6	39.9	18.2	31.6	1013
STCR recommendation	107.3	20.4	89.6	65.8	17.29	95.1	29.4	12.1	22.9	647
100% NP	121.0	21.7	86.1	60.4	12.85	75.4	32.5	16.9	29.4	767
100% NPK + Zn + S	142.3	26.5	98.0	71.6	18.73	103.1	51.4	23.3	38.5	995
100% NPK + Zn + S + FYM/PM @ 5 t/ha	147.7	26.7	108.7	87.5	23.93	115.5	52.8	29.3	45.2	1048
100% NPK –Zn	130.7	23.2	89.2	60.9	15.4	90.9	30.2	17.2	32.8	724
100% NPK – S	124.3	23.8	90.5	57.3	14.17	83.0	33.7	14.8	21.8	566
100%NPK-S+ 1timelime/ha	-	-	-	58.6	15.6	90.8	-	-	-	-
100% N+50% PK	115.7	21.7	78.3	42.3	8.14	57.7	27.4	13.5	21.1	579
50 % NPK	103.8	19.4	71.9	43.3	8.17	53.8	33.9	16.5	30.3	732
50 % NPK + Biofertilizer	100.8	20.2	73.6	58.0	14.31	81.9	38.4	16.3	28.9	750
50% NPK+ 50% GM-N	118.5	21.5	82.4	63.4	15.17	86.6	36.0	19.1	28.0	715
50% NPK+ 50% FYM-N	128.4	22.4	93.5	66.7	15.57	94.4	35.3	19.7	28.3	742
50% NPK +25% GM-N +25% FYM-N	104.6	19.7	95.6	67.0	16.93	91.1	44.8	23.3	33.3	954
FYM @ 10 t/ha	98.6	20.7	63.5	76.9	19.3	113.1	40.9	21.4	32.4	890
FYM@10t/ha +3.0 t/ha Vermicompost +200 kg/ha oil cakes	98.3	20.9	66.5	-	-	-	35.8	18.8	29.2	807
Expt. Mean	**111.2**	**21.0**	**80.3**	**59.9**	**14.4**	**82.4**	**34.7**	**17.2**	**28.1**	**746**
CV (%)	**20.1**	**4.5**	**22.1**	**4.38**	**2.16**	**6.1**	**18**	**17**	**17**	**15**
LSD (0.05)	**11.0**	**13.0**	**16.7**	**4.43**	**9.09**	**4.5**	**13.3**	**6.3**	**10.3**	**240**

Table 5.1.7: Long term soil fertility management in RBCS, K*harif* 2016 Soil fertility status at harvest

Treatments	Maruteru				Titabar			Mandya					
	Org. C (%)	Avail. N (kg/ha)	Avail P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)	Org. C (%)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)	Org. C (%)	Bulk Density	Avail. N (kg/ha)	Avail P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)	Avail . S (kg/ha)
Control	1.08	160	58.6	370	0.6	12.3	89	0.23	1.34	217	12.4	127	6.34
100% PK	1.24	186	78.2	365	0.81	22.63	77	0.28	1.32	262	18.0	225	7.58
100% NK	1.14	190	70.1	314	1.13	26.02	89	0.32	1.27	240	19.7	219	8.62
STCR recommendation	1.12	209	75.8	324	1.22	33.67	88	0.37	1.23	271	28.2	243	10.90
100%NP	1.13	194	91.8	279	1.12	29.33	90	0.3	1.24	263	25.1	183	9.60
100% NPKZnS	1.11	196	98.7	361	1.4	34.67	145	0.33	1.27	328	28.1	220	23.54
100% NPKZnS + FYM/PM @ 5t/ha	1.21	204	98.6	361	1.59	38.83	163	0.38	1.23	357	48.9	276	23.29
100% NPK –Zn	1.12	193	79.6	339	1.35	33	142	0.37	1.31	288	26.0	238	11.07
100% NPK – S	1.16	201	83.1	338	1.33	33.17	137	0.33	1.21	267	25.9	242	10.79
100%NPK-S+ 1timelime/ha	-	-	-	-	0.98	33.5	141	-	-	-	-	-	
100% N+50% PK	1.13	214	67.4	334	1.15	27.5	91	0.36	1.27	289	27.6	216	11.61
50 % NPK	1.14	206	78.6	334	0.83	25.65	82	0.36	1.27	309	25.3	243	10.96
50 % NPK + Biofertilizer	1.25	203	67.9	294	1.37	35.5	129	0.36	1.28	341	44.2	270	11.73
50% NPK+ 50% GM-N	1.19	209	86.1	350	1.47	35.33	140	0.46	1.23	344	44.2	280	11.85
50% NPK + 50% FYM-N	1.14	200	95.5	367	1.55	35.83	153	0.48	1.24	336	46.9	296	11.12
50% NPK + 25%GM-N+25%FYM-N	1.18	174	94.4	368	1.58	36.17	152	0.57	1.23	387	52.0	294	10.96
FYM @ 10 t/ha	1.23	176	92.5	367	1.6	39.33	163	0.54	1.28	343	39.8	278	11.58
FYM@10 t/ha +3.0 t/ha Vermi compost +200 kg/ha oil cakes	1.14	182	98.5	326	-	-	-	0.55	1.29	343	40.1	276	11.98
Expt. Mean	**1.16**	**194**	**83.3**	**341**	**1.24**	**31.32**	**121.9**	**0.39**	**1.26**	**305**	**32.5**	**242.6**	**12.0**
LSD (0.05)	**0.13**	**25**	**5.2**	**61**	**0.24**	**3.12**	**9.31**	**0.05**	**0.06**	**13**	**5.1**	**24.2**	**3.4**
CV (%)	**6.65**	**8**	**3.8**	**11**	**11.81**	**6.0**	**4.6**	**6.19**	**2.29**	**2**	**7.4**	**4.7**	**13.5**

Table 5.1.8. Long term soil fertility management in RBCS Soil enzyme activities in selected treatments after *kharif* 2016

Treatments	Mandya					Maruteru					Titabar				
	PHOS	GLUC	SULF	DHA	FDA	PHOS	GLUC	SULF	DHA	FDA	PHOS	GLUC	SULF	DHA	FDA
Control	34.54	28.74	24.48	36.67	3.00	102.79	22.26	25.31	30.12	3.94	43.85	20.88	21.49	15.42	43.11
NPKZnS	38.81	32.64	25.22	40.28	5.02	113.91	29.47	31.86	36.37	5.33	60.83	30.52	34.76	21.57	67.60
NPKZnS + FYM/ PM @5t/ha	42.65	37.29	26.40	41.44	6.31	118.30	30.69	34.37	37.09	6.71	77.85	34.15	41.50	28.77	75.36
50%NPK + 25% GM-N + 25% FYM-N	40.78	36.94	30.07	42.60	5.52	117.05	30.55	30.54	45.03	5.92	72.44	31.59	38.43	25.85	70.87
FYM@ 10t/ha	56.81	36.17	37.44	43.63	6.74	120.63	31.90	35.65	43.13	7.57	85.73	30.14	45.97	31.54	72.01
Mean	42.72	34.35	28.72	40.92	5.32	114.5	29.0	31.5	38.3	5.9	68.14	29.46	36.43	24.63	65.79
CD (0.05)	3.2	3.6	2.5	3.77	1.2	9.2	5.3	4.9	5.50	1.12	18.29	8.10	9.47	11.67	5.22
CV (%)	16.7	13.9	15.6	12.7	12.34	10.71	19.63	12.84	13.77	13.31	15.19	14.88	14.61	26.23	4.46

PHOS- alkaline phosphatase activity (µg PNP/g soil/h); GLUC-β glucosidase activity (µg PNP/g soil/h); SULF-arylsulfatase activity (µg PNP/g soil/h); DHA-Dehydrogenase activity (µgTPF/g soil/24 h); FDA- Fluorescein Diacetate Hydrolysis activity (µg fluorescein/g soil/0.5 h)

Table 5.1.9. Long term soil fertility management in RBCS Linear trends of changes in *kharif* rice yields (t/ha) from 1989 to 2016

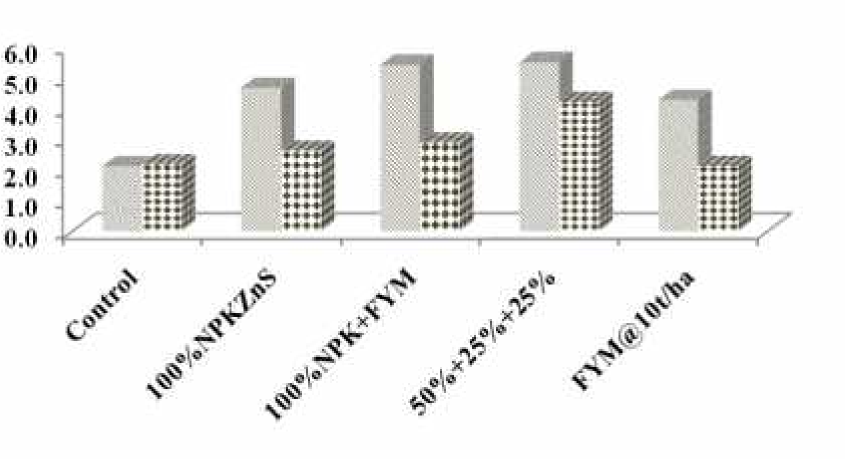
Treatments	Maruteru			Mandya			Titabar		
	Mean Yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)	MeanYield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)	Mean Yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)
Control	2.22	115.5	0.51	2.28	-80.9	3.40	2.06	-71.4	3.12
100 % NPKS Zn	5.03	8.6	4.90	4.74	-45.8	5.38	4.26	26.6	3.88
100 % NPKS Zn + FYM	5.13	94.5	3.24	5.12	70.4	3.73	4.84	87.5	3.09
50% NPK + 25% GM + 25% FYM	4.55	18.1	4.29	5.37	12.8	5.19	3.88	12.3	3.88
FYM @10t/ha	4.44	11.1	4.28	4.14	31.7	3.70	3.91	40.6	3.91

Table 5.1.10. Long term soil fertility management in RBCSLinear trends of changes in *Rabi* rice yields (t/ha) from 1989 to 2016

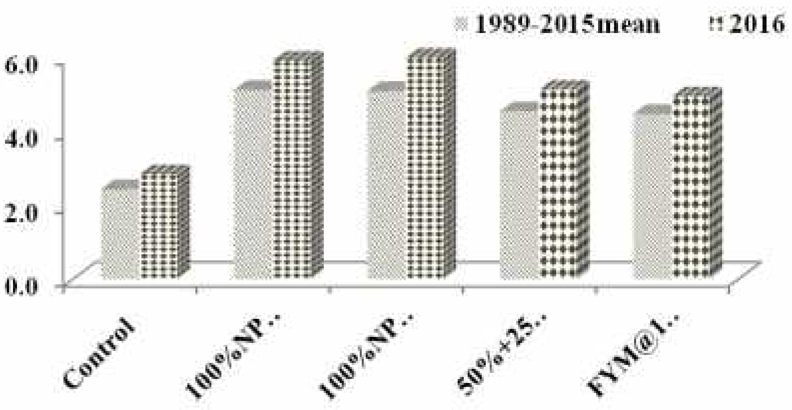
Treatments	Maruteru			Titabar		
	Mean Yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)	Mean Yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)
Control	2.13	24.0	1.69	1.75	-40.2	2.40
100 % NPKS Zn	5.58	35.7	5.05	3.82	34.6	3.26
100 % NPKS Zn + FYM	6.23	47.4	7.15	4.29	71.4	2.83
50% NPK + 25% GM + 25% FYM	5.00	18.5	4.72	3.43	41.7	2.76
FYM @10t/ha	4.00	29.1	3.57	3.42	44.3	2.71

Table: 5.1.11. Long term soil fertility management in RBCS Changes (%) in soil fertiflity parameters in imortant treatments over 1989 to 2016

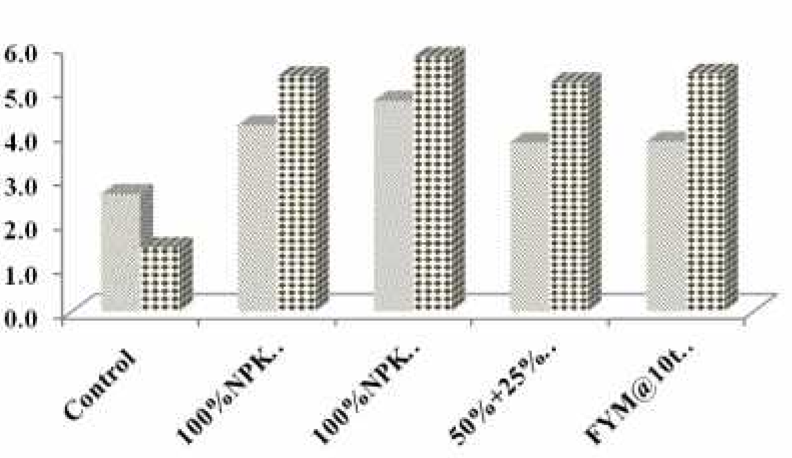
Treatments	Maruteru				Mandya				Titabar		
	Org.C	Avail N	Avail P_2O_5	Avail K_2O	Org. C	Avail N	Avail P_2O_5	Avail K_2O	Org. C	Avail P_2O_5	Avail K_2O
Control	21.3	-46.3	187	-8.9	-34.3	-25.2	-29.5	-27.8	-36.8	-6.8	-39
100%NPKZnS	24.7	-34.2	384	-11.1	-5.7	13.1	59.7	25	47.4	162.9	-0.7
100%NPKZnS+FYM	36	-31.5	383	-11.1	8.6	23.1	177.8	56.8	67.4	193.9	11.6
50%NPK+25%GM+25%FYM	32.6	-41.6	363	-9.4	62.9	33.4	195.5	67	67.4	174.2	4.1
FYM@10t/ha	38.2	-40.9	353	-9.6	54.3	18.3	126.1	58	68.4	197.7	11.6



Grain yield (t ha^{-1}) at Mandya

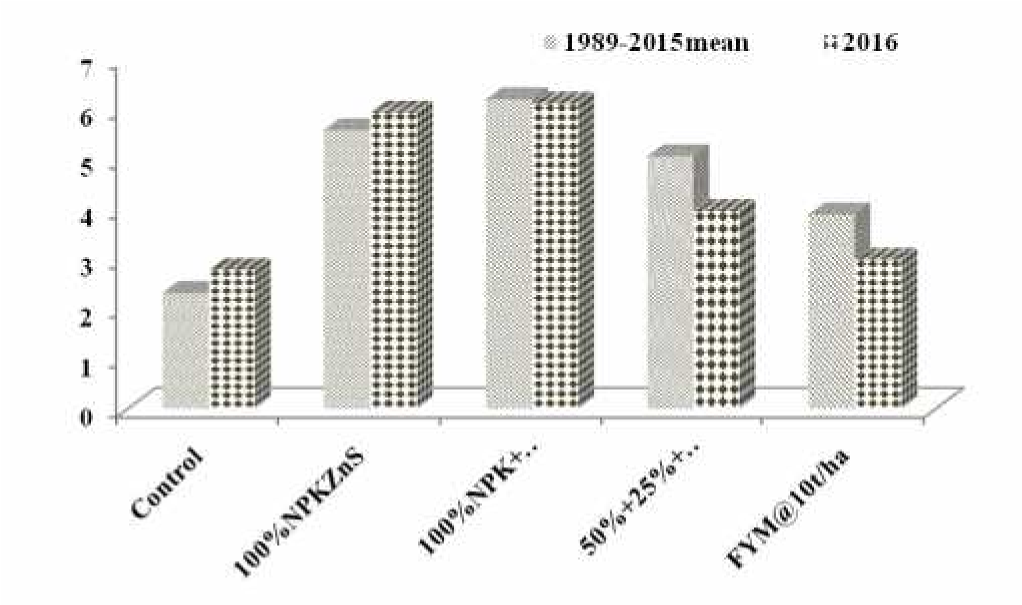


Grain yield (t ha^{-1}) at Maruteru

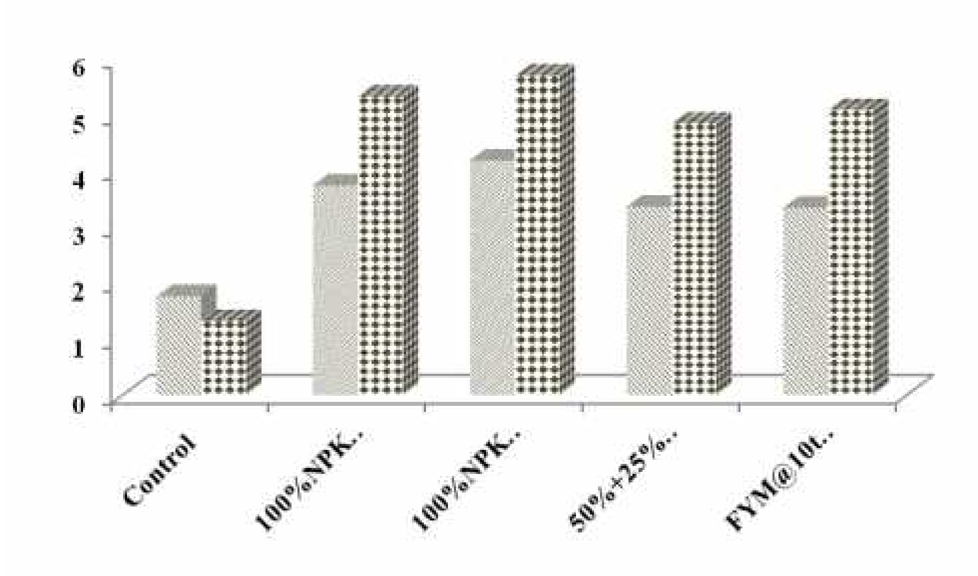


Grain yield (t ha^{-1}) Titabar

Fig. 5.1.1. Long term effects of nutrient management on rice grain yields - *Kharif* (Mean of previous 27 years and current year grain yield)

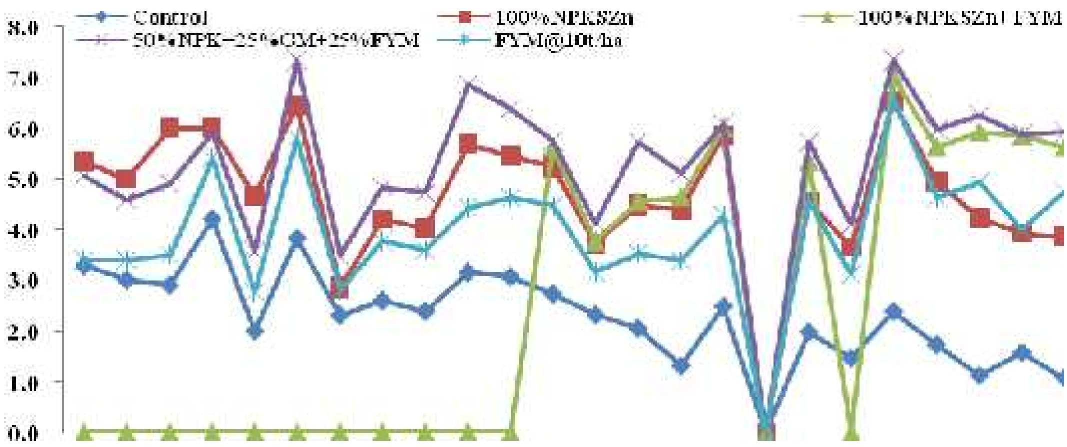


Grain yield (t ha^{-1}) at Maruteru

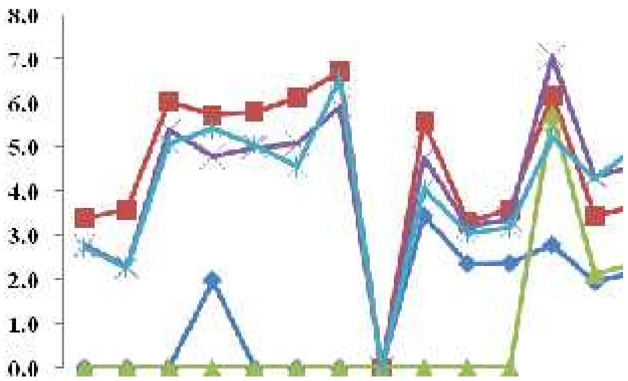


Grain yield (t ha^{-1}) at Titabar

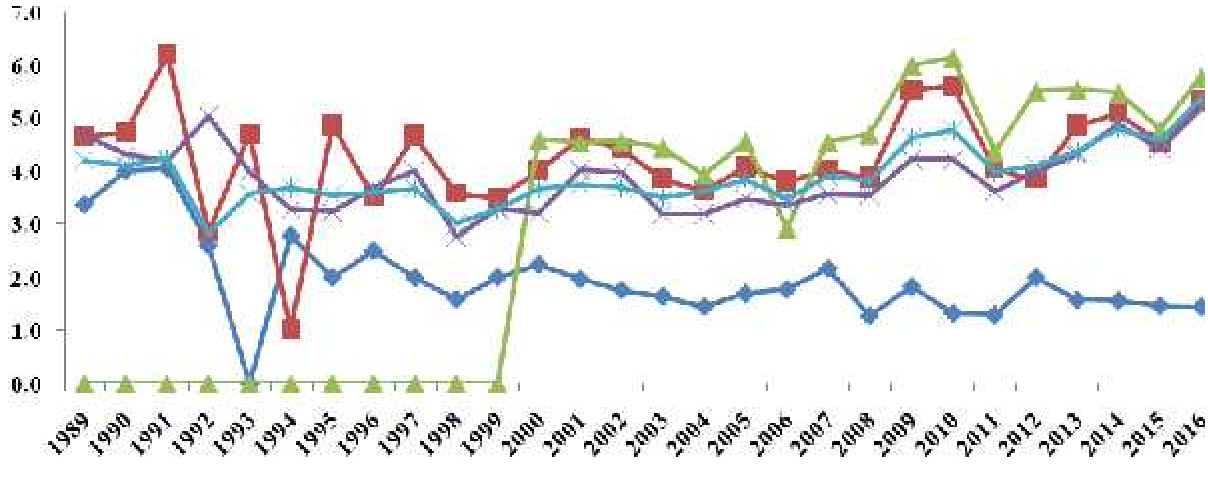
Fig. 5.1.2. Long term effects of nutrient management on rice grain yields - *Rabi* (mean of previous 27 years and current year's and grain yield)



Mandya

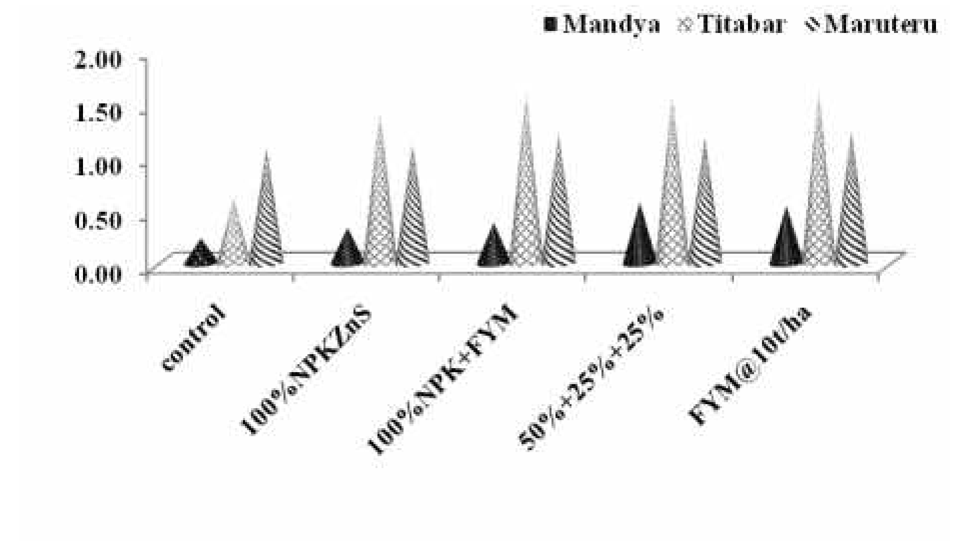


Maruteru

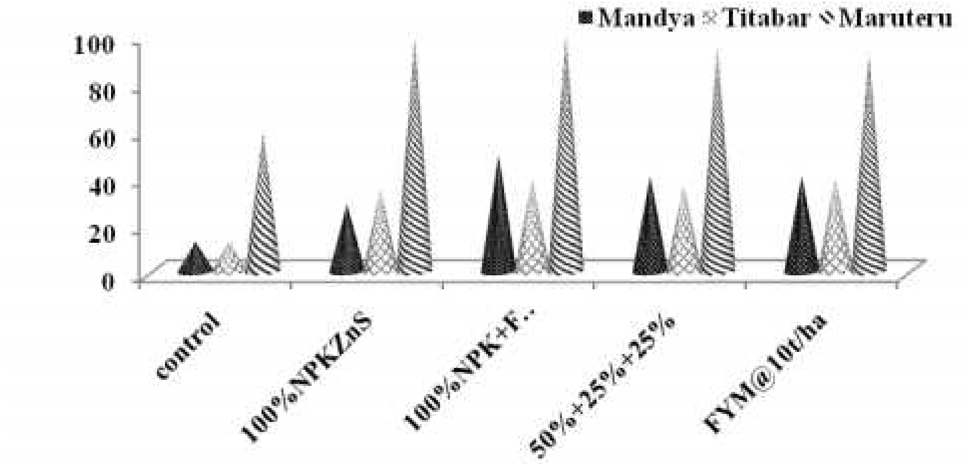


Titabar

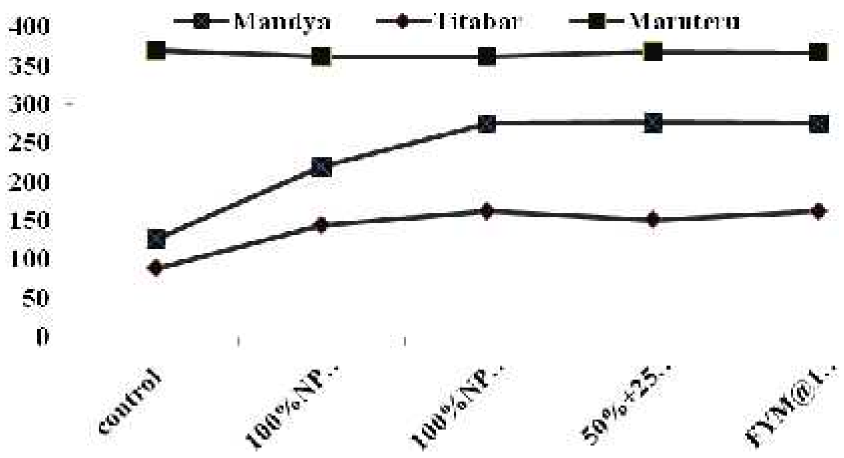
Fig. 5.1.3. Long term soil fertility mamangement in RBCS Trends in crop productivity over 28 years (1989-2016)



Org. Carbon content (%)



Available P_2O_5 content (kg/ha)



Available K_2O content (kg/ha)

Fig. 5.1.4. Long term effects of nutrient management on soil nutrient status– *Kharif*

5. 2. Yield gap assessment and bridging the gap through soil fertility assessment in farmers' fields

Large variations in yield are a major impending problem for rice wheat sustainability in India. The growing concern about impaired soil health, declining / decelerating productivity growth and decreasing factor productivity or efficiency of the nutrients compelling to use increasing levels of fertilizers during the last two decades has raised apprehensions on the productive capacity of the agricultural system. Yield and technology gap is a major problem in increasing paddy production in the irrigated ecosystems of the states. Balanced nutrient application is must to meet the growth requirements of a genotype for realizing the yield potential of several contemporary genotypes. So far, not much systematic effort has been made to study the technological gap existing in various components of rice cultivation. With the available improved latest technologies, it is possible to bridge the yield gap and increase the existing production level up to certain extent. Current fertilizer management practices, in general, are not tailored to site specific soil nutrient supply capacities and crop demand. Blanket fertilizer recommendations are still being followed in large domains with less importance being given to management induced site variations of soil nutrient supply capacities, and crop demand more so when new high yielding cultures with increasing yield potential are being regularly introduced. This has been the major reason for reported nutrient imbalances and un-sustainability in realizing yields. This trial was, therefore, conducted in farmers' fields around few selected centres – Chinsurah, Faizabad and Titabar to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers' fertilizer practices in some new farm sites and fine-tune the fertilizer nutrient requirement for specific target yields in a given environment and validation of fertilizer recommendations for targeted yields. The *kharif* 2016 data received representing the irrigated and shallow lowland rice ecosystems are presented in Tables 5.2.1 to 5.2.11. The test varieties were Sarjoo-52 at Faizabad, Ranjit, Bhadur, Gitesh, Swarna Mahsuri, Aghonibora at Titabar and Shatabdi (IET 4786) at Chinsurah. At Both Titabar and Faizabad 15 farmer sites each were selected for generating information on the field variability in soil fertility and current level of efficiency of farmers' practices. The treatments consisted of nutrient (NPK) omission plots, farmers' fertilizer practice (FFP) and recommended dose of fertilizer (RDF). The details of crop, soil and weather parameters of the experimental sites, presented in the Table 5.2.1, show variation in soil characteristics with reference to pH, organic carbon content, soil texture and available nutrient status.

Table 5.2.2 gives information collected in the new farm sites on yields obtained, nutrient uptake and soil test values in nutrient omission plots (-N, -P, -K). Grain yields at Titabar, Faizabad and Chinsurah, soil test values and nutrient uptake showed considerable variation among the farm sites. In the absence of applied N, the yields ranged from 0.36-0.81 t/ha at Titabar, 4.9 – 6.1 t/ha at Faizabad, 3.87-5.11t/ha at Chinsurah. Similarly, in P omitted plots, the grain yields varied considerably from from 0.55-0.91 t/ha at Titabar, 4.3 – 5.8 t/ha at Faizabad, 4.49-5.16 /ha at Chinsurah.and for K omitted plots the grain yields varied from 0.47-0.91 t/ha at Titabar, 4.1 – 5.65 t/ha at Faizabad, 3.96-4.5 t/ha at Chinsurah. Soil nutrient uptake varied between the sites. On an average each ton of grain accumulated 5.89, 0.82 and

3.2 kg N, P_2O_5 and K_2O at Titabar , 10.61,7.68 and 11.59 at Faizabad and 34.86, 34.65 and 5.09 at Chinsurah. At all these locations grain yields and nutrient uptake in nutrient omitted plots correlated significantly (Table 5.2.3), while soil test values did not match the yields recorded in the nutrient omission plots except for soil P status showing moderate level of relationship (r ~ 0.43) with rice yield and nutrient uptake at both the locations, suggesting perhaps less suitability of current soil testing methods for flooded soils. Linear equations fitted to relate the recorded yields in nutrient omission plots with the uptake of respective nutrients indicated very poor relations to N uptake, P uptake and K uptake.

Table 5.2.4 and Table 5.2.7 show site variations in rice productivity, nutrient uptake and their efficiency of utilization under farmers' fertilizer practices and recommended fertilizer management (RDF) at the test locations. Rice productivity with recommended fertilizer practice varied from 2.12 –3.5 t/ha at Titabar ,5.05-6.56t/ha at Faizabad,3.91-4.65t/ha at Chinsurah whereas,0.5 – 1.4 t/ha in the farmers' fields at Titabar, 4.35-6.05t/ha in the farmers' fields at Faizabad and 4.1-5.2t/ha in the farmers' fields at Chinsurah. While the yields were having considerable variation with the farmers' fertilizer practices, respectively with corresponding variation in nutrient yield, soil test values, uptake and nutrient utilization efficiencies. Strong correlation between yields and nutrient uptake was also recorded for all the nutrients and moderate correlation for P uptake under recommended fertilizer practices and with all the nutrients under farmers practice indicating mismatch of the fertilizer doses.

Fertilizer prescriptions were worked out for Titabar and Faizabad for all the 15 farm sites for yield target of 8.1 t/ha and 8.2 t/ha at both the locations (being the highest yield recorded at the test sites) with reference to grain yields and average uptake of nutrients per ton of grain in nutrient omission plots, and average recovery efficiency and nutrient requirement recorded at the test sites. The target yields were the maximum recorded at the test sites under recommended fertilizer practice (RDF). The fertilizer recommendations presented in Tables 5.2.8 and 5.2.9 show a range of fertilizer doses of major nutrients to achieve the targeted productivity which has already been harvested. High estimates of P and K fertilizer requirements are due to lower recovery efficiency of applied P and higher accumulation of potassium per ton of grain. The study, thus indicated ample scope for improvement in nutrient use efficiency, and an attempt has been made to refine the current blanket recommended dose of fertilizer based on site specific nutrient supply, nutrient use efficiency and crop demand.

Fertilizer recommendations estimated for specific yield targets in the previous years in the farmers' fields around Titabar and Chinsurah were validated in comparison with the current recommended and farmers' fertilizer practices. Table 10 shows SSNM was superior to the currently recommended blanket fertilizer dose or the farmers' fertilizer practice at Titabar and Chinsurah with corresponding improvement in crop nutrition and nutrient use efficiency.

Yield Gap analysis

Yield gap analysis done for all farm fields sites. The need was assessed to ascertain the gaps of technology and compared the yield variations under RDF, SSNM vis a vis farmers field yield gaps. Technology Yield Gap I was estimated based on our recommended practice of SSNM and a target yield and technology Yield Gap 2 was estimated based on our the RDF prevalent across the region as recommended by the research farm /centre. This was compared with the performances at various farmers field selected. The results have been enlisted in the Table No.5.2.11. Very high yield gap 1 and 2 were noticed at Titabar. At Faizabad, Technology yield Gap 1 was manageable but technology yield Gap 2 was also very high. This means that SSNM practice is beneficial at Faizabad but it was not matched at Titabar.

Summary: This trial was conducted in farmers' fields around few selected centres – Chinsurah, Faizabad and Titabar to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers' fertilizer practices in some new farm sites and fine-tune the fertilizer nutrient requirement for specific target yields in a given environment and validation of fertilizer recommendations for targeted yields. The *kharif* 2016 data received representing the irrigated and shallow lowland rice ecosystems revealed wide variations. Soil nutrient uptake varied between the sites matching with the dry matter yields. On an average each ton of grain accumulated 5.89, 0.82 and 3.2 kg N, P_2O_5 and K_2O at Titabar , 10.61,7.68 and 11.59 at Faizabad and 34.86, 34.65 and 5.09 at Chinsurah. Linear equations fitted to relate the recorded yields in nutrient omission plots with the uptake of respective nutrients indicated very poor relations to N uptake, P uptake and K uptake. Rice productivity with recommended fertilizer practice varied from 2.12 –3.5 t/ha at Titabar ,5.05-6.56t/ha at Faizabad,3.91-4.65t/ha at Chinsurah whereas,0.5 – 1.4 t/ha in the farmers' fields at Titabar, 4.35-6.05t/ha in the farmers' fields at Faizabad and 4.1-5.2t/ha in the farmers' fields at Chinsurah. Very high yield gap 1 and 2 were noticed at Titabar. At Faizabad, Technology yield Gap 1 was manageable but technology yield Gap 2 was also very high. This means that SSNM practice is beneficial at Faizabad but it was not matched at Titabar.

Table 5.2.1 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Soil, crop and weather data

Parameter	Titabar	Faizabad	Chinsurah
Variety	**Ranjit, Bhadur, Gitesh, Swarna Mahsuri,Aghonibora**	**Sarjoo-52**	**Shatabdi (IET 4786)**
Crop growth	Good	Satisfactory	Good
RFD (kg NPK/ha)		120:60:60	80-40-40
Farmers' fertilizer practice (kg/ha) (FFP)	Varying,	Varying, N 80 –242; P 40 – 134; K 40 -1210	Varying, N 60 P 30 K 30
% Clay	-	23	-
% Silt	-	21	-
% Sand	-	56	-
Soil Texture	-	Sandy Loam	Clay loam
pH	5.06-5.7	7.3-7.8	6.6-8.0
Org. carbon (%)	0.56-1.26	0.35 – 0.50	0.43-0.71
Avail. N (kg/ha)	188 - 297	180-220	201 - 495
Avail. P_2O_5 (kg/ha)	19.8-32	18-27	55 – 115
Avail. K_2O (kg/ha)	165-274	210-234	243 - 532

Table 5.2.2 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016- Soil nutrient supply potential assessed in nutrient omission plots

Nutrient	Titabar			Faizabad		
	Minimum	**Maximum**	**Mean***	**Minimum**	**Maximum**	**Mean****
Grain yield (t/ha)						
(-)N	0.36	0.81	0.55	4.9	6.1	5.54
(-)P	0.55	0.91	0.69	4.3	5.8	5.13
(-)K	0.47	0.91	0.64	4.1	5.65	4.86
Soil test values (kg/ha)						
N	188	297	231	180	220	197
P_2O_5	19.8	32	24	18	7	5
K_2O	16.5	274	203	200	234	218
Nutrient uptake (kg/ha)						
N	78	172	125	91.4	129.09	111.68
P_2O_5	18.4	48.6	32.6	84.26	127.17	105.94
K_2O	149.2	307.7	232.2	73.74	118.2	93.26
Nutrient	**Chinsurah**					
	Minimum	**Maximum**	**Mean**			
Grain yield (kg/ha)		**Soil Test Values N**			P_2O_5	K_2O
(-)N	3.87	5.11	4.29	183	241	209
(-)P	4.49	5.16	4.77	74	102	89
(-)K	3.96	4.5	4.25	583	628	607

Table 5.2.3 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 Soil nutrient uptake

Nutrient	Titabar			Faizabad		
	Mean yield (t/ha)	Mean uptake (kg/ha)	SNA (kg/t grain)	Mean yield (t/ha)	Mean uptake (kg/ha)	SNA (kg/t grain)
N	0.55	3.3	5.89	5.54	58.8	10.61
P_2O_5	0.67	0.8	0.82	5.13	39.44	7.68
K_2O	0.61	3.1	3.2	4.86	56.34	11.59
Nutrient	Chinsurah					
	Mean yield (t/ha)	Mean uptake (kg/ha)	SNA (kg/t grain)			
N	4.79	167	34.86	-	-	-
P_2O_5	4.04	140	34.65	-	-	-
K_2O	4.12	21	5.09	-	-	-

Table 5.2.4 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Interrelationship between yield, nutrient uptake and soil test value in nutrient omission plots

Nutrient	Correlation (r)	Regression (R^2)	Intercept (kg/ha)	Slope (q/ha)	Correlation (r)	Regression (R^2)	Intercept (kg/ha)	Slope (kg/ha)
	Titabar				**Faizabad**			
Soil test value Vs. Yield								
(-) N	0.35	0.12	0.9	0.003	0.25	0.062	-464.1	18.4
(-) P	0.31	0.09	1.91	0.001	0.29	0.084	2437.1	65.8
(-) K	0.36	0.12	1.93	0.003	0.12	0.014	-924.1	31.2
Yield Vs. Nutrient uptake								
(-) N	0.93	0.86	2.1	0.008	0.94	0.88	-104.1	23.9
(-) P	0.98	0.96	2.4	0.009	0.97	0.94	159.2	46.3
(-) K	0.99	0.98	2.6.	0.008	0.96	0.92	934.2	1.92
Soil test value vs. Nutrient uptake								
(-) N	0.38	0.14	213.5	1.13	0.43	0.18	189.5	1.16
(-) P	0.43	0.18	1.9	1.9	0.35	0.04	19.06	3.18
(-) K	0.34	0.11	102.7	0.16	0.24	0.05	239.6	1.01
	Chinsurah							
Soil test value Vs. Yield								
(-) N	0.80	0.64	0.006	0.54	-	-	-	-
(-) P	0.13	0.02	0.0009	0.57	-	-	-	----
(-) K	0.72	0.32	0.008	0.86	-	-	-	-
Yield Vs. Nutrient uptake								
(-) N	0.78	0.61	0.001	0.25	-	-	-	-
(-) P	0.61	0.38	0.003	0.42	-	-	-	----
(-) K	0.64	0.41	0.0032	0.32	-	-	-	-
Soil test value vs. Nutrient uptake								
(-) N	0.68	0.47	0.0002	0.15	-	-	-	-
(-) P	0.38	0.15	0.0001	0.22	-	-	-	----
(-) K	0.61	0.38	0.0002	0.12	-	-	-	-

Table 5.2.5 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Yield and nutrient use efficiency (Location: Titabar)

Parameter / Nutrients	Rec. dose of fertilizer (RDF)			Farmer's fert. practice (FFP)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (t/ha)	2.12	3.5	2.74	0.5	1.4	0.84
Nutrient uptake (kg/ha)						
N	28.55	55.80	40.09	9.6	87.30	48.5
P_2O_5	6.31	56.41	38.72	2.1	43.2	5.5
K_2O	40.09	76.25	57.96	16.4	76.74	55.8
Nutrient utilization efficiency (kg grain/kg uptake)						
	MIN	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**
N	74.25	62.70	68.31	52.08	16.03	17.32
P_2O_5	335.9	62.04	70.76	238.09	32.41	152.72
K_2O	52.88	45.91	47.27	30.48	18.25	15.05

Table 5.2.6 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Yield and nutrient use efficiency (Location: Faizabad)

Parameter / Nutrients	Rec. dose of fertilizer (RDF)			Farmer's fert. practice (FFP)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (t/ha)	5.05	6.56	5.98	4.35	6.05	5.41
Nutrient uptake (kg/ha)						
N	**98.03**	**144.3**	**123.4**	**81.6**	**131.6**	**108.5**
P_2O_5	**37.92**	**151.1**	**124.2**	**87.6**	**137.07**	**114.5**
K_2O	**45.80**	**145.3**	**119.3**	**82.3**	**132.2**	**109.0**
Nutrient utilization efficiency (kg grain/kg uptake)						
	MIN	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**
N	51.53	45.46	48.46	53.31	45.97	49.86
P_2O_5	133.1	43.4	48.14	49.65	44.13	47.24
K_2O	110.2	45.1	50.16	52.85	45.72	49.63

Table 5.2.7 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Yield and nutrient use efficiency (Location: Chinsurah)

Parameter / Nutrients	Rec. dose of fertilizer (RDF)			Farmer's fert. practice (FFP)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (t/ha)	3.91	4.65	4.28	4.1	5.2	4.4
Nutrient uptake (kg/ha)						
N	**122**	17.5	149	**115**	**186**	145
P_2O_5	**16.2**	31.9	21.9	**17.9**	**27.2**	128
K_2O	**78.7**	105.4	91	**145**	**20.6**	98
Nutrient utilization efficiency (kg grain/kg uptake)						
	MIN	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**
N	32.1	265.7	28.7	35.65	27.9	30.3
P_2O_5	241.3	14.7	195.4	22.9	191.1	34.3
K_2O	49.69	44.12	47	28.2	252.4	44.9

Table 5.2.8 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Site-specific fertilizer recommendation (kg/ha) for a target yield (Location: Titabar)

Site No.	Current yield with RDF (kg/ha)	Current yield with FFP (kg/ha)	Per cent increase in yield over FFP	Fertilizer recommendation for the target yield (8.1 t/ha)		
				N (Urea)	P_2O_5 (SSP)	K_2O (Potash)
1	6.6	3.2	106	78	34	42
2	7.8	3.4	129	92	40	50
3	7.8	4.5	73	92	40	50
4	8.0	4.4	82	94	41	51
5	8.1	4.8	69	95	42	52
6	5.7	3.7	54	67	29	36
7	7.1	3.8	87	84	36	45
8	7.3	2.7	170	86	37	47
9	5.8	2.2	164	68	30	37
10	5.1	1.9	168	60	26	33
11	5.7	2.5	128	67	29	36
12	5.3	2.5	112	62	27	34
13	5.2	2.2	136	61	27	33
14	5.8	2.3	152	68	30	37
15	5.6	2.5	124	66	29	36

Table 5.2.9 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 -Site-specific fertilizer recommendation (kg/ha) for a target yield (Location: Faizabad)

Site No.	Current yield with RDF (kg/ha)	Current yield with FFP (kg/ha)	Per cent increase in yield over FFP	Fertilizer recommendation for the target yield (8.2 t/ha)		
				N (Urea)	P_2O_5 (SSP)	K_2O (Potash)
1	7.5	6.5	15	123	360	174
2	8.1	6.8	19	133	389	188
3	7.2	5.5	31	118	346	167
4	8.2	7.0	17	134	394	190
5	7.7	7.3	5	126	370	178
6	7.2	6.8	6	118	346	167
7	7.5	7.4	1	123	360	174
8	7.2	6.6	9	118	346	167
9	7.8	6.5	20	128	374	181
10	7.5	6.8	10	123	360	174
11	7.5	6.9	9	123	360	174
12	6.3	5.7	11	103	302	146
13	6.8	6.1	11	112	326	158
14	7.6	7.1	7	125	365	176
15	6.8	7.0	-3	112	326	158

Table 5.2.10 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Validation of SSNM recommendations in farmers' fields

Parameters	SSNM	FFP	Current RDF
Titabar (target -6.4 t/ha)			
Grain yield (t/ha)	6.2	2.87	5.42
Nutrient Uptake (kg/ha)			
N	50.72	20.4	41.76
P_2O_5	16.76	6.65	12.65
K_2O	40.66	17.92	34.33
N U E (kg grain /kg nutrient uptake)			
N	122.2	140.6	129.7
P_2O_5	369.9	431.5	428.12
K_2O	152.6	165.3	157.8
Chinsurah			
Grain yield (t/ha)	5.64	5.23	5.48

Table 5.2.11 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2016 - Yield gap in the Farmer's Fields

Site	*Yield of rice as paddy (t ha^{-1})*			*Yield Gap 1(%)*	*Yield Gap 2(%)*
	Recommended as per SSINM	*on-Station*as per RDF*	*on-farmer's field's***	*[(B-C)/B] x100*	*[(A-C)/A] x100*
	(A)	*(B)*	*(C)*		
			Titabar		
1	*6.2*	6.6	3.2	51.5	48.4
2	*6.2*	7.8	3.4	56.4	45.2
3	*6.2*	7.8	4.5	42.3	27.4
4	*6.4*	8.0	4.4	45.0	31.3
5	*6.4*	8.1	4.8	40.7	25.0
6	*6.4*	5.7	3.7	35.1	42.2
7	*6.5*	7.1	3.8	46.5	41.5
8	*6.5*	7.3	2.7	63.0	58.5
9	*6.5*	5.8	2.2	62.1	66.2
10	*6.5*	5.1	1.9	62.7	70.8
11	*6.5*	5.7	2.5	56.1	61.5
12	*6.5*	5.3	2.5	52.8	61.5
13	*6.6*	5.2	2.2	57.7	66.7
14	*6.6*	5.8	2.3	60.3	65.2
15	*6.6*	5.6	2.5	55.4	62.1
			Min	**35.1**	**25.0**
			Max	**63.0**	**70.8**
			Average	**52.5**	**51.6**
			Faizabad		
1	8.2	7.5	6.5	13.3	20.7
2	8.2	8.1	6.8	16.0	17.1
3	8.2	7.2	5.5	23.6	32.9
4	8.2	8.2	7	14.6	14.6
5	8.2	7.7	7.3	5.2	11.0
6	8.2	7.2	6.8	5.6	17.1
7	8.2	7.5	7.4	1.3	9.8
8	8.2	7.2	6.6	8.3	19.5
9	8.2	7.8	6.5	16.7	20.7
10	8.2	7.5	6.8	9.3	17.1
11	8.2	7.5	6.9	8.0	15.9
12	8.2	6.3	5.7	9.5	30.5
13	8.2	6.8	6.1	10.3	25.6
14	8.2	7.6	7.1	6.6	13.4
15	8.2	6.8	7	-2.9	14.6
			Min	**-2.9**	**9.8**
			Max	**23.6**	**32.9**
			Average	**9.7**	**18.7**

5.3 Screening of Germplasm for Sodicity and Management of Sodic Soils in RBCS

Sodic soils which occupy about 3.77m ha in India have high soil pH (8.5 - 11.0) and exchangeable sodium percentage (ESP) of greater or equal to 15, low organic matter content and preponderance of carbonates and bicarbonates of sodium granules or excess salt content which strongly modify the availability of micronutrients and thereby crop productivity. Such soils can be managed in two ways viz. either by growing a crop variety suitable for a particular soil or by ameliorating the soil through the application of soil amendments. Keeping these points in view, a trial was initiated in *kharif* 2014 in sodic soils of Kanpur to screen germplasm for tolerance to sodicity and higher rice productivity under three levels of ameliorative gypsum application {(0, 50 and 100% gypsum recommendation (GR)] in addition to the recommended dose of NPK. The results of the trial conducted in *rabi* 2015-16 and *kharif* 2016 are presented in Tables 5.3.1 to 5.3.4.

Wheat yields (*rabi* 2015-16)

Grain and straw yield of rabi wheat was improved due to gypsum application (Table 5.3.2). The highest grain and straw yields were observed in 100% GR (4.04 and 4.91 t/ha) followed by 50% GR (3.17 and 3.85 t/ha). The lowest grain and straw yields were observed in the treatment without gypsum (1.86 t/ha and 2.26 t/ha, respectively).

Rice Yield parameters, Grain and Straw yields (*kharif* 2016)

Application of gypsum in conjunction with recommended dose of NPK significantly influenced yield parameters of *kharif* rice. Panicle number/ sq m increased by 14.1% with 50% GR and by 39.8% with application of 100% GR. Panicle weight at 100% GR and 50% GR increased over control (without gypsum amendment) by 28.6% and 33.3%, respectively (Table 5.3.3). Significantly higher grain and straw yield of rice was observed due to gypsum application compared to control which did not receive gypsum (Table 5.3.4). 100% GR application along with recommended dose of NPK resulted in the highest grain and straw yields (3.83 and 4.50 t/ha respectively) followed by 50% GR application (3.18 and 3.69 t/ha, respectively). The lowest grain and straw yield (2.05 and 2.38 t/ha) were recorded in the treatment without gypsum amendment.

Significant interaction effects were observed between genotypes and gypsum application (Table 5.3.4). Genotypes DRR Dhan 43 and CSR 36 which received gypsum at 100% GR along with recommended NPK recorded the highest panicle/sq m (511 and 444 respectively) followed by DRR Dhan 42 (438). Highest panicle weight however was recorded in DRR Dhan 42 (2.20 g) followed by CSR 43 (2.17 g) and CSR 36 (2.15 g). NDR 359 and 27P32 recorded the lowest panicles/ sq m (232) and panicle weight (1.16 g) respectively. The highest grain yields of 4.56 t/ha, 4.42 t/ha and 4.39 t/ha was observed with DRR Dhan 43, DRR Dhan 42 and CSR 36 respectively under recommended NPK + 100% GR fertilization. Straw yield also followed similar trends with DRR Dhan 43 yielding 5.32 t/ha, followed by DRR Dhan 42 (5.23 t/ha) and CSR 36 (5.11 t/ha). The other high yielding genotypes were CSR 43 (4.22 t/ha) and US 314 (3.97 t/ha) under the same fertilization regime. The genotype

DRR Dhan 39 fertilized with only the recommended dose of NPK recorded the lowest grain (1.78 t/ha) and straw (2.09 t/ha) yields.

Under natural sodic conditions where only recommended dose of NPK was applied without gypsum amendments, the genotype DRR Dhan 43 recorded the highest grain (2.32 t/ha) and straw yields (2.73 t/ha) indicating that this genotype is tolerant to soil sodicity conditions at Kanpur. The other genotypes that recorded higher yields without gypsum amendment were DRR Dhan 42 (2.30 t/ha), 28P67 (2.24 t/ha) and CSR 36 (2.22 t/ha).

To summarize, gypsum application in conjunction with NPK fertilization improved rice yields in sodic soils of Kanpur. Gypsum application improved grain yields by 59.6-94.7% over non amended control. Among the 17 genotypes evaluated, DRR Dhan 43, DRR Dhan 42, CSR 36 and CSR 43 recorded highest yields (4.22 - 4.56 t/ha) with 100% GR supplementation. The same genotypes (DRR Dhan 43, DRR Dhan 42, CSR 36) also exhibited better tolerance to sodicity compared to other genotypes as was demonstrated by their significantly higher yields (2.22 - 2.32 t/ha) in treatment without gypsum amendment.

Table 5.3.1 Screening of Germplasm for Sodicity and Management of Sodic Soils in RBCS - Soil and crop characteristics

Parameter	**Kanpur**
Cropping system	**Rice - Wheat**
Variety	
Kharif (Rice)	17 genotypes
Rabi (Wheat)	PBW-343
RFD (Kg NPKZn/ha) *Kharif*	150:60:40:50
% Clay	17
% Silt	34
% Sand	49
Soil Texture	Clay Loam, Typic Natrustalf
pH (1:1)	10.2
Organic carbon (%)	0.18
CEC [c mol(p^+)/kg]	12.27
EC (dS/m)	0.98
ESP (%)	78
Available N (kg/ha)	144.5
Available P_2O_5 (kg/ha)	28.5
Available K_2O (kg/ha)	242.6

Table 5.3.2 Screening of Germplasm for Sodicity and Management of Sodic Soils in RBCS, *(*Kanpur- *Rabi 2015-16)*- Grain and Straw Yield of Rabi Wheat

	Grain yield (t/ha)	**Straw yield (t/ha)**
Gypsum Req.		
T1-No amendment	1.86	2.26
T2- 50% GR	3.17	3.85
T3- 100% GR	4.04	4.91
Mean	3.02	3.68

***T1-No amendment, T2- 50% GR , T3- 100% GR**

Table 5.3.3 Screening of Germplasm for Sodicity and Management of Sodic Soils in RBCS - *(*Kanpur- *Kharif 2016)*- Yield parameters

	Panicles m^{-2}				Panicle wt (g)			
Variety/ Gypsum requirement	**T1***	**T2**	**T3**	**Mean**	**T1***	**T2**	**T3**	**Mean**
28P67	290	347	405	347.2	1.47	2.02	2.09	1.86
27P37	321	315	393	343.2	1.21	1.81	1.73	1.58
RP Bio-5477NH-686	312	343	407	354.0	1.41	1.68	2.05	1.72
DRR dhan-43	332	374	511	405.3	1.52	1.51	1.95	1.66
DRRH-92	338	348	424	370.2	1.28	1.96	1.95	1.73
RPBio-4919-50-7	344	327	423	364.8	1.35	1.65	1.82	1.61
27P32	365	327	422	371.1	1.16	2.00	1.91	1.69
KRH-4	304	342	410	352.0	1.42	1.98	1.87	1.75
27P63	304	349	429	360.8	1.53	1.75	1.94	1.74
RP Bio-4919-50-13	272	323	423	339.4	1.57	2.04	1.89	1.83
27P36	261	292	421	324.6	1.53	2.07	1.88	1.83
CSR-43	314	387	421	373.9	1.48	1.93	2.17	1.86
DRR dhan-42	320	405	438	387.7	1.56	1.93	2.20	1.89
DRR dhan-39	251	314	414	326.4	1.54	1.96	1.85	1.78
U.S.-314	282	382	423	362.4	1.67	1.85	2.04	1.85
NDR-359	232	324	409	321.6	1.85	2.04	1.83	1.91
CSR-36	323	396	444	387.7	1.50	1.92	2.15	1.86
Mean	304	347	425	358.4	1.47	1.89	1.96	1.77
CD (0.05)								
Main	13.27				0.18			
Sub	11.46				0.16			
Main x Sub	19.85				0.27			
Sub x Main	23.14				0.32			
CV %								
Main	6.74				18.33			
Sub	3.42				9.55			

***T1-No amendment, T2- 50% GR , T3- 100% GR**

Table 5.3.4 Screening of Germplasm for Sodicity and Management of Sodic Soils in RBCS - (Kanpur- *Kharif 2016)* Grain and Straw Yield

	Grain yield (t/ha)				Straw Yield (t/ha)			
Variety/ Gypsum requirement	**T1***	**T2**	**T3**	**Mean**	**T1***	**T2**	**T3**	**Mean**
28P67	2.24	3.26	3.93	3.15	2.54	3.76	4.52	3.60
27P37	1.81	2.66	3.17	2.55	2.08	3.06	3.69	2.94
RP Bio-5477NH-686	2.05	3.13	3.86	3.01	2.38	3.63	4.61	3.54
DRR dhan-43	2.32	3.70	4.56	3.52	2.73	4.33	5.32	4.13
DRRH-92	1.99	3.14	3.79	2.97	2.35	3.69	4.45	3.50
RPBio-4919-50-7	1.89	2.91	3.57	2.79	2.19	3.38	4.14	3.24
27p32	1.96	3.09	3.75	2.93	2.27	3.56	4.33	3.38
KRH-4	2.01	3.14	3.56	2.90	2.31	3.55	4.17	3.34
27P63	2.16	3.26	3.87	3.10	2.48	3.83	4.47	3.60
RP Bio-4919-50-13	1.98	3.06	3.70	2.91	2.29	3.54	4.29	3.37
27P36	1.86	2.80	3.41	2.69	2.15	3.25	4.50	3.30
CSR-43	2.15	3.47	4.22	3.28	2.49	4.01	4.90	3.80
DRR dhan-42	2.30	3.59	4.42	3.43	2.69	4.21	5.23	4.04
DRR dhan-39	1.78	2.85	3.52	2.72	2.09	3.32	4.12	3.17
U.S.-314	2.16	3.39	3.97	3.17	2.51	3.95	4.65	3.70
NDR-359	1.99	3.08	3.47	2.84	2.29	3.54	4.02	3.28
CSR-36	2.22	3.54	4.39	3.38	2.63	4.15	5.11	3.96
Mean	2.05	3.18	3.83	3.02	2.38	3.69	4.50	3.52
CD (0.05)								
Main	0.12				0.12			
Sub	0.07				0.11			
Main x Sub	0.13				0.18			
Sub x Main	0.17				0.21			
CV %								
Main	7.27				5.99			
Sub	2.61				3.19			

***T1-No amendment, T2- 50% GR , T3- 100% GR**

5.4 Nutrient use efficiency and soil productivity in early and late sown rice

Rice and rice based cropping systems (RBCS) are the most important production systems widely cultivated under diverse soil and agro ecological conditions including large tracts of soils with *in situ* problems and management induced nutrient stresses. Changing climatic conditions such as shifts in rainfall distribution and its intensity, changes in temperature regimes in many vulnerable areas are likely to influence agricultural productivity through their impact on land and water resources besides directly influencing crop calendar, crop growth and efficiency of inputs. While availability of resources determine the cropping pattern and farm operations, shifts in crop calendar strongly influence crop productivity potential as already reported through studies conducted under the coordinated program. Keeping this in view, the study was conducted in *rabi* 2015 - 16 at Maruteru (MTU) and in *kharif* 2016 at six locations *viz*., Faizabad (FZD), Karaikal (KRK), Khudwani (KHD), MTU, Pusa and IIRR, Hyderabad to assess the extent of change in rice productivity and nutrient use efficiency with changing crop calendar.

The treatments consisted of three different times of crop establishment (in main plots) i.e., early, optimum and late sowing by 15 days from optimum time in *rabi* and normal sowing, late sowing (by 15 days after normal sowing) and very late sowing (by 30 days after normal sowing) in *kharif* and integrated multi-nutrient management approaches in sub plots, as strategies to minimize the likely yield loss. The data from six locations are presented in Tables 5.4.1 to 5.4.7. The test varieties were Sarjoo-52 at FZD, TKM 9 at KRK, Jhelum at KHD, MTU-1061 and MTU-1010 at MTU, and DRR Dhan 44 at IIRR. The details of crop, soil and weather parameters of the experimental sites (Table 5.4.1) show variation in soil characteristics with reference to pH, organic carbon content, soil texture and available nutrient status.

Rice productivity

Data presented in Table 5.4.2 show significant effect of planting/sowing time on rice productivity with early sowing recording highest grain yield of 3.79 t/ha at MTU in *rabi* (2015-16). Early planting resulted in significantly higher yields over optimum and late planting by 7% and 14%, respectively. Similar trend was also observed for straw yield as well.

The effect of planting/sowing time significantly influenced the *kharif* (2016) rice productivity at all the six centres (Table 5.4.3). Normal sowing recorded highest grain yield of 5.26, 5.46, 5.27 and 3.61 t/ha at FZD and KRK, MTU and IIRR while at KHD it was at par with late sowing (by 15 days). Very late sowing (by 30 days) resulted in the lowest grain and straw yields at all the centres. The yields with normal sowing were higher over late sowing by 7% at KHD and MTU, 9% at IIRR and 17% at FZD and KRK. Similar trends were observed for straw yield as well.

Nutrient management practices significantly influenced the productivity at all the six locations in *kharif* 2016. The nutrient management practice consisting of 150% RDF + Zn (N-3 splits @ 1/3 +1/3 +1/3 recorded the maximum grain yield of 5.51, 4.64 and 3.84 t/ha at FZD, KRK and IIRR respectively while 150% RDF + Zn (N-3 splits @ 1/2 + 1/4 +1/4) at

KHD, MTU and Pusa. The effect of nutrient management practices was not significant in *rabi* at MTU. Straw yield also followed the similar trend.

Nutrient uptake and use efficiency

Data presented in Tables 5.4.4 and 5.4.5 show significant effect of time of crop establishment on nutrient uptake. In *rabi*, late planting recorded maximum N (73 kg/ha) and K (45 kg/ha) uptake and minimum P (11 kg/ha) uptake in comparison to early and optimum planting at MTU. Though, N uptake did not differ significantly with nutrient management practice, P uptake was the highest with 100% RDF + ZnSFeB + GM + VC + RS while maximum K uptake was observed with 100% RDF (+ZnS).

During *Kharif* season, normal sowing resulted in significantly the highest N, P and K uptake at all the centres over late and very late sowing. As far as nutrient management practice is concerned, 150% RDF + Zn (N-3 splits @ 1/3 + 1/3 +1/3) recorded maximum nutrient uptake at all the centres excluding Pusa where it was on par with 150% RDF + Zn (N-3 splits @ 1/2 + 1/4 +1/4) and 100% NKZn + 150% P (N-3 splits @ 1/3 +1/3 +1/3).

Data presented in Table 5.4.6 show that the nutrient use efficiencies were high under late and very late sowing as compared to normal sowing. The highest use efficiency of N, P and K at FZD; P and K at MTU was under very late sowing (by 30 days); while late sowing (by 15 days) resulted in highest N, P and K use efficiency at KRK and IIRR. As far as the nutrient management practices are concerned, the use efficiencies of N, P and K were the highest under absolute control in almost all the centres.

Summary

Rice productivity was higher under normal sowing over late sowing by 7% at KHD and MTU, 9% at IIRR and 17% at FZD and KRK in *kharif* season while in *rabi*, early planting resulted in significantly higher yields over optimum and late planting by 7% and 14%, respectively at MTU. The nutrient management practice consisting of 150% RDF + Zn (N-3 splits @ 1/3 +1/3 +1/3 recorded the maximum grain yield of 5.51, 4.64 and 3.84 t/ha at FZD, KRK and IIRR respectively while 150% RDF + Zn (N-3 splits @ 1/2 + 1/4 +1/4) at KHD, MTU and Pusa. The nutrient (N, P and K) uptake was maximum under normal sowing at all the centres over late and very late sowing, during *Kharif* season, while in *rabi*, late planting recorded maximum N and K uptake and minimum P uptake in comparison to early and optimum planting at MTU. As far as nutrient management practice is concerned, 150% RDF + Zn (N-3 splits @ 1/3 + 1/3 +1/3) recorded maximum nutrient uptake at all the centres excluding Pusa. Optimum planting in *rabi*, and delayed planting (by both 15 and 30 days) in *kharif* gave higher nutrient use efficiencies. As far as the nutrient management practices are concerned, the use efficiencies of N, P and K were maximum under absolute control in almost all the centres in *kharif* and under Org. manuring~RDF in *rabi* at MTU.

Table: 5.4.1 Nutrient use efficiency and soil productivity in early and late sown rice Crop and soil characteristics

Parameter	Faizabad	Karaikal	Khudwani	Maruteru	Pusa	IIRR
Cropping system	Rice	Rice-Rice	Rice	Rice-Rice		Rice-Rice
Variety						
Kharif	Sarjoo-52	TKM 9	Jhelum	MTU-1061	-	DRR Dhan 44
Rabi	-	-	-	MTU-1010	-	
RFD (Kg NPK/ha)						
Kharif	120:60:60:10	129:27:88	120:60:30	180:90:60:50	-	120:60:60
Rabi	-	-	-	180:90:60:50	-	
Crop growth					-	
Kharif	Good	Good	Good	Good	-	Good
Rabi	-	-	-	Good	-	-
Soil data						
% clay	23	12.65	22	38	-	-
% silt	21	10.50	37	28	-	-
% sand	56	65.20	41	34	-	-
Soil Texture	Sandy Loam	Sandy clay loam	Silty clay loam	Clay loam	-	Clay
pH (1:1)	7.5	6.14	6.98	6.4	-	8.1
Org.carbon (%)	0.42	0.56	1.15	0.65	-	0.62
CEC [c mol (p+)/kg]	13.80	21.4	-	48.6	-	-
EC (ds/m)	1.02	0.07	0.14	1.56	-	0.28
Avail.N (kg/ha)	200	107	220	226	-	198
Avail. P_2O_5(kg/ha)	27	110	15	20	-	76
Avail. K_2O (kg/ha)	234	206	269	358	-	468

Table 5.4.2 Nutrient use efficiency and soil productivity in early and late sown rice Yield parameters, grain and straw yields (*Rabi* 2015-16) at Maruteru

Treatment	Panicles/m^2	Grain yield (t/ha)	Straw yield (t/ha)
Time of crop establishment			
Early sown / planting	286	3.79	4.82
Optimum sown / planting	270	3.55	4.44
Late sown / planting	267	3.32	4.34
CD(0.05)	**12.47**	**0.23**	**0.33**
CV (%)	**4.49**	**13.72**	**7.28**
Nutrient management			
100% RDF + (ZnS)	279	3.65	4.53
100% RDF + (ZnSFeB)	280	3.62	4.54
150% RDF + (ZnSFeB)	274	3.60	4.65
100% RDF + (ZnSFeB) + GM + VC + RS	275	3.46	4.48
Org. manuring~RDF	261	3.44	4.46
Expt. Mean	**274**	**3.55**	**4.53**
CD (0.05) Nutrients	**11.10**	**NS**	**NS**
M in S	**NS**	**NS**	**NS**
S in M	**NS**	**NS**	**NS**
CV (%)	**4.17**	7.30	9.56

Table 5.4.3 Nutrient use efficiency and soil productivity in early and late sown rice Grain and straw yields (*Kharif* 2016)

Treatment	Grain yield (t/ha)						Straw yield (t/ha)					
	FZD	KRK	KHD	MTU	Pusa	IIRR	FZD	KRK	KHD	MTU	Pusa	IIRR
Time of crop establishment												
Normal sowing	5.26	5.46	5.61	5.27	2.07	3.61	6.48	8.31	12.37	6.35	2.75	6.29
Late sowing by 15 days	4.50	4.66	5.24	4.93	1.78	3.31	5.61	5.35	11.45	6.00	2.38	5.99
Very late sowing by 30 days	3.76	3.05	3.91	4.76	1.66	2.93	4.18	4.99	9.40	5.63	2.21	5.65
CD(0.05)	**0.03**	**0.62**	**0.56**	**0.12**	**NS**	**0.27**	**0.13**	**1.47**	**0.83**	**0.20**	**NS**	**NS**
CV (%)	**0.95**	**15.20**	**12.38**	**3.46**	**24.16**	**8.09**	**1.12**	**25.47**	**8.10**	**4.7**	**43.87**	**29.08**
Nutrient management												
100% RDF + Zn (N- 3 splits @ 1/3 + 1/3 + 1/3)	4.54	4.38	3.91	5.35	1.64	3.09	5.50	5.78	11.45	6.37	2.23	6.49
100% RDF + Zn (N-3 splits @ 1/2 + 1/4+1/4)	4.17	4.66	5.07	5.34	1.74	3.20	4.96	6.87	11.40	6.37	2.30	5.55
150% RDF + Zn (N-3 splits @ 1/3 + 1/3 +1/3)	5.51	4.64	5.12	5.77	1.60	3.84	6.68	7.05	11.50	6.99	2.13	7.08
150% RDF + Zn (N-3 splits @ 1/2 + 1/4 +1/4)	5.16	4.23	5.15	5.83	2.00	3.40	6.18	6.04	11.17	6.95	2.65	6.88
100% NKZn + 150% P (N-3 splits @ 1/3 +1/3 +1/3)	4.82	4.54	5.20	5.29	2.16	-	5.80	6.12	11.40	6.27	2.86	-
Absolute control (no fertilizers)	2.84	3.90	3.91	2.33	1.89	2.29	3.41	5.43	9.51	2.95	2.53	3.87
Expt. Mean	**4.51**	**4.39**	**4.92**	**4.98**	**1.84**	**3.28**	**5.42**	**6.22**	**11.07**	**5.98**	**2.45**	**5.97**
CD(0.05) Nutrients	**0.09**	**0.36**	**0.35**	**0.48**	**0.43**	**0.27**	**0.12**	**0.93**	**0.77**	**0.47**	**0.57**	**0.83**
M in S	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
S in M	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**2.50**	**8.60**	**7.49**	**11.63**	**43.81**	**8.43**	**2.73**	**15.56**	**7.29**	**9.61**	**24.17**	**14.36**

Table 5.4.4 Nutrient use efficiency and soil productivity in early and late sown rice
Nutrient uptake (kg/ha), Nutrient use efficiency (kg grain/kg uptake) and Available nutrient status of soils (*Rabi 2015-16)* at Maruteru

Treatment	Nutrient uptake (kg/ha)			Nutrient use efficiency (kg grain/kg uptake)			Available Nutrient status of soils (Kg/ha)		
	N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**
Time of crop establishment									
Early sown / planting	66.30	16.77	37.58	55.56	227.52	103.86	145.95	41.73	372.84
Optimum sown / planting	56.27	16.16	35.08	63.47	222.08	103.38	136.34	30.08	349.84
Late sown / planting	72.69	10.82	45.37	45.81	313.52	74.01	155.36	18.99	287.03
CD (0.05)	**8.79**	**1.37**	**4.81**	**-**	**-**	**-**	**-**	**-**	**-**
CV (%)	**13.32**	**9.27**	**12.07**	**-**	**-**	**-**	**-**	**-**	**-**
Nutrient management									
100% RDF (+ZnS)	65.79	14.99	46.32	55.77	248.62	80.14	155.57	30.70	343.67
100% RDF (+ZnSFeB)	69.43	14.86	40.47	50.29	250.00	90.77	140.59	30.19	323.42
150% RDF+(+ZnSFeB)	62.56	14.09	38.98	58.73	262.92	95.75	147.56	28.80	313.66
100% RDF +(+ZnSFeB) + GM+VC+RS	65.56	15.43	37.87	53.34	233.65	92.81	149.99	29.37	360.00
Org. manuring~RDF	62.09	13.55	33.09	56.61	276.68	109.29	135.71	32.27	342.09
Expt. Mean	65.09	14.58	39.35	54.95	254.37	93.75	145.88	30.27	336.57
CD (0.05)	**NS**	**1.73**	**4.67**	**-**	**-**	**-**	**-**	**-**	**-**
M in S	**NS**	**NS**	**NS**	**-**	**-**	**-**	**-**	**-**	**-**
S in M	**NS**	**NS**	**NS**	**-**	**-**	**-**	**-**	**-**	**-**
CV (%)	**13.99**	**12.19**	**12.20**	**-**	**-**	**-**	**-**	**-**	**-**

Table 5.4.5 Nutrient use efficiency and soil productivity in early and late sown rice
Nutrient uptake (kg/ha) in total dry matter (*Kharif 2016)*

Treatment	Faizabad			Karaikal			Maruteru			Pusa			IIRR		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Time of crop establishment															
Normal sowing	142.77	83.28	70.57	147.73	145.08	397.34	67.13	24.25	82.98	-	86.32	118.11	81.63	13.78	127.58
Late sowing by 15 days	121.33	66.57	57.07	97.40	89.54	249.46	52.05	21.28	75.61	-	76.93	115.67	71.72	12.35	115.05
Very late sowing by 30 days	93.01	52.39	43.77	88.42	78.88	167.70	48.67	19.28	70.54	-	74.14	109.33	67.10	11.69	112.78
CD (0.05)	**0.75**	**0.55**	**2.31**	**19.34**	**20.65**	**29.80**	**1.74**	**1.37**	**4.62**	**-**	**NS**	**NS**	**12.22**	**2.00**	**NS**
CV (%)	**0.89**	**1.15**	**5.73**	**18.79**	**21.35**	**11.86**	**4.41**	**8.95**	**8.56**	**-**	**29.32**	**6.64**	**16.41**	**15.94**	**25.37**
Nutrient management															
100% RDF + Zn (N- 3 splits @ 1/3 + 1/3 +1/3)	119.93	66.15	57.12	106.04	104.65	264.50	59.66	23.44	83.31	-	75.16	115.33	71.87	12.69	123.53
100% RDF + Zn (N-3 splits @ 1/2 +1/4+1/4)	106.54	58.36	45.46	120.84	101.61	269.38	59.18	23.18	82.59	-	81.76	108.44	66.39	11.21	101.41
150% RDF + Zn (N-3 splits @ 1/3 +1/3 +1/3)	154.19	90.38	77.87	121.13	109.44	299.23	71.00	24.93	90.92	-	76.17	118.00	100.90	16.81	155.13
150% RDF + Zn (N-3 splits @ 1/2 +1/4 +1/4)	138.22	80.38	68.43	107.31	106.16	272.10	72.68	25.12	90.51	-	80.73	119.78	89.86	14.94	144.44
100% NKZn+150%P (N-3 splits @ 1/3+1/3 +1/3)	126.63	71.72	62.23	112.27	104.71	276.96	58.34	25.20	82.24	-	87.86	116.78	-	-	-
Absolute control (no fertilizers)	70.70	37.49	32.71	99.52	100.44	246.82	14.84	7.75	28.69	-	73.12	107.89	38.38	7.38	67.82
Expt. Mean	**119.37**	**67.41**	**57.14**	**111.18**	**104.50**	**271.50**	**55.95**	**21.60**	**76.38**	**-**	**79.13**	**114.37**	**73.48**	**12.61**	**118.47**
CD (0.05)	**3.09**	**2.13**	**3.83**	**15.83**	**NS**	**NS**	**6.47**	**2.39**	**7.35**	**-**	**12.80**	**NS**	**5.94**	**0.92**	**14.62**
M in S	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**-**	**NS**	**NS**	**NS**	**NS**	**NS**
S in M	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**-**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**2.14**	**3.84**	**8.16**	**14.79**	**21.22**	**25.35**	**14.07**	**13.44**	**11.70**	**-**	**16.80**	**11.10**	**8.31**	**7.54**	**12.69**

Table 5.4.6 Nutrient use efficiency and soil productivity in early and late sown rice
Nutrient use efficiency (kg grain/kg uptake) (*Kharif* 2016)

Treatment	Faizabad			Karaikal			Maruteru			Pusa			IIRR		
	NUE	PUE	KUE	NUE	PUE	KUE	NUE	PUE	KUE	NUE	PUE	KUE	NUE	PUE	KUE
Time of crop establishment															
Normal sowing	36.8	63.7	77.2	37.2	38.8	14.4	112.8	230.4	65.5	-	23.9	17.6	46.67	233.23	33.29
Late sowing by 15 days	37.5	69.3	80.5	49.4	54.3	20.6	104.8	237.8	66.8	-	25.4	15.6	48.94	280.07	32.02
Very late sowing by 30 days	40.9	74.3	88.8	35.0	39.7	19.6	85.7	256.0	69.8	-	22.3	15.2	44.85	252.23	25.70
Nutrient management															
100% RDF + Zn (N- 3 splits @ 1/3 + 1/3 +1/3)	38.2	69.9	81.9	42.0	43.8	17.5	91.3	231.4	64.7	-	22.2	14.2	43.28	213.17	28.49
100% RDF + Zn (N-3 splits @ 1/2 +1/4+1/4)	39.5	73.1	94.6	39.6	48.8	20.4	91.5	233.3	64.7	-	21.4	16.0	48.50	256.11	35.30
150% RDF + Zn (N-3 splits @ 1/3 +1/3 +1/3)	36.0	61.2	71.1	39.5	43.9	16.7	82.1	232.7	63.7	-	21.8	13.6	38.51	229.81	25.28
150% RDF + Zn (N-3 splits @ 1/2 +1/4 +1/4)	37.6	64.5	76.0	40.6	41.6	16.3	82.1	234.3	64.6	-	24.9	16.8	44.93	269.42	28.28
100% NKZn+150%P (N-3 splits @ 1/3+1/3 +1/3)	38.3	67.7	80.0	42.0	44.7	18.3	92.6	211.4	64.8	-	24.9	18.4	-	-	-
Absolute control (no fertilizers)	40.8	77.9	89.4	39.6	43.0	20.0	167.1	305.4	81.7	-	28.0	17.7	58.87	307.00	34.33
Expt. Mean	**38.4**	**69.1**	**82.2**	40.5	**44.3**	**18.2**	**101.0**	**241.4**	**67.3**	**-**	**23.9**	**16.1**	**46.82**	**255.10**	**30.34**

Table 5.4.7 Nutrient use efficiency and soil productivity in early and late sown rice Available nutrient status of soils (Kg/ha) – (*Kharif 2016)*

Treatment	Karaikal			Khudwani			Maruteru		
	N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**
Time of crop establishment									
Normal sowing	34	26	159	225	23	278	156	65	145
Late sowing by 15 days	38	30	155	229	15	279	163	56	202
Very late sowing by 30 days	36	59	134	231	15	279	170	62	222
Nutrient management									
100% RDF + Zn (N-3 splits @ 1/3 + 1/3 +1/3)	41	36	149	216	30	276	159	65	177
100% RDF + Zn (N-3 splits @ 1/2 +1/4+1/4)	39	50	128	229	15	278	165	62	197
150% RDF + Zn (N-3 splits @ 1/3 +1/3 +1/3)	36	40	139	235	15	283	168	62	210
150% RDF + Zn (N-3 splits @ 1/2 +1/4 +1/4)	37	38	177	236	16	284	173	61	201
100% NKZn+150%P (N-3 splits @ 1/3 +1/3 +1/3)	33	31	130	234	16	279	172	69	206
Absolute control (no fertilizers)	31	34	172	222	14	271	142	47	148
Expt. Mean	**36**	**38**	**149**	**229**	**18**	**278**	**163**	**61**	**190**

5.5 Screening of rice genotypes for acid soils and related nutritional constraints

Acid soils cover about 15 million ha of rice area widely spread in Eastern, North Eastern and coastal regions of the Peninsula and are highly leached, poor in soil fertility and water-holding capacity. These soils are associated with toxicity of iron in rice lowlands, aluminum in the uplands, with depletion of Ca, Mg and K, deficiency of B, Mo, Si and fix large quantities of soluble P which lead to sub optimal productivity of crops. Management options include liming to correct soil acidity, balanced application of P, K, and silicates and organic manuring besides growing tolerant cultures. Identification of suitable genotypes for such situation with high yield potential helps stabilize rice productivity. The trial was, therefore, conducted at four centres *viz.*, Moncompu (Kuttanad, Kerala, soil pH 5.2), Raipur (Chhattisgarh, Soil pH 5.1), Ranchi (Dumka, Jharkhand, soil pH 5.2), and Titabar (Assam, soil pH 5.2) under low land conditions during *kharif* 2016 screening about 11 – 24 genotypes. The results are presented in Tables 5.5.1 – 5.5.8 and briefly discussed. The cultures were evaluated at 2 or 3 set of nutrient management treatments viz., NPK(RD) and NPK (RD)+Lime at Ranchi; and NPK(RD), NPK (RD)+Lime and N (RD)+double PK at Moncompu, Raipur and Titabar. Lime was applied @ 5.9, 4.0 q/ha at Moncompu and Ranchi, respectively, and 10 q/ha at Raipur and Titabar, as per the location specific estimates of lime requirement. The NPK doses applied were: 90-45-45 at Moncompu, 80-50-30 at Raipur, 100-50-25 at Ranchi and 60-20-40 at Titabar.

Grain and straw yields

Grain yields at all the four locations were influenced by genotype and liming (Table 5.5.2-5.5.5). Recommended NPK + lime significantly increased grain yields by 6.4% to 12.1% and straw yields by 3.1% - 8.4% compared to unlimed control (Recommended NPK) and recommended N+double PK treatments at Moncompu (Table 5.5.2). Recommended N+double PK and recommended NPK + lime significantly increased grain yields by 3.6% - 6.2% compared to recommended NPK at Raipur (Table 5.5.3). Similarly, straw yields at Raipur also increased by 1.70% an 7.39% with recommended N+double PK and recommended NPK treatment, compared to unlimed control. A 14.5% increase in grain yield was recorded due to liming at Ranchi (Table 5.5.4). Response to double PK application and liming was also observed at Titabar as grain yield increased by 11% - 19% over control treatment (Table 5.5.5). Highest straw yield (4.73 t/ha) at Titabar was observed with the application of recommended NPK + lime.

Significant interaction effects of genotype and liming/ double PK application were observed for grain yields at Moncompu and Raipur (5.5.2-5.5.3). The highest yields (6.57, 4.10 and 4.06 t/ha) at Moncompu was observed with the genotype Uma with NPK + liming, recommended N+double PK and unlimed control respectively (Table 5.5.2). DRRH-92 with recommended NPK + lime application yielded 3.78 t/ha, followed by Bamleshwari (3.52 t/ha) at recommended N + Double dose of P and K, and 27P-22 (3.50 t/ha) with recommended NPK + lime. Yields of 3.49 t/ha and 3.48 t/ha were obtained from genotypes DRR Dhan 39 and 27-P 37 respectively under the unlimed treatment. Indira Maheswari performed the best under all the nutrient management regimes at Raipur (Table 5.5.3), yielding 8.02 t/ha, 7.19 t/ha and 6.98 t/ha with the application of NPK + lime, recommended N+double PK and recommended NPK alone, respectively. The genotype RP 5974-3-2-8-38-12 was observed to acheive significantly higher yields of 7.19 t/ha and 6.82 t/ha with NPK + lime and recommended N+double PK treatments, respectively. The other high yielding genotypes were 27P-37 (5.57 t/ha with recommended N+double PK) and DRRH-92 (5.11 t/ha with recommended NPK without application of lime).

At Ranchi and Titabar no significant interaction effects were observed between genotypes and liming. (Table 5.6.4-5.5.5). The highest yielding genotypes at Ranchi were Mahamaya (5.94 t/ha) and Indira Maheswari (4.99 t/ha), at recommended NPK + lime application. The three genotypes that registered maximum grain yields with unlimed control treatment are Mahamaya (4.91 t/ha), DRR Dhan- 43 (4.09 t/ha) and MTU 7029 (4.06 t/ha). Prafulla and Gitesh at Titabar produced the highest yields under all the three nutrient management practices. Grain yields of Prafulla were 4.17 t/ha, 5.13 t/ha and 5.33 t/ha with recommended NPK, NPK + liming and recommended N+double PK while yields of Gitesh with the same treatments were 4.47 t/ha, 5.37 t/ha and 5.27 t/ha.

Nutrient uptake

P and K accumulation in grain increased significantly by 14.8% and 13.6% with lime application at Ranchi (Table 5.5.6). Mahamaya was found to be superior to all genotypes in accumulating grain P (20.17 kg/ha and 16.19 kg/ha) and grain K (24.32 kg/ha and 19.62 kg/ha) in both recommended NPK and recommended NPK + lime treatments respectively. At Titabar (Table 5.5.7), supplementing recommended NPK with either double PK or lime significantly increased total uptake by 3.4-10.8% for N, 0.3 – 24.2% for P and 1.8 – 6.8 % for K, over unlimed treatment with recommended NPK alone.

Post harvest soil characteristics

The different nutrient management practices did not significantly affect the organic carbon (%) and available NPK (kg/ha) after harvest of *kharif* rice at Raipur (Table 5.5.8).

Summary

Based on the results from four centres, it can be summarized that genotypes responded differentially to lime and double PK application at different locations with grain yield increase ranging from 3.6% to 19%. The genotypes responsive to liming were Uma, DRRH 92, 27P-22, Shreyas at Moncompu, Indira Maheswari, Mahamaya, RP 5974-3-2-8-38-12, Bamleswari at Raipur, Mahamaya, Indira Maheswari, DRR Dhan 43, DRR Dhan 39 at Ranchi and Gitesh, Prafulla, DRR Dhan 42, 27P37 at Titabar. Genotypes tolerant to native soil acidity were Uma, DRR Dhan 39, DRR Dhan 42, 27P37 at Moncompu, Indira Maheswari, DRRH 92, 27P36, Mahamaya at Raipur, Mahamaya, DRR Dhan 43, MTU7029, TTB 404 at Ranchi and Gitesh, Prafulla 27P36 and Uma at Titabar as they recorded superior yields in comparison to other genotypes in the treatment without liming. Some genotypes like Uma, Bamleswari, DRRH 92 at Moncompu, Indira Maheswari, RP 5974-3-2-8-38-12, 27P37 at Raipur and Gitesh, Prafulla, DRR Dhan 42, Bamleswari at Titabar also responded to the application of recommended N + double PK.

Table 5.5.1 Screening of rice genotypes for soil acidity and related nutritional constraints (*kharif* 2016)
Soil and Crop data

Parameters	**Moncompu**	**Ranchi (Dumka)**	**Raipur**	**Titabar**
Number of varieties evaluated	23	11	23	24
Crop growth	-	-	Good	-
Treatments followed	• NPK (RD) • NPK (RD) + LIME@ 590 kg/ha • N (RD) + double PK	• NPK (RD) • NPK (RD) + LIME @ 4 Q/ha	• NPK (RD) • NPK (RD) + LIME@ 5t /ha • N (RD) + double PK	• NPK (RD) • NPK (RD) + Lime @ 1t/ha • N (RD) + double PK
Rec. fert. Dose (kg N,P_2O_5 and K_2O/ha)	90-45-45	100-50-25	80-50-30	60-20-40
Soil				
% Clay	64.3	23	42	-
% Silt	24.7	34	36	-
% Sand	11.0	43	22	-
Soil texture	Clay	-	Clay	Silty clay
pH(1:2)	5.2 (1:1)	5.2	5.1 (1:1)	5.2
Org.carbon (%)	3.8	0.65	0.51	1.2
CEC (me/100g)	-	16	-	9.3
EC ds/m	0.11	-	0.17	-
Avail.N (kg/ha)	395	320	185	398
Avail. P_2O_5 (kg/ha)	112.4	28.4	11.2	28
Avail. K_2O (kg/ha)	286.4	185	372	178
Max Temperature (^oC)	31.9	-	41.2	-
Min Temperature (^oC)	24.5	-	11.3	-
Rainfall (mm)	1835.6	-	1124.2	-
RH%	80.5	-	90.2	-

Table 5.5.2. Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2016)

Grain and straw yields

Variety	Location - Moncompu							
	Grain yield (t/ha)				Straw yield (t/ha)			
	T1*	T2	T3	Mean	T1*	T2	T3	Mean
Indira maheswari	1.93	1.76	2.41	2.03	3.48	3.17	4.33	3.66
Mahamaya	2.38	1.09	1.25	1.58	4.29	1.97	2.25	2.84
Danteshwari	1.21	1.30	1.04	1.18	2.18	2.35	1.88	2.13
Mahasuganda	2.64	1.63	1.63	1.97	4.76	2.93	2.93	3.54
Safari 17	2.99	2.93	1.56	2.50	5.39	5.27	2.81	4.49
Bamleshwari	2.21	3.01	3.52	2.92	3.98	5.43	6.33	5.25
DRR Dhan-42	3.07	2.02	2.34	2.48	5.53	3.63	4.22	4.46
DRR Dhan -39	3.49	3.00	1.24	2.57	6.28	5.39	2.23	4.63
DRR Dhan -43	2.02	0.98	2.69	1.90	3.63	1.76	4.85	3.41
27 P - 36	1.12	1.63	2.17	1.64	2.02	2.93	3.91	2.95
27 P - 22	2.88	3.50	2.88	3.09	5.18	6.31	5.18	5.55
27 P - 37	3.48	2.67	1.43	2.52	6.26	4.80	2.57	4.54
27 P - 63	2.15	2.15	2.02	2.10	3.87	3.87	3.63	3.79
28 P - 67	1.04	1.16	0.88	1.03	1.88	2.09	1.71	1.89
KRH - 4	1.53	1.64	0.96	1.38	2.74	2.94	1.74	2.47
US - 314	2.14	1.43	2.47	2.01	3.84	2.58	3.96	3.46
DRRH - 92	2.60	3.78	3.19	3.19	4.69	6.80	5.74	5.74
Uma	4.06	6.57	4.10	4.91	7.31	9.14	7.38	7.94
Prathyasa	1.04	1.95	1.63	1.54	1.88	3.51	2.93	2.77
Shreyas	1.77	3.41	2.02	2.40	3.19	6.14	3.63	4.32
RP 5973-4-1-6-129-35	1.43	2.82	2.76	2.34	2.58	5.08	4.97	4.21
RP 5971-2-6-2-1-232	1.90	1.16	0.91	1.32	3.42	2.09	1.63	2.38
RP 5974-4-3-2-8-38-12	1.13	1.72	2.59	1.81	2.04	3.09	4.66	3.27
Mean	2.18	2.32	2.07	2.19	3.93	4.05	3.72	3.90
CD (0.05)								
Main	0.14				0.26			
Sub	0.67				1.17			
Main x Sub	1.33				2.31			
Sub x Main	1.33				2.32			
CV%								
Main	10.86				10.80			
Sub	18.01				17.57			

T1=Recommended NPK, T2= Recommended NPK + Lime, T3= Recommended N + double PK

Table 5.5.3. Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2016)
Grain and straw yields

Variety	Location – Raipur							
	Grain yield (t/ha)				Straw yield (t/ha)			
	T1*	T2	T3	Mean	T1*	T2	T3	Mean
Indira Maheswari	7.19	8.02	6.98	7.40	10.97	10.53	9.98	10.49
Mahamaya	4.69	5.22	4.18	4.70	5.98	6.41	4.94	5.78
Danteswari	1.62	2.86	1.58	2.02	2.78	3.71	2.18	2.89
Mahasugandha	4.27	2.74	3.75	3.59	5.53	5.26	5.75	5.51
Safari -17	3.79	4.17	5.02	4.33	6.66	9.38	7.58	7.87
Bamleswari	4.42	5.21	3.73	4.45	5.53	6.56	4.60	5.56
DDR Dhan -42	3.58	3.36	3.28	3.41	4.79	4.63	4.52	4.65
DDR Dhan -39	3.60	3.39	3.79	3.59	4.53	4.63	4.53	4.56
DDR Dhan -43	4.08	3.90	4.49	4.16	4.72	4.68	5.50	4.97
27P-36	4.74	4.79	4.69	4.74	5.21	5.91	5.50	5.54
27P-22	4.17	4.58	4.50	4.42	5.08	5.50	5.23	5.27
27P-37	4.56	4.53	5.57	4.89	5.57	5.17	6.51	5.75
27P-63	3.50	3.49	3.65	3.55	4.72	4.44	4.42	4.53
28 P -67	4.22	3.79	3.74	3.92	5.23	4.38	4.79	4.80
KRH-4	4.37	3.93	4.35	4.22	4.71	6.47	5.38	5.52
US-314	4.16	5.12	3.90	4.39	5.09	6.60	5.54	5.74
DRRH -92	5.11	4.58	4.89	4.86	5.75	5.75	5.84	5.78
Uma	2.51	3.62	2.23	2.79	3.29	4.35	3.62	3.76
Prathyasa	4.06	3.88	3.81	3.92	4.54	4.69	4.20	4.47
Sreyas	4.68	3.64	4.24	4.19	5.40	4.33	5.59	5.11
RP5973-4-1-6-129-35	4.30	4.39	4.77	4.49	4.10	5.16	5.52	4.93
RP5971-2-6-2-1-232	2.79	2.48	2.52	2.60	3.46	4.14	3.68	3.76
RP5974-3-2-8-38-12	2.79	7.19	6.82	5.60	7.89	7.67	8.05	7.87
Mean	4.05	4.30	4.19	4.18	5.28	5.67	5.37	5.44
CD (0.05)								
Main	0.28				0.28			
Sub	0.78				0.78			
Main x Sub	1.55				1.55			
Sub x Main	1.62				1.62			
CV%								
Main	11.13				9.77			
Sub	11.01				11.13			

T1=Recommended NPK, T2= Recommended NPK + Lime, T3= Recommended N + double PK

Table 5.5.4. Screening of rice genotypes for soil acidity and related nutritional constraints (*kharif* 2016)
Grain yields (t/ha)

Variety	Location – Ranchi (Dumka)		
	T1*	**T2**	**Mean**
MTU7029	4.06	4.45	4.26
Rajshree	3.90	4.07	3.98
TTB-404	4.05	4.24	4.14
Govind	2.79	3.15	2.97
Indira Maheswari	4.01	4.99	4.50
Uma	3.48	4.11	3.80
Mahasugandha	3.40	4.18	3.79
DRR Dhan-39	3.86	4.51	4.18
Mahamaya	4.91	5.94	5.43
DRR Dhan -42	3.79	4.27	4.03
DRR Dhan -43	4.09	4.60	4.35
Mean	**3.85**	**4.41**	**4.13**
CD (0.05) Main	0.43		
Sub	0.64		
Main x Sub	NS		
Sub x Main	NS		
CV% Main	9.75		
Sub	7.84		

T1=Recommended NPK, T2= Recommended NPK + Lime

Table 5.5.5. Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2016)

Grain and straw yields

Variety	Location – Titabar							
	Grain yield (t/ha)				Straw yield (t/ha)			
	T1*	T2	T3	Mean	T1*	T2	T3	Mean
Indira Maheswari	2.52	2.95	2.17	2.54	4.43	4.43	3.77	4.21
Mahamaya	2.40	3.27	2.57	2.74	4.27	4.43	4.10	4.27
Danteshwari	2.47	3.00	2.80	2.76	4.40	4.67	4.20	4.42
Mahasuganda	2.53	2.83	3.10	2.82	4.17	4.03	4.57	4.26
Safari 17	2.43	3.20	3.13	2.92	4.17	4.30	4.50	4.32
Banleshwari	2.77	3.43	3.50	3.23	4.53	4.73	4.73	4.67
DRR Dhan-42	2.50	3.73	3.63	3.29	4.70	4.78	4.42	4.63
DRR Dhan-39	2.93	3.47	3.50	3.30	4.77	4.80	4.77	4.78
DRR Dhan-43	2.50	2.90	2.73	2.71	4.50	4.20	4.17	4.29
27 P-36	3.27	3.67	3.27	3.40	4.73	4.87	4.67	4.76
27 P-22	2.63	3.40	3.07	3.03	4.63	4.63	4.50	4.59
27 P-37	2.80	3.63	3.23	3.22	4.70	4.90	4.67	4.76
28 P-67	3.07	3.20	2.83	3.03	4.50	4.43	4.33	4.42
KRH-4	3.03	3.23	2.83	3.03	4.60	4.53	4.30	4.48
US 314	2.77	3.57	2.90	3.08	5.00	5.00	4.37	4.79
DRRH-92	2.75	3.13	2.60	2.83	4.60	4.53	4.17	4.43
Uma	3.20	3.57	2.93	3.23	4.60	4.63	4.37	4.53
Prathyasa	2.73	3.10	3.20	3.01	4.47	4.40	4.73	4.53
Shreyas	2.80	3.43	3.27	3.17	4.60	4.67	4.70	4.66
RP 5973-4-1-6-129-35	3.13	3.13	3.13	3.13	4.70	4.80	4.57	4.69
RP 5971-2-6-2-1-232	2.90	3.37	2.97	3.08	4.93	4.87	4.00	4.60
RP 5974-3-2-8-38-12	2.90	3.00	3.40	3.10	4.50	4.20	4.80	4.50
Prafulla	4.17	5.13	5.33	4.88	5.53	6.20	6.57	6.10
Gitesh	4.47	5.37	5.27	5.03	6.27	6.53	6.50	6.43
Mean	2.90	3.45	3.22	3.19	4.68	4.73	4.60	4.67
CD (0.05) Main	0.15				0.12			
Sub	0.64				0.60			
Main x Sub	NS				NS			
Sub x Main	NS				NS			
CV% Main	7.67				4.20			
Sub	11.79				7.48			

T1=Recommended NPK, T2= Recommended NPK + Lime, T3= Recommended N + double PK

Table 5.5.6. Screening of rice genotypes for soil acidity and related nutritional constraints (*kharif* 2016)

P and K uptake in grain (kg/ha) - Location – Ranchi

	P uptake			**K uptake**		
Variety	**T1***	**T2**	**Mean**			
MTU7029	12.87	13.71	13.29	14.48	15.04	14.76
Rajshree	12.03	12.13	12.08	14.36	14.15	14.26
TTB-404	13.26	13.88	13.57	15.27	15.98	15.63
Govind	8.62	10.10	9.36	9.45	11.04	10.25
Indira Maheswari	11.62	14.40	13.01	13.22	16.39	14.80
Uma	9.43	11.05	10.24	11.18	12.28	11.73
Mahasugandha	10.62	13.70	12.16	11.99	14.94	13.47
DRR-39	12.37	13.98	13.18	13.53	16.24	14.88
Mahamaya	16.19	20.17	18.177	19.62	24.32	21.97
DRR-42	10.89	11.96	11.43	12.40	13.67	13.03
DRR-43	11.74	13.75	12.74	12.95	14.66	13.81
Mean	**11.79**	**13.53**	**12.66**	**13.50**	**15.34**	**14.42**
CD (0.05)						
Main	1.38			1.55		
Sub	2.02			2.33		
Main x Sub	NS			3.71		
Sub x Main	NS			4.87		
CV%						
Main	10.24			10.10		
Sub	8.10			8.21		

T1=Recommended NPK, T2= Recommended NPK + Lime

Table 5.5.7. Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2016) Nutrient uptake (Location – Titabar)

Variety	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	T1*	**T2**	**T3**	**Mean**	**T1***	**T2**	**T3**	**Mean**	**T1***	**T2**	**T3**	**Mean**
Indira Mahswari	40.79	44.21	35.80	40.27	6.46	7.87	5.83	6.72	61.87	66.29	54.05	60.74
Mahamaya	38.71	46.25	39.86	41.61	7.14	9.65	7.67	8.15	62.43	69.57	59.58	63.86
Danteshwari	41.82	48.15	40.27	43.41	7.50	9.24	7.73	8.16	65.24	72.01	61.77	66.34
Mahasuganda	39.98	42.28	45.05	42.44	8.04	8.64	8.28	8.32	62.70	63.17	69.86	65.24
Safari 17	39.13	45.86	46.24	43.74	7.81	10.03	7.95	8.60	63.24	74.62	70.32	69.39
Bamleshwari	46.14	53.04	49.03	49.40	8.88	11.56	10.12	10.19	68.28	75.02	74.17	72.49
DRR Dhan-42	43.98	54.07	48.25	48.77	8.47	21.57	10.50	13.51	70.61	79.60	70.50	73.57
DRR Dhan-39	45.72	50.76	51.10	49.19	21.75	23.97	9.88	18.53	72.04	76.32	75.15	74.50
DRR Dhan-43	42.09	43.30	41.20	42.20	8.94	9.67	8.53	9.04	71.63	70.77	61.76	68.05
27 P-36	49.70	54.83	47.48	50.67	9.74	11.45	9.13	10.11	74.39	78.48	73.69	75.52
27 P-22	43.09	49.12	46.17	46.13	8.84	10.74	9.24	9.60	70.75	75.12	71.82	72.56
27 P-37	44.93	52.43	47.07	48.14	8.83	10.65	9.51	9.66	71.15	78.58	73.82	74.52
28 P-67	47.19	48.35	42.37	45.97	8.45	9.82	8.73	9.00	70.28	70.40	69.35	70.01
KRH-4	45.94	47.18	41.24	44.79	9.06	11.18	9.07	9.77	72.32	73.55	65.76	70.55
US 314	46.31	52.10	46.15	48.19	9.00	10.92	8.65	9.52	75.60	81.14	68.32	75.02
DRRH-92	45.95	48.78	42.11	45.61	8.93	10.44	7.69	9.02	70.64	72.33	62.87	68.62
Uma	48.89	52.26	44.50	48.55	9.72	10.99	9.75	10.15	71.52	74.44	70.03	72.00
Prathyasa	43.69	47.67	51.04	47.47	8.76	9.61	9.30	9.22	68.51	70.33	76.83	71.89
Shreyas	46.73	52.48	51.56	50.25	8.90	10.60	10.24	9.91	70.71	76.09	76.83	74.54
RP 5973-4-1-6-129-35	50.07	50.15	49.06	49.76	9.23	9.95	10.00	9.73	72.66	74.45	72.53	73.21
RP 5971-2-6-2-1-232	48.71	53.22	44.93	48.95	9.41	10.86	9.73	10.00	74.48	77.44	65.37	72.43
RP 5974-3-2-8-38-12	44.83	44.51	49.00	46.11	9.79	10.73	11.10	10.54	69.72	67.14	80.19	72.35
Prafulla	65.60	78.71	80.43	74.92	12.97	17.89	16.07	15.65	90.42	104.98	112.05	102.48
Gitesh	75.40	87.16	83.95	82.17	14.46	19.10	17.14	16.90	103.51	120.79	119.58	114.63
Mean	46.89	51.95	48.49	49.11	9.63	11.96	9.66	10.42	71.86	76.78	73.18	73.94
CD (0.05) Main	1.96				1.89				2.71			
Sub	8.15				7.96				11.66			
Main x Sub	NS				NS				NS			
Sub x Main	NS				NS				NS			
CV% Main	6.71				30.50				6.16			
Sub	9.69				44.56				9.20			

***T1=Recommended NPK, T2= Recommended NPK + Lime, T3= Recommended N + double PK**

Table 5.5.8. Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2016) Soil properties (Location – Raipur)

Variety	O C(%)				Avail. N (kg/ha)				Avail.P_2O_5 (kg/ha)				Avail K_2O (kg/ha)			
	T1*	T2	T3	Mean	T1*	T2	T3	Mean	T1*	T2	T3	Mean	T1*	T2	T3	Mean
Indira Maheswari	0.52	0.53	0.56	0.54	182.00	185.67	194.67	187.44	11.62	10.78	10.72	11.04	383.67	377.67	370.33	377.22
Mahamaya	0.52	0.50	0.50	0.51	180.33	175.00	175.00	176.78	12.48	12.63	11.59	12.24	365.00	373.67	385.33	374.67
Danteswari	0.55	0.54	0.52	0.54	192.67	189.00	182.00	187.89	10.54	11.20	11.41	11.05	377.67	372.33	365.00	371.67
Mahasugandha	0.53	0.56	0.55	0.55	185.67	194.67	192.67	191.00	10.78	10.72	10.19	10.56	377.67	370.33	368.33	372.11
Safari -17	0.50	0.50	0.52	0.51	175.00	175.00	182.00	177.33	12.63	11.59	11.62	11.95	373.67	385.33	383.67	380.89
Bamleswari	0.54	0.52	0.52	0.53	189.00	182.00	180.33	183.78	11.20	11.41	12.48	11.70	372.33	365.00	365.00	367.44
DDR Dhan -42	0.56	0.55	0.55	0.55	194.67	192.67	192.67	193.33	10.72	10.19	10.54	10.48	370.33	368.33	377.67	372.11
DDR Dhan -39	0.50	0.52	0.53	0.52	175.00	182.00	185.67	180.89	11.59	11.62	10.78	11.33	385.33	383.67	377.67	382.22
DDR Dhan -43	0.52	0.52	0.50	0.51	182.00	180.33	175.00	179.11	11.41	12.48	12.63	12.17	365.00	365.00	373.67	367.89
27P-36	0.55	0.55	0.54	0.55	192.67	192.67	189.00	191.44	10.19	10.54	11.20	10.64	368.33	377.67	372.33	372.78
27P-32	0.52	0.53	0.56	0.54	182.00	185.67	194.67	187.44	11.62	10.78	10.72	11.04	383.67	377.67	370.33	377.22
27P-37	0.52	0.50	0.50	0.51	180.33	175.00	175.00	176.78	12.48	12.63	11.59	12.24	365.00	373.67	385.33	374.67
27P-63	0.55	0.54	0.52	0.54	192.67	189.00	182.00	187.89	10.54	11.20	11.41	11.05	377.67	372.33	365.00	371.67
28 P -67	0.53	0.56	0.55	0.55	185.67	194.67	192.67	191.00	10.78	10.72	10.19	10.56	377.67	370.33	368.33	372.11
KRH-4	0.50	0.50	0.52	0.51	175.00	175.00	182.00	177.33	12.63	11.59	11.62	11.95	373.67	385.33	383.67	380.89
US-314	0.54	0.52	0.52	0.53	189.00	182.00	180.33	183.78	11.20	11.41	12.48	11.70	372.33	365.00	365.00	367.44
DRRH -92	0.56	0.55	0.55	0.55	194.67	192.67	192.67	193.33	10.72	10.19	10.54	10.48	370.33	368.33	377.67	372.11
Uma	0.50	0.52	0.54	0.52	175.00	182.00	184.67	180.56	11.59	11.62	10.80	11.34	385.33	383.67	370.00	379.67
Prathyasa	0.52	0.52	0.52	0.52	182.00	180.33	182.00	181.44	11.41	12.48	11.41	11.77	365.00	365.00	365.00	365.00
Sreyas	0.55	0.55	0.55	0.55	192.67	192.67	192.67	192.67	10.19	10.54	10.19	10.31	368.33	377.67	368.33	371.44
RP5973-4-1-6-129-35	0.52	0.53	0.52	0.53	182.00	185.67	182.00	183.22	11.62	10.78	11.62	11.34	383.67	377.67	383.67	381.67
RP5971-2-6-2-1-232	0.52	0.50	0.52	0.51	180.33	175.00	180.33	178.56	12.48	12.63	12.48	12.53	365.00	373.67	365.00	367.89
RP5974-3-2-8-38-12	0.55	0.54	0.55	0.55	192.67	189.00	192.67	191.44	10.54	11.20	10.54	10.76	377.67	372.33	377.67	375.89
Mean	0.53	0.53	0.53	0.53	184.91	184.68	185.33	184.98	11.35	11.35	11.25	11.32	374.10	373.99	373.22	373.77
CD (0.05) Main	NS				NS				NS				NS			
Sub	0.08				16.04				NS				NS			
Main x Sub	NS				NS				NS				NS			
Sub x Main	NS				NS				NS				NS			
CV% Main	1.09				1.45				8.11				2.73			
Sub	4.59				5.09				15.28				3.88			

T1=Recommended NPK, T2= Recommended NPK + Lime, T3= Recommended N + double PK

5.6 Monitoring soil quality and crop productivity under emerging rice production systems

Depleted soil productivity and reduced ground water level are the main challenges in present day agriculture. Water availability for agriculture and for rice, in particular, will be less in future and hence, we need to explore a new range of water saving technologies for rice production. Same is the case with labour availability also as a result of migration of agricultural labourers to other activities. Some of the newly emerging rice production systems like direct seeded rice (DSR) and aerobic rice (AR) have potential to perform better under such situations. But, these systems often result in lower yields which are attributed to nutritional disorders. Hence, optimum dose and schedule of fertilizer application is necessary to achieve higher yields while sustaining soil health and productivity. Keeping this in view, a medium term study was proposed to assess sustainability of evolving rice production systems like AR, DSR vis-a-vis conventional transplanted system in terms of productivity of the cropping systems, soil quality and carbon sequestration potential and utilization efficiency of resources and inputs. This trial was initiated during kharif *20*13 and continued during kharif 2016 at three locations (Kanpur (KNP), Moncompu (MCP) and Pusa) with three main plot treatments and five sub plot treatments. The main plot treatments included three methods of cop establishment *viz.,* transplanted rice (TPR); direct sown rice under puddled conditions (DSR) and aerobic rice (AR, non-puddle, direct sown) with zero or minimum tillage. The sub plot treatments included five different nutrient combinations with conjunctive use of inorganic and organic sources of nutrients. The results are presented in Table 5.6.1 to 5.6.5. The test varieties were NDR-359 at Kanpur, Uma at Moncompu and Rajendra Bhagwati at Pusa the details of crop, soil characteristic of experimental sites are presented in Table 5.6.1.

Grain and Straw Yields

Grain and straw yield data are presented in Table 5.6.2. At Kanpur, TPR recorded significantly higher grain yield (6.18 t/ha) compared to DSR and AR; at Moncompu DSR recorded higher grain yield (7.09 t/ha*)*, compared to TPR and AR; at Pusa all the systems (TPR, DSR and AR) are on par. At Kanpur TPR recorded 14% higher yield than DSR and 19% higher yield than AR. And at Moncompu, DSR recorded 6.3% yield than TPR and at Pusa all the systems are on par. With regard to nutrient sources at Kanpur and Pusa, RDF+50% NPK through organics sources recorded significantly higher yield (5.96 t/ha and 1.76 t/ha respectively), while at Moncompu, 75% RDF +25% organics recorded superior yield (7.72 t/ha) over other treatments. Lower grain yields at Pusa can be attributed to very late planting due to late onset of monsoon that had led to water scarcity. Straw yields followed the same trend as that grain yield at all the 3 locations.

Nutrient uptake wheat yield and use efficiency

Total nutrients (NPK) uptake by the above ground biomass and nutrient use efficiency is presented in Tables 5.6.3 and 5.6.4. Total NPK uptake just followed the similar trend as of grain yield with maximum uptake in TPR followed by DSR and AR. the nutrient use efficiency was almost same in all the systems and with all nutrient management practices with slightly higher values in DSR at Kanpur.

Wheat yield (*rabi 2016*)

Wheat grain and straw yield data are presented in Table 5.6.3. grain yield in all the systems (TPR, DSR and AR) are on par and TPR recorded significantly higher straw yield (5.1 t/ha) compared to DSR and AR at Kanpur,

As per the Table 5.7.5, almost all soil properties were not influenced by methods of crop establishment at all locations. Similarly, nutrient management practices also did not influence most of the soil properties to a significant level though organics recorded slightly improved values.

To summarise, the fourth year of study on monitoring soil quality and crop productivity under emerging rice production systems at three centres *viz*, Kanapur, Moncompu and Pusa, the results indicated consistently superior performance of transplanted rice over DSR and aerobic rice by 14.5-19% at Kanpur, production systems at Moncompu indicated superior performance of DSR over transplanted by 6.3% and at Pusa all the systems are on par. In case of nutrient management practices maximum yields were obtained with RDF+50% NPK through organics sources recorded significantly higher yield at Kanapur and Pusa while, 75% RDF +25% organics recorded superior higher yield at Moncompu. Nutrient uptake was also higher in transplanted rice followed by DSR and soil available nutrients were high in the plots that received organic manures either alone or in combination with chemical fertilizers.

Table 5.6.1 Monitoring soil quality and crop productivity under emerging rice production systems Soil and crop characteristics

Parameters	**KNP**	**MCP**	**Pusa**
Cropping system	**Rice-Wheat**	**Rice**	**Rice -Wheat**
Variety – kharif	NDR-359	Uma	Rajendra Bhagwati
RDF (kg NPK/ha)	150-75-60	-	-
Crop growth:	-	-	-
Soil characteristic			
% Clay	20.5	68.0	13.0
% Silt	22.7	21.7	31.6
% Sand	56.7	10.3	55.4
Texture	Sandy Loam	Clay loam	Sandy loam
pH (1:2)	7.8	5.73	
Organic carbon (%)	0.40	3.98	-
CEC (cmol (p^+)/kg)	25.8	-	-
EC (dS/m)	0.42	0.06	-
Avail. N (kg/ha)	238.5	407	-
Avail. P_2O_5 (kg/ha)	18.9	74.0	-
Avail. K_2O (kg/ha)	172.3	246	-

Table 5.6.2 Monitoring soil quality and crop productivity under emerging rice production systems Grain and straw yield- *kharif 2016*

Treatment	Kanpur		Moncompu		Pusa	
	Grain yield (t/ha)	Straw yield (t/ha))	Grain yield (t/ha))	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
Method of crop establishment						
Transplanted rice (TPR)	6.18	7.13	6.66	7.97	1.10	1.35
Direct sown rice under puddled conditions (DSR)	5.29	6.11	7.10	9.10	1.25	1.58
Aerobic rice (AR, non-puddle, direct sown) Zero / minimum tillage	5.01	5.94	-	-	1.15	1.39
CD(0.05)	0.06	0.31	0.35	0.89	NS	0.09
CV (%)	1.48	6.24	5.06	10.31	13.03	10.64
Nutrient management						
100% Recommended Dose of Fertilizer (RDF) of the location (STCR based)+Zn+S	5.90	7.05	6.76	7.93	1.49	1.82
75% RDF+25% through organics (GM, FYM, PM, VC etc. as in treatment No.3)	5.65	6.52	7.73	9.4	1.15	1.41
100% recommended NPK through locally available organics (©)	4.80	5.53	5.49	7.48	0.77	0.96
100% RDF + 50% NPK through organics(©)	5.96	6.90	7.57	9.18	1.77	2.11
2t/ha Vermi compost/ poultry manure +50%RDF	5.16	5.96	6.83	8.72	0.66	0.89
CD(0.05)	0.08	3.28	0.52	0.52	NS	0.30
CV (%)	1.81	6.23	7.41	5.92	15.71	21.57
Interaction						
M and T	0.14	NS	0.74	0.74	NS	NS
T and M	0.14	NS	0.72	0.96	NS	NS
Experimental Mean	**0.54**	**6.39**	**6.87**	**8.53**	**0.22**	**1.44**

© =FYM, Vermi compost, rice straw, poultry manure, green manure, bio-fertilisers, crop residues, compost etc.

Table 5.6.3 Monitoring soil quality and crop productivity under emerging rice production systems Total nutrient uptake- *kharif 2016* and wheat grain and straw yield- *rabi 2016*

Treatment	Kanpur(kg/ha)			Kanpur	
	TOT_N	TOT_P	TOT_K	Grain yield (t/ha)	Straw yield (t/ha))
Method of crop establishment					
Transplanted rice (TPR)	148.88	61.17	140.99	4.19	5.07
Direct sown rice under puddleconditions (DSR)	120.66	50.33	119.55	3.62	4.43
Aerobic rice (AR, non-puddle, direct sown) Zero / minimum tillage	117.77	49.74	111.21	3.77	4.13
CD(0.05)	3.06	NS	4.81	NS	0.19
CV (%)	3.06	25.36	5.01	23.6	5.6
Nutrient management					
100% Recommended Dose of Fertilizer (RDF) of the location (STCR based)+Zn+S	143.83	58.17	139.01	4.16	4.94
75% RDF+25% through organics (GM, FYM, PM, VC etc. as in treatment No.3)	131.56	53.85	126.32	3.66	4.46
100% recommended NPK through locally available organics ©	108.38	44.15	104.58	3.23	3.94
100% RDF + 50% NPK through organics ©	142.95	63.85	135.81	4.37	5.35
2t/ha Vermi compost/ poultry manure +50%RDF	118.79	48.72	113.86	3.88	4.02
CD(0.05)	3.81	6.68	5.14	0.75	0.18
CV (%)	3.58	15.07	5.02	23.68	4.78
Interaction					
M and T	NS	NS	NS	NS	NS
T and M	NS	NS	NS	NS	NS
Experimental Mean	**129.1**	**53.75**	**123.92**	3.86	4.54

© =FYM, Vermi compost, rice straw, poultry manure, green manure, bio-fertilisers, crop residues, compost, etc

Table 5.6.4 Monitoring soil quality and crop productivity under emerging rice production systems Nutrient use efficiency (kg grain/kg nutrient uptake) - *kharif 2016*

Treatment	Kanpur(kg/ha)		
	NUE	PUE	KUE
Method of crop establishment			
Transplanted rice (TPR)	41	101	44
Direct sown rice under puddleconditions (DSR)	44	105	44
Aerobic rice (AR, non-puddle, direct sown) Zero / minimum tillage	43	102	45
Nutrient management			
100% Recommended Dose of Fertilizer (RDF) of the location (STCR based)+Zn+S	41	102	42
75% RDF+25% through organics (GM, FYM, PM, VC etc. as in treatment No.3)	43	105	45
100% recommended NPK through locally available organics ©	44	109	46
100% RDF + 50% NPK through organics ©	42	93	44
2t/ha Vermi compost/ poultry manure +50%RDF	43	105	45

© =FYM, Vermi compost, rice straw, poultry manure, green manure, bio-fertilisers, crop residues, compost, etc

Table 5.6.5 Monitoring soil quality and crop productivity under emerging rice production systems
Soil properties at harvest- kharif 2016

Treatment	Kanpur (kg/ha)				Moncompu (kg/ha)			Pusa (kg/ha)				
	% OC	Avail N	P_2O_5	K_2O	% OC	P_2O_5	K_2O	PH	EC	% OC	P_2O_5	K_2O
Method of crop establishment												
Transplanted rice (TPR)	0.59	203.6	29.7	197.9	0.3	75.7	272.0	8.87	0.21	0.61	56.0	113.3
Direct sown rice under puddle conditions (DSR)	0.54	201.9	29.0	199.6	0.29	63.1	297.1	8.94	0.23	0.67	57.2	124.4
Aerobic rice (AR, non-puddle, direct sown) Zero / minimum tillage	0.57	200.6	29.2	193.6	-	-	-	8.99	0.22	0.65	62.9	125.0
CD(0.05)	0.05	0.41	NS	NS	NS	8.85	23.6	NS	0.01	0.02	NS	6.2
CV (%)	1.14	0.26	2.63	6.62	17.95	12.68	8.25	1.72	5.48	5.21	24.45	7.9
Nutrient management												
100% Recommended Dose of Fertilizer (RDF) of the location (STCR based) +Zn +S	3.82	202.1	27.4	193.9	3.24	77.4	240.5	8.93	0.23	0.65	57.4	117.8
75% RDF+25% through organics (GM, FYM, PM, VC etc. as in treatment No.3)	5.08	200.1	29.6	195.8	3.08	68.0	305.8	8.88	0.22	0.64	53.3	119.2
100% recommended NPK through locally available organics (©)	7.4	210.0	31.6	207.8	3.01	52.9	237.4	8.92	0.21	0.68	66.5	123.0
100% RDF + 50% NPK through organics (©)	6.1	191.7	27.0	183.7	2.75	83.8	312.5	8.88	0.22	0.61	61.4	123.2
2t/ha Vermi compost/ poultry manure +50%RDF	5.64	206.2	31.1	204.0	2.85	64.6	326.7	9.08	0.21	0.62	55.3	121.7
CD(0.05)	0.07	0.81	0.86	10.38	NS	8.8	51.21	NS	NS	NS	NS	NS
CV (%)	1.56	0.49	3.54	6.39	13.17	12.29	17.43	2.32	15.71	12.82	26.53	9.04
Interaction												
M and T	0.12	1.4	1.49	NS	NS	12.44	NS	NS	NS	NS	NS	NS
T and M	0.12	1.29	1.41	NS	NS	13.2	NS	NS	NS	NS	NS	NS
Experimental Mean	**5.61**	**202**	**29.3**	**197**	**2.98**	**69.38**	**284.6**	**8.93**	**0.22**	**0.64**	**58.7**	**121**

© =FYM, Vermi compost, rice straw, poultry manure, green manure, bio-fertilisers, crop residues, compost, etc

5.7 Yield maximization of rice through Site Specific Nutrient Management

The conventional blanket fertilizer recommendation causes low fertilizer use efficiency and imbalanced use of fertilizers. Estimation of field specific fertilizer requirements needs site-specific knowledge of crop nutrient requirements, indigenous nutrient supply, and recovery efficiency of applied fertilizer. The site-specific nutrient management (SSNM) approach emphasizes ‘feeding’ rice with nutrients as and when needed and to enable the farmers to optimally fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources such as soil, organic amendments, crop residues, manures, and irrigation water. The SSNM approach does not specifically aim to either reduce or increase fertilizer use. Instead, it aims to apply nutrients at optimal rates and times to achieve high yield and high efficiency of nutrient use by the rice crop, leading to high cash value of the harvest per unit of fertilizer invested. Many still perceive SSNM is complex, requiring an understanding of concepts and methods outside their experience and this slowed the wide-scale promotion and adoption of SSNM by the farmers. For more rapid adoption of SSNM technology by farmers, efforts were made in the consolidation of SSNM research conducted over the last decade across Asia into a simple delivery system by International Plant Nutrition Institute (IPNI) in the form of Nutrient Expert (NE), an easy to use interactive computer based decision tool that can rapidly provide nutrient recommendations for farmers in the presence or absence of soil testing data. Hence, to validate this tool, this collaborative (Soil Science & Agronomy) trial was constituted in 2014 along with IPNI and continued during *rabi* 2015 and *kharif 2016* at 18 centers namely, Aduthurai (ADT), Arundhuthinagar (ARD), Chakdha (CKD), Chinsurah (CHN), Faizabad (FZB), Ghagraghat (GGT), Gangavati (GNV), Kanpur (KNP - only one center where *Rabi* 2015 trail was conducted), Karaikal (KRK), Khudwani (KHD), Maruteru (MTU), Medziphema (MED), Moncompu (MNC), Pattambi (PTB), Puduchery (PDC), Pusa (PSA), Rajendranagar (RNR), Raipur (RPR), Titabar (TTB) with eight treatments in a randomized block design. The treatments included recommended fertilizer of that region (T1), SSNM based on Nutrient expert, which varies with each location (T2), SSNM based on LCC/Green Seeker (50% N as basal and rest 50% based on LCC/Green Seeker (T3), T2 minus N (T4), T2 minus P (T5), T2 minus K (T6), Absolute control without N, P and K (T7) and Optional Farmer’s Fertiliser Practice (T8) and the results are presented in Tables 5.7.1 to 5.7.7.

Initial soil properties

The experimental soil conditions as observed in nine centers were presented in table 5.7.1 to document the inherent variability in the soil properties, plant varieties coupled with variable management practices with resultant crop conditions. The message is that there was variability in the supply potential of the fundamental growth medium, the soil, which needs to be regarded in assessing the plant behavior, which is the basis of SSNM.

Grain yield and straw yield

Mean grain yields ranged from 2930 kg ha^{-1} (PTB) to 9636 kg ha^{-1} (GGT) among the reported locations (Table 5.7.2). Among eight treatments, T_1, T_2, T_3 and T_8 registered the highest grain yield depending on the case. For instance, T_1 in Pusa center recorded the highest yield of 3.9 ton ha^{-1} while in 11 test centers, T_2 (SSNM based on NE recommendations) registered the highest yield ranging from 3.5 to 8.3 tons ha^{-1}. T_3 (SSNM using LCC based recommendations) tested in four centers, recorded the highest yield (ranging from 5.1 to 6.7 ton ha^{-1}). T_8 (where farmers' fertilizer practice was tested) registered the highest rice grain yield in two centers namely Gaghraghat and Gangavati with 10.7 and 9.4 tons ha^{-1}, respectively. Interestingly, the yield recorded in these two centers were the highest in the order among all the treatments and test centers. Absolute control resulted into the lowest grain yields in all the test centers. Analysis of the soil and crop conditions found in some centers (Table 5.7.1) might point to probable inclusion of some more soil properties while it was seen that the data were not reported by all the centers. However, it was apparent that balanced fertilizer application would lead to better production as was seen in majority of test centers when compared to other treatments.

There were differential responses to different treatments in terms of straw yield. For example, T_1 registered the highest straw yield in three test locations (ADT, MNC and PSA) (5.0 to 11.6 tons ha^{-1}) while four sites (showed the highest response in T_2 (SSNM with NE based recommendations) with straw yield ranging from 3.5 to 8 tons ha^{-1} (rounded off values). In six locations T_3 (SSNM with LCC based recommendations) showed the highest performance ranging from 6.2 to 10.5 tons ha^{-1}). Only one site (GGT) interestingly responded with the highest straw yield in T_8. In all the test centers, absolute control recorded the lowest rice straw yields. Overall, SSNM proved to a better option to realize the best possible as it provided for the balanced and probably higher fertilizer inputs as seen in majority instances. Like in the analysis of grain yield, for want of the information from some centers, it is a bit difficult to reason the differential behavior.

Yield components

The data on yield components including tillers and panicles per m^2 were presented in Tables 5.7.4 and 5.7.5. The data were reported from only six centers and mean tiller number per m^2 of all treatments ranged from 171 to 579, the lowest being from Medziphem and the highest being from Moncompu. In majority of the centers, NE based SSNM proved to be better in terms of tiller number per m^2, which signifies the importance of balanced availability of plant nutrients. Another important yield component, panicle number per m^2 varied between 219 (Pattambi) and 416 (Puducherry). In general, the higher panicle number were associated with balanced fertilizer application either based on NE or LCC. It is imperative from the above data that balanced fertilizer application would mean better yield as a result of better yield components.

Nutrient uptake

Total N P K uptake from 6 centers was presented in Table 5.7.6. Three sites each in T_2 and T_3 recorded higher total nitrogen uptake ranging from 63 to 123 kg ha^{-1}. In case of P, five sites recorded the highest in T_2 while one recorded more of P uptake in T_3, where both were SSNM treatments while the range was between 17 and 59 kg ha^{-1}. The total uptake of potassium was seen more in the sites in the order of $T_2 > T_3 > T_6$ where the sites were three, two and one in the order. The range of total K uptake was from 58 to 123 kg ha^{-1}. In general, the total nutrient uptake followed similar trend where balanced nutrition led to better uptake of all the nutrients.

Soil available nutrients

Soil available nutrient status after harvest was presented in Table 5.7.7. In fact the patterns of nutrient availability status was highly variable. Although, it is expected that the absolute control should register the lowest content, the reality was different and there was an irregular pattern in terms of contents of available N, P and K. However, the potassium content was seen higher in T_2 (SSNM based on NE recommendations) in four out of seven test centers.

Summary

It is apparent from the trail conducted in several locations, which in fact varied in soil supply potentials, nutrient recommendations and rice varieties grown coupled with unrecorded differences in management practices that the site specific nutrient management means better performance not only in terms of plant production but also sustaining the soil supplies. Balanced plant nutrition also resulted in to increased important yield attributes including tiller and panicle number per m^2, which directly influence the number of grains thus ultimate rice grain yield. For instance SSNM based on NE recommendation (T_2) recorded an increase in tiller number per m^2 from 112 to 190 % over absolute control while tin T_3, the percentage of increase was from 103 to 176. With regard to the other yield component, panicle per m^2, T_2 and T_3 registered an increase of 107 to 204 and 103 to 188% over absolute control. With some exceptions, the nutrient omission plots and absolute control recorded conclusively lower values of the respective soil available nutrients compared to other treatments in majority of test centers. It is clear from the experimentation at multiple locations that the SSNM takes care of local variance in growing conditions particularly with respect to soil nutrient supplies to maintain the balanced nutrition to enable better plant production. Further evaluation of Nutrient expert is always needed to fine tune the decision support tool for nutrient recommendations in Rice.

Table 5.7.1: Yield maximization of rice through site specific Nutrient Management *(kharif 2016*): Soil and crop characteristics

Variety	CHN	GGT	KNP	KHD	FZB	MNC	PDU	PSA	RPR
	Triguna	**NDGR-201**	**NDR-359**	**-**	**Sarjoo-52**	**Uma**	**RB Bio-226**	**Rajendra Bhagwati**	**Rajeshwari**
Kharif -RDF	130:65:65:25	80:60:40:20	120:60:60:25	-	120:60:60:25	90;45:45	120:40:40	120:60:40:25	120:60:40:20
Nutrient Expert Dose	137:58:54	125:35:66	150:60:40:25:25:25	-	141:51:69	-	125:25:42	-	120:60:60:5
FFP	120:60:60	-	150:30:00	-		100:45:60	-	-	80:40:40
Crop growth: *Kharif*	-	Good	Satisfactory	-	Good	-	Good	-	-
% Clay	-	25	20.18	22	23	-	-	13	19.5
% Silt	-	32	22.92	37	21	-	-	31.6	31.5
% Sand	-	43	56.87	41	56	-	-	55	49
Texture	Clay loam	Sandy loam	Sandy loam	Silty clay loam	Sandy loam	Clay	Clay loam	Sandy loam	Clayey
pH (1:2)	7.1	7.7	7.55	7.01	7.5	5.6	5.05	-	7.3
Organic carbon (%)	2.1	0.43	0.45	1.2	0.42	3.85	0.25	-	0.51
CEC (cmol (p^+)/kg)	-	-	24.8		13.8	-	-	-	-
EC (dS/m)	2.1	-	0.75	0.13	1.02	0.2	0.11	-	0.23
Avail. N (kg/ha)	-	221	235	245	200	401	123	-	181
Avail. P_2O_5 (kg/ha)	-	12.6	19.5	14	27	52	15	-	14
Avail. K_2O (kg/ha)	-	244	165	246	234	292	85	-	388

Table 5.7.2: Yield maximization of rice through site specific Nutrient Management *(kharif 2016*) Grain yield of rice (kg ha-1)

Grain yield of rice (kg ha^{-1})	CHN	CKD	GGT	GNV	KRK	KHD	KNP-R	KNP-K	MED	MNC	FZB	MTU	PDC	PSA	PTB	RNR	RPR	TTB
RDF	6003	4470	9640	8100	4480	7380	4512	5387	5018	6526	5250	5149	5852	3923	3290	7920	4875	5120
SSNM (NE)	6251	4920	10167	7340	4693	7550	4746	5863	5561	7143	6094	6367	6057	3227	3500	8330	5125	5410
SSNM (LCC)	5591	4740	9667	7570	4520	7530	5122	6101	5292	6107	5557	5530	6664	3348	2640	7740	4889	5780
SSNM -N	4688	3290	9083	4710	3773	4940	2348	3214	3829	4652	3785	3989	4438	3095	2540	5860	4028	4580
SSNM –P	5065	3690	9633	6870	4280	5660	3780	4583	4371	6129	4292	5241	4555	3236	3320	7710	4778	4900
SSNM -K	5305	3960	9500	7400	4444	6550	4461	5565	4325	6195	4760	5328	4783	3400	3170	7460	4514	4680
-NPK	4427	2310	8667	3920	3060	4210	1972	2440	3683	3814	3228	2978	4048	2969	2070	4540	3514	3640
FFP	5772	4800	10733	9420	4467	6530	4309	4911	3687	6415	-	4967	4940	3360	2950	-	4583	5190
Exp. mean	**5388**	**4020**	**9636**	**6920**	**4215**	**6290**	**3906**	**4758**	**4471**	**5872**	**4121**	**4943**	**5167**	**3320**	**2930**	**7080**	**4538**	**4910**
CD(0.05)	**512.6**	**520**	**2562**	**640**	**559.4**	**630**	**286.01**	**187.7**	**1778.9**	**870.9**	**273.5**	**947.3**	**571.9**	**762.5**	**470**	**940**	**307.6**	**440**
CV (%)	**5.4**	**7.33**	**15.2**	**5.29**	**7.6**	**5.74**	**4.18**	**2.3**	**22.7**	**8.5**	**3.8**	**10.9**	**6.3**	**13.1**	**9.1**	**7.48**	**3.9**	**5.17**

Table 5.7.3: Yield maximization of rice through site specific Nutrient Management (*kharif 2016*) - Straw yield of rice (kg ha^{-1})

Treatment	CHN	KNP-R	KNP-K	FZB	GGT	KRK	MED	MNC	MTU	PDC	PSA	ADT	KHD	PTB
RDF	7623	5417	6785	6749	12827	7033	6528	7738	5149	9612	5021	11570	8690	3230
SSNM (NE)	7935	4533	7391	7803	13567	7922	7222	7540	6367	10149	4130	11470	8880	3450
SSNM (LCC)	7098	6209	7609	7092	12583	6844	8333	6592	5530	10492	4255	10070	8890	2180
SSNM -N	5952	2835	4018	4944	11867	5178	5139	5115	3989	8580	3961	9830	5580	2490
SSNM –P	6433	4543	5711	5616	12767	6156	6944	7011	5241	8927	4142	11300	6610	3210
SSNM -K	6737	5549	6954	6080	12617	6944	7500	6570	5328	9159	4352	10600	7680	3330
-NPK	5624	2266	3045	4167	11300	5200	6528	4630	2978	8197	3800	6530	4860	1870
FFP	6965	5213	6141	-	14150	7056	6806	7341	4967	9582	4337	-	7660	2800
Exp. mean	**6796**	**4571**	**5957**	**5306**	**12710**	**6542**	**6875**	**6567**	**4943**	**9337**	**4250**	**8920**	**7360**	**2820**
CD(0.05)	**571.8**	**1654.3**	**277.7**	**422.5**	**3314.7**	**1281.2**	**2000.8**	**909.4**	**947.3**	**1047.2**	**968.9**	**740**	**1240**	**730**
CV (%)	**4.8**	**20.67**	**2.7**	**4.6**	**14.9**	**11.2**	**16.6**	**7.9**	**10.9**	**6.4**	**13.0**	**4.71**	**9.65**	**14.86**

Trial 5.7.4: Yield maximization of rice through site specific Nutrient Management (*kharif* 2016)- Tillers/m^2

Treatment	CHN	GGT	MED	MNC	FZB	MTU
RDF	420	232	185	492	325	386
SSNM (NE)	443	240	223	628	364	406
SSNM (LCC)	410	235	183	608	337	376
SSNM -N	292	204	148	555	248	382
SSNM –P	332	226	153	553	263	374
SSNM -K	360	220	190	633	288	391
-NPK	275	166	133	547	192	364
FFP	391	271	148	612	-	358
Exp. mean	**366**	**224**	**171**	**579**	**252**	**380**
CD(0.05)	**57**	**9**	**76**	**81**	**14**	**33**
CV (%)	**8.9**	**2.3**	**25.3**	**8.0**	**3.1**	**5.0**

Table 5.7.5: Yield maximization of rice through site specific Nutrient Management *(kharif 2016*) - Panicles/m^2

Treatment	ADT	ARN	CKD	CHN	GNV	KRK	KNP	MED	MNC	FZB	MTU	PDC	TTB
RDF	358	283	316	368	372	323	298	270	385	318	286	445	238
SSNM (NE)	339	292	348	393	328	357	318	270	363	354	301	465	245
SSNM (LCC)	312	294	324	366	329	335	326	247	358	327	279	493	263
SSNM -N	288	248	290	261	290	295	246	212	305	243	283	359	198
SSNM –P	317	269	297	296	322	315	272	257	355	257	277	385	207
SSNM -K	306	234	291	320	350	332	303	267	392	280	289	420	209
-NPK	166	175	237	237	306	276	181	202	300	186	270	329	152
FFP	-	249	322	328	362	342	289	195	408	-	265	435	242
Exp. mean	**298**	**255**	**303**	**321**	**332**	**322**	**279**	**240**	**358**	**246**	**281**	**416**	**219**
CD(0.05)	**14.6**	**35.3**	**23.7**	**49.2**	**43.9**	**37.6**	**37.0**	**66.9**	**27.8**	**14.1**	**24.8**	**42.9**	**17.6**
CV (%)	**2.8**	**7.9**	**4.5**	**8.75**	**7.5**	**6.68**	**7.6**	**15.94**	**4.43**	**3.27**	**5.03**	**5.88**	**4.6**

Trial 5.7.6: Yield maximization of rice through site specific Nutrient Management - Total nutrient uptake (kg ha^{-1})

Treatment	Nitrogen						Phosphorus						Potassium					
	KNP	MED	FZB	MTU	PDU	RPR	KNP	MED	FZB	MTU	PDU	RPR	KNP	MED	FZB	MTU	PDU	RPR
RDF	131	135	148	102	122	73	29	46	75	24	31	19	137	82	75	97	123	111
SSNM (NE)	145	146	179	118	123	82	33	51	93	27	125	25	151	94	91	118	130	122
SSNM (LCC)	152	147	160	95	125	71	35	50	81	24	32	23	156	107	81	115	133	120
SSNM -N	77	108	105	75	79	54	17	34	54	17	20	12	81	65	53	83	116	82
SSNM –P	111	124	121	103	91	59	24	45	59	20	20	15	115	89	59	104	102	97
SSNM -K	136	121	131	106	83	62	31	48	67	23	23	17	160	90	62	101	97	100
-NPK	56	105	87	51	66	43	13	36	43	13	16	9	61	78	41	58	91	64
FFP	119	100	-	103	111	59	26	35	-	23	29	16	124	78	-	99	134	101
Exp. mean	**116**	**123**	**116**	**94**	**100**	**63**	**26**	**43**	**59**	**21**	**37**	**17**	**123**	**85**	**58**	**97**	**116**	**99**
CD(0.05)	**5**	**34**	**9**	**29**	**18**	**7**	**1**	**12**	**5**	**4**	**100**	**4**	**20**	**20**	**4**	**21**	**21**	**14**
CV (%)	**2.5**	**15.7**	**4.2**	**17.6**	**10.4**	**6.3**	**3.0**	**15.3**	**4.7**	**12.0**	**154.5**	**12.9**	**9.5**	**13.4**	**4.0**	**12.5**	**10.3**	**8.2**

Trial 5.7.7: Yield maximization of rice through site specific Nutrient Management - Soil fertility status at harvest (kg ha^{-1})

Treatment	Available N				Available P_2O_5							Available K_2O						
	KHD	MED	MTU	PDC	KHD	MED	MNC	MTU	PDC	PSA	RPR	KHD	MED	MNC	MTU	PDC	PSA	RPR
RDF	217	193	175	127	14	24	100	54	18	46	16	242	192	207	275	94	181	389
SSNM (NE)	215	203	188	164	13	25	95	53	22	41	17	240	195	218	311	98	173	398
SSNM (LCC)	220	194	179	161	14	25	68	54	21	47	16	236	136	186	275	108	192	389
SSNM -N	213	194	161	179	13	24	85	63	21	44	14	239	132	101	275	84	185	385
SSNM –P	223	210	168	161	13	25	52	48	17	44	14	241	197	191	285	75	187	385
SSNM -K	216	186	171	168	13	24	69	52	20	44	12	225	77	153	264	74	181	388
-NPK	208	194	160	146	13	24	56	37	17	43	13	235	76	111	244	98	203	368
FFP	219	183	180	172	13	23	94	67	23	37	13	246	76	161	259	113	196	386
Exp. mean	**216**	**195**	**173**	**160**	**13**	**24**	**77**	**53**	**20**	**43**	**14**	**238**	**135**	**166**	**273**	**93**	**187**	**386**
CD(0.05)	**7.5**	**36.3**	**33.0**	**40.7**	**1.0**	**3.0**	**12.6**	**5.1**	**8.3**	**11.0**	**1.04**	**12.4**	**145.6**	**15.9**	**71.8**	**19.9**	**20.7**	**36**
CV (%)	**2.0**	**10.6**	**10.9**	**14.6**	**4.4**	**7.2**	**9.3**	**5.5**	**24.1**	**14.5**	**4.2**	**2.96**	**61.5**	**5.5**	**15**	**12.2**	**6.3**	**5.4**

5.8 Bio - Intensive Pest Management (BIPM) in rice under Organic Farming

This trial was initiated during *kharif* 2015 in collaboration with Entomologists to study the influence of organic farming on productivity, grain quality, soil health and Pest dynamics in rice and also to develop a package of bio-intensive pest management (BIPM) practices in organic farming. There are two treatments here viz., BIPM block and Farmers Practice (FP) block. In BIPM block, all organic farming practices involving from seed treatment, nursery application, nutrient and pest management using organic sources only were practiced as per the technical programme. Whereas, in FP block, general POP with RDF and need based application of insecticides were practiced. Each main block was divided into 6 smaller blocks and observations on pest incidence, yield parameters and grain yield were recorded. Plant nutrient (NPK) uptake was calculated using nutrient concentration and dry matter yield. Soil samples were collected before conducting experiment and after harvest and were analysed for important soil properties. The trial was conducted at seven locations viz., [Chinsurah (CHN), IIRR (DRR), Jagdalpur (JDP), Ludhiana (LDN), Puducherry (PDU), Raipur (RPR) and Titabar (TTB)] during *kharif* 2016 and the results are presented in Tables 5.8.1 to 5.8.8.

Grain and straw yields and nutrients uptake

Out of seven locations, grain yield (Table 5.8.2) was significantly superior in BIPM block compared to FP at CHN, JDP and TTB by recording 11, 12 and 40% higher grain yield, respectively. Whereas, both treatments were on par at IIRR, LDN and RPR though BIPM recorded higher yield over FP by 45% at IIRR and lower yield by 12 and 9% at LDN and RPR, respectively. At Puducherry, FP was significantly superior to BIPM treatment by 36%. At CHN, during boro season, BIPM recorded significantly higher values of yield parameters over FP and it reflected in significantly higher grain yield (Table 5.8.3). Straw yield followed the similar trend as that of grain yield and with regard to total nutrient (NPK) uptake at PDU (Table 5.8.4), FP treatment recorded significantly higher uptake of N, P and K by 40, 39 and 36% compared to BIPM treatment.

Observations on Pest incidence

Bio intensive pest management through biointensive approaches for managing pests in organic rice cultivation indicated reduced pest incidence in BIPM plots at Chinsurah, Titabar, Raipur and Jagdalpur; and the pest incidence was on par at Ludhiana both in BIPM and FP. The natural enemies were higher in BIPM plots in all locations. At Hyderabad, though stem borer damage was higher in BIPM plots during the vegetative phase of the crop, the crop stabilized in the reproductive phase. The results also indicated an increase in natural enemy population in the organic BIPM plots (detailed report is given in Entomology progress report).

Grain Quality characteristics

Important nutritional quality parameters estimated in brown rice and given in Tables 5.8.5 and 5.8.6 indicated no specific trend in N, P, K, Fe and Zn contents between BIPM and FP across locations. Similarly, physical and cooking quality parameters presented in Table 5.8.7. were also similar in both BIPM and FP without showing any particular trend in most of the parameters.

Soil Properties after harvest

The important soil properties from five locations (CHN, JDP, PDU and TTB) are presented in Table 5.8.8. Almost all soil properties were on par in both BIPM and FP treatments at all locations except TTB where there was an improvement in soil OC, available N,P and K by 9, 5, 10 and 13%, respectively, in BIPM compared to FP.

Summary

From the second year of study on “Bio-intensive pest management”, it can be summarized that out of seven locations (CHN, IIRR, JDP, LDN, PDU, RPR and TTB), BIPM was significantly superior to FP at CHN, JDP and TTB; on par to FP at IIRR, LDN and RPR; and inferior to FP at PDU in terms of grain yield. The observations on pest incidence indicated the beneficial effect of BIPM at most of the locations. Important physical, cooking and nutritional quality parameters estimated in brown rice indicated no specific trend between BIPM and FP. Except at TTB, BIPM with organics did not influence the soil properties to a larger extent.

Table 5.8.1 Bio-intensive Pest Management (BIPM) in Rice under Organic farming

Soil, Crop and weather data - *Kharif* 2016

Parameter	**Chinsurah**	**IIRR**	**Puducherry**	**Titabar**
Cropping system	Rice-Rice	Rice-Rice	Rice-Rice	Rice-Rice
Variety	Swarna	TN 1	MTU 1010	-
RDF (kg NPK/ha)	60-30-30	100:40:40	120:40:40	-
Crop growth	-	-	Good	Good
Soil Characteristics				
% clay	-	-	32.5	-
% silt	-	-	27.2	-
% sand	-	-	38.3	-
Soil Texture	Clay loam	Clay	Clay loam	Clay
pH (1:1)	7.43	8.1	6.78	5.5
Org.carbon (%)	0.89	0.59	0.29	1.5
EC (dS/m)	0.36	0.30	0.10	-
Avail.N (kg/ha)	213	201	145.6	347
Avail. P_2O_5 (kg/ha)	141	85.2	38.3	16
Avail. K_2O (kg/ha)	471	495	139	148
Weather				
Max. Temp (ºC)	31.3	-	33.1	-
Min. Temp (ºC)	21.9	-	24.4	-
Total Rainfall(mm)	423	-	1968.7	-

Table 5.8.2 Bio-intensive Pest Management (BIPM) in Rice under Organic farming Grain yield (kg/ha) at different locations - *Kharif* 2016

Treatments	**Grain yield (kg/ha)**						
	Chinsurah	**IIRR**	**Ludhiana**	**Puducherry**	**Titabar**	**Raipur**	**Jagdalpur**
BIPM	5509	959	7668	4051	6466	6446	5612
FP	4940	662	7758	5497	4620	7040	4998
t - test	*	NS	NS	**	**	NS	*

Table 5.8.3: Bio-intensive pest management (BIPM) in Rice under Organic farming Boro rice (Location: Chinsurah)

Treatments	**Grain yield (kg/ha)**	**Panicle/m^2**	**Panicle weight (g)**	**Tillers/m^2**	**Straw Yield (kg/ha)**
BIPM	5378	305	3.16	361	6841
FP	4799	290	3.02	342	6151
t-test	*	*	*	NS	*

Table 5.8.4. Bio-intensive Pest Management (BIPM) in Rice under Organic farming Straw yield (kg/ha) at different locations and total nutrient uptake in Puducherry - *Kharif* 2016

Treatments	Straw yield (kg/ha)			Nutrient Uptake (kg/ha) - Puducherry		
	Chinsurah	Puducherry	Titabar	N	P	K
BIPM	6996	7814	1308	94	23	112
FP	6325	10911	1068	132	32	152
t - test	*	**	**	**	**	**

Table 5.8.5: Bio-intensive pest management (BIPM) in Rice under Organic farming Nutrient concentration in brown rice - Kharif 2016

Treatments	Chinsurah (%)			IIRR (%)			Jagdalpur (%)		
	N	P	K	N	P	K	N	P	K
BIPM	1.41	0.26	0.2	1.47	0.19	0.29	1.84	0.12	0.21
FP	1.26	0.34	0.2	1.45	0.2	0.3	1.71	0.18	0.22
t-test	NS	*	NS	NS	NS	NS	NS	*	NS

Contd...Table 5.8.5: Bio-intensive pest management (BIPM) in Rice under Organic farming Nutrient concentration in brown rice - Kharif 2016

Treatments	Ludhiana (%)			Raipur (%)			Puducherry (%)		
	N	P	K	N	P	K	N	P	K
BIPM	1.19	0.25	0.25	1.54	0.32	0.23	1.27	0.28	0.43
FP	1.46	0.29	0.24	1.19	0.31	0.24	1.29	0.28	0.45
t-test	*	NS	*	*	NS	NS	NS	NS	NS

Table 5.8.6: Bio-intensive pest management (BIPM) in Rice under Organic farming Important Nutritional Quality Parameters in brown rice - *kharif* 2016

Treatments	Chinsurah (ppm)		IIRR (ppm)		Jagdalpur (ppm)		Raipur (ppm)		Ludhiana (ppm)	
	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn
BIPM	31.2	12.6	28.6	26.3	28.7	26.1	33.2	25.1	29.7	21.7
FP	25.7	14.1	31.8	26.0	24.4	26.8	26.4	21.8	33.2	25.1
t-test	NS	**	NS	NS	NS	NS	NS	**	*	*

Table 5.8.7: Bio-intensive Pest Management (BIPM) in Rice under Organic farming Physical and Cooking quality parameters - *kharif* 2016

Treatments	Hull %	Mill %	HRR %	KL	KB	L/B	Grain type	Grain chalkiness	ASV	AC %	GC (mm)
Jagdalpur											
BIPM	81.3	69.2	51.3	6.70	1.87	3.58	LS	VOC	5	27.5	41
FP	81.7	77.3	62.8	6.88	1.98	3.47	LS	VOC	5	28.2	46
IIRR											
BIPM	77.9	61.7	-	5.59	2.52	2.21	SB	VOC	6	27.6	22
FP	78.4	62.0	-	5.59	2.50	2.23	SB	VOC	7	26.2	22
Raipur											
BIPM	78.3	67.4	30.8	5.02	2.15	2.33	SB	VOC	6	27.8	36
FP	78.2	68.0	37.6	5.03	2.16	2.32	SB	VOC	6	26.5	24
Ludhiana											
BIPM	82.0	68.0	30.8	5.71	2.12	2.69	MS	VOC	7	28.2	22
FP	81.6	78.2	46.2	6.15	2.18	2.82	LB	VOC	6	27.2	22
Chinsurah											
BIPM	79.4	70.8	62.7	5.39	2.14	2.51	MS	VOC	5	28.1	28.
FP	79.8	73.8	69.7	5.38	2.17	2.47	SB	VOC	5	25.2	22

HRR- Head rice recovery; ASV- Alkali spreading value; AC- Amylose content; GC-Gel consistency; SB-Short bold MS- Medium slender; A-Absent; VOC-very occasionally chalkiness

Table 5.8.8: Bio-intensive Pest Management (BIPM) in Rice under Organic farming Soil properties after harvest – K*harif* 2016

Treatments	Org. C. (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Chinsurah				
BIPM	1.35	119	85	523
FP	1.41	118	92	546
Jagdalpur				
BIPM	0.62	207	-	328
FP	0.50	210	-	265
Puducherry				
BIPM	0.35	138	26	128
FP	0.38	153	24	125
Titabar				
BIPM	1.05	356	16.1	160
FP	0.96	340	14.6	142

5.9. Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system

Despite considerable research on increase N use efficiency (NUE) in rice, the recovery efficiency of N fertilizer achieved by rice farmers ranges between 30 and 40%. Improving efficiency of fertilizer N use is vital to achieve and sustain high crop yields and reduce losses of N that can potentially deteriorate environmental quality. Appropriate modification in fertilizer source or management practices can lead to reduced losses of N and increased fertilizer N use efficiency. For example, slow-release N fertilizers *viz.* coated urea granules is a good source of N to enhance the productivity as well as NUE in rice crop. Neem coated urea is one such slow release N fertilizer where the compound *Azadirachtin*, present in neem can inhibit nitrification that results in reduced denitrification and nitrate leaching losses thus improving the nitrogen utilization by the crop. Keeping this in view, this trial was proposed and conducted at 8 locations [Chinsurah (CHN), IIRR (DRR), Kanpur (KNP), Maruteru (MTU), Moncompu (MCP), Puducherry (PDU), Pusa (PSA), and Raipur (RPR)] in *kharif* 2016 to evaluate the performance of NCU applied at different stages of rice and to study the yield and NUE as affected by NCU applied to rice and the results of the first year are presented in Tables 5.9.1 to 5.9.12.

Grain and Straw yields

Grain yield ranged from 1.65 t/ha in control to 6.86 t/ha in 125% NCU (3sp) across locations (Table 5.9.2). Among the treatments, 125% NCU in 3 splits recorded maximum grain yield at 7 locations with significantly higher yield at 3 locations (KNP, MCP and RPR) than all other treatments and was at par to 100% NCU (3sp) at PDU and MTU. Whereas, at IIRR, 100% NCU in 2 splits (75%+25%) recorded significantly higher grain yield than other treatments. At CHN, NCU resulted in a marginal yield increase over PU and at Pusa, all NCU treatments were on par and significantly superior to PU and control. Across locations, 100% NCU in 3 splits was slightly better than PU in 3 splits while 100% NCU (basal) yielded less than PU (3Sp) at 6 locations except at RPR and IIRR where both treatments were on par. At all 8 locations, control without N application recorded the lowest yield. The treatment, 125% NCU (3sp) recorded higher yield by 5 & 8; 7 & 4; 7 &19; 3 & 20 and 23 & 30% over 100%NCU (3sp) and 100% PU (3sp) respectively, at KNP, MCP, PDU, MTU and RPR. Straw yield followed similar trend as that of grain yield at all locations ranging from 2.44 t/ha in control at IIRR to 7.60 t/ha with 125% NCU (3sp) at RPR across locations (Table 5.9.3).

Yield parameters

The yield parameters, such as tillers and panicles/m^2, grains/panicle, panicle weight and 1000 grain weight recorded by some locations and presented in Tables 5.9.4 - 5.9.7 were higher in the treatments that finally reflected in higher grain yields. Tiller number, Panicle number, gains/panicle and test weight ranged from 222 – 582, 205 – 503, 82-167 and 17.6 - 33.5g, respectively, across locations.

Nutrients uptake and use efficiency

Total nutrients uptake (NPK) and NUE (Recovery %) were presented in Tables 5.9.8 and 5.9.9. Total nutrients uptake followed the similar trend as that of grain yield with maximum uptake in 125% NCU (3sp) and minimum uptake in control. With regard to NUE, the recovery efficiency of N was maximum with 125% NCU (3sp) at four locations (KNP, MTU, PDU and RPR) ranging from 23 - 83% while it was maximum with 100% NCU (2sp) at IIRR.

Soil Properties

Some important soil properties viz., pH, OC, available nutrients were given in tables 5.9.10 - 5.9.12. Available NPK & OC% in general were higher with 125% NCU (3sp) in most of the locations and this could be attributed to the better root and shoot biomass in this treatment that could have resulted in higher values.

Summary

From the first year of study on efficiency of neem coated urea in irrigated rice, it can be summarized that out of 8 locations, 125% NCU in 3 split applications resulted in significantly higher grain yields at 3 locations (KNP, MCP, RPR) while it was on par with 100% NCU in 3 splits at 2 locations (PDU, MTU). The treatment 125%-N through NCU recorded higher yield by 3-23% and 8-34% over 100% NCU and 100% Prilled urea (PU), respectively, across seven locations with an increased N recovery efficiency by 11-29%. This hike in yields with this treatment could be attributed to the increased yield parameters such as panicle number and grain number. Similar trend was observed with regard to nutrients uptake, nitrogen use efficiency and soil properties.

Table 5.9.1: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) Soil and crop characteristics

Cropping system	KNP	MTU	CHN	MCP	PDU	RPR	IIRR	PUSA
Variety	NDR-359	MTU-1061	Satabdi	Uma	CO R51	Maheswari	DRR dhan 44	Rajendra Bhagwati
Cropping System	Rice-Wheat	Rice-Rice	Rice-Rice	Rice	Rice-Rice	Rice-Wheat	Rice-Rice	Rice –Wheat
RDF (kg ha^{-1}) N-P-K-Zn	120-60-60-25	90-60-60	80-40-40-25	90-45-45	120-40-40	120-60-40-20	100-60-40	125-60-40-25
% Clay	20.5	38	-	68.0	31.7	19.5	-	13.0
% Silt	22.7	28	-	21.7	26.4	31.5	-	31.6
% Sand	56.7	34	-	10.3	36.3	49.0	-	55.4
Texture	Sandy Loam	Clay Loam	Clay loam	Clay	Clay loam	Clay	Clay	Sandy loam
pH (1:2)	7.8	6.19	7.2	5.73	5.79	7.3	8.1	
Organic carbon (%)	0.40	1.15	-	3.98	0.27	0.53	0.59	-
CEC (cmol (p^+)/kg)	25.8	48.6	-	-	16.8	-	-	-
EC (dS/m)	0.42	0.57	2.5	0.06	0.12	0.27	0.30	-
Avail. N (kg/ha)	238.5	149	-	407	156.8	155.0	201	-
Avail. P_2O_5 (kg/ha)	18.9	66.3	-	74.0	21.9	12.9	85.2	-
Avail. K_2O (kg/ha)	172.3	364	-	246	155	368.6	495	-

Table 5.9.2: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) Grain yield (t/ha)

Treatments	KNP	MCP	PDU	MTU	RPR	CHN	IIRR	PSA
100 % Prilled urea (PU)	5.12	6.54	5.77	5.35	3.66	5.11	2.43	2.57
75% Neem Coated Urea (NCU)	4.51	5.82	5.65	5.80	3.72	5.03	2.23	3.41
100 % NCU (3 Splits)*	5.26	6.34	6.41	6.21	3.86	5.31	2.76	3.22
125 % NCU (3 Splits)*	5.51	6.81	6.86	6.40	4.75	5.35	2.58	3.45
100% NCU (Basal)	4.77	5.51	4.72	4.43	3.66	4.17	2.53	3.04
100% NCU (2 splits)$	5.17	6.19	5.60	4.50	3.72	4.36	2.84	3.53
100 % NCU (2 splits)+	5.03	5.03	5.09	5.03	3.55	4.95	3.50	2.94
Control	2.55	2.55	3.86	3.43	2.97	2.91	1.67	2.41
Expt. Mean	**4.74**	**5.91**	**5.49**	**5.14**	**3.73**	**4.64**	**2.57**	**3.07**
CV (%)	**2.21**	**6.97**	**7.51**	**10.3**	**3.54**	0.77	**11.6**	**10.7**
CD (0.05)	**0.18**	**0.18**	**0.72**	**0.92**	**0.23**	**9.48**	**0.52**	**0.57**

3 splits* =Basal, Maximum tillering stage and panicle initiation
2splits$ = Basal (50%) and Max tillering (50%)
2 splits+ = Basal (75%) and Max tillering (25%)

Table 5.9.3: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) straw yield (t/ha)

Treatments	KNP	MCP	MTU	PDU	RPR	CHN	IIRR	PUSA
100 % Prilled urea (PU)	6.39	7.54	6.4	10.8	5.86	6.48	3.25	3.83
75% Neem Coated Urea (NCU)	5.6	6.63	6.81	9.97	5.95	6.39	3.27	4.64
100 % NCU (3 Splits)	6.6	6.96	7.19	11.6	6.17	6.76	2.83	4.37
125 % NCU (3 Splits)	6.89	7.51	7.39	11.1	7.6	6.79	3.07	4.69
100% NCU (Basal)	5.9	6.83	5.46	7.76	5.86	5.29	4.23	4.14
100% NCU (2 splits)	6.45	7.27	5.54	8.53	5.95	5.53	3.6	4.8
100 % NCU (2 splits)	6.21	6.39	6.19	8.6	5.68	6.23	4.54	4.01
Control	3.15	5.54	4.12	6.66	4.81	3.58	2.44	3.45
Expt. Mean	5.9	6.83	6.14	9.39	5.99	5.88	3.4	4.24
CV (%)	3	8	7	6	4	9	14	10.4
CD (0.05)	0.27	0.91	0.72	1.04	0.37	0.55	0.84	0.78

Table 5.9.4: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) tillers/m2

Treatments	KNP	MCP	PDU	CHN	RPR	IIRR
100 % Prilled urea (PU)	287	532	504	405	340	306
75% Neem Coated Urea (NCU)	268	510	496	394	321	280
100 % NCU (3 Splits)	301	537	535	407	337	337
125 % NCU (3 Splits)	314	573	541	413	371	375
100% NCU (Basal)	276	485	424	350	355	325
100% NCU (2 splits)	291	582	478	362	341	301
100 % NCU (2 splits)	284	547	490	372	328	432
Control	243	443	355	298	236	222
Expt. Mean	283	526	477	375	328.7	322
CV (%)	2.48	6.26	6.18	10.2	5.04	17.3
CD (0.05)	12.3	57.7	51.7	67.5	28.9	97.5

Table 5.9.5: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*)
Filled Grains/Panicle

Treatments	KNP	MCP	PDU	PUSA	RPR
100 % prilled urea (PU)	139.3	162.3	143.3	82.0	130.6
75% Neem Coated Urea (NCU)	130.3	151.0	136.3	78.4	131.3
100 % NCU (3 Splits)	145.3	159.6	139.6	86.0	124.6
125 % NCU (3 Splits)	155.6	161.0	156.6	91.7	148.0
100% NCU (Basal)	135.3	167.3	130.6	92.9	139.6
100% NCU (2 splits)	142.3	160.0	134.6	91.5	141.0
100 % NCU (2 splits)	136.6	138.6	134.0	96.9	136.0
Control	109.3	117.6	120.6	90.9	114.3
Expt. Mean	**136.7**	**152.2**	**137.0**	**88.8**	**133.2**
CV (%)	**4.44**	**16.1**	**10.7**	**8.22**	**7.0**
CD (0.05)	**10.6**	**43.1**	**25.7**	**12.7**	**16.3**

Table 5.9.6: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*)

Treatments	KNP	MCP	PDU	MTU	RPR	CHN	IIRR	KNP	CHN
	Panicles/m^2							Panicle wt. (g)	
100 % Prilled urea (PU)	280	417	435	216	314	342	279	2.82	3.07
75% Neem Coated Urea (NCU)	260	378	437	225	295	333	260	2.60	3.06
100 % NCU (3 Splits)	293	398	449	242	311	346	319	2.99	3.19
125 % NCU (3 Splits)	306	410	503	248	345	351	333	3.08	3.23
100% NCU (Basal)	268	365	377	181	328	298	309	2.67	2.84
100% NCU (2 splits)	283	418	420	206	315	307	286	2.86	2.93
100 % NCU (2 splits)	276	378	413	214	306	315	389	2.78	2.90
Control	235	363	287	151	210	232	205	2.28	2.64
Expt. Mean	**275**	**391**	**415**	**211**	**303**	**315**	**297**	**2.76**	**2.98**
CV (%)	**2.54**	**8.81**	**6.34**	**5.85**	**5.16**	**9.41**	**18.9**	**2.04**	**6.61**
CD (0.05)	**12.2**	**60.3**	**46.1**	**21.6**	**27.3**	**52.0**	**98.86**	**0.10**	**0.35**

Table 5.9.7: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*)
1000 grain weight (g)

Treatments	KNP	MCP	PDU	PUSA	RPR
100 % prilled urea (PU)	28.7	25.8	18.7	28.2	32.8
75% Neem Coated Urea (NCU)	28.5	26.2	18.3	28.9	32.4
100 % NCU (3 Splits)	28.9	26.8	18	29.5	32.7
125 % NCU (3 Splits)	29.2	26.4	18.9	28.8	33.5
100% NCU (Basal)	28.5	25.7	17.8	28.8	32.9
100% NCU (2 splits)	28.8	26	18.1	28.1	31.4
100 % NCU (2 splits)	28.6	25.8	18	28.3	31.9
Control	28.2	24.9	17.6	28.4	31.4
Expt. Mean	28.6	25.9	18.2	28.7	32.4
CV (%)	0.1	4.39	2.64	2.03	2.29
CD (0.05)	0.05	2	0.84	1.02	1.3

Table 5.9.8: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) Total Nutrient uptake (kg/ha)

Treatments	KNP			MTU			PDU			RPR			IIRR		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
100 % Prilled urea (PU)	124	29	129	26	24	66	129	31	145	48	15	84	42	7	57
75% Neem Coated Urea (NCU)	108	24	112	29	25	70	125	30	137	46	21	98	42	7	55
100 % NCU (3 Splits)*	130	30	134	33	30	75	150	36	161	50	17	92	45	8	50
125 % NCU (3 Splits)*	138	32	141	35	30	84	164	33	162	67	30	124	40	7	56
100% NCU (Basal)	116	26	118	22	20	54	90	22	103	49	19	86	46	8	74
100% NCU (2 splits)$	126	29	131	18	21	59	110	25	108	51	20	89	47	8	70
100 % NCU (2 splits)+	121	27	125	25	24	65	101	24	109	48	22	97	57	10	91
Control	58	13	94	15	16	42	64	21	77	32	14	68	29	5	48
Expt. Mean	**115**	**26**	**123**	**25**	**24**	**64**	**117**	**28**	**125**	**49**	**20**	**92**	**44**	**7.4**	**63**
CV (%)	**2.49**	**2.2**	**16**	**14**	**15**	**13**	**8.5**	**9.4**	**10**	**5.1**	**15**	**5.8**	**11**	**11**	**15**
CD (0.05)	**5.03**	**1.0**	**34**	**6.4**	**6.3**	**15**	**17**	**4.6**	**22**	**4.4**	**5.3**	**9.3**	**8.3**	**1.5**	**15**

Table 5.9.9: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) Nitrogen use efficiency (NUE) - Recovery efficiency %

Treatments	KNP	MTU	PDU	RPR	IIRR
100 % Prilled urea (PU)	55.2	12.5	54.3	14.1	12.6
75% Neem Coated Urea (NCU)	41.9	16.5	50.4	12.2	13.0
100 % NCU (3 Splits)	60.0	20.0	71.7	15.6	16.1
125 % NCU (3 Splits)	66.3	22.9	83.4	29.9	10.8
100% NCU (Basal)	47.9	8.70	21.7	14.4	16.9
100% NCU (2 splits)	56.9	3.60	38.4	16.0	17.3
100 % NCU (2 splits)	52.4	11.9	31.2	13.5	27.7

Table 5.9.10: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) Soil pH

Treatments	KNP	MCP	MTU	PDU	RPR	IIRR
100 % Prilled urea (PU)	7.78	5.41	6.24	5.96	7.33	8.05
75% Neem Coated Urea (NCU)	7.78	5.27	6.19	5.68	7.27	7.99
100 % NCU (3 Splits)	7.8	5.29	6.46	5.99	7.43	8.13
125 % NCU (3 Splits)	7.77	5.31	6.35	5.92	7.23	8.12
100% NCU (Basal)	7.79	5.41	6.46	5.88	7.27	7.94
100% NCU (2 splits)	7.75	5.38	6.37	5.81	7.23	8.08
100 % NCU (2 splits)	7.77	5.32	6.27	5.75	7.37	8.05
Control	7.82	5.47	6.16	5.69	7.2	8.08
Expt. Mean	**7.78**	**5.36**	**6.31**	**5.84**	**7.29**	**8.05**
CV (%)	**0.15**	**5.20**	**2.39**	**2.81**	**1.95**	**1.30**
CD (0.05)	**0.02**	**0.49**	**0.26**	**0.29**	**0.25**	**0.18**

Table 5.9.11: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*) Soil organic Carbon (%)

Treatments	KNP	MCP	MTU	IIRR	RPR					
					OC	EC	Zn	Fe	Cu	Mn
100 % Prilled urea (PU)	0.43	3.57	1.23	0.27	0.60	0.26	1.55	14.9	2.99	11.3
75% Neem Coated Urea (NCU)	0.42	3.47	1.26	0.28	0.58	0.25	1.61	16.3	3.65	10.1
100 % NCU (3 Splits)	0.44	3.64	1.18	0.30	0.60	0.24	1.59	19.8	3.99	10.2
125 % NCU (3 Splits)	0.45	3.88	1.27	0.31	0.61	0.23	1.95	21.0	3.35	13.0
100% NCU (Basal)	0.43	3.41	1.21	0.28	0.58	0.23	1.39	17.3	3.21	10.2
100% NCU (2 splits)	0.43	3.46	1.20	0.32	0.55	0.24	1.44	15.4	3.37	12.5
100 % NCU (2 splits)	0.42	3.48	1.23	0.27	0.58	0.25	1.57	16.9	2.98	11.5
Control	0.41	3.74	1.15	0.31	0.55	0.23	1.25	17.6	3.14	9.53
Expt. Mean	**0.43**	**3.58**	**1.22**	**0.29**	**0.58**	**0.24**	**1.54**	**17.4**	**3.33**	**11.0**
CV (%)	**2.02**	**8.63**	**5.11**	**11.6**	**3.07**	**9.70**	**9.17**	**11.5**	**15.8**	**14.6**
CD (0.05)	**0.02**	**0.54**	**0.11**	**0.06**	**0.03**	**0.04**	**0.25**	**3.50**	**0.92**	**2.83**

Table 5.9.12: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (*Kharif*)

Soil available N (kg/ha)

Treatments	KNP	MCP	PDU	IIRR	RPR
100 % prilled urea (PU)	238.2	194.6	138.1	218.6	175.6
75% Neem Coated Urea (NCU)	238.2	204.0	160.5	229.7	171.4
100 % NCU (3 Splits)	239.8	213.3	141.8	226.0	192.3
125 % NCU (3 Splits)	240.9	217.3	164.2	226.3	221.6
100% NCU (Basal)	234.5	200.0	186.6	217.3	175.6
100% NCU (2 splits)	237.1	208.0	168.0	236.3	163.0
100 % NCU (2 splits)	235.9	204.0	160.5	237.0	163.0
Control	230.8	174.6	104.5	222.3	146.3
Expt. Mean	**236.9**	**202.0**	**153.0**	**226.7**	**176.1**
CV (%)	**0.34**	**6.61**	**10.2**	**5.75**	**6.48**
CD (0.05)	**1.4**	**23.3**	**27.4**	**22.8**	**19.9**

Soil available P_2O_5

Treatments	KNP	MCP	PDU	PUSA	RPR	IIRR
100 % prilled urea (PU)	20.1	87.7	57.3	39.6	12.7	36.7
75% Neem Coated Urea (NCU)	20.3	63.8	57.4	31.9	11.1	38.2
100 % NCU (3 Splits)	20.4	90.9	57.2	30.4	12.0	37.6
125 % NCU (3 Splits)	20.6	95.6	58.2	39.6	14.2	36.2
100% NCU (Basal)	19.7	62.6	57.5	35.0	13.2	37.5
100% NCU (2 splits)	20.1	58.1	57.6	38.0	13.5	36.8
100 % NCU (2 splits)	19.8	42.4	54.7	28.0	12.6	36.2
Control	18.3	69.8	52.4	31.9	10.5	34.1
Expt. Mean	**19.9**	**71.4**	**56.5**	**19.75**	**12.5**	**36.7**
CV (%)	**0.57**	**10.1**	**5.42**	**28.9**	**15.7**	**4.14**
CD (0.05)	**0.20**	**12.6**	**5.37**	**17.5**	**3.45**	**2.66**

Soil available K_2O (kg/ha)

Treatments	KNP	MCP	PDU	PUSA	RPR	IIRR
100 % prilled urea (PU)	179.3	159.3	304.8	198.3	399.9	324.0
75% Neem Coated Urea (NCU)	179.3	159.3	326.3	197.6	393.2	328.2
100 % NCU (3 Splits)	179.5	174.2	325.2	212.0	398.0	352.8
125 % NCU (3 Splits)	179.7	172.6	316.8	200.0	409.2	373.7
100% NCU (Basal)	178.4	132.5	314.6	193.0	396.6	380.8
100% NCU (2 splits)	178.6	140.6	303.5	196.3	401.5	366.2
100 % NCU (2 splits)	178.5	170.5	303.5	196.3	406.1	344.9
Control	172.4	134.2	308.2	186.0	388.3	345.3
Expt. Mean	**178.2**	**155.4**	**312.9**	**197.5**	**399.1**	**352.0**
CV (%)	**0.09**	**6.98**	**7.09**	**7.22**	**4.67**	**8.07**
CD (0.05)	**0.27**	**19.01**	**38.8**	**24.9**	**32.6**	**49.8**

Map showing funded and voluntary centres of Soil Science AICRP

Scientists involved in Soil Science Co-ordinated Programme 2016 (Appendix I)

S.No	State	Organization	Location	Name	Designation	Telephone	E-mail
Funded centres							
1	Andhra Pradesh	ANGRAU	Maruteru	Dr. A. Sireesha	Scientist	09440415808	siridevaharshini@gmail.com
2	Assam	AAU	Titabar	Dr. T.J. Ghose	Sr. Soil Scientist	09435090297	tapanjyoti57@gmail.com
3	Bihar	RAU	Pusa	Dr. Pankaj Singh	Jr. Scientist	09430998401	pankaj.singh30@gmail.com
4	Karnataka	UAS	Mandya	Dr. Y. P. Pragathi	Jr. Scientist	09108024008	pragathipgowda92@gmail.com
5	Kerala	KAU	Moncompu	Dr. V. Mini Dr. Reena Mathew	Assistant Professor (s)	9446494769	minisvilas@gmail.com, reenajose86@yahoo.co.in
6	Puducherry	PJNCOA&RI	Karaikal	Dr. A. Bhaskar	Professor & Head	09443165382	baskara59@gmail.com
7	Uttar Pradesh	CSAUAT	Kanpur	Dr. B. N. Tripathi	Jr. Soil Scientist	09935649510	dr.bnt1957@gmail.com
Voluntary Centres							
1	Jammu &Kashmir	SEKUASTK	Khudwani	Dr. Mujtaba Aezum	Assistant Professor	09906531155	mujtaba230@gmail.com
2	Chattisgarh	IGKV	Raipur	Dr. Anurag	Professor	09329602206	anuragscientist@gmail.com
3	Puducherry	PKKVK	Kurumbapet	Dr. V. PrabhuKumar	Incharge	09489052303	Prabhukumar80@yahoo.com
4	Uttar Pradesh	NDUAT	Faizabad	Dr. Alok pandey	Asst. Professor	09450763127	alokpandey13ster@gmail.com
5	Uttar Pradesh	CSKHPKV	Ghaghraghat	Dr. Tejendra Kumar	Sr. Soil Scientist	07376890924	tejendra.kumar3159@yahoo.com
6	West Bengal	Govt. of WB	Chinsurah	Dr. Malay Kumar Bhowmick	Assistant Agronomist	09434239688	bhowmick_malay@rediffmail.com
7	Uttar Pradesh	SHIATS	Allahabad	Dr. Terence Thomas	Asso. Prof. & Head	09450409481	thomasaaidu@gmail.com
8	Nagaland	SASRD	Mezdiphema	Dr. P. K. Singh	Asst. Professor	-	drpksingh274@rediffmail.com
9	Jharkhand	RAU, Ranchi	Ranchi(Dumka)	Dr. Purnendu B. Saha	Soil Scientist	09934525212	saha_purnendu@yahoo.com
Head quarters							
1	ICAR	ICAR -IIRR	Hyderabad	Dr. K. Surekha	Principal Scientist	09440963382	surekhakuchi@gmail.com
2	ICAR	ICAR -IIRR	Hyderabad	Dr. M.B.B. Prasad Babu	Principal Scientist	09666852265	mbbprasadbabu@gmail.com
3	ICAR	ICAR -IIRR	Hyderabad	Dr. D.V.K. Nageswara Rao	Principal Scientist	09502382943	dvknrao@gmail.com
4	ICAR	ICAR -IIRR	Hyderabad	Dr. Brajendra	Principal Scientist	09177210995	braj_2222@rediffmail.com
5	ICAR	ICAR -IIRR	Hyderabad	Dr. P.C. Latha	Senior Scientist	09866282968	lathapc@gmail.com
6	ICAR	ICAR -IIRR	Hyderabad	Dr. Bandeppa	Scientist	07382594791	bgsonth@gmail.com
7	ICAR	ICAR-IIRR	Hyderabad	Mr. Gobinath, R.	Scientist	09971720207	gnathatr@gmail.com
8	ICAR	ICAR-IIRR	Hyderabad	Dr. Manasa, V.	Scientist	08762497942	vakadamanasa@gmail.com

List of cooperating centers of Soil Science and allotment of trials - 2016-2017 (Appendix II)

S.No	Locations	Trial 1		Trial 2	Trial 3		Trial 4		Trial 5	Trial 6		Trial 7		Trial 8		Trail 9		Allotted	Conducted	Conducted %
		K	R	K	K	R	K	R	K	K	R	K	R	K	R	K	R			
1	Kanpur (F)	-	-	-	X	X	-	-	-	X	X	X	X	-	-	X	-	3	3	100
2	Maruteru (F)	X	X	-	-	-	X	X	-	-	-	X	X	-	-	X	-	4	4	100
3	Titabar (F)	X	X	X	-	-	-	-	X	-	-	-	-	X	X	-	-	4	4	100
5	Chinsurah (V)	-	-	X	-	-	-	-	-	-	-	X	X	X	X	X	-	4	4	100
6	IIRR (IIRR)	-	-	-	-	-	X	-	-	-	-	-	-	X	-	X	-	3	3	100
7	Faizabad (V)	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	3	3	100
8	Ghaghraghat(V)	-	-	-	-	-	NC	NC	-	-	-	X	X	-	-	-	-	2	1	50
9	Karaikal (V)	-	-	NC	-	-	X	-	-	-	-	X	X	-	-	-	-	3	2	66
10	Khudwani(V)	-	-	NC	-	-	X	-	-	-	-	X	-	-	-	-	-	3	2	66
11	Mandya(V)	X	X	-	-	-	NC	NC	-	NC	NC	NC		-	-	NC	-	4	1	25
12	Moncompu(V)	-	-	-	-	-	NC	-	X	X	-	X	-	-	-	X	-	5	4	80
13	Puducherry (V)	-	-	-	-	-	-	-	-	-	-	X	-	x	-	X	-	3	3	100
14	Dumka (Ranchi)(V)	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	1	1	100
15	Raipur(V)	-	-	-	-	-	-	-	X	-	-	X	-	-	-	X	-	4	4	100
16	Allahabad(V)	-	-	-	-	-	NC	-	NC	-	-	-	-	-	-	-	-	2	0	0
17	Medziphema(V)	-	-	NC	-	-	-	-	NC	-	-	X	-	-	-	-	-	3	1	33
18	Pusa(V)	-	-	-	-	-	X	-	-	X	-	X	-	-	-	X	-	4	4	100
19	Ludhiana(V)		-	-	-	-	-	-	-		-	-	-	X	X	-	-	1	1	100
Total allotted		3	3	9	1	1	10	3	6	5	2	14	6	5	3	9		58	45	82

K – kharif R- Rabi; X Indented trials F – Funded center V – Voluntary center X-Conducted NC-Not conducted

Trial No.1: Long- term soil fertility management in rice – based cropping systems (RBCS) (*Kharif and rabi*)

Trial *No*.2: Yield gap assessment and bridging the gap through site specific integrated nutrient management in rice in farmers' fields

Trial No.3: Screening of germplasm for sodicity and management of sodic soils in RBCS (*Kharif and rabi)*

Trial No.4: Nutrient use efficiency and soil productivity under early and late sown/ transplanted rice (*Kharif and rabi)*

Trial No.5: Screening of rice genotypes for tolerance to soil acidity and related nutritional constraints (*Kharif)*

Trial No.6: Monitoring soil quality and crop productivity under emerging rice production systems (*Kharif* and *rabi*)

Trial No.7: Yield maximization of rice through Site Specific Nutrient Management (*Kharif* and *rabi*)

Trial No.8: Bio-intensive pest management (BIPM) in rice under organic farming (*Kharif* and *rabi)*

Trail No 9: Efficiency of Neem Coated Urea (NCU) in irrigated rice eco-system (Kharif and rabi)

ACKNOWLEDGEMENTS

*Our thanks are due to the scientists of different co-operating centres for the conduct of trials and timely reporting of soil science coordinated programme. We thank the technical staff of Soil Science department **Sri CH. Sivanarayana** and Sri **C. Muralidhar Reddy** for their unstinted support in the conduct of trials at IIRR and data compilation. We are extremely thankful to **Dr. B. Sailaja**, Scientist (SS) Computer Applications, IIRR; Smt. S. Gayatri. and Ms. P. Kalpana for the critical support in statistical analysis of data and preparation of map and the adhoc staff (Mrs N.Sailaja, Mr. Nagendra. V, Ms. P. Madhuri, Mr. M. Srikanth, Mr. S. Mahesh, V. Rajeswar, K.V. Prasad Babu and C. Chandrakala) of the department for their assistance in field studies and laboratory analysis. We also thank Sri **K. Ramulu**, Technical Officer, Plant Physiology Section for the help in page setting and printing of the progress report.*