Soil Science

Progress Report of Soil Science Coordinated Program
(*Rabi* and *Kharif* - 2021)

CONTENTS

5. SOIL SCIENCE

Summary

The coordinated evaluation program in soil science addresses the issues related to sustaining productivity of soil and crop systems on long term basis, soil quality and productivity assessment for bridging the gap in farmers' fields, Management of sodic soils using nano Zn formulation, Management of acid soils, residue management in rice based cropping systems, screening of rice germplasm for nitrogen use efficiency (NUE), yield maximization in different rice growing zones and enhancing productivity of organic rice cultivation. A total of eight trails were conducted during *Rabi*-2020 to *Kharif*-2021 in 18 locations (funded as well as voluntary centers and at IIRR) representing typical soil and crop systems and important rice growing regions.

5.1. Long term soil fertility management in rice based cropping system

In the 33rd year of study on long term soil fertility management in RBCS, the treatment RDF + FYM resulted in maximum grain yield at all 3 locations but was significantly superior to RDF at MND only during *Kharif*. FYM alone treatment was on par to RDF in *Kharif* at MND. Nutrient omission (NPK, Zn and S) and reduction of NPK to 50% resulted in yield reduction at all three centers in both seasons. At the end of *Kharif*-2021, there was an improvement in important soil properties with INM and addition of organics and reduction of NPK values was observed in omission plots compared to RDF plots in general. Over a period of 33 years, RDF recorded slightly +ve growth rate in productivity at MTU; more +ve growth rate at TTB and –ve growth rate at MND. Supplementary dose of FYM along with RDF recorded positive growth rate in productivity with 67, 62 and 60 kg/ha/year at MTU, TTB and MND, respectively, compared to RDF where growth rate varied from - 61 kg/ha/year at MND to 33 kg/ha/year at TTB.

5.2. Soil quality and productivity assessment for bridging the yield gaps in farmers' fields

This trial was conducted in farmers' fields around a few selected centers – Chinsurah, Titabar, Pantnagar, Kanpur, Kaul, Moncompu and Ludhiana to assess the variability in soil nutrient supply, its relationship with rice yields at current recommended fertilizer practices. Sharp variations in mean grain yields recorded varied from 2.38 t/ha among low yielders to 5.0 t/ha among high yielders (Chinsurah), 2.48 t/ha among low yielders to 3.43 t/ha among high yielders (Titabar), 4.76 t/ha among low yielders to 6.59 t/ha among high yielders (Kanpur), 2.4 t/ha among low yielders to 4.32 t/ha among high yielders (Moncompu), 2.9 t/ha among low

yielders to 3.21 t/ha among high yielders (Ludhiana), 3.79 t/ha among low yielders to 4.67 t/ha among high yielders (Karaikal) and 4.39 t/ha among low yielders to 5.94 t/ha among high yielders (Pantnagar). Fertilizer prescriptions were worked out and specific fertilizer recommendations were suggested for target yields, The highest level of yield gap (84 %) was recorded at Kaul, followed 52% at Chinsurah, 17% at Ludhiana, 28% at Titabar and Kanpur, 26% at Pantnagar and 44% at Moncompu. The soil quality index was much superior at Moncompu and Chinsurah and the inferior at Titabar.

5.3. Management of sodic soils using nano Zn formulation

Significant genotypic and location-specific differences in yield parameters and yield were observed between the genotypes and treatments evaluated at the three locations. At Ludhiana, MTU 1001 genotype registered highest tillers/m^2 (656), panicles/m^2 (465), grain (5.26 kg/ha) and straw yield (6.94 kg/ha); MTU 1001 exhibited highest N (94.2 kg/ha), P (25.6 kg/ha) and K (517.7 kg/ha) uptake, respectively due to the high concentration of respective nutrients. At Mandya, MTU 1001 genotype registered highest grain yield (6.07 kg/ha) and N uptake (105.6 kg/ha). MTU 1001 performed at both Ludhiana and Mandya. At Faizabad, DRR DHAN 48 performed well with the grain yield (4.20 kg/ha), straw yield (5.24 kg/ha), respectively. Next to MTU 1001 and DRR DHAN 48, CSR 23 performed well at all three centers. While nutrient content in straw, grain and uptake was improved with the 0.5% $ZnSO_4$ over nano Zn application at Ludhiana and reverse was observed at Mandya.

5.4. Management of acid soils

In a study on “Management of Acid soils”, five genotypes were evaluated with three different treatments at three different locations. At Moncompu, application of NPK (RD)+ Silixol spray recorded significantly higher grain yields (4.40 t/ha) compared to other treatments. In acid Soils of Dumka, application of NPK + Rice husk ash followed by Dolomite application recorded significantly higher grain yields (5.57 t/ha), Where as in Titabar, grain yields were not influenced much by various treatments and were at par with each other. Among the varieties, Shreyas (4.40 t/ha) and Uma (4.33 t/ha) at Moncompu, ARRH - 7576 (4.16 t/ha) and Uma (4.15 t/ha) at Titabar performed better compared to other varieties. In Dumka, except Sharboni (4.42 t/ha) all other varieties performed on par with each other with respect to grain yield.

5.5. Residue management in rice based cropping systems

The disposal of huge quantity of paddy residues is a big problem, particularly in North-West Indian states, resulting in farmers preferring to burn the residues *in-situ* leading to air pollution, smog and loss of appreciable amount of plant essential nutrients besides being deleterious to soil microbes. The trial was conducted this year at eight centers. The results showed that the crop residues can be deployed to substitute half of the recommended nitrogen without yield penalty. The crop residue treatments were at par with each other and lower than RDF in terms of nutrient uptake and also maintained higher nutrient use efficiencies over RDF. Post-harvest soil nutrient status was not influenced much by various residue treatments which were at par with each other.

5.6 Screening of rice germplasm for nitrogen use efficiency (NUE)

In a study on "Screening of rice germplasm for NUE, ten genotypes were evaluated at three nitrogen levels (0, 50 and 100% of recommended N) at seven locations. The results indicated that grain yield was significantly higher at 100% RDN and the increase was in the range of 9-40 % over 50% RDN and 13-110% over no N application. The mean maximum yield was recorded by ARRH7576 (4.34 t/ha) followed by Varadhan (4.32 t/ha), CNN5 (4.30 t/ha), CNN3 (4.14 t/ha). Maximum agronomic efficiency (AE) was recorded by ARRH7576 followed by Rasi and MTU 1010 while maximum physiological efficiency (PE) by ARRH7576, CNN1, CNN4 and maximum recovery efficiency (RE) was recorded by Varadhan, CNN3 and MTU 1010.

5.7 Yield maximization of rice in different zones

Three trials were conducted to study the response of rice crop to varied treatments to maximize yield. The treatments included recommended dose of fertilizers (RDF), RDF + 10 tons of FYM, 125% of RDF, 150% RDF, RDF + 2 sprays of micronutrients, fertilizers as per Nutrient Expert, farmer application dose and RDF + 3 sprays of Eco Agra formulation to realize the maximum yield. The testing was done in Karaikal (*Rabi* 2020-21), Maruteru in *Rabi*, 2020-21 and *Kharif* (2021). Specific focus on treatment T6 (Fertilizers as per Nutrient Expert), which is assumed to be site-specific fertilizer management showed differential responses; insignificant responses in Maruteru-*Rabi* and significant effects in Maruteru-*Kharif* in both grain and straw yields and uptake of elements. Similarly, additional treatment T8 (RDF+Eco Agra Spray) had significant effects on grain, straw and uptake of elements differing from some treatments. However, it was on par with T6 (Fertilizers as per Nutrient Expert) never ultimately highlighting the site-specific management.

5.8 Enhancing productivity of Organic Rice cultivation

The second year of study on "Enhancing productivity of Organic Rice cultivation", it revealed that three centers (CHN, KUL and KHD) out of four, showed positive response to the inorganic RDF but, 150% N (FYM) was significantly superior to other treatments in terms of grain yield and yield parameters at MCP. At CHN most of the soil properties improved with 100% N (FYM) organic treatments compared to other treatments.

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 and being continued at 3 centers only. Hence, the results of 33rd year of cropping *i.e., Rabi* 2020-21 and *Kharif*-2021 are presented in Tables 5.1.1 to 5.1.13.

Crop productivity and soil fertility during *Rabi* 2020-21

Grain and straw yields of rice at MTU and TTB are presented in Table 5.1.2. At MTU, grain yield ranged from 2.93 (control) to 6.82 t/ha (RDF+FYM) with a mean of 5.49 t/ha. RDF, RDF + FYM and 50% NPK substituted with GM/FYM/GM+FYM treatments were at par. Omission of N, P, K, Zn and S resulted in yield reduction by 0.36 t/ha in -S to 2.5 t/ha in -N plots over RDF. At Titabar, grain yield ranged from 1.33 t/ha in control to 4.65 t/ha in RDF+FYM which was on par to RDF (4.43 t/ha) and RDF + lime (4.43 t/ha). Here also, omission of nutrients resulted in grain yield reduction by 0.20 t/ha in -Zn and –S to 0.99 t/ha in - N plots over RDF. Fifty per cent (50%) reduction in RDF resulted in 79% yield reduction in silty clay soil of TTB compared to 44% reduction in clay loam soil of MTU over RDF. Straw yields followed the similar trend as that of grain yield at both locations. At MND, cowpea yield ranged from 256 kg/ha to 477 kg/ha with a mean of 353 kg/ha.

Total nutrient (NPK) uptake followed similar trend as that of grain yield with maximum uptake in RDF+ 5t FYM/ha at TTB and MTU except N uptake at MTU and this treatment was on par to RDF (Table 5.1.3). With regard to soil fertility status after harvest at MTU, soil organic carbon content was significantly higher when 50% RDF was substituted with

GM/FYM/GM+FYM compared to RDF and no definite trend was recorded in case of other soil parameters though there was an improvement with addition of organics (Table 5.1.4). In nutrient omission plots of K, there was a significant reduction in available K compared to plots with RDF and RDF+FYM (by 27 and 20%, respectively).

Crop productivity and soil fertility status during *Kharif*-2021

At MTU, RDF+FYM recorded maximum grain yield (5.98 t/ha) that was on par to RDF (5.49 t/ha) and 50% NPK+25% GM-N+ 25% FYM-N (5.12 t/ha) treatments (Table 5.1.5). Omission of major nutrients (N, P and K) resulted in significant yield loss (1.22 to 1.43 t/ha) compared to RDF. At TTB also, RDF+FYM (5.60 t/ha) recorded maximum yield which was significantly superior to all other treatments and on par to RDF (5.30 t/ha). Here also, yield loss due to omission of major and micro nutrients was observed. At MND, RDF+FYM recorded maximum yield (5.64 t/ha) which was significantly superior to RDF (4.56 t/ha) and on par when 50% NPK was replaced either by 50% FYM or by +25% GM-N+ 25% FYM-N (4.94-5.24 t/ha). Here, at MND, RDF (4.56 t/ha) and FYM alone (4.15 t/ha) treatments were at par. Here also, omission plots recorded significantly lower yields. With regard to straw yield, the trend was almost similar to grain yield trend at all locations with higher yields recorded where organics were added. The total nutrients (NPK) uptake by the above ground biomass was almost similar to that of grain yield trend at all locations with minimum uptake in control and maximum in RDF+FYM closely followed by RDF and in treatments where organics were added (Table 5.1.6). Soil fertility status at the end of *Kharif*-2021 (Tables 5.1.7 and 5.1.8) indicated an improvement in most of the soil properties with addition of organics and omission plots recorded reduction in NPK values compared to RDF at MND and TTB and only in K values at MTU.

Long term changes in crop productivity and soil fertility over a period of 33 years

The trends in mean grain yields over 33 years (1989-2021) of *Kharif* and *Rabi* rice at MND, MTU and TTB by fitting to linear function using actual yields and the per cent change in important soil properties in some important treatments were analyzed and presented below.

Linear trends in crop productivity (Tables 5.1.9 and 5.1.10)

During *Kharif* 2021, the treatment, RDF+5 t FYM/ha recorded maximum mean yield at all 3 locations (MND- 5.26; MTU-5.22 and TTB- 4.95 t/ha) with an average increase of 11, 3.2 and 13%, respectively, at MND, MTU and TTB by this treatment over RDF. Linear trends of productivity over the years with current RDF indicated slightly positive growth in the delta soils of MTU (10 kg grain/ha/year) and more positive growth in the acid alluvial soils of TTB (33 kg/ha/year). Additional dose of FYM @5t/ha along with RDF improved the growth rate substantially with 67 kg/ha/year at MTU and 62 kg/ha/year at TTB. Whereas, at MND, RDF recorded –ve growth rate (-61 kg/ha/yr) and RDF+FYM recorded more positive growth rate (60 kg/ha/yr). FYM alone treatment recorded similar growth rate as that of RDF at MTU and next to RDF+FYM at TTB.

During *Rabi* also, RDF+5t FYM recorded maximum mean grain yield both at MTU (6.28 t/ha) and TTB (4.37 t/ha) and this treatment recorded growth rate of 12 and 48 kg/ha/year at MTU and TTB, respectively (Table 5.1.10). Higher growth rate was observed in *Kharif* season compared to *Rabi* season.

Changes in soil fertility compared to initial values (Table 5.1.11)

The Organic carbon (OC) content increased in all treatments at MTU compared to initial values. At MND, maximum positive change was observed in INM treatment with a decrease in control. At TTB, OC decreased in control but increased in treatments with addition of organics. Maximum increase in OC was in FYM alone treatment at MTU and TTB while in INM treatments at MND. Available N decreased in all treatments at MTU but at MND, it decreased in control with a marginal increase in INM and FYM alone treatments. With regard to available P, there was a buildup in all treatments compared to initial value at all three locations. In case of available K, at TTB, there was a decrease and –ve change in all treatments compared to initial value. At MND and MTU, there was a –ve change in control and +ve change in other treatments where the increase was to a greater extent at MND and to a lesser extent at MTU.

Carbon fractions under long-term fertility experiment

In this study, different oxidizable organic carbon fractions were studied under two long term experiments comprising of Rice-Rice and Rice-Cowpea cropping systems at Titabar, Assam and Mandya, Karnataka, respectively along with different combinations of fertilizers and manures. The data on oxidizable C fractions and total organic carbon (TOC) of Titabar and Mandya soils are presented in Table 5.1.12. The results revealed that the C fractions are sensitive to different nutrient management practices. The very labile carbon (VLC) and labile carbon (LC) fractions of Titabar and Mandya soil varied significantly among different treatments. FYM alone treatment recorded significantly higher VLC (3.43 g/kg) and LC (2.61 g/kg) fractions as compared to unfertilized control at Titabar. In case of Mandya soil the VLC, fraction was significantly higher for FYM alone (2.15 g/kg) as compared to control (0.80 g/kg) followed by 50% NPK + 50% GM – N (1.75 g/kg), whereas the LC fraction was significantly higher for 50% NPK + 50% FYM-N (1.45 g/kg) followed by FYM 10 t/ha (1.27 g/kg) and 50% NPK + 50% GM – N (1.02 g/kg). Changes in less labile carbon (LLC) fractions for Titabar and Mandya ranged from 1.67 to 2.73 and 0.35 to 1.30 g/kg, respectively, with significantly higher values were recorded for 50% NPK + 50% FYM-N which was at par with 100% NPK + Zn + S + FYM/PM. Changes in non-labile carbon (NLC) fractions for Titabar and Mandya ranged from 4.37 to 7.33 and 1.17 to 2.28 g/kg, respectively, with significantly higher values were recorded for FYM alone at Titabar and FYM and 100% NPK + Zn + S + FYM/PM for Mandya. Higher TOC was found in FYM @ 10 t/ha (15.32 g/kg) followed by 50% NPK + 50% FYM-N (14.39 g/kg) and 100% NPK + Zn + S + FYM/PM @5 t/ha (14.34 g/kg). The Control plot without any external sources of nutrients found to have the lowest TOC (9.26 g/kg) in soil of Titatbar. In case of Mandya soil also the TOC was significantly higher in FYM @ 10 t/ha (6.28 g/ha) as compared to control (2.72 g/kg) followed by 50% NPK + 50% GM – N (6.26 g/kg) and 50% NPK + 50% FYM-N (6.13 g/kg).

Active pool (AP), Passive pool (PP), Lability Index (LI), Carbon pool Index (CPI) and carbon management indices (CMI) of soils of Titabar and Mandya are presented in Table 5.1.13. The results revealed that the studied parameters are sensitive to different nutrient management practices. The active Pool (AP) and passive Pool (PP) were significantly affected by the different treatments both at Titabar and Mandya. The results indicated that the AP across all the treatments was higher compared to the PP. The highest AP was recorded in FYM alone at both the locations. At Titabar, 50% NPK + 50% FYM-N (9.55 g/kg) recorded significantly higher amount of PP as compared to control (6.51 g/kg) followed by 100% NPK + Zn + S + FYM/PM @ 5 t/ha (9.35 g/kg) and FYM @ 10 t/ha (9.28 g/kg). However, at Mandya FYM @ 10 t/ha (3.55 g/kg) recorded significantly higher amount of PP as compared to control (1.70 g/kg) followed by 50% NPK + 50% GM-N (3.49 g/kg) and 100% NPK + Zn + S + FYM/PM @ 5 t/ha (3.42 g/kg). LI, CPI and CMI was found to be significantly higher under FYM @ 10 t/ha (1.14, 1.65 and 188.6 at Titabar and 1.41, 2.31 and 326.5 at Mandya, respectively) than control (0.93, 1.0 and 92.5 at Titabar and 1.18, 1.0 and 117.6 at Mandya, respectively).

Summary

From the results of 33rd year of study on long term soil fertility management in RBCS, superior performance of RDF+FYM was noticed over other treatments in both seasons at all three locations (MND, MTU and TTB) but this treatment was on par to RDF at TTB and MTU. FYM alone treatment was on par to RDF during *Kharif* at MND only. Omission of major and micro nutrients resulted in yield reduction at all three locations. In general, INM and organics alone treatments resulted in improvement of soil fertility parameters which had reflected positively in rice productivity at all locations. Additional dose of FYM @ 5 t/ha along with RDF resulted in positive growth rate at all three locations. Compared to initial values, changes in soil fertility showed +ve values for OC and P at all 3 locations in INM and organics alone treatments except at MTU where N; and at TTB where K values were –ve in all treatments.

Table 5.1.1: Long term soil fertility management in RBCS, 2021
Soil and crop characteristics

Cropping system	Maruteru	Titabar	Mandya
	Rice-Rice	**Rice-Rice**	**Rice-Rice**
Variety *Kharif*	MTU 1064	Gitesh	KBC-9
Rabi	MTU 1010	Lachit	Cowpea
Recommended Fertilizer Dose (kg NPK /ha)			
Kharif	90:60:60:50	40:20:20:20	100:50:50:20
Rabi	180:90:60:50	40:20:20	-
STCR based dose			
Kharif	84:64:54	60:20:40	124:35:61
Rabi	124:87:60	60:20:40	-
Crop growth: *Kharif*	-	Very Good	-
Rabi	-	Good	-
% Clay	35	42	11.1
% Silt	26	28.5	18.1
% Sand	39	29.5	62.8
Texture	Clay Loam	Silty Clay	Sandy loam
pH (1:2)	5.96	5.4	5.87
Organic carbon (%)	0.96	1.1	0.30
CEC (cmol (p^+)/kg)	48.6	12.5	-
EC (dS/m)	0.66	0.028	0.28
Avail. N (kg/ha)	218	495	208
Avail. P_2O_5 (kg/ha)	62.3	22.4	19.7
Avail. K_2O (kg/ha)	368	112	117.6

Table 5.1.2: Long term soil fertility management in RBCS, *Rabi* 2021 Grain and straw yields of rice and cowpea

Treatments	Grain yield (t/ha)			Straw yield (t/ha)	
	Maruteru	Titabar	Mandya (Cowpea-kg/ha)	Maruteru	Titabar
Control	2.93	1.33	257	4.11	4.36
100% PK	3.93	3.44	285	5.76	4.25
100% NK	4.61	3.58	366	7.42	4.61
STCR recommendation	5.45	3.80	272	8.52	4.58
100% NP	4.90	3.52	318	8.06	4.63
100% NPKZnS	6.68	4.43	367	8.53	5.63
100% NPKZnS + FYM/PM @ 5t/ha	6.82	4.65	419	9.46	5.80
100% NPK –Zn	6.10	4.23	342	8.18	5.40
100% NPK – S	6.32	4.23	390	8.02	5.23
100%NPK-S+1tlime/ha	-	4.43	313	-	5.32
100% N+50% PK	5.72	4.06	314	8.32	5.26
50 % NPK	4.63	2.48	341	7.32	3.45
50 % NPK + Biofertilizer	5.45	3.50	306	7.36	4.76
50%NPK+ 50% GM-N	6.43	3.66	448	7.96	4.76
50% NPK + 50% FYM-N	6.42	3.73	478	8.53	5.00
50% NPK + 25% GM-N+25% FYM-N	6.63	3.53	412	8.02	4.86
FYM @ 10 t/ha	4.56	3.63	385	5.73	5.10
FYM @ 10 t/ha + Split application	5.80	3.96	257	6.84	5.03
Expt. Mean	**5.49**	**3.68**	**360**	**7.53**	**4.89**
CD (0.05)	**0.66**	**0.23**	**37.0**	**1.52**	**0.42**
CV (%)	**7.31**	**3.9**	**6.5**	**12.3**	**5.1**

Table 5.1.3: Long term soil fertility management in RBCS, *rabi* 2021- Total Nutrient uptake(kg/ha)

Treatments	Maruteru			Titabar		
	N	P	K	N	P	K
Control	40.2	14.5	74.8	32.2	6.4	43.2
100% PK	50.0	22.3	140.2	47.8	9.3	54.3
100% NK	80.2	16.0	157.9	48.9	9.9	58.2
STCR recommendation	82.1	34.1	208.9	56.2	10.5	59.7
100% NP	100.1	34.2	166.8	53.0	10.3	57.9
100% NPKZnS	114.2	41.3	177.0	67.3	13.0	72.8
100% NPKZnS + FYM/PM @ 5t/ha	99.2	43.2	226.2	76.6	13.0	80.9
100% NPK – Zn	99.4	32.1	172.9	60.3	11.9	67.9
100% NPK – S	86.9	34.4	185.5	63.5	11.5	68.2
100%NPK-S+1tlime/ha	-	-	-	68.6	11.7	69.3
100% N+50% PK	91.3	29.8	173.0	64.0	11.3	68.3
50 % NPK	78.4	26.9	134.6	37.5	7.1	45.1
50% NPK + Biofertilizer	72.5	29.7	167.3	53.0	9.9	62.7
50% NPK+ 50% GM-N	94.8	32.4	181.5	54.8	10.9	61.6
50% NPK + 50% FYM-N	90.2	38.8	177.8	56.3	10.6	62.7
50% NPK + 25% GM-N+ 25% FYM-N	96.3	38.1	190.8	56.1	10.3	63.6
FYM @ 10 t/ha	54.0	30.1	113.8	56.0	10.4	67.8
FYM @ 10 t/ha + Split Vermi	80.2	26.3	179.9	58.5	10.6	68.1
Expt. Mean	**82.9**	**30.8**	**166.4**	**56.1**	**10.5**	**62.9**
CD (0.05)	**16.9**	**6.0**	**43.5**	**5.8**	**2.0**	**7.9**
CV (%)	**12.4**	**11.9**	**15.8**	**6.3**	**11.9**	**7.6**

Table 5.1.4: Long term soil fertility management in RBCS, *Rabi* 2021
Soil fertility status at harvest

Treatments	Maruteru					
	pH	**EC**	**Org C (%)**	**Avail. N (kg/ha)**	**Avail. P_2O_5 (kg/ha)**	**Avail. K_2O (kg/ha)**
Control	5.96	0.66	0.77	218	59.1	368
100% PK	5.76	0.69	1.09	196	49.7	393
100% NK	6.27	0.78	1.12	245	55.6	351
STCR recommendation	5.74	0.81	1.14	279	51.9	342
100% NP	5.68	0.81	1.02	260	51.7	295
100% NPKZnS	6.06	0.69	1.38	202	52.3	376
100% NPKZnS + FYM/PM @ 5t/ha	5.71	0.88	1.38	237	46.8	354
100% NPK – Zn	5.68	0.73	1.17	273	54.2	347
100% NPK – S	6.50	0.74	0.87	202	50.0	351
100%NPK-S+1t lime/ha	-	-	-	-	-	-
100% N+50% PK	6.10	0.65	0.89	220	52.6	365
50 % NPK	6.12	0.85	1.06	173	54.3	342
50% NPK + Biofertilizer	5.38	0.65	1.41	254	50.8	348
50% NPK+ 50% GM-N	6.01	0.91	1.05	230	53.8	348
50% NPK + 50% FYM-N	5.56	0.74	1.41	256	47.9	339
50% NPK + 25% GM-N+ 25% FYM-N	5.45	0.73	1.41	234	52.0	401
FYM @ 10 t/ha	5.63	0.86	1.41	215	48.0	384
FYM@10 t/ha + 3.0 t/ha Vermicompost +200 kg/ha oil cakes	6.08	0.65	1.03	211	46.1	369
Expt. Mean	5.86	0.75	1.15	230	51.8	357
CD (0.05)	**0.68**	**0.2**	**0.29**	**82.5**	**5.1**	**36.3**
CV (%)	**7.04**	**15.9**	**15.2**	**21.7**	**6.0**	**6.2**

Table 5.1.5: Long term soil fertility management in RBCS, *Kharif* 2021
Yield and yield parameters of rice

Treatments	Grain yield (t/ha)			Straw yield (t/ha)			Panicles/m^2	
	MTU	**TTB**	**MND**	**MTU**	**TTB**	**MND**	**MTU**	**MND**
Control	2.86	1.43	1.82	3.60	2.28	2.21	231	294
100% PK	4.13	4.23	2.13	9.13	5.10	2.49	237	315
100% NK	4.27	4.30	2.66	7.32	5.40	3.12	247	347
STCR recommendation	4.56	5.10	3.80	8.47	6.06	4.08	237	369
100% NP	4.06	4.43	2.63	8.37	5.15	2.87	248	347
100% NPKZnS	5.49	5.30	4.56	9.35	6.16	4.94	263	447
100% NPKZnS + FYM/PM @ 5 t/ha	5.98	5.60	5.64	9.55	6.80	6.16	262	478
100% NPK –Zn	4.75	4.66	3.90	9.19	5.63	4.61	245	417
100% NPK – S	4.78	-	3.56	8.80	-	4.31	261	430
100%NPK-S+ 1timelime/ha	-	4.43	3.81	-	5.20	4.08	-	436
100% N+50% PK	5.09	4.76	3.38	8.96	5.81	3.72	249	404
50 % NPK	4.31	4.00	3.16	8.67	4.88	3.72	227	417
50 % NPK + Bio fertilizer	4.41	2.53	3.89	7.66	3.56	4.74	258	430
50% NPK+ 50% GM-N	4.84	4.60	4.59	9.75	5.68	4.84	256	456
50% NPK + 50% FYM-N	4.89	4.86	4.94	8.96	5.96	5.36	255	451
50% NPK + 25% GM-N+25% FYM-N	5.12	4.83	5.24	9.76	6.40	5.87	251	462
FYM @ 10 t/ha	4.84	4.86	4.15	8.91	6.16	4.81	227	429
FYM@10 t/ha + 3.0 t/ha Vermicompost +200 kg/ha oil cakes	4.72	4.96	4.27	9.36	6.35	4.11	241	424
Expt. Mean	4.65	**4.16**	3.78	8.58	**5.14**	4.22	247	408
CD (0.05)	**1.03**	**0.33**	**0.75**	**1.64**	**0.42**	**0.82**	**21**	**56**
CV (%)	**13.4**	**4.64**	**9.38**	**11.6**	**4.65**	**9.25**	**5.1**	**6.5**

MTU-Maruteru *TTB-Titabar* *MND- Mandya*

Table 5.1.6: Long term soil fertility management in RBCS, *Kharif 2021*
Total Nutrient uptake(kg/ha) in total dry matter

Treatments	Maruteru			Titabar			Mandya		
	N (kg /ha)	P (kg /ha)	K (kg /ha)	N (kg /ha)	P (kg /ha)	K (kg /ha)	N (kg /ha)	P (kg /ha)	K (kg /ha)
Control	23.2	9.0	46	17.2	2.92	19.5	11.7	2.3	15.3
100% PK	51.0	20.1	161	49.9	8.66	49.5	15.0	2.8	17.6
100% NK	41.2	10.9	116	53.9	10.2	54.2	21.1	3.5	23.1
STCR recommendation	49.2	22.3	140	57.9	12.2	60.4	31.5	5.4	31.3
100% NP	47.7	22.9	122	50.8	10.6	51.6	20.4	4.0	21.0
100% NPK + Zn + S	60.1	28.9	143	62.0	13.2	64.1	39.5	7.4	37.9
100% NPK + Zn + S + FYM/PM @ 5 t/ha	64.0	32.5	171	73.6	16.3	81.1	53.7	11.1	50.9
100% NPK –Zn	51.1	19.4	138	54.6	10.3	56.2	34.3	7.4	36.2
100% NPK – S	46.7	20.1	143	-	-	-	31.7	6.4	32.9
100%NPK-S+ 1timelime/ha	-	-	-	53.5	10.3	53.2	31.6	6.9	31.8
100% N+50% PK	52.5	20.6	138	59.0	11.9	63.1	26.8	5.0	28.6
50 % NPK	45.2	20.2	116	50.6	10.2	50.4	25.5	5.2	27.4
50 % NPK + Biofertilizer	45.5	18.8	124	31.6	7.34	27.5	34.0	7.1	37.1
50% NPK+ 50% GM-N	46.7	21.8	159	54.8	11.9	58.5	38.9	8.1	40.0
50% NPK+ 50% FYM-N	56.2	23.9	137	60.4	12.3	61.5	43.1	9.9	44.4
50% NPK +25% GM-N +25% FYM-N	49.0	24.3	164	62.1	12.8	65.6	49.4	11.3	46.1
FYM @ 10 t/ha	51.0	27.9	127	62.1	12.9	61.9	39.8	7.4	36.4
FYM@10t/ha +3.0 t/ha Vermi+200 kg/ha oil cakes	54.5	18.6	158	61.7	14.3	74.6	36.6	6.6	31.7
Expt. Mean	**46.3**	**20.1**	**128.0**	**50.9**	**10.5**	**52.9**	**32.5**	**6.5**	**32.7**
CD (0.05)	**14.1**	**8.3**	**40.8**	**7.56**	**2.6**	**8.5**	**13.0**	**4.1**	**11.5**
CV (%)	**17.5**	**23.5**	**18.2**	**8.51**	**14.4**	**9.2**	**18.9**	**29.9**	**16.6**

Table 5.1.7: Long term soil fertility management in RBCS, *Kharif* 2021
Soil fertility status at harvest

Treatments	Maruteru					Titabar		
	Soil pH	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)
Control	5.30	1.17	153	55.8	345	0.55	14.1	76
100% PK	5.58	1.33	178	49.7	415	0.66	22.0	94
100% NK	5.36	1.32	191	55.6	336	0.80	26.3	115
STCR recommendation	5.35	1.33	148	51.9	340	0.90	36.5	95
100%NP	5.40	1.16	168	51.7	294	0.88	36.5	95
100% NPKZnS	5.85	1.14	165	52.3	421	0.95	40.3	98
100% NPKZnS + FYM/PM @ 5t/ha	5.51	1.36	155	46.8	387	0.93	45.3	98
100% NPK –Zn	5.76	1.25	166	54.2	354	1.10	35.7	107
100% NPK – S	5.61	1.34	165	50.0	359	-	-	-
100%NPK-S+ 1timelime/ha	-	-	-	-	-	1.10	34.0	92
100% N+50% PK	5.56	1.23	137	52.6	364	1.15	34.9	97
50 % NPK	5.51	1.28	142	54.3	332	1.40	35.0	105
50 % NPK + Biofertilizer	5.33	1.26	160	50.8	333	1.47	38.5	103
50% NPK+ 50% GM-N	5.84	1.24	161	53.8	375	1.37	35.2	100
50% NPK + 50% FYM-N	5.77	1.29	142	47.9	363	1.33	38.8	98
50% NPK + 25%GM-N+25%FYM-N	5.69	1.39	165	52.0	434	1.42	39.8	97
FYM @ 10 t/ha	5.68	1.43	208	48.0	463	1.42	42.7	95
FYM@10 t/ha +3.0 t/ha Vermicompost +200 kg/ha oil cakes	5.45	1.41	150	46.1	423	1.47	43.3	115
Expt. Mean	**5.56**	**1.29**	**163**	**51.4**	**373**	**1.10**	34.7	**97.5**
CD (0.05)	**0.57**	**0.22**	**49.4**	**5.7**	**86.0**	**0.19**	**4.71**	**47.6**
CV (%)	**6.9**	**10.5**	**18.5**	**6.8**	**14.0**	**10.2**	**7.94**	**23.1**

Table 5.1.8: Long term soil fertility management in RBCS, *Kharif* 2021
Soil fertility status at harvest (Mandya)

Treatments	Soil pH	Soil O.C. (%)	Avail. N (kg ha^{-1})	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O (kg ha^{-1})
Control	6.8	0.20	216	48.8	103
100% PK	6.9	0.20	228	56.2	156
100% NK	7.1	0.40	232	57.1	189
STCR	6.7	0.40	254	58.2	170
100% NP	6.8	0.40	248	58.3	132
100% NPK + Zn + S	6.7	0.60	283	58.8	239
100% NPKZnS + FYM/PM	6.6	0.80	294	62.0	258
100% NPK – Zn	6.7	0.40	260	56.0	230
100% NPK – S	6.7	0.40	261	57.2	238
100% N + 50% PK	7.0	0.40	253	55.0	197
50% NPK	7.0	0.40	245	55.2	151
50% NPK + 50% GM-N	6.6	0.70	317	55.8	220
50% NPK + 50% FYM-N	6.5	0.80	297	59.1	209
50% NPK + 25% GM-N + 25% FYM-N	6.4	0.80	329	60.1	236
FYM @ 10 t/ha	6.5	0.70	309	56.7	227
FYM @ 10t.ha + 3 t/ha Vermi + 200 kg/ha oil cakes	6.4	0.73	315	59.2	234
Exp. Mean	**6.7**	**0.5**	**270.6**	**57.0**	**201.4**
CD (0.05)	**0.5**	**0.06**	**21.9**	**5.0**	**22.4**
CV (%)	**3.8**	**5.3**	**3.8**	**4.2**	**5.3**

Table 5.1.9: Long term soil fertility management in RBCS
Linear trends of changes in *Kharif* rice yields (t/ha) from 1989 to 2021

Treatments	MTU			TTB			MND		
	Mean yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)	Mean yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)	Mean yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)
Control	2.84	8	2.64	1.98	-55	2.93	2.21	-60	3.19
100% PK	3.50	37	2.86	3.24	42	2.52	2.73	-38	3.37
100% NK	4.07	-5	4.15	3.56	24	3.14	3.40	-79	4.70
100% NP	4.45	-17	4.75	3.77	22	3.39	3.83	-85	5.21
100% NPK + Zn + S	5.06	10	4.88	4.42	40	3.73	4.72	-61	5.23
100% NPKZnS + FYM	5.22	67	3.72	5.01	79	3.24	5.26	60	3.92
100% NPK – Zn	4.67	-10	4.84	4.17	23	3.79	4.51	-54	5.38
100% NPK – S	4.75	2	4.71	4.14	6	4.04	4.41	-51	5.24
100% N + 50% PK	4.44	-2	4.47	3.68	0	3.67	4.02	-73	5.21
50% NPK	4.27	-5	4.36	3.20	-31	3.73	3.75	-46	4.49
50% NPK + 50% GM-N	4.49	9	4.33	3.84	28	3.37	4.75	-8	4.88
50% NPK + 50% FYM-N	4.77	15	4.51	3.99	35	3.39	4.83	52	4.75
50% NPK + 25% GM-N + 25% FYM-N	4.55	12	4.34	4.04	34	3.47	5.38	09	5.23
FYM @ 10 t/ha	4.45	10	4.28	4.11	55	3.18	4.15	19	3.84

Table 5.1.10: Long term soil fertility management in RBCS
Linear trends of changes in *Rabi* rice yields (t/ha) from 1989 to 2021

Treatments	MTU			TTB		
	Mean yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)	Mean yield (t/ha)	Slope (kg/ha/yr)	Intercept (t/ha)
Control	2.28	41	1.43	1.69	-34	2.21
100% PK	3.00	70	1.78	3.02	57	2.13
100% NK	4.10	30	3.57	3.27	29	2.82
100% NP	4.98	10	4.80	3.41	13	3.21
100% NPK + Zn + S	5.71	40	5.01	3.90	34	3.37
100% NPKZnS + FYM/PM	6.28	12	6.56	4.37	48	3.41
100% NPK – Zn	5.21	26	4.76	3.68	21	3.35
100% NPK – S	5.32	29	4.82	3.58	20	3.26
100% N + 50% PK	5.16	18	4.84	3.38	13	3.18
50% NPK	4.27	18	3.96	2.81	-4	2.87
50% NPK + 50% GM-N	4.93	07	4.80	3.37	25	2.99
50% NPK + 50% FYM-N	5.18	35	4.57	3.47	34	2.94
50% NPK + 25% GM-N + 25% FYM-N	5.00	10	4.82	3.48	32	2.99
FYM @ 10 t/ha	4.13	38	3.46	3.50	38	2.91

Table: 5.1.11: Long term soil fertility management in RBCS
Changes (%) in soil fertility parameters over 1989 to 2021

Treatments	Maruteru				Titabar			Mandya			
	OC	N	P	K	OC	P	K	O.C.	N	P	K
Control	31.5	-48.7	174	-15.0	-42.1	6.8	-47.8	-42.9	-50.6	147.7	-12.2
100% NPK + Zn + S	28.1	-44.6	156	3.7	0.0	205.3	-32.9	71.4	15.1	198.5	104.6
100% NPK + Zn + S + 5 t/ha FYM	52.8	-48.0	129	-4.5	2.1	243.2	-32.7	128.6	24.3	214.7	121.0
50% NPK + 25% GM-N + 25% FYM-N	60.7	-30.2	135	14.1	49.5	201.5	-33.8	128.6	13.4	205.1	101.5
FYM @ 10 t/ha	58.4	-49.6	126	4.3	49.5	223.5	-21.2	100.0	9.1	187.8	94.0

Table 5.1.12. Carbon fractions and total organic carbon of soil under various treatments at Titabar, Assam and Mandya, Karnataka

		Titabar					Mandya				
S. No.	**Treatments**	**Very Labile**	**Labile**	**Less Labile**	**Non Labile**	**Total Organic Carbon**	**Very Labile**	**Labile**	**Less Labile**	**Non Labile**	**Total Organic Carbon**
		g/kg					**g/kg**				
T1	**Control-1, No fertiliser or manure**	0.93	1.82	2.14	4.37	9.26	0.80	0.22	0.36	1.34	2.72
T2	**100% PK (-N)**	1.11	2.14	1.87	5.30	10.42	0.93	0.74	0.57	1.27	3.51
T3A	**100% NK in place of 100% N (-P)**	1.74	2.13	1.67	5.60	11.14	1.05	0.63	0.82	1.71	4.21
T4	**100% NP (-K)**	1.76	2.37	1.95	5.93	12.01	1.15	0.71	0.87	1.82	4.55
T5A	**100% NPK + Zn + S**	2.03	2.07	2.36	6.34	12.80	1.35	0.64	0.93	2.00	4.92
T5B	**100% NPK + Zn + S + FYM/PM @5 t/ha**	2.67	2.32	2.61	6.74	14.34	1.55	0.77	1.14	2.28	5.74
T9	**50% NPK**	0.92	2.16	2.43	5.01	10.52	1.10	0.42	0.35	1.82	3.69
T10	**50% NPK + 50% GM - N**	2.63	2.27	1.76	6.91	13.57	1.75	1.02	1.30	2.19	6.26
T11	**50% NPK + 50% FYM-N**	2.31	2.53	2.73	6.82	14.39	1.55	1.45	1.06	2.07	6.13
T13	**FYM 10 t/ha**	3.43	2.61	1.95	7.33	15.32	2.15	0.58	1.27	2.28	6.28
	CD ($p \leq 0.05$)	0.39	0.28	0.24	0.47	1.22	0.16	0.24	0.11	0.11	0.48

Table 5.1.13. Active pool, passive pool, lability index, carbon pool index and carbon management index of soils under different treatments at Titabar, Assam and Mandya, Karnataka

		Titabar, Assam					Mandya, Karnataka				
S. No.	**Treatment**	**Active Pool (g/kg)**	**Passive Pool (g/kg)**	**Lability Index**	**Carbon Pool Index**	**Carbon Management Index**	**Active Pool (g/kg)**	**Passive Pool (g/kg)**	**Lability Index**	**Carbon Pool Index**	**Carbon Management Index**
T1	**Control-1, No fertiliser or manure**	2.75	6.51	0.93	1.00	92.5	1.02	1.70	1.18	1.00	117.6
T2	**100% PK (-N)**	3.25	7.17	0.91	1.13	102.4	1.67	1.84	1.38	1.29	177.9
T3A	**100% NK in place of 100% N (-P)**	3.87	7.27	1.00	1.20	120.4	1.68	2.53	1.24	1.55	192.3
T4	**100% NP (-K)**	4.13	7.88	1.00	1.30	129.3	1.86	2.69	1.26	1.67	211.0
T5A	**100% NPK + Zn + S**	4.10	8.70	0.98	1.38	136.0	1.99	2.93	1.27	1.81	230.1
T5B	**100% NPK + Zn + S + FYM/PM @5 t/ha**	4.99	9.35	1.06	1.55	164.8	2.32	3.42	1.28	2.11	269.5
T9	**50% NPK**	3.08	7.44	0.90	1.14	102.7	1.52	2.17	1.22	1.36	165.1
T10	**50% NPK + 50% GM - N**	4.90	8.67	1.05	1.47	153.2	2.77	3.49	1.37	2.30	315.8
T11	**50% NPK + 50% FYM-N**	4.84	9.55	1.02	1.55	159.0	3.00	3.13	1.40	2.25	316.5
T13	**FYM 10 t/ha**	6.04	9.28	1.14	1.65	188.6	2.73	3.55	1.41	2.31	326.5
	CD ($p \leq 0.05$)	0.48	0.72	0.11	0.06	23.7	0.13	0.30	0.33	0.18	25.7

5.2. Soil quality and productivity assessment for bridging the yield gaps in farmers' Fields (*Kharif)*

Rice production must increase to meet future food requirements amid strong competition for limited resources. Large variations in yield are a major impending problem for rice sustainability in India. Yield gap analysis is a useful method to examine how large the ranges are between potential, desirable rice yields and those actually realized in farmers' fields. Balanced nutrient application is must to meet the growth requirements of a genotype for realizing the yield potential of several contemporary genotypes. In general, current fertilizer management practices, 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 a few selected centers, viz., Chinsurah (pool of 46 farmers), Titabar (pool of 30 farmers), Pantnagar (pool of 60 farmers), Kanpur (pool of 20 farmers), Kaul (pool of 24 farmers), Moncompu (pool of 16 farmers) and Ludhiana (pool of 30 farmers) to assess the variability in soil 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* 2021 data received representing the irrigated and shallow lowland rice ecosystems are presented in Tables 5.2.1 to 5.2.4 The test varieties were Swarna, Khitish, Shatabdi at Chinsurah; Ranjeet, Ranjeet Sub 1, Bahadur, Swarna at Titabar; PR 126, 6, PR121 at Ludhiana; Pioneer 3727, Arize 6444, Sudha, Kaveri 9090 at Kanpur; PR114, CSR-30, PR-1509, 27P-31, PR-114, PR-114, PR-1121 at Kaul; PR1509, PR121, PR126, PD-18, PD-12, PD-10, Pusa-150, Pusa-150, HR-47, Indrasan, Local, hybrid at Pantnagar and Uma at Moncompu. The methodology involved as conduction of a survey in nearby villages during *Kharif* 2021 and *Rabi* 2020-21 involving data collection from various farmers' fields at different locations across different rice ecologies. The farmers were grouped into Low and high yielder's categories. Soil and plant samples were collected from field after harvest and analyzed for their nutrient contents, and soil quality indexes were calculated. For next season crop, site specific recommendations to the farmers have been generated and is being given for higher productivity and soil health improvement. 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 quality index calculated from all the soil samples collected from the farmer’s fields. Sharp variations in mean grain yields recorded varied from 2.38 t/ha among low yielders to 5.0 t/ha among high yielders at Chinsurah, from 2.48 t/ha among low yielders to 3.43 t/ha among high yielders at Titabar, varied from 4.76 t/ha among low yielders to 6.59 t/ha among high yielders at Kanpur, varied from 2.4 t/ha among low yielders to 4.32 t/ha among high yielders at Moncompu, varied from 2.9 t/ha among low yielders to 3.21 t/ha among high yielders at Ludhiana, from 3.79 t/ha among low yielders to 4.67 t/ha among high yielders at Karaikal and from 4.39 t /ha among low yielders to 5.94 t/ha among high yielders at Pantnagar. Soil Parameters data were pooled in different categories and the resulting soil quality index generated showed variations in the quality and health of the soil across different farmer’s categories. The poorest soil quality index was calculated for farmers from Titabar due to considerable variation among the farm sites and soil test values. The soil quality index was much superior at Kaul, Pantnagar and others were at par for all other centers. Large variations were obtained for nutrient uptake between low yielders and high yields across the centers. Soil nutrient uptake for major nutrients varied widely among the sites. At all these locations wide variations in grain yields and nutrient uptake were recorded (Table 5.2.3), while soil test values did not match the yields recorded with rice yield and nutrient uptake at both the locations, suggesting perhaps less suitability of current soil testing methods for flooded soils. However, some centers reported soil quality index at par with their resulting grain yield and nutrient uptake patterns. Table 5.2.3 recorded the nutrient requirement per ton grain yield variations obtained at all the centers. Nutrient requirement calculations were a useful tool to know how the responses were for fertilizers applied per ton of the grain yield obtained.

Fertilizer prescriptions were worked out for all the farm sites and specific fertilizer recommendations were suggested for target yield Chinsurah- 5 t/ha Titabar-3.5 t/ha, Ludhiana-3.5 t/ha, Moncompu -4.5 t/ha, Pantnagar -6.5 t/ha, Kaul-8 t/ha, Kanpur-6.5 t/ha at these locations (being the highest yield recorded at the test sites) with reference to grain yields and average uptake of nutrients and nutrient requirement per ton grain yield 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 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. Thus, this study 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. While the yields were having considerable variation with the farmers' fertilizer practices, respectively with corresponding variation in soil test values and uptake pattern followed. Wide variations in yields were recorded under recommended fertilizer practices and with all the nutrients under farmers practice indicating mismatch of the fertilizer doses.

Yield Gap analysis

Yield gap analysis was done for all farm fields sites. The need was assessed to ascertain the gaps of technology and compared the yield variations among low yielders and high yielders vis a *vis* uptake, soil quality index gaps. Yield Gap was estimated based on the existing gaps in yields which were recorded between the low yielders and the high yielders and what was the prevalent grain yield in those farmers' sites prevalent across the region. The results have been enlisted in the table no.5.2.4. The highest level of yield gap (84 %) was recorded at Kaul, followed by 52% at Chinsurah, 17% at Ludhiana, 28% at Titabar, 26% at Pantnagar, 44% at Moncompu and 28% at Kanpur. This shows a wide gap of grain harvest existed. However, ample scope existed at these centers to increase yields.

Summary

This trial in the form of a survey was conducted in farmers' fields around a few selected centres, viz., Chinsurah (pool of 46 farmers), Titabar (pool of 30 farmers), Pantnagar (pool of 60 farmers), Kanpur (pool of 20 farmers), Kaul (pool of 24 farmers), Moncompu (pool of 16 farmers) and Ludhiana (pool of 30 farmers) to assess the variability in soil 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* 2021 data received representing the irrigated and shallow lowland rice ecosystems. Sharp variations in mean grain yields recorded varied from 2.38 t/ha among low yielders to 5.0 t/ha among high yielders at Chinsurah, from 2.48 t/ha among low yielders to 3.43 t/ha among high yielders at Titabar, varied from 4.76 t/ha among low yielders to 6.59 t/ha among high yielders at Kanpur, varied from 2.4 t/ha among low yielders to 4.32 t/ha among high yielders at Moncompu, varied from 2.9 t/ha among low yielders to 3.21 t/ha among high yielders at Ludhiana, from 3.79 t/ha among low yielders to 4.67 t/ha among high yielders at Karaikal and from 4.39 t/ha among low yielders to 5.94 t/ha among high yielders at Pantnagar. Soil Parameters data were pooled in different categories and the resulting soil quality index generated showed variations in the quality and health of the soil across different farmer's categories. Fertilizer prescriptions were worked out for all the farm sites and specific fertilizer recommendations were suggested for target yield Chinsurah-5 t/ha Titabar-3.5 t/ha, Ludhiana-3.5 t/ha, Moncompu -4.5 t/ha Pantnagar -6.5 t/ha, Kaul-8 t/ha, Kanpur-6.5 t/ha at these locations (being the highest yield recorded at the test sites) with reference to grain yields and average uptake of nutrients and nutrient requirement per ton grain yield recorded at the test sites. The soil quality index was much superior at Pantnagar and were at par for all other centers. The highest level of yield gap (84 %) was recorded at Kaul, followed 52% at Chinsurah,17% at Ludhiana, 28 % at titabar and Kanpur, 26% at Pantnagar and 44% at Moncompu. This shows a wide gap of grain harvest existed. However, ample scope existed at these centers to increase yields.

Table 5.2.1 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *Kharif* 2021 (Soil, crop and weather data)

Parameter	Chinsurah	Titabar	Ludhiana	Kanpur	Kaul	Pantnagar	Moncompu
Variety	Swarna, Khitish, Shatabdi	Ranjeet, Ranjeet Sub 1, Bahadur, Swarna	PR 126, 6, PR121	Pioneer 3727, Arize 6444, Sudha, Kaveri 9090	PR114, CSR-30, PR-1509,27 P-31, PR-114, PR-114, PR-1121	PR1509, PR121, PR126, PD-18, PD-12, PD-10, Pusa-150, Pusa-150, HR-47, Indrasan, Local, hybrid	Uma
Crop growth	Good	Good	Good	Good	Good	Good	Good
RFD (kg NPK/ha)	Varying- 48-24-24, 50-25-25, 60-30-30, 70-35-35, 80-40-40, 90-45-45, 120-80-80	Varying 20-15-20, 20-15-10, 30-15-25, 40-20-25, 25-25-30, 20-15-30, 40-20-30, 30-20-15, 35-20-15, 30-15-30	120-30-30-25	Varying 120-40-0, 100-40-0, 150-60-40, 120-60-0, 120-60-20, 120-60-30, 120-60-40	-	Varying- 180-60-40, 180-60-0, 150-60-40, 150-0-40, 200-60-40, 150-50-30, 120-50-30	90-40-37, 70-35-45, 100-35-45, 90-38-58, 75-32-38, 95-45-50, 90-48-48, 75-40-20, 60-30-20, 90-35-20, 90-30-40, 75-30-30, 80-30-20,
% Clay	-	32-44	-	-	-	-	-
% Silt	-	25.5-30.8	-	-	-	-	-
% Sand	-	22-28	-	-	-	-	-
Soil Texture	-	Sandy loam to silty clay	Loam to Silt Loam	-	-		
pH	6.49-7.66	5.2-5.6	6.6-7.8	7.78-8.54	7.5-9.2	7.0-7.7	3.04-4.96
EC(mmhos /cm)	0.2-0.29	0.01-0.11	-	0.87-1.45	0.11-0.77	0.25-0.45	0.03-0.4
Org. carbon (%)	0.85-1.1	0.5-0.8	0.28-0.75	0.43-0.78	0.39-0.68	0.27-0.5	1.75-4.59
Avail. N (kg/ha)	341-461	220-310	276-357	196-342	135-198	120-218	244-390
Avail. P_2O_5 (kg/ha)	81-99	8.5-14.5	48-66	11.5-23.67	29.31-53.59	7.9-12.3	5.5-24.9
Avail. K_2O (kg/ha)	255-296	105-140	210-277	182-267	223-392	110-230	88.7-358

Table 5.2.2 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *Kharif 2021*

Soil nutrient supply potential vis a vis nutrient uptake assessed among different farmer's categories

Categories/ Nutrient	**Chinsurah** (**Total of 46 sites:** 12 low yielders and 34 high yielders)			**Titabar** (**Total of 30 sites:** 21 low yielders and 9 high yielders)		
	Minimum	**Maximum**	**Mean***	**Minimum**	**Maximum**	**Mean****
Grain yield (t/ha)						
Low Yielders	1.79	3.05	2.38	2.00	2.85	2.48
High Yielders	4.09	5.62	5.00	3.10	4.75	3.43
Nutrient uptake (kg/ha)						
	Low Yielders					
N	-	-	-	-	-	-
P	-	-	-	-	-	-
K	-	-	-	-	-	-
	High Yielders					
N	-	-	-	-	-	-
P	-	-	-	-	-	-
K	-	-	-	-	-	-
Soil Quality Index						
0.9 (Very High)				0.2 (very poor)		

Categories/ Nutrient	**Ludhiana** (Out of 30,3 low yielders,27 high yielders)			**Moncompu** (Out Of 16,7 high yielders, 9 low yielders)		
	Minimum	**Maximum**	**Mean***	**Minimum**	**Maximum**	**Mean****
Grain yield (t/ha)						
Low Yielders	2.9	3.2	2.1	2.10	2.60	2.40
High Yielders				3.25	5.62	4.32
Nutrient uptake (kg/ha)						
	Low Yielders					
N	-	-	-	40.7	50.2	59.4
P	-	-	-	23.3	32.1	27.6
K	-	-	-	55.9	69.0	62.7
	High Yielders					
N	-	-	-	40.7	94.3	63.2
P	-	-	-	23.3	41.4	32.3
K	-	-	-	55.9	96.3	74.3
Soil Quality Index						
(0.8) very good				0.9 (Very High)		

Categories/ Nutrient	Kanpur (Out of 20, 5 low yielders, 15 high yielders)			Pantnagar (Out of 60, 9 low yielders,51 high yielders)		
	Minimum	**Maximum**	**Mean***	**Minimum**	**Maximum**	**Mean****
Grain yield (t/ha)						
Low Yielders	4.59	4.98	4.76	4.0	4.5	4.39
High Yielders	5.31	7.18	6.59	5.0	7.0	5.94
Nutrient uptake (kg/ha)						
	Low Yielders					
N	53.2	56.6	54.9	23.6	40.5	32.4
P	12.7	14.0	13.5	8.10	20.7	13.5
K	96.7	103.5	99.7	43.2	79.05	57.9
	High Yielders					
N	61.2	89.2	71.5	32.4	60.9	45.2
P	15.6	27.7	19.5	4.13	32.7	17.3
K	93.3	173.4	131.3	14.7	116.1	75.3
Soil Quality Index						
0.67 (good)				(0.8) very good		

Categories/ Nutrient	Kaul (Out of 24,14 low yielders, 10 high yielders)					
	Minimum	**Maximum**	**Mean***	**Minimum**	**Maximum**	**Mean****
Grain yield (t/ha)						
Low Yielders	1.3	1.7	1.4			
High Yielders	7.5	9.9	8.8			
Nutrient uptake (kg/ha)						
	Low Yielders					
N	24.3	38.4	30.4			
P	8.3	16.1	11.3			
K	27.8	44.8	35.4			
	High Yielders					
N	145.9	204.5	175.1			
P	47.5	96.7	72.4			
K	146.6	225.6	187.2			
Soil Quality Index						
0.67 (good)						

Table 5.2.3 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *Kharif* 2021 (Nutrient Requirement per ton grain yield)

Farmer's categories	Chinsurah (Total of 46 sites: 12 low yielders and 34 high yielders)			Titabar (Total of 40 sites, 31 low yielders and 9 high yielder sites)		
	Mean yield (t/ha)	**Mean uptake (kg/ha)**	**Nutrient Requirement (kg/t grain)**	**Mean yield (t/ha)**	**Mean uptake (kg/ha)**	**Nutrient Requirement (kg/t grain)**
Low Yielders (12 sites)	2.38	-	-	2.48	-	-
N		-	-		-	-
P		-	-		-	-
K		-	-		-	-
High Yielders (34 sites)	5.00	-	-	3.43	-	-
N		-	-		-	-
P		-	-		-	-
K		-	-		-	-

Farmer's categories	Ludhiana (Out of 30, 8 low yielders, 22 high yielders)			Moncompu (Out Of 20,16 high yielders, 4 low yielders)		
	Mean yield (t/ha)	**Mean uptake (kg/ha)**	**Nutrient Requirement (kg/t grain)**	**Mean yield (t/ha)**	**Mean uptake (kg/ha)**	**Nutrient Requirement (kg/t grain)**
Low yielders	2.9			2.4		
N					59.4	24.7
P					27.6	11.5
K					62.7	26.1
High yielders	3.5			4.32		
N					63.2	14.6
P					32.3	7.5
K					74.3	17.2

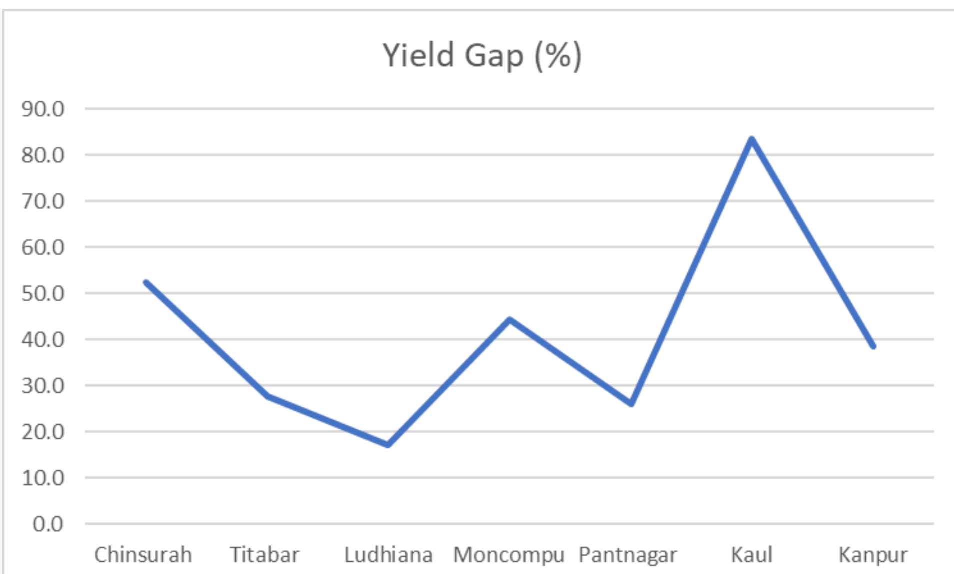
Farmer's categories	Kanpur (Out of 20, 5 low yielders, 15 high yielders)			Pantnagar (Out of 60, 9 low yielders,51 high yielders)		
	Mean yield (t/ha)	**Mean uptake (kg/ha)**	**Nutrient Requirement (kg/t grain)**	**Mean yield (t/ha)**	**Mean uptake (kg/ha)**	**Nutrient Requirement (kg/t grain)**

Low yielders						
N	4.76	54.9	11.53	4.39	32.4	7.38
P		13.5	2.83		13.5	3.07
K		99.7	20.9		57.9	13.1
High yielders						
N	6.59	71.5	10.8	5.94	45.2	7.6
P		19.5	2.95		17.3	2.9
K		131.4	19.8		75.3	12.7
Farmer's categories	**Kaul** (Out of 24,14 low yielders, 10 high yielders)					
	Mean yield (t/ha)	**Mean uptake (kg/ha)**	**Nutrient Requirement (kg/t grain)**			
Low yielders						
N	1.44	30.4	21.11			
P		11.3	7.84			
K		35.4	24.5			
High yielders						
N		175.4	19.9			
P	8.8	72.4	8.22			
K		187.2	21.27			

Table 5.2.4 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *Kharif* 2021 (Site-specific fertilizer recommendation (kg/ha) for a target yield)

Site /centers.	Current yield low yielders group (t/ha)	Current yield High Yielders group (t/ha)	Per cent increase in yield over low yielders groups	Fertilizer recommendation for the target yield (t/ha) Chinsurah- 5, Titabar-3.5 Ludhiana-3.5, Moncompu -4.5 Pantnagar -6.5, Kaul-8, Kanpur-6.5		
				N (Urea)	P_2O_5 (SSP)	K_2O (Potash)
Chinsurah	2.38	5.00	52	100	25	55
Titabar	2.48	3.43	28	70	21	38
Ludhiana	2.90	3.50	17	70	21	38
Moncompu	2.40	4.32	44	65	33	77
Pantnagar	4.39	5.94	26	49	19	82
Kaul	1.44	8.80	84	159	65	170
Kanpur	4.76	6.59	28	70	19	138

Figure 1: Yield gaps existing between low and high yielders at selected farmer's sites across different rice ecosystems



5.3. Management of Sodic soil using nano zinc formulation

Sodic soils have high soil pH (8.5 - 11.0) and exchangeable sodium percentage (ESP) of greater or equal to 15, electrical conductivity of less than 4 dS/m, low organic matter, nutrient content and a preponderance of carbonates and bicarbonates of sodium or excess salt content. These soil characteristics strongly modify the availability of micronutrients and thereby crop productivity. These soils can be managed in by either growing a crop variety suitable for a particular soil or by applying suitable chemical material to withstand the crop in adverse conditions. Sodic soil is deficient in micronutrient like Zn, Fe, Mn and Cu, among these Zn present in the level less than 0.5 ppm. Keeping these points in view, this trial was conducted with nano Zn material to enhance the Zn availability to the plants with various concentration on sodicity soils. This trial has started in Kharif-2021 with the nano Zn chemical in a different concentration (20 and 50 ppm). This trial was taken up in the locations as follows; Ludhiana, Mandya, Faizabad and IIRR. At IIRR, trial has been initiated with 0.5% $ZnSO_4$ and nano Zn 50 ppm level only and varietal comparison has not been taken up during this year. The results of the trial conducted in *Kharif* - 2021 at Faizabad, Ludhiana and Mandya are presented in Tables 5.3.1 to 5.3.12.

Yield Parameters

Yield parameters like tiller number and panicle number per meter square were documented and represented in the table 5.3.2 and 5.3.3. Significant differences were observed in the yield parameters due to varieties and nano Zn treatments at both Ludhiana and Faizabad and Pusa. At Ludhiana, among the 4 genotypes screened, MTU 1001 (656 and 465) recorded the highest tillers/m^2 and panicles/m^2, respectively followed by CSR 23 (674 and 521). Whereas, DRR Dhan 48 produced the least number of tillers/m^2 (419) and panicles/m^2 (306). At Faizabad, DRR DHAN-48 (288 and 283) recorded highest tiller and panicle number/m^2 followed by CSR 23 (265 and 259). MTU 1001 and DRR DHAN 49 were registered on par results with respect to the tiller and panicle number/m^2. In case of Zn treatments, 0.5% Zn spray registered the significantly highest tiller and panicle numbers as 558 and 415 over other treatments. Increment in nano Zn level from 20 to 50 ppm did not improve the tiller and panicle numbers in the rice crop under sodic conditions of Ludhiana. Application of nano Zn @ 50 ppm registered the highest tiller number (285) and panicle number (280) followed by 20 ppm (269 and 264, respectively) at Faizabad. Introduction of nano Zn at Faizabad location can improve the crop yield by improving the yield parameters like tiller and panicle number.

Grain and Straw yields

Grain and straw yields at Faizabad, Ludhiana and Mandya were showed significant differences between the genotypes and Zn treatments (Table 5.3.4 and 5.3.5). The genotype MTU 1001 shown better performance and registered highest yield (5.26 and 6.08 t/ha) at Ludhiana and Mandya, respectively. At Faizabad, DRR DHAN 48 recorded highest yield (4.19 t/ha) among other genotypes. Next to MTU 1001, CSR 23 performed well at all three centers. In case of nano Zn treatment (50 ppm), registered highest grain yield (4.05 and 6.39 t/ha, respectively) at Faizabad and Mandya. At Ludhiana, 0.5% $ZnSO_4$ registered the significantly highest grain yield (4.54 t/ha). Interaction of genotypes and treatments were found to be non-significant.

In case of straw yield, genotype DRR DHAN 48 exhibited highest yield at Faizabad and Mandya as 5.24 and 6.96 t/ha, respectively. Whereas, MTU 1001 has registered 6.94 t/ha at Ludhiana center. Lowest yield was shown by the genotypes, DRR DHAN 48 (4.45 t/ha) at Ludhiana, MTU 1001 (3.87 t/ha) and CSR 23 (6.58 t/ha) at Faizabad and Mandya, respectively. DRR DHAN 48 and MTU 1001 were shown different responses at different locations. While, Zn application significantly increased the straw yield in rice crop at across the centers. Similar to grain yield, straw yield also followed the same pattern as nano Zn 50 ppm exhibited highest yield at Faizabad (5.01 t/ha) and Mandya (7.48 t/ha), but 0.5% $ZnSO_4$ recorded highest yield at Ludhiana (5.73 t/ha). Interaction of genotypes and treatments were found to be non-significant.

Whereas, application 0.5% $ZnSO_4$ and nano Zn @ 50 ppm increased the grain yield by 22 and 21% respectively, over control at IIRR centre.

Nutrient uptake (NPK)

Significant differences of nutrient uptake of NPK were observed in both the locations of Ludhiana and Mandya (Table 5.3.6 and 5.3.7). At Ludhiana, MTU 1001 exhibited highest N (94.2 kg/ha), P (25.6 kg/ha) and K (517.7 kg/ha) uptake, respectively due to the high concentration of respective nutrients followed by CSR 23 genotype as 72.8, 16.3 and 477.9 kg/ha for N, P K uptake, respectively. Out of all the genotypes, DRR DHAN 48 found to be poor performer for NPK uptake at Ludhiana center. Variation in the Zn treatments had significant impact on the NP uptake than K uptake in the rice crop. Highest N (76.1 kg/ha) and P uptake (18.7 kg/ha) was observed at the 0.5% $ZnSO_4$ spray treated plants followed by nano Zn 50 ppm treated plants as N uptake (78.0 kg/ha) and P uptake (20.0 kg/ha), respectively.

While at Mandya, significant difference among the treatment and genotype was observed in the N uptake only. Significantly on par N uptake was found in both DRR DHAN 48 (102.7 kg/ha) and MTU 1001 (105.6 kg/ha) followed by DRR DHAN 49 (99.4 kg/ha) and CSR 23 (94.3 kg/ha). The Varietal difference for P and K uptake was not observed. Whereas, variation in the treatment has registered the significant improvement in the N, P and K uptake. Nano Zn 50 ppm exhibited highest N and K uptake as 119 kg/ha and 118.2 kg/ha, respectively and further reduction was observed as follows; nano Zn 20 ppm, 0.5% $ZnSO_4$ and control. The $ZnSO_4$ application found to be increased the P uptake (16.2 kg/ha) followed by control (15.8 kg/ha). While nano Zn application (20 and 50 ppm) reduced the P uptake.

Zinc uptake

Uptake of Zn in grain, straw and total at the Ludhiana and Mandya was presented in the table 5.3.8 to 5.3.10. At Ludhiana, significant varietal difference on Zn uptake in all grain, straw and total was observed with the various doses of Zn application. Highest Zn uptake in grain, straw was observed with the genotype MTU 1001 (1513 and 3795 g/ha, respectively) followed by CSR 23 (1455 and 3354 g/ha, respectively). Whereas lowest grain, straw and total Zn uptake was exhibited by genotype DRR DHAN 48 (673, 1402 and 2065 g/ha, respectively). While, treatments had a significant impact on Zn uptake in both grain and straw. Application of 0.5% $ZnSO_4$ exhibited a highest Zn uptake (1268, 2794 and 4062 g/ha) in grain, straw and total, respectively. Next to $ZnSO_4$, nano Zn 50 ppm shown second highest Zn uptake (1204, 2654 and 3858 g/ha) in grain, straw and total uptake, respectively. Interaction of genotype and treatment was significant in all three grain, straw and total uptake.

At Mandya, genotypes and treatment had shown their significance with respect to grain, straw and total Zn uptake. Highest grain Zn uptake was shown by CSR 23 (1045 and mg/ha), whereas lowest was recorded in MTU 1001 (965 g/ha). In case of straw, highest was found at DRR DHAN 49 (1562 g/ha) and the lowest (1277 g/ha) was shown by DRR DHAN 48. Treatment has shown highly significant impact on the total Zn uptake (grain + straw). Application of nano Zn 50 ppm registered the highest uptake (1685, 2274 and 3859 g/ha) in grain, straw and total Zn uptake, respectively followed by nano Zn 20 ppm and 0.5% $ZnSO_4$. Interaction of genotype and treatment was non –significant. The genotype CSR 23 found to be prominent genotype and it is showing good uptake of Zn in both grain and straw with application of Zn supplement.

Soil pH and Zn content

Application of Zn and varietal introduction did not have any impact on soil pH. Whereas, application of zinc had improved the soil Zn positively at both Ludhiana and Mandya centers (Table 5.3.11 and 5.3.12). Varietal significance on soil Zn was observed at Mandya alone and the highest Zn values was observed in DRR DHAN 48 and 49 grown soil (0.45 and 0.45 mg/kg, respectively). Whereas treatment significance was observed at both Mandya and Ludhiana centers, application of nano Zn @ 50 ppm shown highest Zn values (0.37 and 0.50 mg/kg) at Ludhiana and Mandya, respectively. Increment in soil Zn was highly improved with the external addition of Zn through $ZnSO_4$ and nano Zn at Ludhiana than Mandya. Introduction of nano Zn @ 50 ppm could be possible way to increase the soil Zn at both Ludhiana and Mandya locations.

Summary

Significant genotypic and location-specific differences in yield parameters and yield were observed between the genotypes and treatments evaluated at the three locations. At Ludhiana, MTU 1001 genotype registered highest tiller/m^2 (656), panicle/m^2 (465), grain (5.23 t/ha) and straw yield (6.94 t/ha); MTU 1001 exhibited highest N (94.2 kg/ha), P (25.6 kg/ha) and K (517.7 kg/ha) uptake, respectively due to the high concentration of respective nutrients. At Mandya, MTU 1001 genotype registered highest grain yield (6.08 t/ha) and N uptake (105.6 kg/ha). At Faizabad, DRR DHAN 48 performed well with the grain yield (4.19 t/ha), straw yield (5.24 t/ha), respectively. Next to MTU 1001 and DRR DHAN 48, CSR 23 performed well at all three centers. Application of $ZnSO_4$ has shown highest Zn uptake (straw + grain) at Ludhiana, whereas nano Zn @ 50 ppm shown highest total Zn uptake at Mandya. Out of four genotypes, MTU 1001 was found best for Zn uptake (grain, straw and total) at Ludhiana, DRR DHAN 49 for straw and total (1562 and 2612 g/ha) at Mandya center. The genotype, CSR 23 stood second at both the centers for Zn uptake. Application of nano Zn @ 50 ppm improved the soil Zn content at both Ludhiana and Mandya.

Table 5.3.1: Management of Sodic soil using nano zinc formulation (Centre information)

Parameters	Ludhiana	Mandya	Faizabad	IIRR
Season	***Kharif* -2021**	***Kharif* -2021**	***Kharif* -2021**	***Kharif* -2021**
Varieties	CSR 23, MTU 1001, DRR DHAN 48 and 49	CSR 23, MTU 1001, DRR DHAN 48 and 49	CSR 23, MTU 1001, DRR DHAN 48 and 49	DRR DHAN 42
Fertilizer dose	-	120:62.5:62.5	120:60:60	120:60:40
Soil pH	8.90	8.11	9.6	8.1
Soil EC (dS/m)	-	0.79	2.85	-
Available N (kg/ha)	-	539	215	119
Available P (kg/ha)	-	94	25	85
Available K (kg/ha)	-	564	238	615
Texture	-	Sandy loam	Sandy loam	Clay
OC (%)	-	0.30	0.38	-
DTPA-Zn (mg/kg)	-	0.42	-	0.50

Table 5.3.2: Effect of sources of Zn and genotypes on Tiller number/m^2 at different locations

Variety	Ludhiana					Faizabad				
	Control	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**
DRR DHAN 48	410	426	412	425	**419**	267	288	290	309	**288**
MTU 1001	646	666	656	658	**656**	221	251	260	275	**252**
CSR 23	660	681	678	680	**674**	240	262	270	288	**265**
DRR DHAN 49	423	461	442	452	**444**	220	250	258	271	**249**
Mean	**534**	**558**	**547**	**554**		**237**	**263**	**269**	**285**	
CD (p=0.05) V	1.44					4.9				
CD (p=0.05) +	3.14					4.0				
VxT	S					NS				
TXV	S					NS				
CV (%) V	0.37					2.6				
CV (%) T	0.72					1.9				

Table 5.3.3: Effect of sources of Zn and genotypes on Panicle number/m^2 at different locations

Variety	Ludhiana					Faizabad				
	Control	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**
DRR DHAN 48	301	312	305	306	**306**	261	282	285	303	**283**
MTU 1001	457	476	466	463	**465**	215	246	254	269	**246**
CSR 23	499	532	522	530	**521**	234	256	263	282	**259**
DRR DHAN 49	311	341	321	335	**327**	214	244	285	266	**244**
Mean	**392**	**415**	**404**	**408**		**231**	**257**	**264**	**280**	
CD (p=0.05) V	1.44					5.06				
CD (p=0.05) T	3.25					3.42				
VxT	S					NS				
TXV	S					NS				
CV (%) V	0.37					2.74				
CV (%) T	1.0					1.66				

Table 5.3.4: Effect of sources of Zn and genotypes on Grain yield (t/ha) at different locations

Variety	Ludhiana					Faizabad					Mandya				
	Control	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**
DRR DHAN 48	3.55	3.77	3.66	3.76	**3.68**	3.36	4.10	4.35	4.97	**4.19**	4.80	5.92	6.36	6.59	**5.60**
MTU 1001	5.19	5.33	5.25	5.26	**5.26**	2.46	2.97	3.23	3.61	**3.07**	5.67	5.87	6.32	6.44	**6.08**
CSR 23	4.38	4.82	4.57	4.89	**4.67**	2.69	3.30	3.55	4.50	**3.39**	4.72	5.39	6.12	6.18	**5.92**
DRR DHAN 49	3.97	4.25	4.13	4.19	**4.14**	2.37	2.95	3.19	3.57	**3.02**	4.56	5.82	6.29	6.37	**5.76**
Mean	**4.27**	**4.54**	**4.40**	**4.53**		**2.72**	**3.33**	**3.58**	**4.05**		**4.94**	**5.75**	**6.27**	**6.39**	
CD (p=0.05) V	0.02					0.11					0.20				
CD (p=0.05) T	0.01					0.10					0.13				
VxT	S					NS					S				
TXV	S					NS					S				
CV (%) V	0.64					4.45					4.09				
CV (%) T	0.54					3.92					2.22				

Table 5.3.5: Effect of source of Zn and genotypes on Straw Yield (t/ha) at different locations

Variety	Ludhiana					Faizabad					Mandya				
	Control	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**
DRR DHAN 48	4.35	4.49	4.47	4.49	**4.45**	4.30	5.10	5.46	6.10	**5.24**	5.89	6.77	7.54	7.62	**6.96**
MTU 1001	6.87	7.02	6.97	6.94	**6.94**	3.18	3.74	4.03	4.53	**3.87**	6.19	6.79	7.15	7.59	**6.92**
CSR 23	5.84	6.09	6.02	6.12	**6.01**	3.43	4.19	4.36	5.05	**4.26**	5.72	6.33	6.98	7.28	**6.58**
DRR DHAN 49	5.05	5.32	5.08	5.13	**5.14**	3.04	3.67	4.05	4.37	**3.78**	5.73	6.76	7.40	7.43	**6.83**
Mean	**5.51**	**5.73**	**5.63**	**5.66**		**3.49**	**4.17**	**4.47**	**5.01**		**5.88**	**6.66**	**7.27**	**7.48**	
CD (p=0.05) V	0.03					0.14					0.21				
CD (p=0.05) T	0.05					0.15					0.41				
VxT	S					NS					NS				
TXV	S					NS					NS				
CV (%) V	0.84					4.89					3.75				
CV (%) T	1.14					4.43					2.08				

Table 5.3.6: Effect of source of Zn and genotypes on Total nutrient uptake (kg/ha) of Ludhiana

Variety	N uptake					P Uptake					K uptake				
	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean
DRR DHAN 48	54.3	61.8	61.0	63.5	**60.1**	11.5	14.0	13.4	14.8	**13.5**	215.6	270.3	240.3	269.4	**248.9**
MTU 1001	86.6	95.8	96.2	98.1	**94.2**	21.3	26.5	26.3	28.5	**25.6**	464.3	561.7	504.1	543.7	**517.7**
CSR 23	66.5	74.9	72.0	77.7	**72.8**	14.2	16.8	15.8	18.2	**16.3**	405.2	525.4	454.4	526.8	**477.9**
DRR DHAN 49	61.9	71.8	70.4	72.8	**69.2**	13.0	17.6	16.7	18.5	**16.5**	252.3	341.7	311.4	339.3	**311.2**
Mean	**67.3**	**76.1**	**74.9**	**78.0**		**15.0**	**18.7**	**18.1**	**20.0**		**334.3**	**424.7**	**376.8**	**419.8**	
CD (p=0.05) V	1.01					0.40					153.2				
CD (p=0.05) T	1.11					0.61					NS				
VxT	NS					S					NS				
TXV	NS					S					NS				
CV (%) V	1.9					3.1					55.1				
CV (%) T	1.87					4.2					38.3				

Table 5.3.7: Effect of source of Zn and genotypes on Total nutrient uptake (kg/ha) of Mandya

Variety	N uptake					P Uptake					K uptake				
	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean
DRR DHAN 48	74.5	99.8	115.5	121.1	**102.7**	16.5	15.9	13.4	17.3	**15.8**	75.9	93.8	112.7	121.5	**101.0**
MTU 1001	89.2	96.8	113.4	123.2	**105.6**	16.8	16.7	14.7	13.4	**15.4**	60.3	91.2	109.7	118.6	**94.9**
CSR 23	68.6	88.8	105.7	113.9	**94.3**	14.1	15.5	14.3	12.0	**14.0**	55.9	85.9	101.5	114.0	**89.4**
DRR DHAN 49	71.1	96.4	112.1	118.0	**99.4**	15.6	16.6	13.1	11.9	**14.3**	76.2	94.0	113.1	118.0	**100.4**
Mean	**75.8**	**95.5**	**111.7**	**119.0**		**15.8**	**16.2**	**13.9**	**13.7**		**67.1**	**91.3**	**109.3**	**118.2**	
CD (p=0.05) V	3.35					NS					NS				
CD (p=0.05) T	4.60					1.4					12.3				
VxT	S					NS					NS				
TXV	S					NS					NS				
CV (%) V	3.95					12.9					14.6				
CV (%) T	4.58					9.16					12.8				

Table 5.3.8: Effect of source of Zn and genotypes on Zn uptake (g/ha) at Ludhiana

Variety	Grain					Straw				
	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean
DRR DHAN 48	558	761	643	730	**673**	1235	1533	1379	1462	**1402**
MTU 1001	1366	1656	1471	1561	**1513**	3494	4083	3749	3855	**3795**
CSR 23	1221	1632	1387	1580	**1455**	2986	3604	3318	3507	**3354**
DRR DHAN 49	676	1019	861	947	**875**	1552	1958	1671	1792	**1743**
Mean	**955**	**1268**	**1090**	**1204**		**2316**	**2794**	**2529**	**2654**	
CD (p=0.05) V	27.9					40				
CD (p=0.05) T	25.5					76				
VxT	S					S				
TXV	S					S				
CV (%) V	3.09					4.16				
CV (%) T	3.14					1.96				

Table 5.3.9: Effect of source of Zn and genotypes on Zn uptake (g/ha) at Mandya

Variety	Grain					Straw				
	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean	Control	0.5% $ZnSO_4$	Nano Zn (20 ppm)	Nano Zn (50 ppm)	Mean
DRR DHAN 48	353	797	1224	1684	**1014**	610	910	1503	2086	**1277**
MTU 1001	387	735	1167	1571	**969**	696	1261	1719	2273	**1487**
CSR 23	355	710	1088	1617	**942**	593	1141	1908	2189	**1458**
DRR DHAN 49	372	777	1182	1869	**1050**	546	1057	2096	2548	**1562**
Mean	**366**	**755**	**1165**	**1685**		**611**	**1092**	**1807**	**2274**	
CD (p=0.05) V	109					234				
CD (p=0.05) T	108					180				
VxT	NS					NS				
TXV	NS					NS				
CV (%) V	11.0					16.4				
CV (%) T	12.9					14.8				

Table 5.3.10: Effect of source of Zn and genotypes on total Zn uptake (g/ha) at different locations

Variety	Ludhiana					Mandya				
	Control	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**
DRR DHAN 48	1793	2294	2022	2191	**2075**	965	1621	2592	3703	**2220**
MTU 1001	4861	5743	5219	5416	**5310**	1084	1997	2886	3837	**2451**
CSR 23	4207	5236	4705	5087	**4809**	946	1936	3132	3873	**2472**
DRR DHAN 49	2228	2977	2532	2739	**2619**	919	1835	3278	4417	**2612**
Mean	**3272**	**4062**	**3620**	**3858**		**978**	**1848**	**2972**	**3959**	
CD (p=0.05) V	83.5					263				
CD (p=0.05) T	51.5					274				
VxT	S					NS				
TXV	S					NS				
CV (%) V	3.15					12.8				
CV (%) T	1.74					11.2				

Table 5.3.11: Effect of source of Zn and genotypes on soil pH at different locations

Variety	Ludhiana					Mandya				
	Control	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**
DRR DHAN 48	8.83	8.93	8.93	8.98	**8.92**	8.20	8.05	7.92	8.15	**8.08**
MTU 1001	8.82	8.90	8.98	8.93	**8.91**	7.97	8.11	8.09	8.15	**8.08**
CSR 23	8.80	8.90	8.93	8.95	**8.9**	8.35	8.16	8.14	8.13	**8.20**
DRR DHAN 49	8.88	8.88	8.90	8.88	**8.88**	8.26	8.23	8.22	7.99	**8.18**
Mean	**8.84**	**8.90**	**8.94**	**8.94**		**8.20**	**8.14**	**8.09**	**8.10**	
CD (p=0.05) V	NS					NS				
CD (p=0.05) T	NS					NS				
VxT	NS					NS				
TXV	NS					NS				
CV (%) V	1.26					4.7				
CV (%) T	1.58					4.7				

Table 5.3.12: Effect of source of Z and genotype on soil DTPA-Zn (mg/kg) at different locations

Variety	Ludhiana					Mandya				
	Control	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**	**Control**	**0.5% $ZnSO_4$**	**Nano Zn (20 ppm)**	**Nano Zn (50 ppm)**	**Mean**
DRR DHAN 48	0.19	0.19	0.27	0.38	**0.26**	0.30	0.50	0.53	0.47	**0.45**
MTU 1001	0.17	0.21	0.27	0.40	**0.26**	0.36	0.35	0.44	0.50	**0.41**
CSR 23	0.17	0.21	0.33	0.37	**0.27**	0.31	0.38	0.47	0.52	**0.42**
DRR DHAN 49	0.17	0.23	0.29	0.36	**0.26**	0.33	0.55	0.44	0.51	**0.45**
Mean	**0.18**	**0.21**	**0.29**	**0.37**		**0.31**	**0.44**	**0.47**	**0.50**	
CD (p=0.05) V	NS					NS				
CD (p=0.05) T	0.08					0.003				
VxT	NS					S				
TXV	NS					S				
CV (%) V	13.2					0.73				
CV (%) T	41.9					0.66				

5. 4 Management of acid soils

Acid soils are wide spread in Eastern, North Eastern and coastal regions of the Indian Peninsula and are poor in soil fertility and are associated with toxicity of iron in lowlands, aluminum in the uplands, with depletion of Ca, Mg and K, deficiency of B, Mo and Si. The soils also 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. In addition, identification of suitable genotypes with high yield potential helps stabilize rice productivity. The trial was, therefore, conducted at three centers viz., Moncompu (Kuttanad, Kerala, soil pH 4.66), Ranchi (Dumka, Jharkhand, soil pH 5.22) and Titabar (Assam, soil pH 5.2) under low land conditions during *kharif* 2021. The selected genotypes were evaluated under three set of nutrient management treatments viz., NPK (RD), NPK (RD)+ Silixol (Si) spray at 3 times (Vegetative, booting and grain filling stage) and NPK + Rice husk ash (RHA) 250 kg/ha during land preparation followed by Dolomite (Do) 250 kg/ha 30 days after transplanting. 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. The experimental results are presented in tables 5.4.1 – 5.4.5 and briefly discussed.

Yield and yield parameters

At Moncompu (MCP), application of either silixol (4.40 t/ha) or Rice husk ash (4.10 t/ha) gave significantly higher grain yields compared to only NPK (3.86 t/ha) and the treatment NPK (RD)+ Silixol spray at 3 times (Vegetative, booting and grain filling stage) recorded significantly higher grain yields compared to only NPK and NPK + Rice husk ash (250 kg/ha) followed by dolomite (250 kg/ha) application (Table 5.4.2). Among the varieties, Shreyas (4.40 t/ha) and Uma (4.33 t/ha) were at par and significantly superior to all other varieties. The straw yields at Moncompu were not influenced by management practices (treatments) but there is a significant difference in varietal response. The variety Sharboni (6.98 t/ha) recorded significantly higher straw yields compared to rest of the treatments. Yield parameters, viz., tillers/m^2 and panicles /m^2, filled grains/panicle and 1000 grain weight followed almost similar trend as that of grain yield where the treatment NPK (RD)+ Silixol spray and the varieties Shreyas and Uma recorded higher values (Table 5.4.3).

At Titabar (TTB), there was no significant difference among the treatments and varieties. The treatment NPK + Silixol spray (4.27 t/ha) and the variety ARRH – 7576 (4.16

t/ha) recorded higher yields compared to rest of the treatments. Straw yield followed a similar trend but the differences are significant (Table 5.4.3).

In acid soils of Dumka, application of NPK + Rice husk ash (250 kg/ha) followed by Dolomite (250 kg/ha) application recorded significantly higher grain yields (5.57 t/ha) compared to only NPK and NPK + Si spray. Among the varieties, except Sharboni (4.42 t/ha) all other varieties performed on par with each other with respect to grain yield.

Total nutrient uptake

Total nutrient uptake at Moncompu was significantly influenced by different treatments and varieties (Table 5.4.3). Among the treatments, NPK (RD) + Silixol spray recorded significantly higher nitrogen uptake (87 kg/ha), phosphorus uptake (35.7 kg/ha), and potassium uptake (96 kg/ha) compared to rest of the treatments. Among the varieties, Shreyas recorded higher nitrogen uptake (83 kg/ha) and phosphorus uptake (34.9 kg/ha) while highest potassium uptake (93 kg/ha) was reported in the variety Sharboni.

In acid soils of Titabar, application of NPK + Silixol spray recorded higher phosphorus uptake (11.02 kg/ha) and potassium uptake (83 kg/ha) compared to rest of the treatments. Potassium uptake by ARRH – 7576 (77 kg/ha), Shreyas (77 kg/ha) and Uma (76 kg/ha) were at par with each other and lowest P uptake (15.2 kg/ha) was noticed in ARRH – 7576.

At Dumka, application of NPK + Rice husk ash (250 kg/ha) followed by Dolomite (250 kg/ha) recorded significantly higher phosphorus uptake (17.5 kg/ha) compared to rest of the treatments (Table 5.4.3). Among the varieties, phosphorus uptake by Vasundhra (17.7 kg/ha), Uma (16.7 kg/ha) and Shreyas (16.6 kg/ha) were at par with each other and lowest P uptake (14.5 kg/ha) was noticed in Sharboni.

Post-harvest soil properties

The available nutrient status (N, P and K), pH and Organic carbon of Titabar soils are presented in Table 5.4.5. The data reveals that except pH, available nitrogen and potassium other soil properties were not influenced much by various treatments and were at par with each other. There is no effect of varieties on the post-harvest soil properties.

Summary

In the first year of study on “Management of Acid soils, five genotypes were evaluated under three different treatments (NPK(RD), NPK (RD)+ Silixol spray and NPK + Rice husk ash followed by Dolomite at three locations. The results indicated that at Moncompu, application of

NPK (RD)+ Silixol spray recorded significantly higher grain yields (4.40 t/ha) compared to other treatments. In acid Soils of Dumka, application of NPK + Rice husk ash followed by Dolomite application recorded significantly higher grain yields (5.57 t/ha) compared to only NPK and NPK + Si spray. Where as in Titabar, grain yields were not influenced much by various treatments and were at par with each other. Among the varieties, Shreyas (4.40 t/ha) and Uma (4.33 t/ha) at Moncompu, ARRH - 7576 (4.16 t/ha) and Uma (4.15 t/ha) at Titabar performed better compared to other varieties. In Dumka, except Sharboni (4.42 t/ha) all other varieties performed on par with each other with respect to grain yield.

Table 5.4.1: Management of acid soils, *Kharif*-2021

Soil and crop characteristics

Parameter	Moncompu [1]	Dumka (Ranchi) [2]	Titabar [3]
Cropping system	Rice-Rice	Rice-Rice	Rice-Rice
RDF (Kg NPK/ha)	90:45:45	100:50:25	60:20:40
Crop growth	Good	Good	Good
Soil characteristics			
% Clay	-	-	42.5
% Silt	-	-	28
% Sand	-	-	29.5
Soil Texture	-	Sandy loam	Silty clay
pH (1:2.5)	4.66	5.22	5.20
Org. carbon (%)	-	0.52	0.9
CEC [c mol (p+)/kg]	-	-	12
EC (ds/m)	0.06	-	0.18
Avail.N (kg/ha)	372	-	410
Avail. P_2O_5 (kg/ha)	69.4	22	22
Avail. K_2O (kg/ha)	183	185	115
DTPA –Zn (mg/kg)	1.55	-	1.0
DTPA –Fe (mg/kg)	241	-	21.5
DTPA –Mn (mg/kg)	2.68	-	-
DTPA –Cu (mg/kg)	1.45	-	-

Table 5.4.2: Management of acid soils, *Kharif*-2021, Grain and Straw yields of rice

Variety / Treatments	Moncompu								Titabar								Dumka			
	Grain yield (t/ha)				Straw yield (t/ha)				Grain yield (t/ha)				Straw yield (t/ha)				Grain yield (t/ha)			
	NPK	NPK+ Si	NPK+ RHA +Do	Mean	NPK	NPK+ Si	NPK+ RHA +Do	Mean	NPK	NPK+ Si	NPK+ RHA +Do	Mean	NPK	NPK+ Si	NPK+ RHA +Do	Mean	NPK	NPK+ Si	NPK+ RHA +Do	Mean
Shreyas	4.15	4.82	4.23	4.40	5.68	6.10	5.33	5.71	3.87	4.25	3.85	3.99	3.87	5.82	5.60	5.09	4.96	5.20	5.52	5.23
Uma	3.97	4.83	4.18	4.33	5.62	5.63	5.30	5.52	4.15	4.35	3.95	4.15	4.15	5.62	5.33	5.03	5.25	5.92	5.61	5.59
Jyoti	3.72	4.38	4.03	4.04	5.17	5.23	4.85	5.08	3.83	4.18	3.93	3.98	3.83	5.43	5.00	4.76	5.12	5.33	5.67	5.38
Vasundhara	3.75	4.10	3.98	3.94	6.38	6.92	6.43	6.58	3.60	4.28	4.03	3.97	3.60	5.33	5.10	4.68	5.57	5.81	6.26	5.88
Shraboni/ ARRH7576	3.70	3.85	4.08	3.88	6.83	7.47	6.65	6.98	4.18	4.27	4.03	4.16	4.18	5.67	5.32	5.06	4.12	4.38	4.77	4.42
Mean	3.86	4.40	4.10	4.12	5.94	6.27	5.71	5.97	3.93	4.27	3.96	4.05	3.93	5.57	5.27	4.92	5.01	5.33	5.57	5.30
CD –M (p= 0.05)	0.22				NS				NS				0.25				0.12			
CD- S (p= 0.05)	0.17				0.25				NS				0.30				0.71			
M X S	0.29				NS				NS				NS				NS			
S XM	0.29				NS				NS				NS				NS			
CV (%) M	8.30				6.94				12.89				7.74				3.37			
CV (%) S	4.12				4.32				10.04				6.25				13.7			

M – Main plot (Treatments), S – Subplot (Varieties)

Table 5.4.3: Management of acid soils, *Kharif*-2021, yield parameters of rice

Variety / Treatments	Moncompu															
	Tillers/m^2				Panicles/m^2				Filled grains/panicle				1000 grain weight (g)			
	NPK	NPK+ Si	NPK+ RHA+Do	Mean	NPK	NPK+ Si	NPK+ RHA+Do	Mean	NPK	NPK+ Si	NPK+ RHA+Do	Mean	NPK	NPK+ Si	NPK+ RHA+Do	Mean
Shreyas	138	153	144	145	127	140	130	132	126	131	124	127	29.2	29.4	29.9	29.5
Uma	134	153	134	140	127	138	126	130	124	123	117	122	28.6	28.3	28.6	28.5
Jyoti	131	144	126	134	127	126	117	123	113	112	110	112	29.6	32.7	31.2	31.2
Vasundhara	127	140	121	129	116	122	113	117	112	104	110	109	27.2	28.2	28.1	27.8
Shraboni/ ARRH7576 (TTB)	121	134	121	125	118	123	119	120	109	111	110	110	28.3	25.7	26.3	26.8
Mean	130	145	129	135	123	130	121	125	117	116	114	116	28.6	28.9	28.8	28.7
CD –M (p= 0.05)	5				NS				NS				NS			
CD- S (p= 0.05)	7				6				4.36				2.64			
M X S	NS				NS				NS				NS			
S XM	NS				NS				NS				NS			
CV (%) M	5				12				9.42				4.0			
CV (%) S	5				5				3.87				9.43			

M – Main plot (Treatments), S – Subplot (Varieties)

Table 5.4.4: Management of acid soils, *Kharif*-2021, Nutrient uptake (kg/ha) by rice

Variety / N levels	Moncompu											
	N uptake				P uptake				K uptake			
	NPK	NPK+ Si	NPK+ RHA+Do	Mean	NPK	NPK+ Si	NPK+ RHA+Do	Mean	NPK	NPK+ Si	NPK+ RHA+Do	Mean
Shreyas	74	96	79	83	29	42	34	35	81	100	86	89
Uma	68	88	76	77	26	39	31	32	76	94	85	85
Jyoti	62	84	72	73	25	32	28	29	71	86	78	78
Vasundhara	64	83	74	73	25	34	30	30	81	99	88	90
Shraboni	66	84	77	76	26	31	31	30	85	103	91	93
Mean	67	87	76	77	26	36	31	31	79	96	86	87
CD (p= 0.05) M	3.72				1.9				6.08			
CD (p= 0.05) S	2.86				2.47				3.87			
M X S	NS				NS				NS			
S XM	NS				NS				NS			
CV (%) M	7.49				9.46				10.78			
CV (%) S	3.83				8.2				4.57			

M – Main plot (Treatments), S – Subplot (Varieties)

Table 5.4.4: Management of acid soils, *Kharif*-2021, Nutrient uptake (kg/ha) by rice

Variety / Treatments	Titabar								Dumka			
	P uptake				K uptake				P uptake			
	NPK	NPK+ Si	NPK+ RHA+Do	Mean	NPK	NPK+ Si	NPK+ RHA+Do	Mean	NPK	NPK+ Si	NPK+ RHA+Do	Mean
Shreyas	8.5	11.2	8.5	11.2	60	88	81	77	13.9	16.8	19.0	16.6
Uma	9.5	11.1	9.5	11.1	68	86	74	76	14.7	17.2	18.1	16.7
Jyoti	8.4	10.3	8.4	10.3	62	81	76	73	13.8	16.5	17.17	15.8
Vasundhara	7.9	10.7	7.8	10.7	57	76	77	70	17.4	17.7	18.0	17.7
Shraboni/ ARRH7576 (TTB)	9.4	11.7	9.45	11.7	68	84	80	77	13.8	14.6	15.2	14.5
Mean	8.7	11.0	8.75	11.0	63	83	77	75	14.7	16.5	17.5	16.2
CD (p= 0.05) M	0.97				4.89				0.34			
CD (p= 0.05) S	NS				4.35				1.58			
M X S	NS				NS				NS			
S XM	NS				NS				NS			
CV (%) M	14.97				10.1				3.24			
CV (%) S	10.94				5.99				9.94			

M – Main plot (Treatments), S – Subplot (Varieties)

Table 5.4.5: Management of acid soils, *Kharif*-2021, post-harvest soil properties

Variety / Treatments	Titabar					Momcompu					
	pH	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	pH	EC	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Treatment											
NPK	5.42	0.84	314	22.0	162	4.63	0.07	3.42	372	70	177
NPK+ Si	6.20	0.87	316	21.8	162	4.66	0.06	3.5	377	72	181
NPK+ RHA + Do	6.40	0.9	315	21.9	163	4.77	0.06	3.57	374	70	184
CD (0.05)	0.03	NS	0.72	NS	NS	0.07	NS	NS	NS	NS	2.25
CV (%)	0.87	0.3	0.35	3.79	1.11	2.2	15.0	3.75	1.34	4.89	1.93
Variety											
Shreyas	5.93	0.87	315	21.3	162	4.69	0.06	3.54	382	72	184
Uma	6.01	0.87	316	22.8	163	4.65	0.07	3.47	377	71	181
Jyoti	6.01	0.87	314	21.9	162	4.68	0.06	3.49	368	70	179
Vasundhara	6.05	0.86	315	21.1	162	4.71	0.06	3.48	372	71	179
ARRH75	6.03	0.88	315	22.4	162	4.7	0.07	3.52	374	69	180
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	6.35	NS	NS
CV (%)	2.12	1.19	0.51	7.1	0.55	2.06	16.1	3.58	1.74	4.3	2.41
Interaction											
M X S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S XM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	6.01	0.87	314	21.9	162.2	4.69	0.06	3.50	374	70.6	180

M – Main plot (Treatments), S – Subplot (Varieties)

5. 5. Residue management in rice-based cropping systems

In India, huge quantities of crop residues (about 371 million tons) are produced annually of which paddy residues constitute 51–57%. The disposal of paddy residues has become a big problem, particularly in North-West Indian states, mainly due to the use of combine harvester and narrow time gap (one to three weeks) between paddy harvesting and planting of wheat in NW India, resulting in farmers preferring to burn the residues in-situ. Burning biomass not only pollutes environment by depleting air quality, emitting greenhouse gases (GHGs), but also causes smog in the environment, results in loss of appreciable amount of plant essential nutrients besides being deleterious to soil microbes. The incineration of crop residues contributes to emissions of harmful air pollutants, which can cause severe impacts on human health too. Thus, proper residue management is of utmost important as it contains plant nutrients and improves the soil-plant-atmospheric continuum. As an alternative strategy, these crop residues can be used for mulching, compost making and in-situ incorporation for improving soil fertility.

Therefore, the trial was initiated to study the influence of crop residues on rice productivity, soil health, pest dynamics and grain quality in rice based cropping systems (RBCS). In the current year, the trial was conducted at eight centers *viz*., Faizabad (FZD), Hazaribagh (HZB), Karaikal (KRK), Khudwani (KHD), Maruteru (MTU), Puducherry (PDU), Pusa (PSA) and IIRR.

The treatments (8) consisted of application of recommended dose of fertilizers (RDF), crop residues in combination with either chemical fertilizer, green manure (GM)/green leaf manure (GLM) to supply the N requirement on equal basis (50%:50%) with and without the addition of Pusa Decomposer, developed by ICAR-IARI, New Delhi (Table 5.5.1). Pusa Decomposer is a microbial consortium, capable of producing hydrolytic enzymes responsible for the degradation of the polysaccharides in plant cell wall resulting in faster decomposition.

The test varieties were BPT-5204 at FZD, Sahabhagi Dhan at HZB, CO-51 at KRK, SR-4 at KHD, MTU-1064 at MTU, TRY R 4 at PDU and Bhagwati at PSA, DRR Dhan-42 at IIRR. The details of crop, soil and weather parameters of the experimental sites (Table 5.5.2) show variation in soil characteristics with reference to pH, organic carbon content, soil texture and available nutrient status. The data from eight locations are presented in Tables 5.5.3 to 5.5.5.

Rice productivity

Data presented in Table 5.5.3 shows that the rice productivity significantly varied with the source of nitrogen application. Supplementation of residues (50% N) in addition to RDF (50% N) alone or along with microbial culture (Pusa Decomposer) gave yields at par with RDF at half (four) of the centers *viz*., KRK, MTU, PDU and PSA. Application of 100% N through RDF resulted in significantly highest grain yield at FZD (4.60 t/ha), HZB (3.82 t/ha) and KHD (7.30 t/ha). At PDU, many of the residue treatments were on par. At IIRR, application of residue + green manure recorded significantly higher grain yields (5.65 t/ha) compared to 100% RDF (4.70 t/ha). The results prove that the crop residues in combination with Pusa decomposer can be deployed to substitute half of the recommended nitrogen without yield penalty. Similar trend was also observed for straw yield as well.

Nutrient uptake and use efficiency

Data presented in Table 5.5.4 show significant effect of source of N application on nutrient uptake. Combined application of crop residues with RDF/MC/GM resulted in nutrient uptake values (43-186 kg N/ha, 11-58 kg P/ha and 35-329 kg K/ha) which were at par with each other and higher than 100% RDF at three centers *viz*., PDU, KRK and IIRR.

Data presented in Table 5.5.5 show lower nutrient use efficiencies in RDF as compared to crop residue treatments which were mostly at par with each other.

Post-harvest soil nutrient status

The available nutrient status (N, P and K) of soils at are presented in Table 5.5.6. The data reveals that the soil nitrogen, phosphorus and potassium contents after harvest of the crop were not influenced much by various residue treatments and were at par with each other.

Summary

Supplementing half of the recommended N through residues (50% N) in addition to either RDF (50% N) or GM, MC yielded at par with each other and either higher or on par with RDF (100% N) in terms of grain yield. The results show that the crop residues along with Pusa decomposer can be deployed to substitute half of the recommended nitrogen without yield penalty. Combined application of crop residues with RDF/MC/GM resulted in nutrient uptake values (43-186 kg N/ha, 12-58 kg P/ha and 35-329 kg K/ha) which were on par with each other and higher than 100% RDF. Nutrient use efficiencies were lower in RDF as compared to crop residue treatments which were mostly at par with each other.

Table: 5.5.1 Residue management in RBCS

Treatments Details

Sl. No	Treatment
1	100% RDF (NPK)
2	50% residue + 50% RDF
3	50% residue + 50% RDF + Pusa Decomposer (PD)
4	Rice residue (50% N) + 50% N GM/GLM
5	Residue (50% N) + 50% N GM/GLM + Pusa Decomposer (PD)
6	Residue (2.5 t/ha) + Pusa Decomposer (PD)
7	Residue (2.5 t/ha)
8	Absolute Control

Table: 5.5.2 Residue management in RBCS
Crop and soil characteristics

Parameter	FZD [1]	HZB [2]	KRK [3]	KHD [4]	MTU [5]	PDU [6]	PSA [7]	IIRR [8]
Cropping system	Rice-Wheat	Rice-Wheat	Rice-Rice	Rice-Wheat	Rice-Rice	Rice-Rice	Rice-Wheat	Rice-Rice
Variety								
Kharif	BPT-5204	Sahabhagi Dhan	CO-51	SR-4	MTU-1064	TRY R 4	Bhagwati	DRR Dhan-42
Rabi	-	-	ADT-46	-	BPT-5204			
RFD (Kg NPK/ha)								
Kharif	120:60:60:25	60:30:30	150:50:50	-	90:60:60:50	150:50:50	120:60:40	120:60:40
Rabi	-	-	150:50:	-	180:90:6	-	-	-
Crop growth								
Kharif	Good	Good	Good	Good	Good	Good	Good	Good
Rabi	-	-	Good	-	Good	-		-
Soil data								
% clay	23	21	17	41	38	-	15	-
% silt	21	22	2	37	28	-	26	-
% sand	56	57	83	22	34	-	59	-
Soil Texture	Sandy Loam	Sandy Loam	Sandy loam	Silty clay	Clay loam	Clay loam	Sandy loam	Clay
pH (1:1)	7.6	-	7.4	6.93	6.02	6.97	8.52	8.1
Org. carbon	0.4	-	0.34	-	1.14	0.26	0.7 %	-
CEC [c mol	13.5	-	8.2	-	42.6	-	-	-
EC (dS/m)	1.02	-	0.11	0.09	0.77	0.30	0.52	-
Avail.N	218	-	185	284	153	146	192	119
Avail. P_2O_5	25	-	23	16	64	35.02	46	85
Avail. K_2O	235	-	120	267	302	121	232	615

Table: 5.5.3 Residue management in RBCS
Grain and straw yields (*Kharif* 2021)

Treatment	Grain yield (t/ha)								Straw yield (t/ha)							
	FZD	**HZB**	**KRK**	**KHD**	**MTU**	**PDU**	**PSA**	**IIRR**	**FZD**	**HZB**	**KRK**	**KHD**	**MTU**	**PDU**	**PSA**	**IIRR**
100% RDF (NPK)	4.60	3.82	4.17	7.30	5.97	5.42	4.85	4.70	6.18	5.08	11.61	10.05	9.76	8.12	6.84	8.40
50% residue + 50% RDF	3.66	2.38	4.14	6.30	4.45	5.07	4.23	4.49	4.94	3.96	13.78	9.31	9.11	7.67	6.03	7.91
50% residue + 50% RDF + PD	3.94	2.37	3.78	6.59	5.10	5.60	4.41	5.01	4.84	3.64	13.00	8.83	9.73	8.40	6.27	9.07
Rice residue (50% N) + 50% N GM/GLM	3.33	1.22	3.61	5.46	4.25	5.06	3.35	5.13	5.16	3.09	12.56	8.32	8.68	7.77	4.88	8.18
Residue (50% N) + 50% N GM/GLM + PD	3.41	1.15	3.86	5.76	4.86	5.46	3.50	5.65	4.60	2.88	13.83	7.47	9.17	8.21	5.10	9.70
Residue (2.5 t/ha) + PD	2.97	1.04	3.45	5.50	4.10	3.79	3.18	4.52	4.01	1.65	12.22	8.19	7.63	5.45	4.70	9.20
Residue (2.5 t/ha)	3.36	0.98	3.34	4.96	4.53	3.37	3.05	4.04	4.53	1.54	12.78	6.87	8.55	4.87	4.54	7.68
Absolute Control	2.68	0.91	3.17	4.46	2.88	2.92	2.97	3.02	3.62	1.44	10.11	6.18	4.47	4.50	4.42	7.20
Expt. Mean	**3.49**	**1.73**	**3.69**	**5.79**	**4.52**	**4.58**	**3.69**	**4.57**	**4.73**	**2.91**	**12.49**	**8.15**	**8.39**	**6.87**	**5.35**	**8.42**
CD (0.05)	**0.19**	**0.28**	**0.43**	**0.32**	**1.17**	**0.43**	**0.48**	**0.71**	**0.29**	**0.60**	**NS**	**1.17**	**1.61**	**0.62**	**0.70**	**1.31**
CV (%)	**3.12**	**9.32**	**6.59**	**3.13**	**14.72**	**5.38**	**7.46**	**8.89**	**3.46**	**11.75**	**16.70**	**8.21**	**10.96**	**5.12**	**7.46**	**8.88**

Table: 5.5.4 Residue management in RBCS
Nutrient uptake (kg/ha) in total dry matter (*Kharif* 2021)

Treatment	FZD			KRK			KHD			MTU			PDU			PSA			IIRR		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
100% RDF (NPK)	125	58.3	73.3	97	18.2	328	186	51.7	230	92.4	47.5	167	103	27.7	126	88.4	20.9	121	90.7	25.4	193
50% residue + 50% RDF	93	41.6	52.8	120	16.9	348	148	38.0	193	69.6	35.7	148	95	24.2	114	73.2	17.5	103	71.4	24.1	175
50% residue + 50% RDF + PD	98	45.3	58.1	87	19.1	337	150	38.7	188	80.1	32.8	148	114	31.7	136	77.8	18.5	108	91.2	31.4	228
Rice residue (50% N) + 50% N GM/GLM	88	39.8	50.5	87	18.2	302	125	27.6	164	68.8	30.9	184	94	23.1	114	56.3	13.4	80	83.4	29.9	144
Residue (50% N) + 50% N GM/GLM + PD	84	38.9	48.8	110	13.4	297	123	27.5	147	75.9	31.1	189	108	30.5	128	60.5	14.3	84.3	95.7	34.2	213
Residue (2.5 t/ha) + PD	66	31.0	41.0	72	19.0	284	116	26.7	154	66.3	25.3	141	66	16.3	72.0	51.0	12.7	76.1	84.3	29.8	211
Residue (2.5 t/ha)	83	40.0	50.1	65	21.8	299	101	20.5	129	70.7	33.3	125	54	13.6	60.7	49.5	11.8	72.4	69.0	24.7	133
Absolute Control	53	25.9	34.7	71	16.3	215	84	15.6	110	43.3	18.7	57	43	11.2	51.1	47.1	11.6	69.9	55.3	19.0	108
Expt. Mean	**86.5**	**40.1**	**51.1**	**88.8**	**17.9**	**301.4**	**129.2**	**30.8**	**164.4**	**70.9**	**31.9**	**145.0**	**84.9**	**22.3**	**100.2**	**63.0**	**15.1**	**89.3**	**80.1**	**27.3**	**175.9**
CD (0.05)	**8.4**	**4.1**	**5.8**	**28.4**	**NS**	**NS**	**9.5**	**3.8**	**21.0**	**19.7**	**11.1**	**50.4**	**11.3**	**4.6**	**12.1**	**10.3**	**2.2**	**16.0**	**10.9**	**5.0**	**41.4**
CV (%)	**5.6**	**5.8**	**6.4**	**18.3**	**37.0**	**18.0**	**4.2**	**7.0**	**7.3**	**15.9**	**19.9**	**19.9**	**7.6**	**11.7**	**6.9**	**9.4**	**8.4**	**10.2**	**7.8**	**10.4**	**13.4**

Table: 5.5.5 Residue management in RBCS
Nutrient use efficiency (kg grain/kg uptake) (*Kharif* 2021)

Treatment	FZD			KRK			KHD			MTU			PDU			PSA			IIRR		
	N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**
100% RDF (NPK)	36.8	79.0	62.9	44.8	240	14.8	39.4	142	31.8	65.7	126	36.0	52.5	197	43.1	55.0	232	40.2	51.8	185	24.5
50% residue + 50% RDF	39.4	88.1	69.4	35.3	288	12.5	42.4	166	32.6	67.1	128	35.6	53.3	209	44.8	57.8	242	41.4	62.9	186	25.6
50% residue + 50% RDF + PD	40.3	87.0	67.8	43.5	214	11.4	44.0	170	34.9	64.9	179	37.3	49.0	178	41.4	56.8	239	40.9	55.0	160	22.0
Rice residue (50% N) + 50% N GM/GLM	37.6	83.8	65.9	41.4	223	12.0	43.8	198	33.4	62.1	143	24.0	54.0	221	44.5	59.4	249	41.9	61.6	174	36.4
Residue (50% N) + 50% N GM/GLM + PD	40.3	87.7	70.2	36.7	312	13.1	47.0	210	39.4	64.5	167	27.7	50.6	180	42.6	57.8	244	41.5	58.9	165	27.4
Residue (2.5 t/ha) + PD	44.6	95.7	72.4	47.7	182	12.3	47.2	207	36.0	61.6	161	29.0	57.2	233	53.1	62.6	251	41.8	53.7	153	21.8
Residue (2.5 t/ha)	40.6	84.1	67.1	51.4	154	12.1	49.0	242	38.6	64.0	142	38.7	62.1	249	55.6	61.7	259	42.2	58.2	162	30.6
Absolute Control	50.2	104	77.4	45.6	282	15.0	53.0	290	41.3	66.8	160	52.4	68.0	262	57.1	63.4	257	42.7	55.7	160	28.4
Expt. Mean	**41.2**	**88.7**	**69.1**	**43.3**	**237.2**	**12.9**	**45.7**	**203.4**	**36.0**	**64.6**	**150.7**	**35.1**	**55.8**	**216.3**	**47.8**	**55.8**	**216.3**	**47.8**	**57.2**	**168.3**	**27.1**
CD (0.05)	**1.3**	**3.7**	**3.7**	**NS**	**NS**	**NS**	**2.6**	**31.7**	**5.9**	**NS**	**NS**	**13.9**	**7.2**	**36.0**	**6.4**	**4.2**	**13.6**	**NS**	**NS**	**NS**	**NS**
CV (%)	**1.8**	**2.4**	**3.0**	**16.8**	**50.5**	**25.8**	**3.2**	**8.9**	**9.3**	**15.5**	**17.8**	**22.6**	**7.4**	**9.5**	**7.7**	**7.4**	**9.5**	**7.7**	**9.1**	**10.7**	**20.8**

Table: 5.5.6 Residue management in RBCS
Post-harvest nutrient of soil soils (kg/ha) (*Kharif* 2021)

Treatment	MTU			PDU			PSA			IIRR		
	N	P	K	N	P	K	N	P	K	N	P	K
100% RDF (NPK)	153	63.5	289	151	36.4	119	261	26.7	228	137	31.3	635
50% residue + 50% RDF	136	63.4	304	153	36.7	121	257	24.1	222	121	29.1	593
50% residue + 50% RDF + PD	153	65.2	293	164	35.8	124	256	25.5	225	158	28.9	718
Rice residue (50% N) + 50% N GM/GLM	108	66.9	286	156	36.9	132	250	21.8	214	158	29.9	759
Residue (50% N) + 50% N GM/GLM + PD	138	62.0	299	167	37.9	128	246	23.0	217	173	31.6	695
Residue (2.5 t/ha) + PD	141	62.5	282	150	36.2	116	243	20.2	213	167	35.4	742
Residue (2.5 t/ha)	132	62.8	290	149	35.6	118	241	19.6	210	127	40.0	671
Absolute Control	152	61.0	309	138	30.9	108	239	18.9	209	110	30.5	706
Expt. Mean	**139.1**	**63.4**	**294.1**	**153.7**	**35.8**	**120.7**	**249.2**	**22.5**	**217.5**	**143.8**	**32.1**	**690.2**
CD (0.05)	**NS**	**NS**	**16.6**	**NS**	**NS**	**13.9**	**NS**	**3.0**	**NS**	**24.6**	**5.7**	**NS**
CV (%)	**16.3**	**6.6**	**3.2**	**8.5**	**9.7**	**6.6**	**4.5**	**7.7**	**6.1**	**9.8**	**10.2**	**8.8**

5.6 Screening of rice germplasm for Nitrogen use efficiency (NUE)

Among the essential nutrients, nitrogen (N) is the major element which is required in large quantities by rice. The most limiting nutrient in irrigated rice is nitrogen and N recovery efficiency is only about 25-40% of applied N in most farmers' fields and N is mostly lost by leaching, gaseous loss through volatilization and surface run off. In the current scenario, consumption of N fertilizer is in linear trend, but its use efficiency is low in most of the production systems. Nitrogen use efficiency depends not only on the efficient fertilizer management, but also on the cultivar that is used. Genetic variation in nitrogen use efficiency in rice was widely studied by many researchers in the different ecosystems. Keeping this in view, the present trial was formulated to evaluate the nitrogen use efficiency (NUE) of a few popular rice varieties in addition to the varieties developed for high NUE. During third year, same 10 entries as in previous year were tested across 7 locations *viz*., Karaikal (KRK), Maruteru (MTU), Pantnagar (PNT), Purulia (PUR), Pusa (PSA), Faizabad (FZB) and Titabar (TTB) with three nitrogen levels control (no nitrogen application), 50 and 100% of recommended dose of N). The details of crop, soil and weather parameters of the experimental sites (Table 5.6.1) show variation in soil characteristics with reference to pH, organic carbon content, soil texture and available nutrient status. The experimental results are presented in Tables 5.6.1 to 5.6.6 and discussed below.

Yield and yield parameters

At Pantnagar (PNT), there was a gradual response up to 100% RDN in case of all varieties which responded significantly at 100% RDN (5.70 t/ha) over 50% RDN (4.75 t/ha) and control (2.71 t/ha). Among the varieties, except CNN1 (4.14 t/ha) and Rasi (4.25 t/ha), all other varieties performed at par with each other (Table no. 5.6.2).

Grain yields at Pusa, varied from 2.00 t/ha at control to 5.91 t/ha at 100% RDN. Application of 100% RDN recorded significantly higher grain yields than control and 50% RDN by 71 and 25%, respectively. Among the varieties, Varadhan (4.83 t/ha) and MTU -1010 (4.73 t/ha) were at par with each other and significantly superior to all other varieties. The lowest yield levels were reported in the variety CNN-2 (2.86 t/ha).

At Purulia, application of nitrogen recorded significantly higher grain yields than zero nitrogen application. Among the varieties, ARRH 7576 (5.56 t/ha) recorded significantly higher grain yields compared to rest of the varieties.

In case of Maruteru (MTU), during *Kharif*, 100% RDN recorded significantly higher yields than control and 50% RDN by 46 and 10%, respectively. Among the varieties, except CNN3 (3.57 t/ha) and Rasi (3.84 t/ha), all other varieties performed at par with each other with respect to grain yield.

During *Rabi* in Maruteru, there was a gradual response up to 100% RDN in case of all varieties that responded significantly at 100% RDN (6.73 t/ha) over 50% RDN (4.80 t/ha) and control (2.64 t/ha). Among the varieties, CNN -5 (5.43 t/ha) recorded significantly superior grain yields compared to rest of the varieties (Table no. 5.6.2). The lowest yield levels were reported in the variety CNN-1 (4.61 t/ha).

At Titabar (TTB), poor grain yields were observed compared to other centers ranging from 2.82 t/ha at control to 3.86 t/ha at 100% RDN. Application of 100% RDN recorded significantly higher grain yields than control and 50% RDN by 36 %. Among the varieties, ARRH 7576 (3.98t/ha) recorded significantly higher grain yields compared to rest of the varieties. The lowest yield levels were reported in the variety Rasi (2.53 t/ha).

At Karaikal (KRK), due to severe leaf folder infestation yield could not be recorded at 50% RDN and 100% RDN levels. In control, among the varieties, CNN3 (5.00 t/ha) recorded maximum yield and the varieties, except ARRH -7576 and MTU 1010, all other were on par with CNN5.

At Faizabad, (FZD) also, 100% RDN recorded significantly higher yield than control and 50% RDN by 73 and 27 %, respectively. Among the varieties, ARRH 7576 (4.45 t/ha) recorded significantly higher grain yields compared to rest of the varieties. The lowest yield levels were reported in the variety CNN 1 (3.05 t/ha).

Averaged over six locations, pooled over varieties, the mean yield data at different N levels indicated an increase at 100% RDN (5.02 t/ha) over 50% RDN (4.12 t/ha) and control (2.78 t/ha) to an extent of 22 and 80%, respectively. Among the varieties, pooled over three N levels, mean maximum yield across six locations was recorded by ARRH7576 (4.34 t/ha) followed by Varadhan (4.32 t/ha), CNN5 (4.30 t/ha), CNN3 (4.14 t/ha). Mean minimum yields were recorded in Rasi (3.52 t/ha).

Straw yields followed almost a similar trend as that of grain yields at all locations (Table no. 5.6.2). The mean straw yield (pooled) indicated an increase at 100% RDN (7.11 t/ha) over 50% RDN (5.42 t/ha) and control (3.78 t/ha) to an extent of 31 and 88%, respectively. Among the varieties, pooled over three N levels, mean maximum straw yields across six locations were recorded by CNN5

(6.17 t/ha) followed by CNN 3 (6.15 t/ha), Varadhan (6.08 t/ha) and ARRH7576 (5.97 t/ha). Mean minimum straw yields were recorded in Rasi (5.31 t/ha).

Application of different doses of nitrogen did not influence the tillers and panicle number at all locations except Pusa, Faizabad and panicles/m^2 in *Kharif* Maruteru where application of nitrogen dose had a significant influence on tiller and panicle number compared to zero nitrogen application (Table no. 5.6.3). Among the varieties, CNN 5, CNN 1, MTU 1010 and TI 93 recorded maximum number in most of the locations.

Nutrient uptake

Total nutrient uptake (Table 5.6.4) also followed the similar trend as that of grain yield trend in most of the locations. Nitrogen uptake ranges from 31.8 kg/ha–186 kg/ha, phosphorus uptake ranges from 5.78 – 78.9 kg/ha while potassium uptake ranges from 21.6 kg/ha-231 kg/ha across the locations. Total nitrogen uptake was maximum at 100% RDN at all locations ranging from 44.2 - 186 kg/ha while nitrogen uptake in control and 50% RDN ranged from 31.8 – 97.9 kg/ha, 41.6 – 148 kg/ha respectively. Among the centers, Titabar with low yields recorded lowest N uptake and Maruteru recorded highest total N uptake than other centers. Among the varieties, Varadhan, MTU1010, TI 93 recorded maximum uptake values at most of the locations.

Post-harvest soil properties

The available nutrient status (N, P and K), pH and organic carbon of Karaikal and Pantnagar soils are presented in Table 5.6.5. The data reveals that except soil available potassium at Karaikal, other soil properties were not influenced much by varietal differences and nitrogen application**.**

Nutrient use efficiency indices

Nitrogen use efficiency indices such as, Agronomic efficiency (AE), Physiological efficiency (PE), Recovery efficiency (RE) were computed using grain yield and N uptake values and presented in Table 5.6.6. Averaged over five locations, among the varieties, pooled over three N levels, mean maximum Agronomic efficiency recorded by ARRH7576 (26.3), Rasi (23.5), MTU 1010 (23.4); mean maximum physiological efficiency recorded by ARRH7576 (38.6), CNN1 (31.7), CNN4 (31.0); mean maximum recovery efficiency recorded by Varadhan (135), CNN3 (134) and MTU 1010 (128).

Summary

In the third year of study on "Screening of rice germplasm for NUE", ten genotypes were evaluated at three nitrogen levels (0, 50 and 100% of recommended N) at seven locations. The results indicated that grain yield was significantly higher at 100% RDN and the increase was in the range of 9-40 % over 50% RDN and 13-110% over no N application. Among the varieties, pooled over three N levels, mean maximum yield across six locations was recorded by ARRH7576 (4.34 t/ha) followed by Varadhan (4.32 t/ha), CNN5 (4.30 t/ha), CNN3 (4.14 t/ha). Yield parameters and nutrient uptake almost followed similar trend as that of grain yield. Mean maximum Agronomic efficiency recorded by ARRH7576 (26.3), Rasi (23.5), MTU 1010 (23.4); mean maximum physiological efficiency recorded by ARRH7576 (38.6), CNN1 (31.7), CNN4 (31.0); mean maximum recovery efficiency recorded by Varadhan (135), CNN3 (134) and MTU 1010 (128).

Table 5.6.1: Screening of rice germplasm for nitrogen use efficiency (NUE), *Kharif*-2021, Soil and crop characteristics

Parameter	TTB [1]	PUR [2]	KRK [3]	MTU-R [4]	MTU-K [4]	PNT [5]	PSA [6]	FZB [7]
Cropping system	Rice-Rice	Rice-Rice	Rice-Rice	Rice-Rice	Rice –Rice	Rice-Wheat	Rice-Wheat	Rice – Rice
RDF (Kg NPK/ha)	60:20:40	70:35:35	150:50:50	90:60:60	180: 90: 60	120:60:30	120:60:40	120:60:60
Soil characteristics								
% clay	-	-	17.4	40	36	25.9	14.9	-
% silt	-		2.0	27	28	61.4	26.2	-
% sand	-		82.76	33	36	12.9	58.2	-
Soil Texture	-		Sandy loam	Clay loam	Clay	Silty clay loam	Sandy loam	-
pH (1:2.5)	5.6		7.36	5.85	0.86	7.5	8.56	7.6
Org. carbon (%)	1.15		0.344	1.15	44.6	0.66	0.6	1.02
CEC [c mol (p+)/kg]	-		8.2	47.6	0.65	23.1	-	0.40
EC (dS/m)	-		0.113	0.79	211	0.35	0.52	-
Avail.N (kg/ha)	425		185	183	68.2	154	190	218
Avail. P_2O_5	18		18.7	62.3	3.6	10.2	39	25
Avail. K_2O	152		119.8	320	16.3	200	209	235
Avail. S	18		16.3	12.5	4.8	20.0	-	-
DTPA –Zn	0.85	-	-	4.0	14.3	0.69	-	-
DTPA –Fe	-	-	-	8.6	12.5	120	-	-
DTPA –Mn (mg/kg)	-	-	-	12.3	1.8	21.6	-	-
DTPA –Cu (mg/kg)	-	-	-	1.2	0.86	6.7	-	-

Table 5.6.2: Screening of rice germplasm for nitrogen use efficiency (NUE), *Kharif*-2021, Grain and Straw yields of rice.

Variety / N levels	Pantnagar								Pusa								Purulia			
	Grain yield (t/ha)				Straw Yield (t/ha)				Grain yield (t/ha)				Straw Yield (t/ha)				Grain yield (t/ha)			
	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean
CNN 1	2.30	4.55	5.58	4.14	2.67	5.13	5.93	4.58	2.56	3.65	5.05	3.75	2.97	4.28	6.14	4.46	3.22	4.22	4.44	3.96
CNN 2	2.68	4.71	5.78	4.39	2.99	4.98	5.92	4.63	2.14	2.74	3.69	2.86	2.51	3.25	4.51	3.43	3.83	4.33	5.00	4.39
CNN 3	2.63	4.70	5.93	4.42	3.18	5.28	5.85	4.77	2.67	3.71	4.74	3.71	3.09	4.43	5.67	4.39	3.06	4.56	5.00	4.20
CNN 4	2.75	4.82	5.82	4.46	2.85	5.30	6.02	4.72	2.79	3.65	4.03	3.49	3.10	4.31	5.74	4.38	3.39	4.44	4.00	3.94
CNN 5	2.88	4.64	5.78	4.43	2.71	5.28	5.78	4.59	3.05	4.28	5.55	4.29	3.52	5.31	6.65	5.16	3.11	3.56	3.50	3.39
ARRH7576	2.79	4.97	5.73	4.50	2.82	5.27	6.02	4.70	3.61	4.48	5.38	4.49	4.15	5.14	6.43	5.24	5.49	6.10	5.10	5.56
Rasi	2.53	4.66	5.57	4.25	3.13	5.35	6.01	4.83	2.00	2.95	3.70	2.88	2.57	3.53	4.47	3.52	2.83	3.05	3.17	3.02
Varadhan	2.89	4.83	5.85	4.52	2.98	5.27	6.01	4.76	3.70	4.91	5.89	4.83	4.18	5.67	7.01	5.62	4.17	4.39	3.94	4.17
MTU 1010	2.78	4.83	5.67	4.43	2.95	5.27	6.08	4.77	3.47	4.82	5.91	4.73	3.73	5.87	7.18	5.59	3.48	3.72	3.37	3.52
TI-93	2.87	4.81	5.30	4.32	2.86	5.23	5.93	4.68	2.44	3.82	4.88	3.72	2.84	4.62	5.91	4.46	2.88	3.15	2.67	2.90
Mean	2.71	4.75	5.70	4.39	2.91	5.24	5.96	4.70	2.84	3.90	4.88	3.88	3.27	4.64	5.97	4.63	3.55	4.15	4.02	3.91
CD -M (p= 0.05)	0.06				0.15				0.19				0.17				0.20			
CD- S (p= 0.05)	0.19				0.16				0.38				0.30				0.27			
M X S	NS				NS				NS				0.52				NS			
S XM	NS				NS				NS				0.81				NS			
CV (%) M	3.2				6.91				10.9				8.19				11.11			
CV (%) S	4.68				3.69				10.32				6.99				7.39			

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/1705.

Contd.

Variety / N levels	**Maruteru**															
	Kharif								***Rabi***							
	Grain yield (t/ha)				**Straw Yield (t/ha)**				**Grain yield (t/ha)**				**Straw Yield (t/ha)**			
	0% RDN	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**
CNN 1	3.63	5.19	5.60	4.81	4.91	7.59	9.54	7.35	2.71	4.49	6.63	4.61	3.17	5.10	7.01	5.09
CNN 2	3.72	4.93	5.07	4.57	3.86	6.61	9.51	6.66	3.36	4.58	6.70	4.88	3.73	5.50	7.36	5.53
CNN 3	2.88	3.68	4.15	3.57	4.54	7.09	9.42	7.02	2.89	5.21	6.54	4.88	3.58	5.34	7.19	5.37
CNN 4	3.91	4.21	4.45	4.19	3.69	5.47	10.03	6.40	2.57	5.11	6.80	4.83	3.00	5.36	7.40	5.25
CNN 5	3.91	5.14	5.81	4.95	3.94	7.94	10.41	7.43	3.20	5.63	7.44	5.43	3.70	5.81	7.73	5.74
ARRH7576	2.47	4.90	5.21	4.19	4.00	7.68	11.13	7.60	2.22	4.83	6.39	4.48	3.55	5.03	6.96	5.18
Rasi	2.60	4.34	4.58	3.84	3.98	6.12	8.01	6.03	2.45	4.65	6.80	4.64	3.62	4.96	7.50	5.36
Varadhan	4.16	4.70	5.63	4.83	4.25	6.41	10.65	7.10	2.28	4.59	6.62	4.50	2.91	5.26	7.46	5.21
MTU 1010	3.67	4.71	5.83	4.74	4.49	7.89	9.66	7.35	2.24	4.48	6.80	4.50	3.05	4.72	7.57	5.11
TI 93	4.27	4.84	5.11	4.74	5.17	7.23	9.93	7.44	2.51	4.43	6.53	4.49	3.43	5.23	7.28	5.31
Mean	3.52	4.66	5.14	4.44	4.28	7.00	9.83	7.03	2.64	4.80	6.73	4.72	3.37	5.23	7.35	5.32
CD (p= 0.05) M	0.37				0.59				0.18				0.23			
CD (p= 0.05) S	0.91				NS				0.31				0.33			
M X S	NS				NS				0.53				NS			
S XM	NS				NS				0.52				NS			
CV (%) M	18.1				18.3				8.43				9.33			
CV (%) S	21.7				20.9				6.89				6.52			

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/1705

Contd…

Variety / N levels	Titabar								Faizabad								Karaikal	
	Grain yield (t/ha)				Straw Yield (t/ha)				Grain yield (t/ha)				Straw Yield (t/ha)				Grain yield (t/ha)	Straw Yield (t/ha)
	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	0% RDN
CNN 1	2.15	2.60	4.43	3.06	3.85	4.65	7.93	5.48	2.13	3.02	3.99	3.05	2.96	4.18	5.39	4.18	4.17	7.81
CNN 2	2.77	2.85	3.47	3.03	4.88	4.80	6.20	5.29	-	-	-	-	-	-	-	-	4.72	8.85
CNN 3	2.77	3.08	3.80	3.22	5.05	6.00	6.80	5.95	-	-	-	-	-	-	-	-	5.00	9.38
CNN 4	2.53	3.02	3.83	3.13	4.53	5.40	6.90	5.61	2.76	3.70	4.66	3.71	3.92	5.13	6.34	5.13	4.58	8.59
CNN 5	2.80	3.13	3.72	3.22	5.05	5.63	6.68	5.79	2.77	3.74	4.88	3.79	3.76	5.22	6.67	5.22	4.44	8.33
ARRH7576	4.28	2.93	4.73	3.98	7.27	5.40	8.61	7.09	3.35	4.49	5.50	4.45	4.66	6.18	7.48	6.10	3.19	5.99
Rasi	2.25	2.63	2.70	2.53	4.03	4.72	4.91	4.55	3.08	4.16	5.27	4.17	4.27	5.78	7.08	5.71	4.03	7.55
Varadhan	2.73	2.53	2.93	2.73	4.93	4.57	5.34	4.95	-	-	-	-	-	-	-	-	4.72	8.85
MTU 1010	3.43	3.03	4.50	3.66	6.17	5.70	8.19	6.69	2.64	3.73	4.79	3.72	3.59	5.06	6.39	5.01	3.19	5.99
TI 93	2.47	2.48	4.48	3.14	4.00	4.38	8.16	5.51	-	-	-	-	-	-	-	-	4.72	8.85
Mean	2.82	2.83	3.86	3.17	4.98	5.13	6.97	5.69	2.79	3.81	4.85	3.81	3.86	5.26	6.56	5.22	4.28	8.02
CD (p= 0.05) M	0.09				0.13				0.02				0.11				-	-
CD (p= 0.05) S	0.27				0.53				0.18				0.28				1.14	2.14
M X S	0.46				0.92				NS				NS				-	-
S XM	0.44				0.88				NS				NS				-	-
CV (%) M	5.86				4.83				1.01				3.61				-	-
CV (%) S	9.02				9.96				5.01				5.56				15.4	15.4

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252, BV/RIL/1705.

Table 5.6.3: Screening of rice germplasm for nitrogen use efficiency (NUE), *Kharif*-2021, yield parameters of rice.

Variety / N levels	Pantnagar								TTB							
	Tillers/m^2				Panicles/m^2				Tillers/m^2				Panicles/m^2			
	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean
CNN 1	165	162	167	164	127	118	132	126	300	283	208	264	223	258	192	225
CNN 2	177	165	162	168	137	118	123	126	225	267	325	272	181	216	226	208
CNN 3	180	160	158	166	127	127	128	127	208	283	317	269	156	240	263	220
CNN 4	173	177	150	167	130	115	120	122	292	308	325	308	254	261	252	256
CNN 5	170	163	135	156	135	120	123	126	308	375	308	331	200	258	215	224
ARRH7576	163	170	138	157	127	118	128	124	292	367	250	303	219	250	229	233
Rasi	170	160	123	151	132	115	125	124	275	283	300	286	212	233	231	225
Varadhan	170	152	137	153	130	133	118	127	200	283	308	264	153	230	227	203
MTU- 1010	160	155	155	157	125	133	125	128	267	342	358	322	242	277	233	251
TI-93	163	147	157	156	133	130	142	135	367	367	300	344	282	267	236	261
Mean	169	161	148	159	130	123	127	127	273	316	300	296	212	249	230	231
CD (p= 0.05) M	NS				NS				NS				NS			
CD (p= 0.05) S	NS				NS				NS				36.34			
M X S	NS				NS				NS				NS			
S XM	NS				NS				NS				NS			
CV (%) M	16.22				11.64				25.08				31.12			
CV (%) S	8.22				11.33				22.57				16.71			

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/1705

Contd.

Variety / N levels	**Maruteru**															
	Kharif								***Rabi***							
	Tillers/m²				**Panicles/m²**				**Tillers/m²**				**Panicles/m²**			
	0% RDN	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**
CNN 1	317	326	344	329	287	279	310	292	474	482	530	495	410	408	457	425
CNN 2	305	321	316	314	269	284	285	280	365	474	427	422	302	403	357	354
CNN 3	283	315	294	297	260	301	263	275	466	441	433	447	397	370	364	377
CNN 4	256	294	309	287	234	285	281	266	397	415	447	420	330	347	376	351
CNN 5	285	292	295	290	258	281	263	268	501	528	434	488	429	453	364	415
ARRH7576	290	301	299	297	263	282	273	273	351	449	434	411	291	373	360	342
Rasi	269	301	313	294	238	294	284	272	402	458	429	430	333	388	361	361
Varadhan	267	331	327	308	238	337	297	291	376	485	427	429	312	413	354	360
MTU 1010	298	283	348	310	250	273	283	269	395	479	373	416	324	408	309	347
TI 93	321	324	331	325	287	295	295	292	376	448	419	414	314	381	351	348
Mean	289	309	318	305	258	291	283	278	410	466	435	437	344	394	365	368
CD M (p= 0.05)	NS				13.79				NS				NS			
CD S (p= 0.05)	NS				NS				54				49			
M X S	NS				NS				NS				NS			
S XM	NS				NS				NS				NS			
CV (%) M	17.23				10.83				39				43			
CV (%) S	14.27				14.02				13				14			

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/1705

Contd

Variety / N levels	PUSA								Faizabad								Karaikal	
	Tillers/m^2				Panicles/m^2				Tillers/m^2				Panicles/m2				Tillers/m^2	Panicles/m^2
	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	0% RDN
CNN 1	182	246	321	250	96	112	124	111	189	228	189	228	182	223	283	229	276	256
CNN 2	164	218	237	207	83	98	106	96	-	-	-	-	-	-	-	-	255	242
CNN 3	203	264	317	261	92	107	119	106	-	-	-	-	-	-	-	-	245	232
CNN 4	221	241	261	24	90	113	126	109	242	281	242	281	235	275	293	268	259	243
CNN 5	217	235	311	254	98	120	133	117	245	280	245	280	238	275	293	269	309	292
ARRH7576	232	251	271	251	111	135	149	132	271	291	271	291	266	286	300	284	260	243
Rasi	153	224	227	201	79	84	92	85	258	282	258	282	253	277	299	276	275	261
Varadhan	248	267	321	279	115	140	152	135	-	-	-	-	-	-	-	-	261	249
MTU 1010	224	243	285	251	108	131	146	128	246	280	246	280	240	274	287	287	267	253
TI 93	167	219	227	204	100	119	140	120	-	-	-	-	-	-	-	-	247	235
Mean	201	241	278	240	97.3	116	129	114	242	274	242	274	236	268	292	265	265	251
CD (p= 0.05) M	6.1				3				2				2				-	-
CD (p= 0.05) S	21.4				6				8				NS				NS	NS
M X S	37.1				NS				13				13				-	-
S XM	35.4				NS				12				12				-	-
CV (%) M	5.5				5				1				2				-	-
CV (%) S	9.5				6				3				3				12.3	11.9

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/1705

Table 5.6.4: Screening of rice germplasm for nitrogen use efficiency (NUE), nutrient uptake (kg/ha)

Variety / N levels	MTU-*Rabi*											
	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean
CNN 1	37	77	117	77	22	26	39	29	65	91	75	77
CNN 2	52	83	115	84	21	24	40	28	56	82	116	85
CNN 3	41	86	121	83	18	25	38	27	77	74	130	94
CNN 4	41	74	123	79	17	27	36	27	52	74	126	84
CNN 5	39	71	129	80	18	29	33	27	62	95	98	85
ARRH7576	39	65	109	71	14	27	36	26	34	61	114	70
Rasi	38	76	135	83	20	27	44	30	32	55	127	71
Varadhan	40	84	151	92	19	29	42	30	22	76	119	72
MTU 1010		87	160	93	12	30	41	28	51	65	128	81
TI 93	41	71	133	81	19	25	38	28	45	57	124	75
Mean	40	78	129	82	18	27	39	28	50	73	116	79
CD (p= 0.05) M	9.31				3.16				2.61			
CD (p= 0.05) S	NS				NS				7.37			
M X S	NS				NS				12.77			
S XM	NS				NS				12.22			
CV (%) M	24,67				24.61				7.19			
CV (%) S	42.62				19.95				9.86			

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/170

Variety / N levels	MTU-*Kharif*											
	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean
CNN 1	53	129	146	109	35	35	46	39	101	135	95	110
CNN 2	64	122	147	111	24	34	41	33	59	96	155	103
CNN 3	54	93	143	96	20	30	37	29	97	91	164	117
CNN 4	60	93	122	92	25	31	38	31	66	72	185	108
CNN 5	52	99	123	91	20	33	33	28	66	122	119	103
ARRH7576	49	97	140	95	14	37	48	33	37	84	177	99
Rasi	55	117	139	104	23	36	40	33	33	63	129	75
Varadhan	86	112	186	128	32	40	50	40	27	90	165	94
MTU 1010	56	148	169	125	15	42	50	35	75	101	157	111
TI 93	97	117	158	124	31	34	44	36	67	72	161	100
Mean	62	113	147	108	24	35	43	34	63	93	151	102
CD (p= 0.05) M	10.19				2.56				7.7			
CD (p= 0.05) S	17.08				5.42				19.93			
M X S	NS				9.4				34.52			
S XM	NS				9.05				33.07			
CV (%) M	20.67				16.51				16.44			
CV (%) S	16.85				16.99				20.7			

Contd.

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/170

Variety / N levels	Pantnagar											
	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean
CNN 1	53	95	116	88	6	13	17	12	34	68	100	67
CNN 2	58	92	118	89	8	14	20	14	40	69	99	69
CNN 3	56	104	116	92	8	16	19	14	41	67	90	66
CNN 4	59	97	118	91	8	14	18	13	38	69	88	65
CNN 5	59	103	117	93	8	13	19	13	34	63	92	63
ARRH7576	56	104	120	93	9	16	22	15	37	71	95	68
Rasi	58	100	118	92	7	13	18	13	44	72	91	69
Varadhan	60	103	122	95	10	15	19	14	38	62	102	68
MTU 1010	58	98	122	92	9	14	18	14	34	71	93	66
TI 93	62	102	120	94	9	29	19	19	40	81	96	72
Mean	58	100	118	92	8	16	19	14	38	69	95	67
CD (p= 0.05) M	2.55				2.62				2.6			
CD (p= 0.05) S	NS				NS				NS			
M X S	NS				NS				NS			
S XM	NS				NS				NS			
CV (%) M	6.04				40.26				8.43			
CV (%) S	5.79				33.81				11.63			

Contd.

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/17

Contd

Variety / N levels	Karaikal			Pusa				Titabar			
	Control			N uptake (kg/ha)				N uptake (kg/ha)			
	N uptake	P uptake	K uptake	0% RDN	50% RDN	100% RDN	Mean	0% RDN	50% RDN	100% RDN	Mean
CNN 1	60	27	179	40	64	96	66	32	46	80	53
CNN 2	82	44	196	34	49	71	51	44	49	67	53
CNN 3	72	39	205	43	67	92	67	44	49	75	56
CNN 4	80	37	194	45	66	83	65	42	54	80	59
CNN 5	86	35	191	46	73	102	74	44	53	74	57
ARRH7576	56	29	131	51	74	99	75	58	55	94	69
Rasi	87	25	170	49	82	113	81	37	50	56	47
Varadhan	98	26	198	56	82	112	83	45	48	61	51
MTU 1010	48	17	131	35	55	75	55	58	55	95	70
TI 93	74	31	196	41	70	97	69	40	42	93	58
Mean	74	31	179	44	68	94	69	44	50	77	57
CD (p= 0.05) M	-	-	-	2.79				1.12			
CD (p= 0.05) S	24.4	NS	50.1	5.61				5.17			
M X S	-	-	-	9.72				8.95			
S XM	-	-	-	9.38				8.52			
CV (%) M	-	-	-	8.87				4.26			
CV (%) S	18.9	30.8	16.2	8.67				9.57			

M – Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/1

Contd.

Variety / N levels	**Faizabad**											
	N uptake (kg/ha)				**P uptake (kg/ha)**				**K uptake (kg/ha)**			
	0% RDN	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**	**0% RDN**	**50% RDN**	**100% RDN**	**Mean**
CNN 1	40	65	92	65	13	22	34	23	23	39	58	40
CNN 4	57	82	114	85	20	31	45	32	37	56	82	58
CNN 5	53	81	123	85	19	31	51	33	31	50	78	53
ARRH7576	69	105	156	110	30	49	79	53	48	79	109	78
Rasi	62	92	134	96	27	41	59	42	42	61	86	63
MTU 1010	54	85	118	86	19	33	52	35	33	54	82	56
Mean	56	85	123	88	53	35	21	36	35	56	82	58
CD (p= 0.05) M	1.6				0.9				1.2			
CD (p= 0.05) S	6.3				3.8				5.3			
M X S	10.3				6.5				NS			
S XM	9.9				6.0				NS			
CV (%) M	3.0				4.2				3.4			
CV (%) S	7.4				10.8				9.4			

Main plot (nitrogen levels), S – Subplot (varieties)

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/170

Table 5.6.5: Screening of rice germplasm for nitrogen use efficiency (NUE), *Kharif*-2021, post-harvest soil properties

Variety / N levels	Karaikal						
	pH	EC (dS/m)	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available S (kg/ha)
Treatments							
0% RDN	6.16	0.08	0.45	157	20	193	38
50% RDN	6.35	0.06	0.30	142	18	180	36
100% RDN	6.34	0.06	0.35	151	21	181	39
CD (0.05)	NS	NS	0.03	NS	NS	NS	NS
CV (%)	7.34	62.12	18.71	15.6	80.22	25.5	34.39
Varieties							
CNN 1	6.45	0.06	0.37	121	16	192	55
CNN 2	6.4	0.08	0.41	131	19	173	35
CNN 3	6.23	0.06	0.41	139	19	176	41
CNN 4	6.14	0.05	0.29	140	21	176	31
CNN 5	6.44	0.05	0.31	137	19	190	30
ARRH7576	6.04	0.06	0.37	219	30	173	44
Rasi	6.06	0.12	0.43	159	18	183	35
Varadhan	6.21	0.07	0.37	166	18	196	34
MTU 1010	6.42	0.07	0.35	143	20	190	36
TI 93	6.44	0.08	0.35	149	18	196	38
CD (0.05)	0.25	NS	NS	36	6	15	12
CV (%)	4.23	76.64	32.23	26	34	8	34
Interaction							
M X S	NS	NS	NS	NS	NS	25.3	NS
S XM	NS	NS	NS	NS	NS	27.9	NS
Mean	6.28	0.07	0.37	150.3	19.75	184.5	37.68

Contd.

Variety / N levels	Pantnagar							
	pH	EC (dS/m)	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Soil DTPA-Zn (mg/kg)	Soil DTPA-Fe (mg/kg)
Treatments								
0% RDN	7.47	0.38	0.59	177	10.7	193	0.51	132
50% RDN	7.44	0.37	0.59	192	9.5	204	0.58	122
100% RDN	7.55	0.35	0.59	255	13.4	207	0.53	120
CD (0.05)	NS	NS	NS	NS	0.95	NS	NS	NS
CV (%)	5.52	34.69	37.04	76.9	18.56	16.6	20.75	17.3
Varieties								
CNN 1	7.34	0.35	0.59	180	11.39	206	0.55	122
CNN 2	7.5	0.37	0.61	187	11.67	202	0.55	122
CNN 3	7.62	0.37	0.58	186	11.4	197	0.52	124
CNN 4	7.57	0.37	0.59	194	11.19	203	0.53	124
CNN 5	7.51	0.41	0.58	189	10.93	202	0.52	124
ARRH7576	7.44	0.36	0.58	193	11.13	201	0.54	127
Rasi	7.48	0.38	0.57	383	11.07	200	0.53	127
Varadhan	7.36	0.34	0.65	190	10.8	195	0.58	130
MTU 1010	7.53	0.38	0.58	193	11.21	200	0.54	122
TI 93	7.48	0.35	0.58	187	11.33	205	0.54	124
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	2.66	25.66	12.2	87.0	7.92	5.9	16.24	7.2
Interaction								
M X S	NS	NS	NS	NS	NS	NS	NS	NS
S XM	NS	NS	NS	NS	NS	NS	NS	NS
Mean	7.48	0.37	0.59	208.4	11.21	201.2	0.54	124.8

Table 5.6.5: Screening of rice germplasm for nitrogen use efficiency (NUE) indices

Variety / N levels	Pantnagar						Pusa						Maruteru (K)					
	AE		PE		RE		AE		PE		RE		AE		PE		RE	
	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN
CNN 1	37	27	54	53	70	52	18	21	45	44	40	47	35	22	21	21	168	103
CNN 2	34	26	59	52	57	50	10	13	43	42	23	31	27	15	21	16	128	92
CNN 3	34	27	44	55	79	50	17	17	44	42	40	41	18	14	20	14	88	99
CNN 4	34	26	55	52	63	49	14	10	40	32	36	32	7	6	9	9	74	70
CNN 5	29	24	40	49	74	49	21	21	45	45	46	47	27	21	26	27	105	79
ARRH7576	36	24	46	46	79	53	15	15	39	37	38	40	54	30	50	30	107	101
Rasi	35	25	51	51	70	50	16	14	29	27	55	53	39	22	28	24	138	94
Varadhan	32	25	45	48	72	52	20	18	46	39	44	47	12	16	20	15	59	112
MTU 1010	34	24	51	45	67	53	23	20	66	60	34	34	23	24	11	19	204	125
TI 93	32	20	48	42	68	48	23	20	47	44	49	47	13	9	29	14	44	68

Contd.

Variety / N levels	Maruteru (R)						Faizabad					
	AE		PE		RE		AE		PE		RE	
	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN	50% RDN	100% RDN
CNN 1	20	22	45	49	44	45	15	15	36	35	42	44
CNN 2	14	19	39	53	35	35	-	-	-	-	-	-
CNN 3	26	20	51	45	51	45	-	-	-	-	-	-
CNN 4	28	24	76	52	37	46	16	16	37	34	42	47
CNN 5	27	24	75	47	36	50	16	18	35	30	46	58
ARRH7576	29	23	98	60	30	39	19	18	31	25	61	73
Rasi	24	24	59	45	42	54	18	18	35	30	51	60
Varadhan	26	24	53	39	49	62	-	-	-	-	-	-
MTU 1010	25	25	42	36	59	70	18	18	35	34	51	53
TI 93	21	22	63	44	34	51	-	-	-	-	-	-

CNN1- RP6252-BV/RIL/1689; CNN2- RP6252-BV/RIL/1690; CNN3- RP6252-BV/RIL/1692; CNN4- RP6252-BV/RIL/1700; CNN5- RP6252-BV/RIL/170

- AE- Agronomic efficiency (kg grain increase/kg N added)
- PE- Physiological efficiency (kg grain increase/ kg N uptake)
- RE- Recovery efficiency (% of N recovered)

5.7 Yield maximization of rice in different zones

It is well known that Genotype x Environment interactions and their management influence the realization of the yield from a given plant variety. So, the site-specific nutrient management is an important approach that emphasizes 'feeding' plants 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. Keeping the variance in supply potential of the soils in mind, an experiment was planned and executed to identify the best treatment that yielded the maximum yield. A collaborative (Soil Science & Agronomy) trial was conducted during *Rabi* 2020-21 and *Kharif* 2021 with eight treatments including Recommended Dose of Fertilizer (RDF) (T1), RDF + 10 tons of FYM per ha (T2), 125% of RDF (T3), 150% of RDF (T4), RDF plus 2 sprays of region specific micronutrients (Sampoorna (KAU) (T5), fertilizer as per the Nutrient Expert, a software developed by the International Plant Nutrition Institute (IPNI) (T6), farmers' application dose (T7) and RDF plus three times spray of 'Eco Agra" (T8) in three replications. The data received from two centers namely Karaikal (*Rabi* 2020-21) and Maruteru (both *Rabi* 2020-21 and *Kharif* 2021 seasons) were analyzed by one factor analysis of variance (ANOVA) method to understand the impact of treatments on the yield and uptake of nutrients. It may be noted that only in Maruteru all eight treatments were tested during *Kharif*. The results were presented in tables 5.7.1 to 5.7.5.

Crop growth conditions

The available experimental soil conditions prior to cropping in both centers were presented in Table 5.7.1 along with plant varieties grown. It is to understand the initial growth conditions in the test centers and even seasons. The contents given in the table are self-explanatory in terms of variability in the soil reaction, electrical conductivity, organic matter content and available N, P and K coupled with varieties grown.

Grain yield

The mean of grain yield across treatments was 5.35, 6.86 and 5.55-tons ha^{-1} realized from Karaikal, *Rabi* and *Kharif* seasons in Maruteru, respectively (Table 5.7.2). Among treatments tried in Karaikal, the lowest grain yield was recorded in T1 (RDF) while the highest was recorded in T2 (RDF + FYM) where other treatments including NE software-based fertilizer management also did not increase yield as against the expected or seen in earlier instances. Maruteru (*Rabi*) realized the lowest and highest in T7 (Farmers' fertilizer practice) with 6.0-ton ha^{-1} and T3 (125% of RDF), with 7.5 tons' ha^{-1}, respectively. Maruteru (*Kharif*) yielded the lowest grain yield (4.43-ton ha^{-1}) in T7 (as probably expected) and the highest yield of 6.18 tons' ha^{-1} in T2 (RDF + FYM) treatments. LSD values of all data columns indicated non-significant and significant differences among the pairs of treatments. However, there was no consistent pattern of influence of treatments on grain yield among the trials except in T7 where the lowest grain yield was recorded in Maruteru during both the seasons. Interestingly, T6, the NE based fertilization, which was known to be site-specific did not create any significant difference in grain yield from other treatments in Matuteru-*Rabi*. But during *Kharif* in Maruteru, T6 showed superiority significantly over T4 and T7 and T8 realized significantly more than T7.

Straw yield

The mean of straw yield (across treatments) was more in Karaikal followed by Maruteru during *Rabi* and *Kharif* with values of 10.43, 9.05 and 9.0-tons ha^{-1} of straw yield (Table 5.7.2), respectively. The straw yield in Karaikal among treatments ranged from 9.43 (T5) to 10.57 tons ha^{-1} (T1), 7.85 (T7) to 9.90 tons ha^{-1} (T3) in Maruteru during *Rabi* and 7.69 (T7) to 9.72 tons ha^{-1} (T4) during *Kharif.* LSD based comparisons indicated that there were significant differences among some treatments in Maruteru during *Rabi* and *Kharif* seasons while it was insignificant in Karaikal. There was no specific pattern of effect of treatments on straw yield also and similarly the lowest straw yield was recorded in T7 in Maruteru during both the seasons. NE based fertilization did not create any significant difference in straw yield with other treatments in Maruteru-*Rabi.* However, the significant superiority of T6 over T1, T2, T5 and T7 was established in Maruteru in *Kharif* season and new treatment T8 also caused significant difference. In fact, the straw yield was significantly more in T8 than T1, T2, T5 and T7 and on par with T6 (NE based fertilization).

Panicles m^{-2}

The order of means of number of panicles m^{-2}, an important yield component across treatments was Karaikal (434) > Maruteru (*Rabi*) (370) > Maruteru (*Kharif*) (232) (Table 5.7.2). Both T4 and T5 registered the lowest (422) while T2 recorded the highest (451) in Karaikal center. The lowest number of panicles m^{-2} was noticed in T6 (348) while the highest recorded was in T1 in Maruteru (*Rabi*). During the *Kharif* season, the number was the lowest recorded in T5 (218) and the highest being in T7 (243). However, in all three datasets, the difference among the means of different treatments was insignificant even with the inclusion of T8.

Nutrient uptake

Grain

The mean of N uptake by grain (across treatments) was 55, 45 and 53 kg ha^{-1} in Karaikal, Maruteru (*Rabi*) and Maruteru (*Kharif*) (Table 5.7.3), respectively. According to

LSD values, the difference between any pair of treatments was non-significant in Karaikal and Maruteru-*Kharif* but being significant in Marateru-*Rabi*. The range of uptake of N in grain 52-59 in Karaikal trial where that difference was insignificant. In Maruteru-*Rabi*, the uptake of N in grain ranged from 41 (T1 & T2) to 56 kg ha^{-1} (T3) and the difference was significant. Though the grain uptake of N ranged between 47 (T2) to 62 (T6) kg ha^{-1}, the difference was insignificant in Maruteru-*Kharif*. However, there were significant differences between other treatment pairs based on LSD comparisons only in Maruteru *Rabi* trial. Similarly, the mean of P uptake by grain (across treatments) was 5, 17 and 21 kg ha^{-1} in Karaikal, Maruteru (*Kharif*) and Maruteru (*Rabi*) (Table 5.7.3) Among the treatments in Karaikal, the range was from 2 to 7 and the difference was insignificant. The difference between the lowest and highest mean grain P uptake was significant in Maruteru-*Rabi* and *Kharif* as per LSD comparisons. With reference to potassium mean (across treatments) uptake in grain, the values were 7, 9 and 16 seen in Maruteru (*Kharif*), Maruteru-*Rabi* and Karaikal (Table 5.7.3). The potassium uptake in grain in Karaikal ranged from 14 – 20 kg ha^{-1}, with insignificant difference. Compared with Karaikal, the uptake was low in Maruteru in both seasons i.e., 8-9 and 6-9 kg ha^{-1} in Maruteru-*Rabi* and *Kharif*, respectively with significant differences between the highest and lowest based on LSD comparisons.

Straw

The mean (across treatments) up take of N by straw was 75, 41 and 40 kg ha^{-1} in Karaikal, Maruteru-*Rabi* and *Kharif*, respectively (Table 5.7.4). Mean (across treatments) P uptake among the sites ranged from 6 to 19 kg ha^{-1} while the range was 121 to 184 kg ha^{-1} for uptake of K by straw. The differences in N uptake by straw were non-significant while in other two trials, the difference was significant. With reference to P, the difference was non-significant in Karaikal and Maruteru (during *Kharif*) but was significant in Maruteru (*Rabi*). In case of K uptake by straw, a non-significant difference was recorded in Karaikal while in other trials, the differences were significant among treatments. It was seen that there was no specific pattern of response in terms of uptake in straw with regards to treatments.

Total uptake

The details given in Table 5.7.5 indicated that the mean (across the treatments) total uptake of N varied from 87 (Maruteru-*Rabi*) to 130 kg ha^{-1} (Karaikal). Mean (across treatments) total P uptake was varying from 10 (Karaikal) to 40 kg ha- (Maruteru-*Rabi*) while it was from 137 (Karaikal) to 193 kg ha^{-1} (Maruteru – *Rabi*). It was seen that T3 recorded then highest content of total uptake of N and P in Karaikal and Maruteru-*Rabi* while the other patterns followed in case of Maruteru-*Kharif.* T6 in all trials registered the lowest total uptake of N in Karaikal, Maruteru-*Rabi* and *Kharif.* The highest total uptake of K was seen in T2 of all three trails while the lowest was seen in T7 in Maruteru-*Rabi* and *Kharif* while T4 recorded the lowest total uptake of K in Karaikal. The difference between the lowest and highest was non-significant in total uptake of N, P and K in Karaikal and total uptake of P in Maruteru-*Kharif*. In the rest of cases, the differences were significant.

Summary

One factor ANOVA of data on grain yield, straw yield, number of panicles m^{-2}, uptake of N, P and K by grain, straw and the total of both gave certain inferences. Treatments caused both insignificant and significant differences in some attributes. For instance, the differences among treatments in Karaikal were in fact non-significant in all the attributes and in Maruteru-*Rabi* and *Kharif* certain attributes had significant differences. With regards to mean grain yield (across treatments) the order in decreasing order of Maruteru-*Rabi* (6.86 tons ha^{-1}) > Maruteru-*Kharif* (5.55 tons ha^{-1}) > Karaikal (5.35 tons ha^{-1}). The realized mean straw yield (across treatments) was in the order of Karaikal (10.43 tons ha^{-1}) > Maruteru-*Rabi* (9.05 tons ha^{-1}) > Matuteru-*Kharif* (8.99 tons ha^{-1}). Similarly, number of panicles m^{-2} was in the order of Karaikal (434) > Maruteru-*Rabi* (370) > Maruteru-*Kharif* (232). There were significant differences among treatment pairs in grain and straw yields realised in Maruteru-*Rabi* and Maruteru-*Kharif*. There were different patterns in terms of differences in treatment effect on uptake of N, P and K in Maruteru-*Rabi* and *Kharif* both in grain and straw. Significant differences were recorded in Maruteru-*Rabi* and *Kharif* trials in total uptake of N and K while in P only Maruteru-*Rabi* had significant differences indicating the pattern of responses which must have had confounded effects of other factors that need further experimentation. LSD based comparisons indicted that the effect of T6 (NE based), which is assumed to be site-specific fertilizer management had no impact at all on grain, straw yield and panicle number in Maruteru-*Rabi*. But in Maruteru-*Kharif*, T6 was better than T1, T2, T5 and T7 in terms of straw yield.

Another treatment, T8, yielded better results than T7 in Maruteru-*Kharif* in terms of grain yield while it was also better than T1, T2, T5 and T7 in terms of straw yield. Similarly, the superiority of T8 was seen in other attributes like grain uptake of P and K, straw uptake of N and K and total uptake of N and K signifying the beneficial role of spray of Eco Agra formulation. Nevertheless, the results of T6 and T8 were on par, which ultimately underscore the benefit of site-specific fertilizer management.

Table 5.7.1: Yield maximization of rice in different zones (*Kharif* 2021): Soil and crop characteristics

Trial center	pH	EC (dSm^{-1})	OC (%)	Av. N	Av. P	Av. K	Texture	Variety	Fertilizer Dose			DOS	DOP
				kg ha^{-1}					RDF	NE	FFP		
KRK	6.1	0.10	0.7	163	30.2	188	Sandy loam	ADT 46	150-26.2-5	159-17-53	172-25-50	4-9-20	24-1-21
MTU-R	5.58	0.75	1.0	179	25.5	233	Clay loam	MTU 1121	180-39-50	141-17-60	205-37-53	31-12-20	10-2-21
MTU- K	6.01	0.64	0.9	182	27.0	271	Clay loam	MTU-1064	90-26-50	118-12-43	101-22-16	23-6-21	29-7-21

Table 5.7.2: Yield maximization of rice in different zones (*Rabi 2020 and Kharif 2021*): Grain, straw yield and panicles/m^2

Treatment	KRK	MTU-R	MTU- K	KRK	MTU -R	MTU – K	KRK	MTU-R	MTU- K
	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Panicles/m^2		
T1 – RDF	4.63	6.49	5.84	10.57	8.56	8.42	442	382	221
T2 - RDF + 10 t FYM/ha	5.98	7.33	6.18	9.87	9.67	8.53	451	370	219
T3- 125% RDF	5.64	7.50	5.91	11.40	9.90	9.54	429	367	241
T4 - 150% RDF	5.21	7.40	5.02	10.07	9.76	9.72	422	375	242
T5 - RDF + Sampoorna (KAU) micronutrient spray	5.36	6.71	5.50	9.43	8.85	8.55	422	371	218
T6 - Fertilizers as per Nutrient Expert	5.42	6.64	5.81	10.26	8.77	9.65	438	348	231
T7 - Farmers application dose	5.25	5.95	4.43	11.39	7.85	7.69	431	376	243
T8 - RDF + Eco Agra spray			5.70			9.81			239
Mean	5.35	6.86	5.55	10.43	9.05	8.99	434	370	232
LSD	NS	0.90	0.71	NS	1.19	1.12	NS	NS	NS
CV (%)	10.3	8.86	8.7	11.8	8.86	8.5	9.4	7.6	7.9

Table 5.7.3: Yield maximization of rice in different zones (*Rabi 2020 and Kharif 2021*): Nutrient uptake – grain (kg ha^{-1})

Treatment	KRK	MTU-R	MTU- K	KRK	MTU-R	MTU- K	KRK	MTU-R	MTU- K
	N uptake - grain (kg ha^{-1})			P uptake - grain (kg ha^{-1})			K uptake - grain (kg ha^{-1})		
T1 – RDF	59	41	56	5	19	18	15	10	9
T2 - RDF + 10t FYM	58	41	52	7	24	20	18	10	9
T3- 125% RDF	54	56	53	5	25	17	14	10	8
T4 - 150% RDF	54	51	47	6	22	15	15	9	6
T5 - RDF + Sampoorna (KAU) micronutrient spray	53	45	55	5	23	18	14	9	8
T6 - Fertilizers as per Nutrient Expert	52	42	62	3	21	18	20	8	7
T7 - Farmers application dose	52	42	48	2	15	12	15	8	6
T8 - RDF + Eco Agra spray			52			18			8
Mean	55	45	53	5	21	17	16	9	7
LSD	NS	9.1	NS	NS	4.7	4.6	NS	1.4	1.5
CV (%)	30.4	13.5	14.4	34.5	15.0	18.6	27.0	10.3	13.4

Table 5.7.4: Yield maximization of rice in different zones (*Rabi 2020 and Kharif 2021*): Nutrient uptake – straw (kg ha^{-1})

Treatment	KRK	MTU-R	MTU- K	KRK	MTU-R	MTU- K	KRK	MTU-R	MTU- K
	N uptake - straw (kg ha^{-1})			P uptake - straw (kg ha^{-1})			K uptake - straw (kg ha^{-1})		
T1 – RDF	83	38	29	4	17	12	149	157	155
T2 - RDF + 10t FYM	61	54	33	5	17	12	158	225	200
T3- 125% RDF	96	49	43	8	23	14	135	176	170
T4 - 150% RDF	77	40	35	6	20	15	90	224	223
T5 - RDF + Sampoorna (KAU) micronutrient spray	72	38	40	5	19	11	100	172	167
T6 - Fertilizers as per Nutrient Expert	64	34	51	3	17	13	107	179	197
T7 - Farmers application dose	73	37	40	10	17	12	109	155	152
T8 - RDF + Eco Agra spray	-	-	51	-	-	13	-	-	193
Mean	75	41	40	6	19	13	121	184	182
LSD	NS	6.6	6.8	NS	3.7	NS	NS	32.3	30.9
CV (%)	24.3	10.8	11.5	44.6	13.6	21.1	28.2	11.8	11.6

Table 5.7.5: Yield maximization of rice in different zones (*Rabi 2020 and Kharif 2021*): Nutrient uptake – total (kg ha^{-1})

Treatment	KRK	MTU-R	MTU- K	KRK	MTU-R	MTU- K	KRK	MTU-R	MTU- K
	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
T1 – RDF	142	79	84	8	36	31	164	167	164
T2 - RDF + 10t FYM	119	94	84	12	41	31	176	235	209
T3- 125% RDF	150	106	96	13	48	31	149	186	178
T4 - 150% RDF	131	91	82	12	42	30	105	233	229
T5 - RDF + Sampoorna (KAU) micronutrient spray	125	83	95	10	41	29	115	182	175
T6 - Fertilizers as per Nutrient Expert	117	77	113	6	38	32	127	187	204
T7 - Farmers application dose	125	79	88	12	33	23	124	163	157
T8 - RDF + Eco Agra spray			103			31			201
Mean	130	87	93	10	40	30	137	193	189
LSD	NS	14.5	13.2	NS	6.9	NS	NS	32.9	30.8
CV (%)	13.3	11.2	9.7	32.3	11.6	12.9	25.7	11.5	11.0

5.8. Enhancing productivity of Organic Rice cultivation

The trial was conducted during *Rabi* 2021-22 and *Kharif* -2021 in collaboration with Agronomy to study the influence of organic practices on productivity, grain quality, soil health and environmental sustainability. Currently, organic produce including organic rice is in huge demand owing to its potential to fetch premium prices in the global market. There were mainly nine treatments during *Kharif* -2021 *viz.*, 1) Absolute Control (No: NPK), 2) 100% RDN, 3) 100% N (FYM), 4) 150% N (FYM), 5) 50% N (FYM)+ 50% N (Green manure/Green Leaf Manure, 6) 50% N (FYM)+ 50% N (Vermicompost), 7) 50% N (FYM)+ 50 % N (Neem / Castor/ any cake), 8) Optional 1- 75% RDN: 50% each through FYM + Vermicompost, 9) Optional 2 – Best State Organic practice and five treatments during *rabi* 2020-21. All organic farming practices starting from seed treatment to harvest were practiced as per the technical programme; observations were recorded on grain and straw yields and other yield parameters. Soil samples were collected before conducting experiment and after harvest and were analyzed for important soil properties. The trial was conducted at four locations *viz*., [Chinsurah (CHN), Kaul (KUL), Moncompu (MCP) and Khudwani (KHD)] during *Kharif*- 2021 and at CHN during *Rabi* 2020-21. The results are presented in Tables 5.8.1 to 5.8.6.

Grain yield, straw yield and yield parameters

Among the four locations, grain yield during *Kharif*-2021 (Table 5.8.1) was significantly superior in inorganic RDF (5.5, 3.1 and 7.0 t/ha) treatment as compared to other treatments recording 103%, 7%, 17% higher yield over 100% N (FYM), as organic at CHN, Kaul and KHD respectively. whereas at MCP (4.9 t/ha) organic treatment 50% N (FYM)+ 50 % N (Green manure/Green Leaf Manure) recorded higher grain yield which was 4.3% higher as compared inorganic RDF. Straw yield followed a similar trend as that of grain yield at most of the locations recording 96%, 23%, 3% and 15% higher yield in inorganic RDF over 100% N (FYM) at CHN, MCP, KUL and KHD respectively. With regard to yield parameters (tillers/m^2, panicles/m^2, 1000 grain weight), organic treatment 150% N (FYM) recorded significantly higher values as compared to other treatments at MCP and KHD, but at CHN inorganic RDF treatment recorded significantly higher as compared to other treatments (Table 5.8.2).

At CHN location, during *Rabi* 2021-22 (Table 5.8.5) grain and straw yields were significantly superior in inorganic RDF as compared to other treatments and with 45% and 43% higher grain and straw yields over Organic POP recommendation. With regard to tiller/m^2, panicles/m^2, 1000 grain wt. (g), in inorganic RDF recorded significantly higher values. Among the organic treatments, FYM @ 10 t/ha + VC 2.5 t/ha + spray of liquid manure recorded highest number of tillers/m^2 (282) and panicles/m^2 (242) and 1000 grain weight as compare other organic treatments.

Soil properties after harvest

The important soil properties from three locations (CHN, KUL and MCP) are presented in Table 5.8.3, 5.8.4. and 5.8.6. At CHN almost all soil properties were higher in 50% N (FYM)+ 50% N (Green manure/Green Leaf Manure) as organic except in soil organic carbon and soil available nitrogen which was highest in 150% N (FYM) organic recommendation and are on par in all treatments (Table 5.8.3). The grain, straw and soil nutrient contents at KUL are presented in table 5.8.4. The highest grain and straw content and an improvement in soil NPK was recorded in inorganic RDF, Among the organic treatments, 150% N (FYM) was superior to other organic treatments. At MCP almost all soil properties were higher in 150 % N (FYM) treatment except in soil organic carbon and soil available sulphur which was highest in 50% N (FYM)+ 50% N (Green manure/Green Leaf Manure) organic recommendation (Table 5.8.6).

Summary

The second year of study on “Enhancing productivity of Organic Rice cultivation”, it revealed that three centres (CHN, KUL and KHD) out of four showed positive response to the inorganic RDF but, at MCP 150% N (FYM) was significantly superior to other treatments in terms of grain yield and yield parameters. At CHN and MCP most of the soil properties improved with 100% N (FYM) and 150 % N (FYM) organic treatments compared to other treatments respectively.

Enhancing productivity of Organic Rice cultivation Soil and crop characteristics.

Cropping system	**CHN**	**MCP**	**KUL**	**KHD**
	Rice-Rice	**Rice-Rice**	Rice- Wheat	Rice-Wheat
Variety	MTU 1064	Pournami	Basmati CSR30	SR-4
Recommended Fertilizer Dose (kg NPK /ha)				
Kharif	80:40:40	90:45:45	60:30:30	-
Crop growth:	Good	Good	Good	Good
% Clay	-	-	25.2	41
% Silt	-	-	25.8	37
% Sand	-	-	52.0	22
Texture	Clay Loam	-	Sandy loam	Silty clay
pH	7.01	4.66	8.2	6.93
Organic carbon (%)	1.40	-	0.50	-
EC (dS/m)	0.50	0.06	0.15	0.09
Avail. N (kg/ha)	563	372	172	284
Avail. P_2O_5 (kg/ha)	158	69.4	26.8	16
Avail. K_2O (kg/ha)	341.2	183	399	267

Table 5.8.1 Enhancing productivity of Organic Rice cultivation

Grain and Straw yield of *Kharif* (Locations: Chinsurah-CHN, Kaul-KUL, Moncompu-MCP, Khudwani- KHD)

Treatment Name	Grain yield (t/ha)				Straw yield (t/ha)			
	CHN	MCP	KUL	KHD	CHN	MCP	KUL	KHD
Absolute Control (No: NPK)	2.4	3.5	2.5	4.5	2.8	5.8	6.2	4.5
100% RDN	5.5	4.7	3.1	7.0	6.5	9.0	7.0	7.0
100 % N (FYM)	2.7	4.7	2.9	6.0	3.3	7.3	6.8	6.0
150 % N (FYM)	2.7	4.8	3.0	5.5	3.2	8.4	6.9	5.5
50 % N (FYM)+ 50 % N (Green manure/Green Leaf Manure	3.4	4.9	3.0	5.6	4.1	7. 1	7.1	5.6
50 % N (FYM)+ 50 % N (Vermicompost)	3.7	4.8	3.0	5.4	4.6	8.2	7.0	5.4
50 % N (FYM)+ 50 % N (Neem / Castor/ any cake)	2. 8	4.7	3.0	5.5	3.3	7.6	7.1	5.5
Optional 1- 75% RDN (50% each through FYM + Vermicompost)	2.7	-	-	6.8	3.3	-	-	6.8
Optional 2-Best State organic practice (Vermicompost @ 50% as basal, 25% at active tillering and 25% at PI)	2.7	-	-		3.3	-	-	
Exp.mean	3.2	4.6	2.9	5.8	3.8	7.6	6.9	5.8
CD (p=0.05)	0.20	0.43	0.25	0.54	0.28	0.66	0.56	0.54
CV (%)	5.08	6.37	6.51	5.39	5.75	5.88	6.26	5.39

Table 5.8.2 Enhancing productivity of Organic Rice Cultivation

Yield parameters of *Kharif* (Locations: Chinsurah- CHN, Kaul-KUL, Moncompu- MCP, Khudwani- KHD)

Treatment	Tillers/m^2			Panicles /m^2			1000 Grain weight (g)			
	CHN	MCP	KHD	CHN	MCP	KHD	CHN	MCP	KUL	KHD
Absolute Control (No: NPK)	258	192	308	220	181	236	20.2	27.3	25.0	25.3
100% RDN	364	228	319	318	205	299	21.5	28.5	25.3	29.3
100 % N (FYM)	250	204	325	217	205	286	19.6	27.6	25.0	26.5
150 % N (FYM)	259	230()	334	225	207	272	20.2	28.6	25.1	26.7
50 % N (FYM)+ 50 % N (Green manure/Green Leaf Manure	251	211	319	209	194	275	19.8	27.4	25.3	25.6
50 % N (FYM)+ 50 % N (Vermicompost)	292	216	321	272	219	282	20.2	27.5	25.5	25.8
50 % N (FYM)+ 50 % N (Neem / Castor/ any cake)	260	181	323	226	201	241	19.8	28.3	25.4	25.8
Optional 1- 75% RDN (50% each through FYM + Vermicompost)	269	-	330	232	-	307	19.9			28.9
Optional 2 – Best State organic practice (Vermicompost @ 50% as basal, 25% at active tillering and 25% at PI)	248	-		215	-	-	20.8			
Exp. Mean	272	209	322	237	202	275	20.2	27.9	25.2	26.7
CD (p=0.05)	28.05	31.36	12.22	28.7	15.8	8.82	0.65	1.99	2.5	0.58
CV (%)	8.06	10.1	2.16	9.47	5.27	1.83	2.51	4.8	7.58	1.24

Table 5.8.3 Enhancing productivity of Organic Rice Cultivation Soil properties after harvest (Location: CHN) *Kharif*

Treatment Name	pH	EC	Org. C (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail K (kg/ha)	Avail S (mg/kg)	DTPA Zn (mg/kg)	DTPA-Fe (mg/kg)	DTPA-Mn (mg/kg)	DTPA-Cu (mg/kg)
Absolute Control (No: NPK)	7.02	0.22	1.19	440	91	285	18.48	17.62	14.19	3.04	5.16
100% RDN	7.04	0.22	1.16	458	89	288	18.96	17.2	14.27	3.06	5.15
100 % N (FYM)	7.04	0.2	1.11	480	98	296	19.52	17.1	14.2	3.09	5.14
150 % N (FYM)	7.07	0.21	1.18	489	95	291	18.44	17.24	14.21	3.06	5.12
50 % N (FYM)+ 50 % N (Green manure/Green Leaf Manure	7.04	0.2	1.11	480	98	296	19.52	17.1	14.2	3.09	5.14
50 % N (FYM)+ 50 % N (Vermicompost)	7.1	0.22	1.18	466	95	294	18.12	17.38	14.26	3.06	5.17
50 % N (FYM)+ 50 % N (Neem / Castor/ any cake)	5.65	0.18	0.88	379	74	225	15.06	13.8	11.43	2.45	4.15
Exp. Mean	6.85	0.21	1.12	456.22	91.68	282	18.30	16.78	13.82	2.98	5.00
CD (p=0.05)	1.55	0.06	0.27	111.94	21.73	63.16	4.44	3.81	3.16	0.68	1.15
CV (%)	17.38	20.61	18.25	18.8	18.15	17.15	18.57	17.38	17.53	17.36	17.63

Table 5.8.4 Enhancing productivity of Organic Rice cultivation

Grain and Straw (N, P, K) uptake and Soil properties after harvest (Location: KUL) *Kharif*

Treatment	Grain			Straw			pH	EC ($dS\ m^{-1}$)	Org. C (%)	Avail. N (kg/ha)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)						
Absolute Control (No NPK)	29.78	10.32	11.84	31.19	13.31	77	8.56	0.14	0.48	124	36.4	337
100% RDN	40.79	15.66	16.46	39.33	17.83	92	8.18	0.13	0.5	171	53.24	383
100 % N (FYM)	38.08	14.41	14.95	37.36	16.73	88	8.32	0.12	0.49	167	50.70	375
150 % N (FYM)	39.77	15.18	14.83	38.27	17.21	92	8.28	0.14	0.49	170	58.54	379
50 % N (FYM)+ 50 % N (Green manure/Green Leaf Manure	38.87	14.28	13.67	38.71	16.81	92	8.58	0.17	0.5	164	55.0	382
50 % N (FYM)+ 50 % N (Vermicompost)	38.59	15.22	15.66	37.2	17.44	91	8.36	0.12	0.49	164	51.84	377
50 % N (FYM)+ 50 % N (Neem / Castor/ any cake)	39.38	13.9	14.4	38.8	16.34	92	8.42	0.13	0.49	166	57.32	379
Exp.mean	37.89	14.14	14.54	37.26	16.52	89.41	8.38	0.14	0.49	161	51.86	373.3
CD (p=0.05)	4.22	2.04	2.17	3.92	2.36	6.56	0.18	0.02	0.03	10.77	9.41	18.3
CV (%)	8.54	11.03	11.42	8.07	10.96	5.62	1.67	12.29	5.44	5.12	13.91	3.75

Table 5.8.5 Enhancing productivity of Organic Rice cultivation

Grain, Straw yield and soil properties of *boro* (Locations: CHN)

Treatment	Grain (t/ha)	Straw (t/ha)	Tillers/ m^2	Panicles/ m^2	1000 grain wt. (g)	Org. C (%)	DTPA-Fe (mg/kg)	DTPA-Zn (mg/kg)	DTPA-Mn (mg/kg)	DTPA -Cu (mg/kg)
Organic POP recommendation	3.4	4.1	252	213	20.18	1.19	14.19	17.62	3.04	5.16
100 % POP recommendation as organic	2.8	3.3	260	226	19.8	1.16	14.27	17.2	3.06	5.15
75 % POP recommendation as organic	2.7	3.2	271	236	19.6	1.11	14.2	17.1	3.09	5.14
FYM @ 10 t/ha + VC 2.5 t/ha + spray of liquid manure	3.5	4.3	282	242	20.2	1.18	14.21	17.24	3.06	5.12
Inorganic RDF	5.2	6.5	370	331	21.5	1.18	14.26	17.38	3.06	5.17
Exp. Mean	3.50	4.3	287	250	20.25	1.16	14.22	17.31	3.06	5.15
CD	0.26	0.33	39	34.3	0.55	NS	NS	NS	NS	NS
CV	5.64	5.78	10.24	10.25	2.02	7	0.67	1.66	0.89	1.48

Table 5.8.6 Enhancing productivity of Organic Rice cultivation

Soil properties after harvest (MCP, *Kharif*)

Treatment	pH	EC	Org. C (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)	Avail. S (mg/kg)	DTPA-Zn (mg/kg)	DTPA-Fe (mg/kg)	DTPA-Mn (mg/kg)	DTPA-Cu (mg/kg)
Absolute Control (No: NPK)	5.06	0.07	3.04	330.73	30.97	127.77	11.35	0.98	184.75	2.45	1.12
100% RDN	5.02	0.06	3.11	355.18	59.21	161.86	11.48	1.05	179.00	2.31	1.11
100 % N (FYM)	5.01	0.06	3.15	354.88	64.55	163.42	10.98	1.05	176.00	2.17	1.11
150 % N (FYM)	5.11	0.07	3.22	405.53	67.31	185.81	11.55	1.09	174.25	2.06	1.05
50 % N (FYM)+ 50 % N (Green manure/Green Leaf Manure	5.08	0.06	3.36	382.63	64.87	190.94	11.83	1.08	175.00	2.02	1.02
50 % N (FYM)+ 50 % N (Vermicompost)	5.10	0.06	3.22	376.88	63.55	184.48	11.05	1.04	175.25	2.06	1.07
50 % N (FYM)+ 50 % N (Neem / Castor/ any cake)	5.05	0.06	3.21	370.80	64.22	168.84	10.85	1.05	175.75	1.98	1.04
Expt. Mean	**5.06**	**0.06**	**3.19**	**368.09**	**59.24**	**169.02**	**11.30**	**1.05**	**177.14**	**2.15**	**1.07**
CD (0.05)	**NS**	**NS**	**0.17**	**4.18**	**0.60**	**0.41**	**0.56**	**0.06**	**2.98**	**0.27**	**0.07**
CV (%)	**2.40**	**21.75**	**3.69**	**0.76**	**0.68**	**0.16**	**3.34**	**3.72**	**1.13**	**8.40**	**4.31**

List of cooperating centers of Soil Science and allotment of trials: 2021

Appendix-I

Sl. No	Locations	Trial 1		Trial 2		Trial 3		Trial 4	Trial 5		Trial 6		Trial 7		Trial 8		Allotted	Conducted	Conducted %
		K	R	K		K	R	K	K	R	K	R	K	R	K	R			
1	Kanpur (F)			x													01	01	100
2	Karaikal (F)								x	x	x		x				06	04	66
3	Kaul (F)			x											x		03	02	66
4	Mandya (F)	x	x			x							x				05	04	80
5	Maruteru (F)	x	x						x	x	x	X	x	X			08	08	100
6	Moncompu (F)			x				x							x		04	03	75
7	Pantnagar (F)			x							x						05	02	40
8	Pusa (F)								x		x						03	02	66
9	Titabar (F)	x	x	x				x			x		x				06	06	100
10	Ludhiana (F)			x		x											03	02	66
11	Chinsurah (V)			x									x		x	x	04	04	100
12	Dumka (V)							x									01	01	100
13	Faizabad (V)					x			x		x						04	03	75
15	Hazaribagh (V)								x								02	01	50
16	Khudwani (V)								x				x		x		03	03	100
17	Puducherry (V)								x								02	01	50
18	Purulia (V)										x						02	01	50
19	IIRR					x			x								02	02	100
Total trials allotted		**3**	**3**	**7**		**4**		**3**	**8**	**2**	**7**	**1**	**6**	**1**	**4**	**1**	**64**	**50**	**78**

K – *Kharif*; R- *Rabi*; X - Conducted by Soil Scientists

Trial No.1: Long-term soil fertility management in rice-based cropping systems (RBCS)

Trial No.2: Soil quality and productivity assessment for bridging the yield gaps in farmers' fields

Trial No.3: Management of sodic soils using nano Zn formulation

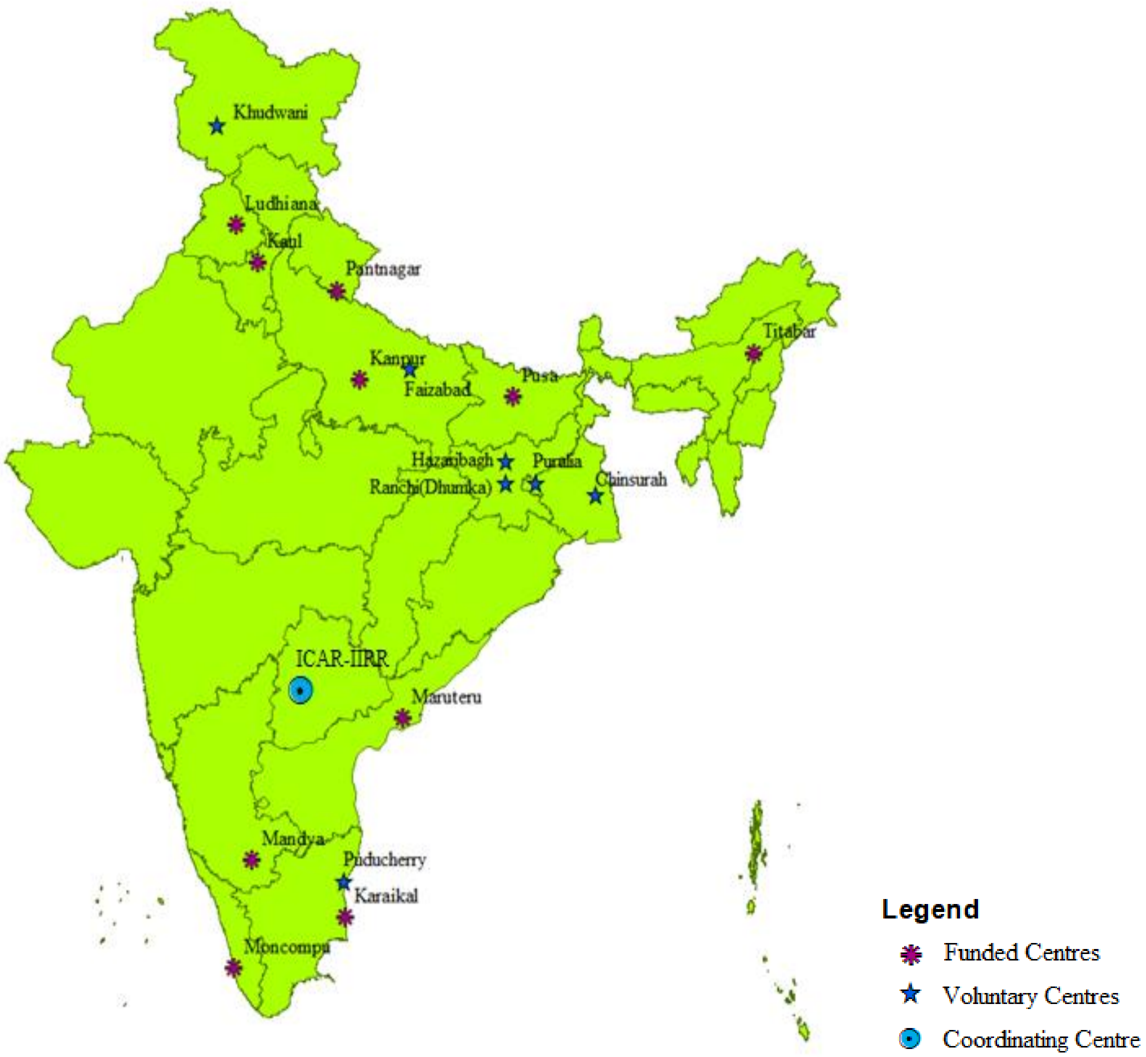
Trial No.4: Management of acid soils

Trial No.5: Residue management in rice-based cropping systems

Trial No.6: Screening of rice germplasm for Nitrogen Use Efficiency (NUE)

Trial No.7: Yield maximization of rice in different Zones

Trial No.8: Enhancing productivity of Organic Rice cultivation



Map showing Soil Science AICRIP Funded and Voluntary centres

Scientists involved in Soil Science Co-ordinated Programme 2021-22 (Appendix I)

S. No	State	Organization	Location	Name	Designation	Telephone	E-mail
Funded centres							
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3	Bihar	RAU	Pusa	Dr. Pankaj Singh	Jr. Scientist	9430998401	pankaj.singh30@gmail.com
4	Karnataka	UAS	Mandya	Dr. Savitha H.R	Assistant professor	9964072409	savitha2094@gmail.com
5	Kerala	KAU	Moncompu	Dr. Biju Joseph	Assistant Professor	9847375249	biju.joseph@kau.in
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Voluntary Centres							
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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 Shri **C. Muralidhar Reddy** (Technical officer) and **K. Padmaja** (Senior technical officer) for their unstinted support in the conduct of trials at IIRR and sample analysis. AICRIP Intranet(http://www.aicrip-intranet.in) has been used for the data analysis and report generation. We are thankful to **Dr. B. Sailaja**, Principal Scientist (Computer Application), IIRR and Team of AKMU-GIS Cell (S. Gayatri, G. Chaitanya, C. Manjula, M. Shalini and K. Sharan) for their support in statistical analysis of data and the adhoc staff (Thaiseen Tabasum, Swarna, Humera Quadriya, Mr. S. Mahesh, G. Srikanth, M. Srikanth and Mini.V) of the department for their assistance in field studies and laboratory analysis. We also thank Shri **K. Ramulu**, Technical Officer, Plant Physiology Section for the help in page setting and printing of the progress report.