Soil Science

Progress Report of Soil Science Coordinated Program
(*Rabi* and *Kharif* - 2023)

SOIL SCIENCE

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Summary

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

From the study on long term soil fertility management in RBCS, 35th year results indicated superior performance of RDF + FYM in recording maximum grain yield at all three locations but was significantly superior to RDF at TTB and MND during *Kharif* only. FYM alone treatment was on par to RDF during rabi at TTB and *Kharif* at MND. Nutrient omission and reduction of NPK to 50% resulted in yield reduction at all three centers in both seasons. Fifty per cent (50%) reduction in NPK resulted in more loss at TTB compared to other two centres in both seasons. Addition of organics improved soil fertility in general. Considerable reduction of soil available NPK was observed in omission plots compared to RDF at all three locations. Supplementary dose of FYM along with RDF recorded higher growth rate in productivity with 80, 72 and 55 kg/ha/year at MTU, TTB and MND, respectively, over a period of 35 years.

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 centres – Chinsurah (pool of 31 farmers), Pantnagar (pool of 40 farmers), Kanpur (pool of 21 farmers) and Kaul (pool of 20 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 basic hypothesis aimed was that by systematically assessing soil quality and productivity and implementing appropriate management strategies, farmers can bridge yield gaps and achieve sustainable agricultural production in their fields. The *kharif* 2023 data received representing the irrigated and shallow lowland rice ecosystems. Sharp variations in mean grain yields recorded varied from 2.12 t/ha among low yielders to 4.74 t /ha among high yielders at Chinsurah, varied from 5.07 t/ha among low yielders to 6.97t /ha among high yielders at Kanpur, varied from 4.5 t/ha among low yielders to 5.8 t/ha among high yielders at Pantnagar, from 3.1 t/ha among low yielders to 5.8 t/ha among high yielders at Kaul. 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 farmers categories. Fertilizer prescriptions were worked out for all the farm sites and specific fertilizer recommendations were suggested or target yield: Chinsurah – 4.76 t/ha Pantnagar - 6.0 t/ha, Kaul – 6.6 t/ha, Kanpur – 7.0 t/ha (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 poorest soil quality index was calculated for farmers from Chinsurah due to considerable variation among the farm sites and soil test values. The highest level of yield gap (49.7 %) was recorded at Chinsurah, followed 27.7 at Kaul, 27.2 % at Kanpur, 17.3% at Pantnagar. This shows a wide gap in grain harvest existed. However, ample scope existed at these centres to increase yields.

5.3. Management of Sodic Soils Using Nano Zinc Formulations

In a study on "Management of Sodic soils using nano zinc formulations", two genotypes were evaluated with six different set of nutrient management practices at four different locations. Significant genotypic and location-specific differences in yield parameters and yield were observed at all four locations. At Kanpur, soil application of $ZnSO_4$ @ 50 kg/ha registered higher grain (4.30 t/ha) and straw (5.82 t/ha) yields whereas at Mandya, foliar application of nano Zn @ 50 ppm recorded significantly higher grain (5.99 t/ha) and straw yields (6.74 t/ha). Foliar spray of silicic acid @ 80 ppm has recorded higher grain yields (3.62 and 3.76 t/ha) at Pusa and Faizabad respectively. In case of Varieties, DRR Dhan 48 found superior at Pusa and Faizabad and CSR23 performed better at Kanpur and Mandya. Nutrient uptake also followed similar trend as that of grain and straw yields. The variety DRR Dhan 48 has accumulated higher amount of NPK and Zn at Pusa and Faizabad and CSR 23 recorded significantly higher nutrient uptake at Kanpur and Mandya.

5.4. Management of acid soils

Application of RDF + dolomite + potassium silicate increased yields both at Moncompu (48.87%) and Titabar (19.89%) when compared to sole RDF application, while RDF + dolomite + Silixol recorded highest yields at Titabar with an increase of 24.58% over control treatment. At both Moncompu and Titabar, the variety Uma yielded significantly higher than Vasundhara, recording an increase of 6.83% at Moncompu and 7.36% at Titabar. RDF + dolomite applied in combination with either RHA, potassium silicate or Silixol produced an ameliorative effect at Titabar by significantly increasing soil pH. RDF + dolomite when combined with potassium silicate increased the uptake of PKZn by 78.98, 67.75 and 65.48% at Moncompu over sole RDF application while RDF + dolomite in combination with Silixol at Titabar recorded the highest increase uptake of NPK by 61.15, 84.42 and 69.85% respectively under control RDF application.

5.5. Residue management in rice-based cropping systems

The disposal of huge quantities 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 amounts of plant essential nutrients besides being deleterious to soil microbes. The trial was conducted this year at eight centres. 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. Nano-fertilizers for increasing nutrient use efficiency, yield, and economic returns in transplanted rice

The trial on “Nano-fertilizers for increasing nutrient use efficiency, yield and economic returns in transplanted rice” was continued in the second year at 24 locations with seven treatments (in collaboration with Agronomy). The results indicated that additional application of nano urea with 100% RDN improved the yield, yield parameters and N uptake at Jagdalpur, Kaul, Kanpur, Coimbatore, Khudwani, NRRI and Sabour. At Bankura, Khudwani and Karaikal, the higher NUE was observed with 75% RDN + two sprays of nano urea treatment, but 100% RDN + two sprays of nano urea treatment registered a higher NUE at the rest of the locations. Replacement of 25 and 50% of RDN with nano urea spray at two intervals recorded a declining trend in the grain yield to the tune of -2 to 25.9% at the majority of the locations. While two sprays of nano urea in addition to 100% RDN, improved the grain yield to the tune of 0.7% (Ludhiana) to 33.5% (Khudwani). However, nano urea treatment alone registered, a yield decline to -10.6% (Chiplima), -20.0% (NRRI), -13.6% (Karaikal), -36.2 (Ludhiana) and -28.8% (Gangavati).

5.7. Yield maximization of rice in different zones

-Included in the Agronomy Report-

5.8. Evaluation of Organic fertilizers and Natural farming practices for enhancing productivity and soil health

In the second year of study on “Evaluation of Organic fertilizers and Natural farming practices for enhancing productivity and soil health”, out of five treatments, Integrated Crop Management (pest management) was significantly superior as compared to other treatments at MNC, MND, PNT, PUSA, PUD and TTB in terms of grain yield and yield parameters. At CHN, MNC, MND, PNT and PUSA most of the soil properties improved with Integrated Crop Management ((pest management)) while at TTB, soil properties improved with AI-NPOF package compared to other treatments.

5.9. Assessment of bio fortified rice genotypes response to Zn application and assessing agronomic bio fortification potential

In the first year study, "Assessment of bio fortified rice genotypes response to Zn application and assessing agronomic bio fortification potential" was experimented in five locations with five varieties and three Zn treatments. The application of 0.5% Zn at different growth stages led to higher grain yield and elevation in Zn content in grains in bio fortified varieties at majority of the locations.

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 35^{th} year of cropping *i.e., Rabi* 2022-23 and *Kharif*-2023 are presented in Tables 5.1.1 to 5.1.11.

Crop productivity and soil fertility during *Rabi* 2022-23

Grain and straw yields of rice at MTU and TTB and cowpea at MND are presented in Table 5.1.2. At MTU, grain yield ranged from 2.87 (control) to 6.96 t/ha (RDF+FYM) with a mean of 5.48 t/ha. RDF, RDF + FYM and 50% NPK substituted with FYM treatments were at par and significantly superior to other treatments. Omission of N, P, K, Zn and S resulted in yield reduction by 1.19 t/ha in -S to 2.21 t/ha in -N plots over RDF. FYM alone treatment was on par to STCR recommendation. At Titabar, grain yield ranged from 1.27 t/ha in control to 4.58 t/ha in RDF+FYM which was on par to RDF (4.35 t/ha). Here also, omission of nutrients resulted in grain yield reduction by 0.28 t/ha in -Zn to 0.86 t/ha in - N plots over RDF. Here, at TTB, FYM alone treatment was on par to RDF and RDF+FYM and was significantly superior to NPK omission plots. Fifty per cent (50%) reduction in RDF resulted in 29% yield reduction in silty clay soil of TTB compared to 14% 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, in cowpea, grown on residual nutrient content, grain yield ranged from 194 kg/ha in control plot to 433 kg/ha in 50%NPK+25%FYM+25%GM plot with a mean of 310 kg/ha.

Total nutrient (NPK) uptake followed almost similar trend as that of grain yield with minor variations among the treatments and control recorded minimum uptake at both TTB and MTU (Table 5.1.3). With regard to soil fertility status after harvest at MTU, soil organic carbon content was significantly higher where organics were added along with RDF and in FYM alone treatment (1.41%) compared to RDF (1.02%) which was 38% higher than RDF treatment. No definite trend was observed in case of other soil parameters though there was an improvement with addition of organics (Table 5.1.4). At TTB, almost all soil parameters were maximum in RDF+FYM treatment. Here, in nutrient omission plots, there was a significant reduction in all soil fertility parameters compared to plots with RDF and RDF+FYM (Table 5.1.4 a).

Crop productivity and soil fertility status during *Kharif*-2023

At MTU, the treatment, RDF+FYM recorded maximum yield (7.65 t/ha) that was significantly superior to all treatments except RDF (7.24 t/ha) which was at par to RDF+FYM (Table 5.1.5). Omission of all nutrients resulted in significant yield loss (1.14 t/ha in -K and 1.70 t/ha in -N plots) compared to RDF. At TTB, RDF+FYM (5.63 t/ha) recorded significantly higher yield than all other treatments. Here also, significant yield loss due to omission of major and micro nutrients was observed. At MND, RDF+FYM recorded maximum yield (5.73 t/ha) which was significantly superior to all other treatments and on par when 50% NPK was replaced by 25% GM-N+ 25% FYM-N (5.41 t/ha). Significant yield reduction to an extent of 1.07 t/ha in –S plots to 2.78 t/ha in –N plots was observed. With regard to FYM alone treatment, it recorded significantly lower yield compared to RDF at MTU and TTB but on par to RDF at MND. 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 the treatments where organics were added (Table 5.1.6). Soil fertility status at the end of *Kharif*-2023 (Tables 5.1.7 and 5.1.8) indicated an improvement in most of the soil properties with addition of organics and higher values were recorded in RDF+FYM and FYM alone treatments for most of the properties at all 3 locations. Omission plots recorded reduction in NPK values compared to RDF at all 3 locations. Organic carbon values were significantly higher in FYM alone and RDF+FYM than all other treatments followed by the treatments where organics were added and control recorded the lowest values at all 3 locations.

Long term changes in crop productivity and soil fertility over a period of 35 years

The trends in mean grain yields over 35 years (1989-2023) 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

During *Kharif* 2023 (Table 5.1.9), the treatment, RDF+5t FYM/ha recorded maximum mean yield at all 3 locations (MND- 5.31; MTU-5.34 and TTB- 5.06 t/ha) with an average increase of 12.3, 4.1 and 13.2%, respectively, at MND, MTU and TTB by this treatment over RDF. Linear trends of productivity over the years with current RDF indicated positive growth in the delta soils of MTU and acid alluvial soils of TTB (21 and 43 kg grain/ha/year, respectively) and negative growth in the sandy loam of MND (-23 kg grain/ha/year). Additional dose of FYM @ 5t/ha along with RDF improved the growth rate substantially with 80, 72 and 55 kg/ha/year at MTU, TTB and MND, respectively. Next to this treatment, FYM alone treatment recorded more positive growth rate compared to RDF at TTB and MND.

During *Rabi* also, RDF+5t FYM recorded maximum mean grain yield both at MTU (6.34 t/ha) and TTB (4.39 t/ha) and this treatment recorded growth rate of 12 and 41 kg/ha/year at MTU and TTB, respectively compared to RDF where growth rate was 4 and 34 kg/ha/year, respectively (Table 5.1.10).

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

More positive change in organic carbon (OC) content was observed in the treatments with organics at all 3 locations compared to RDF over 35 years’ period. At TTB and MND, negative change was observed in control. Maximum increase in OC was in FYM alone treatment at MTU and TTB; and with RDF+FYM 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 compared to RDF. With regard to available P, there was a buildup in all treatments compared to initial value at all locations except in control at TTB where the per cent change was negative. In case of available K, at MTU, there was a decrease and negative change in all treatments compared to initial value. At MND and TTB, there was a negative change in control and positive change in other treatments where the increase was to a greater extent at MND and to a lesser extent at TTB.

Summary

In the 35th year of study on long term soil fertility management in RBCS, RDF+FYM recorded maximum yield but this treatment was on par to RDF at TTB and MTU in *rabi* and significantly superior to RDF at TTB and MND in *kharif*. FYM alone treatment was on par to RDF during *rabi* at TTB and *kharif* at MND. 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 and OC was significantly higher in FYM and RDF+FYM treatments. Additional dose of FYM @ 5 t/ha along with RDF resulted in higher growth rate than RDF at all three locations. Over a period of 35 years, changes in soil fertility showed significant accumulation of OC and P at all 3 locations and K at TTB in INM and organics alone treatments over RDF.

Table 5.1.1: Long-term soil fertility management in RBCS, 2023
Soil and crop characteristics

Cropping system	Maruteru		Titabar	Mandya
	Rice-Rice		Rice-Rice	Rice-Cowpea
Variety - *Kharif*	MTU 1061		Gitesh	Rice- KMP 220
Rabi	MTU 1010		Disang	Cowpea- KBC-9
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	-		-	-
Rabi	-		-	-
Crop growth: *Kharif*	-		-	-
Rabi	-		-	-
% Clay	38		42	11.1
% Silt	28		28.5	18.1
% Sand	34		29.5	62.8
Texture	Clay Loam		Silty Clay	Sandy loam
pH (1:2)	6.63 (Kharif)	4.95 (Rabi)	5.4	5.87
Organic carbon (%)	1.07	1.23	1.1	0.30
CEC (cmol (p^+)/kg)	48.9	48.9	12.5	-
EC (dS/m)	0.69	0.91	0.028	0.28
Avail. N (kg/ha)	184	230	495	208
Avail. P_2O_5 (kg/ha)	33.9	42.0	22.4	19.7
Avail. K_2O (kg/ha)	397	395	112	117.6

Table 5.1.2: Long-term soil fertility management in RBCS, *Rabi* 2023
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	2.87	1.27	193.9	3.99	1.51
100% PK	4.49	3.49	248.8	4.4	4.12
100% NK	5	3.65	225.5	5.27	4.31
STCR recommendation	5.27	4.12	264.5	6.45	4.87
100% NP	5.32	3.74	260.8	6.42	4.4
100% NPKZnS	6.7	4.35	293.8	6.82	5.15
100% NPKZnS + FYM/PM @ 5t/ha	6.96	4.58	412.6	7.02	5.42
100% NPK –Zn	5.34	4.07	266.1	6.56	4.81
100% NPK – S	5.51	3.64	259.8	6.59	4.28
100%NPK-S+1tlime/ha	-	4.19	-	-	4.97
100% N+50% PK	5.85	3.38	292.5	6.04	4
50 % NPK	4.51	2.58	298.9	5.66	3.05
50 % NPK + Biofertilizer	5.76	3.34	270.4	6.74	3.93
50%NPK+ 50% GM-N	6	3.9	379.2	6.71	4.61
50% NPK + 50% FYM-N	6.76	4.13	382.8	7.12	4.9
50% NPK + 25% GM-N+25% FYM-N	5.99	4.21	433.2	6.64	4.98
FYM @ 10 t/ha	5.13	4.39	393.9	6.51	5.21
FYM @ 10 t/ha + VC+Oil Cakes	5.67	-	390.7	6.07	-
Expt. Mean	5.48	3.71	309.8	6.18	4.38
CD (0.05)	0.7	0.3	37.0	0.68	0.4
CV (%)	7.76	5.72	5.6	6.69	6.39

Table 5.1.3: Long-term soil fertility management in RBCS, *Rabi* 2023- Total Nutrient uptake (kg/ha)

Treatments	Maruteru			Titabar		
	N	P	K	N	P	K
Control	26.86	11.24	63.69	18.87	3.83	26.68
100% PK	36.4	16.67	68.5	52.35	11.54	80.13
100% NK	52.42	15.63	86.06	56.37	10.74	83.99
STCR recommendation	52.86	19.03	92.86	64.49	13.83	96.12
100% NP	67.7	20.53	103.01	58	12.39	78.68
100% NPKZnS	77.56	27.33	111.43	70.39	16.07	108.62
100% NPKZnS + FYM/PM @ 5t/ha	68.88	30.37	105.17	74.89	17.86	121.95
100% NPK – Zn	63.41	21.45	103.38	64.58	14.58	102.04
100% NPK – S	58.37	23.49	110.35	59.93	11.79	90.01
100%NPK-S+1tlime/ha	-	-	-	76.5	13.4	105.84
100% N+50% PK	58.04	22.86	99.23	52.91	10.35	85.58
50 % NPK	52.28	19.07	68.3	38.88	7.84	54.29
50% NPK + Biofertilizer	54.71	23.02	94.29	54.73	12.64	85.54
50% NPK+ 50% GM-N	63.19	23.96	102.88	61.83	13.36	98.51
50% NPK + 50% FYM-N	62.49	26.63	118.38	66.24	15.45	104.26
50% NPK + 25% GM-N+ 25% FYM-N	58.6	23.96	116.26	68.28	15.3	104.84
FYM @ 10 t/ha	42.89	21.96	93.38	-	-	-
FYM @ 10 t/ha + VC + Oil Cakes	56.74	23.9	84.2	-	-	-
Expt. Mean	56.08	21.83	95.37	58.70	12.56	89.19
CD (0.05)	12.24	8.04	42.99	5.5	1.73	9.2
CV (%)	13.22	22.31	27.32	6.63	9.76	7.29

Table 5.1.4: Long-term soil fertility management in RBCS, *Rabi* 2023
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	5.94	1.05	MTU	163.3	49.7	383.3
100% PK	5.66	0.91	0.87	147.3	74.3	445.0
100% NK	5.86	1.21	1.09	184.0	58.7	466.7
STCR recommendation	5.6	1.00	1.12	209.3	69.6	448.7
100% NP	5.79	1.16	1.14	195.0	70.2	344.7
100% NPKZnS	5.8	1.00	1.02	152.0	74.7	448.7
100% NPKZnS + FYM/PM @ 5t/ha	5.67	0.96	1.41	177.7	77.1	480.7
100% NPK – Zn	5.68	0.95	1.38	204.7	65.2	433.3
100% NPK – S	5.65	0.95	1.17	152.0	66.9	412.0
100%NPK-S+1t lime/ha	-	-	-	-	-	-
100% N+50% PK	5.72	1.00	0.87	164.7	68.3	368.7
50 % NPK	5.69	1.12	0.89	129.3	64.9	420.7
50% NPK + Biofertilizer	5.64	0.89	1.06	190.3	60.0	394.7
50% NPK+ 50% GM-N	5.73	1.06	1.41	173.0	65.8	408.7
50% NPK + 50% FYM-N	5.71	0.87	1.05	192.0	78.2	447.7
50% NPK + 25% GM-N+ 25% FYM-N	5.7	0.92	1.41	176.0	69.5	420.3
FYM @ 10 t/ha	5.68	0.89	1.41	161.3	70.9	482.0
FYM@10 t/ha + VC + Oil Cakes	5.6	0.85	1.41	158.3	72.8	557.3
Expt. Mean	5.71	0.99	1.16	172.4	68.0	433.1
CD (0.05)	0.27	0.41	0.24	62.0	10.4	119.7
CV (%)	2.85	25.01	12.80	21.8	9.3	16.8

Table 5.1.4 a: Long-term soil fertility management in RBCS, *Rabi* 2023
Soil fertility status at harvest

Treatments	TTB					
	Org C (%)	Avail. N (kg/ha)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)	Avail. S (kg/ha)	Avail. Zn (kg/ha)
Control	0.57	140.3	11.6	78.0	10.7	0.56
100% PK	0.98	255.0	23.17	94.4	12.4	0.70
100% NK	1.19	176.3	26.57	112.3	14.6	0.83
STCR recommendation	1.23	284.0	35.17	95.7	15.9	0.87
100% NP	1.03	177.3	34.27	94.2	20.2	0.82
100% NPKZnS	1.58	346.3	39.23	151.0	22.3	0.95
100% NPKZnS + FYM/PM @ 5t/ha	1.79	385.0	41.23	161.0	27.9	1.22
100% NPK – Zn	1.06	284.3	37.67	148.3	24.5	0.82
100% NPK – S	1.14	352.7	36.5	150.7	24.3	0.88
100%NPK-S+1t lime/ha	1.19	361.0	33.57	157.1	24.3	0.87
100% N+50% PK	1.03	277.0	26.77	161.0	23.2	0.75
50 % NPK	0.8	218.7	36.17	158.3	25.3	0.83
50% NPK + Biofertilizer	1.3	348.0	36.4	168.1	30.7	0.85
50% NPK+ 50% GM-N	1.65	383.3	36.83	160.1	32.3	0.88
50% NPK + 50% FYM-N	1.58	346.3	38	168.3	29.7	0.91
50% NPK + 25% GM-N+ 25% FYM-N	1.61	367.7	38.83	168.3	35.3	1.00
FYM @ 10 t/ha	-	-	-	-	-	-
FYM@10 t/ha + VC + Oil Cakes	-	-	-	-	-	-
Expt. Mean	1.233125	294.0	33.24875	139.2	23.3	0.86
CD (0.05)	0.1	36.0	1.62	9.1	2.6	0.09
CV (%)	5.93	8.7	3.44	4.6	7.8	7.58

Table 5.1.5: Long-term soil fertility management in RBCS, *Kharif* -2023
Grain and straw yields of rice

Treatments	Grain yield (t/ha)			Straw yield (t/ha)		
	MTU	TTB	MND	MTU	TTB	MND
Control	3.43	1.55	1.96	3.48	2.15	2.73
100% PK	5.54	4.09	2.31	8.09	5.56	3.12
100% NK	5.91	4.21	2.64	7.38	5.84	3.68
STCR recommendation	5.79	4.77	3.77	8.45	6.63	4.44
100% NP	6.10	4.25	2.68	9.10	5.86	3.64
100% NPKZnS	7.24	5.35	5.09	9.56	7.43	5.82
100% NPKZnS + FYM/PM @ 5 t/ha	7.65	5.63	5.73	9.64	7.80	6.62
100% NPK –Zn	5.92	4.59	3.87	7.45	6.34	4.93
100% NPK – S	5.76	4.46	4.02	8.77	6.18	4.33
100%NPK-S+ 1timelime/ha	-	4.53	-	-	6.27	-
100% N+50% PK	6.29	3.80	4.44	8.39	5.23	5.34
50 % NPK	6.59	2.78	3.43	7.24	3.81	3.37
50 % NPK + Bio fertilizer	6.01	4.25	3.68	7.52	5.88	4.73
50% NPK+ 50% GM-N	5.34	4.81	4.78	8.12	6.67	5.70
50% NPK + 50% FYM-N	6.68	4.81	4.53	8.59	6.69	5.57
50% NPK + 25% GM-N+25% FYM-N	6.72	5.09	5.41	9.56	7.03	5.39
FYM @ 10 t/ha	6.19	4.99	4.98	8.23	6.89	5.94
FYM@10 t/ha + VC + Oil Cakes	6.59	-	4.58	9.89	-	5.57
Expt. Mean	6.10	4.35	3.99	8.20	6.02	4.76
CD (0.05)	0.86	0.19	0.35	0.95	0.38	0.43
CV (%)	8.55	3.11	3.97	7.04	4.50	4.27

Table 5.1.6: Long-term soil fertility management in RBCS, *Kharif 2023*
Total Nutrient uptake(kg/ha)

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	24.8	9.7	46.1	18.9	4.1	29.3	10.9	2.6	16.7
100% PK	55.9	23.9	145.9	54.8	12.3	85.6	16.6	2.9	11.8
100% NK	45.2	13.4	121.6	53.8	11.4	89.2	19.6	3.5	7.7
STCR recommendation	56.9	25.3	143.0	66.7	13.7	102.6	28.6	5.7	33.0
100% NP	58.4	29.5	134.6	59.5	10.8	82.1	21.7	5.0	27.4
100% NPK + Zn + S	66.2	34.5	149.1	78.9	17.0	122.9	43.1	8.9	46.4
100% NPK + Zn + S + FYM/PM @ 5 t/ha	77.4	37.9	175.0	83.6	17.4	137.6	52.9	11.6	53.6
100% NPK –Zn	53.1	21.0	115.2	67.2	14.7	106.0	30.9	7.2	37.8
100% NPK – S	52.5	22.4	144.3	69.7	12.0	101.8	32.5	7.5	34.7
100%NPK-S+ 1timelime/ha	-	-	-	73.6	11.3	104.5	-	-	-
100% N+50% PK	56.7	23.1	132.6	54.0	9.7	88.4	38.0	7.6	37.6
50 % NPK	52.7	25.6	102.0	38.8	7.5	53.6	27.4	5.8	24.8
50 % NPK + Biofertilizer	54.6	22.7	123.8	63.9	13.1	100.3	32.1	6.6	34.0
50% NPK+ 50% GM-N	46.9	22.1	134.7	68.2	13.7	112.5	38.1	8.6	42.0
50% NPK+ 50% FYM-N	65.4	28.0	134.0	72.8	14.7	112.1	35.5	9.0	1799.2
50% NPK +25% GM-N +25% FYM-N	60.1	28.6	163.2	74.7	15.2	116.3	46.5	9.8	43.6
FYM @ 10 t/ha	53.4	31.5	120.7	72.6	16.1	117.3	44.0	8.9	42.7
FYM@10t/ha +3.0 t/ha Vermi+200 kg/ha oil cakes	67.7	24.0	169.1				40.0	7.9	38.8
Expt. Mean	55.7	24.9	132.6	63.0	12.6	97.8	32.8	7.0	137.2
CD (0.05)	15.1	8.0	30.0	4.7	1.7	7.8	9.8	2.5	2556.4
CV (%)	16.5	19.4	13.7	5.2	9.3	5.6	14.1	16.6	879.2

Table 5.1.7: Long-term soil fertility management in RBCS, *Kharif*-2023
Soil fertility status at harvest

Treatments	Maruteru				Titabar			
	Org. C (%)	Avail. N (kg/ha)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)	Org. C (%)	Avail N (Kg/ha)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)
Control	1.18	163.7	57.0	361.0	0.54	143.6	11.1	67.2
100% PK	1.33	178.3	71.6	402.7	0.93	260.2	18.7	77.5
100% NK	1.30	187.3	65.8	342.0	1.14	180.0	21.4	92.5
STCR recommendation	1.33	190.3	68.5	348.3	1.17	291.3	27.9	99.3
100%NP	1.15	187.0	75.4	301.3	0.99	181.0	29.3	90.2
100% NPKZnS	1.14	198.0	69.6	403.3	1.51	356.3	37.2	154.8
100% NPKZnS + FYM/PM @ 5t/ha	1.37	178.3	84.4	369.0	1.70	396.6	38.1	183.5
100% NPK –Zn	1.25	189.3	62.0	349.0	1.01	292.0	27.1	157.7
100% NPK – S	1.34	182.3	74.1	359.3	1.10	362.6	32.7	148.5
100%NPK-S+ 1timelime/ha	-	-	-	-	1.13	371.2	31.2	152.2
100% N+50% PK	1.23	267.0	70.5	371.0	0.98	285.1	26.5	85.6
50 % NPK	1.28	173.7	65.2	347.7	0.77	223.7	26.6	85.8
50 % NPK + Biofertilizer	1.26	214.7	74.5	352.7	1.22	357.4	34.2	157.5
373.750% NPK+ 50% GM-N	1.24	185.7	65.8	352.3	1.58	394.5	32.0	142.1
50% NPK + 50% FYM-N	1.29	200.3	68.5	339.0	1.53	355.6	32.7	159.3
50% NPK + 25%GM-N+25%FYM-N	1.39	180.3	72.9	419.3	1.55	378.7	33.0	159.7
FYM @ 10 t/ha	1.43	180.7	71.4	415.7	1.73	401.2	38.5	175.1
FYM@10 t/ha +3.0 t/ha Vermicompost +200 kg/ha oil cakes	1.36	206.7	72.2	394.7	-	-	-	-
Expt. Mean	1.29	192.0	70.0	366.4	1.21	307.7	29.3	128.7
CD (0.05)	0.15	40.5	9.5	36.2	0.10	37.9	4.4	11.4
CV (%)	6.87	12.8	8.2	6.0	5.99	8.7	10.5	6.3

Table 5.1.8: Long-term soil fertility management in RBCS, *Kharif* 2023
Soil fertility status at harvest (Mandya)

Treatments	Mandya			
	Org. C (%)	Avail. N (kg/ha)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)
Control	0.23	218.8	37.7	97.1
100% PK	0.35	220.5	45.9	129.0
100% NK	0.35	248.8	42.2	139.0
STCR recommendation	0.41	253.9	49.2	143.7
100%NP	0.44	259.2	48.4	126.0
100% NPKZnS	0.55	273.8	52.7	214.6
100% NPKZnS + FYM/PM @ 5t/ha	0.66	252.0	60.7	253.9
100% NPK –Zn	0.34	262.9	50.3	222.8
100% NPK – S	0.36	267.3	52.7	235.7
100%NPK-S+ 1timelime/ha	-	-	-	-
100% N+50% PK	0.45	259.8	49.9	237.7
50 % NPK	0.54	236.4	46.3	243.4
50 % NPK + Biofertilizer	0.57	278.3	51.8	228.4
373.750% NPK+ 50% GM-N	0.61	292.8	52.2	233.0
50% NPK + 50% FYM-N	0.69	299.8	52.2	245.1
50% NPK + 25%GM-N+25%FYM-N	0.64	314.7	62.3	254.0
FYM @ 10 t/ha	0.63	320.7	53.3	243.2
FYM@10 t/ha +3.0 t/ha Vermicompost +200 kg/ha oil cakes	0.59	312.2	54.4	233.2
Expt. Mean	0.49	268.9	50.7	204.7
CD (0.05)	0.05	17.0	5.3	9.6
CV (%)	4.62	3.0	4.9	2.2

Table 5.1.9: Long-term soil fertility management in RBCS
Linear trends of changes in *Kharif rice* yields (t/ha) from 1989 to 2023

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	2.87	12	2.57	1.96	-50	2.88	2.20	-51	3.09
100% PK	3.58	44	2.78	3.29	43	2.51	2.70	-36	3.33
100% NK	4.13	6	4.02	3.60	27	3.12	3.35	-73	3.35
100% NP	4.52	-3	4.58	3.79	22	3.39	3.76	-81	3.76
100% NPK + Zn + S	5.13	21	4.75	4.47	43	3.71	4.73	-23	4.73
100% NPKZnS + FYM	5.34	80	3.46	5.06	72	3.38	5.31	55	5.31
100% NPK – Zn	4.72	0	4.73	4.20	22	3.79	4.47	-50	4.47
100% NPK – S	4.79	8	4.65	4.16	7	4.02	4.38	-46	4.38
100% N + 50% PK	4.52	11	4.31	3.67	-2	3.70	4.05	-55	4.05
50% NPK	4.38	14	4.13	3.20	-26	3.67	3.72	-41	3.72
50% NPK + 50% GM-N	4.55	18	4.22	3.88	29	3.35	4.75	-7	4.75
50% NPK + 50% FYM-N	4.83	23	4.41	4.03	37	3.37	4.82	2	4.82
50% NPK + 25% GM-N + 25%FYM-N	4.64	25	4.19	4.10	37	3.44	5.39	8	5.39
FYM @ 10 t/ha	4.52	20	4.15	4.15	54	3.19	4.18	22	4.18

Table 5.1.10: Long-term soil fertility management in RBCS
Linear trends of changes in *Rabi* rice yields (t/ha) from 1989 to 2023

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	2.32	41	1.42	1.66	-32	2.20
100% PK	3.09	72	1.75	3.02	48	2.23
100% NK	4.12	29	3.59	3.27	23	2.89
100% NP	4.96	6	4.85	3.43	15	3.19
100% NPK + Zn + S	5.76	4	5.00	3.93	34	3.38
100% NPKZnS + FYM/PM	6.34	12	6.29	4.39	41	3.52
100% NPK – Zn	5.21	22	4.81	3.70	21	3.35
100% NPK – S	5.33	25	4.86	3.58	17	3.29
100% N + 50% PK	5.17	17	4.85	3.41	15	3.16
50% NPK	4.29	18	3.96	2.83	-1	2.85
50% NPK + 50% GM-N	4.96	12	4.72	3.39	23	3.01
50% NPK + 50% FYM-N	5.24	39	4.52	3.50	33	2.95
50% NPK + 25% GM-N + 25% FYM-N	5.03	14	4.77	3.53	34	2.96
FYM @ 10 t/ha	4.21	45	3.39	3.56	41	2.88

Table: 5.1.11: Long-term soil fertility management in RBCS
Changes (%) in soil fertility parameters over 1989 to 2023

Treatments	Maruteru			Titabar			Mandya			
	OC	N	K	OC	P	K	OC	N	P	K
Control	-	-45.1	-11.1	-43.2	-15.9	-54.0	-34.3	-53.3	91.4	-17.0
100% NPK + Zn + S	28.1	-33.6	-0.7	58.9	181.8	6.0	57.1	3.2	167.5	83.4
100% NPK + Zn + S + 5 t/ha FYM	53.9	-40.2	-9.1	78.9	188.6	25.7	88.6	22.1	208.1	117.0
50% NPK + 25% GM-N + 25% FYM-N	56.2	-39.5	3.2	63.2	150.6	9.4	82.9	22.1	216.2	117.1
FYM @ 10 t/ha	60.7	-39.6	2.2	82.1	191.7	19.9	80.0	16.9	170.6	107.9

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

Sustainable rice production is essential to meet future food requirements while ensuring environmental stewardship and social equity. Adopting sustainable practices involves optimizing resource use, minimizing environmental impacts, and enhancing resilience to climate change. By embracing sustainability principles in rice production, we can not only meet the growing demand for rice but also safeguard the environment, conserve natural resources, and support the livelihoods of millions of farmers worldwide, thereby securing food security for future generations. Assessing soil quality and productivity is crucial for bridging yield gaps in farmers' fields. Ecology-wise and region wise yield gap analysis is a useful method to examine how large the ranges are between potential, desirable rice yields and those realized in farmers' fields. Proper and balanced nutrient application is must to meet the growth requirements of a genotype for realizing the yield potential of several contemporary genotypes. Current fertilizer management practices are age-old, in general, and 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 centres – Chinsurah (pool of 31 farmers), Pantnagar (pool of 40 farmers), Kanpur (pool of 21 farmers), Kaul (pool of 20 farmers). The specific aim was 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 validate fertilizer recommendations for targeted yields. The *kharif* 2023 data received representing the irrigated and shallow lowland rice ecosystems are presented in Tables 5.2.1 to 5.2.5. The test varieties were Swarna, Khitish, Shatabdi at Chinsurah, CSR 30, PB 1847, VNR 2222, PR 114, PB 1718, PB 1509, PB 1121at Kaul, Pioneer 3727, Kaveri 9090, Arize 6449, Arize 6450, JK, Sudha, Arize 6444 Pioneer 273037, Pioneer 203031 and Pioneer 203037 at Kanpur and Pusa 150, PD 10, PD18, PD 12, Hybrid, Local, HR47, Sarbat at Pantnagar. The methodology involved as conduction of a survey in nearby villages during *Kharif* 2023 involving data collection from various farmers' fields at different locations across different rice ecologies. The farmers' fields were grouped into two categories of 'low' and 'high' yield. Soil and plant samples were collected from the field after harvest and analysed for their nutrient contents, and soil quality indexes were calculated. For next season's crop, site-specific recommendations to the farmers have been generated and are being given for higher productivity and soil health improvement. The details of crop, soil and weather parameters of the experimental sites, presented in 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 farmers' fields. Sharp variations in mean grain yields recorded varied from 2.12 t /ha among low yielders to 4.74 t /ha among high yielders at Chinsurah, varied from 5.07 t /ha among low yielders to 6.97t /ha among high yielders at Kanpur, varied from 4.5 t /ha among low yielders to 5.8 t /ha among high yielders at Pantnagar from 3.1 t /ha among low yielders to 5.8 t/ha among high yielders at Kaul. 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 chinsurah due to considerable variation among the farm sites and soil test values. The soil quality index was much superior at Kanpur, Pantnagar and Kaul. Table 5.2.3 recorded the nutrient requirement per ton grain yield variations obtained at all the centres. Nutrient requirement calculations were useful to know how the responses were for fertilizers applied per ton of the grain yield and were worked out for all the farm sites and varied as : Pantnagar – 8.31,1.02,5.96 kg/t grain for N, P, K respectively for low yielders group of farmers and 8.18,1.46,4.92 kg/t grain for N, P, K respectively for high yielders group of farmers respectively, Kaul – 16.29,5.90,1.95 kg/t grain for N, P, K respectively for low yielders group of farmers and 17.28,6.76,2.26 kg/t grain for N, P, K respectively for high yielders group of farmers respectively, Kanpur – 23.4,6.6,14 kg/t grain for N, P, K respectively for low yielders group of farmers and 22.71,40.85,22.42 kg/t grain for N, P, K respectively for high yielders group of farmers at these locations Large variations were seen for nutrient uptake between low yielders and high yields across the centres. Soil nutrient uptake for major nutrients varied widely among the sites. Nutrient requirement values proved that large variations were recorded among the two different groups of farmers and also among the NPK nutrients. (Table 5.2.3), while soil test values did not match the yields recorded with rice yield and nutrient uptake at both locations, suggesting perhaps less suitability of current soil testing methods for flooded soils. Fertilizer prescriptions were worked out for all the farm sites and specific fertilizer recommendations were suggested for target yield: Chinsurah – 4.76 t/ha, Pantnagar - 6.0 t/ha**,** Kaul – 6.6 t/ha, Kanpur – 7.0 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 the lower recovery efficiency of applied P and higher accumulation of potassium per ton of grain. The study, thus indicated ample scope for improvement in nutrient use efficiency, and an attempt has been made to refine the current blanket recommended dose of fertilizer based on site-specific nutrient supply, nutrient use efficiency and crop demand. The yields had considerable variation with the farmers' fertilizer practices, respectively with corresponding variations in soil test values and uptake patterns followed. Wide variations in yields were recorded under recommended fertilizer practices and with all the nutrients under farmers' practice indicating a mismatch of the fertilizer doses.

However, some centres reported soil quality index at par with their resulting grain yield and nutrient uptake patterns.

Yield Gap analysis

Yield gap analysis was done for all farm fields. The need was assessed to ascertain the gaps in technology and compare the yield variations among low yielders and high yielders vis-a-vis uptake, and 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 across the region. The results have been enlisted in the table no.5.2.4. The highest level of yield gap (49.7 %) was recorded at Chinsurah followed 27.7 at Kaul, 27.2 % at Kanpur, 17.3% at Pantnagar. This shows a wide gap of grain harvest existed. However, ample scope existed at these centre to increase yields.

Summary: This trial was, conducted in farmers' fields around a few selected centres – Chinsurah (pool of 31 farmers), Pantnagar (pool of 40 farmers), Kanpur (pool of 21 farmers) and Kaul(pool of 20 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 basic hypothesis aimed was that systematically assessing soil quality and productivity and implementing appropriate management strategies, farmers can bridge yield gaps and achieve sustainable agricultural production in their fields. The *kharif* 2023 data received representing the irrigated and shallow lowland rice ecosystems. Sharp variations in mean grain yields recorded varied from 2.12 t /ha among low yielders to 4.74 t /ha among high yielders at Chinsurah, varied from 5.07 t /ha among low yielders to 6.97t /ha among high yielders at Kanpur, varied from 4.5 t /ha among low yielders to 5.8 t /ha among high yielders at Pantnagar, from 3.81 t /ha among low yielders to 5.8 t/ha among high yielders at Kaul. 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 – 4.76 t/ha Pantnagar - 6.0 t/ha, Kaul – 6.6 t/ha, Kanpur – 7.0 t/ha (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 poorest soil quality index was calculated for farmers from Chinsurah due to considerable variation among the farm sites and soil test values. The highest level of yield gap (49.7 %) was recorded at Chinsurah, followed by 27.7 at Kaul, 27.2 % at Kanpur, and 17.3% at Pantnagar. This shows a wide gap in grain harvest existed. However, ample scope existed at these centres to increase yields.

Table 5.2.1. Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, K*harif* 2023

Soil, crop and weather data

Parameter	Chinsurah	Kanpur	Kaul	Pantnagar
Variety	Swarna , Khitish, Shatabdi	Pioneer 3727 Kaveri 9090 Arize 6449 Arize 6450 JK Sudha Arize 6444 Pioneer 273037 Pioneer 203031 Pioneer 203067	CSR 30 PB 1847 VNR 2222 PR 114 PB 1718 PB 1509 PB 1121	Pusa 150 PD 10 PD18 PD 12 Hybrid Local HR47 Sarbati
Crop growth	Good	Good	Good	good
RFD (kg NPK/ha)	Varying- 48-24-24, 50-25-25, 60-30-30, 70-35-35, 80-40-40	Varying 120,60,60 150,60,60 120,60,40 150,60,40 120,60,60 120,60,40	-	190:60:40 150:60:40 150:50:30 150:60:50 200:60:40 200:70:45
% Clay	-	-	-	
% Silt	-	-	-	
% Sand	-	-	-	
Soil Texture	-	-	-	
pH	6.49-7.20	7.98-8.82	7.84-8.98	7.0-8.0
EC(mmhos /cm)	0.18-0.44	0.85-1.41	0.19-0.66	0.17-0.54
Org. carbon (%)	0.85-1.28	0.43-0.78	0.44-0.67	0.28-0.72
Avail. N (kg/ha)	378-507	220-289	145-194	118-215
Avail. P_2O_5 (kg/ha)	85-103	14-25	26-44	6.9-17.3
Avail. K_2O (kg/ha)	265-320	185-274	323-398	138-219

Table 5.2.2. Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *Kharif*-2023

- Soil nutrient supply potential vis a vis nutrient uptake assessed among different farmers' categories

Categories/ Nutrient	**Chinsurah (total of 31 sites,** 12 low yielders and 19 high yielder sites)			**Kanpur (total of 30 sites, 2**1 low yielders and 9 high yielder sites)		
	Minimum	**Maximum**	**Mean***	**Minimum**	**Maximum**	**Mean****
Grain yield (t/ha)						
Low Yielders	1.79	2.33	2.12	4.72	5.43	5.07
High Yielders	4.27	4.98	4.74	6.18	7.37	6.97
Nutrient uptake (kg/ha)						
	Low Yielders					
N	-	-	-	107.1	127.56	117.33
P	-	-	-	25.93	45.04	33.48
K	-	-	-	13.06	126.84	69.95
	High Yielders					
N	-	-	-	137.1	180.5	158.9
P	-	-	-	43.59	320.59	286.9
K	-	-	-	128.1	182.5	157.3

Categories/ Nutrient	**Kaul**(Out of 20,14 low yielders, 6 high yielders)			**Pantnagar**(Out of 40,14 low yielders, 26 high yielders)		
	Minimum	**Maximum**	**Mean***	**Minimum**	**Maximum**	**Mean****
Grain yield (t/ha)						
Low Yielders	2.8	3.3	3.1	4.3	4.9	4.5
High Yielders	4.8	8.8	5.8	5.0	6.8	5.8
Nutrient uptake (kg/ha)						
	Low Yielders					
N			77.57	49.45	80.84	63.83
P			28.13	8.17	12.22	10.01
K			9.30	48.6	72.85	58.31
	High Yielders					
N			113.93	69.5	9	55
P			44.59	115.91	15.86	97.02
K			14.93	85.70	12.43	78.99

Table 5.2.3. Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2023
- Nutrient Requirement per ton grain yield

Farmers categories	Chinsurah			Kanpur		
	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	-	-	5.07		-
N		-	-		117.33	23.4
P		-	-		33.48	6.6
K		-	-		69.95	14
High Yielders (34 sites)	4.73	-	-	6.97	-	-
N		-	-		158.9	22.71
P		-	-		286.9	40.85
K		-	-		157.3	22.42

Farmers categories	Kaul			Pantnagar		
	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	77.57	16.29	4.83	63.83	8.31
P		28.13	5.90		10.01	1.02
K		9.30	1.95		58.31	5.96
High yielders						
N	6.59	113.93	17.28	5.84	**47.8**	8.18
P		44.59	6.76		**8.58**	1.46
K		14.93	2.26		**28.69**	4.92

Table 5.2.4 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2023
Site-specific fertilizer recommendation (kg/ha) for a target yield

Site /centres	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-4.75 Kaul-6.6,Kanpur-7.0,Pantnagar-6.0		
				N (Urea)	P_2O_5 (SSP)	K_2O (Potash)
Chinsurah	2.38	4.73	49.7	95	24	53
Pantnagar	4.83	5.84	17.3	49	12	30
Kaul	4.76	6.59	27.7	114	44	20
Kanpur	5.07	6.97	27.2	158	42	156

Table 5.2.5 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2023
Soil Quality Indices

Site /centres.	Soil Quality Indices low yielders group	Soil Quality Indices Yielders group (high yielders)
Chinsurah	0.72	0.45
Pantnagar	0.37	0.5
Kaul	0.5	0.67
Kanpur	0.46	0.88

5.3. Management of Sodic Soils Using Nano Zinc Formulations

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 and 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 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 micronutrients 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 in sodic soils. This trial has started in *Kharif-2021* with the nano Zn chemicals in a different concentration (20 and 50 ppm). In the current year, this trial was conducted at four different locations viz., *Kanpur, Mandya, Pusa and Faizabad*. The selected genotypes (CSR 23 and DRR Dhan 48) were evaluated under different set of nutrient management practices (Control; $ZnSO_4$ @ 0.5 % foliar spray; Nano Zn @ 20 ppm foliar spray; Nano Zn @ 50 ppm foliar spray; Soil application of $ZnSO_4$ @ 50 kg/ha; Silicic acid @ 40 ppm and Silicic acid @ 80 ppm). The experimental results are presented in tables 5.3.1- 5.3.14 and briefly discussed.

Yield Parameters

Yield parameters like tiller number and panicle number per meter square were represented in the table 5.3.2 and 5.3.3. Significant differences were observed in the tiller number due to varieties and treatments at all the centers except Pusa. Among the treatments, soil application of $ZnSO_4$ @ 50 kg/ha has produced highest tiller number (416) at Kanpur; foliar spray of silicic acid 80 ppm has recorded significantly higher tiller number (312) at Pusa; whereas foliar application of nano Zn @ 50 ppm has produced highest tiller number at Mandya (427) and Faizabad (304). In case of Varieties, DRR Dhan 48 registered significantly higher tiller number at all the locations except Mandya where CSR 23 registered higher tiller number per square meter. Panicles/m^2 differed significantly among the varieties and treatments at all locations except Pusa. Among the treatments, foliar application of nano Zn @ 50 ppm has registered higher panicle number at Mandya (304) and Faizabad (300) whereas soil application of $ZnSO_4$ @ 50 kg/ha has recorded higher panicle number at Kanpur (287). With respect to varieties, CSR 23 produced higher panicles at Kanpur (262) and Mandya (270) where as DRR Dhan 48 produced higher panicle number at Pusa (278) and Faizabad (297).

Grain and Straw yields

Grain and straw yields showed significant differences between the genotypes and treatments and depicted in table 5.3.4 and 5.3.5. At Kanpur, soil application of $ZnSO_4$ @ 50 kg/ha registered higher grain (4.30 t/ha) and straw (5.82 t/ha) yields whereas foliar application of nano Zn @ 50 ppm recorded on par grain (4.02 t/ha) and straw yields (5.38 t/ha). Between the varieties, CSR 23 has recorded significantly higher grain (3.71 t/ha) and straw (4.89 t/ha) yields compared to DRR Dhan 48.

In case of Mandya, foliar application of nano Zn @ 50 ppm recorded significantly higher grain (5.99 t/ha) and straw yields (6.74 t/ha) compared to all other treatments. With respect to varieties, CSR23 produced significantly higher grain (5.48 t/ha) and straw yields (6.22 t/ha) than CSR23.

At Pusa, foliar spray of silicic acid spray @ 80 ppm has produced significantly higher grain yield (3.62 t/ha) which was on par with soil application of $ZnSO_4$ @ 50 kg/ha (3.47 t/ha), foliar spray of nano Zn @ 50 ppm (3.40 t/ha) and silicic acid spray of 40 ppm (3.36 t/ha). Whereas, soil application of $ZnSO_4$ @ 50 kg/ha has registered higher straw yield (5.3 t/ha) which was on par with foliar spray of nano Zn @ 50 ppm (5.28 t/ha) and silicic acid spray of 80 ppm (5.14 t/ha). Between the varieties, DRR Dhan 48 has recorded significantly higher grain (3.45 t/ha) and straw (4.61 t/ha) yields compared to CSR 23.

In Faizabad, foliar spray of silicic acid spray @ 80 ppm has produced significantly higher grain yield (3.76 t/ha) and straw yield (4.45 t/ha) which was on par with foliar spray of nano Zn @ 50 ppm and silicic acid spray of 40 ppm. With respect to varieties, DRR Dhan 48 was significantly superior to CSR 23. Interaction between treatments and genotypes was found to be non-significant at most of the locations.

Nutrient uptake

Significant differences in nutrient uptake of NPK and Zn were observed at all the locations (Table 5.3.7 to 5.3.10). At Kanpur, soil application of $ZnSO_4$ @ 50 kg/ha has recorded higher NPKZn uptake; at Mandya, foliar spray of nano Zn @ 50 ppm has recorded higher NPK uptake whereas soil application of $ZnSO_4$ @ 50 kg/ha has recorded higher Zn uptake (265 g/ha). In case of Pusa, higher N and P uptake was noticed in Silicic acid 80 ppm spray and higher potassium and Zn uptake was recorded with soil application of $ZnSO_4$ @ 50 kg/ha. Whereas at Faizabad, foliar spray of nano Zn @ 50 ppm has recorded higher NP uptake and maximum k uptake was noticed with silicic acid 80 ppm spray. In case of varieties, DRR Dhan 48 has accumulated higher amount of NPKZn at Pusa and Faizabad and CSR 23 recorded significantly higher nutrient uptake at Mandya and Kanpur.

Uptake of Zn in Grain and straw: Zinc accumulation in grain and straw significantly differed among the treatments at all the locations however, varietal difference was non-significant (Table 5.3.11 - 5.3.13). Uptake of Zinc was more in straw compared to grain at all the locations due to higher concentration of Zn and higher straw yields. Soil application of $ZnSO_4$ @ 50 kg/ha has registered higher grain and straw Zn uptake at Kanpur and Pusa, Grain Zn uptake at Mandya. Whereas Nano Zn @ 50 ppm foliar spray accumulated more amount of Zn in and straw at Mandya.

Post-harvest soil Zn status: The available Zn status in soil after harvest was significantly differed among the treatments but not between the varieties (Table 5.3.14). Application of $ZnSO_4$ @ 50 kg/ha has recorded significantly higher Zn status in Mandya (1.89 mg/kg) and Pusa (0.76 mg/kg) compared to rest of the treatments.

Summary:

Significant genotypic and location-specific differences in yield parameters and yield were observed at all four locations. At Kanpur, soil application of $ZnSO_4$ @ 50 kg/ha registered higher grain (4.30 t/ha) and straw (5.82 t/ha) yields whereas at Mandya, foliar application of nano Zn @ 50 ppm recorded significantly higher grain (5.99 t/ha) and straw yields (6.74 t/ha). Foliar spray of silicic acid @ 80 ppm has recorded higher grain yields (3.62 and 3.76 t/ha) at Pusa and Faizabad respectively. In case of Varieties, DRR Dhan 48 found superior at Pusa and Faizabad and CSR23 performed better at Kanpur and Mandya. Nutrient uptake also followed similar trend as that of grain and straw yields. The variety DRR Dhan 48 has accumulated higher amount of NPK and Zn at Pusa and Faizabad and CSR 23 recorded significantly higher nutrient uptake at Kanpur and Mandya.

Table 5.3.1: Management of Sodic soil using nano zinc formulations (Crop and soil characteristics)

Parameters	Kanpur	Mandya	Pusa	Faizabad
Season	***Kharif* -2023**	***Kharif* -2023**	***Kharif* -2023**	***Kharif* -2023**
Varieties	CSR 23, DRR Dhan 48	CSR 23, DRR Dhan 48	CSR 23 DRR Dhan 48	CSR 23 DRR Dhan 48
Fertilizer dose	150:60:60	125:62.5:50	120:60:40:50	120:60:60:2
Soil pH	9.90	8.67	9.71	9.6
Soil EC (dS/m)	0.23	0.39	0.67	2.85
Available N (kg/ha)	147	269	168	210
Available P (kg/ha)	12.4	34.1	17.4	25
Available K (kg/ha)	208	280	113	235
Texture	Sandy Clay Loam	Sandy Loam	Sandy Loam	Sandy Loam
OC (%)	0.21	0.57	0.38	0.39
DTPA-Zn (mg/kg)	0.48	0.65	0.48	-

Table 5.3.2: Management of Sodic soils using nano Zn formulations, Tillers /m^2 of rice at different locations

Treatments/ Varieties	Kanpur			Mandya			Pusa			Faizabad		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	286	291	288	362	335	348	218	275	247	245	285	265
$ZnSO_4$ @ 0.5 % foliar spray	332	346	339	374	365	369	265	311	288	266	272	269
Nano Zn @ 20 ppm foliar spray	355	367	361	426	416	421	267	318	292	280	299	289
Nano Zn @ 50 ppm foliar spray	376	391	384	431	422	427	273	313	293	293	315	304
Soil application of $ZnSO_4$ @ 50 kg/ha	396	437	416	420	394	407	283	325	304	279	308	294
Silicic acid @ 40 ppm	324	348	336	399	394	397	264	308	286	273	315	294
Silicic acid @ 80 ppm	334	349	342	405	403	404	295	329	312	288	317	302
Mean	343	361	352	402	389	396	266	311	289	275	301	288
CD M	28.5			23.0			NS			6.27		
CD S	15.2			7.52			8.35			2.97		
M X S	NS			NS			NS			7.85		
S XM	NS			NS			NS			7.12		
CV (%) M	6.4			4.63			14.5			2.07		
CV (%) S	6.50			2.87			4.87			1.85		

Table 5.3.3: Management of Sodic soils using nano Zn formulations, panicles /m^2 of rice at different locations

Treatments/ Varieties	Kanpur			Mandya			Pusa			Faizabad		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	221	216	219	224	223	224	196	249	222	241	281	261
ZnSO4 @ 0.5 % foliar spray	259	246	253	256	245	251	238	278	258	263	268	265
Nano Zn @ 20 ppm foliar spray	267	258	263	276	267	272	242	285	264	276	295	285
Nano Zn @ 50 ppm foliar spray	279	261	270	312	296	304	243	281	262	290	310	300
Soil application of $ZnSO_4$ @ 50 kg/ha	291	283	287	281	275	278	254	291	273	276	304	290
Silicic acid @ 40 ppm	253	241	247	268	265	267	236	274	255	268	310	289
Silicic acid @ 80 ppm	265	252	259	275	274	275	266	293	280	284	313	298
Mean	262	251	256	270	263	267	239	278	259	271	297	284
CD M	9.23			18.0			NS			6.14		
CD S	5.71			NS			8.35			3.11		
M X S	NS			NS			NS			8.24		
S XM	NS			NS			NS			7.28		
CV (%) M	2.86			5.38			14.7			2.06		
CV (%) S	3.36			6.92			4.87			1.97		

Table 5.3.4: Management of Sodic soils using nano Zn formulations, Grain yields (t/ha) of rice at different locations

Treatments/ Varieties	Kanpur			Mandya			Pusa			Faizabad		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	2.88	2.61	2.74	4.59	4.52	4.56	2.53	3.02	2.78	2.22	3.04	2.63
$ZnSO_4$ @ 0.5 % foliar spray	3.52	3.25	3.38	5.31	5.27	5.29	2.78	3.32	3.05	2.64	3.69	3.16
Nano Zn @ 20 ppm foliar spray	3.88	3.52	3.7	5.65	5.62	5.64	2.89	3.39	3.14	2.86	3.96	3.41
Nano Zn @ 50 ppm foliar spray	4.17	3.87	4.02	6.02	5.96	5.99	3.22	3.57	3.4	3.25	4.20	3.72
Soil application of $ZnSO_4$ @ 50 kg/ha	4.43	4.17	4.30	5.73	5.64	5.68	3.32	3.62	3.47	3.09	4.11	3.6
Silicic acid @ 40 ppm	3.42	3.18	3.30	5.44	5.34	5.39	3.22	3.51	3.36	3.06	4.25	3.66
Silicic acid @ 80 ppm	3.68	3.43	3.56	5.63	5.57	5.6	3.52	3.72	3.62	3.19	4.34	3.76
Mean	3.71	3.43	3.57	5.48	5.42	5.45	3.07	3.45	3.26	2.90	3.94	3.42
CD M	0.43			0.25			0.32			0.11		
CD S	0.20			NS			0.16			0.05		
M X S	NS			NS			NS			0.14		
S XM	NS			NS			NS			0.13		
CV (%) M	9.57			3.67			7.71			3.19		
CV (%) S	8.63			3.75			7.50			2.77		

Table 5.3.5: Management of Sodic soils using nano Zn formulations, Straw yields (t/ha) of rice at different locations

Treatments/ Varieties	Kanpur			Mandya			Pusa			Faizabad		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	3.72	3.41	3.56	5.65	5.23	5.44	3.88	4.61	4.24	2.62	3.58	3.1
ZnSO4 @ 0.5 % foliar spray	4.58	4.28	4.43	5.94	5.89	5.92	4.36	5.1	4.73	3.11	4.35	3.73
Nano Zn @ 20 ppm foliar spray	5.09	4.69	4.89	6.35	6.27	6.31	4.41	5.14	4.78	3.39	4.69	4.04
Nano Zn @ 50 ppm foliar spray	5.54	5.22	5.38	6.82	6.65	6.74	4.93	5.62	5.28	3.83	4.97	4.4
Soil application of $ZnSO_4$ @ 50 kg/ha	5.98	5.67	5.82	6.48	6.24	6.36	4.89	5.71	5.3	3.66	4.63	4.14
Silicic acid @ 40 ppm	4.45	4.19	4.32	5.99	5.94	5.96	4.58	4.98	4.78	3.62	5.06	4.34
Silicic acid @ 80 ppm	4.85	4.57	4.71	6.33	6.23	6.28	5.00	5.28	5.14	3.77	5.13	4.45
Mean	4.89	4.58	4.73	6.22	6.06	6.14	4.58	4.61	4.89	3.43	4.63	4.03
CD M	0.58			0.24			0.37			0.19		
CD S	0.27			0.12			0.3			0.11		
M X S	NS			NS			NS			NS		
S XM	NS			NS			NS			NS		
CV (%) M	9.81			3.13			6.05			4.56		
CV (%) S	8.52			2.9			9.25			4.80		

Table 5.3.7: Management of Sodic soils using nano Zn formulations, Total nutrient uptake of rice at Kanpur

Treatments/ Varieties	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)			Zn uptake (g/ha)		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	37.5	35.1	36.3	12.9	11.9	12.4	48.1	45.0	46.6	112	109	111
$ZnSO_4$ @ 0.5 % foliar spray	51.0	48.5	49.8	17.6	16.9	17.3	63.9	60.5	62.2	194	184	189
Nano Zn @ 20 ppm foliar spray	60.1	55.0	57.6	19.7	18.9	19.3	72.1	67.8	69.9	227	215	221
Nano Zn @ 50 ppm foliar spray	66.8	64.2	65.5	22.5	22.2	22.4	79.5	77.4	78.4	271	260	266
Soil application of $ZnSO_4$ @ 50 kg/ha	74.2	71.2	72.7	25.1	24.7	24.9	87.7	85.7	86.7	309	299	304
Silicic acid @ 40 ppm	49.5	47.2	48.3	17.0	16.2	16.6	61.1	59.1	60.1	165	166	166
Silicic acid @ 80 ppm	54.8	52.0	53.4	18.5	17.6	18.1	67.6	65.0	66.3	189	180	185
Mean	56.2	53.2	54.7	19.0	18.3	18.6	68.5	65.7	67.1	209	202	206
CD M	10.5			2.57			9.27			35.8		
CD S	2.80			NS			NS			NS		
M X S	NS			NS			NS			NS		
S XM	NS			NS			NS			NS		
CV (%) M	15.2			10.9			10.9			13.8		
CV (%) S	7.71			9.05			8.53			8.57		

Table 5.3.8: Management of Sodic soils using nano Zn formulations, Total nutrient uptake of rice at Mandya

Treatments/ Varieties	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)			Zn uptake (g/ha)		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	76.7	69.9	73.3	12.6	10.9	11.8	59.9	54.2	57.0	121	127	124
$ZnSO_4$ @ 0.5 % foliar spray	93.1	94.3	93.7	15.4	17.3	16.4	67.9	70.0	69.0	184	182	183
Nano Zn @ 20 ppm foliar spray	103.3	104.6	103.9	20.9	21.8	21.3	88.6	87.4	88.0	203	210	207
Nano Zn @ 50 ppm foliar spray	120.3	117.3	118.8	27.2	25.9	26.5	102.6	97.0	99.8	252	254	253
Soil application of $ZnSO_4$ @ 50 kg/ha	100.8	97.4	99.1	20.3	19.8	20.0	77.7	74.8	76.2	263	267	265
Silicic acid @ 40 ppm	89.9	89.9	89.9	18.9	19.7	19.3	69.0	67.5	68.3	179	182	180
Silicic acid @ 80 ppm	96.7	96.3	96.5	22.9	21.2	22.1	72.0	71.5	71.7	193	197	195
Mean	97.2	95.6	96.4	19.7	19.5	19.6	76.8	74.6	75.7	199	202	200
CD M	4.30			2.73			7.59			7.5		
CD S	NS			NS			2.10			NS		
M X S	NS			1.7			NS			NS		
S XM	NS			2.28			NS			NS		
CV (%) M	3.54			11.0			7.97			2.97		
CV (%) S	2.74			4.94			4.18			3.62		

Table 5.3.9: Management of Sodic soils using nano Zn formulations, Total nutrient uptake of rice at Pusa

Treatments/ Varieties	**N uptake (kg/ha)**			**P uptake (kg/ha)**			**K uptake (kg/ha)**			**Zn uptake (g/ha)**		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	38.6	51.6	45.1	11.6	11.7	11.7	46.3	69.0	57.6	189	285	237
$ZnSO_4$ @ 0.5 % foliar spray	47.9	62.5	55.2	12.7	11.9	12.3	53.7	81.0	67.3	233	332	282
Nano Zn @ 20 ppm foliar spray	55.4	63.1	59.2	12.4	11.9	12.2	56.5	84.3	70.4	280	360	320
Nano Zn @ 50 ppm foliar spray	62.5	72.2	67.3	13.0	12.4	12.7	68.3	95.0	81.6	334	428	381
Soil application of $ZnSO_4$ @ 50 kg/ha	67.7	76.0	71.8	12.9	12.1	12.5	69.4	98.2	83.8	358	451	405
Silicic acid @ 40 ppm	59.5	65.6	62.5	14.1	13.3	13.7	62.8	75.9	69.4	235	325	280
Silicic acid @ 80 ppm	69.9	75.4	72.7	16.3	14.0	15.1	71.5	91.5	81.5	280	362	321
Mean	57.3	66.6	61.9	13.2	12.4	12.8	61.2	84.9		273	363	318
CD M	5.65			1.15			11.4			18.3		
CD S	2.94			0.75			4.94			21.9		
M X S	NS			NS			NS			NS		
S XM	NS			NS			NS			NS		
CV (%) M	7.25			7.09			12.4			4.60		
CV (%) S	7.17			8.85			10.2			10.4		

Table 5.3.10: Management of Sodic soils using nano Zn formulations, Total nutrient uptake of rice at Faizabad

Treatments/ Varieties	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	38.7	58.9	48.8	20.0	32.2	26.1	27.4	40.4	33.9
$ZnSO_4$ @ 0.5 % foliar spray	47.9	80.5	64.2	26.4	43.7	35.1	36.2	53.5	44.8
Nano Zn @ 20 ppm foliar spray	56.4	85.1	70.7	32.0	50.8	41.4	41.4	62.5	52.0
Nano Zn @ 50 ppm foliar spray	68.2	97.9	83.1	38.8	57.6	48.2	49.6	68.4	59.0
Soil application of $ZnSO_4$ @ 50 kg/ha	61.0	84.8	72.9	33.7	48.0	40.9	43.4	59.3	51.3
Silicic acid @ 40 ppm	61.9	93.9	77.9	35.4	57.6	46.5	46.2	69.9	58.0
Silicic acid @ 80 ppm	66.0	96.3	81.1	36.3	58.4	47.3	48.1	72.4	60.2
Mean	57.1	85.3	71.2	31.8	49.8	40.7	41.7	60.9	65.0
CD M	4.24			2.86			3.12		
CD S	2.09			1.43			1.67		
M X S	5.54			3.71			4.41		
S XM	4.94			3.32			3.82		
CV (%) M	5.66			6.69			5.78		
CV (%) S	5.29			6.18			5.84		

Table 5.3.11: Management of Sodic soils using nano Zn formulations, uptake of Zinc in grain and straw of rice at Kanpur

Treatments/ Varieties	Grain Zn uptake			Straw Zn uptake		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	37	35	36	74	75	75
$ZnSO_4$ @ 0.5 % foliar spray	75	70	73	119	114	116
Nano Zn @ 20 ppm foliar spray	89	83	86	138	132	135
Nano Zn @ 50 ppm foliar spray	106	101	103	165	160	163
Soil application of $ZnSO_4$ @ 50 kg/ha	123	118	120	187	182	184
Silicic acid @ 40 ppm	67	66	67	98	99	99
Silicic acid @ 80 ppm	74	72	73	115	109	112
Mean	82	78	80	128	124	126
CD M	13.5			2.5		
CD S	NS			NS		
M X S	NS			NS		
S XM	NS			NS		
CV (%) M	13.4			16.2		
CV (%) S	13.2			9.59		

Table 5.3.12: Management of Sodic soils using nano Zn formulations, uptake of Zinc in grain and straw of rice at Mandya

Treatments/ Varieties	Grain Zn uptake			Straw Zn uptake		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	36	37	36	86	90	88
$ZnSO_4$ @ 0.5 % foliar spray	68	69	68	117	114	115
Nano Zn @ 20 ppm foliar spray	75	80	78	128	130	129
Nano Zn @ 50 ppm foliar spray	99	98	98	153	156	155
Soil application of $ZnSO_4$ @ 50kg/ha	111	115	113	153	153	153
Silicic acid @ 40 ppm	68	73	70	112	109	110
Silicic acid @ 80 ppm	75	77	76	118	119	119
Mean	76	78	77	124	124	124
CD M	4.3			5.1		
CD S	NS			NS		
M X S	NS			NS		
S XM	NS			NS		
CV (%) M	4.47			3.32		
CV (%) S	6.19			3.28		

Table 5.3.13: Management of Sodic soils using nano Zn formulations, uptake of Zinc in grain and straw of rice at Pusa

Treatments/ Varieties	Grain Zn uptake			Straw Zn uptake		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	62	101	82	128	184	156
$ZnSO_4$ @ 0.5 % foliar spray	83	119	101	150	213	182
Nano Zn @ 20 ppm foliar spray	103	139	121	177	221	199
Nano Zn @ 50 ppm foliar spray	119	158	139	215	270	242
Soil application of $ZnSO_4$ @ 50 kg/ha	125	162	143	234	289	261
Silicic acid @ 40 ppm	82	119	100	154	206	180
Silicic acid @ 80 ppm	99	132	116	182	229	205
Mean	96	133	115	177	230	204
CD M	13			22		
CD S	8			17		
M X S	NS			NS		
S XM	NS			NS		
CV (%) M	9.13			8.70		
CV (%) S	10.6			12.6		

Table 5.3.14: Management of Sodic soils using nano Zn formulations, Post-harvest soil zinc status

Treatments/ Varieties	Mandya			Pusa		
	CSR 23	DRR Dhan 48	Mean	CSR 23	DRR Dhan 48	Mean
Control	0.79	0.88	0.84	0.57	0.53	0.55
ZnSO4 @ 0.5 % foliar spray	0.96	0.91	0.94	0.6	0.6	0.6
Nano Zn @ 20 ppm foliar spray	0.98	0.98	0.98	0.59	0.58	0.58
Nano Zn @ 50 ppm foliar spray	1.02	1.11	1.06	0.61	0.58	0.6
Soil application of $ZnSO_4$ @ 50 kg/ha	1.94	1.84	1.89	0.77	0.74	0.76
Silicic acid @ 40 ppm	0.78	0.88	0.83	0.59	0.58	0.58
Silicic acid @ 80 ppm	0.87	0.83	0.85	0.61	0.6	0.6
Mean	1.05	1.06	1.05	0.62	0.60	0.61
CD M	0.06			0.05		
CD S	NS			NS		
M X S	NS			NS		
S XM	NS			NS		
CV (%) M	4.18			6.68		
CV (%) S	5.82			7.86		

5. 4 Management of Acid Soils (*Kharif*)

Acid soils are widespread 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, aluminium in the uplands, with depletion of Ca, Mg and K, and deficiency of B, Mo and Si. The soils also fix large quantities of soluble P, which leads 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, the identification of suitable genotypes with high yield potential helps stabilize rice productivity. The trial was, therefore, conducted at two centres *viz*., Moncompu (Kuttanad, Kerala, soil pH 4.46) and Titabar (Assam, soil pH 5.3) under irrigated conditions during *Kharif* 2023. The genotypes Uma and Vasundhara were evaluated under eight sets of nutrient management treatments *viz*., i) RDF, ii) RDF + Silixol spray (at vegetative, booting and grain filling stage), iii) RDF + Rice husk ash, 500 kg/ha (300 kg/ha basal and 200 kg/ha 30 days after transplanting), iv) RDF + Dolomite, 500 kg/ha (300 kg/ha basal and 200 kg/ha 30 days after transplanting), v) RDF + Silixol spray (at vegetative, booting and grain filling stage) + Dolomite 250 kg/ha, 30 days after transplanting, vi) RDF + Rice husk ash, 250 kg/ha during land preparation + Dolomite 250 kg/ha, 30 days after transplanting, vii) RDF + Potassium Silicate Solution- Four sprays at 15 days interval starting from 15 DAT (days after transplanting) and viii) RDF + Dolomite + Potassium Silicate Solution- Four sprays at 15 days intervals starting from 15 DAT (days after transplanting). The details of crop, soil, and weather parameters of the experimental sites (Table 5.4.1) show variations in soil characteristics with reference to pH, organic carbon content, soil texture and available nutrient status. The experimental results are presented in Tables 5.4.2 – 5.4.11 and briefly discussed.

Yield and yield parameters

At Moncompu (MCP), the application of dolomite + potassium silicate in combination with RDF (4.60 t/ha) and application of RDF + dolomite (4.35t/ha) yielded significantly higher than other treatments (Table 5.4.4). The yields obtained with RDF + RHA (4.14 t/ha) and RDF + Dolomite + RHA (4.06 t/ha) application were on par, while the treatment that received only the recommended dose of fertilizer (RDF) recorded the lowest yield of 3.09 t/ha. Among varieties, the yield of Uma (3.91 t/ha) was significantly higher than Vasundhara (3.66 t/ha) at MCP. Straw yields recorded with RDF + dolomite + potassium silicate (7.74 t/ha) and RDF + dolomite (7.45 t/ha) were on par and significantly higher than other treatments. The highest number of tillers/m^2, panicles/m^2 and filled grain/panicle were recorded in RDF + dolomite

(207, 155, 115 respectively) which was on par with RDF + dolomite + potassium silicate (204, 158, 117 respectively) and RDF + dolomite + RHA (198, 151, 108 respectively) which were significantly higher in comparison to other treatments (Table 5.4.2). Similar to grain yield, the variety Uma recorded significantly higher tillers/m^2 (192), and filled grain/panicle (105). Thousand-grain weight was not significantly influenced by both nutrient management and varieties.

At Titabar (TTB), significant differences were observed in nutrient management treatments (Table 5.4.5), with the highest yield recorded in RDF + dolomite + Silixol spray treatment (4.51 t/ha), which was on par with RDF + dolomite + potassium silicate (4.34). The other treatments recorded comparable on-par yields ranging from 4.19 t/ha to 3.98 t/ha, while the lowest yields were observed in the treatments with RDF + RHA (3.89 t/ha) and sole RDF application (3.62 t/ha). Between the varieties, the genotype Uma recorded significantly superior yields (4.23 t/ha) compared to Vasundhara (3.94 t/ha). Straw yields followed similar trends as grain yields at Titabar for both nutrient management and varieties. A significantly higher number of tillers/hill (16), panicles/hill (14) and filled grain/ panicle (114) were observed following the application of RDF + dolomite + Silixol spray (Table 5.4.3). Significantly higher tillers/hill (14), panicles/hill (12) and filled grain/ panicle (105) were observed in the variety Uma.

Total nutrient uptake

Different nutrient management practices significantly influenced total NPK uptake at Moncompu (Table 5.4.6). Among the treatments, RDF + dolomite + potassium silicate recorded significantly higher phosphorus uptake (44.01kg/ha), potassium uptake (111.84 kg/ha) and zinc uptake (281.29 g/ha) compared to the rest of the treatments. No significant differences were observed between genotypes for nutrient uptake. RDF + dolomite + Silixol spray recorded significantly higher nitrogen, phosphorus and potassium uptake (74.37 kg/ha, 13.85 kg/ha and 100.72 kg/ha, respectively) at Titabar (Table 5.4.7) compared to other treatments, while the variety Uma recorded significantly higher NPK uptake (63.51kg/ha, 11.31kg/ha and 87.46 kg/ha respectively) than Vasundhara.

Post-harvest soil properties

No significant effect of nutrient management was observed for soil pH and EC and soil OC% at Moncompu (Table 5.4.8). Between the varieties, soil EC was significantly higher in Vasundhara (0.13). The available N and P in soil were significantly higher under treatments with RDF + RHA (317.10 and 53.87 kg/ha respectively) and RDF + dolomite

(316.35 and 56.25 kg/ha respectively). No treatment differences were observed for soil-available potassium and zinc due to nutrient management practices (Table 5.4.9. No significant differences between varieties were observed for soil available nutrients. At Titabar, application of RDF + dolomite + RHA (6.15), RDF + dolomite + potassium silicate (6.13) and RDF + dolomite + Silixol (6.12) significantly increased the soil pH (Table 5.4.10). The soils grown with genotype Uma recorded significantly higher pH (5.68) compared to the soils with Vasundhara (5.66). Significantly higher accumulation of organic carbon was observed in the treatments with RDF + RHA (0.89%) and RDF + dolomite + RHA (0.88%). The available nitrogen status in soil showed a significant increase due to RDF + dolomite + RHA (319.83 kg/ha) and RDF + dolomite + Silixol (317.00 kg/ha) compared to other treatments. All treatments except RDF, RDF + Silixol and RDF + potassium silicate significantly increased soil available phosphorus (20.10-23.00 kg/ha). The available potassium in soil showed a significant increase due to RDF + dolomite + RHA (164.67 kg/ha), RDF + dolomite (162.67 kg/ha) and RDF + dolomite + potassium silicate (162.00 kg/ha) compared to other treatments (Table 5.4.11). No significant differences between varieties were observed for soil available nutrients at Titabar.

Summary

In comparison to the sole RDF application, RDF + dolomite + Silixol significantly improved the yield at Titabar by 24.58%, while the treatment RDF + dolomite + potassium silicate improved yields significantly at both at Moncompu (48.87%) and Titabar (19.89 %). The variety Uma recorded significantly higher yields over Vasundhara at both locations ranging from 6.83% from Moncompu to 7.36% at Titabar. Application of RDF + dolomite + RHA, RDF + dolomite + potassium silicate and RDF + dolomite + Silixol at Titabar, resulted in a significant increase in soil pH (6.15, 6.13 and 6.12 respectively) over control RDF treatment (5.2) indicating the improved ameliorative potential of application of RDF + dolomite (5.17) in combination with RHA, potassium silicate and Silixol. The effect of nutrient management on NPKZn uptakes varied with locations. At Moncompu, RDF + dolomite + potassium silicate increased the uptake of PKZn by 78.98, 67.75 and 65.48% respectively while at Titabar, RDF + dolomite + Silixol increased the uptake of NPK by 61.15, 84.42 and 69.85% respectively over sole RDF application.

Table 5.4.1: Management of acid soils (*Kharif*-2023)

Soil and crop characteristics

Parameter	**Moncompu**	**Titabar**
Cropping system	Rice - Rice	Rice -Fallow
Rice Variety	Vasundhara, Uma	Vasundhara, Uma
RDF (kg NPK/ha)	90:45:45	60:20:40
Crop growth	Good	Good
Soil Characteristics		
pH (1:2.5)	4.46	5.3
Org. carbon (%)	3.12	0.85
CEC [cmol (p+)/kg]		12.1
EC (ds/m)	0.09	
Avail.N (kg/ha)	322.8	311
Avail. P_2O_5 (kg/ha)	56.2	21.1
Avail. K_2O (kg/ha)	242.6	161.5
Avail S (mg/kg)	12.4	-
DTPA –Zn (mg/kg)	1.32	-
DTPA –Fe (mg/kg)	283	-
DTPA –Mn (mg/kg)	1.94	-
DTPA –Cu (mg/kg)	1.58	-

Table 5.4.2: Management of acid soils (*Kharif*-2023)

Yield parameters at Moncompu

Treatments	Tillers m^{-2}			Panicles m^{-2}			Filled grains/panicles			1000 grain weight (g)		
	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean
RDF	164	171	168	124	131	128	91	93	92	26.87	27.20	27.03
RDF + Silixol	173	179	176	132	136	134	88	93	90	26.73	26.90	26.82
RDF + RHA*	184	192	188	142	148	145	98	103	101	27.10	27.90	27.50
RDF + Dolomite	201	213	207	152	159	155	113	118	115	27.23	27.70	27.47
RDF + Dolomite + Silixol	185	189	187	140	144	142	97	102	100	27.47	27.87	27.67
RDF + Dolomite + RHA	194	202	198	148	153	151	104	113	108	27.07	27.60	27.33
RDF + K-Silicate	182	186	184	139	140	140	88	97	93	26.37	26.80	26.58
RDF + Dolomite +K-Silicate	201	207	204	153	164	158	115	119	117	27.17	27.70	27.43
Mean	**185**	**192**	**189**	**141**	**147**	**144**	**99**	**105**	**102**	**27.00**	**27.46**	**27.23**
Nutrient management												
CD (0.05)	13.23			10.66			13.26			NS		
CV%	5.60			5.92			10.40			4.44		
Varieties												
CD (0.05)	6.02			NS			4.04			NS		
CV%	5.17			6.74			6.43			3.17		
Interaction -M X S	NS			NS			NS			NS		
Interaction -S X M	NS			NS			NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.3: Management of acid soils (*Kharif*-2023)

Yield parameters at Titabar

	Tillers/hill			Panicles/hill			Filled grains/panicle		
Treatments	**Vasundhara**	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**
RDF	12	11	11	9	9	9	82	94	88
RDF + Silixol	15	15	15	12	13	12	96	106	101
RDF + RHA*	12	13	13	11	11	11	94	97	96
RDF + Dolomite	13	13	13	11	11	11	93	97	95
RDF + Dolomite + Silixol	16	16	16	14	14	14	110	119	114
RDF + Dolomite + RHA	13	14	14	11	12	12	107	109	108
RDF + K-Silicate	13	14	14	12	12	12	98	101	99
RDF + Dolomite +K-Silicate	15	15	15	13	13	13	107	115	111
Mean	**14**	**14**	**14**	**11.5**	**12**	**12**	**98**	**105**	**102**
Nutrient management									
CD (0.05)	1.25			1.40			12.96		
CV%	7.32			9.56			10.31		
Varieties									
CD (0.05)	NS			0.44			5.33		
CV%	7.07			6.11			8.57		
Interaction -M X S	NS			NS			NS		
Interaction -S X M	NS			NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.4: Management of acid soils (*Kharif*-2023)

Grain and straw yields at Moncompu

Treatments	Grain yield (t/ha)			Straw yield (t/ha)		
	Vasundhara	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**
RDF	3.01	3.17	3.09	5.15	5.43	5.29
RDF + Silixol	3.04	3.22	3.13	5.20	5.52	5.36
RDF + RHA*	4.00	4.28	4.14	6.85	7.38	7.12
RDF + Dolomite	4.25	4.44	4.35	7.30	7.60	7.45
RDF + Dolomite + Silixol	3.55	3.74	3.65	6.12	6.40	6.26
RDF + Dolomite + RHA	3.87	4.25	4.06	6.62	7.25	6.93
RDF + K-Silicate	3.14	3.39	3.27	5.40	5.77	5.58
RDF + Dolomite +K-Silicate	4.44	4.75	4.60	7.62	7.87	7.74
Mean	**3.66**	**3.91**	**3.78**	**6.28**	**6.65**	**6.47**
Nutrient management						
CD (0.05)	0.39			0.63		
CV%	8.34			7.77		
Varieties						
CD (0.05)	0.23			NS		
CV%	10.08			10.48		
Interaction -M X S	NS			NS		
Interaction -S X M	NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.5: Management of acid soils (*Kharif*-2023)

Grain and straw yields at Titabar

Treatments	**Grain yield (t/ha)**			**Straw yield (t/ha)**		
	Vasundhara	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**
RDF	3.46	3.79	3.62	3.77	4.13	3.95
RDF + Silixol	4.11	4.27	4.19	4.51	4.65	4.58
RDF + RHA*	3.73	4.04	3.89	4.07	4.41	4.24
RDF + Dolomite	3.84	4.12	3.98	4.19	4.50	4.34
RDF + Dolomite + Silixol	4.37	4.64	4.51	4.78	4.91	4.84
RDF + Dolomite + RHA	3.93	4.24	4.08	4.29	4.65	4.47
RDF + K-Silicate	3.88	4.22	4.05	4.23	4.61	4.42
RDF + Dolomite +K-Silicate	4.20	4.48	4.34	4.65	4.83	4.74
Mean	**3.94**	**4.23**	**4.08**	**4.31**	**4.59**	**4.45**
Nutrient management						
CD (0.05)	0.27			0.30		
CV%	5.39			5.37		
Varieties						
CD (0.05)	0.14			0.16		
CV%	5.64			6.02		
Interaction -M X S	NS			NS		
Interaction -S X M	NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.6: Management of acid soils (*Kharif*-2023)

Nutrient (NPK) uptake at Moncompu

Treatments	Total phosphorous uptake (kg/ha)			Total potassium uptake (kg/ha)			Total zinc uptake (g/ha)		
	Vasundhara	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**
RDF	23.02	26.15	24.59	64.00	69.33	66.67	163.79	176.18	169.98
RDF + Silixol	23.63	26.25	24.94	66.73	72.70	69.72	163.73	175.12	169.42
RDF + RHA*	36.10	41.94	39.02	95.09	104.21	99.65	233.42	254.10	243.76
RDF + Dolomite	40.06	40.37	40.21	105.90	109.27	107.58	262.65	279.98	271.31
RDF + Dolomite + Silixol	30.94	31.39	31.17	83.51	88.25	85.88	222.38	226.19	224.29
RDF + Dolomite + RHA	37.36	42.60	39.98	96.36	106.48	101.42	244.18	268.31	256.25
RDF + K-Silicate	27.09	28.36	27.73	73.24	79.36	76.30	179.44	185.42	182.43
RDF + Dolomite +K-Silicate	44.43	43.58	44.01	109.87	113.81	111.84	277.04	285.54	281.29
Mean	**32.83**	**35.08**	**33.95**	**86.84**	**92.93**	**89.88**	**218.33**	**231.35**	**224.84**
Nutrient management									
CD (0.05)	6.25			10.09			39.17		
CV%	14.73			8.98			13.94		
Varieties									
CD (0.05)	NS			NS			NS		
CV%	15.46			13.25			13.69		
Interaction -M X S	NS			NS			NS		
Interaction -S X M	NS			NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.7: Management of acid soils (*Kharif*-2023)

Nutrient (NPK) uptake at Titabar

Treatments	Total nitrogen uptake (kg/ha)			Total phosphorous uptake (kg/ha)			Total Potassium uptake (kg/ha)		
	Vasundhara	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**
RDF	42.95	49.34	46.15	6.95	8.08	7.51	56.00	62.59	59.30
RDF + Silixol	63.44	67.04	65.24	10.48	12.06	11.27	81.11	87.92	84.51
RDF + RHA*	49.01	54.07	51.54	8.21	9.83	9.02	66.80	84.14	75.47
RDF + Dolomite	51.83	57.25	54.54	8.72	9.92	9.32	69.17	80.52	74.84
RDF + Dolomite + Silixol	70.90	77.84	74.37	13.22	14.47	13.85	96.99	104.46	100.72
RDF + Dolomite + RHA	55.03	63.58	59.30	8.80	10.63	9.71	75.41	86.25	80.83
RDF + K-Silicate	58.14	64.90	61.52	9.99	11.72	10.85	81.30	92.64	86.97
RDF + Dolomite +K-Silicate	66.62	74.10	70.36	11.88	13.78	12.83	92.45	101.12	96.78
Mean	**57.24**	**63.51**	**60.38**	**9.78**	**11.31**	**10.54**	**77.40**	**87.46**	**82.43**
Nutrient management									
CD (0.05)	5.69			1.50			7.06		
CV%	7.61			11.48			6.92		
Varieties									
CD (0.05)	2.18			1.06			4.44		
CV%	5.89			16.43			8.81		
Interaction -M X S	NS			NS			NS		
Interaction -S X M	NS			NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.8: Management of acid soils (*Kharif*-2023)

Post-harvest soil characteristics at Moncompu

Treatments	Soil pH			Soil EC (dS/m)			Soil OC %		
	Vasundhara	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**
RDF	4.06	4.12	4.09	0.13	0.12	0.13	3.18	3.2	3.19
RDF + Silixol	4.17	4.24	4.21	0.14	0.11	0.13	3.22	3.21	3.22
RDF + RHA*	4.55	4.49	4.52	0.13	0.11	0.12	3.21	3.22	3.22
RDF + Dolomite	4.47	4.54	4.51	0.12	0.13	0.13	3.17	3.19	3.18
RDF + Dolomite + Silixol	4.26	4.37	4.31	0.14	0.12	0.13	3.17	3.15	3.16
RDF + Dolomite + RHA	4.47	4.47	4.47	0.13	0.10	0.12	3.2	3.13	3.17
RDF + K-Silicate	4.18	4.30	4.24	0.15	0.12	0.13	3.15	3.18	3.17
RDF + Dolomite +K-Silicate	4.32	4.38	4.35	0.13	0.12	0.13	3.18	3.19	3.18
Mean	4.31	4.36	4.34	0.13	0.12	0.13	3.19	3.18	3.18
Nutrient management									
CD (0.05)	NS			NS			NS		
CV%	5.81			19.02			5.05		
Varieties									
CD (0.05)	NS			0.02			NS		
CV%	5.25			18.91			10.19		
Interaction -M X S	NS			NS			NS		
Interaction -S X M	NS			NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.9: Management of acid soils (Kharif-2023)

Post-harvest soil characteristics at Moncompu (Soil available nutrients)

Treatments	Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)			Available Zn (mg/kg)		
	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean
RDF	283.10	278.40	280.75	51.60	50.53	51.07	239.93	236.90	238.42	4.06	4.12	4.09
RDF + Silixol	284.43	282.00	283.22	52.27	53.90	53.08	239.90	241.60	240.75	4.17	4.24	4.21
RDF + RHA*	315.77	318.43	317.10	52.83	54.90	53.87	242.37	244.43	243.40	4.55	4.49	4.52
RDF + Dolomite	313.83	318.87	316.35	55.27	57.23	56.25	238.90	243.20	241.05	4.47	4.54	4.51
RDF + Dolomite + Silixol	305.33	308.87	307.10	49.47	51.63	50.55	244.43	241.10	242.77	4.26	4.37	4.31
RDF + Dolomite + RHA	297.10	315.07	306.08	54.50	55.10	54.80	242.17	241.23	241.70	4.47	4.47	4.47
RDF + K-Silicate	294.70	283.07	288.88	54.83	52.90	53.87	239.13	244.47	241.80	4.18	4.30	4.24
RDF + Dolomite +K-Silicate	309.90	311.60	310.75	51.43	50.37	50.90	244.87	245.80	245.33	4.32	4.38	4.35
Mean	300.52	302.04	301.28	52.78	53.32	53.05	241.46	242.34	241.90	4.31	4.36	4.34
Nutrient management												
CD (0.05)	20.62			3.68			NS			NS		
CV%	5.47			5.54			5.57			8.18		
Varieties												
CD (0.05)	NS			NS			NS			NS		
CV%	5.97			9.64			6.90			9.25		
Interaction -M X S	NS			NS			NS			NS		
Interaction -S X M	NS			NS			NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Table 5.4.10: Management of acid soils (Kharif-2023)

Post-harvest soil characteristics at Titabar

Treatments	**Soil pH**			**Soil OC %**		
	Vasundhara	**Uma**	**Mean**	**Vasundhara**	**Uma**	**Mean**
RDF	5.20	5.20	5.20	0.84	0.83	0.84
RDF + Silixol	5.20	5.20	5.23	0.85	0.84	0.8
RDF + RHA*	5.23	5.10	5.17	0.87	0.90	0.89
RDF + Dolomite	6.03	6.07	6.05	0.85	0.85	0.85
RDF + Dolomite + Silixol	6.10	6.13	6.12	0.80	0.84	0.84
RDF + Dolomite + RHA	6.13	6.17	6.15	0.90	0.87	0.88
RDF + K-Silicate	5.27	5.37	5.32	0.84	0.85	0.84
RDF + Dolomite +K-Silicate	6.13	5.23	6.13	0.85	0.84	0.84
Mean	**5.66**	**5.68**	**5.67**	**0.86**	**0.86**	**0.85**
Nutrient management						
CD (0.05)	0.18			0.03		
CV%	5.67			2.69		
Varieties						
CD (0.05)	0.10			NS		
CV%	2.92			2.52		
Interaction -M X S	NS			NS		
Interaction -S X M	NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties), MCP- Moncompu, TTB- Titabar

Table 5.4.11: Management of acid soils (Kharif-2023)

Post-harvest soil characteristics at Titabar (Soil available nutrients)

Treatments	Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean	Vasundhara	Uma	Mean
RDF	310.00	312.67	311.33	20.60	20.00	20.33	160.00	159.33	159.67
RDF + Silixol	310.00	311.00	310.50	20.33	20.00	20.10	161.00	160.30	160.67
RDF + RHA*	313.33	312.00	312.67	22.33	21.67	22.00	163.33	162.00	162.67
RDF + Dolomite	315.33	314.67	315.00	22.00	21.33	21.67	160.33	161.00	160.67
RDF + Dolomite + Silixol	316.67	317.33	317.00	23.00	21.67	22.33	161.33	161.67	161.50
RDF + Dolomite + RHA	321.67	318.00	319.83	23.33	22.00	22.67	165.00	164.33	164.67
RDF + K-Silicate	312.00	311.67	311.83	22.00	20.33	21.17	162.33	161.33	161.83
RDF + Dolomite +K-Silicate	313.33	316.33	314.83	24.00	22.00	23.00	162.00	162.00	162.00
Mean	**314.04**	**314.21**	**314.13**	**22.21**	**21.12**	**21.70**	**161.92**	**161.50**	**161.71**
Nutrient management									
CD (0.05)	4.04			1.53			2.71		
CV%	1.04			5.71			1.35		
Varieties									
CD (0.05)	NS			0.83			NS		
CV%	1.43			6.25			0.73		
Interaction -M X S	NS			NS			NS		
Interaction -S X M	NS			NS			NS		

*Rice husk ash, M – Main plot (Nutrient management), S – Subplot (Varieties)

Trial 5: Residue management in rice-based cropping systems

In India, huge quantities of crop residues (about 500 million tons) are produced annually of which paddy residues constitute around 50%. The disposal of paddy residues has become a big problem, particularly in North-Western states, mainly due to the use of combine harvesters and the 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 the environment by depleting air quality, and emitting greenhouse gases (GHGs) but also causes smog in the environment, resulting in the loss of appreciable amounts 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 importance 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.

Keeping this in view, the present trial was initiated, in *Kharif* 2023, to study the influence of crop residues on rice productivity in rice-based cropping systems (RBCS). In the current year, the trial was conducted at eight centers *viz*., Faizabad (FZD), Khudwani (KHD), Kanpur (KPR), Karaikal (KRK), Maruteru (MTU), Moncompu (MCU), Pantnagar (PNT) and Pusa (PSA).

Last year, the treatments were simplified to six combinations consisting of application of recommended dose of fertilisers (RDF), crop residues in combination with chemical fertilizers, 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.) along with an absolute control. Pusa Decomposer is a microbial consortium, capable of producing hydrolytic enzymes responsible for the degradation of the polysaccharides in plant cell walls resulting in faster decomposition.

The test varieties were Samba Mahsuri Sub-1 at FZD, Shalimar Rice-4 at KHD, Sarjoo-52 at KNP, ADT 37 at KRK, Uma at MCU, MTU-1061 at MTU, Pant Dhan-18 at PNT and Rajendra Bhagwati at PSA. The details of crop, soil and weather parameters of the experimental sites (Table 5.5.2) show variations 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 5.5.8.

Rice productivity

Data presented in Tables 5.5.3 & 4 shows that the rice productivity significantly varied with the source of nitrogen. Application of 100% RDF resulted in significantly highest grain yield only at two centres *viz*., FZD (4.57 t/ha) and PNT (4.28 t/ha) while at other centers it was on par with residue application combined with microbial culture (*Pusa Decomposer*). Supplementation of recommended N through residues both at 25% and 50% along with *Pusa Decomposer* gave yields on par with 100% RDF at more than half of the centres studied *viz*., KHD, KNP, MCU, MTU and PUSA. At KRK the treatment differences were not significant. The results prove that the crop residues in combination with Pusa Decomposer can be deployed to substitute up to half of the recommended nitrogen without yield penalty. A similar trend was also observed for straw yield as well.

Nutrient uptake and use efficiency

Data presented in Table 5.5.5 show a significant effect of the source of N application on nutrient uptake. Application of RDF alone or 50% RDF combined with crop residues/MC/GM resulted in nutrient uptake values (18-146 kg N/ha, 2.8-51.9 kg P/ha and 14-197 kg K/ha) which were at par with each other and significantly higher than absolute control, across the centres.

Data presented in Table 5.5.6 show lower nutrient use efficiencies in RDF as compared to crop residue treatments which were mostly at par with each other, at most of the centres.

Post-harvest soil nutrient status:

The available nutrient status (N, P and K) of soils are presented in Table 5.5.7 & 8. 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) along with microbial consortium, Pusa Decomposer or GM, MC yielded at par with RDF (100% N) in terms of grain yield at more than half of the centres. The results show that the crop residues along with Pusa decomposer can be deployed to substitute half of the recommended nitrogen without yield penalty. Application of RDF alone or combined with crop residues/MC/GM to supply the N requirement on equal basis (50%:50%) resulted in nutrient uptake values (18-146 kg N/ha, 2.8-51.9 kg P/ha and 14-197 kg K/ha) which were at par with each other and significantly higher than absolute control, across the centres. 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	Treatments
1	100% RDF (Recommended Dose Fertilizer)
2	50% Residue + 50% RDF
3	50% Residue + 50% RDF + Pusa decomposer
4	50% Residue + 50% GM/GLM
5	75% RDF + 25% residue + Pusa Decomposer
6	Absolute control

Table: 5.5.2 Residue management in RBCS
Crop and soil characteristics

Parameter	**FZD [1]**	**KNP [2]**	**KRK [3]**	**KHD [4]**	**MTU [5]**	**MCU [6]**	**PNT [7]**	**PSA [8]**
Cropping system	Rice-Wheat	Rice-Wheat	Rice-Rice	Rice-Mustard	Rice-Rice	Rice-Rice	Rice-Wheat	Rice-Wheat
Kharif	Sambha Mahsuri	Sarjoo-52	ADT 37	Shalimar Rice-4	MTU-1061	Uma	Pant Dhan-18	Rajendra Bhagwati
Rabi	-	-	BPT 5204	-	-	-	-	-
Kharif	120:60:60	120: 60: 60	150:60:60	120:60:30	90: 60: 60	90:45:45	120:60:30	120:60:40
Rabi	-	-	-	-	-	-	-	-
Kharif	Good	Good	Good	Good	Good	Good	Good	Good
Rabi	-	-	-	-	-	-	-	-
% clay	23	17.83	17.4	37	38	-	25.9	15
% silt	21	22.77	2	45	28	-	61.4	26
% sand	56	59.4	82.76	18	34	-	12.9	59
Soil Texture	Sandy loam	Sandy loam	Sandy loam	Silty clay loam	Clay loam	Sandy loam	Silty clay loam	Sandy loam
pH (1:1)	7.6	7.8	6.24	6.5	6.12	4.98	7.4	8.59
Org. carbon (%)	0.42	0.49	0.625	0.73	1.36	3.12	0.63	0.51
CEC [cmol(p+)/kg]	13.5	-	10.2	-	48.6	-	23.5	-
EC (ds/m)	1.04	0.56	0.26	0.08	0.69	0.06	0.34	0.19
Avail.N (kg/ha)	218	219	290	315	132	309.4	152	239.8
Avail. P_2O_5 (kg/ha)	25	23.2	38.1	18.7	50.07	46.7	10.1	19.2
Avail. K_2O (kg/ha)	235	209	216	217	440	201.8	205	208.2

Table: 5.5.3 Residue Management in RBCS
Grain and straw yields (*Kharif* 2023)

Treatment	Grain yield (t/ha)								Straw yield (t/ha)							
	FZD [1]	**KNP [2]**	**KRK [3]**	**KHD [4]**	**MTU [5]**	**MCU [6]**	**PNT [7]**	**PSA [8]**	**FZD [1]**	**KNP [2]**	**KRK [3]**	**KHD [4]**	**MTU [5]**	**MCU [6]**	**PNT [7]**	**PSA [8]**
100% RDF	4.57	5.02	3.27	7.63	7.63	5.19	4.28	5.49	5.02	6.96	7.42	8.55	8.69	8.45	4.68	8.94
50% Residue + 50% RDF	3.29	4.48	3.45	6.45	6.77	4.04	3.36	4.76	3.63	6.18	7.41	7.16	7.97	7.64	4.19	8.11
50% Residue + 50% RDF + Pusa decomposer	3.72	4.75	3.27	6.69	7.28	4.25	3.70	4.93	4.12	6.59	6.84	7.88	9.16	7.84	4.18	7.97
50% Residue + 50% GM/GLM	2.92	4.27	3.27	6.14	7.67	3.91	3.50	4.53	3.27	5.91	6.51	8.2	8.96	7.1	4.18	7.66
75% RDF + 25% residue + Pusa Decomposer	3.92	4.93	2.98	7.39	7.45	4.95	3.83	5.10	4.38	6.83	7.27	8.21	8.92	8.24	4.2	8.01
Absolute control	2.44	2.11	2.77	5.6	3.75	2.85	1.23	3.28	2.72	2.89	6.76	6.26	4.94	6.15	1.46	6.23
Expt. Mean	3.47	4.26	3.17	6.65	6.76	4.19	3.32	4.68	3.85	5.89	7.04	7.71	8.11	7.57	3.81	7.82
CD (0.05)	0.11	0.45	NS	0.95	0.67	0.84	0.08	0.7	0.14	0.62	NS	1.07	0.93	0.89	0.09	0.86
CV (%)	2.16	7.06	11.94	9.52	6.58	13.3	1.61	9.94	2.39	6.95	16	9.22	7.64	7.77	1.65	7.33

Table: 5.5.4 Residue Management in RBCS
Grain and straw yields (*Rabi 2022*-23)

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Total Nutrient uptake (kg/ha)						Nutrient use efficiency (Kg grain/kg uptake)					
	KRK	MTU	KRK	MTU	KRK			MTU			KRK			MTU		
					N	P	K	N	P	K	N	P	K	N	P	K
100% RDF	4.01	7.89	9.03	9.98	112	25.4	227	109	43.8	170	36.1	161	17.9	73.1	181	47.0
50% Residue + 50% RDF	4.69	7.44	10.48	7.88	137	28.1	260	91	36.2	125	34.3	168	18.0	83.5	212	60.7
50% Residue + 50% RDF + Pusa decomposer	4.79	7.73	10.63	9.50	115	37.5	267	95	39.1	156	45.5	130	18.1	82.1	201	50.0
50% Residue + 50% GM/GLM	4.88	6.70	10.78	7.50	123	40.1	287	85	27.0	118	40.6	138	17.1	81.1	259	57.3
75% RDF + 25% residue + Pusa Decomposer	-	6.82	-	7.40	-	-	-	82	34.1	117	43.4	198	18.5	83.6	203	58.7
Absolute control	3.50	3.69	7.95	5.40	81	18.1	190	53	17.7	94	40.0	159	18.0	70.6	211	39.6
Expt. Mean	4.37	6.71	9.77	7.94	114	29.8	246	86	33.0	130	12.5	57	2.9	79.0	211	52.2
CD (0.05)	0.51	0.77	1.74	0.74	NS	NS	41.9	19.8	8.6	29.3	NS	NS	NS	NS	NS	9.5
CV (%)	7.63	7.60	11.54	6.20	20.2	33.5	11.0	15.4	17.3	14.9	20.2	23	10.5	11.2	23.0	12.1

Table: 5.5.5 Residue Management in RBCS

Nutrient uptake (Kg/ha) in total dry matter (*Kharif* 2023)

Treatment	FZD [1]			KNP [2]			KRK [3]			KHD [4]			MTU [5]			MCU [6]			PNT [7]			PSA [8]		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
100% RDF	102	44.5	63	103	29.1	105	146	15.5	197	130	24.9	116	-	50.6	119	100	51.9	165	77	15.9	75	123	28.2	142
50% Residue + 50% RDF	59	24.4	37	95	27.5	96	132	10.8	174	106	20.9	97	-	39.1	98	86	41.5	141	55	9.1	35	104	23.0	119
50% Residue + 50% RDF + Pusa decomposer	74	31.5	45	105	30.9	103	125	10.2	191	110	21.4	105	-	43.8	106	100	50.5	171	60	10.5	39	108	23.7	119
50% Residue + 50% GM/GLM	50	18.8	30	93	25.8	91	122	8.6	168	105	20.9	107	-	38.2	91	97	43.8	187	61	10.4	40	96	20.7	109
75% RDF + 25% residue + Pusa Decomposer	62	22.2	36	105	29.6	104	130	10.2	180	123	24.5	112	-	49.5	116	100	43.0	197	67	12.3	52	112	24.9	125
Absolute control	34	11.5	19	37	9.4	39	116	8.6	165	86	16.1	81	-	27.3	75	49	21.1	74	18	2.8	14	72	14.9	80
Expt. Mean	63	25.5	39	89.9	25.4	89.8	128	10.7	179	110	21.5	103	-	41.4	101	89	41.9	156	56.4	10.1	42.7	102	22.5	116
CD (0.05)	4.0	2.29	2.7	9.3	3.2	10.7	NS	3.9	NS	13.2	3.34	14.4	-	9.5	14.1	17.0	8.7	30.8	3.1	1.36	2.48	11.8	3.22	15.6
CV (%)	4.2	5.96	4.7	6.9	8.5	7.9	13.4	24.5	20.1	7.95	10.3	9.32	-	15.2	9.3	12.8	13.7	13.1	3.64	8.91	3.85	7.65	9.47	8.92

Table: 5.5.6 Residue management in RBCS

Nutrient use efficiency (Kg grain/kg uptake) (*Kharif* 2023)

Treatment	**FZD [1]**			**KNP [2]**			**KRK [3]**			**KHD [4]**			**MTU [5]**			**MCU [6]**			**PNT [7]**			**PSA [8]**		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
100% RDF	44.6	103	72.7	48.6	173	47.8	22.8	231	16.8	58.8	306	67.0	-	103	43.8	76.5	147	46.2	55.4	270	56.8	44.7	194	38.8
50% Residue + 50% RDF	55.4	135	89.5	47.1	164	47.0	26.1	343	20.9	60.7	308	66.2	-	104	40.9	80.5	167	49.7	60.7	370	96.6	45.6	207	39.8
50% Residue + 50% RDF + Pusa decomposer	50.2	118	83.1	45.1	154	46.3	26.7	320	17.3	60.7	314	64.1	-	97	40.2	74.2	146	42.8	61.6	354	94.8	45.5	208	41.8
50% Residue + 50% GM/GLM	58.6	156	98.7	45.8	166	46.8	26.7	398	19.6	58.5	295	57.9	-	102	43.0	79.7	181	41.1	57.7	340	87.3	47.4	219	41.7
75% RDF + 25% residue + Pusa Decomposer	63.2	176	110	47.0	167	47.3	22.9	324	16.9	60.0	302	66.4	-	101	42.7	74.4	174	38.5	57.3	318	74.2	45.6	205	41.1
Absolute control	72.0	213	128	56.2	223	55.1	25.3	330	17.4	64.8	346	69.2	-	105	38.2	77.2	178	51.2	67.3	445	86.6	45.9	219	40.8
Expt. Mean	57.3	150	97.0	48.3	174	48.4	25.1	324	18.1	60.6	312	65.1	-	102	41.5	77.1	165	44.9	60.0	350	82.7	45.8	209	40.7
CD (0.05)	2.08	10.2	5.5	4.9	26.4	NS	NS	NS	NS	3.7	NS	NS	-	NS	NS	NS	NS	NS	3.23	39.4	6.08	NS	12.4	NS
CV (%)	2.4	4.5	3.8	6.68	10.0	15.5	15.4	28.2	19.7	4.04	7.95	7.74	-	7.38	9.62	11.6	12.9	14.0	3.57	7.48	4.88	6.94	3.94	12.3

Table: 5.5.7 Residue management in RBCS
Post-harvest nutrient status of soil (Kg/ha) (*Kharif* 2023)

Treatment	KNP			KRK			KHD			MCU			MTU			PNT			PSA		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
100% RDF	289	16.3	231	214	23.0	213	255	28.0	105	314	45.7	189	167	90.7	331	178	12.9	190	267	27.3	234
50% Residue + 50% RDF	292	13.9	215	208	22.9	205	229	30.7	142	307	41.5	205	156	91.2	349	165	11.2	157	260	25.0	227
50% Residue + 50% RDF + Pusa decomposer	303	14.1	220	212	22.5	209	260	28.6	171	307	42.2	213	168	93.1	364	164	11.7	166	264	23.7	224
50% Residue + 50% GM/GLM	308	13.7	210	210	21.8	165	246	32.2	193	300	40.0	208	174	91.2	333	162	11.6	160	253	22.0	217
75% RDF + 25% residue + Pusa Decomposer	292	14.8	221	213	22.9	210	264	30.6	119	309	46.3	197	157	92.6	370	171	10.6	173	263	26.0	229
Absolute control	271	12.2	181	195	20.4	203	273	32.9	125	277	36.6	173	135	88.7	293	137	8.9	159	237	19.4	208
Expt. Mean	293	14.1	213	209	22.2	201	254	30.5	143	302	42.0	198	159	91.3	340	163	11.1	167	257	23.9	223
CD (0.05)	NS	1.2	18	9.13	1.53	NS	NS	NS	55	NS	5.5	23.6	NS	NS	26.1	7.66	0.54	9.66	NS	4.8	NS
CV (%)	5.78	5.74	5.48	2.90	4.57	19.4	13.7	26.7	25.4	5.10	8.71	7.92	13.0	2.9	5.1	3.12	3.21	3.83	6.2	13.3	6.7

Table: 5.5.8 Residue management in RBCS
Post-harvest nutrient status of soils (Kg/ha) (*Rabi 2022*-23)

Treatment	KRK			MTU		
	N	P	K	N	P	K
100% RDF	171	6.43	110	195	88.3	397
50% Residue + 50% RDF	184	4.44	172	165	87.5	520
50% Residue + 50% RDF + Pusa decomposer	174	7.07	129	196	89.4	472
50% Residue + 50% GM/GLM	184	4.41	152	164	91.0	634
75% RDF + 25% residue + Pusa Decomposer	-	-	-	166	89.7	690
Absolute control	172	3.25	101	162	83.1	416
Expt. Mean	177	5.12	133	175	88.1	521
CD (0.05)	NS	NS	NS	NS	4.63	118
CV (%)	5.79	61.7	31.8	13.9	3.49	15.1

Trial 5.6. Nano-fertilizers for increasing nutrient use efficiency, yield, and economic returns in transplanted rice

The Nitrogen Use Efficiency (NUE) in agricultural systems has remained low; meaning that on a global scale, more than 50% of the N applied to agricultural soils is potentially lost into the environment. The current NUE needs to be improved substantially by increasing the efficiency of agricultural systems, adopting environmentally sound agronomic practices, and exploring disrupting technologies. Nano-fertilizers possess unique features that enhance plants' performance in ultra-high absorption, increase production, rise in photosynthesis, and significant expansion in the leaves' surface area. It would be very helpful if we use nano-fertilizers for specific crops such as rice to minimize the potential negative effects brought about by the extensive use of chemical inputs without compromising production and nutritional benefits. In this background and based on a one-year field study with objectives 1. To study the efficiency of nano-fertilizers in increasing the growth and yield of rice crops and 2. To find out the nutrient use efficiency of nano-fertilizers in rice crop. A total of seven treatments namely**,** T1: Recommended dose of nitrogen (RDN) through urea (recommended P and K) T2: T1+ Two foliar sprays Nano-Urea @ 2% at active tillering and panicle initiation stages, T3: 50 % of RDN + Two foliar sprays Nano-urea @ 2% (AT and PI) T4: 75 % RDN T5: 75% of RDN + Two foliar sprays Nano-urea @ 2% (AT and PI) and T6: Control (no application of fertilizer) in addition to this new treatment T7: Nano urea spray alone (4 sprays @ 4ml/L, 15 days' interval) which was included in this trial based on the recommendation received from the recently held 52^{nd} ARGM**.** The trial was laid out in randomized block design (RBD) with three replications. [The trial was conducted in collaboration with Agronomy in a total of 24 locations (ARI-Rajendranagar, BNK-Bankura, CHT-Chatha, CHP-Chiplima, CBT-Coimbatore, FZB-Faizabad, JDP-Jagdalpur, JGL-Jagtial, KNP-Kanpur, KRK-Karaikal, KUL-Kaul, KHD-Khudwani, LDH-Ludhiana, MND-Mandya, MTU-Maruteru, MNC-Moncompu, NVS-Navsari, NLR-Nellore, PNR-Pantnagar, PTB-Pattambi, PDU-Puducherry, PSA-Pusa, SBR-Sabour and NRRI, Cuttack)]. The results of the second-year study were summarized and presented in Tables 5.6.2 to 5.6.7 and the salient findings are as follows.

Yield parameters like tiller number and panicle number per meter square were documented and represented in **Table 5.6.2**. Significant differences were observed in the yield parameters due to variations in treatments at all the locations. Application of 100 % RDN along with two sprays of nano urea at active tillering and panicle initiation stage registered the highest tiller and panicle numbers (per m^2) at Kanpur (338, 305), Jagdalpur (367, 355), Maruteru (322, 249), Puducherry (328, 289), Coimbatore (385, 362), Mandya (399, 370), NRRI (287, 280), Sabour (286, 284) which was on par with the recommended dose of N treated plots. At a few centres, application of 75% RDN and two sprays of nano urea recorded higher tiller and panicle numbers (per m^2) *i.e.*, Chiplima (369, 322), Gangavati (363, 323) and Pattambi (396, 383), respectively. Whereas, the application of 50% RDN combined with two sprays (T3) and 75% RDN alone also improved the tiller numbers in all centres over absolute control but not to the level of T1 treatment. The application of nano urea alone (four sprays) was found on par with the control treatment and the improvement was insignificant at Chiplima, Khudwani, and Karaikal locations. In general, the order of improvement was observed as T6<T4=T3<T5<T1=T2 across the locations.

Grain and straw yields at all the locations showed significant differences with the addition of nano urea treatments (**Table 5.6.3**). Similar to yield attributes, the application of 100% RDN and two sprays of nano urea at two critical stages of rice crop recorded the highest grain and straw yields at a majority of the locations *i.e.*, Kaul (5236 and 5616 kg/ha), Kanpur (5380 and 6940 t/ha), Jagdalpur (5722 and 7886 kg/ha), Maruteru (6638 and 7803 kg/ha), Coimbatore (6620 and 8480 kg/ha), Chatha (3133 and 7096 kg/ha), NRRI (5640 and 5720 kg/ha Moncompu (3826 and 4766 kg/ha), Ludhiana (8875 and 12505 kg/ha) and Sabour (5047 and 6150 kg/ha), respectively. At Bankura (5492 kg/ha grain yield), Pattambi (5400 kg/ha grain yield) and Puducherry (5477 kg/ha grain and 7975 kg/ha straw) exhibited the highest yields to the application of 75% RDN along with two sprays of nano urea followed by 100% RDN + two sprays of nano urea. At Navsari, Karaikal, and Mandya, RDN outperformed and registered higher grain yields *i.e.*, 5349, 3067, and 5782 kg/ha, respectively. While, application of nano urea alone at four intervals recorded on par results with control (No N) plots at Chiplima, NRRI, Khudwani, and Karaikal centres. The percent variation with the different treatments over the locations was depicted in Figures 1a and 1b. Replacement of 25 and 50% of RDN with nano urea spray at two intervals recorded a declining trend in the grain yield to the tune of -2 to 25.9% at the majority of the locations. While two sprays of nano urea in addition to 100% RDN, improved the grain yield to the tune of 0.7 5 (Ludhiana) to 33.5% (Khudwani). However, nano urea treatment alone registered, a yield decline to -10.6% (Chiplima), -20.0% (NRRI), -13.6% (Karaikal), -36.2 (Ludhiana) and -28.8% (Gangavati).

The total N uptake of rice plants was documented and represented in Table 5.6.4. Additional two sprays of nano urea with RDN registered the highest N uptake in rice plants grown at Coimbatore (133.4 kg/ha), Khudwani (146.3 kg/ha), Kanpur (108.3 kg/ha), Sabour (97.0 kg/ha) and NRRI (90.2 kg/ha) which was on par with the 75% RDN + two sprays of nano urea treatment. Surprisingly, Pusa centre (105.2 kg/ha) showed positive and highest uptake with the nano urea (four sprays) alone treatment over other treatments. At Navasari, the highest N uptake was recorded with RDN application which was higher than the rest of the treatments. The effect of nitrogen application through conventional fertilizer and nano urea significantly improved the soil available N in rice (Table 5.6.5). Either application of 100 % RDN or 100% RDN + foliar sprays of urea positively improved the soil available N over absolute N control across the locations. Treatments namely, T4 (75% RDN) and T5 (75% RDN + 2 sprays of nano urea) recorded on par value across the locations, which can be considered that additional spray of nano urea in the plant did not have a beneficial role in the improvement of soil N.

The use of nano urea in rice crops did not significantly improve the BC ratio (Economic returns) across the locations (Table 5.6.6). The highest benefit and returns were observed with T2 at Jagadalpur (1.4), Mandya (2.3), Maruteru (2.1), Sabour (2.2) and Coimbatore (2.2). Whereas, other treatments registered a lower BC ratio than T2. In general, an additional application of nano urea along with 100% RDN was on par with the 100% RDN treatments and did not fetch much monetary benefit in irrigated rice crops. The application of nano urea has increased the NUE (Agronomic efficiency) at few locations (Figure 2). The highest use efficiency was exhibited in T2 (100% RDN + two sprays of nano urea) at Jagdalpur (33.6) and Pusa (23.0) followed by other treatments. While at Mandya, application of T3 (50% RDN + nano urea spray) recorded higher NUE (103.3) followed by 75% RDN alone (74.8).

Summary:

Application of nano urea improved the tiller, panicle numbers, and grain yield of rice crops over the absolute N control. Out of all treatments, two sprays of nano urea along with RDN application performed well with the tiller, panicle numbers, yield, and N uptake at the majority of the locations. However, the replacement of nitrogen requirement through nano urea was found to be ineffective with respect to grain yield enhancement, yield attributes, N content etc., across the locations. At the end of the second-year trial, results exhibited that replacement of either 25 or 50% RDN with nano urea did not influence the yield improvement and other parameters in rice crops.

Table 5.6.1: List of centers with trial details

S. No	Centre name	Variety	Soil Type	Soil values (Initial)	Fertilizer Dose
1	ARI, Rajendranagar				
2	Bankura	Ajit	Red and Lateritic soil		70:35:35
3	Chatha	Basmati 370	Sandy Loam	245:14:146	30:20:10
4	Chiplima				
5	Coimbatore		Clay Loam	224:17.5:421	150:50:50
6	Jagdalpur		Red Soil	227:19:380	100:60:30
7	Jagtial				
8	Kanpur		Sandy Loam		120:60:60
9	Karaikal				
10	Kaul			160:12:320	
11	Khudwani			323:17: 247	120:60:30
12	Ludhiana		Sandy Loam	270:15:185	105:30:30
13	Mandya	93 R	Red Sandy Loam soil	284:60:264	100:50:50
14	Maruteru				90:60:60
15	Moncompu				
16	Navsari		Clay	282:38:0	100:30:0
17	Nellore		Sandy Clay loam	163:128:507	120:60:40
18	Pantnagar	-	-	-	-
19	Pattambi	-	--	-	-
20	Puducherry	RP Bio 226	Clay Loam	156.8:35:106	120:40:40
21	Pusa		Sandy Loam	214:15:114	120:60:40
22	Ranchi				
23	Sabour		Silty Loam	161:27:198	100:40:20
24	NRRI				

Table 5.6.2: Effect of nano urea application growth parameters of Rice (Tiller (T) and Panicle (P) Numbers per m^2)

Treatments	BNK		KUL		KNP		JDP		MNC		MTU		PUD	
	T	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**
T1: Recommended dose of N (RDN)	301	235	275	262	297	276	341	334	196	186	281	245	297	249
T2: T1+ Two sprays of Nano-Urea	336	263	293	284	338	305	367	355	192	182	322	249	328	289
T3: 50% RDN+ Two sprays Nano-Urea	304	243	239	229	271	266	270	264	180	176	249	210	262	225
T4: 75% RDN	347	269	250	241	282	270	313	306	176	166	290	235	320	276
T5: 75% RDN + Two sprays Nano-Urea	343	276	264	254	317	291	326	318	188	188	274	241	335	297
T6: Nano urea Spray alone (4 sprays)	-	-	-	-	-	-	-	-	-	-	-	-		
T7: Control (no N)	282	222	229	219	265	231	126	119	172	169	248	166	240	212
Mean	**319**	**252**	**258**	**248**	**289**	**279**	**290**	**283**	**184**	**174**	**277**	**224**	**297**	**258**
CD (p=0.05)	**15**	**10**	**19**	**16**	**6**	**6.0**	**52**	**51**	**15**	**13**	**48**	**31**	**6**	**5**
CV (%)	**2.6**	**2.2**	**4**	**3.5**	**1.2**	**1.2**	**9.8**	**9.9**	**5.7**	**4.7**	**10**	**7**	**1**	**1**

T= Tiller numbers per m^2, P = Panicle number per m^2

Treatments	PTB		CBT		MND		NLR		NVS		NRRI		RNR	
	T	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**
T1: Recommended dose of N (RDN)	330	322	361	342	382	348	454	405	350	340	278	269	267	258
T2: T1+ Two sprays of Nano-Urea	371	340	385	362	399	370	412	369	336	325	287	280	292	269
T3: 50% RDN+ Two sprays Nano-Urea	376	355	346	327	360	327	387	295	317	304	264	259	289	227
T4: 75% RDN	329	325	358	335	369	330	398	398	325	314	268	262	259	242
T5: 75% RDN + Two sprays Nano-Urea	396	383	370	347	393	358	394	394	323	311	270	263	272	246
T6: Nano urea Spray alone (4 sprays)	-	-	-	-	-	-	-	-	-	-	254	249	-	-
T7: Control (no N)	280	267	221	203	323	289	399	399	292	281	238	229	270	225
Mean	**347**	**332**	**340**	**319**	**371**	**337**	**407**	**360**	**324**	**312**	**265**	**258**	**275**	**244**
CD (p=0.05)	**24**	**26**	**11.6**	**8.0**	**48**	**44**	**NS**	**NS**	**33**	**33**	**5**	**6**	**19**	**29**
CV (%)	**3.9**	**4.3**	**1.9**	**1.4**	**7**	**7**	**13**	**13**	**6**	**6**	**1.1**	**1.4**	**4.0**	**7**

T= Tiller numbers per m^2, P = Panicle number per m^2

Treatments	CHP		CHT		GNV		KHD		KRK		KUL		SBR	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
T1: Recommended dose of N (RDN)	347	297	225	201	331	294	525	451	236	210	275	262	263	260
T2: T1+ Two sprays of Nano-Urea	333	278	249	228	348	312	511	437	245	224	293	284	286	284
T3: 50% RDN+ Two sprays Nano-Urea	368	324	197	175	355	308	489	434	249	237	239	229	216	214
T4: 75% RDN	286	259	199	177	320	285	483	423	244	224	250	241	224	223
T5: 75% RDN + Two sprays Nano-Urea	369	322	216	190	363	323	510	447	240	207	264	254	237	235
T6: Nano urea Spray alone (4 sprays)	251	213	-	-	277	244	465	401	232	208	-	-	-	-
T7: Control (no N)	240	194	155	136	237	203	456	388	228	210	230	219	189	188
Mean	**313**	**269**	**207**	**184**	**308**	**272**	**491**	**426**	**239**	**217**	**258**	**248**	**235**	**234**
CD (p=0.05)	**73**	**73**	**7**	**5**	**35**	**31**	**67**	**53**	**64**	**61**	**19**	**16**	**44**	**44**
CV (%)	**13**	**15**	**1.8**	**1.5**	**6.5**	**6.6**	**7.7**	**7.0**	**15**	**16**	**4**	**3.5**	**10**	**10**

Table 5.6.3: Effect of nano urea application growth parameters of Rice (Grain (kg/ha) and straw yield (kg/ha))

	BNK		KUL		KNP		JDP		MNC		MTU	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T1: Recommended dose of N (RDN)	4812	6742	4703	5400	5090	6540	5510	7022	3779	4866	6150	7506
T2: T1+ Two sprays of Nano-Urea	5119	5595	5236	5616	5380	6940	5722	7886	3826	4766	6638	7803
T3: 50% RDN+ Two sprays Nano-Urea	4988	6734	3780	4260	4630	5700	4085	5423	3142	3966	5215	6260
T4: 75% RDN	5298	7264	4276	4716	4920	5890	4745	6407	3250	3877	4841	5840
T5: 75% RDN + Two sprays Nano-Urea	5492	7722	4480	5160	5300	6580	5111	6617	3313	3777	5602	6750
T6: Nano urea Spray alone (4 sprays)	-	-	-	-	-	-	-	-	-	-	-	-
T7: Control (no N)	4527	5713	2860	3196	3240	3420	2358	3328	2737	2737	3921	4706
Mean	**5039**	**6812**	**4222**	**4725**	**4760**	**5890**	**4588**	**6114**	**3341**	**4169**	**5394**	**6477**
CD (p=0.05)	**108.5**	**671**	**265**	**374**	**110**	**150**	**422**	**837**	**337**	**312**	**745**	**884**
CV (%)	**1.2**	**5.4**	**3.5**	**4.4**	**1.3**	**1.4**	**5.1**	**7.5**	**6.7**	**9.7**	**7.6**	**7.5**

	PTB		CBT		MND		NLR		NVS		PDU (K)	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T1: Recommended dose of N (RDN)	3800	8166	6176	8170	5782	8401	4526	5233	5349	6740	4714	6760
T2: T1+ Two sprays of Nano-Urea	3866	7722	6620	8480	3126	9152	4879	5108	5091	6399	5177	7463
T3: 50% RDN+ Two sprays Nano-Urea	3033	7035	5396	7216	5172	7681	4022	4103	4449	6286	4621	6656
T4: 75% RDN	4133	8863	5620	7296	4998	7533	4665	4735	4635	5991	5093	7358
T5: 75% RDN + Two sprays Nano-Urea	5400	7151	6320	8260	5617	8348	4466	4621	4647	6036	5477	7975
T6: Nano urea Spray alone (4 sprays)	-	-	-	-	-	-	-	-	-	-	-	-
T7: Control (no N)	3500	7866	2110	3170	3801	6127	3598	4000	4113	6649	4044	5932
Mean	**3922**	**7800**	**5373**	**7098**	**5249**	**7873**	**4359**	**4633**	**4714**	**6350**	**4854**	**7024**
CD (p=0.05)	**959**	**745**	**92**	**139**	**489**	**872**	**295**	**778**	**698**	**623**	**128**	**191**
CV (%)	**13.4**	**5.3**	**0.9**	**1.1**	**5.1**	**6.1**	**3.7**	**9.2**	**8.1**	**5.4**	**1.5**	**1.5**

Continued…..

	CHP		CHT		NRRI		KHD		KRK		LDH	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T1: Recommended dose of N (RDN)	6580	7400	2890	6536	5300	5530	8466	8710	3067	6566	8815	12292
T2: T1+ Two sprays of Nano-Urea	6507	7010	3133	7096	5640	5720	8300	8560	2555	5611	8875	12505
T3: 50% RDN+ Two sprays Nano-Urea	6925	8615	2740	6070	4380	5420	7933	8360	2822	5877	7244	11067
T4: 75% RDN	6125	6963	2789	6270	4870	5450	7766	8156	2855	6700	8122	11421
T5: 75% RDN + Two sprays Nano-Urea	6824	8478	2820	6343	4180	5480	8200	8370	3022	6366	8290	11611
T6: Nano urea Spray alone (4 sprays)	5880	6613	-	-	4240	5290	7233	7756	2650	5905	5625	8205
T7: Control (no N)	5400	6037	2163	4496	3840	4960	6666	7136	2466	5866	4720	7779
Mean	**6320**	**7302**	**2755**	**6135**	**4778**	**5407**	**7795**	**8150**	**2777**	**6127**	**7384**	**10697**
CD (p=0.05)	**958**	**1528**	**45**	**98**	**344**	**151**	**686**	**799**	**636**	**1435**	**695**	**884**
CV (%)	**8.5**	**11.8**	**0.9**	**0.9**	**4.0**	**1.6**	**6.3**	**5.5**	**12.9**	**13.2**	**5.3**	**4.7**

	PSA		RNR		SBR		GNV	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T1: Recommended dose of N (RDN)	4801	6825	5253	8400	4860	5719	5175	5000
T2: T1+ Two sprays of Nano-Urea	5273	6812	5473	7333	5047	6150	5312	5833
T3: 50% RDN+ Two sprays Nano-Urea	3525	4616	3910	6866	3966	4737	4729	5000
T4: 75% RDN	4209	5656	4313	7466	4380	5235	4375	5416
T5: 75% RDN + Two sprays Nano-Urea	4552	6013	4490	6666	4590	5650	5341	5000
T6: Nano urea Spray alone (4 sprays)	5536	7248	3789	6000	-	-	3683	3750
T7: Control (no N)	2508	3462	6017	8400	3062	3819	3083	2916
Mean	**4343**	**5804**	**4749**	**7304**	**4317**	**5218**	**4405**	**4583**
CD (p=0.05)	**830**	**1163**	**793**	**1007**	**331**	**415**	**868**	**2019**
CV (%)	**10.8**	**11.3**	**9.4**	**7.8**	**4.2**	**4.4**	**11.3**	**25.2**

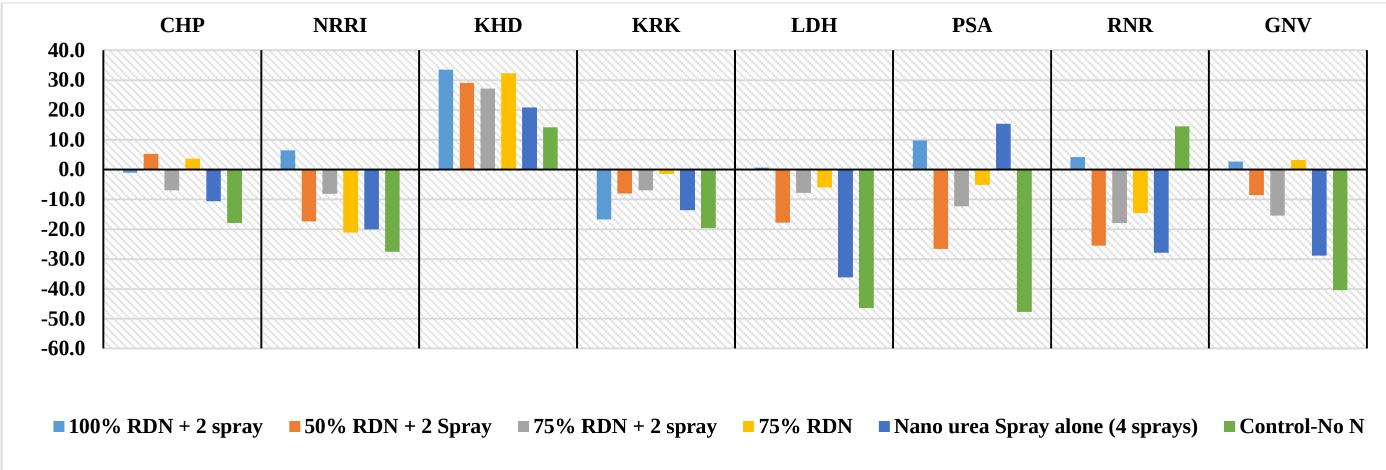

Figure 1a. Percent change over RDN treatment (Total of 7 treatments)

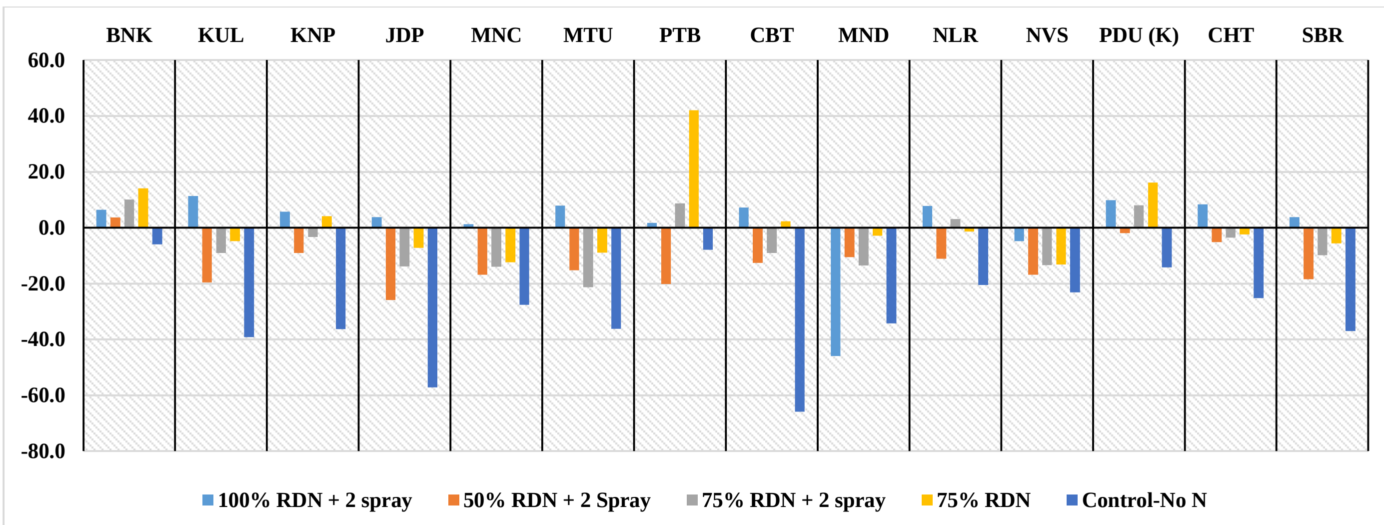

Figure 1b. Percent change over RDN treatment (Total of 6 treatments)

Table 5.6.4: Effect of nano urea application on total N uptake (kg/ha) in rice

	CBT	KHD	KNP	NVS	PSA	PDU	SBR	NRRI
T1: Recommended dose of N (RDN)	124.4	145.0	92.1	92.9	76.4	83.2	92.3	83.4
T2: T1+ Two sprays of Nano-Urea	133.4	146.3	108.3	89.6	83.0	100.6	97.0	90.2
T3: 50% RDN+ Two sprays Nano-Urea	107.8	132.3	70.3	82.6	63.5	81.2	79.8	68.4
T4: 75% RDN	114.8	131.7	80.8	80.4	74.7	98.0	85.8	75.6
T5: 75% RDN + Two sprays Nano-Urea	127.8	145.0	103.3	84.8	87.0	111.3	91.4	82.0
T6: Nano urea Spray alone (4 sprays)	-	122.3	-	-	105.2			61.9
T7: Control (no N)	80.9	106.7	42.0	69.3	33.7	63.1	56.7	52.8
Mean	**114.8**	**132.7**	**82.9**	**83.3**	**74.8**	**89.6**	**83.8**	**73.5**
CD (p=0.05)	**8.2**	**15.5**	**1.2**	**10.3**	**16.0**	**3.5**	**5.4**	**5.4**
CV (%)	**3.9**	**5.5**	**1.6**	**6.8**	**12.0**	**2.1**	**3.6**	**4.0**

Table 5.6.5: Effect of nano urea application on available N (kg/ha) in soil

	CBT	CHP	CHT	JDP	KHD	KRK	NVS	PSA	SBR	NRRI
T1: Recommended dose of N (RDN)	217.8	361.0	234.6	225.3	342.3	243.6	243.7	203.3	153.3	342.3
T2: T1+ Two sprays of Nano-Urea	224.5	352.0	238.6	234.3	335.3	264.5	246.9	199.7	153.6	360.2
T3: 50% RDN+ Two sprays Nano-Urea	20.8	420.0	265.4	226.0	336.0	256.1	242.7	196.0	148.3	327.4
T4: 75% RDN	214.0	294.3	227.3	224.3	336.7	234.2	247.6	216.7	154.3	346.7
T5: 75% RDN + Two sprays Nano-Urea	223.3	400.7	231.4	225.3	330.3	241.5	235.2	214.7	153.4	333.5
T6: Nano urea Spray alone (4 sprays)	-	229.0	-	-	316.7	178.7	-	225.0	-	306.6
T7: Control (no N)	194.3	276.7	222.8	229.3	316.7	225.8	245.5	163.0	142.5	271.3
Mean	**213.8**	**333.4**	**236.6**	**227.4**	**330.5**	**234.9**	**243.6**	**202.6**	**150.9**	**326.8**
CD (p=0.05)	**6.7**	**84.0**	**43.3**	**5.9**	**16.4**	**78.1**	**27.7**	**23.7**	**1.5**	**19.1**
CV (%)	**1.7**	**14.2**	**10.1**	**1.3**	**2.8**	**18.7**	**6.30**	**6.6**	**0.6**	**3.3**

Table 5.6.6: Effect of nano urea application on Benefit: Cost Ratio in rice

	JDP	MNC	MND	MTU	NVS	PSA	PUD	SBR	CBT
T1: Recommended dose of N (RDN)	1.4	1.7	2.2	2.1	1.8	2.1	2.1	2.1	2.1
T2: T1+ Two sprays of Nano-Urea	1.4	1.5	2.3	2.1	1.6	2.2	2.1	2.2	2.2
T3: 50% RDN+ Two sprays Nano-Urea	0.9	1.3	2.0	1.7	1.4	1.5	2.0	1.7	1.8
T4: 75% RDN	1.1	1.4	2.0	1.6	1.6	1.8	2.1	1.9	2.0
T5: 75% RDN + Two sprays Nano-Urea	1.2	1.3	2.1	1.8	1.5	1.9	2.2	2.0	2.2
T6: Nano urea Spray alone (4 sprays)	-	-	-	-	-	2.3	-	-	-
T7: Control (no N)	0.1	1.0	1.6	1.4	1.5	1.2	2.0	1.3	1.1

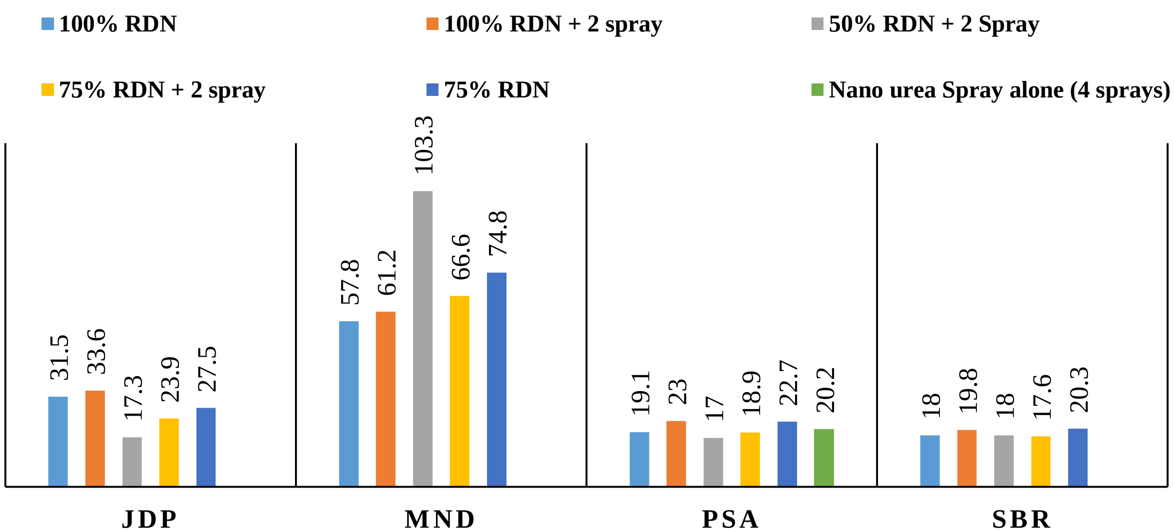

Figure 2: Effect of nano urea application on Nutrient Use Efficiency (NUE) in rice

Trial 5.8. Evaluation of Organic fertilizers and Natural farming practices for enhancing Productivity and soil health

The trial was conducted during *Rabi* 2022-23 and *kharif*-2023 in collaboration with Agronomy to "Evaluate the Organic fertilizers and Natural farming practices for enhancing the productivity and soil health" and its influence 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 five treatments *viz.*, 1) Control, 2) Complete Natural Farming (NF), 3) AI-NPOF package (All India Network Programme on Organic Farming), 4) Integrated Crop Management (with organic pest management practices) and 5) Integrated Crop Management (need-based pesticides). All 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 an experiment and after harvest and were analysed for important soil properties. The trial was conducted at nine locations viz., [Moncompu-MNC, Mandya-MND, Khudwani-KHD, Pantnagar-PNT, Pusa-PUSA, Puducherry-PUD and Titabar-TTB] during *Kharif*- 2023 and at Chinsurah-CHN and Karaikal-KRK during *rabi*- 2022-23. The results are presented in Tables 5.8.1 to 5.8.18.

Grain, straw yield and yield parameters

Among the seven locations, grain yield during *Kharif*-2023 (Table 5.8.2) was significantly superior in (T5) Integrated Crop Management (need based pesticides) [5.03, 3.21, 2.05, 3.53, 4.23, 4.68 t/ha] treatment as compared to other treatments recording 40%, 98%, 64%, 14.3%, 8.5% and 50%, higher yield over complete natural farming, at MNC, MND, PNT, PSA, PUD and TTB, respectively. Whereas at KHD, (6.93 t/ha) T4 Integrated Crop Management recorded higher grain yield which was 21 % higher as compared to complete natural farming. Straw yield followed an almost similar trend as that of grain yield at most of the locations (Table 5.8.3) recording 18%, 67%, 43% 18%, 14% and 23% higher yields in integrated crop management (need-based pesticides) over complete natural farming at MNC, MND, PNT, PUSA, PUD and TTB, respectively. Whereas at KHD, Integrated Crop Management recorded 25 % higher over complete natural farming. With regard to yield parameters (tillers/m^2, panicles/m^2, 1000 grain weight), and nutrient uptake the treatment integrated crop management (need based pesticides) recorded significantly higher values as compared to other treatments MNC, MND, PNT, PUSA, PUD and TTB, but at KHD the Integrated Crop Management treatment recorded significantly higher as compared to other treatments (Table 5.8.4 to 5.8.10).

At CHN, KRK location, during rabi 2022-23 (Table 5.8.11 and 5.8.12) grain yields were significantly superior in integrated crop management (need based pesticides) as compared to other treatments with 116% and 15% higher grain and straw yields over complete NF treatment and Straw yield followed almost similar trend as that of grain yield. With regard to tillers/m^2, panicles/m^2, 1000-grain wt. (g), in integrated crop management (need based pesticides) recorded significantly higher values and the highest number of tillers/m^2 (405) and panicles/m^2 (401) and but 1000-grain weight (21.75 g) integrated crop management as compared to other organic treatments respectively at CHN.

Soil properties after harvest

At CHN, MNC, MND, PNT and PUSA most of the soil properties improved with Integrated Crop Management (pest management), at KHD, PNT (P &K uptake) with Integrated Crop Management and at TTB improved with AINPOF package, as compared to other treatments. The important soil properties from nine locations (TTB, CHN, KRK, MNC, MND, KHD, PNT, PUSA and PUD) are presented in Table (5.8.10 to 5.8.18) respectively.

Summary

In the second year of study on “Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health”, out of five treatments, Integrated Crop Management (pest management) was significantly superior as compared to other treatments at MNC, MND, PNT, PUSA, PUD and TTB in terms of grain yield and yield parameters. At CHN, MNC, MND, PNT and PUSA most of the soil properties improved with Integrated Crop Management ((pest management)) while at TTB, soil properties improved with AI-NPOF package compared to other treatments.

- ❖ In the second year of study on evaluation of Organic fertilizers and Natural farming practices, Integrated Crop Management (with need based pesticides) was significantly superior in terms of grain yield and yield parameters.
- ❖ Most of the soil properties improved with Integrated Crop Management ((pest management)) and AI-NPOF practices.

Table 5.8.1 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Soil and crop characteristics

Parameters	CHN	MNC	MND	KHD	PNT	PUSA	PUD	TTB	KRK (Rabi)
Cropping system	**Rice**	**Rice - Rice**	**Rice**	Rice-Brown-Mustard	**Rice-Wheat**	**Rice-wheat**	**Rice – Rice**	**Rice -Fallow**	-
Variety – Kharif	Sukumar	Pournami	KMP-175	Shalimar Rice-4	Pant Dhan-24	Rajendra Nilam	ADT 54	Bokul Joha	KKLR 2
RDF (kg NPK/ha)		90:45:45	100:50:50	120:60:30	120:60:30	120:60:40	150:50:50	-	
Crop growth:	-	-	-	-		-	-	-	Good
Soil characteristic									
% Clay	-	-	-	37	25.9	15	-	35	12.6
% Silt	-	-	-	45	61.4	29	-	34	9.2
% Sand	-	-	-	18	12.9	56	-	27	75.4
Texture	Clay Loam	-	-	Silty clay loam	Silty clay loam	Sandy loam	Clay loam	Silty Clay	Sandy loam
pH (1:2)	7.51	4.96	7.47	6.5	7.5	8.3	6.80	5.3	6.6
Organic carbon (%)	1.20	3.24	0.50	0.73	0.61	0.52	0.31	0.58	0.81
CEC (cmol (p^+)/kg)		-	-		23.9	-	-	10.1	12.9
EC (dS/m)	0.4	0.08	0.12	0.08	0.32	0.29	0.27	0.13	0.061
Avail. N (kg/ha)	525	302.3	228.5	309	142	254	156	284	163
Avail. P_2O_5 (kg/ha)	120	71.7	17.7	17.6	9.85	31.5	41	22.5	34.7
Avail. K_2O (kg/ha)	386.5	248.2	171.7	208	215	143.4	158	127	151.2

Table 8.2 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Grain yield of *kharif* (Locations: MNC, MND, KHD, PNT, PUSA, PUD and TTB)

Treatment	Grain yield (t/ha)						
	MNC	**MND**	**KHD**	**PNT**	**PUSA**	**PUD**	**TTB**
Control	3.59	1.57	4.93	0.88	2.79	2.2	2.48
Complete NF	4.25	1.62	5.73	1.25	3.09	3.9	3.12
AI-NPOF package	4.31	2.62	6.29	1.42	3.14	3.81	3.33
Integrated Crop Management	4.9	3.12	6.93	2.04	3.48	4.11	3.45
Integrated Crop Management (need-based pesticides **)**	5.03	3.21	6.84	2.05	3.53	4.23	4.68
Exp. mean	**4.416**	**2.428**	**6.144**	**1.528**	**3.206**	**3.65**	**3.412**
CD (0.05)	**0.56**	**0.02**	**0.87**	**0.06**	**0.35**	**0.57**	**0.7**
CV (%)	**8.25**	**0.63**	**9.23**	**2.76**	**7.07**	**8.32**	**13.35**

Table 8.3 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Straw yield of *kharif* ((Locations: MNC, MND, KHD, PNT, PUSA, PUD and TTB)

Treatment	Straw yield (t/ha)						
	MNC	MND	KHD	PNT	PUSA	PUD	TTB
Control	5.95	2.08	5.91	1.22	4.14	3.16	6.1
Complete NF	7.16	2.38	6.56	1.58	4.53	5.53	7.45
AI-NPOF package	7.31	3.18	7.48	2.05	4.58	5.49	7.15
Integrated Crop Management	8.31	3.77	8.25	2.36	5.1	6.25	7.4
Integrated Crop Management (need-based pesticides)	8.48	3.98	8.23	2.26	5.35	6.28	9.18
Exp. mean	**7.442**	**3.078**	**7.286**	**1.894**	**4.74**	**5.342**	**7.456**
CD (0.05)	**1.11**	**0.06**	**0.96**	**0.07**	**0.58**	**0.95**	**1.39**
CV (%)	**9.72**	**1.25**	**8.53**	**2.36**	**7.93**	**9.43**	**12.14**

Table 8.4 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield parameters and nutrients uptake of *kharif* (Locations: MNC)

Treatment Name	Tiller Number/m^2	Panicle number/m^2	1000 grain wt (g)	Grain P (%)	Grain K (%)	Grain Zn (ppm)	Straw P (%)	Straw K (%)	Straw Zn (ppm)
Control	141	126.25	25.98	0.36	0.36	17.04	0.28	1.17	18.07
Complete NF	174	158	26.3	0.39	0.37	17.27	0.27	1.2	19.38
AI-NPOF package	195	180.5	26.53	0.38	0.41	19.73	0.29	1.18	24.45
Integrated Crop Management	205	190.5	27.1	0.41	0.39	19.08	0.3	1.24	21.35
Integrated Crop Management (need-based pesticides)	212	194.75	26.58	0.39	0.38	20.87	0.31	1.26	23.8
Exp. mean	**185**	**170**	**26.50**	**0.39**	**0.38**	**18.79**	**0.29**	**1.21**	**21.41**
CD (0.05)	**28.29**	**27.16**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**9.91**	**10.37**	**5.21**	**15.12**	**9.49**	**10.16**	**17.74**	**7.64**	**16.32**

Table 8.5 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield parameters and nutrients uptake of *kharif* (Locations: MND)

Treatment Name	Tiller Number/m^2	Panicle number/m^2	1000 grain wt (g)	Grain N (%)	Grain P (%)	Grain K (%)	Grain Zn (mg/kg)	Straw N (%)	Straw P (%)	Straw K (%)	Straw Zn (mg/kg)
Control	178	147	17.45	0.62	0.05	0.24	5.33	0.51	0.02	0.3	8.34
Complete NF	196	159	17.97	0.92	0.06	0.27	6.77	0.6	0.03	0.41	8.69
AI-NPOF package	197	165	18.00	0.87	0.07	0.26	6.76	0.58	0.06	0.41	8.66
Integrated Crop Management	252	199	21.04	1.07	0.09	0.37	7.58	0.67	0.08	0.49	10.57
Integrated Crop Management (need-based pesticides)	260	205	21.48	1.12	0.11	0.42	8.15	0.7	0.09	0.52	11.76
Exp. mean	**216**	**175**	**19.19**	**0.92**	**0.08**	**0.31**	**6.92**	**0.61**	**0.06**	**0.43**	**9.60**
CD (0.05)	**12.56**	**10.85**	**0.51**	**0.01**	**0.01**	**0.01**	**0.15**	**0.03**	**0.02**	**0.01**	**0.38**
CV (%)	**3.77**	**4.03**	**1.73**	**0.82**	**8.58**	**1.43**	**1.38**	**3.03**	**19.9**	**1.47**	**2.59**

Table 8.6 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield parameters and nutrients uptake of *kharif* (Locations: KWD**)**

Treatment Name	Tiller Number/m^2	Panicle number/m^2	1000 grain wt (g)	Grain N (%)	Grain P (%)	Grain K (%)	Straw N (%)	Straw P (%)	Straw K (%)
Control	308	268	24.15	51.81	9.8	11.5	25.78	6.55	63.28
Complete NF	320	284	24.50	61.82	11.86	13.38	30.08	7.71	70.58
AI-NPOF package	352.	301	26.18	68.37	13.6	15.31	35.37	9.35	82.45
Integrated Crop Management	381	317	27.20	78.51	14.3	18.46	40.53	10.61	93.33
Integrated Crop Management (need-based pesticides)	377	324	27.08	76.29	14.63	18.97	41.09	10.83	92.68
Exp. mean	**348**	**298**	**25.82**	**67.36**	**12.84**	**15.52**	**34.57**	**9.01**	**80.46**
CD (0.05)	**29**	**29.74**	**2.08**	**10.72**	**2.96**	**3.26**	**4.63**	**1.68**	**10.66**
CV (%)	**5.41**	**6.47**	**5.23**	**10.33**	**14.95**	**13.63**	**8.7**	**12.12**	**8.6**

Table 8.7 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield parameters and nutrients uptake of *kharif* (Locations: PNT**).**

Treatment Name	Tiller Number/m^2	Panicle number/m^2	1000 grain wt (g)	Grain N (%)	Grain P (%)	Grain K (%)	Grain Zn	Straw N (%)	Straw P (%)	Straw K (%)	Straw Zn (mg/kg)
Control	90	83	15.88	0.89	0.08	0.74	8.1	0.35	0.11	0.35	9
Complete NF	112	97	19.1	0.98	0.1	0.83	9.4	0.41	0.13	0.52	10.45
AI-NPOF package	117	110	19.08	1.03	0.14	0.8	10.28	0.47	0.22	0.57	13.18
Integrated Crop Management	128	116	20.05	1.06	0.15	0.98	11.08	0.59	0.23	0.76	14.75
Integrated Crop Management (need-based pesticides)	133	116	20.1	1.06	0.14	0.9	11.38	0.65	0.24	0.7	16.38
Exp. mean	**116**	**104**	**18.84**	**1.00**	**0.12**	**0.85**	**10.05**	**0.49**	**0.19**	**0.58**	**12.75**
CD (0.05)	**5.51**	**4.93**	**0.72**	**0.04**	**0.02**	**0.04**	**0.41**	**0.07**	**0.03**	**0.06**	**0.93**
CV (%)	**3.08**	**3.06**	**2.49**	**2.52**	**9.01**	**2.84**	**2.65**	**9.2**	**8.88**	**7.17**	**4.75**

Table 8.8 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield parameters and nutrients uptake of *kharif* (Locations: PUSA**)**

Treatment Name	Tiller Number/m^2	Panicle number/m^2	1000 grain wt (g)	Grain N (%)	Grain P (%)	Grain K (%)	Straw N (%)	Straw P (%)	Straw K (%)
Control	209	192	26.48	1.35	0.29	1.26	0.65	0.07	1.3
Complete NF	230	205	26.8	1.39	0.3	1.26	0.71	0.07	1.33
AI-NPOF package	236	214	26.93	1.39	0.31	1.3	0.67	0.08	1.33
Integrated Crop Management	251	226	27.13	1.4	0.32	1.34	0.76	0.08	1.41
Integrated Crop Management (need-based pesticides)	260	243	27.33	1.42	0.33	1.35	0.76	0.08	1.42
Exp. mean	**237**	**216**	**26.93**	**1.39**	**0.31**	**1.30**	**0.71**	**0.08**	**1.36**
CD (0.05)	**27.1**	**15.98**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.01**	**NS**
CV (%)	**7.42**	**4.81**	**6.54**	**6.15**	**10.12**	**6.96**	**7.89**	**4.8**	**4.31**

Table 8.9 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield parameters and nutrients uptake of *kharif* (Locations: PUD)

Treatment Name	Tiller Number/m^2	Panicle number/m^2	Grain N (%)	Grain P (%)	Grain K (%)	Straw N (%)	Straw P (%)	Straw K (%)	Soil OC (%)
Control	196	111	0.86	0.18	0.31	0.3	0.17	0.79	0.26
Complete NF	389	273	1.13	0.28	0.43	0.42	0.22	1.09	0.34
AI-NPOF package	406	259	1.1	0.27	0.41	0.43	0.21	1.15	0.37
Integrated Crop Management	447	309	1.29	0.29	0.44	0.42	0.23	1.2	0.32
Integrated Crop Management (need-based pesticides)	458	316	1.27	0.29	0.45	0.44	0.23	1.28	0.33
Exp. mean	**379**	**253**	**1.13**	**0.26**	**0.41**	**0.40**	**0.21**	**1.10**	**0.32**
CD (0.05)	**55.42**	**52.67**	**0.17**	**0.05**	**NS**	**0.07**	**NS**	**0.2**	**NS**
CV (%)	**7.76**	**11.04**	**8.21**	**9.4**	**13.2**	**9.5**	**14.26**	**9.65**	**14.44**

Table 8.10 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield parameters and nutrients uptake of *kharif* (Locations: TTB)

Treatment Name	Tiller Number/m^2	Panicle number/m^2	1000 grain wt (g)	Total N Uptake (kg/ha)	Total P Uptake (kg/ha)	Total K Uptake (kg/ha)	Soil pH	Soil OC (%)	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Soil Zn (mg/kg)
Control	242	216	37.73	133.2	22.25	138.4	5.2	0.58	257.73	19.23	114.88	0.61
Complete NF	254	247	11.6	133.28	22.6	140.1	5.63	0.5	248.75	18.55	110.93	0.8
AI-NPOF package	305	299	12.53	134	22.6	140.48	5.48	0.5	246.63	17.93	114.33	0.72
Integrated Crop Management	259	253	11.48	134.53	22.65	141.3	5.13	0.45	235.13	16.78	112.13	0.72
Integrated Crop Management (need-based pesticides)	302	300	12.33	138.25	23.3	144.13	5.08	0.48	234.13	16.73	105.53	0.74
Exp. mean	**272**	**263**	**17.13**	**134.65**	**22.68**	**140.88**	**5.30**	**0.50**	**244.47**	**17.84**	**111.6**	**0.72**
CD (0.05)	**23.5**	**45.6**	**NS**	**2.34**	**0.4**	**2.4**	**0.18**	**0.06**	**12.82**	**1.59**	**NS**	**0.11**
CV (%)	**5.61**	**11.26**	**136.07**	**1.13**	**1.14**	**1.1**	**2.19**	**8.33**	**3.4**	**5.8**	**6.02**	**9.89**

Table 8.11 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield, yield parameters and soil properties after harvest of *rabi* (Locations: Chinsurah)

Treatment Name	Grain yield (t/ha)	Straw yield (t/ha)	Tiller Number/ m^2	Panicle number /m^2	1000 grain wt (g)	Soil EC (dS/m)	Soil OC (%)	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Soil Zn (mg/kg)
Control	2.33	2.75	258	219	20.18	0.21	1.19	449.75	92.25	290.43	17.28
Complete NF	2.73	3.24	249.25	215	20.3	0.21	1.16	460.75	89.5	291.58	17.35
AI-NPOF package	3.44	4.21	257.75	214	19.65	0.21	1.17	473.25	93.25	288	17.25
Integrated Crop Management	5.48	6.48	364	319	21.75	0.21	1.11	477.5	96.25	288.33	17.25
Integrated Crop Management (need-based pesticides)	5.91	6.52	405	401	20.08	0.23	1.17	474.3	96.25	291.88	17.33
Exp. mean	**3.978**	**4.64**	**306.8**	**274**	**20.39**	**0.21**	**1.16**	**467.1**	**93.5**	**290.04**	**17.29**
CD (0.05)	**0.21**	**0.26**	**34.08**	**23.51**	**0.9**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**3.44**	**3.64**	**7.21**	**5.57**	**2.86**	**6.72**	**7.03**	**5.13**	**5.47**	**1.85**	**1.62**

Table 8.12 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Yield, yield parameters, nutrients uptake and soil properties of *Rabi* (Locations: KRK)

Treatments	Grain Yield (t/ha)	Straw Yield (t/ha)	Grain N (%)	Grain P (%)	Grain K (%)	Straw N (%)	Straw P (%)	Straw K (%)	Soil pH	Soil EC (dS/m)	Soil OC%	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Control	4.99	5.47	1.15	0.09	0.84	0.49	0.11	2.02	5.76	0.59	0.48	85.08	10.36	151.31
Complete NF	5.13	6.55	1.27	0.11	0.79	0.46	0.2	2.05	5.65	0.57	0.56	95.55	18.57	175.48
AI-NPOF package	5.75	7.03	1.33	0.13	0.84	0.45	0.16	2.51	5.74	0.65	0.49	107.56	18.25	224.36
Integrated Crop Management	5.24	7.53	1.4	0.1	0.81	0.52	0.14	3.18	5.58	0.67	0.55	113.15	15.21	276.3
Integrated Crop Management (need-based pesticides)	5.91	7.96	1.44	0.1	0.81	0.57	0.23	2.23	5.59	0.79	0.61	130.13	23.19	225.56
Exp. mean	**5.404**	**6.91**	**1.32**	**0.11**	**0.82**	**0.50**	**0.17**	**2.40**	**5.66**	**0.65**	**0.54**	**106.29**	**17.12**	**210.60**
CD (0.05)	**0.44**	**NS**	**0.15**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.11**	**NS**	**24.44**	**NS**	**71.47**
CV (%)	**5.3**	**15.56**	**7.43**	**64.58**	**6.79**	**36.55**	**52.66**	**27.57**	**2.72**	**11.38**	**25.57**	**14.92**	**41.44**	**22.02**

Table 8.13 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Nutrients uptake and Soil properties after harvest of *kharif* (Locations: MNC)

Treatment Name	Soil OC (%)	Soil N (kg/ha)	Soil K (kg/ha)	Soil P (kg/ha)	Soil Zn (mg/kg)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Control	3.06	263.08	59.23	212.7	1.06	29.65	82.01
Complete NF	3.14	301.48	71.88	240.2	1.17	36.45	100.83
AI-NPOF package	3.2	311.5	75.35	249.9	1.01	37.06	103.03
Integrated Crop Management	3.09	300.7	70.25	239	0.94	43.99	122.2
Integrated Crop Management (need-based pesticides)	3.1	299.95	68.43	227	0.84	45.35	124.21
Exp. mean	**3.12**	**295.34**	**69.03**	**233.8**	**1.004**	**38.5**	**106.46**
CD (0.05)	**NS**	**28.55**	**8.18**	**11.66**	**NS**	**8.37**	**13.52**
CV (%)	**5.37**	**6.27**	**7.7**	**3.24**	**16.89**	**14.11**	**8.24**

Table 8.14 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Nutrients uptake and Soil properties after harvest of *kharif* (Locations: MND)

Treatment Name	Soil pH	Soil EC (dS/m)	Soil OC%	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Soil Zn (mg/kg)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Control	7.49	0.12	0.5	228.03	17.67	164.13	0.48	20.08	1.24	10.09
Complete NF	7.49	0.13	0.55	239.75	18.91	178.58	0.6	28.93	1.78	14.1
AI-NPOF package	7.48	0.13	0.56	241.03	18.66	175.05	0.6	40.95	3.7	19.87
Integrated Crop Management	7.34	0.13	0.53	259.3	22.5	182.18	1.06	58.66	5.7	29.99
Integrated Crop Management (need-based pesticides)	7.42	0.13	0.53	256.23	22.87	185.28	1.12	63.67	6.74	33.94
Exp. mean	**7.44**	**0.13**	**0.53**	**244.86**	**20.12**	**177.04**	**0.77**	**42.49**	**3.83**	**21.60**
CD (0.05)	**NS**	**NS**	**0.02**	**0.42**	**0.15**	**9.53**	**0.01**	**0.63**	**0.65**	**0.6**
CV (%)	**0.98**	**7.58**	**2.2**	**0.11**	**0.49**	**3.49**	**0.54**	**0.96**	**10.97**	**1.79**

Table 8.15 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Nutrients uptake and Soil properties after harvest of *kharif* (Locations: KWD)

Treatment Name	Soil pH	Soil EC (dS/m)	Soil OC (%)	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Control	6.33	0.26	0.66	292.75	12.63	143.95	4115.38	878.15	4340.75
Complete NF	6.28	0.26	0.72	299	13.83	158.38	5530.13	1192.46	5416.56
AI-NPOF package	6.23	0.25	0.82	337.75	14.68	171.8	7008.52	1569.02	7230.67
Integrated Crop Management	6.4	0.26	0.78	329.5	16.53	180.4	8799.68	1872.41	8991.08
Integrated Crop Management (need-based pesticides)	6.48	0.25	0.77	331.5	16.18	176.23	8657.07	1892.72	8973.03
Exp. mean	**6.34**	**0.26**	**0.75**	**318.1**	**14.77**	**166.15**	**6822.16**	**1480.95**	**6990.42**
CD (0.05)	**NS**	**NS**	**0.08**	**27.07**	**1.74**	**11.84**	**1456.12**	**290.37**	**1489.34**
CV (%)	**4.82**	**10.82**	**6.67**	**5.52**	**7.63**	**4.62**	**13.85**	**12.73**	**13.83**

Table 8.16 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Nutrients uptake and Soil properties after harvest of *kharif* (Locations: PNT)

Treatment Name	Soil pH	Soil EC (dS/m)	Soil OC(%)	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Soil Zn (mg/kg)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Control	7.13	0.24	0.25	121.25	115.25	7.78	28.05	11.98	2.07	10.72
Complete NF	7.28	0.24	0.42	142.5	119.75	9.48	9.65	18.66	3.19	18.45
AI-NPOF package	7.35	0.41	0.67	158.5	140.5	11.13	9.78	24.28	6.39	23.05
Integrated Crop Management	7.25	0.42	0.7	170.5	142.75	13.58	11.65	35.53	8.44	37.83
Integrated Crop Management (need-based pesticides)	7.25	0.45	0.51	170.5	143.5	13.48	13.03	36.46	8.41	34.29
Exp. mean	**7.25**	**0.35**	**0.51**	**152.65**	**132.35**	**11.09**	**14.43**	**25.38**	**5.7**	**24.87**
CD (0.05)	**NS**	**0.05**	**0.04**	**8.79**	**7.61**	**1.06**	**NS**	**1.85**	**0.56**	**1.4**
CV (%)	**1.72**	**10.01**	**5.43**	**3.74**	**3.73**	**6.21**	**123.96**	**4.74**	**6.36**	**3.66**

Table 8.17 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Nutrients uptake and Soil properties after harvest of *kharif* (Locations: PUSA)

Treatment Name	Soil pH	Soil EC (dS/m)	Soil OC (%)	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Control	8.38	0.33	0.45	218.5	26.25	121.55	64.44	10.92	88.96
Complete NF	8.31	0.28	0.47	230.5	28.13	126.9	75	12.33	99.33
AI-NPOF package	8.28	0.26	0.54	241.75	28.73	129.88	74.12	13.07	101.7
Integrated Crop Management	8.32	0.3	0.49	256.25	32.85	143.68	87.11	15.31	118.1
Integrated Crop Management (Pest management)	8.3	0.29	0.51	257.5	32.48	146.03	90.69	16.06	123.27
Exp. mean	**8.32**	**0.29**	**0.49**	**240.9**	**29.69**	**133.61**	**78.27**	**13.54**	**106.27**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**15.22**	**9.71**	**2.53**	**13.33**
CV (%)	**0.82**	**10.72**	**8.39**	**7.83**	**10.92**	**7.39**	**8.05**	**12.13**	**8.14**

Table 8.18 Evaluation of Organic fertilizers and Natural farming practices for enhancing the productivity and soil health Nutrients uptake and Soil properties after harvest of *kharif* (Locations: PUD)

Treatment Name	Soil PH	Soil EC (dS/m)	Soil OC (%)	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Control	6.57	0.24	0.26	115.73	39.33	131	28.53	9.26	31.79
Complete NF	6.43	0.31	0.34	138.13	46.67	157.33	67.31	22.74	77
AI-NPOF package	6.69	0.32	0.37	145.33	49.33	155.67	65.36	21.85	78.27
Integrated Crop Management	6.6	0.34	0.32	141.87	46.33	162	79.2	26.14	93.34
Integrated Crop Management (need-based pesticides)	6.54	0.3	0.33	138.13	47	159.33	81.12	26.71	99.31
Exp. mean	**6.57**	**0.30**	**0.32**	**135.83**	**45.73**	**153.07**	**64.30**	**21.34**	**75.94**
CD (0.05)	**NS**	**0.06**	**NS**	**NS**	**NS**	**NS**	**14.37**	**4.61**	**19.13**
CV (%)	**1.79**	**9.92**	**14.44**	**9.57**	**11.14**	**8.78**	**11.87**	**11.47**	**13.38**

Trial 5.9. Assessment of bio fortified rice genotypes response to Zn application and assessing agronomic bio fortification potential

Bio fortification, also known as biological fortification, involves the development and cultivation of nutritionally enriched food crops using modern biotechnology methods, traditional plant breeding, and agricultural techniques to enhance their bioavailability and address nutritional deficiencies in the human population. It is a burgeoning and cost-effective method, addressing the inadequacy of micronutrients in staple crops like rice, a consequence of agricultural systems prioritizing yield over human health, by enhancing the nutrient content to alleviate micronutrient deficiencies in populations with limited dietary diversity. Recent zinc-enriched varieties and newly developed genotypes necessitate evaluation of their reaction to applied zinc fertilizers to devise nutrient management strategies and determine their potential for agronomic biofortification.

Keeping this in view, the trial was conducted during *kharif*- 2023 with objectives

1) To evaluate the response of the fortified rice genotypes/varieties to the zinc application
2) To study the agronomic biofortification potential of the rice varieties.

The experiments were laid out in factorial RBD, consisting two factors viz., I) Rice genotypes/varieties (5); II) Zn doses (3). The treatment details are represented in table 5.9.1. From the beginning of farming until harvest, all practices were carried out in accordance with the technical programme; observations regarding grain and straw yields as well as other yield metrics were noted. Prior to starting the experiment and during harvest, soil samples were collected and significant soil characteristics were examined. Following harvesting, plant samples were also obtained, and their zinc accumulation was evaluated. The trial was conducted at five locations *viz., Cuttack, Maruteru, Pusa, Titabar, and Varanasi* during Kharif-2023. The results are presented in Table 5.9.2 to 5.9.12.

Yields

Grain and straw yields showed significant differences between the genotypes and treatments and depicted in table 5.9.3 to 5.9.5. At Cuttack, application of T3: FS of 0.5% Zn at stage, PI stage and 1 WAF treatment registered higher grain (5.01 t/ha) and straw (6.46 t/ha) yields as compared to control grain (3.78 t/ha) and straw (5.77 t/ha) yields. Between the varieties, V1: Swarna has recorded higher grain yield (5.18 t/ha) which is significantly at par with V2: CR Dhan 315 whereas V2: CR Dhan 315 registered higher straw yield (7.39 t/ha);

CG Zinc Rice-1 recorded lowest grain (3.46 t/ha) and straw (4.56 t/ha) yields. Application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment recorded significantly higher harvest index (43.8) which is at par with application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF as compared to control (39.5). In case of Varieties, V1: Swarna recorded significantly higher harvest index (47.1) as compared to all other varieties whereas V4: DR Dhan 48 registered lowest harvest index (37.7). Interaction between treatments and genotypes was found to be significant in case of straw yield and harvest index. The straw yield was higher (8.06 t/ha) in interaction between V2: CR Dhan 315 and T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment. However, interaction between V1: Swarna and T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment resulted in higher harvest index (48.8).

In case of Maruteru, there was no significant difference found between Zn treatments. However, there was significant variation in interaction of both Zn treatments and rice varieties. The grain and straw yields were found to be higher (7.45 t/ha and 9.42 t/ha, respectively) in interaction between V2: CR Dhan 315 and T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment. In terms of varieties, V2: CR Dhan 315 recorded significantly higher grain (7.49 t/ha) and straw (8.99 t/ha) yields as compared to all other varieties. Harvest index was higher (44.7) in case of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment whereas V1: Swarna showed higher (47.7) harvest index among the varieties.

At Pusa, the grain and straw yields was recorded higher (4.40 t/ha and 5.55 t/ha) under application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF which is statistically at par with application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF (3.92 t/ha and 5.16 t/ha). However, there was no significant difference among the treatments in case of harvest index. Between the varieties, V1: Swarna produced substantially higher grain yield (5.08 t/ha) whereas the straw yield was found highest (5.69 t/ha) in V2: CR Dhan 315 which was on par with V1: Swarna. The harvest index was significantly influenced by the varieties. Among the varieties, V1: Swarna produced higher (47.3) harvest index which is significantly at par with V3: DR Dhan 45 (45.1) and V4: DR Dhan 48 (45.6) respectively. There was no significant difference between interaction of Zn treatments and genotypes.

In Titabar, the grain yield found to be higher (3.36 t/ha) in case of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment which is on par with T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment whereas the highest straw yield (5.30 t/ha) was recorded with application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF. In case of harvest index, it was resulted highest (40.0) with the application of T3: FS of 0.5% Zn at AT stage, PI stage and

1 WAF which is significantly at par with T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment. There is no significant difference among the varieties in terms of grain yield and harvest index, however the straw yield was significantly influenced by varieties. V5: CG Zinc Rice-1 produced higher straw yield (5.47 t/ha) which is on par with V3: DR Dhan 45 (5.37 t/ha). Interaction between treatments and genotypes was found to be significant in case of straw yield and harvest index. The straw yield was found to be higher in interaction between V2: CR Dhan 315 and T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment (6.49 t/ha), conversely the harvest index was higher (52.2) with interaction of V2: CR Dhan 315 and T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment.

In case of Varanasi, among Zn treatments, the application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF registered significantly higher grain (4.59 t/ha) and straw (11.52 t/ha) yields. Among the varieties, V3: DR Dhan 45 produced higher grain yield (5.14 t/ha) which is on par with V2: CR Dhan 315 whereas the straw yield was higher in case of V2: CR Dhan 315 which is statistically at par with V3: DR Dhan 45. Similarly, the harvest index was significantly influenced by both application of Zn treatments and varieties. The application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF registered higher harvest index (27.8) which is significantly at par with T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment (26.5). In case of varieties, V1: Swarna recorded higher harvest index (28.9) which is significantly at par with V2: CR Dhan 315 (27.3), V3: DR Dhan 45 (28.7) and V4: DR Dhan 48 (28.0). There was no significance difference found between interaction of treatments and genotypes.

Yield Attributes

Yield parameters like tiller number and panicle number per m^2, spikelet fertility and test weight were represented in the table 5.9.6 to 5.9.9. Tiller numbers per m^2 varied significantly across different varieties and treatments at all centres. Among the treatments, T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF, resulted in the higher tiller number per m^2 at Titabar (519.2), and Varanasi (343.1). However, at Cuttack, Maruteru and Pusa, the application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF yielded the higher tiller number per m^2 (442.9, 402.6 and 391.1, respectively).

There were significant differences in the number of panicles per square meter among the various varieties and Zn treatments across all locations. Within the treatments, T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF produced higher number of panicles per m^2 at

Cuttack (336.4), Titabar (420.2) and Varanasi (291.0) except at Maruteru and Pusa, application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF produced higher (307.0 and 365.1) panicle number per m^2 respectively.

Regarding varieties, V2: CR Dhan 315, exhibited a higher tiller number per square meter and panicle number per square meter at Cuttack, Maruteru, and Pusa, except for Titabar and Varanasi. At Titabar, V5: CG Zinc Rice-1 showed a higher tiller number per square meter, however V1: Swarna produced higher number of panicles per square meter. At Varanasi, higher tiller number and panicle number per m^2 were produced by V5: CG Zinc Rice-1.

Interaction between treatments and varieties was found to be significant in case of tiller number per square meter and panicle number per square meter at Maruteru and Varanasi. At Maruteru, the tiller number per m^2 and panicle number per m^2 were found to be higher (495.0 and 336.0, respectively) in interaction between of V2: CR Dhan 315 and T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment, whereas it was higher (403.7 and 374.7, respectively) in interaction between V5: CG Zinc Rice-1 and T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment at Varanasi.

Spikelet fertility also varied significantly across different treatments at Cuttack, Pusa and Titabar except Maruteru and Varanasi. Conversely, varietal difference was only found at Cuttack and Varanasi. Within the treatments, application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF recorded higher spikelet fertility at Cuttack (83.3 %) and Titabar (91.5 %) which is significantly at par with T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment (90.9 %), however at Pusa, it was recorded higher (91.0 %) under T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment. In case of varieties, V5: CG Zinc Rice-1 registered higher (84.4 %) spikelet fertility at Cuttack, whereas it was recorded higher in V4: DR Dhan 48 (89.0 %) at Varanasi. Interaction between treatments and genotypes was found to be significant only at Varanasi, where spikelet fertility was registered higher (90.1 %) in interaction between V4: DR Dhan 48 and T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment.

There were significant differences found in test weight at all locations except Maruteru and Pusa in terms of Zn treatments, however varietal differences were found at all locations. Among the treatments, application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF registered higher test weight at Cuttack (23.0 g), Titabar (25.1) and Varanasi (22.9 g) and it was on par with application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment (24.9 g) at Titabar. In case of varieties, V2: CR Dhan 315 recorded significantly higher (25.2

g) test weight than other varieties at Cuttack, whereas in Maruteru, V2: CR Dhan 315 (24.9 g) also registered higher test weight however it was significantly at par with V3: DR Dhan 45 (24.1 g) and V5: CG Zinc Rice-1 (23.5 g). In case of Pusa, the test weight was recorded higher in V5: CG Zinc Rice-1 (38.2 g) which is on par with V1: Swarna (36.0 g), V3: DR Dhan 45 (33.9 g) and V4: DR Dhan 48 (34.3 g), whereas at Titabar, V5: CG Zinc Rice-1 exhibited significantly higher (26.4 g) test weight than other varieties and in Varanasi, higher test weight was registered under V5: CG Zinc Rice-1 (25.3 g) which is at par with V2: CR Dhan 315 (24.8 g). Interaction between treatments and genotypes was found to be non-significant at all locations.

Plant Zinc Content

Significant differences in grain Zn content were observed at all the locations with respect to Zn treatments (Table 5.9.10). Among the treatments, the application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF, resulted in higher grain Zn content at Cuttack (35.3 mg/kg), Maruteru (32.2 mg/kg) and Varanasi (42.9 mg/kg) which is on par with application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF (33.0 mg/kg) at Cuttack and Maruteru. Conversely, at Pusa and Titabar, the higher grain Zn content (38.1 mg/kg and 38.4 mg/kg) was observed with the application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment which was at par with the treatment T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF (37.6 mg/kg) at Titabar. Varietal difference was observed in grain Zn content at all the locations. Between varieties, V5: CG Zinc Rice-1 exhibited higher grain Zn content at Cuttack (41.7 mg/kg), Maruteru (28.2 mg/kg), and Titabar (39.7 mg/kg) however at Maruteru it was on par with and V4: DR Dhan 48 (26.8 mg/kg). In case of Pusa, higher grain Zn content was found in V3: DR Dhan 45 (37.9 mg/kg) which was at par with both and V4: DR Dhan 48 (35.9 mg/kg) and V5: CG Zinc Rice-1 (35.9 mg/kg). At Varanasi, higher grain Zn content was observed in V4: DR Dhan 48 (39.3 mg/kg) which is on par with V1: Swarna (39.0 mg/kg) and V2: CR Dhan 315 (39.1 mg/kg). Interaction between treatments and varieties was found to be significant only at Varanasi, where higher grain Zn content (46.1 mg/kg) was found in interaction between V1: Swarna and T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment.

The Zn content in the straw was affected significantly across different varieties and treatments at all centres (Table 5.9.11). Application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF registered higher straw Zn content at Maruteru (32.7 mg/kg), Titabar (43.0 mg/kg) and Varanasi (94.6 mg/kg), conversely at Maruteru it was significantly at par with application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF (31.7 mg/kg). In case of Cuttack and Pusa the higher straw Zn content was recorded under the application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment (46.1 mg/kg and 41.7 mg/kg, respectively), however at Cuttack, it was on par with the application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF (45.4 mg/kg). Regarding varieties, V4: DR Dhan 48 displayed higher straw Zn content at Maruteru (33.6 mg/kg), Pusa (41.9 mg/kg) and Varanasi (71.7 mg/kg). At Maruteru, it was on par with V3: DR Dhan 45 (30.8 mg/kg), however at Pusa it was on par with V2: CR Dhan 315 (40.4 mg/kg) and V5: CG Zinc Rice-1 (39.9 mg/kg) and at Varanasi it was significantly at par with V1: Swarna (70.1 mg/kg). In case of Cuttack and Titabar, V3: DR Dhan 45 exhibited higher straw Zn content (56.2 mg/kg and 43.7 mg/kg, respectively) which was significantly at par with V2: CR Dhan 315 (53.5 mg/kg and 38.5 mg/kg, respectively) and V5: CG Zinc Rice-1 (46.3 mg/kg and 38.7 mg/kg respectively). Interaction between treatments and varieties was found to be significant at Pusa, Titabar and Varanasi. In Pusa, higher straw Zn content (45.7 mg/kg) was obtained in interaction between V5: CG Zinc Rice-1 and T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment whereas at Titabar, the straw Zn content was found to be higher (57.4 mg/kg) in interaction between V3: DR Dhan 45 and the straw Zn content was higher in Varanasi, the straw Zn content was higher (101.8 mg/kg) in interaction between V1: Swarna and T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF treatment.

Post-harvest soil zinc status

Following harvest, the available Zn status in soil significantly varied among the treatments at all locations (Table 5.9.12). The application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment exhibited higher Zn status in soil at Cuttack (1.44 mg/kg), Maruteru (1.42 mg/kg), Pusa (0.60 mg/kg), Titabar (2.03 mg/kg) and Varanasi (0.82 mg/kg), however at Pusa it was on par with application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF (0.58 mg/kg). At Cuttack and Titabar, significant difference in soil Zn content due to effect of varieties and at Varanasi higher content was observed under V3: DR Dhan 45 which was at par with V2: CR Dhan 315 and at Titabar higher content was observed under V2: CR Dhan 315.

Summary

At all five locations, significant variations in yield attributes and overall yields were observed based on genotype and location. Application of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF exhibited higher grain yield at Cuttack, Titabar and Varanasi whereas application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment registered higher grain yield at Pusa.

The treatment effects were found to be non-significant at Maruteru. Among varieties, V1: Swarna performed better at Cuttack and Pusa, whereas V2: CR Dhan 315 found superior at Maruteru and in case of Titabar, V5: CG Zinc Rice-1 Performed more effectively whereas V3: DR Dhan 45 exhibited superior performance at Varanasi. Grain zinc content showed notable variations across all locations concerning zinc treatments. Among the treatments, the use of T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF, led to increased zinc content in grains at Cuttack, Maruteru and Varanasi. In contrast, at Pusa and Titabar, significantly higher grain zinc content was noted with the application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment. The variety V5: CG Zinc Rice-1 exhibited higher grain Zn content at Cuttack, Maruteru and Titabar whereas at Pusa V3: DR Dhan 45 has accumulated higher amount of Zn and the variety V4: DR Dhan 48 exhibited superior performance in terms of Zn accumulation at Varanasi. The application of T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF treatment showed elevated zinc levels in the post- harvest soil across all locations.

Table: 5.9.1 Assessment of biofortified rice genotypes response to Zn application and assessing agronomic biofortification potential

Treatments Details

Rice Varieties Name		Zn Doses	
V1	Swarna	T1	Control with no Zinc
V2	CR Dhan 315	T2	Soil test-based Zinc application (STBZ)+ Foliar spray of 0.5% Zinc at PI stage and 1 week after flowering
V3	DR Dhan 45		
V4	DR Dhan 48	T3	Foliar spray of 0.5% Zinc at active tillering (AT) stage, panicle initiation (PI) stage and 1 week after flowering
V5	CG Zinc Rice-1		

.

Table: 5.9.2 Assessment of biofortified rice genotypes response to Zn application and assessing agronomic biofortification potential

Soil and crop characteristics

Parameters	NRRI	MTU	Pusa	TTB	BHU
Cropping system	Rice	Rice	Rice	Rice	Rice
Season	Kharif	Kharif	Kharif	Kharif	Kharif
RDF (kg NPK/ha)	80:40:40	90:60:60	120:60:40	60:20:40	150:60:40
Soil characteristic					
% Clay	33.2	38	14	40.5	23.66
% Silt	52.7	28	31	29.5	26.13
% Sand	14.1	34	55	30.0	50.21
Texture	Sandy clay loam	Clay loam	Sandy loam	Silty clay	Sandy clay loam
CEC (cmol (P+) / kg	16.7	48.9	-	11.5	-
pH (1:2)	5.6	6.63	8.24	5.2	7.13
EC (dS/m)	0.45	0.69	0.28	0.11	0.19
Organic carbon (%)	0.62	1.07	0.48	0.85	0.28
Avail. N (kg/ha)	288.5	184	232	237	190.0
Avail. P2O5 (kg/ha)	38.5	33.9	32.6	20.1	40.3
Avail. K2O (kg/ha)	249.8	397	140.5	157	240.0
DTPA –Zn (mg/kg)	0.81	1.10	0.54	0.76	0.65

Table: 5.9.3 Effect of biofortified rice genotypes response to Zn application on Grain yield (t/ha) of rice at different locations

Treatments/ Varieties	NRRI				MTU				Pusa				TTB				BHU			
	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean
V1: Swarna	4.43	5.43	5.70	5.18	5.93	6.83	5.77	6.18	4.17	5.65	5.41	5.08	2.63	2.87	3.02	2.84	4.28	4.80	5.03	4.70
V2: CR Dhan 315	4.25	5.33	5.73	5.10	7.44	7.59	7.45	7.49	3.48	3.81	3.84	3.71	2.45	2.68	3.56	2.90	4.21	5.00	5.28	4.83
V3: DR Dhan 45	4.15	4.71	5.29	4.72	5.43	5.71	5.61	5.59	3.68	5.08	4.21	4.32	2.32	2.61	2.92	2.62	4.47	5.07	5.89	5.14
V4: DR Dhan 48	3.13	3.79	4.40	3.78	4.49	5.00	5.74	5.08	3.93	5.24	3.96	4.38	1.86	2.96	3.90	2.91	4.39	4.17	4.86	4.48
V5: CG Zinc Rice-1	2.96	3.50	3.93	3.46	4.43	3.25	3.68	3.79	1.95	2.22	2.16	2.11	2.89	3.53	3.40	3.27	1.24	1.48	1.87	1.53
Mean	3.78	4.55	5.01		5.54	5.68	5.65		3.44	4.40	3.92		2.43	2.93	3.36		3.72	4.10	4.59	
CD (0.05) T	0.18				NS				0.50				0.56				0.27			
CD (0.05) V	0.23				0.33				0.64				NS				0.35			
T*V	NS				0.58				NS				NS				NS			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.4 Effect of biofortified rice genotypes response to Zn application on Straw yield (t/ha) of rice at different locations

Treatments/ Varieties	NRRI				MTU				Pusa				TTB				BHU			
	T1	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**
V1: Swarna	5.63	5.75	5.98	**5.79**	8.02	6.97	5.55	**6.85**	5.06	6.15	5.66	**5.62**	4.92	5.27	5.55	**5.25**	10.99	11.41	12.20	**11.53**
V2: CR Dhan 315	6.69	7.43	8.06	**7.39**	8.40	9.15	9.42	**8.99**	5.03	6.26	5.78	**5.69**	4.62	6.49	3.26	**4.79**	11.88	12.89	13.73	**12.83**
V3: DR Dhan 45	6.41	6.75	6.90	**6.69**	7.35	8.55	8.20	**8.03**	4.88	5.51	5.06	**5.15**	5.47	5.11	5.53	**5.37**	12.20	12.78	13.11	**12.69**
V4: DR Dhan 48	5.85	6.18	6.55	**6.19**	6.58	6.37	7.25	**6.73**	4.72	5.44	5.41	**5.19**	4.81	5.25	4.85	**4.97**	11.51	11.01	11.94	**11.49**
V5: CG Zinc Rice-1	4.28	4.59	4.82	**4.56**	6.16	4.02	4.94	**5.04**	3.28	4.38	3.88	**3.85**	6.07	4.40	5.93	**5.47**	6.02	6.26	6.63	**6.30**
Mean	**5.77**	**6.14**	**6.46**		**7.30**	**7.01**	**7.07**		**4.59**	**5.55**	**5.16**		**5.18**	**5.30**	**5.02**		**10.52**	**10.87**	**11.52**	
CD (0.05) T	0.16				NS				0.51				0.16				0.33			
CD (0.05) V	0.21				0.46				0.65				0.21				0.42			
T*V	0.37				0.79				NS				0.36				NS			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.5 Effect of biofortified rice genotypes response to Zn application on Harvest index of rice at different locations

Treatments/ Varieties	NRRI				MTU				Pusa				TTB				BHU			
	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean
V1: Swarna	44.0	48.5	48.8	**47.1**	42.5	49.6	51.1	**47.7**	45.1	48.0	48.8	**47.3**	34.9	35.6	31.8	**34.1**	27.9	29.6	29.2	**28.9**
V2: CR Dhan 315	38.8	41.8	41.5	**40.7**	47.0	45.3	44.2	**45.5**	41.0	37.9	39.9	**39.6**	34.7	29.2	52.2	**38.7**	26.1	28.0	27.8	**27.3**
V3: DR Dhan 45	39.3	41.1	43.4	**41.3**	42.6	40.1	40.6	**41.1**	42.7	47.6	44.8	**45.1**	29.8	34.0	34.8	**32.8**	26.8	28.4	31.0	**28.7**
V4: DR Dhan 48	34.9	38.0	40.2	**37.7**	40.5	44.0	44.3	**42.9**	45.4	49.1	42.1	**45.6**	28.0	36.2	44.7	**36.3**	27.6	27.4	29.0	**28.0**
V5: CG Zinc Rice-1	40.7	43.3	44.9	**43.0**	41.8	44.7	42.7	**43.1**	37.6	35.1	35.7	**36.2**	32.5	44.6	36.6	**37.9**	17.1	18.9	21.9	**19.3**
Mean	**39.5**	**42.5**	**43.8**		**42.9**	**44.7**	**44.6**		**42.4**	**43.6**	**42.3**		**32.0**	**35.9**	**40.0**		**25.1**	**26.5**	**27.8**	
CD (0.05) T	1.3				NS				NS				4.1				1.7			
CD (0.05) V	1.7				2.4				4.8				NS				2.2			
T*V	2.9				4.2				NS				9.3				NS			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.6 Effect of biofortified rice genotypes response to Zn application on Tiller Number/m^2 of rice at different locations

Treatments/ Varieties	NRRI				MTU				Pusa				TTB				BHU			
	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean
V1: Swarna	421.7	440.0	421.7	**427.8**	336.0	462.0	363.0	**387.0**	383.3	395.3	396.0	**391.6**	451.0	457.6	554.4	**487.7**	281.3	326.0	326.0	**311.1**
V2: CR Dhan 315	436.3	480.3	432.7	**449.8**	462.0	495.0	363.0	**440.0**	364.7	396.7	416.7	**392.7**	443.3	502.7	474.1	**473.4**	245.3	253.7	276.3	**258.4**
V3: DR Dhan 45	421.7	432.7	436.3	**430.2**	396.0	396.0	297.0	**363.0**	374.3	372.7	393.7	**380.2**	413.6	443.3	541.2	**466.0**	284.7	332.3	347.7	**321.6**
V4: DR Dhan 48	392.3	407.0	425.3	**408.2**	320.0	363.0	462.0	**381.7**	343.0	405.0	394.0	**380.7**	349.8	411.4	446.6	**402.6**	282.7	320.3	361.7	**321.6**
V5: CG Zinc Rice-1	396.0	454.7	480.3	**443.7**	297.0	297.0	264.0	**286.0**	282.3	386.0	319.0	**329.1**	443.3	514.8	579.7	**512.6**	346.7	378.7	403.7	**376.3**
Mean	**413.6**	**442.9**	**439.3**		**362.2**	**402.6**	**349.8**		**349.5**	**391.1**	**383.9**		**420.2**	**466.0**	**519.2**		**288.1**	**322.2**	**343.1**	
CD (0.05) T	25.3				11.3				29.6				27.2				7.7			
CD (0.05) V	32.7				14.6				38.2				35.1				10.0			
T*V	NS				25.3				NS				NS				17.3			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.7. Effect of biofortified rice genotypes response to Zn application on Panicle number/m^2 of rice at different locations

Treatments/ Varieties	NRRI				MTU				Pusa				TTB				BHU			
	T1	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**
V1: Swarna	302.3	336.7	345.7	**328.2**	325.0	330.0	328.0	**327.7**	360.3	370.7	371.3	**367.4**	396.0	407.0	429.0	**410.7**	234.7	250.3	270.0	**251.7**
V2: CR Dhan 315	324.3	343.3	353.7	**340.4**	321.0	336.0	333.0	**330.0**	341.7	372.7	391.0	**368.4**	363.0	396.0	407.0	**388.7**	227.3	247.0	262.3	**245.6**
V3: DR Dhan 45	299.0	314.3	336.7	**316.7**	310.0	322.0	286.0	**306.0**	344.7	343.7	366.3	**351.6**	363.0	374.0	451.0	**396.0**	212.7	243.7	257.0	**237.8**
V4: DR Dhan 48	265.7	286.3	304.0	**285.3**	198.0	299.0	304.0	**267.0**	317.0	375.7	368.3	**353.7**	319.0	352.0	363.0	**344.7**	213.3	265.3	291.0	**256.6**
V5: CG Zinc Rice-1	282.3	325.0	342.0	**316.4**	274.0	248.0	241.0	**254.3**	253.0	363.0	292.0	**302.7**	341.0	429.0	451.0	**407.0**	304.0	336.7	374.7	**338.4**
Mean	**294.7**	**321.1**	**336.4**		**285.6**	**307.0**	**298.4**		**323.3**	**365.1**	**357.8**		**356.4**	**391.6**	**420.2**		**238.4**	**268.6**	**291.0**	
CD (0.05) T	10.7				14.2				28.9				25.7				8.1			
CD (0.05) V	13.8				18.4				37.3				33.2				10.4			
T*V	NS				31.8				NS				NS				18.1			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.8. Effect of biofortified rice genotypes response to Zn application on Spikelet Fertility (%) of rice at different locations

Treatments/ Varieties	NRRI				MTU				Pusa				TTB				BHU			
	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean
V1: Swarna	75.6	77.4	77.9	**76.9**	91.6	89.9	88.7	**90.1**	86.0	91.1	85.1	**87.4**	90.6	91.3	91.8	**91.2**	80.0	86.9	86.1	**84.4**
V2: CR Dhan 315	79.9	84.2	85.5	**83.2**	93.8	95.8	91.8	**93.8**	85.0	90.6	86.4	**87.3**	86.6	91.2	92.1	**90.0**	88.3	86.0	80.7	**85.0**
V3: DR Dhan 45	82.8	83.2	81.5	**82.5**	91.8	88.3	95.3	**91.8**	84.9	91.4	89.0	**88.4**	89.7	90.9	91.6	**90.7**	81.7	76.3	82.2	**80.0**
V4: DR Dhan 48	79.3	84.7	85.3	**83.1**	95.4	94.7	95.9	**95.3**	84.8	90.5	88.8	**88.0**	89.7	90.4	91.0	**90.4**	88.5	90.1	88.4	**89.0**
V5: CG Zinc Rice-1	83.3	83.6	86.4	**84.4**	90.9	92.2	86.7	**89.9**	86.0	91.6	89.2	**88.9**	90.1	90.6	90.8	**90.5**	80.0	80.0	75.3	**78.4**
Mean	**80.2**	**82.6**	**83.3**		**92.7**	**92.2**	**91.7**		**85.3**	**91.0**	**87.7**		**89.3**	**90.9**	**91.5**		**83.7**	**83.9**	**82.5**	
CD (0.05) T	1.6				NS				1.1				1.2				NS			
CD (0.05) V	2.1				NS				NS				NS				3.6			
T*V	NS				NS				NS				NS				6.3			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at stage, PI stage and 1 WAF]

Table: 5.9.9. Effect of biofortified rice genotypes response to Zn application on test weight (g) of rice at different locations

Treatments/ Varieties	Cuttack				Maruteru				Pusa				Titabar				Varanasi			
	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean
V1: Swarna	19.3	20.3	20.9	**20.2**	20.0	19.5	19.3	**19.6**	36.3	37.1	34.7	**36.0**	23.1	23.3	23.3	**23.3**	20.9	21.6	22.7	**21.8**
V2: CR Dhan 315	24.0	24.6	27.0	**25.2**	23.2	27.6	23.9	**24.9**	25.8	28.6	26.7	**27.1**	23.9	24.1	24.2	**24.1**	23.3	25.3	25.9	**24.8**
V3: DR Dhan 45	22.5	23.5	23.1	**23.0**	23.4	28.2	20.9	**24.1**	33.7	34.5	33.3	**33.9**	25.7	26.0	26.5	**26.0**	22.5	23.5	24.6	**23.5**
V4: DR Dhan 48	18.8	18.9	20.4	**19.4**	12.6	14.4	16.3	**14.4**	34.5	35.0	33.3	**34.3**	24.4	24.6	24.8	**24.6**	12.9	13.9	14.4	**13.7**
V5: CG Zinc Rice-1	22.2	22.9	23.8	**23.0**	25.1	23.6	21.7	**23.5**	42.2	39.2	33.1	**38.2**	26.1	26.4	26.7	**26.4**	23.8	25.2	27.0	**25.3**
Mean	**21.4**	**22.0**	**23.0**		**20.9**	**22.7**	**20.4**		**34.5**	**34.9**	**32.3**		**24.6**	**24.9**	**25.1**		**20.7**	**21.9**	**22.9**	
CD (0.05) T	0.6				NS				NS				0.2				0.5			
CD (0.05) V	0.7				3.4				4.8				0.3				0.7			
T*V	NS				NS				NS				NS				NS			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.10. Effect of biofortified rice genotypes response to Zn application on Grain Zn Content (mg/kg) of rice at different locations

Treatments/ Varieties	Cuttack				Maruteru				Pusa				Titabar				Varanasi			
	T1	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**
V1: Swarna	23.1	29.0	37.0	**29.7**	18.3	27.4	28.2	**24.7**	28.6	34.2	29.5	**30.8**	22.2	38.1	34.3	**31.5**	29.8	41.1	46.1	**39.0**
V2: CR Dhan 315	17.7	33.1	33.6	**28.1**	24.6	29.7	32.2	**28.9**	33.0	38.5	35.4	**35.6**	31.5	36.0	36.2	**34.6**	32.7	40.4	44.2	**39.1**
V3: DR Dhan 45	20.1	28.0	30.4	**26.2**	25.6	26.4	33.1	**28.4**	37.7	38.8	37.2	**37.9**	36.4	36.5	42.6	**38.5**	29.0	37.0	40.9	**35.6**
V4: DR Dhan 48	25.6	30.7	31.2	**29.2**	28.2	33.4	33.7	**31.8**	32.9	40.4	34.3	**35.9**	40.9	37.9	34.5	**37.8**	32.1	40.0	45.7	**39.3**
V5: CG Zinc Rice-1	36.5	44.1	44.4	**41.7**	28.9	36.7	33.9	**33.2**	33.1	38.6	36.1	**35.9**	35.4	43.4	40.2	**39.7**	33.4	36.2	37.6	**35.8**
Mean	**24.6**	**33.0**	**35.3**		**25.1**	**30.7**	**32.2**		**33.1**	**38.1**	**34.5**		**33.3**	**38.4**	**37.6**		**31.4**	**38.9**	**42.9**	
CD (0.05) T	3.9				2.8				2.4				4.0				1.6			
CD (0.05) V	5.1				3.6				3.0				5.2				2.1			
T*V	NS				NS				NS				NS				3.7			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.11. Effect of biofortified rice genotypes response to Zn application on Straw Zn Content (mg/kg) of rice at different locations

Treatments/ Varieties	Cuttack				Maruteru				Pusa				Titabar				Varanasi			
	T1	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**
V1: Swarna	24.0	23.9	24.0	**24.0**	22.9	29.4	26.9	**26.4**	33.6	37.9	38.5	**36.7**	23.7	36.6	30.9	**30.4**	50.3	58.0	101.8	**70.1**
V2: CR Dhan 315	44.6	58.0	57.8	**53.5**	27.3	29.1	28.5	**28.3**	39.0	43.5	40.4	**40.9**	35.2	32.2	48.2	**38.5**	44.4	60.9	94.1	**66.5**
V3: DR Dhan 45	54.6	57.1	56.9	**56.2**	27.0	33.0	32.5	**30.8**	38.5	37.3	36.3	**37.4**	33.7	40.1	57.4	**43.7**	41.4	45.9	95.8	**61.0**
V4: DR Dhan 48	19.8	33.7	31.5	**28.3**	24.5	36.3	40.1	**33.6**	38.6	44.2	42.9	**41.9**	35.0	38.0	36.6	**36.5**	42.4	72.9	99.9	**71.7**
V5: CG Zinc Rice-1	24.8	57.8	56.5	**46.3**	20.2	30.6	35.6	**28.8**	38.4	45.7	35.7	**39.9**	29.1	44.9	42.0	**38.7**	44.9	67.3	81.4	**64.6**
Mean	**33.6**	**46.1**	**45.4**		**24.4**	**31.7**	**32.7**		**37.6**	**41.7**	**38.8**		**31.3**	**38.4**	**43.0**		**44.7**	**61.0**	**94.6**	
CD (0.05) T	10.8				3.41				2.2				4.8				3.0			
CD (0.05) V	13.9				4.40				2.8				6.2				3.9			
T*V	NS				NS				4.9				10.7				6.8			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF]

Table: 5.9.12. Effect of biofortified rice genotypes response to Zn application on post-harvest soil zinc status (mg/kg) of rice at different locations

Treatments/ Varieties	Cuttack				Maruteru				Pusa				Titabar				Varanasi			
	T1	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**	**T1**	**T2**	**T3**	**Mean**
V1: Swarna	0.65	1.20	2.03	**1.29**	1.01	1.44	1.32	**1.26**	0.53	0.60	0.57	**0.57**	1.06	1.98	1.18	**1.40**	0.67	0.81	0.69	**0.72**
V2: CR Dhan 315	2.06	1.23	1.09	**1.46**	1.17	1.33	1.42	**1.31**	0.53	0.60	0.58	**0.57**	1.25	3.10	1.01	**1.78**	0.56	0.87	0.70	**0.71**
V3: DR Dhan 45	0.74	2.13	1.73	**1.54**	1.30	1.41	1.14	**1.29**	0.54	0.61	0.58	**0.57**	1.16	1.93	1.13	**1.41**	0.63	0.79	0.69	**0.70**
V4: DR Dhan 48	0.94	1.34	0.87	**1.05**	1.00	1.54	1.13	**1.22**	0.53	0.61	0.59	**0.58**	0.89	1.04	1.09	**1.01**	0.74	0.82	0.69	**0.75**
V5: CG Zinc Rice-1	1.36	1.32	1.06	**1.25**	1.01	1.36	1.30	**1.22**	0.54	0.61	0.59	**0.58**	0.99	2.08	1.02	**1.36**	0.58	0.82	0.76	**0.72**
Mean	**1.15**	**1.44**	**1.36**		**1.10**	**1.42**	**1.26**		**0.53**	**0.60**	**0.58**		**1.07**	**2.03**	**1.08**		**0.64**	**0.82**	**0.71**	
CD (0.05) T	0.08				0.10				0.03				0.29				0.04			
CD (0.05) V	0.10				NS				NS				0.37				NS			
T*V	0.17				0.22				NS				0.65				0.10			

[T1: Control with no Zn; T2: STBZ+ FS of 0.5% Zn at PI stage and 1 WAF; T3: FS of 0.5% Zn at AT stage, PI stage and 1 WAF

Appendix-I

List of cooperating centers of Soil Science and allotment of trials: 2023 -24

Sl. No	Locations	Trial 1		Trial 2		Trial 3		Trial 4	Trial 5		Trial 6		Trial 7		Trial 8		Trail 9		Allotted	Conducted	Conducted %
		K	R	K		K	R	K	K	R	K	R	K	R	K	R	K	R			
1	Kanpur (F)			x		x			x		x		x						09	05	56
2	Karaikal (F)								x	x	x		x			x			05	05	100
3	Kaul (F)			x															01	01	100
4	Mandya (F)	x	x			x							x		x				05	05	100
5	Maruteru (F)	x	x						x	x	x		x				x		10	07	70
6	Moncompu (F)							x	x		x		x		x				08	05	63
7	Pantnagar (F)			x					x				x		x				07	04	57
8	Pusa (F)					x			x				x		x		x		05	05	100
9	Titabar (F)	x	x					x					x		x		x		06	06	100
10	Ludhiana (F)																		-	-	-
11	Bankura												x	x					02	02	100
12	Chinsurah (V)			x									x		x				06	03	50
13	Chiplima (V)										x		x						03	02	67
14	Faizabad (V)					x			x		x		x						04	04	100
15	Khudwani (V)								x		x		x		x				04	04	100
16	NRRI, Cuttack(V)										x						x		04	02	50
17	Puducherry (V)												**x**		x				02	02	100
18	Varanasi (V)																x		01	01	100
Total trials conducted		**03**	**03**	**04**		**04**		**02**	**08**	**02**	**08**		**14**	**1**	**08**	**01**	**05**		**82**	**63**	**77**

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

Trial No.1: **Long-term soil fertility management in rice-based cropping systems** (RBCS): 03 (Mandya, Maruteru, Titabar)

Trial No.2: **Soil quality and productivity assessment for bridging the yield gaps in farmers' fields:** 04 (Kanpur, Kaul, Pantnagar, Chinsurah)

Trial No.3: **Management of sodic soils using nano Zn formulation:** 04 (Kanpur, Mandya, Pusa, Faizabad)

Trial No.4: **Management of acid soils:** 02 (Moncompu, Titabar)

Trial No.5**: Residue management in rice-based cropping systems**: 08 (Kanpur, Karaikal, Maruteru, Moncompu, Pantnagar, Pusa, Faizabad, Khudwani)

Trial No.6: **Nano-fertilizers for increasing nutrient use efficiency, yield and economic returns in transplanted rice**: 08 (Kanpur, Karaikal, Maruteru, Moncompu, Chiplima, Faizabad, Khudwani, NRRI cuttack)

Trial No.7: **Yield maximization of rice in different zones:** 14 (Kanpur, Karaikal, Mandya, Maruteru, Moncompu, Pantnagar, Pusa, Titabar, Bankura, Chinsurah, Chiplima, Faizabad, Khudwani, Puducherry)

Trial No.8: **Enhancing productivity of Organic Rice cultivation**: 09 (Karaikal, Mandya, Moncompu, Pantnagar, Pusa, Titabar, Chinsurah, Khudwani, Puducherry).

Trial No.9: **Assessment of bio fortified rice genotypes response to Zn application and assessing agronomic bio fortification potential** (Maruteru, Pusa, Titabar, NRRI, Varanasi)

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