SOIL SCIENCE

Progress Report of Soil Science Coordinated Programme

(*Rabi* and *Kharif* 2013)

5. SOIL SCIENCE

CONTENTS

5. SOIL SCIENCE

Summary

The coordinated program in soil science addresses issues related to sustaining productivity of soil and crop systems on long-term basis, site specific nutrient management based on nutritional status in farmers' fields, efficient use of irrigation water, management of micronutrients in problem soils, genotypic variability in iron and zinc in rice and their enrichment, screening for tolerance to soil acidity related problems, nutrient use efficiency and crop productivity under late planted conditions, nutrient requirement of recently released varieties and hybrids and monitoring soil quality and productivity under emerging systems of rice production. A total of 10 trials were conducted during *rabi* 2012-13 and *kharif* 2013 in 15 locations representing typical soil and crop systems and important rice growing regions.

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

From the trial on "Long term soil fertility management in RBCS", which is in the 25th year, the results indicated the consistent superiority of conjunctive use of 100% RDF + 5t FYM/ha over all other treatments at all three locations and FYM alone increased grain yield by 25% over RDF at Mandya. Omission of N, P, K, Zn & S and reduction of 50% nutrients resulted in significant yield reduction at all locations. Improved nutrients uptake with supplementary use of organics indicated the beneficial effect of organic manures for nutrient uptake which has ultimately resulted in higher grain yields. Soil fertility status at the end of *kharif* -2013 indicated an improvement of organic carbon, available nutrient status and bulk density values with supplementary and/ or complete organic manuring treatment compared to inorganic fertilization alone at all locations and most of these values were maximum with 50% NKP + 25% GM-N +25% FYM-N/ 100% RFD ZnS/ FYM@ 10 t/ha and control plots recorded the lowest values. Linear trends of rice productivity over 25 years indicated near stable to slightly negative growth rate at Maruteru ; improved growth at Titabar and a negative growth rate at Mandya (-3, 14 and -43 kg grain /ha/year, respectively, at MTU, TTB and MND) with current RDF and a positive growth of about 100 kg/ ha/year at all locations with a supplementary dose of 5 t FYM/PM along with RDF.

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

In order to fine tune the current fertilizer practices on the basis of realistic assessment of soil fertility and its variability across farm units for realizing region or cluster-specific yield

targets, this trial was conducted in more than 30 farmers' fields around Titabar, Chinsurah, Karaikal and Mandya centers representing irrigated and shallow low lands, besides validating the fertilizer prescriptions for target yields generated in the previous years in farmers' fields around Titabar and Mandya in comparison with farmers' and recommended fertilizers practices at these locations. Rice productivity with recommended fertilizer practice varied from 4.4 –5.6 t/ha at Titabar and 2.94 – 6.81 t/ha at Mandya while the yields were lower with farmers' fertilizer practices in these locations with corresponding variation in nutrient uptake, nutrient utilization and recovery efficiencies. Fertilizer doses estimated based on the nutrient uptake and its efficiency at each site for yield targets of 6.1 t/ha varied substantially between the sites from the currently followed blanket dose indicating the importance of site characteristics for recommending fertilizer prescriptions. Validation of SSNM recommendations estimated in the previous year in representative farm sites showed promising results particularly at Mandya and Titabar and increase in the yields over farmers' fertilizer practices and current recommendations indicating the importance of location and site specific input management for sustaining soil and crop productivity.

5.3 Management of micronutrients in rice-based cropping system in sodic, acid and neutral soils

The proposed trial to evaluate efficiency of management practices to improve rice productivity in problem soils was conducted at three locations (sodic soils of Kanpur, acidic soils of Ranchi and Moncompu). Gypsum application significantly improved rice yields but not wheat yields at Kanpur. Application of organic manures along with NPK alone or supplemented with micronutrients, recorded increases in wheat yields by 13.7% and rice yields by 19.6% compared to similar treatments without organic manure addition. At Ranchi, marginal increase in rice yield was observed by the application of organic manure along with NPK and micronutrients.

5.4 Screening of rice germplasm for high iron and zinc contents

About 160 cultures including four checks were screened at 11 locations to study the influence of environment on rice productivity and micronutrient contents and identify promising cultures. Strong interaction effects of genotypes and locations were observed for both Fe and Zn content. The relationship between yield and nutrient content in brown rice did not show any significant correlation at all the locations for both Zn and Fe. Among the cultures, Kadamkudy and Vasumati recorded the highest Zn (384 g/ha) and Fe uptake (491 g/ha), respectively, while the lowest Zn uptake in IR 83294-66-2-2-3-2 (110 g/ha) and IR 83668-35-2-2-2 (150 g/ha) and Fe uptake in Improved Chittimutyalu (102 g/ha). As in the past, cultures Aghonibora and Vasumati are found promising for accumulation of both Fe and Zn at different locations.

5.5 Nutrient and water requirement for aerobic rice cultivation

The relative efficiency of utilizing water and requirement of nutrients under aerobic rice cultivation was assessed at Kanpur (Indo-Gangetic Plains) and Mandya (Cauvery Command) under three water regimes and a combination of nutrient (NPK) applications. Water regimes significantly influenced the performance of aerobic rice at both the locations. The NPK requirement at Kanpur and Mandya was estimated to be 18.4, 5.2 and 20.1 kg and 10.2, 2.9 and 5.8 kg per tonne of grain production, respectively. Productivity of water (kg grain/ha mm water used) ranged from 2.0-3.0 and 0.9-1.6 kg grain/ha mm water at Kanpur and Mandya, respectively. The per cent saving in water requirement with 100 and 75% CPE irrigation ranged from 27.7 to 54.1 and 29.9 to 57.2 at Kanpur and Mandya, respectively over 150% CPE. Irrigation equivalent to 75% of CPE appeared to be optimum for aerobic rice system saving about 26% irrigation water at Kanpur and 30% at Mandya over 150% CPE.

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

Based on the results from five centres (DRR, Ghaghraghat, Karaikal, Khudwani and Maruteru), the grain yield data indicated higher productivity with early planting over optimum planting time at Karaikal, Khudwani and Maruteru by 24, 10 and 9%, respectively. Whereas, at all 5 locations, delayed planting resulted in yield reduction by about 13-40% . With regard to nutrient management, at most of the locations, INM performed well recording maximum yields and at four locations, 100% organics also performed on par with 100% RDF and INM treatments. In general, INM and 150% RDF for nutrient uptake and INM and 100% organics for nutrient use efficiency along with early and optimum time of planting were found superior at most of the locations.

5.7 Screening of genotypes suitable for acid soils and related nutritional constraints

In the trial on evaluation of genotypes for tolerance to soil acidity and related nutritional constraints conducted at 3 centres (Moncompu, Ranchi and Titabar), about 12 – 23 genotypes were screened under limed and unlimed conditions and with different fertilizer regimes. The results indicated that response to liming varied with both locations and genotype. Liming increased grain yield by 9.5% and 25.9 – 66.7% at Ranchi and Titabar respectively but not at Moncompu. Among genotypes, the genotype IET 22218 (NP 218) recorded the maximum yield at all nutrient management practices (3.39 - 5.03 t/ha) at Moncompu indicating its ability to produce high yields under acidic as well as ameliorated conditions while Vardhan and 27P-63 were found to respond to liming with 33.5% and 26.9% increase in yield respectively in the treatment receiving lime compared to unlimed control. The varieties Jarava, RP-Bio-226 and Dhanrasi were found promising at Ranchi while Prafulla, Aghonibora and SS-3 performed better under acid soil conditions of Titabar.

5.8 Nutrient requirement of recently released varieties and hybrids of different duration groups

The trial was conducted at five locations (DRR, Karaikal, Faizabad, Maruteru and Chinsurah) in *kharif* 2013 to assess the requirements of all major nutrients (NPK) of recently released varieties and hybrids of mid early to mid duration group grown under different environments. The genotypic responses to a set of combination of nutrient levels (0-60-100, 120-0-100,120-60-0, 60-60-100,120-60-100, 180-60-100 kg N, kg P_2O_5, and kg K_2O/ha) in terms of yield and nutrient accumulation were recorded. The genotypes selected for the study were 3 hybrids *viz*., VNR 203 (IET 21423), 27P31(IET 21832) 27P63 (IET 21832) and one HYV IET 22218 (NP 218) which have been released for their high yield potential and resistance to biotic stresses. The highest yielding nutrient treatment for each genotype and location was selected for working out the nutrient requirements based on the nutrient accumulation. Uptake of nutrients varied with nutrient application levels and their combinations at all locations, recording increasing accumulation of NPK up to 180 kg/ha at DRR. The test genotypes accumulated nutrients differentially reflecting broadly the location, environment and yield potential of respective genotype. Nutrient requirement in general varied from 12.7 – 34.7kg N, 3.51-17.56 kg P_2O_5 and 11.1 – 28.7 kg K_2O per ton of grain production. Among the test cultures, nutrient requirement for hybrids was less compared to HYVs at Maruteru and was more at DRR, Chinsurah and Faizabad.

5.9 Studies on partitioning of zinc and iron and prospects for enrichment in rice

Three rice cultures, *viz*., Aghonibora, one location specific genotype promising for high Zn and Fe content in grains, and a non - promising one were grown at 4 locations with a set of treatments to supply zinc and iron through soil and spray schedules in addition to recommended NPK. The varieties differed significantly in grain yield at Kaul, Maruteru and Titabar while nutrient treatments at Karaikal and Maruteru. Maximum yield was recorded by

HKR 127 at Kaul and MTU 1075 at Maruteru and Prafulla at Titabar. Of the five nutrient combinations tested, use of micronutrients in combination with recommended NPK, organic manure and cytokinin spray yielded significantly superior to control and at par with the other nutrient treatments at Karaikal and Maruteru. At Karaikal, Kaul and Maruteru genotypes did not influence concentration and uptake of Zn and Fe both in grain and straw. Nutrient combinations recorded also significant differences with the combined use of organics, micronutrients and cytokinin spray giving rise to maximum Zn and Fe concentration and uptake in both grain and straw. With regard to partitioning, major portion of the absorbed micronutrients remained in straw. About 74 and 71% of Zn and Fe at Kaul, 54 and 68% at Karaikal and 56 and 74% at Maruteru were retained in straw while 26 and 29%, 46 and 32% and 44 and 26% translocated to grain, respectively.

5.10 Sustaining soil and crop productivity under different rice production systems

The first year results of the trial on "monitoring soil and crop productivity under emerging rice production systems" conducted at two centers viz; Jagtial and Mandya indicated maximum rice productivity in transplanted rice at Jagtial showing its superiority over direct seeded rice and aerobic rice by 68 and 180%, respectively. Whereas, at Mandya, transplanted and direct seeded rice were at par and superior to aerobic rice by 52 and 21%, respectively. Substitution of 25 % RDF through organics gave similar grain yield as 100 % RDF + Zn + S at Jagtial and at Mandya, reduction of RDF to 20% resulted in drastic reduction of grain yield although 2 t/ha of concentrated organic manure was applied. NPK uptake was maximum in TPR which was significantly superior to other two systems both at Jagtial and Mandya. Among the nutrient sources, maximum uptake was recorded with 100 % RDF+ 50 % organics followed by 100 % RDF. Though nutrient uptake was comparatively less in direct sown and aerobic rice than transplanted rice, the nutrient use efficiency was better in case of direct sown and aerobic rice. In general, soil available nutrients were higher in the plots that received organic manures.

DETAILED REPORT

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

Long-term studies with well-defined nutrient management treatments and cropping systems were initiated in 1989-90 at 4 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. Results of 25th year of cropping i.e., *rabi* 2012 – 13 (Maruteru and Titabar) and *kharif* 2013 (Mandya, Maruteru and Titabar) are presented in Tables 5.1.1 to 5.1.11 and Figs. 5.1.1a & b. The report also includes linear growth trends of crop productivity and per cent changes in certain critical soil characteristics.

Crop productivity and soil fertility during *rabi* 2012-13

Grain and straw yields of *rabi* rice at Maruteru and Titabar are presented in Table 5.1.2. Grain yield at Maruteru ranged from 1.96 (control) to 6.90 (100% RDF ZnS) t/ha with a mean of 5.38 t/ha. Omission of N, P, K, Zn & S resulted in significant yield reduction of about 0.53 t/ha (-S) to 4.03 t /ha (-N) showing significant role of N in crop productivity. Zinc contributed to 12% increase in grain yield. 50% RDF and remaining 50% N substitution by FYM also resulted in similar grain yield on par with 100% RDF ZnS and 100% RDF + 5 t FYM. At Titabar, mean grain was low (3.65 t/ha) with a range of 1.66 t/ha in control to 4.63 t/ha in 100% RDF + 5 t FYM. Here, FYM@ 10 t/ha also recorded (4.10 t/ha) grain yield equivalent to RDF (4.24 t/ha). Reduction of NPK by 50% resulted in significant yield loss and this could be compensated to a large extent (46-50%) by providing 50% N through organics or biofertilizer, Azospirillum. Here also, Zn and S contributed significantly to grain yield increase by 10 and 14%, respectively, over NPK alone. Straw yield followed similar trend as grain yield recording maximum yields with 100% RDF + 5 t FYM at both locations (8,96 and 5.48 t/ha, respectively, at Maruteru and Titabar).

Total nutrient uptake by above ground dry matter was maximum with 100% RDF +5 t FYM/ha at Maruteru and Titabar followed by RDF alone at Maruteru (Table 5.13). At Titabar, addition of organics resulted in better nutrient accumulation that was superior to many chemical treatments. Soil organic carbon and available nutrients, in general were higher when organic manures were applied as supplementary dose or substituted for 50% RDF (Table 5.1.4).

Crop productivity and soil fertility status during *kharif* 2013

Gain yield data in Table 5.1.5 indicated maximum rice productivity of 6.06, 5.40 and 5.53 t/ha with 100% RDF + 5 t/ha FYM at Mandya, Maruteru and Titabar, respectively, recording an increase of 52, 6 and 14% over 100% RDF. In light textured soils of Mandya, grain yields increased significantly with 50% and 100% substitution of RDF by organics compared to 100% RDF alone and this substitution did not help at Maruteru and Titabar. The newly introduced treatments, 100% RDF + liming and extra organic sources at Titabar could not yield better or even equal to 100% RDF . Response to major nutrients (NPK) was significant at all locations while to Zn at Maruteru and Titabar and to S at Titabar only. STCR recommendation did not match the grain yields recorded with 100% RDF ZnS at Mandya and Maruteru while at Titabar, STCR and local RDF recorded on par yields. The straw yields almost followed the same trend as grain yields. The data on nutrients (NPK) uptake by total drymatter is presented in Table 5.1.6. The N and K uptake values are very low at Mandya recording maximum NPK uptake (65.4, 45.9, and 64.9 kg NPK/ha) with 50% RDF + 25% GM +25% FYM followed by 100% RDF + 5 t FYM indicating the beneficial effect of organic manures for nutrient uptake which has ultimately resulted in higher grain yield. At Maruteru and Titabar, maximum NPK uptake (85, 21,162 and 92,21 and 88 kg/ha, respectively) was recorded with 100% RDF+ 5 t FYM where grain yield was also maximum. No specific trend was observed in case of nutrient use efficiency and nutrient requirement values. Soil fertility status at the end of *kharif* -2013 (Table 5.1.8) indicated an improvement of organic carbon, available nutrient status and bulk density values with supplementary and/ or complete organic manuring compared to inorganic fertilization alone at all locations and most of these values were maximum with 50% NKP + 25% GM-N +25% FYM-N/ 100% RFD ZnS/ FYM@ 10 t/ha and control plots recorded the lowest values. The increase in organic carbon, available N, P_2O_5 and K_2O over 100% inorganics (100% RDFZnS) was about 29-54, 7-20, 16-62 and 29-64%, respectively with INM treatments. Whereas, the per cent increase in OC, available N, P_2O_5 and K_2O with INM over control was about 97-170, 28-61, 120-260 and 35-134 %, respectively, across 3 locations.

Long term changes in crop productivity and soil fertility

The trends in mean grain yields of *kharif* and *rabi* rice at Mandya, Maruteru and Titabar and the per cent change in some of the important soil fertility parameters over the years (since *kharif* 1989) in each treatment were analysed by fitting to linear function using actual yields.

Trends in crop productivity

Recommended fertilizer practice (100% NPKZnS) resulted in producing highest rice productivity at all the locations with a mean grain yield (over 25 years) of 4.80, 4.98 and 4.18 t/ha, respectively, at Mandya, Maruteru and Titabar (Table 5.1.9 and Fig. 5.1.1a). The yields improved further on an average by 0.2 - 0.5 t/ha at these locations with the supplementation of 5 t/ha of organic manure (FYM/PM). Average response to applied nutrients ranged from 1.22 to 1.92 t/ha for N, 0.54 - 0.70 t/ha for K, 0.14 to 0.31 t/ha for Zn and 0.20 - 0.27 t/ha for S and this response increased over the years.

Analysis of linear trends of *kharif* rice productivity over the years with current RDF practices indicated near stable to slightly negative growth in the delta soils of Maruteru (-3 kg grain/ha/year); with an improvement in rice productivity in the acid alluvial soils of Titabar (14 kg grain /ha /year) and a negative trend in the light textured soils of Mandya (-43 kg grain/ ha/ year). Supplementary application of FYM /PM @ 5 t/ha along with RDF improved the yield growth substantially to positive levels of 100 kg /ha/year at all three locations. The beneficial effect of organics to an extent of 50% substitution of NPK was more perceptible in the light textured soils of Mandya (10 -51 kg /ha / year) compared to other locations (2-24 kg /ha /year). Skipping of any of the nutrients or reducing the doses showed a negative growth rate of rice yields at all locations.

During *rabi* (Table 5.1.10), mean yields over 25 years were higher with the application of FYM /PM @ 5 t/ha along with RDF at Maruteru and Titabar (6.31 & 4.12 t/ha, respectively) which was higher by 14 and 12%, respectively over RDF. Here also, response to N was more. Linear trend analysis indicated that 50% substitution of NPK through organics resulted in positive growth rate of 4 – 16 kg /ha /year at Titabar while skipping of nutrients and reducing the dose showed a negative growth rate. Whereas, the trends in growth rate at Maruteru during *rabi* could not give any specific explanation.

Changes in soil fertility (Table 5.1.11 and Fig. 5.1.1b)

Changes in some of the important soil fertility parameters such as organic carbon, available N, P and K using the initial values and current year were analysed for 3 locations. At Mandya, there was positive accumulation in soil OC with INM treatments (10 – 62%) and even with 100% organics (FYM @ 10 t/ha) by 56%. There was a slight decline with current RDF (by 0.8%) and control recorded maximum decline of -38%. The OC at Maruteru recorded a gain of 4% in control to 111% in 50% N substitution with FYM. This positive growth rate is higher compared to previous year. At Titabar, similar to Mandya, control recorded a decline of – 47% in OC and RDF + 5 t FYM /ha recorded maximum percent accumulation (72%). There was a huge decline in soil available N in all the treatments (-29 to - 47%) at Maruteru and positive growth rate was observed at Mandya with complementary use of organics. Per cent change in P was positive at Mandya and Titabar in all treatments except control that showed a decline and at Maruteru, the % change was – 47 to 45 in different treatments. There was a positive growth in available K in light textured soils of Mandya while it was negative in acid alluvial soils of Titabar. In the deltaic alluvial soils of Maruteru, addition of organics resulted in positive growth of K. Though the % changes in soil fertility parameters did not match exactly with linear trends of productivity in all treatments, to some extent, some of these changes in some treatments such as RDF + FYM and supplementation with organics reflected positively in rice productivity at these locations.

Summary

In the 25th year of study on long term soil fertility management in RBCS, the results indicated the superiority of conjunctive use of 100% RDF + 5t FYM/ha over all other treatments at all three locations and FYM alone increased grain yield by 25% over RDF at Mandya. Omission of certain nutrients and reduction of 50% nutrients resulted in significant grain yield reduction at all locations. Improved nutrient uptake with supplementary use of organics resulted in higher grain yields. Compared to inorganic fertilizers alone, INM / complete organics resulted in substantial soil fertility improvement at all locations. Linear trends of rice productivity over 25 years indicated near stable to slightly negative growth rate at Maruteru ; improved growth at Titabar and a negative growth rate at Mandya (-3, 14 and -43 kg grain /ha/year, respectively, at Maruteru, Titabar and Mandya) with current RDF and a positive growth of about 100 kg/ ha/year at all locations with a supplementary dose of 5 t FYM/PM along with RDF.

Table 5.1.1: Long term soil fertility management in RBCS, 2013

Soil and crop characteristics

Cropping system	**Mandya**	**Maruteru**	**Titabar**
	Rice-Cowpea	**Rice-Rice**	**Rice-Rice**
Variety – *kharif*	Thanu (KMP 101)	MTU-1061	Ranjit
Rabi	C-152	MTU-1010	Lachit
Recommended Fertilizer Dose (kg NPK /ha)			
Kharif	100:50:50:20	90:60:60:50	40:20:20
Rabi	100:50:50;20	180:90:60:50	60:20:40
STCR		84-56-45(Kharif) 130-109-89(Rabi)	-
Crop growth: *Kharif*	Satisfactory	Satisfactory	Satisfactory
Rabi	-	-	Good
% Clay	11.1	38	42.0
% Silt	18.1	28	28.0
% Sand	62.8	34	29.0
Texture	Sandy loam	Clay loam	Silty Clay
pH (1:2)	5.87	5.77	5.4
Organic carbon (%)	0.30	0.57	1.1
CEC (cmol (p^+)/kg)	-	48.6	12.5
EC (dS/m)	0.28	0.97	0.28
Avail. N (kg/ha)	208	164	495
Avail. P_2O_5 (kg/ha)	19.7	15.4	22.4
Avail. K_2O (kg/ha)	117.6	423	112

Table 5.1.2: Long term soil fertility management in RBCS, *rabi* 2012-13
Grain and straw yields of rice

Treatments	**Grain yield (t/ha)**		**Straw yield (t/ha)**		**Panicles /m2**
	Maruteru	**Titabar**	**Maruteru**	**Titabar**	**Maruteru**
Control	1.96	1.66	3.22	2.85	238
100% PK	2.87	3.64	3.23	4.29	359
100% NK	3.78	3.52	6.10	4.45	296
STCR recommendation	6.63	3.98	7.94	4.55	325
100% NP	6.20	3.71	6.61	4.44	422
100% NPKZnS	6.90	4.24	7.33	4.77	405
100% NPKZnS + FYM/PM @ 5t/ha	6.70	4.63	8.96	5.48	360
100% NPK –Zn	6.16	3.84	6.97	4.68	377
100% NPK – S	6.37	3.73	7.25	4.70	404
100% N+50% PK	6.63	3.28	7.12	4.53	332
50 % NPK	4.16	2.60	5.86	3.84	327
50 % NPK + Biofertilizer	4.47	3.84	6.00	4.55	350
50%NPK+50%GM-N	4.78	3.79	7.19	4.35	385
50% NPK + 50% FYM-N	6.48	3.91	7.30	4.77	391
50% NPK + 25% GM-N+25% FYM-N	5.76	3.89	7.10	4.61	282
FYM @ 10 t/ha	4.61	4.10	4.83	5.04	269
Expt. Mean	**5.38**	**3.65**	**6.43**	**4.50**	**349**
CV (%)	**5.83**	**3.97**	**6.13**	**3.93**	**8.28**
CD (0.05)	**0.513**	**0.204**	**0.657**	**0.25**	**48.3**

Table 5.1.3: Long term soil fertility management in RBCS, *rabi* 2012-13
Total nutrient uptake (kg/ha)

Treatments	Maruteru			Titabar		
	N	P	K	N	P	K
Controls	26.7	8.31	45.04	28.4	4.86	30.7
100% PK	32.0	13.9	43.8	55.5	10.9	53.2
100% NK	71.3	14.5	98.3	56.7	9.54	51.5
STCR recommendation	117	30.0	102	59.7	12.7	53.9
100% NP	101	24.7	100	57.7	11.4	53.2
100% NPKZnS	111	25.8	110	74.1	13.4	61.7
100% NPKZnS + FYM/PM @ 5t/ha	103	37.9	145	83.5	17.1	71.2
100% NPK – Zn	98.7	23.8	121	64.3	12.9	61.3
100% NPK – S	91.3	26.8	115	61.5	13.2	59.0
100% N+50% PK	110	27.4	86.0	54.7	14.3	56.7
50 % NPK	54.1	17.8	74.0	43.1	9.40	45.6
0 % NPK + Biofertilizer	61.3	21.1	74.0	59.2	12.6	57.9
50% NPK+ 50% GM-N	77.8	22.7	79.5	59.6	13.1	60.0
50% NPK + 50% FYM-N	87.6	27.5	91.2	63.5	16.1	61.2
50% NPK + 25% GM-N+ 25% FYM-N	79.5	26.3	128	65.6	14.6	61.8
FYM @ 10 t/ha	41.7	20.1	59.1	71.5	15.1	67.7
Expt. Mean	**79.11**	**23.02**	**92.13**	**59.9**	**12.6**	**56.64**
CV (%)	**23.68**	**11.97**	**27.17**	**15.1**	**11.1**	**5.98**
LSD (0.05)	**31.23**	**4.59**	**41.73**	**9.51**	**2.45**	**6.33**

Table 5.1.4: Long term soil fertility management in RBCS, *rabi* 2012-13
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	6.11	0.76	1.12	143	20.6	333
100% PK	5.87	0.63	1.44	150	24.1	319
100% NK	5.87	0.90	1.43	169	19.0	304
STCR recommendation	6.08	0.73	1.44	163	21.5	299
100% NP	5.99	0.81	1.37	140	24.9	261
100% NPKZnS	6.32	0.73	1.23	159	25.7	288
100% NPKZnS + FYM/PM @ 5t/ha	6.09	0.81	1.42	156	30.3	375
100% NPK –Zn	6.07	0.85	1.34	132	24.1	292
100% NPK – S	6.22	0.87	1.40	192	23.8	311
100% N+50% PK	6.25	0.84	1.30	135	25.5	289
50 % NPK	6.18	0.90	1.12	139	22.2	283
50 % NPK + Biofertilizer	6.01	0.57	1.48	137	22.0	255
50% NPK+ 50% GM-N	5.55	0.65	1.47	191	23.8	302
50% NPK + 50% FYM-N	5.39	0.81	1.87	148	37.4	342
50% NPK + 25% GM-N+25% FYM-N	5.83	0.94	1.58	138	27.1	319
FYM @ 10 t/ha	5.83	0.95	1.64	160	38.4	417
Expt. Mean	**5.98**	**0.80**	**1.42**	**137**	**25.6**	**312**
CV (%)	**5.87**	**19.26**	**11.93**	**12.5**	**12.34**	**10.96**
LSD (0.05)	**0.58**	**0.26**	**0.28**	**31.54**	**6.55**	**57.09**

Table 5.1.5: Long term soil fertility management in RBCS, *kharif* 2013
Yield and yield parameters of rice

Treatments	Grain yield(t/ha)			Straw yield (t/ha)			Panicles/m2	
	MND	MTU	TTB	MND	MTU	TTB	MND	MTU
Control	1.06	2.25	1.58	1.41	3.47	3.63	213	210
100% PK	2.07	2.80	3.83	2.20	4.38	4.65	224	234
100% NK	2.10	3.29	3.67	2.50	4.78	4.59	244	217
STCR recommendation	3.20	4.50	4.65	3.23	6.90	5.51	530	240
100% NP	2.23	3.34	3.78	2.60	4.95	4.84	244	227
100% NPKZnS	3.99	5.08	4.86	4.51	6.35	5.84	432	259
100% NPKZnS + FYM/PM @ 5t/ha	6.06	5.40	5.53	6.27	7.30	6.28	518	248
100% NPK –Zn	3.75	4.32	4.51	4.29	5.83	5.59	361	231
100% NPK – S	3.59	4.60	4.08	4.22	5.83	4.84	416	234
100%NPK-S+ limiting @1.0 t/ha	-	-	4.33	-	-	4.98		
100% N+50% PK	2.50	3.24	3.60	2.97	4.38	4.60	454	242
50 % NPK	3.08	3.52	2.60	3.17	5.37	3.55	424	239
50 % NPK + Biofertilizer	3.45	3.75	3.82	3.61	5.83	4.50	237	228
50% NPK+ 50% GM-N	4.63	3.36	4.18	4.89	5.23	5.24	457	238
50% NPK + 50% FYM-N	4.74	3.28	4.37	5.26	5.26	5.48	523	226
50% NPK + 25% GM-N+25% FYM-N	6.05	3.26	4.30	6.44	5.16	5.56	538	235
FYM @ 10 t/ha	5.00	3.78	4.36	6.01	5.50	5.61	513	228
FYM@10t/ha +3.0 t/ha Vermicompost+200 kg/ha oil cakes	-	-	3.94	-	-	5.04	-	-
Expt. Mean	**3.59**	**3.74**	**3.10**	**3.98**	**5.40**	**5.02**	**395**	**233**
CV (%)	**6.54**	**8.22**	**5.99**	**0.17**	**7.29**	**5.69**	**23**	**4.44**
LSD (0.05)	**0.51**	**0.51**	**0.34**	**8.38**	**0.66**	**0.40**	**195**	**0.017**

MND-Mandya MTU-Maruteru TTB-Titabar

Table 5.1.6: Long term soil fertility management in RBCS, *kharif 2013*
Nutrient uptake (kg/ha) in total dry matter

Treatments	Mandya			Maruteru			Titabar		
	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	6.3	2.8	4.6	27.12	8.3	70.4	27.3	6.1	39.7
100% PK	14.7	7.2	10.9	38.2	14.1	84.5	52.0	10.5	57.2
100% NK	15.1	8.6	14.5	47.8	13.6	91.8	50.5	11.0	58.5
STCR recommendation	22.9	16.0	24.9	74.0	20.0	157.0	64.6	15.6	72.2
100% NP	18.8	10.6	15.8	53.6	14.9	100.0	49.8	12.6	59.1
100% NPK + Zn + S	35.4	20.8	35.3	74.2	21.8	123.0	75.5	16.5	75.9
100% NPK + Zn + S + FYM/PM @ 5 t/ha	60.4	37.3	54.3	85.5	21.0	162.0	92.1	20.9	87.6
100% NPK –Zn	29.8	18.5	28.2	60.6	17.2	108.0	62.8	16.4	69.5
100% NPK – S	26.2	17.8	30.7	62.0	15.3	105.0	56.3	13.0	60.7
100%NPK-S+ limiting @1.0 t/ha	-	-	-	-	-	-	63.4	11.8	57.9
100% N+50% PK	18.9	12.8	20.9	44.3	12.9	82.5	50.6	10.8	56.0
50 % NPK	30.2	16.4	26.0	43.9	14.1	101.0	36.6	8.7	41.0
50 % NPK + Biofertilizer	33.9	19.6	32.9	51.6	14.6	125.0	59.6	10.5	59.1
50% NPK+ 50% GM-N	45.0	29.6	42.6	45.0	14.4	100.0	65.2	12.0	67.0
50% NPK+ 50% FYM-N	49.3	35.3	50.9	45.0	14.2	113.0	73.9	13.8	71.5
50% NPK +25% GM-N +25% FYM-N	65.4	45.9	64.9	44.6	12.5	112.0	76.1	14.3	73.8
FYM @ 10 t/ha	53.9	32.0	47.0	44.0	15.5	117.0	70.2	14.5	71.6
FYM@10t/ha+3.0t/ha Vermicompost+200 kg/ha oil cakes	-	-	-	-	-	-	68.4	13.6	61.7
Expt. Mean	**32.9**	**20.7**	**31.5**	**52.59**	**15.3**	**109.0**	**60.8**	**12.9**	**63.3**
CV (%)	**8.4**	**4.2**	**8.8**	**20.9**	**14.8**	**10.8**	**6.0**	**10.1**	**6.9**
LSD (0.05)	**5.94**	**9.6**	**5.93**	**18.33**	**3.79**	**19.81**	**6.05**	**2.17**	**7.17**

Table 5.1.7: Long term soil fertility management in RBCS, *kharif* 2013
Nutrient use efficiency (kg grain/kg nutrient uptake) and nutrient requirement (g/kg grain)

Treatments	Mandya						Maruteru						Titabar					
	(Nutrient use efficiency (kg grain/kg uptake)			Nutrient requirement (g /kg grain)			Nutrient use efficiency (kg grain/kg uptake)			Nutrient requirement (g /kg grain)			(Nutrient use efficiency (kg grain/kg uptake)			Nutrient requirement (g /kg grain)		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Control	231	384	170	4.35	2.65	5.92	82.9	272	31.9	12.3	3.81	31.7	60.1	256	41.1	16.7	3.76	24.4
100% PK	190	291	142	5.26	3.46	7.08	74.8	233	33.6	13.4	4.31	29.8	74.9	366	68.0	13.4	2.69	14.7
100% NK	145	245	139	6.88	4.08	7.17	75.4	200	33.2	13.9	5.01	30.4	74.6	334	64.5	13.4	2.92	15.5
STCR recommendation	128	201	139	7.78	4.98	7.16	74.6	262	28.9	13.7	3.85	34.6	74.8	298	66.7	13.4	3.24	15.0
100% NP	141	211	118	7.1	4.75	8.44	70.0	244	36.3	14.5	4.14	28.0	75.6	300	63.6	13.3	3.36	15.8
100% NPKZnS	113	195	113	8.89	5.24	8.93	62.1	225	28.9	16.4	4.47	35.0	63.3	294	63.0	15.8	3.46	15.9
100% NPKZnS + FYM/PM @ 5t/ha	111	163	100	8.95	6.15	9.95	74.6	237	29.0	13.6	4.33	34.6	59.0	264	62.1	17.0	3.85	16.1
100% NPK –Zn	133	206	126	7.51	4.91	7.94	65.1	225	33.7	16.1	4.47	30.1	71.9	276	64.9	14.0	3.61	15.4
100%NPK-S	117	205	137	8.52	4.92	7.27	68.4	235	41.4	14.7	4.29	24.3	70.5	313	65.8	14.2	3.27	15.3
100%NPK-S+ limiting @1.0 t/ha	-	-	-	-	-	-	-	-	-	-	-	-	65.1	368	72.0	15.4	2.85	14.1
100% N+50% PK	119	196	132	8.41	5.16	7.58	63.8	258	33.5	15.8	3.90	30.1	68.7	333	62.5	14.6	3.11	16.2
50 % NPK	118	188	102	8.46	5.31	9.78	72.1	254	40.4	14.0	3.97	25.2	71.6	300	64.0	14.0	3.32	15.7
50 % NPK + Biofertilizer	105	176	102	8.52	5.67	9.81	92.2	243	33.0	12.1	4.12	31.9	64.1	363	64.7	15.6	2.76	15.5
50%NPK+ 50%GM-N	109	157	103	9.21	6.41	9.71	76.5	336	43.6	13.3	3.36	23.0	63.2	349	61.6	15.8	2.92	16.3
50% NPK + 50% FYM-N	93.7	134	96.8	10.69	7.44	10.3	82.0	256	39.6	13.7	4.02	25.6	60.8	317	62.5	16.5	3.1	16.0
50% NPK + 25% GM-N+25% FYM-N	93.2	132	92.6	10.73.	7.58	10.8	83.0	252	34.7	12.5	4.03	28.9	57.0	301	59.2	17.6	3.3	17.0
FYM @ 10 t/ha	106	156	93.1	9.41	6.41	.10.8	75.7	258	30.0	13.6	3.87	33.6	61.5	300	60.4	16.3	3.37	16.6
FYM@10t/ha+3.0t/ha Vermicompost+200kg/ha oil cakes	-	-	-	-	-	-	-	-	-	-	-	-	57.5	291	63.8	17.4	3.45	15.7
Expt. Mean	**128**	**202**	**119**	**8.23**	**5.32**	**8.67**	**74.57**	**249**	**34.4**	**13.9**	**4.12**	**29.8**	**66.34**	**312**	**62.79**	**15.24**	**3.24**	**16.17**
CV (%)	**20.5**	**12.1**	**6.74**	**6.65**	**9.09**	**6.18**	**22.62**	**20.2**	**13.19**	**21.1**	**14.68**	**12.6**	**5.90**	**5.90**	**6.69**	**5.73**	**8.67**	**6.41**
LSD (0.05)	**7.47**	**52.2**	**17.2**	**1.17**	**1.03**	**1.14**	**28.13**	**83.8**	**7.58**	**4.92**	**1.01**	**6.25**	**6.46**	**6.46**	**6.93**	**1.44**	**0.46**	**1.71**

Table 5.1.8 Long term soil fertility management in RBCS, *kharif* 2013
Soil fertility status at harvest

Treatments	Mandya					Maruteru						Titabar				
	Org. C (%)	Avail. N (kg/ha)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)	BD (g/cc)	pH	EC dS/m	Org. C (%)	Avail. N (kg/ha)	Avai.l P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)	Org. C (%)	Avail. S (kg/ha)	Avail. P_2O_5 (kg/ha)	Avail. K_2O (kg/ha)
Control	0.22	218	12.5	124	1.34	5.73	0.79	0.93	158	14.2	358	0.61	10.1	9.3	67.7
100% PK	0.25	261	18.0	222	1.29	5.27	1.95	1.53	204	17.9	424	0.94	14.2	18.7	79.3
100% NK	0.33	241	19.4	218	1.26	5.63	1.12	1.62	178	11.8	401	1.04	14.4	20.3	85.7
STCR recommendation	0.36	271	28.1	243	1.23	5.63	1.03	1.45	182	16.2	412	1.15	16.7	24.7	89.7
100%NP	0.31	262	25.1	183	1.24	5.50	1.07	1.60	163	19.5	358	0.98	18.0	22.3	87.0
100% NPKZnS	0.35	328	28.6	220	1.23	5.63	1.10	1.25	170	33.7	366	1.28	19.7	31.0	140.0
100% NPKZnS + FYM/PM @ 5t/ha	0.39	362	49.4	277	1.23	5.47	0.99	1.58	199	30.0	393	1.63	22.7	37.8	151.0
100% NPK –Zn	0.38	283	25.9	242	1.29	5.43	1.05	1.38	186	25.4	420	1.01	18.0	29.7	130.3
100% NPK – S	0.37	266	25.8	242	1.20	5.50	1.19	1.54	200	18.1	369	1.00	18.3	30.2	140.0
100%NPK-S+ limiting @1.0 t/ha						-						0.96	21.3	33.7	136.7
100% N+50% PK	0.36	286	28.0	219	1.28	5.57	1.09	1.84	188	11.5	334	0.93	21.3	30.0	97.0
50 % NPK	0.37	303	25.2	245	1.28	5.63	1.15	1.35	168	10.9	334	0.73	18.7	21.0	99.7
50 % NPK + Biofertilizer	0.37	341	46.8	272	1.28	5.47	0.88	1.60	175	12.7	369	1.20	19.3	29.3	116.7
50% NPK+ 50% GM-N	0.5	344	44.1	282	1.23	5.47	1.25	1.85	209	14.1	482	1.32	21.3	32.7	129.0
50% NPK + 50% FYM-N	0.5	337	47.0	295	1.22	5.33	0.91	1.88	198	30.9	455	1.33	20.7	33.8	121.7
50% NPK + 25%GM-N+25%FYM-N	0.57	386	52.2	302	1.22	5.37	0.98	1.75	212	22.4	432	1.25	21.7	33.7	138.0
FYM @ 10 t/ha	0.55	340	40.4	281	1.25	5.40	1.10	1.80	195	32.3	517	1.60	23.7	35.5	146
FYM@10 t/ha +3.0 t/ha Vermicompost +200 kg/ha oil cakes	-	-	-	-	-	-	-	-	-	-	-	1.28	29.3	30.2	135
Expt. Mean	**0.38**	**302**	**32.3**	**242**	**1.25**	**5.50**	**1.04**	**1.56**	**187**	**20.1**	**402**	**1.13**	**19.4**	**27.9**	**116.2**
CV (%)	**6.3**	**13.5**	**7.6**	**5.3**	**2.3**	**4.2**	**22.2**	**22.2**	**12.4**	**35.4**	**1.6**	**6.40**	**15.4**	**6.1**	**6.5**
LSD (0.05)	**0.05**	**41.0**	**5.27**	**27.4**	**0.06**	**0.39**	**0.38**	**0.38**	**38.6**	**11.99**	**78.1**	**0.12**	**4.94**	**2.84**	**12.37**

Table 5.1.9: Long term soil fertility management in RBCS Linear trends of changes in *kharif rice* yields (t/ha) from 1989 to 2013

Treatments	MND			MTU			TTB		
	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	2.33	-90.1	3.49	2.14	142.3	2.18	2.13	-81.7	3.21
100% PK	2.88	-36.7	3.35	3.34	36.0	2.86	2.96	8.5	2.85
100% N	3.59	-110.7	5.01	4.02	-23.2	4.32	3.36	-7.2	3.46
100% NP	4.07	-106.4	5.43	4.44	-40.8	4.97	3.62	0.5	3.61
100% NPK + Zn + S	4.80	-43.3	5.36	4.98	-3.0	5.02	4.18	13.8	4.00
100% NPKZnS + FYM/PM	5.09	99.9	3.23	5.00	100.9	3.13	4.73	99.8	2.88
100% NPK – Zn	4.66	-66.0	5.51	4.67	-21.8	4.96	4.07	18.8	3.83
100% NPK – S	4.60	-48.2	5.22	4.72	-2.6	4.75	4.09	-3.2	4.14
100% N + 50% PK	4.22	-95.3	5.44	4.39	-18.3	4.63	3.68	-2.7	3.72
50% NPK	3.86	-59.3	4.62	4.25	-12.8	4.42	3.30	-43.7	3.87
50% NPK + 50% GM-N	4.83	10.0	4.71	4.38	-10.6	4.52	3.65	1.6	3.63
50% NPK + 50% FYM-N	4.90	10.0	4.46	4.63	-10.6	4.73	3.73	1.6	3.75
50% NPK + 25% GM-N + 25% FYM-N	5.49	50.6	4.84	4.47	4.5	4.41	3.76	-13.7	3.94
FYM @ 10 t/ha	4.16	46.3	3.57	4.37	-1.9	4.40	3.79	23.9	3.48

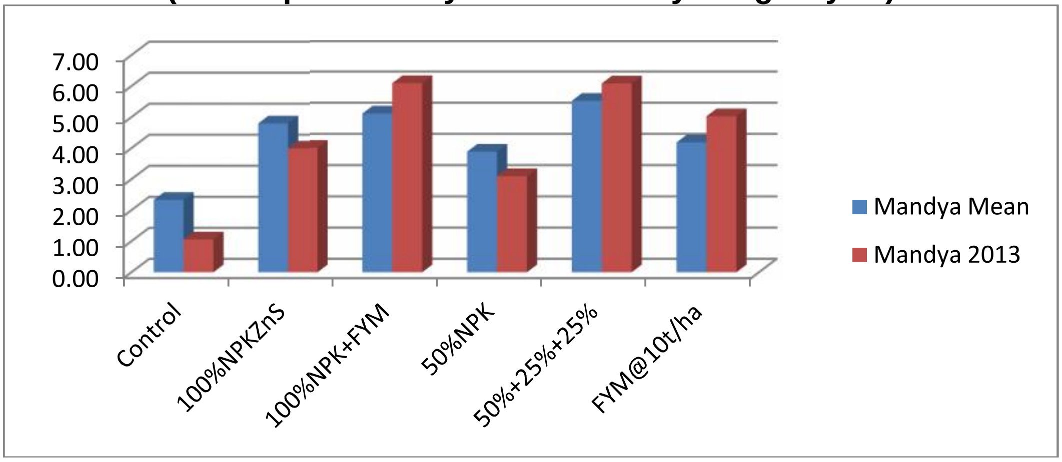
Table 5.1.10: Long term soil fertility management in RBCS Linear trends of changes in *rabi rice* yields (t/ha) from 1989 to 2013

Treatments	Titabar		Maruteru	
	Mean (t/ha)	Slope (kg/ha/yr)	Mean (t/ha)	Slope (kg/ha/yr)
Control	1.80	-45.6	2.00	-13.8
100% PK	2.74	46.8	2.70	68.6
100% N	3.07	-1.1	3.90	12.6
100% NP	3.29	-7.0	4.89	0.7
100% NPK + Zn + S	3.69	9.8	5.51	35.0
100% NPKZnS + FYM/PM	4.12	30.5	6.31	-47.7
100% NPK – Zn	3.51	-6.6	5.04	2.2
100% NPK – S	3.42	-8.0	5.13	7.0
100% N + 50% PK	3.24	-24.6	5.05	14.6
50 % NPK	2.77	-25.0	4.10	-12.2
50% NPK + 50% GM-N	3.21	3.6	4.78	-34.6
50% NPK + 50% FYM-N	3.26	3.6	5.03	-34.6
50% NPK + 25% GM-N+25% FYM-N	3.29	15.8	4.96	19.0
FYM @ 10 t/ha	3.25	11.1	3.98	37.2

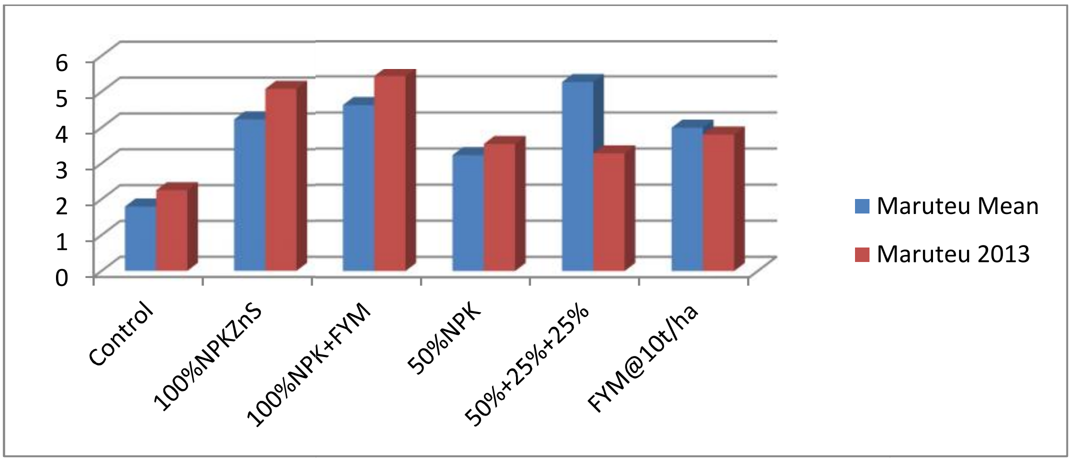
Table: 5.1.11. Long term soil fertility management in RBCS
Changes (%) in soil fertility parameters over 1989 to 2013

Treatments	Mandya				Maruteru				Titabar		
	OC	N	P	K	OC	N	P	K	OC	P	K
Control	-37.7	-24.8	-29.0	-29.5	4.4	-47.0	-30.4	-11.8	-35.8	-29.5	-53.8
Control / 100%PK	-29.2	-10.0	2.3	26.1	71.7	-31.5	-12.3	4.4	-1.1	41.7	-45.8
100% N	-6.5	-16.9	10.2	23.9	81.8	-40.3	-42.2	-1.2	9.5	53.8	-41.5
STCR recommendation	2.0	-6.6	59.7	38.1	62.7	-38.9	-20.6	1.5	21.1	87.1	-38.7
100% NP	-12.2	-9.7	42.6	4.0	79.6	-45.3	-4.4	-11.8	3.2	68.9	-40.6
100% NPK + Zn + S	-0.8	13.1	62.5	25.0	40.3	-43.0	65.2	-9.9	34.7	134.8	-4.4
100% NPK + Zn + S + 5 t/ha FYM	10.5	24.8	180.7	57.4	77.3	-33.2	47.1	-3.2	71.6	186.4	3.1
100% NPK–Zn	7.6	-2.4	47.2	37.5	54.9	-37.6	24.5	3.4	6.3	125.0	-11.0
100% NPK–S	4.8	-8.3	46.6	37.5	72.8	-32.9	-11.3	-9.1	5.3	128.8	-4.4
100% N + 50% PK	2.0	-1.4	59.1	24.4	106.5	-36.9	-43.6	-17.7	-2.1	127.3	-33.7
50 % NPK	4.8	4.5	43.2	39.2	51.5	-43.6	-46.6	-17.7	-23.2	59.1	-31.9
50% NPK + Azospirillum	4.8	17.6	165.9	54.5	79.6	-41.3	-37.7	-9.1	26.3	122.0	-20.3
50% NPK + 50% GM-N	41.6	18.6	150.6	60.2	107.6	-29.9	-30.9	18.7	38.9	147.7	-11.9
50% NPK + 50% FYM-N	41.6	16.2	167.0	67.6	111.0	-33.6	51.5	12.1	40.0	156.1	-16.9
50% NPK + 25% GM-N + 25% FYM-N	61.5	33.1	196.6	71.6	96.4	-28.9	9.8	6.4	31.6	155.3	-5.7
FYM @ 10 t/ha	55.8	17.2	129.5	59.7	102.0	-34.6	58.3	27.3	68.4	168.9	-0.3

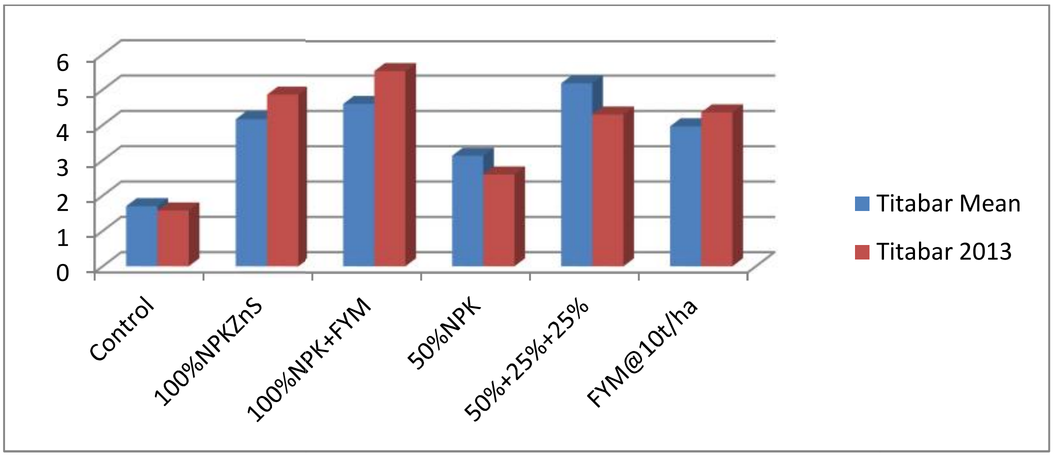
Fig. 5.1.1a Long term effects of nutrient management on rice grain yields (mean of previous 24 years and current year's grain yield)



Grain yield (t/ha) at Mandya (*Kharif*)

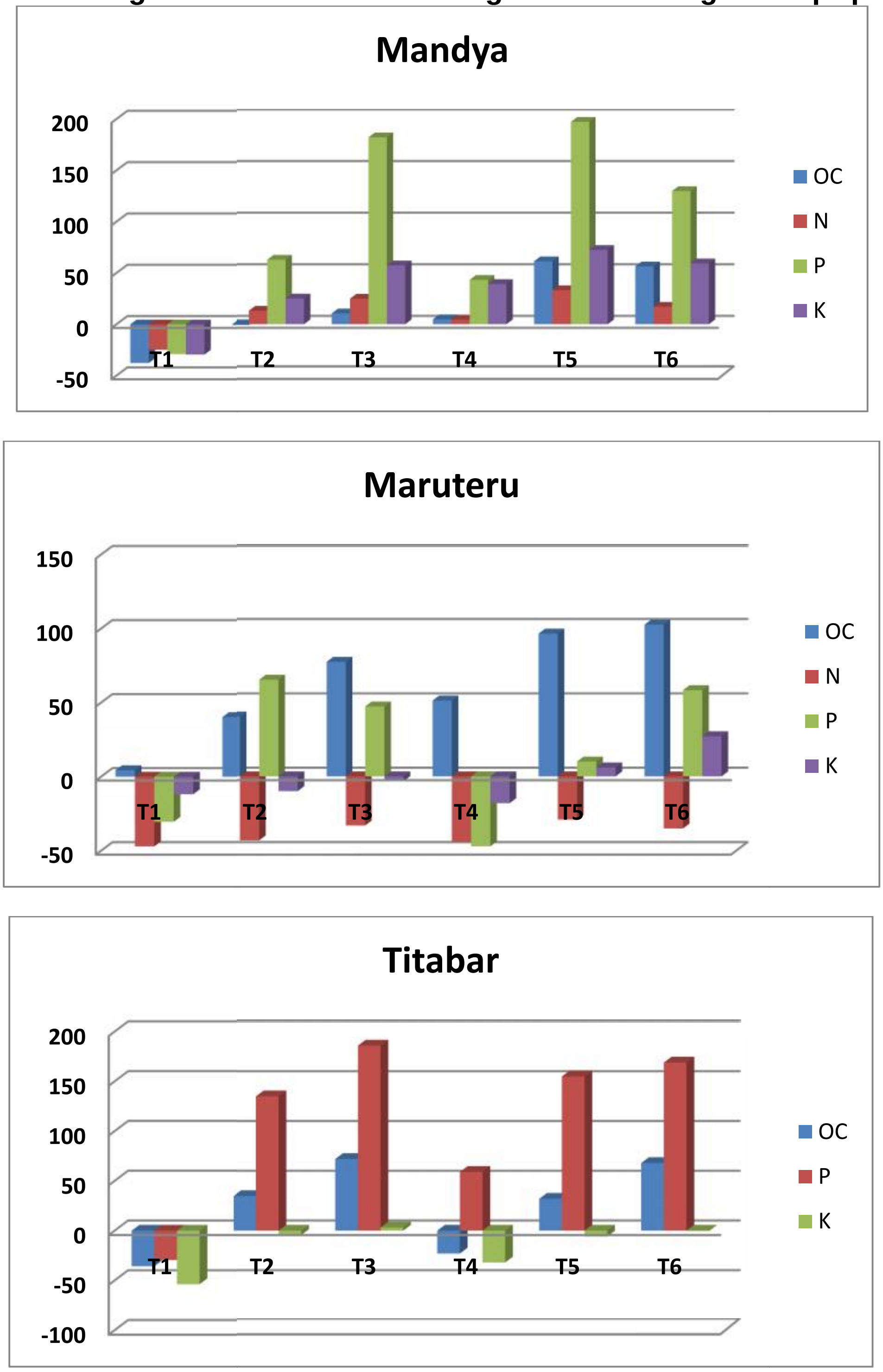


Grain yield (t/ha) at Maruteru (*Kharif*)



Grain yield (t/ha) at Titabar (*Kharif*)

Fig. 5.1.1b Long term effects of nutrient management on % change in soil properties



T1 - Control, T2 - RDF, T3 - RDF+FYM/PM, T4 - 50%RDF, T5 - 50%NPK+50% FYMN, T6 - FYM-10t/ha

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

The growing concern about impaired soil health, declining / decelerating productivity growth and decreasing factor productivity or efficiency of the nutrients compelling to use increasing levels of fertilizers during the last two decades has raised apprehensions on the productive capacity of the agricultural system. Current fertilizer management practices, in general, are not tailored to site specific soil nutrient supply capacities and crop demand. Blanket fertilizer recommendations are still being followed in large domains with less importance being given to management induced site variations of soil nutrient supply capacities, and crop demand especially when new high yielding cultures with increasing yield potential are being regularly introduced. This has been the major reason for reported nutrient imbalances and un-sustainability in realizing yields. This trial was, therefore, conducted in farmers' fields around few selected centres – Chinsurah, Karaikal, Titabar and Mandya to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers' fertilizer practices in some new farm sites and fine-tune the fertilizer nutrient requirement for specific target yields in a given environment and validation of fertilizer recommendations for targeted yields at Mandya and Titabar. The *kharif* 2013 data received from Mandya (Karnataka), Titabar (Assam), Chinsurah (West Bengal) and Bhajancoa (Karaikal, Pondicherry) representing the irrigated and shallow lowland rice ecosystems are presented in Tables 5.2.1 to 5.2.10. The test varieties were popular HYVs (Bahadur and Ranjit) at Titabar, KMP 101, BR 2655, MTU 1001, IR 64, KRH-2 & KRH-4 at Mandya, Swarna and Swarna sub -1 at Chinsurah and CR 1009,ADT 38,White Ponni at Karaikal in Pondicherry. At Mandya and Titabar 10 and 15 farmer sites each were selected for generating information on the field variability in soil fertility and current level of efficiency of farmers' practices. The treatments consisted of nutrient (NPK) omission plots, farmers' fertilizer practice (FFP) and recommended dose of fertilizer (RDF). The details of crop, soil and weather parameters of the experimental sites, presented in the Table 5.2.1, show variation in soil characteristics with reference to pH, organic carbon content, soil texture and available nutrient status.

Table 5.2.2 gives information collected at Mandya and Titabar in the new farm sites on yields obtained, nutrient uptake and soil test values in nutrient omission plots (-N, -P, -K). Grain yields at Mandya, soil test values and nutrient uptake at both the locations showed considerable variation among the farm sites. In the absence of applied N, the yields ranged from 2.0 – 3.0 t/ha at Titabar and 1.9 – 3.4 t/ha at Mandya. Similarly, in P omitted plots, the grain yields varied considerably from 2.0 to 3.6 t/ha at Mandya and from 1.7 – 5.5 t/ha at Titabar and in K omitted plots the grain yields varied from 2.2 to 4.1 t/ha at Mandya and from 1.8 – 2.9 t/ha at Titabar. Soil nutrient uptake varied between the sites matching with the dry matter yields. On an average each ton of grain accumulated 17.9, 2.72 and 21.3 kg N, P_2O_5 and K_2O at Titabar and 10.3, 3.89 and 12.4 kg at Mandya. At both the locations grain yields and nutrient uptake in nutrient omitted plots correlated significantly (Table 5.2.3), while soil test values did not match the yields recorded in the nutrient omission plots except for soil P status showing moderate level of relationship (r ~ 0.70) with rice yield and nutrient uptake at both the locations, suggesting perhaps less suitability of current soil testing methods for flooded soils. Linear equations fitted to relate the recorded yields in nutrient omission plots with the uptake of respective nutrients indicated that about 90% yield variation at the locations could be related to N uptake, 39 % with P uptake and 13% with K uptake. The relationship between yield and nutrient uptake was much stronger in Titabar compared to that at Mandya .

Table 5.2.4 and Table 5.2.5 show site variations in rice productivity, nutrient uptake and their efficiency of utilization under farmers' fertilizer practice and recommended fertilizer management (RDF) at the test locations (60:20:40 kg NPK/ha at Titabar and 100:50:50 kg NPK/ha at Mandya). Rice productivity with recommended fertilizer practice varied from 4.4 – 5.6 t/ha at Titabar and 2.76 – 4.57 t/ha in the farmers' fields at Mandya while the yields varied considerably with farmers' fertilizer practices in the Assam valley and Karnataka plateau region, with corresponding variation in nutrient uptake, nutrient utilization and recovery efficiencies. Strong correlation between yields and nutrient uptake was also recorded for all the nutrients at Mandya and moderate correlation for P uptake under recommended fertilizer practices and with all the nutrients under farmers practice indicating mismatch of the fertilizer doses. The estimated nutrient uptake requirement per ton of grain with RDF averaged 16.9,3.07 and 16.07 kg N, P_2O_5 and K_2O at Titabar, while at Mandya these values ranged from 4.21-12.95, 1.90- 7.26, and 4.01– 22.05 kg N, P_2O_5 and K_2O per ton of grain with RDF practice. Nutrient uptake per unit of grain yield with RDF was lower as compared to farmers' practice at Titabar whereas RDF was higher as compared to farmers' practice at Mandya indicating less efficiency of nutrient management.

Fertilizer prescriptions were worked out for all the farm sites for yield target of 6.1 t/ha at both the locations (being the highest yield recorded at the test sites) with reference to grain yields and average uptake of nutrients per ton of grain in nutrient omission plots, and average recovery efficiency and nutrient requirement recorded at the test sites. The target yields were the maximum recorded at the test sites under recommended fertilizer practice (RDF). The fertilizer recommendations presented in Tables 5.2.6 and 5.2.7 show a range of fertilizer doses of major nutrients to achieve the targeted productivity which has already been harvested. For the targeted yield of 6.1 t/ha nutrient levels to be applied at the recorded efficiency varied with sites from 74.1-163.7 kg N/ha, 10.9-25.9 and 61.2-208.4 kg P_2O_5 and K_2O/ha in the Assam valley soils as against a blanket RDF that was being followed. In the Cauvery command region at Mandya the estimated fertilizer prescriptions, because of large site variations, were much lower which ranged from 53.3-80.4 kg N, 29.0-42.5 kg P_2O_5 and 92.9-131.6 kg K_2O/ha. High estimates of P and K fertilizer requirements are due to lower recovery efficiency of applied P and higher accumulation of potassium per ton of grain. The study, thus indicated ample scope for improvement in nutrient use efficiency, and an attempt has been made to refine the current blanket recommended dose of fertilizer based on site specific nutrient supply, nutrient use efficiency and crop demand.

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

Summary

This trial was conducted in farmers' fields at Chinsurah, Karaikal, Titabar and Mandya to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers' fertilizer practices. Grain yields at Mandya, soil test values and nutrient uptake at both the locations showed considerable variation among the farm sites. In the absence of applied N, the yields ranged from 2.0 – 3.0 t/ha at Titabar and 1.9 – 3.4 t/ha at Mandya. Similarly, in P omitted plots, the grain yields varied considerably from 2.0 to 3.6 t/ha at Mandya and from 1.7 – 5.5 t/ha at Titabar and in K omitted plots the grain yields varied from 2.2 to 4.1 t/ha at Mandya and from 1.8 – 2.9 t/ha at Titabar. Soil nutrient uptake varied between the sites matching with the dry matter yields. On an average each ton of grain

accumulated 17.9, 2.72 and 21.3 kg N, P_2O_5 and K_2O at Titabar and 10.3, 3.89 and 12.4 kg at Mandya. Rice productivity with recommended fertilizer practice varied from 4.4 –5.6 t/ha at Titabar and 2.76 – 4.57 t/ha in the farmers' fields at Mandya while the yields varied considerably with farmers' fertilizer practices in the Assam valley and Karnataka plateau region, with corresponding variation in nutrient uptake, nutrient utilization and recovery efficiencies. The estimated nutrient uptake requirement per ton of grain with RDF averaged 16.9,3.07 and 16.07 kg N, P_2O_5 and K_2O at Titabar, while at Mandya these values ranged from 4.21-12.95, 1.90- 7.26, and 4.01– 22.05 kg N, P_2O_5 and K_2O per ton of grain with RDF practice. For the targeted yield of 6.1 t/ha nutrient levels to be applied at the recorded efficiency varied with sites from 74.1-163.7 kg N/ha, 10.9-25.9 and 61.2-208.4 kg P_2O_5 and K_2O/ha in the Assam valley soils as against a blanket RDF that was being followed. In the Cauvery command region at Mandya the estimated fertilizer prescriptions, because of large site variations, were much lower which ranged from 53.3-80.4 kg N, 29.0-42.5 kg P_2O_5 and 92.9-131.6 kg K_2O/ha.

Table 5.2.1 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields *kharif* 2013

Soil, crop and weather data

Parameter	Mandya	Titabar	Karaikal	Chinsurah
Variety	KMP 101, BR 2655, MTU 1001, IR 64, KRH-2 & KRH-4	Ranjit	CR 1009, ADT 38 White Ponni	Swarna, Swarna Sub 1
Crop growth	Good	Satisfactory	Good	Good
RFD (kg NPK/ha)	100:50:50	60:20:40	90:60:60	75:75:90
Farmers' fertilizer practice (kg/ha) (FFP)	Varying, N 55 –113; P 29 – 68; K 23 - 92	Varying, N 55 –113; P 29 – 68; K 23 - 92	Varying, N 55 –113; P 29 – 68; K 23 - 92	Varying, N 30 – 90; P 30 – 40; K 50 - 60
% Clay	-	44-52	38	-
% Silt	-	23-30	28	-
% Sand	-	22-28	34	-
Soil Texture	-	-	Clay loam	Clay loam-Sandy loam
pH	6.56-7.35	5.4-5.7	6.13-7.3	6.6-7.1
Org. carbon (%)	0.51-0.67	0.75 – 1.15	0.36-0.78	0.43-0.71
Avail. N (kg/ha)	265 - 386	365 - 485	189-296	390 - 470
Avail. P_2O_5 (kg/ha)	22 - 44	12.5 – 18.5	26-79	55 – 79
Avail. K_2O (kg/ha)	165 - 367	130 - 165	229-513	225 - 330

Table 5.2.2 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, Soil nutrient supply potential assessed in nutrient omission plots, *kharif* 2013

Nutrient	Titabar			Mandya		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (kg/ha)						
(-)N	2000	3000	2568	1993	3473	2760
(-)P	1700	5500	2303	2093	3680	2946
(-)K	1800	2900	2250	2213	4193	3159
Soil test values (kg/ha)						
N	389	460	410	213	338	299
P_2O_5	12	125	41	29	47	39
K_2O	125	150	135	139	286	207
Nutrient uptake (kg/ha)						
N	27.2	67.5	45.8	11.56	38.91	28.34
P_2O_5	3.47	17.2	6.25	6.55	18.24	11.45
K_2O	32.70	70.07	47.92	17.48	79.31	39.03

Soil nutrient uptake						
Nutrient	Titabar			Mandya		
	Mean yield (t/ha)	Mean uptake (kg/ha)	NR (kg/t grain)	Mean yield (t/ha)	Mean uptake (kg/ha)	NR (kg/t grain)
N	2.56	45.8	17.9	2.76	28.34	10.3
P_2O_5	2.30	6.25	2.72	2.94	11.45	3.89
K_2O	2.25	47.92	21.3	3.15	39.03	12.4

Table 5.2.3 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields *kharif* 2013

Interrelationship between yield, nutrient uptake and soil test value in nutrient omission plots

Nutrient	Correlation (r)	Regression (R^2)	Intercept (kg/ha)	Slope (q/ha)	Correlation (r)	Regression (R^2)	Intercept (kg/ha)	Slope (kg/ha)
	Titabar				Mandya			
Soil test value Vs. Yield								
(-) N	-0.23	0.05	3.43	-0.05	-0.14	0.021	3618	-3.03
(-) P	0.15	0.02	2.41	0.006	0.38	0.144	4.18	0.004
(-) K	-.0.49	0.24	5.02	- 0.01	-0.01	-0.011	3244	-1.54
Yield Vs. Nutrient uptake								
(-) N	0.69	0.47	223	1.37	0.71	0.51	1541	52.48
(-) P	0.70	0.49	1.56	0.12	0.59	0.34	1.51	0.24
(-) K	0.66	0.44	865	1.07	0.65	0.42	922	43.71
Soil test value vs. Nutrient uptake								
(-) N	0.12	0.01	383	0.54	-0.24	0.08	301	-0.88
(-) P	0.37	0.02	92.15	-7.69	-0.13	0.0064	42.30	-0.23
(-) K	0.13	0.01	123	0.21	-0.31	0.10	252	-0.99

Table 5.2.4 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields Yield and nutrient use efficiency (Location: Mandya), *kharif* 2013

Parameter / Nutrients	Rec. dose of fertilizer (RDF)			Farmer's fert. practice (FFP)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (t/ha)	2.94	6.81	4.05	2.76	4.87	3.67
Nutrient uptake (kg/ha)						
N	12.38	88.24	43.73	20.85	59.86	36.46
P_2O_5	5.6	49.63	22.78	9.98	29.63	18.9
K_2O	11.79	150.22	69.44	34.78	99.26	62.18
Recovery efficiency (%) of applied fertilizer)						
N	12.6	58.8	29.2	20.9	59.9	36.5
P_2O_5	22.9	81.4	46.2	20.0	59.3	37.8
K_2O	24.4	191.2	95.1	46.4	132.3	82.9
Nutrient utilization efficiency (kg grain/kg uptake)						
	MIN	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**
N	77.14	163.93	100.46	132.69	81.41	100.59
P_2O_5	**256.9**	**167.2**	**175.2**	277.2	164.5	194.0
K_2O	47.5	169.5	67.0	79.5	49.1	59.0
Nutrient requirement (kg/ton grain)						
N	4.21	12.95	10.79	7.55	12.29	9.93
P_2O_5	1.90	7.28	5.62	3.61	6.08	5.14
K_2O	4.01	22.05	17.14	12.60	20.81	16.94

Yield Vs. Nutrient uptake

	Recommended fertilizer dose (RDF)			Farmers' fertilizer practice (FFP)		
	Correlation (r)	Regression (R^2)	Slope (b)	Correlation (r)	Regression (R^2)	Slope (b)
N	0.95	0.89	54.67	0.95	0.91	63.31
P_2O_5	0.95	0.90	0.17	0.78	0.61	131.28
K_2O	0.93	0.86	31.40	0.95	0.90	36.52

Table 5.2.5 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields Rice productivity and nutrient use efficiency in farmers' fields (Location: Titabar), *kharif* 2013

Parameter/ nutrient	Rec. dose of fert. (RDF)			Farmer's fert. practice (FFP)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (t/ha)	4.40	5.60	5.03	1.2	2.5	1.9
Nutrient uptake (kg/ha)						
N	60.7	107.1	85.5	15.5	55.7	36.6
P_2O_5	10.48	22.07	15.46	2.74	10.61	6.22
K_2O	51.28	99.17	80.85	20.50	61.05	43.76
Recovery efficiency (%) of applied fertilizer						
N	75.9	29.9	85.5	19.4	69.6	45.8
P_2O_5	133.9	63.1	165.3	7.8	30.3	17.8
K_2O	106.9	44.2	134.7	34.2	101.8	72.9
Nutrient utilization efficiency (kg grain/kg uptake)						
N	72.5	52.3	58.8	77.4	44.9	51.9
P_2O_5	42.0	25.4	32.5	43.8	23.6	30.6
K_2O	85.8	56.5	62.2	58.5	41.0	43.4
Nutrient requirement (kg/ton grain)						
N	13.75	19.12	16.90	12.91	22.28	19.26
P_2O_5	2.38	3.94	3.07	2.28	4.24	3.27
K_2O	11.65	17.70	16.07	17.08	24.42	23.03

Yield Vs. Nutrient uptake

	Recommended fertilizer dose (RDF)			Farmers' fertilizer practice (FFP)		
	Correlation (r)	Regression (R^2)	Slope (b)	Correlation (r)	Regression (R^2)	Slope (b)
N	0.6	0.4	0.02	0.4	0.2	0.02
P_2O_5	0.3	0.1	0.05	0.5	0.3	0.1
K_2O	0.5	0.3	0.02	0.3	0.1	0.01

Table 5.2.6 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields *kharif* 2013

Site-specific fertilizer recommendation (kg/ha) for a target yield (Location: Mandya)

Site No.	Current yield with RDF (kg/ha)	Current yield with FFP (kg/ha)	Per cent increase in yield over FFP	Fertilizer recommendation for the target yield (6.8 t/ha)		
				N	P_2O_5	K_2O
1	2947	3473	-	57.6	29.0	103.1
2	3667	3153	14.02	59.3	32.9	118.2
3	4980	4240	14.86	69.5	39.4	131.6
4	6807	4873	28.41	80.4	31.5	129.3
5	3580	3420	4.47	69.2	31.9	92.9
6	3833	3540	7.64	66.7	35.4	115.1
7	3100	2767	10.74	69.7	38.6	107.0
8	3613	3580	0.91	67.6	42.5	124.2
9	4140	4087	1.28	68.5	35.5	117.0
10	3833	3540	7.64	66.7	35.4	115.1

Table 5.2.7 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields *kharif* 2013

Site-specific fertilizer recommendation (kg/ha) for target yield (Location: Titabar)

Site No.	Current yield with RDF (t/ha)	Current yield with FFP (t/ha)	Per cent increase in yield over FFP	Fertilizer recommendation (kg/ha) target yield (5.6t/ha)		
				N	P_2O_5	K_2O
1	4.8	1.9	60.4	97.2	13.6	111.9
2	4.9	2	59.2	88.5	16.3	133.0
3	5.1	2	60.8	92.8	20.2	139.9
4	5.2	2.1	59.6	74.1	10.9	61.2
5	5.5	2	63.6	103.7	19.6	134.7
6	4.9	1.5	69.4	81.1	13.6	88.7
7	5.1	2	60.8	105.0	19.9	121.4
8	5.4	2.1	61.1	115.7	20.7	138.1
9	5.6	1.8	67.9	131.0	18.2	134.4
10	4.8	1.9	60.4	106.8	18.4	124.8
11	4.9	1.8	63.3	123.4	18.1	143.0
12	4.8	1.6	66.7	138.6	20.2	161.6
13	4.4	1.2	72.7	163.7	25.6	208.4
14	5.5	2.5	54.5	104.3	17.0	115.1
15	5.2	2.1	59.6	115.3	25.9	156.8

Table 5.2.8 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields Validation of SSNM recommendations in farmers' fields, *kharif* 2013

Parameter	SSNM	FFP	Current RDF	CD (0.05)	SSNM	FFP	Current RDF	CD (0.05)
Mandya (target -6.4 t/ha)					Titabar i (Target 6.1 t/ha)			
Grain yield (t/ha)	7.07	4.36	5.05	0.2	5.83	2.16	5.0	0.3
Nutrient Uptake (kg/ha)					Nutrient Uptake (kg/ha)			
N	78.5	44.4	51.6	2.3	91.6	36.3	74.4	6.2
P_2O_5	37.5	21.5	26.5	1.1	18.9	8.7	13.2	1.1
K_2O	83.8	53.5	62.7	3.5	108.6	45.6	79.8	2.9
N U E (kg grain /kg nutrient uptake)					N U E (kg grain /kg nutrient uptake)			
N	90.1	98.5	97.9	6.1	63.7	59.7	66.7	9.8
P_2O_5	188.8	203.2	190.8	10.6	308.2	248.6	374.8	16.6
K_2O	84.3	81.7	80.6	3.4	53.7	47.5	62.2	8.1

Table 5.2.9 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields Nutrient managements evaluated in validation trials *kharif* 2012

Fertilizer practice	Mandya			Titabar		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
SSNM	50-90	54 - 92	54-95	58-80	22-28	24-65
RDF	100	50	50	60	20	50
FFP				20-45	18-22	14-20
Varieties	KMP 101 (Thanu)			Ranjit		

Table 5.2.10 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields Site-specific fertilizer recommendation (kg/ha) for targeted yields, *kharif* 2013

Rice ecosystem	State	Location	Current yields with RDF (t/ha)	Current yields with FFP (t/ha)	Yield targets (t/ha)	Fertilizer recommendations for target yields		
RSLL	Assam	Titabar (20)	2.6 – 5.3	1.8-2.9	5.3	50 -220	15 - 42	26 -67
		Titabar (12)	3.9 – 4.95	2.6 -3.1	5.0	53 - 79	30 -42	40 -64
		Titabar (10)	4.1 – 5.6	2.3 -4.2	5.5	44 - 78	22 - 38	22 – 35
		Titabar (10)	4.0 -6.5	2.9 -4.5	6.5	48 - 74	17 - 23	15 – 36
		Titabar (15)	4.1 – 6,25	2,8 -4,25	6.25	45 - 86	7-17	31 - 69
		Titabar (20)	4.5 – 6.1	2.0 -3.5	6.1	58 - 118	19 - 31	24 - 74
Irrigated	Karnataka	Mandya (10)	4.5 – 6.7	4.3 – 6.4	6.7	102 - 169	50 - 70	91- 132
		Mandya (8)	3.7 – 6.5	3.7 – 7.1	7.1	12 - 119	20 -62	16 – 60
		Mandya (10)	3.7 – 6.4	2.8 – 5.9	6.4	110 - 127	61 - 69	112 - 157
		Mandya (10)	3.7 – 6.4	3.4 – 5.9	6.4	51 - 90	57 - 92	54 – 94
		Mandya (10)	3.5 – 6.1	3.2 – 4.9	6.1	101- 230	57 - 110	43 - 122

5.3 Management of micronutrients in rice based cropping systems

Availability of plant nutrients to crops is strongly dependent on physico-chemical nature of soils. Micronutrient deficiency in Indian soils has emerged as one of the major constraints to crop productivity. The problem is further compounded by issues of soil salinity, alkalinity and soil acidity commonly observed in many rice growing regions of India. High soil pH (8.5 - 11.0) and exchangeable sodium percentage (ESP), low organic matter content and presence of calcium carbonate granules or excess salt content in salt affected soils strongly modify the availability of micronutrients and thereby crop productivity. Acid soils suffer due to deficiencies of phosphorus, potassium, calcium, magnesium, molybdenum and boron and toxicities of aluminum and iron. Such soils can be managed in two ways viz. either by growing a crop suitable for a particular soil or by ameliorating the soil through the application of soil amendments.

Keeping these points in view, this trial was initiated in *kharif* 2010 and conducted at two locations (Kanpur and Ranchi) this year (*rabi* 2012-13 and *kharif* 2013) to study the direct, residual and cumulative effects of soil amelioration and micronutrient application on the nutrition and productivity of rice based cropping systems.

In sodic soils (Kanpur), the treatments consisted of three levels of gypsum amendment in main-plots and application of micronutrients (Zn, Fe, Mn) in addition to recommended NPK with and without organic matter in the sub-plots. In acidic soils of Ranchi in addition to liming, Zn, boron and silicon were the micronutrients applied along with recommended NPK fertilizers and FYM application. The results of the trial conducted in *rabi* 2012 and *kharif* 2013 are presented in Tables 5.3.1 to 5.3.6.

Wheat productivity and nutrient utilization efficiency at Kanpur (*rabi* 2012)

Rabi wheat yields which were not influenced by application of gypsum at Kanpur (Table 5.3.2) were significantly influenced by the nutrient management. Application of organic manures along with NPK alone or supplemented with micronutrients recorded higher yields (2.52 t/ha to 2.78 t/ha) than similar treatments without organic manure addition (2.18 - 2.48 t/ha). Excepting for nitrogen and phosphorus uptake which increased by 15.6-29.2% and 23.3-39.9% respectively due to gypsum application, non significant effects of gypsum amelioration were recorded for uptake of K, nutrient use efficiencies and requirements of NPK (Table 5.3.3).

Nutrient management significantly influenced the uptake of major nutrients (Table 5.3.4). Highest N (67. 7 -65.0 kg N/ha) and K (58.6-55.1 kg K/ha) uptake were observed in treatments OM + NPK/ NK +Zn/ NPK + Zn + Fe while the highest P uptake (13.8 and 13.3 kg/ha) was observed with OM + NPK + Zn + Fe and OM + NPK + Zn application. Although K use efficiency and requirement was not affected by nutrient management, N and P use efficiencies (NUE, PUE) and requirements (NR, PR) differed significantly between treatments with the highest use efficiencies and lowest requirements being recorded in treatments that did not receive organic manures. Highest NUE (43.8 kg grain/kg uptake) and lowest NR (22.9 kg uptake /t grain) were recorded in NPK + Zn + Fe + Mn. Highest phosphorus use efficiency (255.7 kg grain/kg uptake) and lowest PR (3.9 kg uptake /t grain) were observed in the treatment that received NPK alone as fertilizers.

Rice productivity and nutrient utilization efficiency at Kanpur (*kharif* 2013)

Gypsum application exerted significant positive effects on grain and straw yields of *kharif* rice at Kanpur (Table 5.3.2). Grain yields (3.33 t/ha at 50% GR and 3.46 t/ha at 100% GR) and straw yields (4.22 t/ha at 50% GR and 4.38 t/ha at 100% GR) did not vary significantly between the rates of gypsum application, indicating a possibility of saving on gypsum application. Nutrient management practices significantly influenced both grain and straw yields. Complementing recommended NPK dose and micronutrients with organic manure resulted in significant increases in yield. Application of OM + NPK + Zn + Fe + Mn (3.84 and 4.82 t/ha), OM + NPK + Zn + Fe (3.77 and 4.73 t/ha) and OM + NPK + Zn (3.67 and 4.66 t/ha) resulted in highest grain and straw yields respectively. Inorganic fertilization resulted in lower average grain yields (2.98 t/ha) compared to similar treatments supplemented with organic manures (3.57 t/ha) accounting for an increase of about 19.6%.

The uptake use efficiencies and nutrient requirements of the major nutrients (N, P and K) were not influenced by gypsum application (Table 5.3.4). Although Zn uptake increased (by 9.9% and 16.2%) due to gypsum (50% and 100% GR respectively) application, micronutrient uptake and efficiency parameters generally followed similar trends as that of macronutrients (Table 5.3.5).

Nutrient management practices exerted significant effect on nitrogen and phosphorus uptake. While OM + NPK + Zn + Fe + Mn (91.0 and 10.2 kg/ha), OM + NPK + Zn + Fe (90.9 and 10.9 kg/ha) and OM + NPK + Zn (85.2 and 9.8 kg/ha) was found to have the highest nitrogen and phosphorus uptake respectively, the use efficiencies and requirement of these nutrients were not influenced by nutrient management. Potassium, however, showed significant response to nutrient management practices in terms of uptake, use efficiency and potassium requirement. Organic manuring was found to increase potassium uptake; the highest uptake (83.5 kg/ha) was recorded with OM + NPK + Zn + Fe application. The highest K use efficiency (60.1 kg grain/ kg uptake) and lowest K requirement (17.3 kg uptake/t grain) were observed in OM + NPK + Zn and Om + NPK respectively.

The uptake of zinc, iron and manganese were influenced by nutrient application practices. Addition of organic manure along with application of recommended NPK and micronutrients improved Zn, Fe and Mn uptake by 35.3%, 11.5% and 33.1% respectively. Zinc and manganese demonstrated similar uptake pattern as OM + NPK + Zn + Fe + Mn (236.8 and 1398.6 g/ha), OM + NPK + Zn + Fe (242.9 and 1460 g/ha) and OM + NPK + Zn (235.1 and 1398.3 g/ha) recorded the highest Zn and Mn uptake respectively. The application of NPK alone without organic manure and micronutrient application revealed the highest zinc use efficiency and the lowest zinc requirement. Manganese use efficiency and requirement was not influenced by nutrient management. With respect to iron, the highest uptake (1082.3 g/ha) was observed in OM + NPK treatment, while the treatment OM + NPK + Zn + Fe and OM + NPK registered the highest use efficiency (4.4 kg grain/ g uptake) and lowest requirement (365.9 g uptake/ t grain) respectively.

Rice productivity and nutrient utilization efficiency at Ranchi (*kharif* 2013)

Liming, FYM and micronutrient application to the acid soils of Ranchi did not significantly influence rice grain yields (Table 5.3.6). Application of NPK + FYM + Zn + B+ Si was observed to support numerically higher grain yields (4.08 t/ha) and significantly higher straw yields (4.82 t/ha) compared to other treatments. Phosphorus and boron uptake were influenced by nutrient management approaches at Ranchi. Highest phosphorus accumulation of 14.1 kg/ha and 13.8 kg/ha was recorded in NPK + FYM + lime and NPK + FYM + Zn + B + Si application. Boron application to soil along with recommended dose of NPK and in combination with Zn, Si and FYM was observed to increase boron accumulation by 22.8%.

To summarize, rice yields in sodic soils of Kanpur were improved by gypsum application and fertilization practices. Gypsum application improved grain yields by 11.3% while organic fertilization in combination with recommended fertilizer (macronutrient and micronutrient) increased grain yields by 19.6%. Supplementation of NPK and micronutrients with organic manure like FYM resulted in marginal increases in rice yields in acid soils of Ranchi.

Table 5.3.1 Management of micronutrients in rice based cropping systems Soil and crop characteristics

Parameter	Kanpur	Ranchi
Cropping system	**Rice - Wheat**	**Rice**
Variety		
Kharif (Rice)	CSR 13	Naveen
Rabi (Wheat)	PBW343	-
RFD (Kg NPK/ha) *Kharif*	150:60:40	-
% Clay	28.9	21
% Silt	32.6	34
% Sand	38.4	45
Soil Texture	Clay Loam	Sandy clay loam
pH (1:1)	9.8	5.10
Organic carbon (%)	0.21	0.52
CEC [c mol(p^+)/kg]	12.8	13
EC (dS/m)	0.96	-
ESP (%)	62	-
Available N (kg/ha)	147	290
Available P_2O_5 (kg/ha)	54.04	22.6
Available K_2O (kg/ha)	298	185
Zn (mg/kg)	0.48	0.56
Fe (mg/kg)	4.16	-
Mn (mg/kg)	2.30	-
Avail B (mg/kg)		0.52

Trial 5.3.2 Management of micronutrients in sodic soils, *(rabi / kharif 2012-13)*
Kanpur : **Yield and yield parameters**

Treatment	*Rabi*-Wheat		*Kharif*- Rice	
	Grain Yield (t/ha)	Straw Yield (t/ha)	Grain Yield (t/ha)	Straw Yield (t/ha)
Gypsum application				
Control	2.24	2.72	3.05	3.76
50% GR	2.54	3.08	3.33	4.22
100% GR	2.77	3.39	3.46	4.38
CD (0.05)	**NS**	**NS**	**0.38**	**0.48**
CV (%)	**26.23**	**26.46**	**14.74**	**14.70**
Nutrient management				
NPK only	2.48	3.01	2.42	3.00
NPK + Zn	2.40	2.91	3.10	3.89
NPK + Zn + Fe	2.37	2.88	3.17	3.99
NPK + Zn + Fe + Mn	2.18	2.65	3.25	4.11
OM + NPK	2.78	3.41	3.00	3.76
OM + NPK + Zn	2.71	3.32	3.67	4.66
OM + NPK + Zn + Fe	2.67	3.25	3.77	4.73
OM + NPK + Zn + Fe + Mn	2.52	3.08	3.84	4.82
Expt. Mean	**2.51**	**3.06**	**3.28**	**4.12**
CD (0.05)	**0.28**	**0.30**	**0.36**	**0.38**
Interaction (MxS)	**NS**	**NS**	**NS**	**NS**
CV (%)	**11.72**	**10.28**	**11.67**	**9.63**

Trial 5.3.3 Management of micronutrients in sodic soils, (*rabi* 2012), Kanpur
Nutrient uptake, use efficiency and requirement of wheat

Treatment	Nutrient uptake (kg/ha)			Nutrient use efficiency (kg grain/kg uptake)			Nutrient requirement (kg uptake/t grain)		
	N	P	K	N	P	K	N	P	K
Gypsum application									
Control	52.0	9.5	44.2	43.0	236.8	51.2	23.3	4.3	19.8
50% GR	60.1	11.7	51.1	42.3	219.2	49.8	23.7	4.6	20.1
100% GR	67.2	13.3	57.5	41.4	211.3	48.3	24.2	4.8	20.7
CD (0.05)	**11.2**	**0.9**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**23.4**	**9.5**	**30.5**	**6.5**	**21.4**	**15.7**	**6.3**	**20.4**	**15.1**
Nutrient management									
NPK only	58.4	9.7	50.1	42.5	255.7	49.5	23.6	4.0	20.3
NPK + Zn	56.1	10.5	47.4	42.9	230.0	51.2	23.4	4.4	19.8
NPK + Zn + Fe	56.1	11.2	47.5	42.4	214.3	50.4	23.6	4.7	20.0
NPK + Zn + Fe + Mn	49.9	9.7	42.0	43.8	228.1	52.1	22.9	4.4	19.2
OM + NPK	67.7	11.8	58.6	41.2	236.5	47.7	24.3	4.3	21.0
OM + NPK + Zn	65.4	13.3	56.0	41.6	205.3	48.9	24.1	4.9	20.6
OM + NPK + Zn + Fe	65.0	13.8	55.1	41.1	195.0	48.6	24.3	5.2	20.6
OM + NPK + Zn + Fe + Mn	59.6	11.8	50.9	42.3	214.4	49.7	23.7	4.7	20.2
Expt. Mean	**59.8**	**11.5**	**50.9**	**42.2**	**222.4**	**49.8**	**23.7**	**4.6**	**20.2**
CD (0.05)	**6.4**	**1.3**	**5.0**	**1.2**	**11.7**	**NS**	**0.6**	**0.2**	**NS**
Interaction (MxS)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**11.2**	**11.6**	**10.4**	**2.9**	**5.5**	**7.2**	**2.8**	**5.3**	**7.0**

Trial 5.3.4 Management of micronutrients in sodic soils, (*kharif* 2013), Kanpur
Nutrient uptake, use efficiency and requirement of rice

Treatment	Nutrient uptake (kg/ha)			Nutrient use efficiency (kg grain/kg uptake)			Nutrient requirement (kg uptake/t grain)		
	N	P	K	N	P	K	N	P	K
Gypsum application									
Control	68.3	8.2	58.2	45.6	385.2	54.4	22.2	2.7	19.3
50% GR	78.8	8.8	61.7	42.6	388.5	55.8	23.7	2.7	18.7
100% GR	78.3	9.1	67.8	44.6	392.9	52.6	22.6	2.6	19.8
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**18.4**	**8.3**	**22.7**	**12.5**	**14.3**	**23.7**	**12.8**	**17.3**	**18.5**
Nutrient management									
NPK only	55.7	6.8	52.4	44.7	368.6	48.0	23.0	2.9	21.6
NPK + Zn	67.2	7.0	54.6	46.5	444.5	58.8	21.7	2.3	17.7
NPK + Zn + Fe	68.3	7.8	64.4	46.8	417.5	50.0	21.6	2.5	20.5
NPK + Zn + Fe + Mn	73.1	8.5	62.1	44.9	382.2	52.7	22.4	2.6	19.5
OM + NPK	69.6	8.6	51.3	43.8	355.6	60.0	23.2	2.9	17.3
OM + NPK + Zn	85.2	9.8	63.4	43.5	379.8	60.1	23.2	2.7	17.5
OM + NPK + Zn + Fe	90.9	10.9	83.5	41.8	362.6	46.2	24.0	2.9	22.1
OM + NPK + Zn + Fe + Mn	91.1	10.2	68.6	42.5	400.1	58.4	23.6	2.7	17.8
Expt. Mean	**75.1**	**8.7**	**62.5**	**44.3**	**388.9**	**54.3**	**22.8**	**2.7**	**19.5**
CD (0.05)	**11.7**	**1.8**	**11.6**	**NS**	**NS**	**10.7**	**NS**	**NS**	**3.6**
Interaction (MxS)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**16.3**	**21.4**	**19.5**	**11.0**	**20.1**	**20.8**	**11.0**	**21.4**	**19.9**

Trial 5.3.5 Management of micronutrients in sodic soils, (*kharif* 2013), Kanpur
Micronutrient uptake, use efficiency and requirement of rice

Treatment	Micronutrient uptake (g/ha)			Micronutrient use efficiency (kg grain/g uptake)			Micronutrient requirement (g uptake/ t grain)		
	Zn	Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn
Gypsum application									
Control	186.9	819.3	1133.4	16.7	3.8	2.8	61.2	274.8	370.8
50% GR	205.4	981.4	1215.3	16.6	3.5	2.8	61.5	298.2	363.9
100% GR	217.2	915.4	1275.5	16.3	3.8	2.8	62.9	269.1	363.4
CD (0.05)	**22.0**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**13.5**	**26.8**	**21.1**	**17.4**	**14.3**	**9.6**	**19.1**	**15.1**	**9.9**
Nutrient management									
NPK only	132.6	728.2	811.5	18.4	3.4	3.1	54.7	298.0	333.5
NPK + Zn	175.0	809.6	1051.0	17.8	3.9	3.0	56.5	259.8	336.5
NPK + Zn + Fe	177.2	912.2	1147.6	18.0	3.6	2.8	56.0	291.6	366.5
NPK + Zn + Fe + Mn	206.1	975.4	1135.8	16.4	3.4	2.9	63.2	302.0	346.4
OM + NPK	219.8	1082.3	1261.5	13.9	2.9	2.5	73.4	365.9	419.4
OM + NPK + Zn	235.1	897.6	1398.3	15.7	4.3	2.7	64.6	243.4	376.9
OM + NPK + Zn + Fe	243.0	871.2	1460.3	15.7	4.4	2.7	64.7	232.5	385.6
OM + NPK + Zn + Fe + Mn	236.8	966.5	1398.6	16.3	4.0	2.8	61.8	252.3	363.5
Expt. Mean	**203.2**	**905.4**	**1208.1**	**16.5**	**3.7**	**2.8**	**61.9**	**280.7**	**366.0**
CD (0.05)	**33.7**	**134.8**	**243.8**	**2.0**	**0.6**	**NS**	**8.3**	**52.1**	**NS**
Interaction (MxS)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**17.4**	**15.7**	**21.2**	**12.5**	**16.4**	**14.8**	**14.1**	**19.5**	**16.1**

Trial 5.3.6 Management of micronutrients in acid soils, (Ranchi, *kharif* 2013)
Yields and nutrient uptake by grain

Treatment	Grain Yield (t/ha)	Straw Yield (t/ha)	P uptake (kg/ha)	K uptake (kg/ha)	B uptake (kg/ha)
NPK(RD)	3.32	3.65	10.48	12.36	73.48
NPK(RD)+ FYM	3.68	4.20	13.00	15.82	113.60
NPK(RD)+ FYM + LIME	3.78	4.35	14.11	16.26	102.03
N+ 2(PK)	3.65	4.12	13.33	17.11	99.84
NPK+ Zn	3.53	3.89	10.46	15.20	99.73
NPK+ Zn +B	3.60	4.03	11.65	14.63	118.22
NPK+ Zn +B +Si	3.69	4.21	12.20	14.49	119.40
NPK+ FYM + Zn +B +Si	4.08	4.82	13.78	16.30	142.34
Expt. Mean	**3.67**	**4.16**	**12.38**	**15.27**	**108.58**
CD (0.05)	**NS**	**0.54**	**1.92**	**NS**	**19.99**
CV (%)	**7.36**	**7.39**	**8.89**	**8.65**	**10.52**

5.4 Screening of rice germplasm for high iron and zinc contents

Micronutrient deficiency, particularly of Fe is the most common and widespread nutritional disorder among the rice eating population. Biofortification - *the enrichment of staple food crops with essential micronutrients* - by utilizing the rich genetic variability in the germplasm is one of the important options available to fight micronutrient malnutrition or 'hidden hunger'. Keeping this in view, the present trial was conducted during *kharif* 2013 at 10 locations (Faizabad, Karaikal, Kaul, Khudwani, Mandya, Maruteru, Moncompu, Raipur, Titabar and Hyderabad) representing diverse environments and productivity potential, to identify the promising and stable rice germplasm for high Fe and Zn content and assess the influence of environment on the accumulation of micronutrients in the grain. About 160 cultures collected from all over the country were screened including two checks (Aghonibora and Vasumathi) promising for high Zn and Fe content to estimate the influence of environment on rice productivity and micronutrient contents in brown rice. The trial was conducted in RBD with three replications in 4 centres and with two in 4 centres and plot size varied from 2-9 m^2. Dehusked (brown rice) samples from the centres were analyzed for Fe and Zn concentration by atomic absorption spectrophotometry at DRR and the results presented in Tables 5.4.1 to 5.4.9 are discussed briefly.

Grain yield

Grain yields of common set of cultures at the test locations showed significant differences in productivity. Mean yield of the cultures varied from the lowest of 2.7 t/ha at Moncompu to the highest of 6.0 t/ha at Kaul (Table 5.4.2). Though the mean productivity of Aghonibora was the highest (4.9 t/ha), it was at par with that of Dathat-23 (4.5 t/ha) and NDR-2026 (4.6 t/ha), while that of IR 83294-66-2-2-3-2 was the lowest (2.7 t/ha). The environments of Mandya and Moncompu appeared to be unfavourable as the yields of the common cultures were low. Comparatively the yields were higher in neutral alluvial, and heavy textured soils at Kaul and Maruteru. Among the cultures, CSAR – 840 yielded significantly the highest (8.0 t/ha) at Kaul while Makom the lowest (1.2 t/ha) at Mandya.

Micronutrient (Zn, Fe) accumulation in brown rice

The influence of environment on the nutrient contents was estimated by analyzing the accumulation of zinc and iron in the brown rice (dehusked, unpolished) in the common set of cultures. The Zn and Fe content of brown rice varied across locations. Kadamakudy recorded the highest Zn content (80 ppm) while IR 83294-66-2-2-3-2 the lowest (40 ppm). The Fe content was highest in PB-1 (96 ppm) and lowest in Karthika (29 ppm). The Zn content was highest at Maruteru (112 ppm) which was at par with that of Karaikal (100 ppm) and lowest at DRR (17 ppm) and Kaul (19 ppm). Kaul recorded the highest Fe content (99 ppm) and Karaikal (23 ppm) and Moncompu (29 ppm) the lowest. The zinc and iron contents ranged from 8 – 197 ppm and 6 - 307 ppm, respectively (Table 5.4.2). Variety wise Zn and Fe contents showed variation indicating apparent influence of environment on grain Zn and Fe content but did not show relationship with soil micronutrient status or pH.

The micronutrient accumulation in brown rice and grain yields were further analyzed for assessing the relationship with rice productivity. Though, the correlation between yield and micronutrient content of some test cultures was significant, it did not show any specific trend. However, no significant relationship between grain yields and Zn and Fe was observed at different locations (Table 5.4.3 and 4).

Micronutrient uptake

The uptake of Fe and Zn varied among varieties and locations. Kadamakudy and Vasumati recorded the highest Zn (384 g/ha) and Fe uptake (491 g/ha) respectively while the lowest Zn uptake was observed in IR83294-66-2-2-3-2 (110 g/ha) and Fe uptake in Improved Chittimutyalu (102 g/ha) (Table 5.4.5). Among the locations the highest Zn uptake at Maruteru (604 g/ha) and Fe uptake at Kaul (542 g/ha) were recorded.

Promising cultures for zinc and iron content in brown rice

About 160 cultures including 21 common entries were screened for their relative contents of iron and zinc in the rice grain. The data presented in the Table 5.4.6 indicated mean zinc and iron content in brown rice across the test locations. Higher zinc and iron contents were recorded at Maruteru and Bankura, respectively. Promising cultures showing higher Zn and Fe contents (> mean + SD) were location specific. Among the 21 check varieties, Aghonibora and Vasumati showed promise in many locations for higher Fe and / or Zn contents (Tables 5.4.7 to 5.4.9).

Summary

In summary, the trial was conducted at 10 locations in which a total of about 160 cultures were screened including 21 common entries to study the influence of environment on rice productivity and micronutrient contents. Strong interaction effects of genotypes and locations were observed for both Fe and Zn content. The relationship between yield and Zn and Fe content in brown rice was not significant. Among the cultures, Kadamakudy and Vasumati recorded the highest Zn (384 g/ha) and Fe uptake (491 g/ha) respectively while the lowest Zn uptake in IR83294-66-2-2-3-2 (110 g/ha) and Fe uptake in Improved Chittimutyalu (102 g/ha). Cultures Aghonibora and Vasumati are being found consistently promising for accumulation of both Fe and Zn at different locations.

Table 5.4.1 Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Site characteristics

Parameter	BNK	DRR	FZB	KRK	Kaul	KDW	MND	MTU	MCP	TTB
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
% clay	17	-	23	52.65	-	-	9.8	38	30	45
% silt	27	-	21	14.75	-	-	20.2	28	21	32
% sand	56	-	56	28.72	-	-	70.0	34	49	23
Texture	Sandy loam	Clay	Sandy loam	Silty clay loam	Clay loam	Silty clay loam	Sandy loam	Clay loam	Silty Clay	Silty Clay
pH	5.5	7.3	7.5	7.4	7.8	-	6.65	6.4	6.3	5.5
OC (%)	0.65	0.7	0.4	0.5	3.2	-	0.37	0.7	3.9	1.2
CEC [c mol (p^+)/kg]		16	14	45.6	12.8	-	-	48.6	15	12
EC (dSm^{-1})	0.11	0.3	1.02	0.21	0.29	-	0.31	1.56	0.08	0.15
Avail. Zn (ppm)	0.7	-	-	-	0.7	-	0.6	1.6	2.5	0.9
Avail. Fe (ppm)	7.5	-	-	-	8.1	-	-	30.2	591.5	28.5
No. of entries tested	**20**	**21**	**21**	**47**	**20**	**23**	**22**	**85**	**50**	**24**

Table 5.4.2 Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Relationship between grain yield and micronutrient (Zn & Fe) content (mg/kg) in BR of common entries
a) Grain yield (kg/ha) of common varieties

Cultures	BNK	KRK	MND	MTU	MCP	DRR*	KAUL*	Mean
IR83668-35-2-2-2	2633	4167	4091	5280	1440	2800	5500	3582
IR83294-66-2-2-3-2	3400	2250	2778	3280	1417	3033	3833	2658
IR-75862-206	3733	4250	3636	5595	2987	3595	-	4000
IR-64	3133	5000	3939	4395	2008	4570	5500	3746
IR84722-82-2-3-3-3	2900	2333	3788	5365	2237	4445	6167	3388
Improved Chittimutyalu	4067	2500	3030	2635	2056	3583	-	2801
IR-82475-110-2-2-1-2	5467	2917	3535	5695	2674	3523	5500	4124
Karthika	-	4333	3434	4500	3924	4438	6167	4048
NDR-2008	4500	3833	2727	6505	3390	4390	6500	3995
CSAR-840	4067	3167	3030	6640	2516	2550	8000	3887
Kadamakudy	2900	4000	1919	7440	3450	3145	5833	3890
Dathat-23	4500	5500	2424	5910	4012	3720	4833	4482
Gouri	3933	5083	2677	5250	4109	3140	6500	4184
NDR-2026	4333	4417	3081	7180	4082	3700	5333	4550
Pratyusha	4067	5000	3232	4333	3302	3320	6333	3985
PB-1	3667	5000	2121	2690	2522	1808	7833	3271
Makom	3633	5750	1212	5550	3969	2198	5333	3974
PS-14	3567	5250	4141	4335	1882	2813	6500	3818
Shusk Samrat	3733	5333	3586	4350	2588	3620	5500	3965
Vasumati	4233	5500	1768	5355	1486	3560	7500	3688
Aghonibora	6467	5833	3030	6385	2315	1935	4667	4902
Mean	3759	4363	3009	5175	2737	3328	5965	
	Loc.		Var.		Var X Loc		Loc X Var	
CD (0.05)	519		427		955		1058	
CV (%)	22.28		12.52					

**Not considered for statistical analysis as the trial was not replicated.*

B) Zinc content (ppm) in brown rice (BR) of common varieties

Cultures	BNK	KRK	MND	MTU	MCP	DRR	KAUL	Mean
IR83668-35-2-2-2	42.83	41.00	47.75	57.50	84.00	23.00	15.25	44.48
IR83294-66-2-2-3-2	42.83	28.25	45.25	72.25	58.00	19.25	15.50	40.19
IR-75862-206	45.83	24.25	43.25	70.75	63.00	12.75	-	43.31
IR-64	40.83	17.50	72.75	35.75	84.50	12.50	25.25	41.30
IR84722-82-2-3-3-3	41.33	16.00	60.25	86.25	59.00	15.00	25.50	43.33
Improved Chittimutyalu	38.33	51.75	47.25	135.00	84.50	17.00	18.75	56.08
IR-82475-110-2-2-1-2	38.67	70.50	40.25	195.00	54.50	16.50	20.00	62.20
Karthika	-	166.50	32.75	122.25	53.50	15.00	8.25	66.38
NDR-2008	36.17	130.75	32.50	128.25	53.50	15.75	18.00	59.27
CSAR-840	38.17	186.25	19.25	113.25	96.50	17.25	19.00	69.95
Kadamakudy	37.33	120.50	75.50	193.00	93.00	19.25	22.75	80.19
Dathat-23	44.00	130.25	43.75	61.50	37.50	20.25	20.50	51.11
Gouri	41.50	150.50	15.00	197.00	93.50	21.75	16.75	76.57
NDR-2026	36.17	51.75	19.25	195.00	85.50	12.25	14.75	59.24
Pratyusha	33.50	195.25	21.50	65.75	63.00	17.00	26.00	60.29
PB-1	34.83	96.25	37.25	61.00	43.00	19.25	23.00	44.94
Makom	34.50	121.50	32.25	128.00	43.00	15.00	26.75	57.29
PS-14	39.83	171.00	28.50	108.00	90.00	15.50	15.75	66.94
Shusk Samrat	40.00	72.50	26.00	190.50	71.50	17.25	14.75	61.79
Vasumati	35.50	76.75	173.00	61.50	46.50	20.00	22.25	62.21
Aghonibora	32.83	176.25	20.25	79.50	148.00	20.75	21.00	71.23
Mean	**38.75**	**99.77**	**44.45**	**112.24**	**71.69**	**17.25**	**19.49**	
	Loc.		**Var.**		**Var X Loc**		**Loc X Var**	
CD (0.05)	**3.89**		**20.63**		**54.58**		**53.40**	
CV (%)	**12.69**		**48.11**					

C) Iron content (ppm) in brown rice of common varieties

Cultures	BNK	KRK	MND	MTU	MCP	DRR	KAUL	Mean
IR83668-35-2-2-2	81.83	29.75	15.75	46.50	42.00	36.75	78.75	47.33
IR83294-66-2-2-3-2	92.17	15.75	22.50	11.75	25.50	34.00	101.75	43.35
IR-75862-206	81.00	32.50	9.50	43.75	18.50	26.75	-	35.33
IR-64	89.17	20.25	7.00	22.75	40.00	22.00	99.50	42.95
IR84722-82-2-3-3-3	94.33	20.50	6.00	21.50	19.50	46.75	96.50	43.58
Improved Chittimutyalu	83.17	21.25	26.75	27.25	23.00	34.25	103.00	45.52
IR-82475-110-2-2-1-2	83.50	24.25	12.00	24.43	38.00	52.75	64.00	42.70
Karthika	-	14.50	17.75	26.50	17.50	34.00	64.50	29.13
NDR-2008	79.50	21.75	20.75	52.50	24.00	30.50	138.50	52.50
CSAR-840	85.00	22.00	13.25	79.75	20.50	39.50	76.00	48.00
Kadamakudy	104.67	14.50	56.25	30.25	28.50	55.25	83.25	53.24
Dathat-23	83.00	18.00	21.50	68.75	12.00	36.00	80.25	45.64
Gouri	82.67	20.75	9.25	73.75	27.50	53.25	65.00	47.45
NDR-2026	80.67	11.00	14.25	70.00	20.50	35.75	89.75	45.99
Pratyusha	75.83	34.25	15.75	29.25	21.00	35.75	85.25	42.44
PB-1	77.33	39.75	227.25	109.00	20.00	45.25	151.50	95.73
Makom	80.33	26.50	109.25	30.75	49.00	37.75	82.25	59.40
PS-14	69.50	15.50	59.75	25.50	30.00	54.25	127.75	54.61
Shusk Samrat	34.83	23.75	23.25	30.25	20.50	43.25	91.50	38.19
Vasumati	42.17	11.50	20.50	307.00	48.50	41.75	172.75	92.02
Aghonibora	36.83	46.75	23.25	122.00	56.00	132.50	125.25	77.51
Mean	**76.88**	**23.08**	**34.83**	**59.68**	**28.67**	**44.19**	**98.85**	
	Loc.		**Var.**		**Var X Loc**		**Loc X Var**	
CD (0.05)	**8.27**		**25.17**		**66.5**		**65.50**	
CV (%)	**29.22**		**63.58**					

Table 5.4.3: Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Correlation coefficients of grain yield Vs micronutrient contents in BR among common cultures

Variety	Grain yield (kg/ha)		Zn content (ppm)		Fe content (ppm)		Correlation coefficients	
	Min	Max	Min	Max	Min	Max	Zn	Fe
IR83668-35-2-2-2	1440	5500	23	84	16	82	-0.50	0.09
IR83294-66-2-2-3-2	1417	3833	19	72	12	102	-0.32	0.62
IR-75862-206	2987	5595	13	71	10	81	0.31	0.27
IR-64	2008	5500	13	85	7	100	-0.79	0.04
IR84722-82-2-3-3-3	2237	6167	15	86	6	97	0.10	0.35
Improved Chittimutyalu	2056	4067	17	135	21	103	-0.61	0.82
IR-82475-110-2-2-1-2	2674	5695	17	195	12	84	0.33	0.48
Karthika	3434	6167	15	167	15	65	-0.23	0.92
NDR-2008	2727	6505	16	131	21	139	0.15	0.74
CSAR-840	2516	8000	17	186	13	85	-0.12	0.75
Kadamakudy	1919	7440	19	193	15	105	0.54	-0.20
Dathat-23	2424	5910	20	130	12	83	0.49	0.42
Gouri	2677	6500	15	197	9	83	0.37	0.39
NDR-2026	3081	7180	12	195	11	90	0.79	0.61
Pratyusha	3232	6333	17	195	16	85	0.26	0.70
PB-1	1808	7833	19	96	20	227	0.07	0.13
Makom	1212	5750	15	128	27	109	0.68	-0.54
PS-14	1882	6500	16	171	16	128	0.06	0.49
Shusk Samrat	2588	5500	17	191	21	92	0.03	0.57
Vasumati	1486	7500	20	173	12	307	-0.46	0.52
Aghonibora	1935	6467	20	176	23	133	0.14	-0.08

Table 5.4.4: Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Correlation coefficients of grain yield Vs micronutrient contents in BR among genotypes at various locations

Location	Grain yield (kg/ha)		Zn content (ppm)		Fe content (ppm)		Correlation coefficients	
	Min	Max	Min	Max	Min	Max	**Fe**	**Zn**
Bankura	2633	6467	33	46	35	105	-0.43	-0.51
Karaikal	2250	5833	16	195	11	47	0.42	0.25
Mandya	1212	4141	15	173	6	227	-0.29	-0.48
Maruteru	2635	7440	36	197	12	307	0.34	0.14
Moncompu	1417	4109	38	148	12	56	-0.17	-0.35
DRR	1808	4570	12	23	22	133	-0.48	-0.51
Kaul	3833	8000	8	27	64	173	0.12	0.34

Table 5.4.5 Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Location and genotype effects on accumulation of Zn and Fe in grain in common varieties
a) Zinc uptake (g/ha) of common varieties

Cultures	BNK	KRK	MND	MTU	MCP	DRR	KAUL	Mean
IR83668-35-2-2-2	113	171	195	304	121	64	84	150
IR83294-66-2-2-3-2	146	64	126	237	82	58	59	110
IR-75862-206	171	103	157	396	188	46	0	152
IR-64	128	88	287	157	170	57	139	147
IR84722-82-2-3-3-3	120	37	228	463	132	67	157	172
Improved Chittimutyalu	156	129	143	356	174	61	-	146
IR-82475-110-2-2-1-2	211	206	142	1111	146	58	110	283
Karthika	-	722	112	550	210	67	51	285
NDR-2008	163	501	89	834	181	69	117	279
CSAR-840	155	590	58	752	243	44	152	285
Kadamakudy	108	482	145	1436	321	61	133	384
Dathat-23	198	716	106	363	150	75	99	244
Gouri	163	765	40	1034	384	68	109	366
NDR-2026	157	229	59	1400	349	45	79	331
Pratyusha	136	976	69	285	208	56	165	271
PB-1	128	481	79	164	108	35	180	168
Makom	125	699	39	710	171	33	143	274
PS-14	142	898	118	468	169	44	102	277
Shusk Samrat	149	387	93	829	185	62	81	255
Vasumati	150	422	306	329	69	71	167	216
Aghonibora	212	1028	61	508	343	40	98	327
Mean	**152**	**462**	**126**	**604**	**195**	**56**	**106**	

b) Iron uptake (g/ha) of common varieties

Cultures	BNK	KRK	MND	MTU	MCP	DRR	KAUL	Mean
IR83668-35-2-2-2	215	124	64	246	60	103	433	**178**
IR83294-66-2-2-3-2	313	35	63	39	36	103	390	**140**
IR-75862-206	302	138	35	245	55	96	-	**124**
IR-64	279	101	28	100	80	101	547	**177**
IR84722-82-2-3-3-3	274	48	23	115	44	208	595	**187**
Improved Chittimutyalu	338	53	81	72	47	123	-	**102**
IR-82475-110-2-2-1-2	456	71	42	139	102	186	352	**193**
Karthika	-	63	61	119	69	151	398	**144**
NDR-2008	358	83	57	342	81	134	900	**279**
CSAR-840	346	70	40	530	52	101	608	**250**
Kadamakudy	304	58	108	225	98	174	486	**208**
Dathat-23	374	99	52	406	48	134	388	**214**
Gouri	325	105	25	387	113	167	423	**221**
NDR-2026	350	49	44	503	84	132	479	**234**
Pratyusha	308	171	51	127	69	119	540	**198**
PB-1	284	199	482	293	50	82	1187	**368**
Makom	292	152	132	171	194	83	439	**209**
PS-14	248	81	247	111	56	153	830	**247**
Shusk Samrat	130	127	83	132	53	157	503	**169**
Vasumati	179	63	36	1644	72	149	1296	**491**
Aghonibora	238	273	70	779	130	256	585	**333**
Mean	**296**	**103**	**87**	**320**	**76**	**139**	**542**	

Table 5.4.6 Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Zinc and iron content (mg/kg) in brown rice of genotypes grown at different locations

Genotype	Bankura		DRR		Karaikal		Kaul		Mandya	
	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
IR83668-35-2-2-2	42.83	81.83	23.00	36.75	41.00	29.75	15.25	78.75	47.75	15.75
IR83294-66-2-2-3-2	42.83	92.17	19.25	34.00	28.25	15.75	15.50	101.75	45.25	22.50
IR-75862-206	45.83	81.00	12.75	26.75	24.25	32.50	-	-	43.25	9.50
IR-64	40.83	89.17	12.50	22.00	17.50	20.25	25.25	99.50	72.75	7.00
IR84722-82-2-3-3-3	41.33	94.33	15.00	46.75	16.00	20.50	25.50	96.50	60.25	6.00
Improved Chittimutyalu	38.33	83.17	17.00	34.25	51.75	21.25	18.75	103.00	47.25	26.75
IR-82475-110-2-2-1-2	38.67	83.50	16.50	52.75	70.50	24.25	20.00	64.00	40.25	12.00
Karthika	-	-	15.00	34.00	166.50	14.50	8.25	64.50	32.75	17.75
NDR-2008	36.17	79.50	15.75	30.50	130.75	21.75	18.00	138.50	32.50	20.75
CSAR-840	38.17	85.00	17.25	39.50	186.25	22.00	19.00	76.00	19.25	13.25
Kadamakudy	37.33	104.67	19.25	55.25	120.50	14.50	22.75	83.25	75.50	56.25
Dathat-23	44.00	83.00	20.25	36.00	130.25	18.00	20.50	80.25	43.75	21.50
Gouri	41.50	82.67	21.75	53.25	150.50	20.75	16.75	65.00	15.00	9.25
NDR-2026	36.17	80.67	12.25	35.75	51.75	11.00	14.75	89.75	19.25	14.25
Pratyusha	33.50	75.83	17.00	35.75	195.25	34.25	26.00	85.25	21.50	15.75
PB-1	34.83	77.33	19.25	45.25	96.25	39.75	23.00	151.50	37.25	227.25
Makom	34.50	80.33	15.00	37.75	121.50	26.50	26.75	82.25	32.25	109.25
PS-14	39.83	69.50	15.50	54.25	171.00	15.50	15.75	127.75	28.50	59.75
Shusk Samrat	40.00	34.83	17.25	43.25	72.50	23.75	14.75	91.50	26.00	23.25
Vasumati	35.50	42.17	20.00	41.75	76.75	11.50	22.25	172.75	173.00	20.50
Aghonibora	32.83	36.83	20.75	132.50	176.25	46.75	21.00	125.25	20.25	23.25
Mean	**38.75**	**76.88**	**17.25**	**44.19**	**99.77**	**23.08**	**19.49**	**98.85**	**44.45**	**34.83**
SD	**3.66**	**18.34**	**3.03**	**22.15**	**60.06**	**9.22**	**4.75**	**29.93**	**33.84**	**50.02**
Min	**32.83**	**34.83**	**12.25**	**22.00**	**16.00**	**11.00**	**8.25**	**64.00**	**15.00**	**6.00**
Max	**45.83**	**104.67**	**23.00**	**132.50**	**195.25**	**46.75**	**26.75**	**172.75**	**173.00**	**227.25**

Table 5.4.6 (contd.) Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Zinc and iron content (mg/kg) in brown rice of genotypes grown at different locations

Genotype	Maruteru		Moncompu		Faizabad	
	Zn	Fe	Zn	Fe	Zn	Fe
IR83668-35-2-2-2	57.50	46.50	84.00	42.00	56.75	38.00
IR83294-66-2-2-3-2	72.25	11.75	58.00	25.50	59.25	40.25
IR-75862-206	70.75	43.75	63.00	18.50	16.00	28.75
IR-64	35.75	22.75	84.50	40.00	18.75	57.00
IR84722-82-2-3-3-3	86.25	21.50	59.00	19.50	27.25	37.50
Improved Chittimutyalu	135.00	27.25	84.50	23.00	35.50	43.00
IR-82475-110-2-2-1-2	195.00	24.43	54.50	38.00	34.75	38.25
Karthika	122.25	26.50	53.50	17.50	26.75	43.25
NDR-2008	128.25	52.50	53.50	24.00	24.25	33.25
CSAR-840	113.25	79.75	96.50	20.50	18.50	37.00
Kadamakudy	193.00	30.25	93.00	28.50	30.25	35.25
Dathat-23	61.50	68.75	37.50	12.00	43.00	29.50
Gouri	197.00	73.75	93.50	27.50	73.75	36.00
NDR-2026	195.00	70.00	85.50	20.50	75.00	38.00
Pratyusha	65.75	29.25	63.00	21.00	47.50	33.50
PB-1	61.00	109.00	43.00	20.00	43.75	31.50
Makom	128.00	30.75	43.00	49.00	25.00	42.00
PS-14	108.00	25.50	90.00	30.00	42.00	45.00
Shusk Samrat	190.50	30.25	71.50	20.50	37.00	35.00
Vasumati	61.50	307.00	46.50	48.50	78.83	100.17
Aghonibora	79.50	122.00	148.00	56.00	99.16	85.17
Mean	**112.24**	**59.68**	**71.69**	**28.67**	**43.48**	**43.21**
SD	**54.09**	**64.00**	**25.77**	**12.12**	**22.70**	**17.70**
Min	**35.75**	**11.75**	**37.50**	**12.00**	**16.00**	**28.75**
Max	**197.00**	**307.00**	**148.00**	**56.00**	**99.16**	**100.17**

Table 5.4.6 (contd.) Screening of rice germplasm for high zinc and iron contents, *kharif* 2013

Genotype	Titabar		Genotype	Khudwani	
	Zn	Fe		Zn	Fe
IET22218	20.00	28.00	SR-1	15.50	71.25
IET22110	31.00	25.00	SR-2	18.50	49.75
27P-31	24.50	32.00	SR-3	20.00	54.75
VNR203	22.00	20.00	SKAU-90	13.25	51.25
Vasumathi	32.00	40.00	SKAU-292	19.75	50.50
SS-13	52.00	38.00	SKAU-309	18.25	52.00
TKM-9	43.00	36.00	SKAU-330	20.00	49.75
SS11	37.00	28.00	SKAU-337	21.50	50.75
Sampada	18.00	20.00	SKAU-339	20.50	55.00
SS-10	22.50	17.00	SKAU-404	20.50	45.75
SS-4	38.00	27.00	SAKU-405	21.25	54.25
IET21844	41.00	35.00	K-116	19.25	69.25
SS7	47.00	29.00	TKM-9	22.50	69.75
TTB404	45.00	30.00	CH-900	22.00	57.50
AXP_white	59.00	35.00	CH-1007	26.00	59.25
SS-20	40.00	28.00	CH-1039	22.00	55.75
SS-14	52.00	32.00	Urizug	34.00	63.25
SS-17	35.00	26.00	Chenab	22.25	71.50
Gitesh	39.00	45.00	M.budji	28.25	62.25
Disang	18.00	20.00	Jhelum	18.50	52.00
SS-8	24.00	18.00	Vasumathi	27.75	65.75
Jalashree	32.00	30.00			
Aghonibora	38.00	27.00			
Ranjit	19.00	16.00			
Mean	**34.54**	**28.42**	**Mean**	**21.50**	**57.68**
SD	**11.81**	**7.53**	**SD**	**4.53**	**8.00**
Min	**18.00**	**16.00**	**Min**	**13.25**	**45.75**
Max	**59.00**	**45.00**	**Max**	**34.00**	**71.50**

Table 5.4.7 Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Promising cultures with higher concentration of Zn in brown rice

S.No.	Location	Range of Zn (ppm) in common varieties	Cultures
1.	Bankura	33 - 46	IR 83668-35-2-2-2, IR 83294-66-2-2-3-2, IR 75862-206, Dathat-23
2.	DRR	12 - 23	IR 83668-35-2-2-2
3.	Faizabad	16 - 99	Aghonibora, Vasumati, Gouri, NDR-2026
4.	Karaikal	16 - 195	Aghonibora, Karthika, CSAR – 840, Pratyusha, PS-14
5.	Kaul	8 - 27	IR-64, Makom
6.	Khudwani	13 - 34	Vasumathi
7.	Mandya	15 - 173	Vasumati
8.	Maruteru	36 - 197	IR 82475-110-2-2-1-2, Shusk Samrat
9.	Moncompu	38 - 148	Aghonibora
10.	Titabar	18 - 59	Vasumathi

Table 5.4.8 Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Promising cultures with higher concentration of Fe in brown rice

S.No.	Location	Range of Fe (ppm) in common varieties	Cultures
1.	Bankura	35 - 105	Kadamakudy
2.	DRR	22 - 133	Aghonibora
3.	Faizabad	29 - 100	Aghonibora, Vasumati
4.	Karaikal	11 - 47	Aghonibora, IR 75862-206, Pratyusha, PB-1
5.	Kaul	64 - 173	Vasumati, NDR – 2008, PB-1
6.	Khudwani	46 - 72	Vasumathi
7.	Mandya	6 - 227	Makom
8.	Maruteru	12 - 307	Vasumati, Aghonibora
9.	Moncompu	12 - 56	Vasumati, Aghonibora, Makom
10.	Titabar	16 - 45	IET21844

Table 5.4.9: Screening of rice germplasm for high zinc and iron contents, *kharif* 2013
Promising cultures with higher concentration of both Zn and Fe in brown rice

S.No.	Location	Culture
1.	Faizabad	Aghonibora and Vasumati
2.	Karaikal	Aghonibora
3.	Khudwani	Vasumathi
4.	Moncompu	Aghonibora

5.5 Nutrient and water requirement for aerobic rice cultivation

The water-use efficiency of irrigated lowland rice is very low as it consumes 3000-5000 liters of water to produce one kg of rice. Low land rice requires 1500 to 3000 mm of water, much of is lost through deep percolation and seepage. However, the declining water availability to agriculture and to rice in particular threatens the sustainability of the irrigated rice ecosystem. Aerobic rice, a production system where rice is grown in well-drained, non-puddled, and non-saturated soils offers an option to optimize irrigation water use. Integrated approach involving controlled irrigation of maintaining near saturation soil conditions, proper land leveling and tillage, growing improved and water use efficient rice varieties and efficient nutrient and weed management need to be evaluated under different farm situations to optimize resource use. Nutrients, which have strong interaction with water, also contribute to the overall productivity of the crop and the resource. Keeping this in view, the trial has been initiated in 2010 at Indo-Gangetic Plains (IGP) (Kanpur, UP, light textured soil) to assess relative efficiency of utilizing water and requirement of nutrients under aerobic rice cultivation. It was extended in 2012 to Cauvery Command (Mandya, Karnataka, light textured soil) also. Data received from the two centers are presented in Tables 5.5.1 to 5.5.5 and summarized hereunder. The treatments consisted of three water regimes (irrigation equivalent to cumulative pan evaporation (CPE) of 150, 100 and 75 per cent) with a combination of nutrient (NPK) applications having four nitrogen levels (0, 60, 120 & 180 kg/ha), and two each of P (0 & 60 kg/ha) and K (0 & 100 kg/ha). The soils at both the test sites were of near neutral pH (6.35 -7.8), low in organic carbon (0.30 – 0.49%) and available N status, high in P and medium in K status (Table 5.5.1).

Data presented in Table 5.5.2 show significant effect of water regimes on both grain and straw yields at Mandya and on grain yield alone at Kanpur. Irrigation to compensate 75% of CPE out yielded other two water regimes at both Kanpur (IGP) and Mandya (Cauvery Command). Average rice productivity was 3.3 and 1.4 t/ha, respectively at Kanpur and Mandya. Response to applied nutrients (based on mean yield) was significant for N (up to 180 kg N/ha) and P (60 kg P_2O_5/ha) at Kanpur and up to 180 kg N, 60 kg P_2O_5 and 100 kg K_2O/ha at Mandya increasing the yields by 2.01 t/ha with N and 0.46 t/ha with P application at Kanpur. The corresponding yield increase in Mandya was 0.67, 0.39 and 0.33 t/ha with the application of N, P and K respectively. The treatment 180:60:100 kg NPK/ha recorded the highest grain yield at both Kanpur (4.1 t/ha) and Mandya (1.75 t/ha). The interaction effects of water regimes and nutrients were not significant at both Kanpur and Mandya.

Data on the nutrient uptake (Tables 5.5.3 and 5.5.4) show significant effect of water regimes for N alone at Kanpur and for N, P and K at Mandya. In IGP, N uptake was significantly higher with irrigation up to 75% CPE while at Mandya the NPK uptake at 75 and 100% CPE was on par and higher than at 150% CPE. Application of nutrients up to 180 kg N, 60 kg P_2O_5 and 100 kg K_2O/ha influenced positively with significant improvement in the uptake of N, P and K at both the sites. However, significant interaction effects of water regimes and nutrient application on nutrient uptake (N and P) was observed only at Mandya. At the highest yield level of 2.06 t/ha at Mandya under 75% CPE with $N_{120}P_{60}K_{100}$ the crop accumulated 21, 6 and 12 kg NPK/ha. This works out to a nutrient requirement of 10.2, 2.9 and 5.8 kg NPK/t of grain. At Kanpur the crop required 18.4, 5.2 and 20.1 kg of NPK/t grain production irrespective of water regime.

The productivity of irrigation water including rainfall was estimated by measuring the quantum of water used and effective rainfall (75%) besides including about 50 mm irrigation water required for plowing (Table 5.5.6). About 1189 – 1602 mm irrigation water (including effective rainfall) at Kanpur and 968- 1357 mm at Mandya was used for imposing different water regimes to compensate 75-150% evaporation loss. Productivity of water (kg grain/ha mm water used) ranged from 2.0-3.0 and 0.9-1.6 kg grain/ha mm water at Kanpur and Mandya, respectively depending on the water regime. This works out to a water requirement of 1187-2585 and 3380-7899 l/kg grain production at Kanpur and Mandya, respectively depending on the water regime. The per cent saving in water requirement with 100 and 75% CPE irrigation ranged from 27.7 to 54.1 and 29.9 to 57.2 at Kanpur and Mandya, respectively over 150% CPE. Irrigation equivalent to 75% of cumulative pan evaporation appeared to be optimum for aerobic rice system based on water productivity with no yield penalty both the centres.

Summarizing the results, the study indicated significant effect of water regimes on the performance of aerobic rice at both the locations. Response to N, P and K was significant with increase in grain yield by 2.01 t/ha with N and 0.46 t/ha with P application at Kanpur and 0.67, 0.39 and 0.33 t/ha of NPK at Mandya, respectively. Application of nutrients improved the uptake NPK up to 180 kg N, 60 kg P and 100 kg K both at Kanpur and Mandya. The NPK requirement at Kanpur and Mandya was estimated to be 18.4, 5.2 and 20.1 kg and 10.2, 2.9 and 5.8 kg per tonne of grain production, respectively. Productivity of water (kg grain/ha mm water used) ranged from 2.0-3.0 and 0.9-1.6 kg grain/ha mm water at Kanpur and Mandya, respectively. The per cent saving in water requirement with 100 and 75% CPE irrigation ranged from 27.7 to 54.1 and 29.9 to 57.2 at Kanpur and Mandya, respectively over 150% CPE. Irrigation equivalent to 75% of CPE appeared to be optimum for aerobic rice system saving about 26% irrigation water at Kanpur and 30% at Mandya over 150% CPE.

Table: 5.5.1 Nutrient and water requirement for aerobic rice cultivation, *Kharif* 2013
Soil and Crop Characteristics

Parameter	Kanpur	Mandya
Crop		
Variety	NDR 359	Raksha
Crop growth	Good	Good
Recommended fertilizer dose (KgNPK/ha)	As per treatments	As per treatments
% Clay	21.25	11.50
% Silt	23.12	19.30
% Sand	55.62	69.20
Soil texture	Sandy loam	Sandy loam
pH (1:2)	7.8	6.35
Organic carbon (%)	0.49	0.30
EC (dS/m)	0.87	0.21
Available N (kg/ha)	248	198
Available P_2O_5 (kg/ha)	48	17.9
Available K_2O (kg/ha)	206	123.8

Table 5.5.2 Nutrient and water requirement for aerobic rice cultivation, *kharif* 2013
Yield (t/ha)

Treatments	**Kanpur**		**Mandya**	
	Grain	Straw	Grain	Straw
Water regimes				
IW/CPE-150%	3.23	4.04	1.16	0.81
IW/CPE-100%	2.95	3.68	1.48	1.05
IW/CPE- 75%	3.57	4.44	1.55	1.07
CD (0.05)	0.42	0.61	0.10	0.05
CV (%)	13.99	16.28	7.76	5.88
Nutrient application				
$N_0P_{60}K_{100}$	2.09	2.51	1.08	0.67
$N_{120}P_0K_{100}$	3.19	3.97	1.20	0.87
$N_{120}P_{60}K_0$	3.37	4.20	1.26	0.90
$N_{60}P_{60}K_{100}$	3.09	3.84	1.50	1.13
$N_{120}P_{60}K_{100}$	3.65	4.63	1.59	1.22
$N_{180}P_{60}K_{100}$	4.10	5.18	1.75	1.06
CD (0.05)	**0.32**	**0.36**	**0.12**	**0.10**
CV (%)	**10.23**	**9.25**	**8.80**	**10.16**
S in M	**NS**	**NS**	**0.20**	**0.16**
M in S	**NS**	**NS**	**0.19**	**0.15**
Expt. Mean	**3.25**	**4.05**	**1.40**	**0.98**

Table 5.5.3 Nutrient and water requirement for aerobic rice cultivation, *Kharif* 2013
Nutrient uptake (kg/ha), NUE (kg/kg) and Nutrient requirement (kg/t) (Location: Kanpur)

Treatments	**Nutrient uptake (kg/ha)**			**Use Efficiency (kg/kg)**			**Nutrient requirement (kg/t)**		
	N	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**
Water regimes									
IW/CPE-150%	59.16	17.43	65.60	55.32	189.65	49.83	18.13	5.33	20.16
IW/CPE-100%	53.08	15.34	58.94	56.15	195.89	50.60	17.86	5.16	19.85
IW/CPE- 75%	67.42	18.29	71.39	53.21	198.98	50.46	18.87	5.08	19.91
CD (0.05)	8.79	NS	NS	0.75	NS	NS	0.24	NS	NS
CV (%)	15.86	21.29	21.15	1.48	15.92	8.47	1.44	16.33	8.54
Nutrient application									
$N_0P_{60}K_{100}$	36.54	9.99	39.55	57.92	209.06	52.88	17.43	4.80	18.93
$N_{120}P_0K_{100}$	57.05	14.24	64.71	56.00	224.26	49.25	17.86	4.47	20.34
$N_{120}P_{60}K_0$	62.46	18.38	62.36	54.09	183.24	54.24	18.49	5.48	18.49
$N_{60}P_{60}K_{100}$	54.34	15.96	60.67	56.92	194.85	50.96	17.58	5.15	19.64
$N_{120}P_{60}K_{100}$	69.57	20.17	76.89	52.65	181.70	47.54	19.01	5.52	21.07
$N_{180}P_{60}K_{100}$	79.37	23.36	87.66	51.78	175.92	46.94	19.34	5.70	21.37
CD (0.05)	**6.08**	**1.64**	**5.85**	**2.12**	**8.02**	**2.16**	**0.83**	**0.20**	**0.84**
CV (%)	**10.55**	**10.02**	**9.31**	**4.13**	**4.28**	**4.46**	**4.71**	**3.91**	**4.35**
S in M	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
M in S	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Expt. Mean	**59.89**	**17.02**	**65.31**	**54.89**	**194.84**	**50.30**	**18.28**	**5.19**	**19.97**

Table 5.5.4 Nutrient and water requirement for aerobic rice cultivation, *Kharif* 2013
Nutrient uptake (kg/ha), NUE (kg/kg) and Nutrient requirement (kg/t) (Location: Mandya)

Treatments	**Nutrient uptake (kg/ha)**			**NUE (kg/kg)**			**Nutrient requirement (kg/t)**		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Water regimes									
IW/CPE-150%	11.62	3.79	6.31	99.47	303.85	183.05	10.07	3.32	5.49
IW/CPE-100%	15.67	4.76	8.22	95.38	314.44	182.79	10.53	3.19	5.52
IW/CPE-75%	16.05	4.96	8.55	98.13	316.96	185.39	10.25	3.17	5.44
CD (0.05)	0.81	0.33	0.50	3.65	5.03	1.71	0.37	0.07	0.06
CV (%)	6.04	8.02	7.01	4.04	2.72	1.00	3.89	2.25	1.24
Nutrients									
$N_0P_{60}K_{100}$	10.13	3.38	5.72	106.48	320.67	189.28	9.41	3.13	5.34
$N_{120}P_0K_{100}$	12.09	3.76	6.71	99.67	320.39	179.37	10.06	3.14	5.59
$N_{120}P_{60}K_0$	13.29	4.08	6.16	94.74	306.21	202.62	10.59	3.31	4.97
$N_{60}P_{60}K_{100}$	16.04	5.08	8.71	93.98	298.18	172.62	10.68	3.37	5.80
$N_{120}P_{60}K_{100}$	16.64	5.51	10.22	94.91	317.57	172.10	10.57	3.16	5.82
$N_{180}P_{60}K_{100}$	18.51	5.23	8.60	96.12	307.53	186.52	10.42	3.29	5.40
CD (0.05)	**1.15**	**0.40**	**0.60**	**4.10**	**15.97**	**8.48**	**0.42**	**0.08**	**0.24**
CV (%)	**8.28**	**9.17**	**8.13**	**4.36**	**5.73**	**4.80**	**4.23**	**5.21**	**4.54**
S in M	**2.00**	**0.69**	**1.03**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
M in S	**1.98**	**0.71**	**0.96**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Expt. Mean	**14.45**	**4.51**	**7.69**	**97.65**	**311.76**	**183.75**	**10.29**	**3.23**	**5.49**

Table 5.5.5 Nutrient and water requirement for aerobic rice cultivation, 2013
Water productivity under different water regimes

Water regimes	**Water input*** (ha mm)		**Mean yield** (kg/ha)		**Water productivity** (kg grain/ha mm)		**Water requirement** (litres/kg grain)	
	Kanpur	**Mandya**	**Kanpur**	**Mandya**	**Kanpur**	**Mandya**	**Kanpur**	**Mandya**
IW/CPE-150%	1602	1357	3233	1157	2.02	0.85	2585	7899
IW/CPE-100%	1317 (17.8)	1263 (6.9)	2949	1481	2.24	1.17	1870 (27.7)	5534 (29.9)
IW/CPE-75%	1189 (25.8)	968 (29.9)	3565	1551	3.00	1.60	1187 (54.1)	3380 (57.2)

*Includes water applied through irrigation, effective rainfall (75% for aerobic rice) during the crop growth and about 50 mm used for land preparation. Rainfall: 1023 mm at Kanpur and 562 mm at Mandya
Figures in parentheses are per cent water saved

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

Rice and rice based cropping systems are most important production systems widely cultivated under diverse soil and agro ecological conditions including large tracts of soils with *in situ* problems and management induced nutrient stresses. Changing climatic conditions of shifts in rainfall distribution and its intensity, changes in temperature regimes in many vulnerable areas are likely to influence agricultural productivity through its impact on land and water resources besides directly influencing crop calendar, crop growth and efficiency of inputs. While availability of resources determine the cropping pattern and farm operations, shifts in crop calendar strongly influence crop productivity potential as already reported through studies conducted under the coordinated program. Keeping this in view, this study has been initiated in *kharif* 2011 at few selected locations to assess the extent of change in rice productivity and nutrient use efficiency due to changing crop calendar and identify management options to mitigate the loss in yield and nutrient use efficiency. The treatments consisted of early to delayed crop establishment (15 days from optimum time) and integrated multi-nutrient management approaches as strategies to minimize the likely yield loss. The trial was conducted at five locations [DRR, Ghaghraghat (GHT), Karaikal (KRK), Khudwani (KHU) and Maruteru (MTU)] and data are presented in Tables 5.6.1 to 5.6.8.

Rice and Wheat productivity

At Karaikal, the effect of *kharif* rice cropping calendar influenced the *rabi* rice productivity alone recording significantly higher grain yield in the plots where early planting was done over optimum and late planting. Whereas, wheat grain yield at Ghaghraghat was not influenced by k*harif* crop calendar. Nutrient management practices did not influence *rabi* crop productivity. During *kharif*, planting time exerted significant influence on grain yield at Karaikal (KRK), Khudwani (KHU) and Maruteru (MTU) recording highest yields with early planting (4.34, 6.57 and 5.61 t/ha at KRK, KHU and MTU, respectively). Though not significant, at DRR also, higher yield was recorded with early planting which was higher by 7.3 and 33.6% over optimum and late planting, respectively. Whereas, at GHT, optimum planting recorded higher grain yield by 13 and 35% over early and late planting, respectively.

Nutrient management influenced rice grain yields significantly at GHT, KRK and KHU while non- significant effect was observed at DRR and MTU. At GHT, maximum yield of 4.88 t/ha was recorded with INM ie., 100% RDF (+ZnSFeB) + GM + VC + RS followed by 3.75 t/ha with 100% organic manuring. At KRK, INM and 100% organics were on par and superior to other treatments recording 3.76 and 3.77 t/ha, respectively. Whereas, at KHU, 100% RDF along with micronutrients and INM recorded higher yields of 6.34 - 6.51 t/ha. With regard to straw yield, at 3 locations (KRK, KHU and MTU), early planting; at one location (GHT), optimum planting ; and at one location (DRR), late planting recorded maximum straw yields. INM treatment recorded higher straw yield at most of the locations.

Nutrient uptake and use efficiency

During *rabi*, total nutrient uptake was maximum with early planting and none of the nutrient management treatments influenced the nutrient uptake at KRK. Nutrient use efficiency did not follow any specific trend. During *kharif*, at DRR, only P uptake was influenced by time of planting where it was higher and on par with early and optimum planting (21-24 kg/ha) and none of the nutrient management practices influenced the NPK uptake. At KHU, NPK uptake and at MTU, P uptake alone were significantly higher with early planting. In general, INM and 150% RDF (+ZnSFeB) treatments recorded higher nutrient uptake values. Nutrient use efficiency did not follow any particular trend though early and optimum planting and INM and 100% organics recorded higher nutrient use efficiency values in most of the locations and delayed planting caused reduction in nutrient use efficiency.

Soil nutrient status after harvest

The soil available nutrients after harvest of *rabi* crop at KRK and after *kharif* crop at KHU did not follow any particular trend either with different planting schedules or with nutrient management practices.

Summary

From the results of five centres (DRR, GHT, KRK, KHU and MTU), the grain yield data indicated higher productivity with early planting over optimum planting time at KRK, KHU and MTU by 24, 10 and 9%, respectively and at all 5 places, delayed planting resulted in yield reduction by about 13-40% . At most of the locations, INM performed well recording maximum yields and at four locations, 100% organics also performed on par with 100% RDF and INM treatments . In general, INM and 150% RDF for nutrient uptake and INM and organics for nutrient use efficiency along with early and optimum time of planting were found superior at most of the locations.

Table: 5.6.1 Nutrient use efficiency and soil productivity in early and late sown rice Crop and soil characteristics

Parameter	DRR	GHT	KRK	KHU	MTU
Cropping system	Rice-Rice	Rice-Wheat	Rice-Rice-Pulse	Rice	Rice-Rice
Variety					
Kharif	PA6444	NDGR-201	ADT 43	Jhelum	MTU-1061
Rabi	IR 64	Wheat-PBW443	ADT 45	*Brwon sarson*-BS-3	-
RFD (Kg/NPK/ha)					-
Kharif	120:60-40	120:60:40:20	160:60:30	120:60:30	90:60:60
Rabi	-	120:60:40	136-34-95-25	60:30:20	-
Crop growth					
Kharif	Good	Good	-	good	Good
Rabi	-	Good	-		-
Soil data					
% clay	55	28	23	22	38
% silt	25	33	12	37	28
% sand	20	39	56	41	34
Soil Texture	Clay	Silty clay loam	Sandy clay loam	Silty clay loam	Clay loam
pH (1:1)	8.2	7.9	6.32	6.73	6.40
Org.carbon (%)	0.96	0.42	0.52	1.11	0.65
CEC [c mol (p+)/kg]	-	-	24.56		48.6
EC (ds/m)	0.50	-	0.13	0.11	1.56
Avail.N (kg/ha)	286	220	112	212	226
Avail. P_2O_5 (kg/ha)	56	14.8	109	12.5	19.71
Avail. K_2O (kg/ha)	385	203	114	246	358

DRR – Directorate of Rice Research, GHT- Ghaghraghat, KRK- Karaikal, KHU – Khudwani, MTU- Maruteru

Table 5.6.2 Nutrient use efficiency and soil productivity in early and late sown rice Yield parameters, grain and straw yields, *rabi* - 2013

Treatments	KRK-Rice			GHT-Wheat		
	Panicles/m^2	Grain yield (t/ha)	Straw yield (t/ha	Panicles/m^2	Grain yield (t/ha)	Straw yield (t/ha)
Time of crop establishment						
Early sown / planting	485	3.71	5.16	287	2.71	4.16
Optimum sown / planting	364	2.89	4.80	302	2.88	4.28
Late sown / planting	372	3.22	4.23	275	2.75	4.02
CD(0.05)	NS	0.26	NS	8.79	NS	NS
CV (%)	27	13.4	31.5	3.93	18.46	17.45
Nutrient management						
100% RDF (+ZnS)	399	3.26	4.68	272	2.86	4.06
100% RDF (+ZnSFeB)	392	3.40	4.80	298	2.71	4.06
150%RDF+(+ZnSFeB)	437	3.46	4.45	285	2.69	4.19
100%RDF +(+ZnSFeB) + GM+VC+RS	407	3.35	4.83	304	2.84	4.39
Organic manuring~RDF	384	3.12	4.52	281	2.81	4.07
Expt. Mean	**407**	**3.28**	**4.73**	**288**	**2.78**	**4.16**
CD(0.05) Nutrients	**NS**	**NS**	**NS**	**8.28**	**NS**	**NS**
M in S	**NS**	**NS**	**NS**	**NS**	**NS**	**0.72**
S in M	**NS**	**NS**	**NS**	**NS**	**NS**	**0.78**
CV (%)	**15**	**12.38**	**11.64**	**3.48**	**13.65**	**12.16**

Table 5.6.3 Nutrient use efficiency and soil productivity in early and late sown rice Nutrient uptake and Nutrient use efficiency, Karaikal - *Rabi* 2012-13

Treatments	Nutrient uptake (kg/ha)			Nutrient use efficiency(kg grain/kg uptake)		
	N	P	K	NUE	PUE	KUE
Time of crop establishment						
Early sown / planting	52.2	19.5	145	71.1	190	25.5
Optimum sown / planting	47.0	16.2	119	125	178	24.3
Late sown / planting	39.2	13.2	91.9	94.9	243	35.0
CD(0.05)	NS	2.07	24.3	-	-	-
CV (%)	25.7	21.3	34.4	-	-	-
Nutrient management						
100% RDF (+ZnS)	45.3	16.3	121	72.0	200	26.9
100% RDF (+ZnSFeB)	48.9	16.7	121	69.5	204	69.5
150% RDF+(+ZnSFeB)	45.7	15.8	111	75.7	218	75.7
100% RDF +(+ZnSFeB) + GM+VC+RS	46.9	16.6	122	71.4	201	27.5
Org. manuring~RDF	42.4	16.0	116	73.6	195	26.9
Expt. Mean	**46.1**	**16.4**	**119**	**81.6**	**210**	**41.5**
CD(0.05) Nutrients	**NS**	**NS**	**NS**	**-**	**-**	**-**
-M in S	**NS**	**NS**	**NS**	**-**	**-**	**-**
-S in M	**NS**	**NS**	**NS**	**-**	**-**	**-**
CV (%)	**12.2**	**10.2**	**12.7**	**-**	**-**	**-**

Table 5.6.4 Nutrient use efficiency and soil productivity in early and late sown rice Soil nutrient status after harvest, Karaikal - *Rabi* 2012-13

Treatments	Soil nutrient status				
	pH	EC (dS/m)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Time of crop establishment					
Early sown / planting	6.14	0.11	45.7	9.41	120
Optimum sown / planting	6.15	0.11	43.9	8.37	119
Late sown / planting	6.58	0.11	47.4	8.94	194
CD(0.05)	**0.19**	**NS**	**1.55**	**NS**	**21.3**
CV (%)	**4.98**	**43.1**	**5.73**	**66**	**24.8**
Nutrient management					
100% RDF (+ZnS)	6.21	0.14	46.0	5.88	107
100% RDF (+ZnSFeB)	6.17	0.09	47.4	7.67	112
150%RDF+(+ZnSFeB)	6.17	0.11	45.6	9.97	136
100%RDF +(+ZnSFeB) + GM+VC+RS	6.37	0.13	46.0	10.6	130
Org. manuring~RDF	6.41	0.09	44.6	9.60	174
Expt. Mean	**6.29**	**0.11**	**45.7**	**8.91**	**145**
CD (0.05) Nutrients	**0.19**	**NS**	**NS**	**NS**	**50.9**
-M in S	**0.33**	**NS**	**4.25**	**NS**	**NS**
-S in M	**0.32**	**NS**	**3.98**	**NS**	**NS**
CV (%)	**3.17**	**63.0**	**5.58**	**53.1**	**36.4**

Table 5.6.5 Nutrient use efficiency and soil productivity in early and late sown rice
Yield parameters, grain and straw yields, *kharif* - 2013

Treatments	Panicles/m²		Grain yield (t/ha)					Straw yield (t/ha)					HI				
	GHT	MTU	DRR	GHT	KRK	KHU	MTU	DRR	GHT	KRK	KHU	MTU	DRR	GHT	KRK	KHU	MTU
Crop establishment																	
Early sown / planting	270	278	4.97	3.95	4.34	6.57	5.61	4.17	6.45	6.51	11.6	7.81	0.54	0.38	0.40	0.35	0.42
Optimum sown / planting	293	244	4.63	4.46	3.49	5.96	5.16	4.39	8.37	6.28	10.9	7.56	0.52	0.35	0.36	0.35	0.41
Late sown / planting	194	193	3.72	3.30	3.10	5.83	4.47	5.60	5.54	4.14	10.5	7.26	0.40	0.37	0.43	0.36	0.38
CD(0.05)	15.5	18.8	NS	NS	0.53	0.23	0.23	NS	1.73	0.52	0.48	NS	0.02	0.01	-	NS	0.02
CV (%)	7.95	12.1	21.3	35.5	18.8	5.8	7.1	31.4	32.9	11.9	6.6	14.9	7.3	4.4	-	1.59	6.35
Nutrient management																	
100% RDF (+ZnS)	226	239	4.23	3.15	3.63	6.38	4.87	4.43	5.29	5.65	11.5	6.96	0.49	0.38	0.39	0.36	0.41
100% RDF (+ZnSFeB)	238	242	4.36	3.58	3.61	6.51	5.25	4.61	6.28	5.53	12.0	7.26	0.50	0.36	0.39	0.35	0.42
150%RDF(+ZnSFeB)	257	241	4.63	4.16	3.48	6.13	4.99	4.99	7.30	5.63	11.1	8.14	0.49	0.36	0.38	0.36	0.38
100%RDF(+ZnSFeB) + GM+VC+RS	284	242	4.61	4.88	3.76	6.34	5.29	5.02	8.62	5.85	11.5	8.19	0.48	0.36	0.39	0.35	0.39
Org. manuring ~ RDF	256	228	4.36	3.75	3.77	5.24	5.00	4.56	6.44	5.56	9.5	7.17	0.49	0.37	0.40	0.36	0.41
Expt. Mean	**253**	**238**	**4.44**	**3.90**	**3.65**	**6.12**	**5.08**	**4.72**	**6.79**	**5.64**	**11.1**	**7.55**	**0.49**	**0.37**	**0.39**	**0.35**	**0.4**
CD(0.05) Nutrients	**29**	**NS**	**NS**	**0.97**	**0.16**	**0.45**	**NS**	**NS**	**0.51**	**NS**	**0.84**	**0.66**	**NS**	**NS**	**-**	**NS**	**0.03**
M in S	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**1.15**	**NS**	**NS**	**-**	**NS**	**0.05**
S in M	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**1.12**	**NS**	**NS**	**-**	**NS**	**0.04**
CV (%)	**13.9**	**5.5**	**13.0**	**6.1**	**5.4**	**7.6**	**7.4**	**13.8**	**9.1**	**9.4**	**7.7**	**9.0**	**6.0**	**3.4**	**-**	**1.5**	**6.9**

Table 5.6.6 Nutrient use efficiency and soil productivity in early and late sown rice
Nutrient uptake (kg/ha) in total dry matter, *kharif* -2013

Treatments	DRR			Ghaghraghat			Khudwani			Maruteru		
	N	P	K	N	P	K	N	P	K	N	P	K
Crop establishment												
Early sown / planting	80.5	24.0	44.9	72.7	29.4	137	119	30.6	115	79.4	22.7	139
Optimum sown / planting	73.1	21.0	43.9	91.6	37.5	183	108	26.5	100	72.9	21.7	138
Late sown / planting	74.0	14.8	45.2	59.2	22.8	119	98.5	25.5	96	77.2	19.4	142
CD (0.05)	**NS**	**3.9**	**NS**	**-**	**-**	**-**	**5.4**	**1.33**	**5.26**	**NS**	**1.61**	**NS**
CV (%)	**28.2**	**30.1**	**45.5**	**-**	**-**	**-**	**7.66**	**7.43**	**7.79**	**9.2**	**13.2**	**14.8**
Nutrient management												
100% RDF (+ZnS)	67.9	19.2	41.6	60	25.7	122	103	26.0	100	73.8	20.9	136
100% RDF (+ZnSFeB)	79.1	22.3	57.1	112	25.3	142	113	29.6	109	75.7	22.0	139
150% RDF+(+ZnSFeB)	74.8	19.5	42.9	87.4	36.7	157	123	32.4	117	93.6	22.8	148
100% RDF +(+ZnSFeB) + GM+VC+RS	77.3	21.3	41.1	91.7	36.9	176	120	28.9	111	79.17	21.8	159
Org. manuring~RDF	80.5	17.4	40.5	68.4	28.7	128	83	20.9	81	60.26	19.0	115
Expt. Mean	**75.9**	**19.9**	**44.7**	**-**	**-**	**-**	**108.7**	**27.56**	**104**	**76.5**	**21.3**	**139**
CD (0.05)	**NS**	**NS**	**NS**	**-**	**-**	**-**	**9.3**	**2.04**	**8.54**	**7.19**	**1.32**	**12.26**
M in S	**NS**	**NS**	**NS**	**-**	**-**	**-**	**NS**	**NS**	**NS**	**12.5**	**2.28**	**21.24**
S in M	**NS**	**NS**	**NS**	**-**	**-**	**-**	**NS**	**NS**	**NS**	**11.5**	**2.28**	**20.75**
CV (%)	**14.31**	**25.17**	**32.46**	**-**	**-**	**-**	**8.8**	**7.62**	**8.43**	**9.66**	**7.19**	**9.02**

Table 5.6.7 Nutrient use efficiency and soil productivity in early and late sown rice
Nutrient use efficiency (kg grain/kg uptake), *kharif* -2013

Treatments	DRR			GHT			KHU			MTU		
	NUE	PUE	KUE	NUE	PUE	KUE	NUE	PUE	KUE	NUE	PUE	KUE
Time of crop establishment												
Early sown / planting	61.7	207	110	54.3	134	28.8	55.2	214	56.5	70.7	248	40.7
Optimum sown / planting	63.3	220	105	48.7	118	24.4	55.1	224	59.0	70.8	268	37.7
Late sown / planting	50.2	251	82.2	55.7	144	15.4	58.8	229	60.4	66.8	306	31.5
Nutrient management												
100% RDF (+ZnS)	62.2	220	101	52.5	122	25.8	61.9	245	63.8	65.6	235	35.8
100% RDF (+ZnSFeB)	55.1	195	76.4	31.9	141	16.7	57.6	219	59.7	69.4	233	37.8
150% RDF+(+ZnSFeB)	61.9	237	107	47.6	113	26.4	49.8	189	52.4	53.3	228	33.7
100% RDF +(+ZnSFeB) + GM+VC+RS	59.6	216	112	53.2	132	27.7	53.0	195	57.1	66.8	302	33.2
Org. manuring~RDF	54.2	250	107	90.6	130	29.2	63.1	250	63.1	83.0	434	43.5
Expt. Mean	**58.5**	**225**	**100**	**54.3**	**129**	**24.3**	**56.7**	**220**	**59.2**	**68.3**	**282**	**37.0**

Table 5.6.8 Nutrient use efficiency and soil productivity in early and late sown rice
Soil nutrient status after harvest, *Kharif* - 2013

	KHU					MTU	
Treatments	**pH**	**0C (%)**	**Avail N (kg/ha)**	**Avail P (kg/ha)**	**Avail K (kg/ha)**	**pH**	**OC (%)**
Time of crop establishment							
Early sown / planting	6.87	1.19	228	13.6	246	5.47	0.89
Optimum sown / planting	6.97	1.21	228	13.4	243	5.22	1.03
Late sown / planting	6.95	1.22	229	14.0	245	5.23	1.03
CD(0.05)	NS	0.01	NS	0.08	NS	NS	NS
CV (%)	4.0	1.41	6.05	0.85	1.2	7.6	21.0
Nutrient management							
100% RDF (+ZnS)	7.04	1.15	220	13.2	236	5.33	1.02
100% RDF (+ZnSFeB)	7.04	1.19	223	13.2	241	5.37	1.04
150%RDF+(+ZnSFeB)	6.91	1.22	232	13.8	249	5.34	0.88
100%RDF +(+ZnSFeB) + GM+VC+RS	6.93	1.17	233	14.3	246	5.31	0.98
Org. manuring~RDF	6.73	1.30	234	14.1	251	5.33	0.99
Expt. Mean	**6.93**	**1.21**	**228**	**13.7**	**245**	**5.34**	**0.98**
CD (0.05) Nutrients	**NS**	**0.03**	**9.72**	**0.54**	**NS**	**NS**	**NS**
-M in S	**NS**	**NS**	**NS**	**0.93**	**NS**	**NS**	**NS**
-S in M	**NS**	**NS**	**NS**	**0.83**	**NS**	**NS**	**NS**
CV (%)	**6.0**	**2.34**	**4.37**	**4.03**	**5.38**	**4.4**	**25.9**

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

Acid soils cover about 15 million ha of rice area widely spread in Eastern, North Eastern and coastal regions of the Peninsula and are highly leached, poor in soil fertility and water-holding capacity. These soils are associated with toxicity of iron in rice lowlands, aluminum in the uplands, with depletion of Ca, Mg and K, deficiency of B, Mo, Si and fix large quantities of soluble P which lead to sub optimal productivity of crops. Management options include liming to correct soil acidity, balanced application of P, K, and silicates and organic manuring besides growing tolerant cultures. Identification of suitable genotypes for such situation with high yield potential helps stabilize rice productivity. The trial was, therefore, conducted at 3 centres *viz.*, Moncompu (Kuttanad, Kerala, soil pH 4.98), Ranchi (Dhumka, Jharkhand, soil pH 5.2) and Titabar (Assam, soil pH 5.2) under low land conditions during *kharif* 2013 screening about 10 – 23 genotypes. The results are presented in Tables 5.7.1 – 5.7.7 and briefly discussed. The cultures were evaluated at 2 or 3 set of nutrient management treatments viz., NPK (RD) and NPK (RD) + Lime at Ranchi; and NPK (RD), NPK (RD) + Lime and N (RD) + double PK / N (RD) + double PK + Lime at other locations (Moncompu and Titabar). Lime was applied @ 5.9, 4.0 and 10 q/ha at Moncompu, Ranchi and Titabar, respectively, as per the location specific estimates of lime requirement. The NPK doses applied were: 90-45-15 at Moncompu, 100-50-25 at Ranchi and 60-20-40 at Titabar.

Grain and straw yields

Significant interaction effects of genotype and liming were observed for grain and straw yields at Moncompu (Table 5.7.2). The genotype IET 22218 recorded the maximum yield at all nutrient management practices (5.03 t/ha, 4.92 t/ha and 3.39 t/ha) indicating its ability to produce high yields under acidic as well as ameliorated conditions while Varadhan and 27P-63 were found to respond to liming with 33.5% and 26.9% increase in yield respectively, in the treatment receiving lime compared to unlimed control. Application of N (RD) + double PK increased yields of Sampada, 27P-31 and 27P-63 by 1.7%, 25% and 2.7% respectively, compared to the treatment that received only NPK as fertilizer. A 1.9% increase in yield of 27P-63 over NPK (RD + Lime) treatment was observed in N (RD) + double PK treatment and no other varieties were observed to respond to application of double dose of PK. Recommended NPK application alone or in combination with lime recorded comparable yields (3.24 and 3.20 t/h respectively) while N (RD) + double PK was found to significantly reduce grain yields (2.49 t/ha). The culture IET 22218 (NP 218) recorded the highest grain yield (4.44 t/ha) while the lowest yielding genotype was Aghonibora (2.00 t/ha). Straw yields did not follow the pattern of grain yields with the highest straw yield being recorded in Sampada (12.29 t/ha) with the application of (NPK (RD) + Lime. Generally straw yields were not influenced by nutrient management, while among the varieties, the highest straw yield (8.89 t/ha) was observed for the culture IET 22218.

Application of lime significantly improved grain and straw yields (9.5% and 14.5% respectively) at Ranchi (Table 5.7.3). Significant variation within genotypes was observed for grain and straw yields with Jarava recording highest grain (7.51 t/ha) and straw yields (10.81 t/ha). Birsamati (3.62 t/ha) and Rajshree (6.27 t/ha) recorded lowest grain and straw yields respectively. No interaction effect between nutrient management and varieties was observed at Ranchi.

Nutrient management and varieties interacted significantly at Titabar (Table 5.7.4) with Prafulla (5.2 t/ha) recording the highest grain yield with N (RD) + double PK + lime application. Comparable higher yields (4.8 t/ha grain) were also observed in IET -21344 under the same nutrient management practice. The lowest grain yield of 0.63 t/ha was recorded for TKM-9 receiving only NPK (recommended) fertilizer. In general, application of N (RD) + double PK + Lime was found to support higher grain yields (3.15 t/ha) compared to NPK (1.89 t/ha) and NPK (RD) + Lime (2.38 t/ha). Among varieties, Prafulla (5.2 t/ha) and IET -21344 (4.8 t/ha) recorded comparably higher grain yields, while the lowest yields were observed in TKM-9 (1.01 t/ha). Straw yields followed almost similar trends as that of grain yields at Titabar. Recommended N + double PK + lime was observed to significantly reduce the grain sterility (8%) compared to recommended NPK (17%) and recommended NPK + lime (13%) treatments.

Nutrients uptake

Nitrogen, phosphorus, potassium and iron accumulation, use efficiency and requirements were not influenced by fertilizer management and liming at Moncompu (Table 5.7.5). Significant varietal differences for accumulation of nutrients were observed at Moncompu. For nitrogen, IET-22218 recorded the highest uptake and use efficiency (142.9 kg/ha and 32.4 kg grain/ kg uptake respectively) and consequently with lower N requirement (32.2 kg /t grain). The highest potassium accumulation was observed in VNR-203 (110.0 kg/ha) and IET-22218 (100.5 kg/ha) and Varadhan exhibited the highest use efficiency (89.1

kg grain/kg uptake) and lowest requirement for the production of a ton of grain (14.2 kg). IET-22218 also recorded the highest iron accumulation of 887.5 g/ha. No significant interaction effects were observed between fertilizer management, liming and varieties for nutritional parameters at Moncompu.

At Ranchi (Table 5.7.6), liming was found to significantly improve accumulation of grain phosphorus (increase of 17.9%) and potassium (increase of 12.1%). Jarava was found to be superior to all varieties in accumulating of phosphorus (22.5 kg/ha) and potassium (26.2 kg/ha) in grain.

Nitrogen, phosphorus, potassium and iron accumulation in grain displayed similar trends as that of grain yields at Titabar (Table 5.7.7). Prafulla receiving recommended N + double PK + lime accumulated significantly higher N (49.48 kg/ha), P (9.68 kg/ha), K (27.8 kg/ha) in grain compared to other treatments. As with grain yields, application of N (RD) + double PK + Lime was found to support higher nutrient accumulation compared to NPK and NPK (RD) + Lime. Among the varieties, Prafulla recorded maximum NPK uptake in grain, while the lowest accumulation was observed in TKM-9.

Summary

Based on the results from 3 centres, genotypes responded differentially to lime application at different locations. At Moncompu, lime application did not influence grain yields while at Ranchi and Titabar, genotypes responded significantly to lime applications. The genotypes IET 22218 at Moncompu, Jarava at Ranchi and Prafulla at Titabar were found promising under acid soil conditions.

Table 5.7.1 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2013)
Soil and Crop data

Parameters	Moncompu	Ranchi (Dhumka)	Titabar
Varieties evaluated	12	10	23
Crop growth	-	-	-
Treatments	• NPK (RD) • NPK (RD) + LIME@ 590 kg/ha • N (RD) + double PK	• NPK (RD) • NPK (RD) + LIME @ 4 Q/ha	• NPK (RD) • NPK (RD) + LIME @ 1t/ha • N (RD) + double PK + lime
Rec. fert. Dose (kg N,P_2O_5 and K_2O/ha)	90-45-15	100-50-25	60-20-40
Soil	-	-	-
% Clay	-	23	-
% Silt	-	34	-
% Sand	-	43	-
Soil texture	Clay	Sandy clay loam	Clay loam
pH(1:2)	4.5	5.18	5.2
Org.carbon (%)	2.39	0.65	1.4
CEC (me/100g)	-	16	10.2
Avail.N (kg/ha)	284	320	435
Avail. P_2O_5 (kg/ha)	3.47	28.4	14.5
Avail. K_2O (kg/ha)	238	185	110
DTPA Fe (ppm)	-	-	-
DTPA Zn(ppm)	-	0.61	0.85

Table 5.7.2 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2013)
Grain and straw yields

Variety	Location - Moncompu							
	Grain yield (t/ha)				Straw yield (t/ha)			
	T1*	T2	T3	Mean	T1*	T2	T3	Mean
Vardhan	2.30	3.07	1.88	2.42	3.75	5.37	2.92	4.01
Akshayadhan	3.20	2.91	2.49	2.87	11.00	6.64	5.03	7.56
Sampada	3.02	3.39	3.07	3.16	12.29	6.15	5.69	8.04
IET-22110	3.39	2.65	2.06	2.70	7.07	3.72	6.09	5.63
IET-22218	5.03	4.92	3.39	4.44	8.80	9.11	8.75	8.89
Aghonibora	2.41	2.01	1.59	2.00	7.86	6.46	7.61	7.31
VNR-203	3.68	2.89	2.05	2.87	11.56	9.08	5.73	8.79
27P-31	3.15	3.17	3.23	3.18	10.62	7.71	7.28	8.54
27P-63	2.94	3.73	3.02	3.23	11.61	6.22	7.42	8.42
RP Bio-226	3.28	3.25	2.12	2.88	8.80	7.58	6.22	7.53
Mean	**3.24**	**3.20**	**2.49**	**2.97**	**9.34**	**6.80**	**6.27**	**7.47**
CD (0.05) Main	**0.19**				**4.47**			
Sub	**0.32**				**2.27**			
Main x Sub	**0.56**				**3.94**			
CV% Main	**8.81**				**83.61**			
Sub	**11.53**				**32.24**			

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

The varieties Jarava and Dhanarasi was not harvested due to late maturity

Table 5.7.3 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2013)

Grain and straw yields

Variety	Location - Ranchi					
	Grain yield (t/ha)			Straw yield (t/ha)		
	T1*	T2	Mean	T1*	T2	Mean
Rajshree	4.11	4.68	4.40	5.75	6.78	6.27
MTU7029	4.41	5.04	4.73	5.64	7.01	6.33
Birsamati	3.38	3.86	3.62	7.11	8.46	7.79
Akshayadhan	4.49	5.37	4.93	6.38	7.78	7.08
Dhanrasi	5.78	6.64	6.21	8.37	11.08	9.73
DRR Dhan 39	5.36	6.21	5.79	7.39	9.07	8.23
Varadhan	5.39	5.39	5.39	7.71	7.97	7.84
RP-Bio-226	6.40	6.46	6.43	9.02	9.24	9.13
Jarava	7.27	7.74	7.51	10.32	11.30	10.81
Sampada	5.86	6.09	5.98	8.70	8.84	8.77
Mean	**5.25**	**5.75**	**5.50**	**7.64**	**8.75**	**8.20**
CD (0.05) Main	**0.33**			**0.54**		
Sub	**0.96**			**1.42**		
Main x Sub	**NS**			**NS**		
CV% Main	**5.36**			**5.93**		
Sub	**9.01**			**8.92**		

**T1=Recommended NPK, T2= Recommended NPK + Lime*

Table 5.7.4 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2013)

Grain and straw yields (Titabar)

	Grain yield (t/ha)				Straw yield (t/ha)				Sterility%			
	T1*	T2	T3	Mean	T1*	T2	T3	Mean	T1*	T2	T3	Mean
TKM-9	0.63	0.90	1.5	1.01	1.68	2.57	3.9	2.72	20	18	15	18
Jaya	0.82	1.53	3.8	2.05	2.17	3.40	5.2	3.59	18	16	10	15
Prafulla	2.60	3.67	5.2	3.82	4.33	5.55	6.7	5.53	16	12	8	12
AP- red-2	1.80	3.77	3.6	3.06	3.93	5.63	5.2	4.92	18	11	6	12
27P-63	1.63	2.00	2.3	1.98	3.91	4.30	3.8	4.00	14	14	7	12
SS-13	1.60	2.03	2.4	2.01	3.38	3.90	4.0	3.76	18	15	6	13
SS-11	1.60	1.93	2.2	1.91	2.92	3.87	3.8	3.53	19	15	8	14
Aghoni bora	3.33	3.70	4.3	3.78	5.85	5.43	5.8	5.69	16	12	6	11
VNR-203	2.50	3.53	4.0	3.34	4.60	5.47	5.6	5.22	17	11	6	11
TTB-404	2.03	2.43	2.8	2.42	3.88	4.50	4.5	4.29	15	12	9	12
IET-22218	1.73	2.03	2.4	2.05	3.18	4.00	4.1	3.76	20	14	10	15
Sampada	1.68	2.13	2.6	2.14	3.07	3.93	4.2	3.73	19	14	10	14
Jarava	1.60	1.93	2.5	2.01	2.95	3.73	4.1	3.59	16	13	10	13
27P-31	1.93	2.23	2.8	2.32	3.53	4.20	4.6	4.11	17	14	9	13
SS-10	2.13	2.27	2.8	2.40	3.91	4.32	4.5	4.24	16	12	8	12
IET-21344	1.87	2.17	4.8	2.95	3.44	4.07	6.3	4.60	17	13	6	12
SS-3	2.97	3.67	4.1	3.58	5.93	5.20	5.7	5.61	14	11	6	10
SS-1	1.77	2.03	2.7	2.17	3.65	3.92	4.3	3.96	15	15	10	13
K-12 AXP	1.90	2.17	3.0	2.36	3.80	4.10	4.7	4.20	15	14	9	13
IET-21844	1.77	2.03	2.8	2.20	3.74	3.90	4.5	4.05	16	12	9	12
IET-22110	0.77	1.20	3.1	1.69	3.10	3.10	5.0	3.73	19	14	8	14
Ranjit	2.37	2.83	3.4	2.87	4.03	4.70	5.4	4.71	17	12	6	12
SS-17	2.33	2.60	3.4	2.78	4.13	4.65	5.8	4.86	14	10	7	10
Mean	**1.89**	**2.38**	**3.15**	**2.47**	**3.70**	**4.28**	**4.86**	**4.28**	**17**	**13**	**8**	**13**
CD (0.05) Main	**0.17**				**0.16**							
Sub	**0.46**				**0.57**							
Main x Sub	**0.91**				**1.12**							
CV% Main	**11.34**				**5.77**							
Sub	**10.97**				**7.76**							

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

Table 5.7.5 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2013)

Nutrient uptake, use efficiency and requirement of rice (Moncompu)

Treatment	Nutrient uptake				Nutrient use efficiency				Nutrient requirement			
	N	P	K	Fe	N	P	K	Fe	N	P	K	Fe
	(kg/ha)			g/ha	(kg grain/kg uptake)			kg /g	(kg uptake/t grain)			(g /t)
Nutrient management												
NPK (RD)	151.03	12.2	116.0	639.6	23.2	297.1	36.4	10.5	47.5	3.8	36.8	198.1
NPK (RD) + Lime@ 590 kg/ha	107.95	7.4	49.6	544.1	31.7	454.0	75.1	11.0	33.9	2.4	16.4	170.1
N (RD) + double PK	103.31	6.2	53.7	346.3	25.2	414.0	53.6	20.3	43.7	2.6	23.1	143.5
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**45.2**	**52.8**	**133.8**	**119.0**	**26.1**	**37.6**	**72.1**	**81.3**	**35.9**	**39.3**	**138.8**	**112.1**
Varieties												
Varadhan	78.5	5.8	34.8	327.1	31.7	428.5	89.1	13.0	31.6	2.4	14.2	130.3
Akshayadhan	106.8	9.2	61.9	467.2	27.2	374.2	61.7	12.5	37.7	3.2	21.8	165.1
Sampada	137.7	9.6	89.6	400.5	26.9	391.0	44.5	14.9	41.5	2.9	29.0	118.6
IET-22110	96.2	6.9	65.2	346.0	29.3	402.9	62.8	26.5	36.5	2.6	23.5	128.9
IET-22218	142.9	9.6	100.5	887.5	32.4	503.0	46.3	10.3	32.2	2.1	22.7	189.8
Aghonibora	117.7	7.7	84.6	510.7	18.5	294.3	26.2	9.6	61.0	3.8	45.6	262.5
VNR-203	139.0	9.3	110.0	536.0	21.9	350.9	34.0	13.0	47.2	3.0	36.8	178.4
27P-31	135.4	9.7	61.6	594.4	24.0	344.7	60.1	9.8	43.5	3.1	19.2	191.6
27P-63	134.0	10.0	67.3	568.3	28.6	372.4	69.4	10.7	45.5	3.4	21.7	190.7
RP Bio-226	119.4	8.1	55.3	462.2	26.4	421.9	56.1	19.0	40.2	2.7	20.0	149.7
Expt. Mean	**120.8**	**8.6**	**73.1**	**510.0**	**26.7**	**388.4**	**55.0**	**13.9**	**41.7**	**2.9**	**25.4**	**170.6**
CD (0.05)	**37.9**	**NS**	**45.3**	**241.4**	**7.6**	**NS**	**33.8**	**9.5**	**13.1**	**NS**	**18.1**	**78.8**
Main x Sub	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**26.5**	**34.6**	**31.2**	**39.9**	**24.1**	**25.7**	**30.9**	**57.8**	**26.5**	**35.4**	**35.9**	**39.0**

Table 5.7.6 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2013)

Nutrient uptake of rice (Ranchi)

Treatment	Nutrient uptake in grain (kg/ha)	
Nutrient management	**P**	**K**
NPK (RD)	15.6	19.0
NPK (RD) + Lime@ 590 kg/ha	18.4	21.3
CD (0.05)	**1.2**	**1.3**
CV (%)	**6.1**	**5.8**
Varieties		
Rajshree	13.7	16.1
MTU7029	14.6	16.9
Birsamati	11.7	14.9
Akshayadhan	14.6	16.4
Dhanrasi	19.2	24.3
DRR Dhan39	19.3	22.2
Varadhan	17.1	19.3
RP-Bio-226	19.8	23.7
Jarava	22.5	26.2
Sampada	17.7	21.5
Expt. Mean	**17.0**	**20.1**
CD (0.05)	**1.9**	**2.3**
Main x Sub	**NS**	**NS**
CV (%)	**9.7**	**9.6**

Table 5.7.7 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2013)
Nutrient uptake of rice grain (Titabar)

Variety	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)				Fe uptake (g/ha)			
	T1*	T2	T3	Mean	T1*	T2	T3	Mean	T1*	T2	T3	Mean	T1*	T2	T3	Mean
TKM-9	5.9	6.9	12.6	8.5	1.0	1.3	2.5	1.6	2.6	3.5	7.8	4.6	148.8	192.0	306.0	215.6
Jaya	6.7	11.7	33.7	17.4	1.5	2.5	6.2	3.4	3.8	6.5	20.2	10.1	196.0	441.0	975.0	537.3
Prafulla	21.3	31.4	49.4	34.0	4.2	6.2	9.6	6.7	11.4	16.9	27.8	18.7	650.0	1045.5	1352.0	1015.8
AP- red-2	14.7	28.7	29.0	24.1	2.5	4.8	5.3	4.2	9.0	17.4	16.8	14.4	450.0	950.0	765.0	721.7
27P-63	14.8	12.5	19.1	15.5	2.6	2.9	3.2	2.9	8.2	9.1	10.7	9.4	490.0	539.0	600.0	543.0
SS-13	10.3	13.9	19.2	14.4	1.9	2.5	3.5	2.6	6.5	8.4	11.1	8.7	276.0	435.6	504.0	405.2
SS-11	12.1	16.0	22.5	16.8	2.6	3.2	3.4	3.1	8.0	10.0	12.9	10.3	352.5	446.5	539.0	446.0
Aghoni bora	23.2	29.8	35.9	29.6	4.8	5.4	8.8	6.3	13.1	14.8	23.5	17.1	759.5	906.5	1150.0	938.7
VNR-203	20.5	31.4	36.5	29.5	3.4	4.8	6.7	5.0	10.6	15.0	19.4	15.0	681.5	728.5	960.0	790.0
TTB-404	16.8	20.6	26.9	21.4	3.0	3.6	5.0	3.9	8.5	10.2	13.4	10.7	460.0	552.0	686.0	566.0
IET-22218	14.3	16.4	24.0	18.2	2.6	3.0	4.1	3.2	8.1	9.2	12.5	9.9	428.4	470.0	576.0	491.5
Sampada	12.7	17.0	21.3	17.0	2.3	2.9	3.9	3.0	7.6	9.5	12.1	9.7	503.5	609.5	702.0	605.0
Jarava	14.0	17.2	25.0	18.7	2.3	2.6	4.4	3.1	8.3	9.8	13.5	10.6	468.0	546.0	742.0	585.3
27P-31	14.5	17.9	24.9	19.1	2.8	3.1	4.5	3.5	9.2	10.5	14.8	11.5	475.0	550.0	663.0	562.7
SS-10	15.3	17.3	26.6	19.7	2.7	2.9	4.6	3.4	8.4	9.2	15.5	11.1	594.0	636.0	756.0	662.0
IET-21344	12.4	15.3	42.6	23.4	2.6	2.4	7.1	4.1	8.4	8.4	23.3	13.4	424.0	450.0	1248.0	707.3
SS-3	17.4	26.5	38.7	27.5	3.3	5.5	7.2	5.3	12.6	16.6	21.0	16.7	588.0	969.0	1020.0	859.0
SS-1	9.1	14.8	20.6	14.8	2.0	2.6	3.5	2.7	7.1	8.7	11.6	9.1	345.0	477.0	583.0	468.3
K-12 AXP	11.6	16.7	24.5	17.6	1.9	2.5	3.6	2.6	8.6	11.1	13.1	10.9	414.0	546.0	650.0	536.7
IET-21844	9.5	13.2	23.5	15.4	2.1	2.3	4.0	2.8	7.3	9.9	15.4	10.9	352.0	459.0	681.2	497.4
IET-22110	4.0	7.2	28.1	13.1	0.8	1.1	3.8	1.9	2.6	5.1	17.4	8.4	192.0	252.0	714.0	386.0
Ranjit	12.5	18.9	29.1	20.2	2.7	3.7	5.8	4.0	8.2	14.0	17.8	13.3	598.0	637.0	780.0	671.7
SS-17	14.1	20.5	27.2	20.6	2.8	3.3	9.1	5.1	11.3	12.1	17.0	13.4	588.0	765.0	850.0	734.3
Mean	**13.4**	**18.3**	**27.8**	**19.8**	**2.5**	**3.3**	**5.2**	**3.7**	**8.2**	**10.7**	**16.0**	**11.6**	**453.7**	**591.4**	**774.0**	**606.4**
CD (0.05) Main	**0.7**				**0.8**				**0.6**							
Sub	**3.8**				**0.9**				**1.6**							
Main x Sub	**6.5**				**1.5**				**2.8**							
CV% Main	**3.7**				**23.3**				**5.7**							
Sub	**16.5**				**21.2**				**12.2**							

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

5.8 Nutrient requirements of recently released rice varieties and hybrids

Large variation is observed in nutrient absorption and utilization among genotypes and crops. Balanced nutrient application is must to meet the growth requirements of a genotype for realizing the yield potential of several contemporary genotypes. Release of varieties and hybrids of high yield potential with varied yield expression under different rice growing environments warrants precise assessment of nutrient requirements of such varieties for arriving at the fertilizer prescriptions to ensure harvestable yield potential on sustainable basis besides optimizing input use. The trial was, therefore, conducted at five locations (DRR, Karaikal, Faizabad, Maruteru and Chinsurah) in *kharif* 2013 to assess the requirements of all major nutrients (NPK) of recently released varieties and hybrids of mid early to mid duration group grown under different environments. The varietal responses to a combination of nutrient levels (6) (0, 60,120 and 180 kg N, 0 and 60 kg P_2O_5, and 0 and 100 kg K_2O/ha) and a set of combination of nutrient levels as 0-60-100, 120-0-100,120-60-0, 60-60-100,120-60-100, 180-60-100 kg N, kg P_2O_5, and kg K_2O/ha) and nutrient accumulation in the dry matter under standard cultural practices were recorded. The genotypes selected for the study were 3 hybrids *viz.*, VNR 203 (IET 21423), 27P31(IET 21832) 27P63 (IET 21832) and one HYV IET 22218 (NP 218) which have been released for their high yield potential and resistance to biotic stresses. Results received from the 5 locations are presented in the Tables 5.8.1 to 5.8.4 and briefly discussed hereunder. Site characteristics presented in the Table 5.8.1 show wide variation in soil texture (sandy loam, silty clay, silty clay loam to clay loam), available nutrient status (N – 188 to 430, P_2O_5 - 24 – 66, and K_2O - 234 - 586 kg/ha) and growing environments (coastal humid to semi arid tropics). The crop growth recorded at each centre was satisfactory to good and all the management practices as per treatments were followed.

Rice productivity

The data on rice grain and straw yields, presented in the Table 5.8.2 indicated differential genotype responses to environments and nutrient application. Average productivity of rice at the test locations ranged from 3.97 – 4.9 t/ha highest being recorded under semi arid irrigated conditions at DRR. However, straw yield was maximum (10.1t/ha) at Faizabad. Interaction effects of genotypes and nutrient application were significant at Chinsurah, Faizabad, Maruteru and Karaikal and were non significant at DRR. Hybrids yielded more than the HYVs by 11 - 34% in all the centres. Very low coefficients of variations were recorded at Faizabad and Karaikal (3.88 to 6.36%). Response to nutrient application was location specific, to an extent reflecting soil and crop growing environment. Mean yields increased significantly up to 180-60-100 kg N, P_2O_5, and K_2O/ha at Chinsurah, up to 120-0-100kg NPK at DRR, up to 180-60-100 kg N, P_2O_5, and K_2O/ha at Faizabad, Karaikal and Maruteru. Among the test cultures VNR 203 (IET 21423): was most productive at Chinsurah, IET 21832 (27P31) at Faizabad, while IET 22218 was promising at Faizabad. The highest yielding nutrient treatment for each genotype and location was selected for working out the nutrient requirements based on the nutrient accumulation. Straw yield trends apparently followed that of grain yield with regard to nutrient application.

Nutrient uptake and recovery efficiency

Nutrient accumulation in the total dry matter at harvest is reported from DRR, Faizabad Maruteru and Chinsurah (Table 5.8.3). Highest mean Nitrogen uptake (165.58) was recorded at DRR. Highest Phosphorus uptake (81.58) was recorded at Faizabad and highest potassium uptake (98.57) was recorded at Maruteru. Interaction effects of genotypes and NPK uptake in both grain and straw were non significant at DRR and significant at Faizabad, Chisurah and Maruteru. Among the test cultures VNR 203 (IET 21423): IET 21832 (27P31), 27P63 (IET 21832) , IET 22218: HYV: all recorded highest N and P uptake at Faizabad, Among the test cultures VNR 203 (IET 21423) and IET 21832 (27P31) recorded highest potassium uptake at Chinsurah, 27P63 (IET 21832) and IET 22218 recoded highest potassium uptake at Maruteru, IET 21542 recorded highest N uptake at DRR. Mean N uptake ranged from 74.9 – 163.58 kg/ha, Mean P uptake ranged from 15.33 -81.58 kg/ha and K uptake ranged from 62.40-98.57 kg/ha. Genotypes differed in their capacity to accumulate nutrients. Uptake of nutrients varied with nutrient application levels and their combinations at all locations, recording increasing accumulation of NPK up to 180 kg/ha at DRR. Based on the nutrient uptake data fertilizer recovery was estimated which ranged from 42- 67.2% for N, 27.6 - 136.2% for P and 61.6 to 73.30% for applied K.

Nutrient requirement

Based on the uptake of nutrients recorded at the highest yields of each variety and location, nutrient requirement (kg nutrient uptake/ton grain) was estimated (Table 5.8.4). The test genotypes accumulated nutrients differentially reflecting broadly the location environment and genotype yield potential. Nutrient requirement in general varied from 12.7 – 34.7kg N, 3.51-17.56 kg P_2O_5 and 11.1 – 28.7 kg K_2O per ton of grain production. Among the test cultures nutrient requirement for hybrids was less compared to HYVs at Maruteru and was more at DRR, Chinsurah and Faizabad.

Summary

In summary, the results indicated differential response of genotypes to nutrient application and test environment with reference to yield and nutrient accumulation. Average productivity of rice at the test locations ranged from 3.97 – 4.9 t/ha highest being recorded under semi arid irrigated conditions at DRR. Hybrids yielded more than the HYVs by 11 - 34% in all the centres. Mean yields increased significantly up to 180-60-100 kg N, P_2O_5, and K_2O/ha at Chinsurah, up to 120-0-100kg NPK at DRR, up to 180-60-100 kg N, P_2O_5, and K_2O/ha at Faizabad, Karaikal and Maruteru. Among the test cultures VNR 203 (IET 21423): was most productive at Chinsurah and Faizabad, IET 21832 (27P31) at Faizabad and DRR . 27P63 (IET 21832):was most productive at Faizabad and Karaikal, while IET 22218 was promising at Faizabad, Maruteru and Karaikal. Mean N uptake ranged from 74.9 – 163.6 kg/ha, Mean P uptake ranged from 15.3 -81.4 kg/ha and K uptake ranged from 62.4-98.6 kg/ha. Based on the nutrient uptake data, fertilizer recovery was estimated which ranged from 42- 67.2% for N, 27.6 -136.2% for P and 61.6 to 73.30% for applied K. Nutrient requirement in general varied from 12.7 – 34.7kg N, 3.51-17.56 kg P_2O_5 and 11.1 – 28.7 kg K_2O per ton of grain production. Among the test cultures nutrient requirement for hybrids was less compared to HYVs at Maruteru, and was more at DRR, Chinsurah and Faizabad

Table 5.8.1 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2013
Soil and crop data

Parameters	Chinsurah (CHN)	DRR	Faizabad (FZD)	Karaikal (KRKL)	Maruteru (MTU)
Variety	As per treatments	As per treatments	As per treatments	As per treatments	As per treatments
Crop growth	Satisfactory	Satisfactory	Good	Satisfactory	Satisfactory
Soil					
% Clay	-	52	23	52.65	38
% Silt	-	22	21	14.75	28
% Sand	-	24	56	28.72	34
Soil texture	Clay loam	Clay	Sandy loam	Silty Clay loam	clay loam
pH(1:2)	7.1	8.1	7.5	7.43	6.60
Org.carbon (%)	0.70	0.72	0.40	0.52	0.54
CEC (me/100g)	-	-	13.02	45.6	48.6
EC (dS/m)	0.27	variable	1.02	0.21	0.95
Avail.N (kg/ha)	430	270	200	210	188
Avail. P_2O_5 (kg/ha)	65	24	24	106	27.8
Avail. K_2O (kg/ha)	262	402	234	586	348

Table 5.8.2 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2013

Grain and straw yield (kg / ha)

Treatment	Grain yield (kg/ha)					Straw yield (kg/ha)				
	Chinsurah	DRR	Faizabad	Karaikal	Maruteru	Chinsurah	DRR	Faizabad	Karaikal	Maruteru
Varieties(hybrids/HYVs)										
IET 21423 (VNR 203)	5170	4713	5018	4139	2874	5852	6982	10127	5602	4950
IET 21832 (27P31)	3337	3738	4913	3681	2996	4285	6982	9876	5148	3756
IET 21832	3720	4223	5227	3750	2949	4952	5000	9067	5819	4751
IET 22218	3661	4010	4451	4278	3851	5426	6326	8638	6829	4897
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**12.53**	**15.76**	**11.92**	**14.59**	**17.37**	**14.60**	**36.67**	**31.88**	**7.17**	**19.02**
Nutrients										
$N_0P_{60}K_{100}$	3594	4113	3241	3076	3290	4500	6438	6799	5188	4394
$N_{120}P_0K_{100}$	3708	4544	4330	3715	3192	5228	8233	10610	5257	4558
$N_{120}P_{60}K_0$	3931	4083	4559	4000	3020	5194	6945	10287	6063	5163
$N_{60}P_{60}K_{100}$	4217	3831	5453	4069	3091	5078	6353	9405	6194	4270
$N_{120}P_{60}K_{100}$	4183	4281	5717	4347	3289	5306	7564	9390	6083	5143
$N_{180}P_{60}K_{100}$	4192	4174	6113	4620	6828	5467	3181	10070	6287	4528
Expt. Mean	**3972**	**4171**	**4901**	**3961**	**3167**	**5128**	**7060**	**9427**	**5849**	**4588**
CD(0.05) Nutrients	**473**	**345**	**155**	**231**	**298**	**462**	**337**	**145**	**286**	**312**
Interaction S in M	**236**	**NS**	**77**	**115**	**1427**	**165**	**NS**	**31**	**192**	**1446**
M in S	**478**	**NS**	**157**	**234**	**563**	**405**	**NS**	**76**	**471**	**713**
CV (%)	**14.60**	**10.15**	**3.88**	**14.59**	**6.30**	**11.20**	**31.20**	**2.39**	**11.40**	**19.02**

Table 5.8.3 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2013

Nutrient uptake (kg/ha)

Treatment	Nitrogen (N)				Phosphorus (P_2O_5)				Potassium (K_2O)			
	DRR	**Faizabad**	**Maruteru**	**Chinsurah**	**DRR**	**Faizabad**	**Maruteru**	**Chinsurah**	**DRR**	**Faizabad**	**Maruteru**	**Chinsurah**
Varieties (hybrids/HYVs)												
IET 21423(VNR 203)	125.1	165.3	79.00	104.9	43.1	83.7	14.84	34.9	83	111.3	107.16	112.4
IET 21832 (27P31)	88.48	161.9	60.23	72.75	32.75	67.5	13.53	26.01	65.63	91.1	80.18	84.94
IET 21832	80.59	160.4	77.50	78.24	30.22	88.0	14.90	29.45	47.97	83.9	103.66	82.56
IET 22218	85.51	167.1	84.42	91.0	28.20	88.1	18.14	29.2	60.87	23.5	104.88	97.5
CD (0.05)	**25.6**	**39.6**	**NS**	**6.9**	**NS**	**NS**	**NS**	**NS**	**5.1**	**6.6**	**12.5**	**8.2**
CV (%)	**25.3**	**15.25**	**20.7**	**22.24**	**31.4**	**26.69**	**18.7**	**24.00**	**31.4**	**20.17**	**26.8**	**24.48**
Nutrients												
$N_0P_{60}K_{100}$	91	113	61	76.4	37	63	14	51	71	27.4	89	81.8
$N_{120}P_0K_{100}$	108	164.9	68	84.5	39	87.5	15	72	102.9	25.9	96	99.0
$N_{120}P_{60}K_0$	96.8	165.5	78	82.8	30.4	89.8	17	67.5	80.6	29.4	110	99.5
$N_{60}P_{60}K_{100}$	87.5	174.7	76	86.4	29.6	83.8	15	58.3	97.1	33.3	94	92.5
$N_{120}P_{60}K_{100}$	96.6	173.7	77	89.3	35.5	75.3	16	72.0	95.5	32.5	104	97.9
$N_{180}P_{60}K_{100}$	89.8	190.4	92.60	101.0	29.8	91.6	16.85	65.5	102.2	31.0	95.28	95.5
Expt. Mean	**91.64**	**163.58**	**74.39**	**84.61**	**32.75**	**81.58**	**15.33**	**29.36**	**62.40**	**88.91**	**98.57**	**92.17**
CD(0.05) Nutrients	**NS**	**3**	**2.1**	**3.8**	**NS**	**2.6**	**3.9**	**1.91**	**NS**	**2.2**	**9.5**	**4.2**
Interaction S in M	**NS**	**4.01**	**1.9**	**NS**	**NS**	**5.3**	**7.9**	**NS**	**NS**	**4.4**	**9.1**	**NS**
M in S	**NS**	**8.03**	**NS**	**NS**	**NS**	**5.7**	**8.9**	**NS**	**NS**	**4.2**	**18.2**	**NS**
CV (%)	**23.6**	**15.39**	**21.5**	**22.0**	**31.3**	**25.60**	**20.0**	**22.85**	**29.6**	**18.51**	**27.9**	**24.11**
Av. NRE (%)	**52.3**	**87.2**	**42.0**	**46.6**	**53.3**	**135.2**	**27.6**	**50.1**	**62.4**	**73.3**	**81.6**	**76.6**

Table 5.8.4 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2013
Nutrient requirement of test varieties (kg/ha)

Location	Variety (hybrids/HYVs)	Maximum yield (kg/ha)	NPK level (kg/ha)	Nutrient uptake (kg/ha)			NR (kg uptake / ton grain)		
				N	P_2O_5	K_2O	N	P_2O_5	K_2O
Faizabad	IET 21423(VNR 203)	6575	$N_{180}P_{60}K_{100}$	188.5	55.61	114.4	28.5	8.42	17.3
	IET 21832 (27P31)	6510	$N_{180}P_{60}K_{100}$	203.9	98.33	105.6	31.3	15.12	16.2
	IET 21832	6475	$N_{180}P_{60}K_{100}$	193.01	120.65	95.25	14.53	18.75	14.8
	IET 22218	5510	$N_{120}P_{60}K_{100}$	179.48	86.01	78.96	32.5	15.6	14.18
	Hybrids	5010	$N_{60}P_{60}K_{100}$	177.79	61.82	115.91	34.78	12.1	22.7
	HYVs	4912	$N_{120}P_{0}K_{100}$	160.85	87.52	84.50	32.6	17.85	17.2
Chinsurah	IET 21423(VNR 203)	6133	$N_{120}P_{0}K_{100}$	121.31	37.31	119.18	19.8	6.1	19.5
	IET 21832 (27P31)	5666	$N_{60}P_{60}K_{100}$	114.29	30.60	108.27	20.35	5.35	19.2
	IET 21832	4666	$N_{0}P_{60}K_{100}$	89.77	35.28	105.05	19.3	7.6	22.82
	IET 22218	4733	$N_{60}P_{60}K_{100}$	111.90	38.54	90.83	23.6	8.0	19.1
	Hybrids	4966	$N_{120}P_{60}K_{100}$	89.15	28.76	77.94	18.1	5.78	15.7
	HYVs	4678	$N_{60}P_{60}K_{100}$	78.85	24.03	70.28	17.14	5.14	15.0
DRR	IET 21423(VNR 203)	6070	$N_{0}P_{60}K_{100}$	147.05	52.81	101.96	24.09	8.52	16.5
	IET 21832 (27P31)	4640	$N_{120}P_{60}K_{0}$	105.76	53.25	81.04	22.8	11.52	17.6
	IET 21832	5050	$N_{120}P_{60}K_{100}$	65.19	46.68	63.53	12.7	9.15	12.4
	IET 22218	4810	$N_{180}P_{60}K_{100}$	82.85	30.24	60.88	17.08	6.25	12.5
	Hybrids	5890	$N_{180}P_{60}K_{100}$	108.98	45.64	65.62	18.4	7.74	11.1
	HYVs	4870	$N_{120}P_{0}K_{100}$	85.84	47.78	51.22	17.62	9.81	10.51
Maruteru	IET 21423(VNR 203)	3352	$N_{180}P_{60}K_{100}$	85.93	20.61	146.49	25.6	5.9	43.5
	IET 21832 (27P31)	3945	$N_{120}P_{60}K_{0}$	69.17	15.38	88.64	17.7	3.9	22.49
	IET 21832	3885	$N_{0}P_{60}K_{100}$	75.06	18.13	124.15	19.3	4.66	31.95
	IET 22218	7100	$N_{60}P_{60}K_{100}$	94.57	25.56	131.18	13.3	3.56	18.46
	Hybrids	3870	$N_{60}P_{60}K_{100}$	71.30	16.58	98.72	18.3	4.2	25.57
	HYVs	4579	$N_{60}P_{60}K_{100}$	94.57	25.56	131.18	20.69	5.59	28.70

5.9 Studies on partitioning of zinc and iron and prospects for enrichment in rice

Variability in nutrient acquisition and its utilization by genotypes for yield expression is well documented which is being exploited to develop of nutrient efficient green varieties as well as utilize in bio-fortification studies in particular that of micronutrients. The latter is being explored as an important option to overcome malnutrition of iron (Fe) and zinc (Zn) through rice development. While identifying through large scale screening and utilizing the genetic variation in rice germplasm is one of the important steps for development of micronutrient dense rice cultures, it is important to evaluate the distribution and partitioning of micronutrients in such identified promising cultures in relation to plant growth and nutrition, and explore the possibility of enriching the grains with micronutrients through management options in different rice growing environments and soil types. Keeping this in view, the trial initiated in *kharif* 2010 was conducted at 4 locations (Kaul, Karaikal, Maruteru and Titabar) of diverse soil and climatic conditions and productivity potentials during *kharif* 2013.

Three rice cultures, *viz*., Aghonibora, one location specific genotype promising for high Zn and Fe content in grains, and a non - promising one were grown with a set of treatments to supply zinc and iron through soil and spray schedules. The treatments included – recommended NPK (T1), NPK + 10 kg Zn/ha + 0.5% Fe spray (T2), NPK + 10 kg Zn/ha + 0.5% Fe spray + organic matter (T3), NPK + 10 kg Zn/ha + 0.5% Fe spray + Cytokinin (8 ppm) spray (T4) and NPK + 10 kg Zn/ha + 0.5% Fe spray + organic matter + Cytokinin (8 ppm) spray (T5). The additional spray of cytokinin @ 8ppm was included as it is known to improve the mobilization of nutrients and photosynthates from source tissues. The partitioning of micronutrients between vegetative and reproductive parts at harvest was studied by analyzing the grain and straw samples for Fe and Zn concentration at DRR and the results are presented in Tables 5.9.1 to 5.9.6.

Grain and Straw yields

Grain yields at Kaul, Karaikal, Maruteru and Titabar ranged from 7.26 – 8.61, 2.32 – 2.88, 3.46 – 4.96, 4.7 – 5.5 t/ha, respectively and straw yields at Kaul, Karaikal and Maruteru from 10.01 – 11.38, 4.07 – 4.45, 4.25 – 7.72 t/ha, respectively. While grain yield differences due to varieties were significant at Kaul, Maruteru and Titabar, the nutrient treatments were significant only at Karaikal and Maruteru. The culture HKR 127 at Kaul and MTU 1075 at Maruteru and Prafulla at Titabar recorded maximum yield. Among the nutrient combinations, use of micronutrients, organic manure and cytokinin spray were significantly superior to control and at par with the other nutrient treatments at Karaikal and Maruteru.

Micronutrients Concentration and Uptake

At all the three locations, Karaikal, Kaul and Maruteru genotypes did not influence concentration and uptake of Zn and Fe both in grain and straw. Nutrient combinations recorded significant differences with the combined use of organics, micronutrients and cytokinin spray giving rise to maximum Zn and Fe concentration and uptake in both grain and straw.

Major portion of the absorbed micronutrients remained in straw at all the centres. At Kaul, out of total uptake of Zn and Fe, maximum amount of 74 & 71 % of Zn and Fe respectively, were retained in straw while 26 and 29% were translocated to grain. At Karaikal, 54 and 68% of Zn and Fe were retained in straw and 46 and 32% translocated to grain. Similarly at Maruteru also, 56 and 74% were retained in straw with 44 and 26% of Zn and Fe being translocated to grain.

Summary

The grain yield differences due to varieties at Kaul, Maruteru and Titabar, and nutrient treatments at Karaikal and Maruteru were significant. The culture HKR 127 at Kaul and MTU 1075 at Maruteru and Prafulla at Titabar recorded maximum yield. Among the nutrient combinations, use of NPK + micronutrients + organic manure and cytokinin spray were significantly superior to control and at par with the other nutrient treatments at Karaikal and Maruteru in grain yield. At Karaikal, Kaul and Maruteru genotypes did not influence concentration and uptake of Zn and Fe both in grain and straw. Nutrient combinations recorded significant differences with the combined use of organics, micronutrients and cytokinin spray giving rise to maximum Zn and Fe concentration and uptake in both grain and straw. With regard to partitioning, major portion of the absorbed micronutrients remained in straw. About 74 and 71% of Zn and Fe at Kaul, 54 and 68% at Karaikal and 56 and 74% at Maruteru were retained in straw while 26 and 29%, 46 and 32% and 44 and 26% translocated to grain, respectively.

Table 5.9.1 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2013
Soil and crop data

Parameters	Kaul	Karaikal	Maruteru	Titabar
Varieties taken	HKR-47, HKR-127	Aghonibora TKM 9, ADT 43	Aghonibora, MTU-1001, MTU-1075	Jaya, Aghonibora Prafulla
Crop growth	-	-	-	-
RFD (KgNPK/ha)	150-60-0	125-50-50	90-60-60	60-20-40
Soil				-
% Clay	-	21.65	38	45
% Silt	-	17.50	28	32
% Sand	-	57.69	34	23
Soil texture	Clay loam	Sandy clay loam	Clay loam	Silty Clay loam
pH(1:2)	7.7	5.74	6.40	5.5
Org. carbon (%)	0.33	0.24	0.65	0.9
CEC (me/100g)	13	20	49	12
EC (dS/m)	0.26	0.183	1.56	0.18
Avail.N (kg/ha)	145	112	226	485
Avail. P_2O_5 (kg/ha)	41	44	20	18
Avail. K_2O (kg/ha)	305	386	358	115
DTPA Zn (ppm)	0.68	-	-	0.88
DTPA Fe (ppm)	8.6	-	-	26.5

Table 5.9.2 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2013
Grain and straw yields, micronutrient concentration and uptake **Location: Kaul**

Treatment	Yield (t/ha)		Nutrient content (ppm)				Nutrient uptake (g/ha)			
	Grain	Straw	Grain		Straw		Grain		Straw	
			Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
Variety										
HKR-47	7.26	10.01	25	79	43	116	184	568	424	1159
HKR-127	8.61	11.38	28	84	67	168	237	716	755	1931
CD (0.05)	0.52	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	4	10	3	18	5	41	8	25	13	53
Nutrient										
T1	7.87	10.75	19	59	36	93	150	472	386	1025
T2	7.70	10.48	23	75	43	104	184	570	479	1120
T3	7.93	10.58	31	78	45	122	205	636	494	1274
T4	7.98	10.73	27	88	51	184	249	706	539	1976
T5	8.18	10.93	33	106	99	208	264	826	1047	2331
Expt. Mean	**7.93**	**10.70**	**27**	**81**	**55**	**142**	**210**	**642**	**589**	**1546**
CD (0.05)	NS	0.37	4.78	22.81	27.32	78.94	52.41	221.00	310.00	1027.00
Interaction: M in S	1.64	NS	7	32	39	112	74	313	438	1452
S in M	1.53	NS	6	35	35	129	70	356	405	1729
CV (%)	112	9	15	23	41	46	20	28	43	54

Table 5.9.3 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2013
Grain and straw yields, micronutrient concentration and uptake
Location: Karaikal

Treatment	Yield (t/ha)		Nutrient content (ppm)				Nutrient uptake (g/ha)			
	Grain	Straw	Grain		Straw		Grain		Straw	
			Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
Variety										
Aghonibora	2.88	4.45	105	53	68	80	319	155	299	360
TKM 9	2.32	4.37	118	48	83	64	268	111	358	280
ADT 43	2.40	4.07	94	56	75	51	228	134	308	208
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	24.58	1.94	50	27	66	78	69	18	67	71
Nutrient										
T1	2.28	4.02	20	32	37	38	45	71	159	150
T2	2.49	4.12	79	42	52	38	187	126	278	156
T3	2.31	4.40	107	52	67	45	307	123	223	195
T4	2.70	4.43	143	59	86	43	401	163	359	191
T5	2.89	4.50	180	78	135	162	420	183	590	720
Expt. Mean	**2.53**	**4.29**	**106**	**53**	**75**	**65**	**272**	**133**	**322**	**283**
CD (0.05)	0.29	0.60	65	30	66	77	175	72	279	302
Interaction: M in S	0.50	NS	112	52	115	133	303	124	483	574
S in M	1.23	NS	136	52	136	147	147	118	571	580
CV (%)	9	11	49	45	70	94	51	43	69	85

Table 5.9.4 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2013
Grain and straw yields, micronutrient concentration and uptake
Location: Maruteru

Treatment	Yield (t/ha)		Nutrient content (ppm)				Nutrient uptake (g/ha)			
	Grain	Straw	Grain		Straw		Grain		Straw	
			Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
Variety										
Aghonibora	3.46	4.25	152	165	94	336	520	576	405	1476
MTU-1001	4.20	7.72	143	218	128	403	599	936	1009	3094
MTU-1075	4.96	5.93	130	157	138	344	633	781	809	2029
CD (0.05)	0.59	0.17	NS	NS	23	NS	74	NS	158	564
CV (%)	14	2.93	22	101	19	32	13	119	21	25
Nutrient										
T1	4.01	5.16	40	64	66	163	172	271	377	1056
T2	4.17	5.85	150	160	128	391	598	694	647	2019
T3	4.31	5.89	169	166	122	387	713	639	745	2210
T4	4.22	6.12	172	231	141	421	701	1020	901	2626
T5	4.32	6.80	175	281	143	447	735	1199	1034	3087
Expt. Mean	**4.21**	**5.96**	**141**	**180**	**120**	**362**	**584**	**765**	**741**	**2200**
CD (0.05)	**0.28**	**0.43**	**30**	**107**	**43**	**104**	**144**	**525**	**285**	**631**
Interaction: M in S	**0.49**	**0.74**	**51**	**186**	**76**	**180**	**249**	**910**	**493**	**1093**
S in M	**0.72**	**0.69**	**55**	**247**	**71**	**197**	**234**	**1217**	**467**	**1121**
CV (%)	**7**	**7**	**22**	**61**	**37**	**30**	**25**	**71**	**39**	**29**

Table 5.9.5 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2013
Grain yield, micronutrient concentration and uptake
Location: Titabar

Treatment	Grain Yield (t/ha)	Grain content (ppm)*		Grain uptake (g/ha)*	
		Zn	Fe	Zn	Fe
Variety					
Jaya	4.7	12	139	55	653
Aghonibora	5.4	32	249	172	1355
Prafulla	5.5	28	245	157	1349
CD (0.05)	0.33	-	-	-	-
CV (%)	6.27	-	-	-	-
Nutrient					
T1	5.0	20	197	100	998
T2	5.1	23	207	125	1120
T3	5.3	28	222	151	1209
T4	5.3	26	217	140	1169
T5	5.3	23	213	123	1097
CD (0.05)	0.18	-	-	-	-
Interaction: M in S	0.31	-	-	-	-
S in M	0.43	-	-	-	-
CV (%)	3.54	-	-	-	-
Expt. Mean	**5.2**	**24**	**211**	**128**	**1119**

** Not considered for statistical analysis as the data is not replicated*

Table 5.9.6 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2013
Per cent micronutrient uptake in grain and straw

Centre	Grain		Straw	
	Zn	Fe	Zn	Fe
Kaul	26	29	74	71
Karaikal	46	32	54	68
Maruteru	44	26	56	74

5.10 Sustaining soil and crop productivity under different rice production systems

Depleted soil productivity and reduced ground water level are the main challenges in present day agriculture. Water availability for agriculture and for rice, in particular, will be less in future and hence, we need to explore a new range of water saving technologies for rice production. Same is the case with labour availability also as a result of migration of agricultural labourers to other activities. Some of the newly emerging rice production systems like direct seeded rice and aerobic rice have potential to perform better under such situations. But, these systems often result in lower yields which are attributed to nutritional disorders. Hence, optimum dose and schedule of fertilizer application is necessary to achieve higher yields while sustaining soil health and productivity. Keeping this in view, a medium term study was proposed to assess sustainability of evolving rice production systems like aerobic rice (AR), direct seeded rice (DSR) vis-à-vis conventional transplanted system in terms of productivity of the cropping systems, soil quality and carbon sequestration potential and utilization efficiency of resources and inputs. This trial was initiated at 2 locations (Jagtial and Mandya) during *kharif* 2013 with three main plot treatments and five sub plot treatments. The main plot treatments included 3 methods of cop establishment *viz*., transplanted rice (TPR), direct sown rice under puddled conditions (DSR) and aerobic rice (AR, non-puddle, direct sown) with zero or minimum tillage. The sub plot treatments included five different nutrient combinations with conjunctive use of inorganic and organic sources of nutrients. The results are presented in Tables 5.10.1 to 5.10.5

The results pertaining to grain and straw yields are presented in Table 5.10.2. At Jagtial, TPR recorded significantly higher grain yield over DSR and AR by 68 and 180%, respectively. DSR was superior to AR by 67% and AR recorded the minimum yield (1.88 t/ha). With regard to nutrient sources, STCR based RDF and addition of 25% and 50% organics along with 75 –100% RDF were superior to 100% organics and mixture of organics (@ 2 t/ha) with 20% RDF by about 31 %. At Mandya, TPR and DSR were at par and significantly superior to AR by 25 and 21%, respectively. Here, 100% RDF + 50% organics recorded maximum yield (1.56 t/ha) followed by 100% RDF (1.40 t/ha) and lowest yield (0.93 t/ha) was obtained with mixture of organics plus 20% RDF. Straw yield at Jagtial was maximum with TPR and nutrient combinations with 25 and 50% organics recorded maximum straw yield followed by 100% RDF. At Mandya, straw yield followed similar trend as grain yield and here, the grain and straw yields were very low even in transplanted rice.

Nutrient uptake and use efficiency

As per the table 5.10.3, NPK uptake followed similar trend as grain yield with maximum uptake in TPR which was significantly superior to other two systems both at Jagtial and Mandya. Similarly, nutrient sources also influenced the nutrient uptake recording maximum uptake with 100% RDF+ 50% organics followed by 100% RDF. The nutrient uptake values are very low at Mandya due to very low N content in grain and K content in straw in addition to low grain yields. With regard to nutrient use efficiency (Table 5.10.4), DSR recorded maximum efficiency for N and K at Jagtial and for N at Mandya while it was maximum in case of AR for P at Jagtial and for P and K at Mandya indicating that DSR and AR can use the absorbed nutrients more efficiently. The maximum NPK use efficiency was recorded in case of nutrient enriched organics (Vermi-compost/Poultry manure) with 20 % RDF.

Soil properties after Harvest

The data on soil properties presented in table 5.10.5 indicated that none of the soil properties were influenced by either methods of crop establishment or nutrient sources at Jagtial. Whereas, at Mandya, AR recorded significantly lower O.C (by 7%) and available K (3-10%) but higher P_2O_5 (5-8%) than other two systems. With regard to nutrient sources, 100% organics recorded significantly higher O.C (0.75%) than other treatments and 100% RDF in conjunction with 50% organics recorded significantly higher available N, P_2O_5 and K_2O (387, 36.2 and 270 kg/ha, respectively).

Summary

The first year results of the trial at two centers *viz*; Jagtial and Mandya indicated maximum rice productivity in transplanted rice at Jagtial showing its superiority over direct seeded rice and aerobic rice by 68 and 180%, respectively. Whereas, at Mandya, transplanted and direct seeded rice were at par and superior to aerobic rice by 52 and 21%, respectively. Substitution of 25 % RDF through organics gave similar grain yield as 100 % RDF + Zn + S at Jagtial and at Mandya, reduction of RDF to 20% resulted in drastic reduction of grain yield although 2 t/ha of concentrated organic manure was applied. Though nutrient uptake was comparatively less in direct sown and aerobic rice than transplanted rice, the nutrient use efficiency was better in case of direct sown and aerobic rice. In general, soil available nutrients were higher in the plots that received organic manures.

Table 5.10.1 Sustaining Soil and crop productivity under different rice production systems

Soil, crop and weather data - *Kharif* 2013

Parameter	Jagtial	Mandya
Cropping system	Rice-Pulse	Rice
Variety	JGL-1798	Raksha
RFD (Kg/NPK/ha)	217:312:66.7:20	100:50:50:20
Crop growth	-	Good
Soil data		
% clay	43.62	11.10
% silt	21.50	18.10
% sand	34.80	62.80
Soil Texture	Sandy clay loam	Sandy loam
Bulk density (g/cc)	1.47	-
pH (1:1)	7.71	5.87
Org.carbon (%)	0.45	0.30
EC (dS/m)	0.22	0.28
Avail.N (kg/ha)	125	208
Avail. P_2O_5 (kg/ha)	22.4	19.7
Avail. K_2O (kg/ha)	293	117
Weather		
Max. Temp (oC)	31.12	-
Min. Temp (oC)	21.3	-
Total Rainfall(mm)	1132	-

Table 5.10.2 Sustaining soil and crop productivity under different rice production systems Grain and straw yields – *Kharif* 2013

Treatments	Jagtial		Mandya	
	Grain yield (t/ha)	**Straw yield (t/ha**	**Grain yield (t/ha)**	**Straw yield (t/ha)**
Methods of crop establishment				
Transplanted rice (TPR)	5.27	7.62	1.39	1.87
Direct sown rice under puddled conditions (DSR)	3.14	3.00	1.34	1.83
Aerobic rice (AR, non-puddle, direct sown)	1.88	2.93	1.11	1.58
CD(0.05)	0.45	0.74	0.05	0.11
CV (%)	16.8	21.1	6.0	9.4
Nutrient management				
100% (RDF) -STCR based+Zn+S	3.82	4.85	1.40	1.84
75% RDF+25% through organics (GM, FYM, PM, VC etc)	3.86	5.03	1.24	1.69
100% NPK through organics .	2.85	3.65	1.26	1.78
100% RDF + 50% through organics	3.68	5.24	1.56	2.08
2 t/ha Vermi compost / poultry manure + 20%RDF	2.95	3.82	0.93	1.40
Expt. Mean	**3.43**	**4.51**	**1.28**	**1.76**
CD(0.05)	**0.60**	**0.68**	**0.06**	**0.15**
M in S	**NS**	**1.18**	**0.10**	**NS**
S in M	**NS**	**1.20**	**0.10**	**NS**
CV (%)	**21**	**18**	**4.7**	**8.4**

Table 5.10.3 Sustaining soil and crop productivity under different rice production systems Nutrient uptake (kg/ha) - *kharif* 2013.

Treatments	Jagtial			Mandya		
	N	P	K	N	P	K
Methods of crop establishment						
Transplanted rice (TPR)	112	22.2	164	14.5	9.32	16.3
Direct sown rice under puddled conditions (DSR)	64.7	11.8	72.2	13.0	8.63	13.5
Aerobic rice (AR, non-puddle, direct sown)	53.5	6.73	65.5	10.5	5.84	9.65
CD (0.05)	40.8	4.03	61.3	0.80	0.16	0.81
CV (%)	27.6	15.4	31.7	9.72	3.12	9.56
Nutrient management						
100% (RDF) -STCR based+Zn+S	90.2	15.3	116	14.6	8.92	15.3
75% RDF+25% through organics (GM, FYM, PM, VC etc)	89.2	12.3	105	11.6	8.13	13.2
100% NPK through organics .	59.1	13.4	82.8	12.5	8.06	12.5
100% RDF + 50% through organics	97.8	16.1	121	19.2	10.8	19.0
2 t/ha Vermi compost / poultry manure + 20%RDF	48.5	10.9	77.2	5.70	3.80	5.82
Expt. Mean	**76.96**	**13.6**	**100**	**12.7**	**7.93**	**13.1**
CD (0.05)	**18.9**	**NS**	**16.6**	**1.03**	**0.64**	**1.00**
M in S	**NS**	**NS**	**NS**	**1.78**	**1.1**	**1.73**
S in M	**NS**	**NS**	**NS**	**1.66**	**0.99**	**1.62**
CV (%)	**19.53**	**38.5**	**18.3**	**8.28**	**8.23**	**13.1**

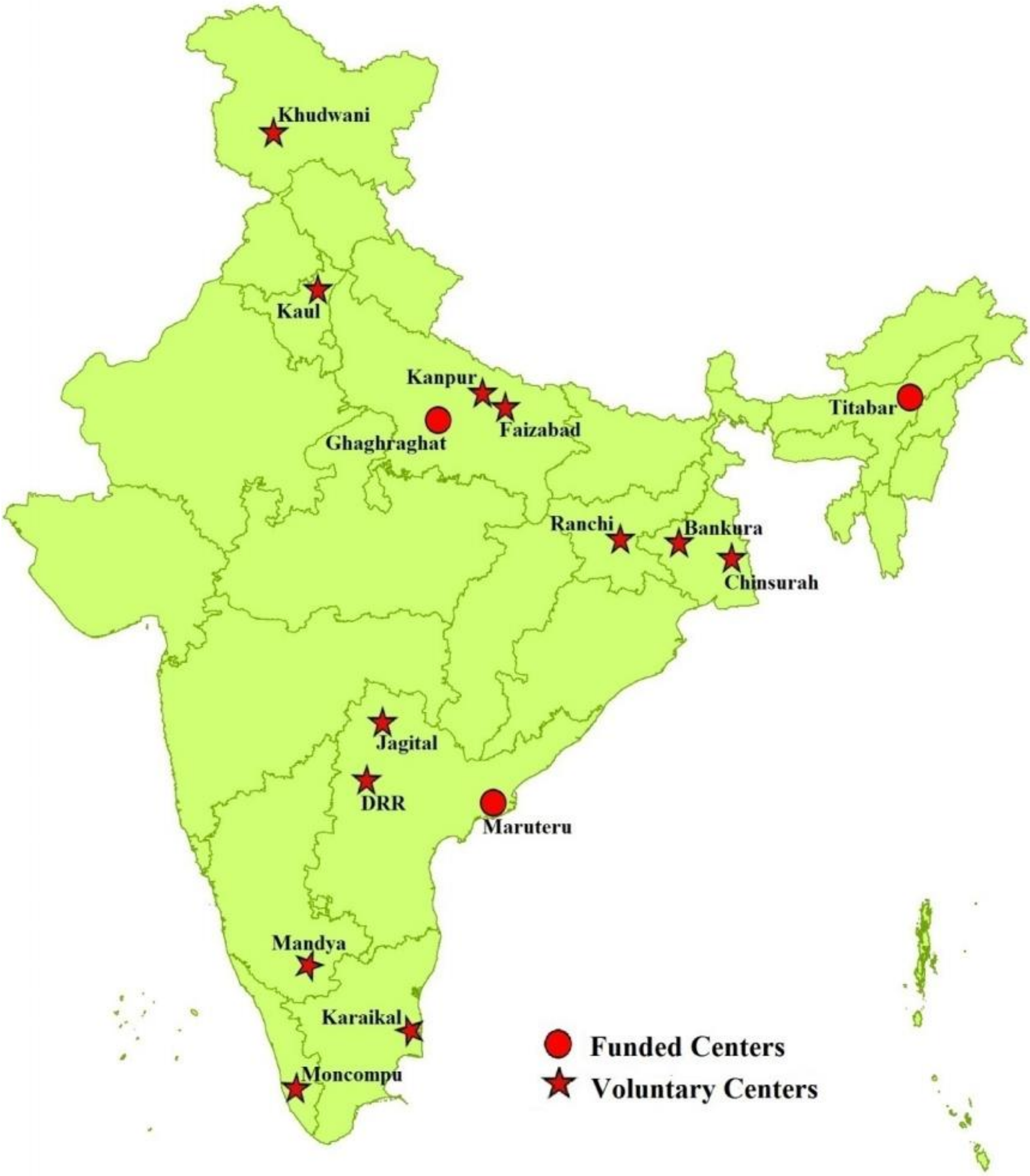
Table 5.10.4 Sustaining soil and crop productivity under different rice production systems Nutrient use efficiency (kg grain/kg nutrient uptake) - *Kharif* 2013

Treatments	Jagtial			Mandya		
	NUE	PUE	KUE	NUE	PUE	KUE
Methods of crop establishment						
Transplanted rice (TPR)	47.0	237	32.1	95.9	149	85.3
Direct sown rice under puddled conditions (DSR)	48.5	266	43.5	155	155	99.3
Aerobic rice (AR, non-puddle, direct sown)	35.1	279	28.7	105	190	115
CD (0.05)	-	-	-	-	-	-
CV (%)	-	-	-	-	-	-
Nutrient management						
100% (RDF) -STCR based+Zn+S	42.4	249	32.9	98.6	161	94.1
75% RDF+25% through organics (GM, FYM, PM, VC etc)	43.3	313	36.8	106	152	93.9
100% NPK through organics .	48.2	212	34.4	100	156	100
100% RDF + 50% through organics	37.6	228	30.4	81	144	82.1
2 t/ha Vermi compost / poultry manure + 20%RDF	60.8	270	38.2	163	245	160
Expt. Mean	**45.4**	**257**	**34.6**	**113**	**169**	**104**

Table 5.10.5 Sustaining soil and crop productivity under different rice production systems
Soil properties at harvest - *kharif* 2013

Treatments	Jagtial					Mandya				
	pH	OC(%)	Avail N (kg/ha)	Avail P_2O_5 (kg/ha)	Avail K_2O (kg/ha)	pH	OC(%)	Avail N (kg/ha)	Avail P_2O_5 (kg/ha)	Avail K_2O (kg/ha)
Methods of crop establishment										
Transplanted rice (TPR)	7.25	0.75	286	35.5	289	6.88	0.61	314	26.9	239
Direct sown rice under puddled conditions (DSR)	7.32	0.78	264	46.3	317	5.86	0.61	312	27.8	222
Aerobic rice (AR, non-puddle, direct sown)	7.25	0.77	241	41.2	312	6.7	0.57	320	29.1	217
CD(0.05)	NS	NS	NS	NS	NS	NS	0.01	2.9	1.05	3.07
CV (%)	3.84	5.88	10.6	41.3	35	14.28	0.24	1.49	5.81	2.09
Nutrient management										
100% (RDF) -STCR based+Zn+S	7.36	0.76	282	36.9	293	6.36	0.38	288	26.9	227
75% RDF+25% through organics (GM, FYM, PM, VC etc)	7.21	0.75	244	44.0	280	5.35	0.58	346	30.5	239
100% NPK through organics .	7.34	0.76	274	43.5	316	6.87	0.75	285	24.6	205
100% RDF + 50% through organics	7.24	0.78	275	39.8	306	6.77	0.60	387	36.2	270
2 t/ha Vermi compost / poultry manure + 20%RDF	7.21	0.78	243	40.5	332	7.06	0.67	270	21.4	188
Expt. Mean	**7.27**	**0.77**	**264**	**41.0**	**306**	**6.48**	**0.60**	**226**	**27.9**	**226**
CD (0.05) Nutrients	**NS**	**NS**	**NS**	**NS**	**NS**	**0.87**	**0.02**	**92**	**0.95**	**2.54**
M in S	**NS**	**NS**	**NS**	**NS**	**NS**	**1.50**	**0.03**	**4.4**	**1.65**	**4.4**
S in M	**NS**	**NS**	**NS**	**NS**	**NS**	**1.39**	**0.03**	**4.38**	**1.61**	**4.38**
CV (%)	**3.0**	**21.1**	**10.4**	**38**	**27**	**13.7**	**3.39**	**1.15**	**3.51**	**1.15**

Map Showing Soil Science AICRIP Funded and Voluntary Centers



Scientists involved in Soil Science Co-ordinated Programme 2013 (Appendix I)

S.No	State	Organization	Location	Name	Designation	Telephone	E-mail
Funded centers							
1	Andhra Pradesh	ANGRAU	Maruteru	Dr. Ch. Srinivas	Sr. Soil Scientist	09440415303	chvasu@yahoo.com
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3	Uttar Pradesh	CSAUAT	Kanpur	Dr. Devendra Singh	Jr. Soil Scientist	09450136063	vkyadu @g mail.com
Voluntary Centers							
1	Chattisgarh	IGAU	Raipur	Dr. Vinay Bachkaiya	Soil Scientist	09406236558	Vinay_igau@redifmail.co.in
2	Jammu &Kashmir	SEKUASTK	Khudwani	Dr. Ashaq Hussain	Soil Scientist	01931 238 246	Ahshah71@gmail.com
3	Karnataka	UAS	Mandya	Dr. S.R.K.Murthy	Associate professor	09632202521	srkmurthy@gmail.com
4	Kerala	KAU	Moncompu	Dr. Navin Leno	Assistant Professor	-	nlenof@gmail.com
5	Pondicherry	PJNCARI	Karaikal	Dr. A. Bhasker	Professor, Soil Science	09443165382	drabasker@yahoo.co.in
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12	Andhra pradesh	ANGRAU	Jagtial	Dr. K. Rajamani	Soil Scientist	09492202914	Kasthuri.agrico114@gmail.com
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3	ICAR	DRR	Rajendranagar	Dr. M.B.B. Prasad Babu	Senior Scientist	09666852265	mbbprasadbabu@gmail.com
4	ICAR	DRR	Rajendranagar	Dr. Brajendra	Senior Scientist	09177210995	braj_2222@rediffmail.com
5	ICAR	DRR	Rajendranagar	Dr. P.C. Latha	Scientist	09866282968	lathapc@gmail.com

List of cooperating centres of Soil Science and allotment of trials- 2013 (Appendix II)

S.No	Locations	Trial 1		Trial 2	Trial 3		Trial 4	Trial 5	Trial 6		Trial 7	Trial 8	Trial 9	Trial 10		ALLOTED	conducted	Cond-ucted (%)	NC
		K	R	K	K	R	K	K	K	R	K	K	K	K	R				
1	DRR	-	-	-	-	-	X	-	X	NC	-	X	NC	-	-	5	3	60	2
2	Kanpur (F)	-	-	NC	X	X	-	X	-	-	-	-	-	NC	NC	6	3	50.0	3
3	Maruteru (F)	X	X	X	-	-	X	-	X	NC	-	X	X	-	-	8	7	87.5	1
4	Titabar (F)	X	X	X	-	-	X	-	-	-	X	-	X	-	-	6	6	100.0	0
5	Bankura (V)	-	-	NC	-	-	X	-	-	-	-	-	-	-	-	2	1	50.0	1
6	Chinsurah (V)	-	-	X	-	-	-	-	-	-	-	X	-	-	-	2	2	100.0	0
7	Faizabad (V)	-	-	-	-	-	X	-	-	-	-	X	-	-	-	2	2	100.0	0
8	Ghagraghat (V)	-	-	NC	-	-	-	-	X	X	-	NC	-	-	-	4	2	50.0	2
9	Karaikal (V)	-	-	X	-	-	X	-	X	X	-	X	X	-	-	6	6	100.0	0
10	Khudwani (V)	-	-	NC	-	-	X	-	X	NC	-	-	NC	-	-	5	2	40.0	3
11	Mandya (V)	X	X	X	-	-	X	X	-	-	-	-	-	X	NC	7	6	85.7	1
12	Moncompu (V)	-	-	NC	-	-	X	-	-	-	X	-	-	-	-	3	2	66.6	1
13	Ranchi (Dhumka) (V)	-	-	NC	X	NC	-	-	-	-	X	-	-	-	-	4	2	50.0	2
14	Raipur (V)	-	-	NC	-	-	NC	-	NC	NC	-	-	-	-	-	4	0	0.0	4
15	Kaul (V)	-	-	NC	-	-	X	-	-	-	-	-	X	-	-	3	2	66.6	1
16	Jagtial (V)	-	-	---	-	-	-	-	-	-	-	--	-	X	NC	2	1	50.0	1
Total allotted		3	3	13	2	2	11	2	6	6	3	6	6	3	3	69	47	68.0	22
X- CONDUCTED		3	3	5	2	1	10	2	5	2	3	5	4	2	0	47			
NC-NOTCONDUCTED		0	0	8	0	1	1	0	1	4	0	1	2	1	3				

K – kharif R- Rabi; X Indented trials X+ Seed material from VR Babu F – Funded center V – Voluntary center

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

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

Trial No.3: Management of micronutrients in rice based cropping systems (Kharif and Rabi) (In collaboration with Agronomists)

Trial No.4: Screening of rice germplasm for Zn and Fe contents (in collaboration with Plant Breeders) – Kharif

Trial No.5: Nutrient and water requirement of Aerobic rice cultivation (Kharif and/or Rabi))

Trial No.6: nutrient use efficiency and soil productivity in early and late sown rice

Trial No.7: Screening of genotypes for acidity and related nutritional constraints (Kharif)

Trial No.8: Nutrient requirement of recently released varieties/hybrids of different duration groups (Kharif)

Trial No. 9: Studies on partitioning of zinc and iron in rice and prospects for their enrichment (Kharif)

Trial No. 10: Sustaining soil and crop productivity under different rice production systems (kharif and rabi)

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