Progress Report of Soil Science Coordinated Programme (*rabi* and *kharif* 2010)

5. SOIL SCIENCE

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5. Soil Science

Summary

The coordinated program in soil science addresses issues related to sustaining productivity of soil and crop systems, site specific nutrient management, efficient use of irrigation water, management of micronutrients in salt affected soils, genotypic variability and enrichment of iron and zinc in rice, and tolerance to soil acidity related problems, management of crop residues, evaluation of nutritional status of rice in farmers' fields and nutrient requirement of recently released varieties and hybrids. A total of 10 trials, proposed during the last group meetings, were conducted during *rabi* and *kharif* 2010 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

The 22^{nd} year of study conducted at 3 locations (Mandya, Maruteru and Titabar) indicated significant improvement in rice productivity with the supplementation of recommended fertilizer dose (100% NPKZnS) with 5 t/ha FYM in rabi and kharif in all the locations and with the substitution of 50% NPK by FYM at Mandya. Corresponding increase in nutrient accumulation in dry matter and improvement in soil nutrient status and organic carbon was also recorded at these locations. Response to P and K was significant and that of Zn and S at Titabar, while 50% reduction in PK or NPK dose from RDF decreased rice yields by 0.8 to 1.2 t/ha. Average accumulation of N, P_2O_5 and K_2O in the dry matter was 42, 21 and 33 kg at Mandya, and 48, 9 and 32 kg at Titabar which amounts to 11.6, 5.8 and 9.2 kg and 11.2, 2.2 and 7.6 kg NPK per ton of grain indicating unusually very low accumulation of N and K at Mandya and of all the nutrients at TTB

Rice productivity growth (linear) improved @ 11 – 251 kg grain /ha/year or was near stable in the Godavari delta system (Maruteru) with most of the treatments except those not supplied with P and K (@ -12 to -20 kg/ha/yr) while in Assam valley (Titabar) and plateau region (Mandya) the productivity declined in most of the treatments @ 2-39 kg/ha/year at Titabar and more intensely at Mandya @ 15 – 107 kg/ha/year. With the application of FYM+RDF and / or with INM treatments (FYM) the growth was positive at all the locations and correspondingly sustained or improved soil fertility. At Mandya, however, mismatch of yield trends with soil fertility changes suggests for analysis of other soil parameters and a relook into current fertilizer recommendations.

5.2. Rice productivity in relation to internal supply capacity of nutrients in farmers' fields

This trial was conducted in farmers' fields around few selected centres at Mandya, Mauteru and Titabar, to assess variability in soil nutrient supply, its relationship with rice yields at current fertilizer practices, and to fine-tune the fertilizer nutrient requirement for specific target yields in a given environment. Nutrient uptake requirement / t of grain ranged from 13.6-16.9, 2.7-4.4 and 9.2-14.4 kg N, P_2O_5 and K_2O at Titabar and 10.5 - 15.5 kg N, 4.5-8.5 kg P_2O_5 and 17.7- 26.3 kg K_2O at Mandya with RDF showing considerable variation among the farm sites. The yields were less by 22-85% and up to 32% with farmers' fertilizer practices, respectively at these locations compared to RDF with corresponding variations in nutrient uptake, nutrient utilization and recovery efficiencies. Fertilizer recommendations for target yield of 6.5 t/ha at Titabar varied with sites from 32 - 84 kg N, 15-28 kg P_2O_5 and 17 – 44 kg K_2O / ha as against the blanket RDF of 40:20:20 NPK/ha, while at Mandya it varied from 67-86 kg N, 28-48 kg P_2O_5 and 42 – 88 kg K_2O / ha as against 100:50:50 NPK/ha for target yield of 6.4 t/ha. SSNM was superior to the currently recommended blanket fertilizer dose or the soil test-based recommendation (uniform dose followed) and farmers' fertilizer practice at both the locations.

5.3 Management of micronutrients in rice-wheat system in sodic soil

This trial was initiated in *kharif* 2009 at Kanpur to study the direct, residual and cumulative effects of micronutrients on the nutrition and productivity of rice wheat cropping system in sodic soils. With few modifications the trial was conducted in *kharif* 2010 which showed significant response to gypsum application in terms of yield and nutrient accumulation at both 50 and 100% of requirement. Micronutrient management of supplementing zinc at 50 kg $ZnSO_4$/ha or combined application of zinc and iron (30 kg Fe-EDTA / ha) with or without organic manures improved rice productivity and utilization efficiency of nutrients like N, P and Fe that resulted in reduced requirement of these nutrients including zinc.

5.4 Screening of rice germplasm for high iron and zinc contents

The study was conducted at 11 locations screening 185 cultures which also included four varieties (checks) promising for high Zn and Fe content to study the influence of environment on rice productivity and micronutrient contents. The effect was significant influencing rice productivity and Zn contents in the brown rice and total uptake across locations and genotypes, while that of Fe varied between locations with strong interaction effects of genotypes and locations. The relationship, however, between Fe and zinc contents in brown rice and grain yield was not significant despite observed variations in grain yields and micronutrient contents in all the common set of genotypes evaluated. Several location specific promising cultures for high Fe and Zn content were identified which included the Njavara group at Moncompu, Pathani 23 and Jodumani from Karaikal, swarna sub 1 at Kanpur, few NDR and scented cultures at Faizabad and Khudwani, resectively and Bhutmuri at Bankura.

5.5 Nutrient and water requirement for aerobic rice cultivation

The study initiated in *kharif* 2010 indicated no effect of water regimes on the performance of aerobic rice (non-puddled, direct sown and near saturated field water regime) at DRR and Kanpur. Response to applied nutrients was significant for N at DRR and for N and P at Kanpur increasing grain yield by 0.3 – 0.6 to 1.2 t / ha. Application of nutrients improved N and K accumulation up to 60 and 100 kg / ha, respectively at DRR and increased uptake of all the nutrients up to 120, 60 and 50 kg/ha of NPK application at Kanpur. At the highest yield level of 5.2 and 4.0 t / ha at DRR and Kanpur, the nutrient uptake requirement was estimated to be 20.3, 7.6 and 25.9 Kg and 18.4, 5.4 and 21 kg NPK /t grain at DRR and Kanpur. Water productivity (kg grain/mm water used) ranged from 4.0 – 4.6 at Kanpur and 3.9 to 4.8 kg grain / mm water at DRR depending on the water regime, based on which irrigation equivalent to 100% of cumulative pan evaporation (CPE) appeared to be optimum for aerobic rice system at the test locations without yield loss and saving, 16.3 and 12.5 per cent of irrigation water, respectively.

5.6 Management of crop residues in rice based cropping systems

The trial to study the influence of different residue management strategies on crop yield and soil fertility was conducted at seven locations under two different rice based cropping systems during the previous *rabi* and *kharif* seasons. In the rice –wheat cropping systems at Faizabad, Ghaghraghat and Kanpur, straw (5 t/ha) + green manure (5 t/ha) incorporation resulted in the highest yields and nutrient uptakes for both *rabi* and *kharif* crop. Maximum enhancement in nutrient use efficiencies and in accumulation of soil available NPK and soil organic carbon was also observed with the same treatment at these locations. In the rice –rice system at Chinsurah, similar positive effect on crop yields and soil parameters was observed with incorporation of straw along with microbial inoculum.

5.7 Screening genotypes suitable for acid soils and related nutritional constraints

The fourth year results on screening of rice genotypes for acid soils in lowland rice ecosystem at Titabar (Assam) and Ranchi (Jharkhand) indicated variable genotype response to lime application and Fe toxicity stress. Liming influenced the productivity of rice under lowland conditions significantly at both the locations. Doubling the dose of P and K did not give additional yield advantage though it had increased grain P and K uptake at Titabar. Based on the observations on crop productivity and uptake of major nutrients, IET 10016, WL 21, Jaya and IET 20974 were promising for acid soils while IET 21519 was tolerant to Fe toxicity at Titabar. IET 21528, IET 21531 and IET21519 gave higher grain yields in the acid soils of Ranchi.

5.8 Nutritional status of rice in farmers' fields in relation to productivity

The results of this study organized in representative farm sites (148) around Ghagraghat, Mandya, Titabar, Maruteru and Karaikal representing Indo-gangetic plains, Brahamputra basin, southern plateau region and Godavari / Cauvery delta indicated wide variability among farm sites in rice productivity, soil nutrient supply and nutrient use efficiency of genotypes. Average rice productivity was highest at Titabar, Assam followed by Maruteru, Karaikal, Ghaghraghat and Mandya reflecting broadly the soil quality status. Nutrient harvest index calculated across farmers' fields at these sites indicated steep variation for all the nutrients and low nutrient harvest index at Mandya and Titabar due to poor nutrient concentration in the grain and straw

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

The results indicate differential response of genotypes to nutrient application which was specific to different test environments. Overall, the yield response was significant up to 120, 60, 50 kg NPK /ha for HYVs at most of the locations, while there was no response to P application at Chinsurah. Based on the nutrient accumulation and yield response to fertilizer application, the estimated nutrient uptake requirements for hybrids and HYVs across the locations ranged from 15 – 24 kg N, 5-11 kg P2O5 and 15 – 43 kg K2O per ton of grain production. By regression analysis the nutrient requirement of the test cultures ranged from 14 - 30 kg N, 3 – 10 kg P_2O_5, and 9 – 28 kg K_2O/t grain. K requirement was high at DRR based on uptake for the highest recorded yield of HYVs, but was optimum by statistical method. At Karaikal, however, it was high for both the genotype groups.

5.10 Studies on partitioning of zinc and iron in rice and prospects of enrichment

The first year of study conducted at Aduthurai, Karaikal, DRR and Maruteru indicated that culture Aghonibora (promising for high Zn and Fe content) was most productive at DRR and Aduthurai. Response to zinc application was significant at Aduthurai, DRR and Karaikal, and for iron spraying at Maruteru. Organic manuring along with micronutrients was most productive at all the locations. Micronutrient (Zn, Fe) content in the tissue varied with the genotypes with Aghonibora recording highest zinc content in all plant parts at harvest time at Karaikal and was second best next to ADT43 for both zinc and iron contents at Aduthurai at PI stage. Varietal variations for micronutrient accumulation (uptake) were recorded at Aduthurai where Aghonibora accumulated maximum Fe and Zn in the biomass. Application of micronutrients improved iron uptake in grain at Karaikal and of both the nutrients at Aduthurai. Much of the nutrients were located in stem portion and only 6 – 16% and 18 - 22% of Fe and Zn translocated to the grain. Among the varieties Aghonibora was most promising with improved zinc and iron accumulation in grain upon micronutrient application at Aduthurai and that of iron at Karaikal.

Detailed Report

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

Long-term studies, with well-defined treatment combinations and cropping systems, on the dynamics of soil and crop productivity help in identifying the constraints that influence sustainability of the production system in relation to management. The study was initiated in 1989-90 at selected locations representing major rice growing regions and cropping systems viz., Mandya (rice-cowpea), Maruteru (rice-rice) and Titabar (rice-rice). Results of 22nd year of cropping i.e., *rabi* 2009-10 and *kharif* 2010 received from the three centers are presented in Tables 5.1.1 to 5.1.13 and Fig. 5.1.1. It also included analysis of growth trends of soil and crop productivity and changes in in certain critical soil characteristics.

Crop productivity and soil fertility status (r*abi* 2009-10 – 22nd year)

Grain and straw yields of *rabi* rice at Maruteru (MTU) and Titabar (TTB) and that of cowpea (residual crop) at Mandya (MND) are presented in the Table 5.1.2. The cowpea yields ranged from 0.5 to 0.8 t/ha (average 0.66t/ha) with significant residual effect of all major nutrients applied alone or partly substituted with organic sources. Rice yields at TTB were low (average 2.9 t/ha) despite boro season being a highly productive environment mainly due to delayed planting. Highest yield was recorded when recommended fertilizer dose (100% NPKZnS) was supplemented with 5 t/ha FYM at both the locations and was superior to all other treatments at TTB. Response to P and K was significant at both the locations and that of Zn and S at TTB, while 50% reduction in PK or NPK dose from RDF significantly decreased rice yields by 0.8 to 1.2 t/ha. Application of biofertilizer (Azospirillum) did not show any impact on rice productivity at both locations, while it improved by 0.5 t/ha at MTU when substituted with organic manures to supply 50% N. The INM treatments showed significant residual effect on cowpea crop at Mandya recording highest yields (0.81 t/ha). Soil test based nutrient application which was introduced about two years back did not stabilize the yields comparable to currently followed fertilizer recommendations probably due to extreme depletion of nutrients as evident from marginal improvement in nutrient uptake over other treatments receiving major nutrients.

Straw yield followed similar trend as that of grain recording maximum yield with 100% RDF plus 5 t/ha of FYM both at MTU and TTB, and with INM treatments at Mandya. Partial substitution of 50% N with organics was effective in restoring straw yields at par with recommended fertilizer dose both at Mandya and Titabar. The data on panicle number recorded at Maruteru also followed the same trend as that of grain yield recording maximum number (567/m^2) with RDF+5t FYM/ha.

The beneficial effect of additional dose of organic sources on nutrient accumulation in the crop (Table 5.1.3) under R-R system was apparent recording highest uptake only when RDF was supplemented with 5t/ha of FYM which was superior to the recommended dose for N and P uptake at MTU and that of P at TTB, while substitution of 50% N with FYM / GM improved only N uptake at TTB and that of P at MTU over 50% NPK dose. Only K uptake increased significantly by about 30% over only N application. Mean N uptake by rice ranged from 37-95 kg/ha, that of P from 7-23 kg/ha and of K from 28-128 kg/ ha at these locations for an average productivity of 2.9-4.7t/ha, which amounts to an average accumulation of about 20, 4.9 and 27 kg N, P_2O_5 and K_2O per ton of grain at MTU, and 13, 2.4 and 10 kg N PK / t at TTB. With recommended fertilizer dose the crop accumulated relatively higher N and K (27 and 30kg) per ton of grain at MTU and relatively much less of all nutrients (15, 3, 13kg) at TTB indicating a need for refining the fertilizer dose in these regions.

Nutrient use efficiency at MTU (Table 5.1.4) ranged from 36-59 kg grain / kg N uptake, 160-286 kg grain for P and 25-47 kg grain for K indicating imbalanced nutrition of P and K. Similarly, at TTB the

NUE for all major nutrients, though as non-significant for treatment effects, showed large deviation from the reported range for cereals (Table 5.1.5).

Post harvest soil analysis after *rabi* crop at MTU and Mandya (MND) (Table 5.1.6) indicated substantial increase in organic carbon content by 13-59% with the application of organics, while supplementation with FYM over RDF improved available NPK by 24, 52 and 26% in the deltaic alluvium at MTU. Similarly, the availability of major nutrients improved considerably at Mandya with the application of organic manures.

Crop productivity, nutrient uptake and soil fertility status (*kharif* 2010)

Average yields recorded in *kharif at* the test centers ranged from 3.6-4.8 t/ha with highest yields (5.7- 6.1 t/ha) recorded with supplementation of RDF with FYM at MTU and TTB, and with the substitution of 50% N by organics in the light texured soils at Mandya (5.1.7). These were superior to those recorded with RDF at MND and TTB. Response to major nutrients was significant at all the locations particularly for K at Mandya and MTU, and for K, Zn and S at TTB. Soil test based fertilizer recommendation did not perfom well while azospirillum inoculation was promising at MTU and TTB improving rice yields significantly over that of 50% NPK dose. The yields with the biofertilizer were, however, not comparable with RFD treatment at all locations. Similarly in INM treatments substitution of 50% N with organics was promising at MND and MTU, and was significant over RDF at MND and comparable at MTU while in acid alluvial soils at TTB the yields with INM treatments were less by 1.1-1.3 t/ha over RDF treatment. The results suggest that application of organics over and above RDF could improve crop and soil productivity at all the locations, while there is scope for economising fertilzer nutrients through partial substitution with green manures and FYM in the light textured soils at Mandya as well as MTU. However, 50% reduction in NPK application could not be compensated by substitution with organics at TTB indicationg the criticality of current recommended dose.

The data on nutrient uptake rercorded at MND and TTB is presented in the Table 5.1.8, which showed similar trend as that of grain yields. The average accumulation of N, P_2O_5 and K_2O in the dry matter was 42, 21 and 33 kg at Mandya, and 48, 9 and 32 kg at TTB which amounts to 11.6, 5.8 and 9.2 kg and 11.2, 2.2 and 7.6 kg NPK per ton of grain, which indicate unusually very low accumulation of Nand K at Mandya and of all the nutrients at TTB. The nutrient accumulation in the highest yielding treatment showed similar trend as also reflected in the internal efficiency of the nutrients at these locations (Tables 5.1.9 and 5.1.10). The data also indicated a very low nutrient supply potential of the soil at these locations as observed in low uptake when nutrients like N and K were omitted or applied at reduced level.

Soil fertility status in the post harvest samples (*kharif* 2010) recorded at Mandya and Titabar (Table 5.1.11) show a overall improvement in organic carbon, available status of major nutrients and reduced soil strength with organic manuring and INM treatments at both the locations when applied as a suppliment or substitution of recommended fertilizer dose. At Titabar, however, supplementary dose of FYM along with 100% RDF was far superior to RDF alone in improving organic carbon by 20%, available P_2O_5 by 32% and available K_2O by 13 per cent.

Long term changes in crop productivity and soil fertility

The trends in mean grain yields of *kharif* rice crop that was followed by non-rice (cowpea) or rice crop during the *rabi* season, and the changes (%) in some of the important soil fertility parameters over the years (since *kharif* 1989) in each treatment were analyzed by fitting to a linear function using actual mean yields.

Crop productivity (Table 5.1.13): Recommended fertilizer practice (100% RDF) for most of the period, resulted in producing highest rice productivity at all the locations with mean grain yield (22 years) of 4.2, 4.8 and 5.1 t/ha respectively at Titabar, Mandya and Maruteru, which, however, improved the yields further on average by 0.2 – 0.5 t/ha particularly in TTB and Mandya with the supplementation of organic manure (FYM @ 5 t/ha). Analysis of linear trends of *kharif* rice productivity over the period indicated improvement in productivity @ 11 – 251kg grain /ha/year or is stable in the Godavari delta system (Maruteru); highest growth being recorded with FYM supplementing recommended fertilizer practice. In treatments where nutrients like P and K were not applied, the productivity declined @ 12 – 20 kg grain/ha/year in the delta system. Integrated use of organic sources (INM) as a substitute to supply 50% of N dose along with half the NPK dose improved the yield growth to 18 – 40 kg/ha/year from 6-9 kg/ha/year recorded with 50% of RDF application. However, in the Assam valley (Titabar) and plateau region (Manaya) rice productivity declined in most of the treatments @ 2-39 kg/ha/year at Titabar and more intensely at Mandya @ 15 – 107 kg/ha/year, which improved to positive growth only when FYM was applied additionally over RDF and / or with RDF at Titabar and with INM treatments (FYM) at Mandya. To a large extent this trend was also reflected in the yields estimated by linear equation (intercept) and the average yields.

Changes in soil fertility (Table 5.1.14 and Fig. 5.1.1)

Changes in some of the important soil parameters such as organic carbon (OC) and available P and K over the years were analysed. At Titabar (acid alluvial soils) there was a decline in OC by 25 – 58% and of K by 31 – 64%, while soil available P increased by 15 – 161% in all the treatments except in control. Much of the decline in soil potassium and organic carbon content was when some of the plant nutrients were not applied or the dose reduced by half including in INM treatments. In the Godavari delta system (Maruteru) there was a positive growth in soil OC by 30 – 112%, while it was negative in available K (5 – 32%) and of P (5 – 49%). However, at Mandya despite positive changes in soil fertility over the years in most of the treatments except a small loss of OC in plots not supplied with P or K, the yields were not sustainable indicating a need to review the current fertilizer recommendations for the region as the yields declined even with RDF. In general, INM treatments were found to maintain P fertility partially at Maruteru and substantially at Titabar, the treatment showed very encouraging change in all the soil parameters at Mandya. To an extent these changes in soil fertility have matched the trends in rice productivity growth at the test locations.

Summary: The results of 22nd year of study show that supplementing recommended fertilizer dose (100% NPKZnS) with 5 t/ha FYM was superior to all other treatments at Maruteru and Titabar with corresponding increase in nutrient accumulation and improvement in soil nutrient status and organic carbon. Response to P and K was significant and that of Zn and S at TTB, while 50% reduction in PK or NPK dose from RDF decreased rice yields by 0.8 to 1.2 t/ha. The trend in rice productivity and nutrient uptake during *kharif* was also similar to that of rabi season, while substitution of 50% fertilizers with FYM was superior in sandy loams at Mandya. The average accumulation of N, P_2O_5 and K_2O in the dry matter was 42, 21 and 33 kg at Mandya, and 48, 9 and 32 kg at Titabar which amounts to 11.6, 5.8 and 9.2 kg and 11.2, 2.2 and 7.6 kg NPK per ton of grain indicating unusually very low accumulation of N and K at Mandya and of all the nutrients at TTB. The data also indicated a very low nutrient supply potential of the soil at these locations as observed in low uptake nutrients with limited or no supply of N and K.

Rice productivity growth (linear) improved @ 11 – 251 kg grain /ha/year or was near stable in the Godavari delta system (Maruteru) with most of the treatments except those not supplied with P and / or K (@ -12 to -20 kg/ha/yr) which improved with INM treatments, while in Assam valley (Titabar) and plateau region (Mandya) the productivity declined in most of the treatments @ 2-39 kg/ha/year at Titabar and more intensely at Mandya @ 15 – 107 kg/ha/year. Application of FYM+RDF and / or with INM treatments (FYM) the growth was positive at all the locations and correspondingly sustained or

improved soil fertility. At Mandya, however, mismatch of yield trends with soil fertility changes suggests for analysis of other soil parameters and a relook into current fertilizer recommendations.

Table 5.1.1: Long term soil fertility management in RBCS, 2010
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	60:20:40:20
Rabi	-	180:90:60:50	40:20:20
Crop growth: *Kharif*	Satisfactory	Satisfactory	Average
Rabi	-	Satisfactory	Average
% Clay	11.1	64.5	42.0
% Silt	18.1	22.0	28.0
% Sand	62.8	12.5	28.2
Texture	Sandy loam	Clay	Silty clay
pH (1:1)	5.87	6.2	5.2
Organic carbon (%)	0.30	0.79	1.08
CEC (cmol (p^+)/kg)	-	-	12.5
EC (dS/m)	0.28	0.52	0.28
Avail. N (kg/ha)	208	170	492
Avail. P_2O_5 (kg/ha)	19.7	20.8	22.4
Avail. K_2O (kg/ha)	117.6	265	112

Table 5.1.2: Long term soil fertility management in RBCS, *rabi* 2009 -10
Yield and yield parameters

Treatments	Grain yield (t/ha)			Straw yield (t/ha)			Panicles/m^2
	Mandya (CP)	Maruteru (Rice)	Titabar (Rice)	Mandya	Maruteru	Titabar	Maruteru
Control	0.470	2.25	1.25	0.399	3.31	1.28	300
100% PK	0.499	2.53	2.83	0.441	4.49	2.90	340
100% N	0.543	4.83	2.72	0.482	5.30	2.73	488
STCR recommendation	-	4.71	3.03	-	5.98	2.90	480
100% NP	0.612	4.95	2.85	0.519	5.88	2.82	507
100% NPKZnS	0.707	5.71	3.72	0.690	6.26	3.67	550
100% NPKZnS + FYM/PM @ 5t/ha	0.724	5.81	4.22	0.643	6.48	3.83	567
100% NPK –Zn	0.718	5.50	3.02	0.658	6.39	3.07	540
100% NPK – S	0.731	5.44	2.93	0.672	5.86	2.73	537
100% N+50% PK	0.683	4.90	2.55	0.601	5.62	2.68	517
50 % NPK	0.647	4.79	2.50	0.563	5.83	2.57	454
50 % NPK + Biofertilizer	-	4.63	2.58	-	6.29	2.63	468
50% NPK+ 50%GM-N	0.723	5.11	2.78	0.649	5.99	2.83	511
50% NPK + 50% FYM-N	0.760	5.34	2.80	0.679	6.24	2.93	528
50% NPK + 25% GM-N+25% FYM-N	0.805	5.33	3.32	0.736	6.11	3.32	523
FYM @ 10 t/ha	0.618	4.04	3.30	0.578	4.92	3.37	406
Expt. Mean	0.660	4.74	2.90	0.594	5.68	2.89	482
CD (0.05)	0.152	0.59	0.46	0.161	0.84	0.43	40
CV (%)	10.7	7.5	9.5	12.5	8.9	9.0	5.0

Table 5.1.3: Long term soil fertility management in RBCS, *rabi* 2009 - 10

Nutrient uptake by rice (kg/ha)

Treatments	Nitrogen		Phosphorus		Potassium	
	Maruteru	Titabar	Maruteru	Titabar	Maruteru	Titabar
Control	24.5	12.2	8.1	3.0	59.5	12.6
100% PK	64.0	31.7	13.0	6.7	100.4	29.0
100% N	81.6	28.7	16.9	6.3	105.4	27.2
STCR recommendation	81.7	32.0	18.7	6.7	133.8	29.1
100% NP	99.7	31.1	20.9	6.9	121.1	24.9
100% NPKZnS	133.1	42.0	27.4	9.7	152.1	39.3
100% NPKZnS + FYM/PM @ 5t/ha	160.1	48.9	32.3	11.9	165.0	30.0
100% NPK –Zn	92.6	41.7	23.2	7.2	140.3	28.3
100% NPK – S	99.5	42.4	25.5	7.0	132.5	25.9
100% N+50% PK	97.4	36.7	25.0	6.3	127.1	25.9
50 % NPK	101.3	33.5	26.2	5.7	127.8	22.9
0 % NPK + Biofertilizer	94.0	37.4	21.7	6.7	139.0	25.5
50% NPK+ 50%GM-N	97.8	39.3	32.0	6.4	137.3	27.3
50% NPK + 50% FYM-N	107.1	40.9	24.3	7.2	145.8	27.8
50% NPK + 25% GM-N+25% FYM-N	96.0	47.4	32.7	7.9	142.8	31.5
FYM @ 10 t/ha	85.3	48.9	18.6	7.7	115.7	33.7
Expt. Mean	94.7	37.2	22.9	7.1	127.9	27.6
LSD (0.05)	20.3	9.0	5.0	1.6	21.4	10.2
CV(%)	12.9	14.6	13.2	13.8	10.0	22.1

Table 5.1.4: Long term soil fertility management in RBCS, *rabi* 2009 -10 (Maruteru)

Nutrient use efficiency (kg/kg) and requirement (kg/t)

Treatments	Nutrient use efficiency (kg grain / kg uptake)			Nutrient requirement (kg uptake/t grain)		
	N	P	K	N	P	K
Control	93.2	277.9	39.1	11.1	3.6	27.2
100% PK	39.5	194.5	25.3	25.3	5.2	39.8
100% N	59.3	286.8	47.1	16.9	3.5	22.0
STCR recommendation	58.3	251.5	36.3	17.8	4.0	29.6
100% NP	49.9	241.2	41.0	20.1	4.3	24.5
100% NPKZnS	43.0	208.4	37.7	23.3	4.8	26.9
100% NPKZnS + FYM/PM @ 5t/ha	36.4	180.2	35.3	27.6	5.6	28.4
100% NPK –Zn	59.4	237.1	39.5	16.9	4.2	25.5
100% NPK – S	55.7	216.2	41.1	18.2	4.7	24.4
100% N+50% PK	50.5	196.4	40.9	20.0	5.1	26.5
50 % NPK	48.7	193.5	37.5	21.0	5.5	26.7
50 % NPK + Biofertilizer	50.1	213.6	33.5	20.4	4.7	30.1
50% NPK+ 50%GM-N	52.3	162.2	37.9	19.2	6.3	27.0
50% NPK + 50% FYM-N	50.6	221.2	36.6	20.2	4.5	27.3
50% NPK + 25% GM-N+25% FYM-N	56.5	165.4	37.5	18.1	6.2	26.8
FYM @ 10 t/ha	47.3	220.4	34.9	21.1	4.6	28.7
Expt. Mean	53.2	216.7	37.6	19.8	4.8	27.6
LSD (0.05)	13.9	48.6	10.8	4.4	1.2	7.7
CV(%)	15.7	13.4	17.2	13.3	15.3	16.7

Table 5.1.5: Long term soil fertility management in RBCS, *rabi* 2009 -10 (Titabar)
Nutrient use efficiency (kg/kg) and requirement (kg/t)

Treatments	Nutrient use efficiency (kg grain / kg uptake)			Nutrient requirement (kg uptake/t grain)		
	N	P	K	N	P	K
Control	102.3	413.9	99.3	9.8	2.4	10.1
100% PK	89.7	427.9	98.3	11.2	2.4	10.2
100% N	94.8	434.8	100.2	10.6	2.3	10.0
STCR recommendation	94.9	452.1	104.6	10.6	2.2	9.6
100% NP	91.9	415.8	115.7	10.9	2.4	8.7
100% NPKZnS	89.0	384.2	94.7	11.3	2.6	10.6
100% NPKZnS + FYM/PM @ 5t/ha	86.1	356.5	266.1	11.6	2.8	6.9
100% NPK –Zn	72.9	420.4	107.0	13.8	2.4	9.4
100% NPK – S	69.5	421.7	114.6	14.4	2.4	8.8
100% N+50% PK	69.4	408.4	98.7	14.4	2.5	10.2
50 % NPK	79.0	428.0	111.8	12.7	2.3	9.0
50 % NPK + Biofertilizer	67.8	409.8	99.5	14.8	2.5	10.1
50% NPK+ 50%GM-N	70.0	425.2	104.7	14.3	2.4	9.6
50% NPK + 50% FYM-N	68.4	400.8	97.3	14.7	2.5	10.3
50% NPK + 25% GM-N+25% FYM-N	72.7	423.9	107.4	13.8	2.4	9.3
FYM @ 10 t/ha	65.1	417.0	97.7	15.4	2.4	10.2
Expt. Mean	80.2	415.0	113.6	12.8	2.4	9.6
LSD (0.05)	7.3	NS	NS	1.2	NS	NS
CV(%)	5.5	8.9	61.1	5.6	9.0	13.3

Table 5.1.6: Long term soil fertility management in RBCS, *rabi* 2009 -10
Soil fertility status at harvest

Treatments	Maruteru					Mandya			
	Org C (%)	Avail. N (kg/ha)	Avail.P_2O_5 (kg/ha)	Avail.K_2O (kg/ha)	Soil pH	Org C (%)	Avail. N (kg/ha)	Avail.P_2O_5 (kg/ha)	Avail.K_2O (kg/ha)
Control	0.79	169.9	9.1	265.2	6.20	0.35	288	29.43	240
100% PK	1.14	179.6	31.1	402.9	6.45	0.38	288	26.43	320
100% N	0.93	196.3	12.5	284.3	6.58	0.33	313	21.54	238
STCR recommendation	1.18	179.6	13.0	342.5	6.44	-	-	-	-
100% NP	1.01	204.7	17.6	292.5	6.47	0.36	324	27.87	275
100% NPKZnS	1.21	234.0	28.7	341.2	6.59	0.35	303	23.45	243
100% NPKZnS + FYM/PM @ 5t/ha	1.37	289.8	43.8	427.6	6.35	0.35	345	29.65	275
100% NPK –Zn	1.10	221.4	18.3	335.0	4.48	0.45	312	46.54	295
100% NPK – S	1.09	208.9	15.8	321.9	6.58	0.58	398	42.22	285
100% N+50% PK	1.16	200.5	13.7	314.3	6.43	0.50	375	46.22	299
50 % NPK	1.13	192.2	13.5	302.3	6.85	0.58	390	44.45	285
50 % NPK + Biofertilizer	1.13	192.2	16.4	338.2	6.35	-	-	-	-
50% NPK+ 50%GM-N	1.20	208.9	17.8	344.8	6.77	0.58	365	55.87	338
50% NPK + 50% FYM-N	1.24	208.9	26.7	384.6	6.28	0.56	395	47.34	290
50% NPK + 25% GM-N+25% FYM-N	1.28	196.3	18.4	417.3	6.48	0.50	344	41.45	290
FYM @ 10 t/ha	1.41	192.2	38.0	410.1	6.34	0.54	376	33.43	265
Expt. Mean	1.15	204.7	20.9	345.3	6.35	-	-	-	-
-LSD (0.05)	0.16	36.6	3.3	23.0	NS	-	-	-	-
-CV (%)	8.46	10.7	9.5	4.0	13.88	-	-	-	-

Table 5.1.7: Long term soil fertility management in RBCS, kharif *2009*
Yield and yield parameters of rice

Treatments	Grain yield (t/ha)			Straw yield (t/ha)			Panicles/m^2
	MND	MTU	TTB	MND	MTU	TTB	MTU
Control	1.12	4.01	1.33	2.25	5.90	1.32	211
100% PK	2.07	4.47	3.31	2.29	7.01	2.80	256
100% N	2.04	4.45	3.84	2.38	7.10	2.90	282
STCR recommendation	2.12	4.06	3.85	2.28	9.04	3.17	331
100% NP	2.38	4.51	3.84	2.53	8.65	2.80	309
100% NPKZnS	4.23	5.44	5.62	4.35	8.48	3.77	303
100% NPKZnS + FYM/PM @ 5t/ha	5.93	5.67	6.13	6.00	6.89	3.97	288
100% NPK –Zn	3.94	5.20	5.03	4.14	5.89	3.15	296
100% NPK – S	3.89	5.37	5.22	4.55	8.84	2.98	304
100% N+50% PK	2.08	4.53	3.85	2.21	8.74	2.98	308
50 % NPK	2.99	4.11	3.02	2.93	8.58	2.73	314
50 % NPK + Biofertilizer	3.23	4.17	4.00	3.35	8.83	2.72	318
50% NPK+ 50%GM-N	4.62	5.37	4.20	4.78	6.32	2.82	228
50% NPK + 50% FYM-N	6.01	5.21	4.53	6.11	9.34	3.20	344
50% NPK + 25% GM-N+25% FYM-N	6.27	5.54	4.20	6.42	6.31	3.30	308
FYM @ 10 t/ha	4.94	5.09	4.77	5.16	6.38	3.77	279
Expt. Mean	3.62	4.82	4.17	3.86	7.64	3.02	292
LSD (0.05)	1.29	0.49	0.34	1.29	0.64	0.21	18
CV(%)	16.8	6.10	4.9	15.7	4.98	4.2	3.63

MND-Mandya MTU-Maruteru TTB-Titabar

Table 5.1.8: Long term soil fertility management in RBCS, *kharif 2010*
Nutrient uptake (kg/ha) in total dry matter

Treatments	Nitrogen (kg N/ha)		Phosphorus (kg P_2O_5/ha)		Potassium (kg K_2O/ha)		Zinc (g/ha)
	MND	TTB	MND	TTB	MND	TTB	MND
Control	9.1	13.1	5.3	3.2	12.1	13.3	30.9
100% PK	14.0	33.4	11.4	7.3	16.2	29.4	44.6
100% N	18.3	38.9	8.3	8.2	16.2	30.7	52.5
STCR recommendation	20.7	38.7	11.4	8.6	18.3	32.3	54.9
100% NP	19.2	39.8	9.5	8.6	18.0	26.4	53.4
100% NPK+Zn+S	47.3	57.5	24.0	13.0	37.9	43.9	108.3
100% NPK + Zn + S + FYM/PM @ 5 t/ha	70.7	68.6	34.9	16.3	57.5	49.5	166.8
100% NPK –Zn	35.6	59.6	21.3	9.8	34.6	31.6	77.9
100% NPK – S	41.2	62.0	20.1	10.1	27.5	30.8	83.1
100% N+50% PK	21.2	47.9	9.1	8.0	16.0	30.1	42.7
50 % NPK	36.3	35.4	15.9	6.8	27.6	23.9	78.4
50 % NPK + Biofertilizer	41.6	48.9	19.4	8.2	33.4	26.8	97.7
50% NPK+ 50%GM-N	62.9	51.2	26.7	8.9	39.9	29.0	123.7
50% NPK+ 50% FYM-N	81.6	56.6	44.0	10.1	59.2	33.4	173.1
50% NPK +25% GM-N +25% FYM-N	94.5	53.9	49.0	10.0	70.3	32.6	208.9
FYM @ 10 t/ha	64.3	68.1	30.1	11.8	46.9	40.8	133.9
Expt. Mean	42.4	48.3	21.3	9.3	33.2	31.5	95.7
LSD (0.05)	16.8	6.0	7.4	1.6	14.9	2.9	33.6
CV (%)	18.5	7.5	16.4	10.1	21.0	5.6	16.5

Table 5.1.9: Long term soil fertility management in RBCS, kharif 2010 (Mandya)
Nutrient use efficiency (kg/kg) and requirement (kg/t)

Treatments	Nutrient use efficiency (kg grain / kg uptake)			Nutrient requirement (kg uptake/t grain)		
	N	P	K	N	P	K
Control	125.4	218.7	99.6	8.2	4.8	10.9
100% PK	149.4	182.2	129.0	6.7	5.5	7.8
100% N	111.6	247.0	130.4	9.0	4.1	7.9
STCR recommendation	102.7	191.5	119.6	9.7	5.5	8.6
100% NP	123.9	251.1	132.3	8.1	4.0	7.6
100% NPKZnS	89.8	182.6	114.5	11.1	5.6	8.8
100% NPKZnS + FYM/PM @ 5t/ha	83.9	169.8	104.0	11.9	5.9	9.7
100% NPK –Zn	113.2	184.7	119.2	8.9	5.4	8.6
100% NPK – S	94.5	199.0	146.3	10.6	5.1	7.0
100% N+50% PK	97.9	227.2	131.6	10.2	4.4	7.7
50 % NPK	82.2	189.3	108.4	12.2	5.3	9.2
50 % NPK + Biofertilizer	77.6	172.2	97.0	12.9	5.9	10.3
50% NPK+ 50%GM-N	73.2	172.6	115.4	13.7	5.9	8.7
50% NPK + 50% FYM-N	73.5	135.7	101.0	13.6	7.4	9.9
50% NPK + 25% GM-N+25% FYM-N	66.3	127.4	88.8	15.1	7.9	11.3
FYM @ 10 t/ha	76.8	164.7	107.0	13.1	6.1	9.5
Expt. Mean	96.4	188.5	115.3	10.9	5.5	9.0
LSD (0.05)	21.0	62.5	NS	1.5	1.7	NS
CV(%)	10.2	15.6	13.7	6.6	14.8	14.4

Table 5.1.10 Long term soil fertility management in RBCS, *kharif* 2010 (Titabar)
Nutrient use efficiency (kg/kg) and requirement (kg/t)

Treatments	Nutrient use efficiency (kg grain / kg uptake)			Nutrient requirement (kg uptake/t grain)		
	N	P	K	N	P	K
Control	102.3	420.1	101.3	9.8	2.4	10.1
100% PK	100.6	455.3	112.7	10.1	2.2	8.9
100% N	98.9	470.1	125.5	10.1	2.1	8.0
STCR recommendation	101.0	451.0	119.6	10.1	2.2	8.4
100% NP	96.5	446.9	145.5	10.4	2.2	6.9
100% NPKZnS	98.7	438.1	128.0	10.2	2.3	7.8
100% NPKZnS + FYM/PM @ 5t/ha	89.4	378.1	124.3	11.2	2.6	8.1
100% NPK –Zn	84.6	513.3	159.9	11.8	2.0	6.3
100% NPK – S	84.1	514.1	169.5	11.9	1.9	5.9
100% N+50% PK	80.4	482.5	128.1	12.4	2.1	7.8
50 % NPK	85.5	446.4	126.7	11.7	2.3	7.9
50 % NPK + Biofertilizer	81.9	490.9	149.6	12.3	2.1	6.8
50% NPK+ 50%GM-N	82.0	473.7	144.6	12.2	2.1	7.0
50% NPK + 50% FYM-N	80.4	451.3	135.7	12.5	2.2	7.4
50% NPK + 25% GM-N+25% FYM-N	77.9	423.1	129.1	12.8	2.4	7.8
FYM @ 10 t/ha	70.0	405.9	117.2	14.3	2.5	8.6
Expt. Mean	88.4	453.8	132.3	11.5	2.2	7.7
LSD (0.05)	8.4	67.7	18.5	1.4	0.3	1.2
CV(%)	12.4	8.9	8.4	7.1	9.2	9.1

Table 5.1.11 Long term soil fertility management in RBCS, *kharif* 2010

Soil fertility status at harvest

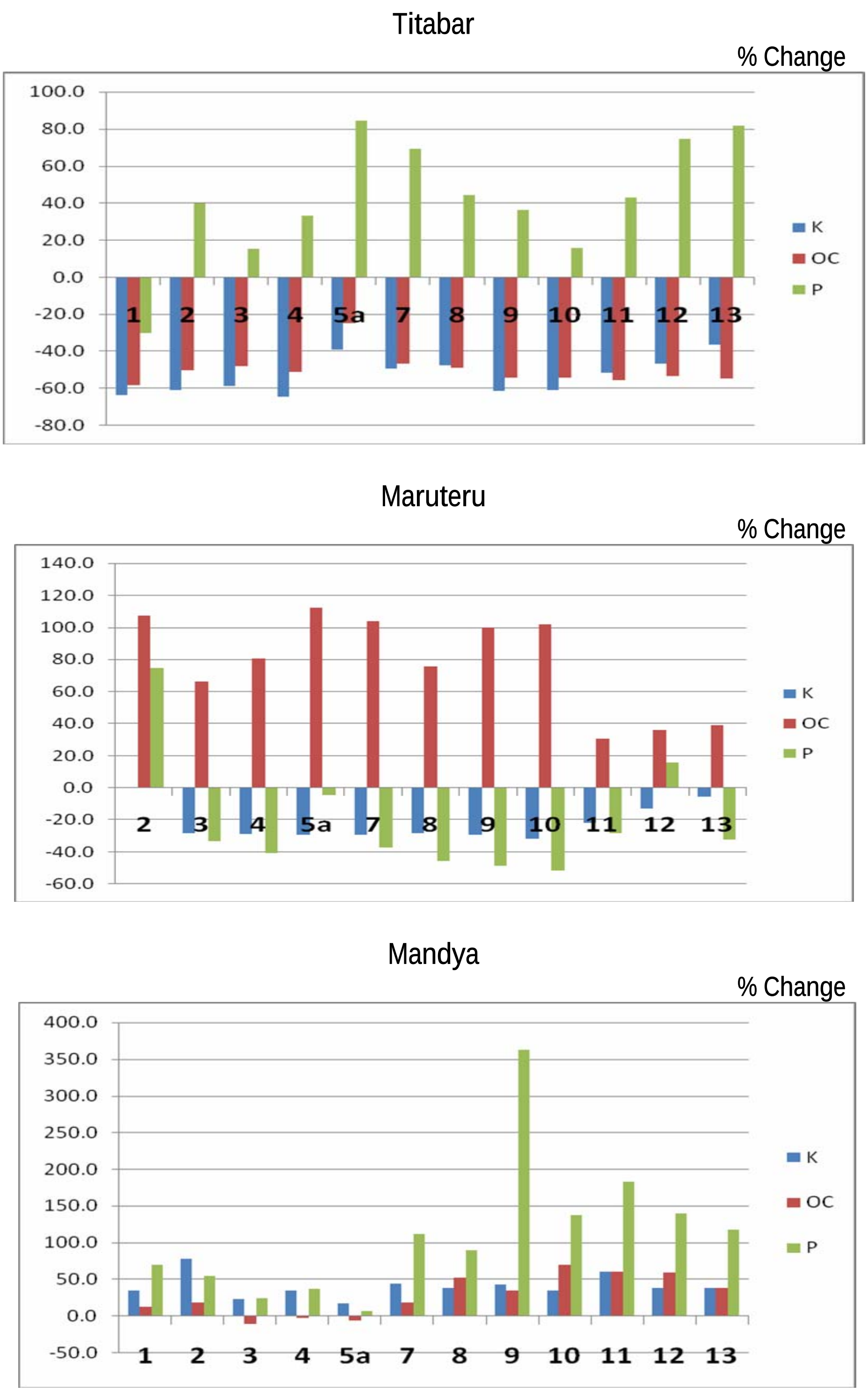
Treatments	Titabar			Mandya				
	Org C (%)	Avail.P_2O_5 (kg/ha)	Avail.K_2O (kg/ha)	Org C (%)	Avail. N (kg/ha)	Avail.P_2O_5 (kg/ha)	Avail.K_2O (kg/ha)	BD (g/cc)
Control	0.64	8.1	71.8	0.25	221.5	14	143	1.31
100% PK	0.77	16.2	82.0	0.32	258.0	21.3	237.5	1.30
100% N	0.95	14.3	91.5	0.34	270.5	20.4	217.5	1.28
STCR recommendation	1.01	16.5	90.4	0.33	286.0	23.8	267.0	1.28
100% NP	0.90	18.0	87.0	0.31	259.5	24.5	172.5	1.305
100% NPKZnS	1.40	27.3	147.0	0.36	346.0	32.6	251.0	1.31
100% NPKZnS + FYM/PM @ 5t/ha	1.68	35.9	166.0	0.39	366.5	43.3	295.0	1.27
100% NPK –Zn	1.00	30.3	124.3	0.39	276.0	25.9	247.5	1.27
100% NPK – S	0.96	27.1	133.3	0.37	263.5	24.9	261.5	1.29
100% N+50% PK	0.89	24.5	102.0	0.38	303.0	28.7	225.0	1.27
50 % NPK	0.79	19.7	92.7	0.35	313.0	25.5	265.0	1.26
50 % NPK + Biofertilizer	1.00	26.8	103.3	0.35	344.0	35.0	274.0	1.26
50% NPK+ 50%GM-N	1.04	24.0	108.7	0.50	351.0	45.6	289.0	1.23
50% NPK + 50% FYM-N	1.13	29.5	122.8	0.57	364.0	45.9	286.5	1.22
50% NPK + 25%GM-N+25%FYM-N	1.13	30.0	138.7	0.58	382.5	53.3	321.0	1.19
FYM @ 10 t/ha	1.45	39.1	154.3	0.54	347.5	39.5	264.0	1.21
Expt. Mean	1.05	24.2	113.5	0.39	309.5	31.5	251.1	1.27
LSD (0.05)	0.13	4.7	17.3	0.05	25.8	6.3	33.9	0.03
CV (%)	7.52	11.8	9.1	5.5	3.9	9.4	6.3	1.0

Table: 5.1.12 Long term soil fertility management in RBCS, *kharif 2010*
Linear trends of changes in grain yield (t/ha) from 1989 to 2010

Treatments	Titabar			Maruteru			Mandya		
	Slope (t/ha)	Mean (t/ha)	Intercept (t/ha)	Slope (t/ha)	Mean (t/ha)	Intercept (t/ha)	Slope (t/ha)	Mean (t/ha)	Intercept (t/ha)
Control	-0.092	2.19	3.32	0.098	3.00	2.42	-0.091	2.47	3.47
100% PK	0.016	2.98	2.78	0.046	3.35	3.04	-.0031	3.01	3.24
100% N	-0.019	3.34	3.67	-0.012	4.09	4.33	-0.107	3.76	4.88
100% NP	-0.015	3.57	3.86	-0.020	4.57	4.9	-0.095	4.24	5.12
100% NPK+Zn+S	0.016	4.17	4.3	0.021	5.07	4.95	-0.044	4.84	5.44
100% NPKZnS + FYM/PM @ 5t/ha	0.120	4.62	5.88	0.251	5.08	0.18	0.074	5.04	5.53
100% NPK –Zn	00.00	3.99	4.28	0.011	4.82	4.84	-0.058	4.81	5.6
100% NPK – S	-0.002	4.1	4.37	0.022	4.81	4.67	-0.056	4.72	5.41
100% N+50% PK	-0.017	3.64	3.96	0.006	4.50	4.43	-0.087	4.38	5.13
50 % NPK	-0.039	3.23	3.74	0.009	4.35	4.24	-0.05	3.99	4.51
50% NPK+ 50%GM-N	-0.008	3.62	3.94	0.018	4.49	4.43	-0.015	4.69	4.75
50% NPK+ 50% FYM-N	-0.009	3.71	4.04	0.025	4.75	4.43	0.036	4.83	4.53
50% NPK+25% GM-N+25%FYM-N	-0.029	3.74	4.3	0.04	4.59	4.24	0.034	5.33	5.05
FYM @ 10 t/ha	0.019	3.74	3.73	0.032	4.5	4.11	0.042	4.07	3.88

Table: 5.1.13. Long term soil fertility management in RBCS
Changes in soil fertility parameters over 1989 to 2010

Treatments	Titabar			Maruteru			Mandya		
	K	OC	P	K	OC	P	K	OC	P
	(% change)								
Control	-63.6	-58.2	-30.2	4.6	107.3	74.7	35.6	12.9	70.1
100% N	-58.7	-47.8	15.3	-28.2	66.1	-33.5	22.9	-10.8	24.5
100% NP	-64.4	-50.8	33.3	-28.7	80.4	-40.7	35.5	-2.7	37.3
100% NPK+Zn+S	-38.8	-24.7	84.5	-29.1	112.3	-4.7	18.1	-5.4	6.6
100% NPK –Zn	-49.3	-46.5	69.3	-29.2	103.7	-37.1	43.9	18.4	111.5
100% NPK – S	-47.5	-48.9	44.1	-28.5	75.8	-45.7	38.3	52.6	89.3
100% N+50% PK	-61.3	-54.4	36.1	-29.5	100.0	-48.5	43.3	35.1	362.2
50 % NPK	-60.9	-54.3	15.9	-31.8	101.8	-51.6	35.3	70.6	137.7
50% NPK+ 50%GM-N	-51.4	-55.4	42.9	-22.0	30.4	-28.2	61.2	61.1	183.6
50% NPK+ 50% FYM-N	-46.7	-53.3	74.6	-13.2	36.3	15.6	39.0	60.0	140.3
50% NPK+25% GM -N+25%FYM - N	-36.3	-54.4	81.8	-5.4	39.1	-32.1	38.6	38.9	118.2
FYM @ 10 t/ha	-31.1	-30.0	160.7	-7.8	43.9	46.2	44.9	38.5	67.2



T1- Control, T2-100% PK, T3-100% N, T4-100% NP, T5-100% NPK, T6-100% NPK – Zn, T7-100% NPK – S, T8-100% N + 50% PK, T9-50 % NPK, T10-50% NPK+ 50% GM-N, T11-50% NPK+ 50% FYM-N, T12-50% NPK + 25% GM-N+25% FYM - N, T13-FYM @ 10 t/ha

Fig: 5.1.1 Long term effects of treatments on soil nutrient status

5.2: Rice productivity in relation to internal supply capacity of nutrients in farmers' fields

A review of current fertilizer management practices is always necessary to fine-tune the fertilizer recommendations based on site specific soil nutrient supply capacities and crop demand as new high yielding cultures with increasing yield potential are being regularly introduced. Standalone / blanket fertilizer recommendations followed for diverse soil ecosystems with less importance given to management induced site variations has been the major reason for nutrient imbalances and unsustainability in realizing the yield potentials of modern varieties. This trial was, therefore, conducted in farmers' fields around few selected centres at Mandya, Maruteru and Titabar, to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers' fertilizer practices, and fine-tune the fertilizer nutrient requirement for specific target yields in the given environment. The fertilizer requirements for specific target yields estimated in 2009 were further validated in some of the tested farm sites in comparison with farmers' and recommended fertilizers practices at these locations. The *kharif* 2010 data received from Mandya (Karnataka), Maruteru(AP) and Titabar (Assam), representing irrigated and shallow lowland rice ecosystems are presented in the Tables 5.2.1 to 5.2.8 The test varieties were popular HYVs (Ranjit, and Gitesh at Titabar, three HYVs (KMP 101, MTU 1001) and one hybrid (KRH2) at Mandya and MTU 7029 at Maruteru.

The treatments consisted of nutrient (NPK) omission plots, farmers' fertilizer practice (FFP), recommended dose of fertilizer (RDF) and integrated nutrient management (INM). Table 5.2.1 gives information collected at Mandya, Maruteru 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 3.5 to 5.5 t/ha at Titabar and 1.67 to 4.75 t/ha at Mandya. Similarly, in P or K omitted plots, the grain yields varied from 2.77-3.17 t/ha at Mandya and 3.5 - 4.3 t/ha at Titabar. In the absence of applied N, the yields ranged from 4.22- 4.62 t/ha at Maruteru. Similarly, in P or K omitted plots, the grain yields varied from 4.89-5.75 t/ha and 4.03-4.78 t/ha. Soil nutrient uptake varied between the sites matching considerably with the dry matter yields. On an average each ton of grain accumulated 13.6, 2.6 and 10.44 kg N, P_2O_5 and K_2O at Titabar and 8.58, 4.33 and 18.29 kg at Mandya in the nutrient omission plots.

At both the locations grain yields and nutrient uptake in nutrient omitted plots correlated significantly (Table 5.2 2). Significant linear equations were fitted to relate the recorded yields in nutrient omission plots with uptake of respective nutrients. About 32% yield variation could be related to N uptake, 19% with P uptake and 4% with K uptake at Titabar while about 93 - 97% yield variation could be related to NPK uptake at Mandya. The relationship between yield and nutrient uptake was much stronger at Mandya compared to Titabar.

Table 5.2.3 and Table 5.2.4 show site variations in rice productivity, nutrient uptake and their efficiency of nutrient utilization under farmers' fertilizer practice and recommended fertilizer management (RDF) (40:20:20 NPK/ha at Titabar and 100:50:50 kg NPK / ha at Mandya). Rice productivity with recommended fertilizer practice varied from 4.0-6.5 t/ha and 2.85-4.5 t/ha in the farmers' fields at Titabar and 3.6-6.36 and 2.8-5.92 t/ha at Mandya, respectively. The yields were less by 22-85% and up to 32 % with farmers' fertilizer practices, respectively in the Assam valley and Karnataka plateau region with corresponding variation in nutrient uptake, nutrient utilization and recovery efficiencies. Nutrient recovery efficiencies were higher with RDF for N, P and K at both the locations, while NUE was marginally higher under farmers' fertilizer practices because of comparatively low level of rice productivity and less nutrient applications. Strong correlation between yields and nutrient uptake was also recorded for N, P and K at

Titabar and for N, P and K at Mandya. The estimated nutrient uptake requirement per ton of grain ranged from.13.6-16.9, 2.7-4.4 and 9.2-14.4 kg N, P_2O_5 and K_2O at Titabar, while at Mandya these ranged between10.5- 15.5kg N, 4.5-8.5 kg P_2O_5 and 17.7 - 26.3 kg K_2O 7 per ton of grain with RDF practice. Nutrient requirement was marginally higher with RDF compared to FFP in Assam and at Mandya because of less efficiency of nutrients under farmers' practice.

The basic data *viz*., the nutrient requirement (kg / t) for producing one ton of rice yield and fertilizer efficiencies were calculated from each plot. The percent nutrient contributions from fertilizer nutrients at Titabar with RDF were found to be 78.8, 60.3 and 111.0 and with farmers' practice 49.36, 36.21 and 79.06 for nitrogen, phosphorus and potassium, respectively. Similarly, at Mandya it varied from 55, 54 and 67 in RDF and 55, 51 and 59 for nitrogen, phosphorus and potassium, respectively in farmers' practice. This result indicated that nutrient contribution from the fertilizer source in RDF is more than those with farmers' practice. Fertilizer prescriptions were worked out for all the farm sites for yield targets of 6.5 and 6.4 t/ha, respectively at Titabar and Mandya. The target yields were the maximum recorded at the test sites under recommended fertilizer practice (RDF). The fertilizer recommendations are presented in Tables 5.2.5 and 5.2.6. For the target yield of 6.5 t/ha at Titabar the fertilizer recommendations varied with sites from 37 - 74 kg N, 1-23 kg P_2O_5 and 15 – 36 kg K_2O / ha as against a blanket RDF of 40:20:20 NPK/ha being followed. However, at Mandya the estimated fertilizer prescriptions varied from 109 - 127 kg N, 28-48 kg P_2O_5 and 42 – 88 kg K_2O / ha as against a blanket RDF (100:50:50 NPK/ha) being followed. High estimates of K fertilizer requirements are due to low recovery efficiency of applied K. 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 *kharif*- 2009 for the farmers' fields in Titabar and Mandya were validated in comparison with the current recommended practices and also soil test crop response based recommendations for the locations (Table 5.2.7 and 5.2.8). Site specific nutrient management (SSNM) prescribed for specific yield targets of 5.0 and 6.7 t/ ha was tested at 5 farm sites at Titabar and 6 sites at Mandya, respectively. SSNM was superior to the currently recommended blanket fertilizer dose or the soil test-based recommendation (uniform dose followed) and farmers' fertilizer practice at both the locations. Rice productivity improved by at Titabar with corresponding increase in nutrient uptake. The study suggests scope for further improvement in rice yields through realistic assessment of soil nutrient supply and the efficiency of soil and fertilizer nutrients which are utilized for recommending site specific fertilizer prescriptions.

Summary

This trial was conducted in farmers' fields around three selected centres at Mandya, Maruteru and Titabar, to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers' practices, and fine-tune the fertilizer nutrient requirement for specific target yields in a given environment. The estimated nutrient uptake requirement per ton of grain ranged from.13.6-16.9, 2.7-4.4 and 9.2-14.4 kg N, P_2O_5 and K_2O at Titabar, while at Mandya these ranged between10.5 - 15.5kg N, 4.5-8.5 kg P_2O_5 and 17.7 - 26.3kg K_2O per ton of grain with RDF practice, showing a considerable variation among the farm sites. About 45 - 57% yield variation in fertilizer applied plots could be related to N uptake, 18 - 48% with P uptake and 11 - 32% with K uptake at Titabar, while more than 90% of yield variation to N and K uptake and 68% with P uptake at Mandya. The yields were less by 22-85% and up to 32 % with farmers' fertilizer practices, respectively in the Assam valley and Karnataka plateau region compared to curerently recommended fertilizer practices with corresponding variation in nutrient uptake, nutrient utilization and recovery efficiencies. SSNM was superior to the currently recommended blanket fertilizer dose or the soil test-based recommendation (uniform dose followed) and farmers' fertilizer practice at both the locations.

Table 5.2.1 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2010
Soil nutrient supply potential assessed in nutrient omission plots

Nutrient omitted	Titabar**			Mandya*		
	Minimum	Maximum	Mean*	Minimum	Maximum	Mean**
Grain yield (t/ha)						
(-)N	3.5	5.5	4.5	1.67	4.75	2.68
(-)P	3.0	5.0	4.3	1.87	3.83	2.77
(-)K	3.5	5.0	4.3	2.08	6.44	3.17
Maruteru Grain yield (t/ha)						
(-)N	4.22	4.62	4.41	NA	NA	NA
(-)P	4.89	5.75	5.33	NA	NA	NA
(-)K	4.03	4.78	4.48	NA	NA	NA
Soil test value (kg/ha)						
Nutrient	Minimum	Maximum	Mean	Minimum	Maximum	Mean
N	410	512	469	214	334	287
P_2O_5	11	18	14	17.5	34.5	26.9
K_2O	118	168	147	184	267	223

** Mean of 10 farm sites* *** Mean of 10 farm sites*

Nutrient uptake (kg/ha) in nutrient omission plots						
Nutrient	Titabar			Mandya		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
N	43.9	73.0	61.5	11.3	60.5	23
P_2O_5	7.7	21.0	11.2	7.5	21.6	12.0
K_2O	32.4	60.0	44.9	29.1	162.0	58.0

Soil nutrient availability (SNA) in nutrient omission plots						
Nutrient	Titabar			Mandya		
	Mean yield (t/ha)	Mean uptake (kg/ha)	SNA (kg/t grain)	Mean yield (t/ha)	Mean uptake (kg/ha)	SNA (kg/t grain)
N	4.5	61.5	13.6	2.68	23	8.58
P_2O_5	4.3	11.2	2.6	2.77	12.0	4.33
K_2O	4.3	44.9	10.44	3.17	58.0	18.29

SNA- Soil nutrient availability (uptake) (kg) / ton of grain

Table 5.2.2 Rice productivity in relation to internal supply capacity of nutrients
In Farmer's fields, *kharif* 2010
Interrelationship between yield, nutrient uptake and soil test value in nutrient omission plots

Nutrient	Correlation (r)	Regression (R^2)	Intercept (kg/ha)	Slope (kg/ha)	Correlation (r)	Regression (R^2)	Intercept (kg/ha)	Slope (kg/ha)
	Titabar**				Mandya*			
Soil test value Vs. Yield								
(-) N	0.53	0.28*	492.7	58.3	-0.03	0.0008	390.5	34.3
(-) P	0.35	0.13*	18.45	3.3	0.39	0.15*	34.7	8.45
(-) K	0.62	0.38*	143.11	39.05	0.35	0.12*	254.9	23.5
Yield Vs. Nutrient uptake								
(-) N	0.69	0.32*	2.49	4.58	0.96	0.93**	1.33	0.99
(-) P	0.44	0.19*	3.39	4.88	0.98	0.97**	0.8	0.54
(-) K	0.63	0.04*	2.44	10.3	0.98	0.97**	1.3	1.03
Soil test value vs. Nutrient uptake								
(-) N	0.36	0.13	39.21	228	-0.39	0.13*	555.9	495.58
(-) P	0.13	0.08*	13.06	7.85	0.06	0.004	24.24	13.39
(-) K	0.64	0.41*	89.29	32.7	-0.31	0.09	202.4	171.1

** Significant at 5%* *** Significant at 1%* *NS non significant*

Table 5.2.3 Rice productivity in relation to internal supply capacity ofnutrients In farmers' fields, *kharif* 2010

Yield and nutrient use efficiency in farmers' fields (Location: Titabar)

Parameter / Nutrients	Rec. dose of fertilizer (RDF)			Farmer's fert. practice (FFP)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (t/ha)	4.00	6.5	5.51	2.85	4.5	3.75
Nutrient uptake (kg/ha)						
N	57.9	109.5	86.69	35.9	65.0	54.29
P_2O_5	13.1	26.1	18.08	7.5	56.0	10.86
K_2O	12.0	25.2	61.06	30.5	56.4	43.48
Recovery efficiency (%) of applied fertilizer						
N	59.6	99.5	78.8	32.7	59.1	49.36
P_2O_5	43.8	86.8	60.3	24.9	52.0	36.21
K_2O	84.8	138.8	111.0	55.5	102.5	79.06
Nutrient utilization efficiency (kg grain / kg uptake)						
	Min	Max	Mean	Min	Max	Mean
N	59.0	76.2	64.14	57.2	85.5	69.8
P_2O_5	227.3	365.3	312.21	224.4	414.4	353.8
K_2O	76.0	108.6	91.05	62.1	105.9	88.01
Nutrient requirement (kg/ton grain)						
N	13.6	16.9	15.78	11.7	16.5	14.5
P_2O_5	2.7	4.4	3.27	2.4	4.5	2.91
K_2O	9.2	14.4	11.17	9.3	16.1	11.7

Yield Vs. Nutrient uptake at Titabar

	Recommended fertilizer dose				Current farmer practice			
	Correlation (r)	Regression (R^2)	Slope (b)	Intercept	Correlation (r)	Regression (R^2)	Slope (b)	Intercept
N	0.76	0.57*	0.06	1.94	0.68	0.45*	0.59	1.46
P_2O_5	0.69	0.48*	1.32	3.27	0.43	0.18*	0.79	2.67
K_2O	0.57	0.32*	0.8	2.63	0.34	0.11*	0.42	2.75

** Significant at 5%* *** Significant at 1%* *NS non significant*

Table 5.2.4 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2010

Rice productivity and nutrient use efficiency in farmers' fields (Location: Mandya)

Parameter/ nutrient	Rec. dose of fert. (RDF)			Farmer's fert. practice (FFP)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grain yield (t/ha)	3.6	6.36	4.69	2.8	5.92	4.24
Nutrient uptake (kg/ha)						
N	45.3	97.4	62	32.8	92.5	55
P_2O_5	20.1	54.2	32	15.9	43.9	27
K_2O	76.9	169.7	101	57.8	147.3	88
Recovery efficiency (%) of applied fertilizer						
N	45.3	65.0	55	32.8	92.5	55
P_2O_5	38.8	67.4	54	31.7	87.7	51
K_2O	43.6	110.4	67	38.5	98.2	59
NUE						
N	64.7	95.0	78	64.0	90.0	79
P_2O_5	117.3	220.9	155	134.9	215.2	159
K_2O	38.0	56.3	49	40.2	59.1	50
Nutrient requirement (kg/ton grain)						
N	10.5	15.5	13	11.1	15.6	13
P_2O_5	4.5	8.5	7	4.6	7.4	6
K_2O	17.7	26.3	21	16.9	24.9	20

Yield Vs. Nutrient uptake

	Recommended fertilizer dose (RDF)				Farmers' fertilizer practice (FFP)			
	Correlation (r)	Regression (R^2)	Slope	Intercept	Correlation (r)	Regression (R^2)	Slope	Intercept
N	0.97	0.93*	1.21	1.85	0.82	0.9*	0.69	1.49
P_2O_5	0.83	0.68*	0.79	2.22	0.95	0.89*	0.18	1.09
K_2O	0.97	0.93*	1.65	2.21	0.99	0.98*	1.01	1.36

** Significant at 5% ** Significant at 1% NS non significant*

Table 5.2.5 Rice productivity in relation to internal supply capacity of nutrients I n farmers' fields, *kharif* 2010

Site-specific fertilizer recommendation (kg/ha) for a 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 (6.5t/ha)		
				N	P_2O_5	K_2O
1	5.10	3.50	45.7	70	23	31
2	4.80	2.85	68.4	74	22	36
3	5.60	3.80	47.4	63	17	32
4	5.80	3.75	54.7	48	22	31
5	5.80	4.00	45.0	38	19	23
6	6.50	4.00	62.5	-	-	-
7	5.50	3.10	77.4	37	21	22
8	5.50	4.50	22.2	58	1	15
9	6.50	3.50	85.7	-	-	-
10	4.00	4.50	-11.1	48	20	23

Table 5.2.6 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2010

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

Site No.	Current yield with RDF (t/ha)	Current yield with FFP (t/ha)	Per cent increase in yield over FFP	Fertilizer recommendation for the target yield (6.4 t/ha)		
				N	P_2O_5	K_2O
1	4.76	5.33	-10.7	115	61	112
2	4.43	3.41	29.9	113	67	156
3	4.3	3.43	25.4	131	69	149
4	6.3	5.92	6.4	110	60	-
5	4.29	4.08	5.1	127	68	157
6	3.7	2.8	32.1	121	63	154
7	3.63	4.28	-15.2	114	59	120
8	4.49	3.42	31.3	109	48	122
9	4.65	3.78	23.0	118	69	147
10	6.36	5.92	7.4	-	-	-

Table 5.2.7 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2010

Validation of SSNM recommendations in farmers' fields

Parameter	SSNM	STCR	Current RDF	CD (0.05)
*Titabar (Target 5.0 ton/ha)				
Grain Yield (t/ha)	5.77	5.25	5.18	0.39
Nutrient Uptake (kg/ha)				
N	96.5	80.1	77.9	6.9
P_2O_5	18.5	15.5	13.8	1.9
K_2O	68.9	57.8	54.8	4.8
* *Mandya (Target 6.7 t/ha)				
Grain Yield (t/ha)	6.84	4.5	4.19	0.54
Nutrient Uptake (kg/ha)				
N	71.5	39.4	34.3	6.9
P_2O_5	35.1	19.6	17.9	3.3
K_2O	94.8	54.3	42.8	12.8

** Average of 5 sites* *** Average of 6 sites*

Table 5.2.8 Rice productivity in relation to internal supply capacity of nutrients in farmers' fields, *kharif* 2010

Nutrient managements evaluated in validation trials *kharif* 2010

Fertilizer practice	Titabar			Mandya
	N	P_2O_5	K_2O	N + P_2O_5 + K_2O
SSNM	58-78	29-39	24-34	266 – 377
STCR	60	20	40	200
RDF	40	20	20	150 – 250
Varieties	Ranjit and Gitesh			KMP 101

5.3 Management of micronutrients in rice-wheat system in sodic soil

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 soil salinity and alkalinity commonly observed in many rice growing regions in the arid and semi arid tracts in India. Crops grown on such problem soils encounter nutritional disorders and toxicities.

Rice is the most preferred crop in the reclamation of salt affected soils, estimated to cover about 8.6 Mha in India, for its tolerance to the stress, and high requirement of water during the growing period. Optimum management of micronutrients is extremely important for sustainable crop production in such saline and alkaline / sodic soils. Alkaline soils are improved by chemical reclamation to enhance crop productivity which are characterized by high soil pH (8.5 - 11.0) and exchangeable sodium percentage (ESP) of more than 15, low organic matter content and presence of calcium carbonate granules which strongly modify the availability of micronutrients and soil / crop productivity. Zinc deficiency has been widely reported in such salt affected and also in near nuatral soils, while iron is often limiting to the crop due to high soil pH and presence of CaCO3 even in lowlands. Low availability of manganese has been reported in rice – wheat cropping systems in about 3.0 M ha particularly in light texured soils. Keeping these points in view, this trial was initiated in *kharif* 2010 at Kanpur and Mandya to study the direct, residual and cumulative effects of micronutrients on the nutrition and productivity of rice wheat cropping system in sodic soils. The trial was also extended to other locations in collaboration with Agronomists to cover near neutral and acid soils.

The treatments consisted of three levels of gypsum amendment (Control, 50% gypsum requirement [GR] and 100% GR) in main-plots and application of micronutrients viz., zinc (50 kg $ZnSO_4$/ha), zinc + iron (30 kg Fe- EDTA / ha), zinc + iron + manganese (30 kg $MnSO_4$/ha) in addition to recommended NPK (150-60-40 kg N-P_2O_5-K_2O/ha) with and without organic matter in the sub-plots. The soil type at Kanpur is clay loam with a pH of 9.8, CEC of 12.8 [cmol (p^+)/kg], EC of 0.96 (dS/m), ESP of 62 and micronutrient concentration of 0.48 mg/kg Zn, 4.16 mg/kg Fe and 2.30 mg/kg Mn. The results of the trial conducted in *kharif* 2010 are presented in Tables 5.3.1 to 5.3.3.

Rice productivity

Gypsum application up to 100% GR significantly improved rice productivity by 6-15% over contriol and 50%GR (Table 5.3.2) and straw yields by 7-15%. Number of panicles/sq.m and panicle weight also increased significantly by gypsum application at both the levels. The application of organic manures improved rice productivity by 23 per cent on an average, while the crop responded significantly only to zinc application increasing rice yield by 0.6 t/ha (30%) without organic manuring and by 0.2 t/ha (6.0%) in the presence of manures. Irrespective of organic manuring, rice yield improvement to Fe and Mn application was marginal. Highest grain (3.4 t/ha) and straw (4.8 t/ha) yields were recorded with the application of Zn, Fe and Mn combined with organic matter and NPK. Application of organic matter also influenced positively straw yields as well as yield parameters. Lowest grain and straw yields were recorded with NPK devoid of micronutrients and organic matter.

Nutrient uptake and utilization efficiency

The data on nutrient uptake recorded at Kanpur in sodic soils also showed the positive influence of gypsum application on nutrient uptake improving accumulation of all major (NPK) and micronutrients (Fe, Zn) in the dry matter up to 50% GR and up to 100%GR that of P, K and Zn uptake.

Soil application of zinc alone or in combination with iron improved crop nutrition, while organic manuring supplementing recommended NPK dose and / or along with zinc and iron (chelated form) substantially improved accumulation of all the nutrients. The impact of manganese application on crop nutrition, irrespect of organic manure application, was negligible on nutrient accumulation and rice productivity.

Nutrient use efficiency (NUE), in terms of grain production per unit weight of nutrient accumulation in the dry matter, improved with gypsum and micronutrient application particularly of N and Fe, while organic manuring along with micronutrients increased NUE of P and Fe resulting in reduced requirement of these nutrients including zinc (Table 5.3.3).

In summary, the study showed significant response of rice (in terms of yield and nutrient accumulation) to gypsum application at both 50 and 100% of requirement. Micronutrient management of supplementing zinc at 50 kg $ZnSO_4$/ha or combined application of zinc and iron (30 kg Fe-EDTA / ha) with or without organic manures improved rice productivity and utilization efficiency of nutrients like N, P and Fe that resulted in reduced requirement of these nutrients including zinc.

Trial 5.3.1 Management of micronutrients in rice - wheat cropping system in sodic soils

(*Kharif* 2010) Location: Kanpur

Parameter	Kanpur
Cropping system	Rice - Wheat
Variety	
Kharif (Rice)	CSR 13
Rabi (Wheat)	PBW343
RFD (Kg NPK/ha) *Kharif*	150:60:40
Soil Data	
% Clay	28.9
% Silt	32.6
% Sand	38.4
Soil Texture	Clay Loam
pH (1:1)	9.8
Organic carbon (%)	0.21
CEC [c mol(p^+)/kg]	12.8
EC (dS/m)	0.96
ESP (%)	62
Available N (kg/ha)	147
Available P_2O_5 (kg/ha)	54
Available K_2O (kg/ha)	298
Zn (kg/ha)	0.48
Fe (kg/ha)	4.16
Mn (kg/ha)	2.30

Trial 5.3.2 Management of micronutrients in rice - wheat cropping system in *sodic soils, rabi / kharif 2010) Location: Kanpur*

Rice and wheat productivity and nutrient uptake

Treatment	GY (t/ha)	SY (t/ha)	Nutrient uptake (kg/ha)			Micro – Nutrient uptake (g/ha)		Panicles/sq.m	Pan. wt (g)
			N	P	K	Fe	Zn		
Control	2.62	3.57	63.0	16.4	55.5	347.3	204.7	358	2.88
50% GR	3.01	4.18	71.6	18.8	73.0	457.0	-	370	3.24
100% GR	3.19	4.48	71.0	21.1	82.4	444.2	261.7	382	3.46
CD (0.05)	0.11	0.20	4.0	2.3	15.4	NS	NS	7.99	0.18
CV (%)	4.51	6.00	7.4	15.6	27.3	87.1	38.4	2.69	7.20
NPK	2.09	2.86	43.8	12.2	32.7	307.5	135.9	282	2.06
NPK + Zn	2.72	3.73	60.5	16.1	46.4	386.9	181.3	355	3.27
NPK + Zn + Fe	2.84	3.89	60.1	17.0	61.8	430.4	315.7	364	3.30
NPK + Zn + Fe + Mn	2.92	4.03	60.2	16.5	57.8	206.1	234.5	373	3.31
OM + NPK	3.03	4.22	67.3	16.0	51.0	441.9	172.4	383	3.35
OM + NPK + Zn	3.22	4.50	63.9	17.3	56.2	317.7	154.8	396	3.40
OM + NPK + Zn + Fe	3.31	4.63	73.3	18.5	62.5	446.1	224.0	400	3.41
OM + NPK + Zn + Fe + Mn	3.38	4.78	74.9	17.9	76.0	242.2	219.5	407	3.47
Expt. Mean	2.94	4.08	68.5	18.8	70.3	416.2	210.7	370	3.20
CD (0.05): Nutrients	0.17	0.23	7.1	2.9	17.9	NS	NS	13	0.19
M in S	NS	NS	12.6	NS	NS	52.4	NS	NS	NS
S in M	NS	NS	12.3	NS	NS	49. 2	NS	NS	NS
CV (%)	6.22	5.94	10.9	16.2	26.8	71.7	44.4	3.6	6.2

Trial 5.3.3 Management of micronutrients in rice - wheat cropping system in sodic soils *(kharif* 2010) Location: Kanpur

Nutrient utilization efficiency in rice

Treatment	Nutrient use effiency (kg grain /kg)			Nutrient use effiency (kg grain /g)		Nutrient requirement (kg/t)			Micronutrient requirement (g/kg)	
	N	P	K	Fe	Zn	N	P	K	Fe	Zn
Control	41.9	160.7	54.9	10.8	17.1	24.1	6.3	19.1	0.133	0.080
50% GR	43.0	162.7	50.7	13.1	-	23.7	6.2	22.5	0.150	-
100% GR	45.5	154.2	42.8	11.5	13.9	22.3	6.6	24.1	0.135	0.083
CD (0.05)	2.4	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	6.9	13.9	40.2	138.7	97.1	7.4	17.7	32.2	97.9	38.0
NPK	41.7	151.4	65.0	6.7	22.0	24.0	6.7	15.7	0.169	0.076
NPK + Zn	40.6	158.9	59.6	8.5	14.7	24.9	6.6	17.2	0.154	0.075
NPK + Zn + Fe	43.4	151.2	45.2	13.8	10.9	23.4	6.6	22.4	0.158	0.132
NPK + Zn + Fe + Mn	43.5	158.4	54.9	13.3	12.0	23.1	6.3	20.2	0.079	0.092
OM + NPK	40.2	168.6	60.9	8.7	21.9	24.9	5.9	17.1	0.156	0.063
OM + NPK + Zn	45.2	166.4	56.0	9.0	26.7	22.5	6.0	17.9	0.113	0.053
OM + NPK + Zn + Fe	40.4	160.9	53.1	11.6	13.7	24.8	6.3	19.5	0.150	0.076
OM + NPK + Zn + Fe + Mn	40.4	169.6	44.9	14.9	15.0	24.9	6.0	23.1	0.082	0.071
Expt. mean	43.5	159.2	49.5	11.8	15.5	23.4	6.4	21.9	0.139	.082
CD (0.05): Nutrients	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
M in S	7.7	NS	NS	NS	NS	3.9	NS	NS	0.2	NS
S in M	7.6	NS	NS	NS	NS	3.8	NS	NS	0.2	NS
CV (%)	10.6	13.0	33.4	76.9	66.5	9.8	15.0	28.0	65.9	49.3

5.4 Screening rice germplasm for high iron and zinc contents

Biofortification with micronutrients of cultivars of staple food crops like rice by utilizing the rich genetic variation in rice germplasm is one of the important options available to fight malnutrition of iron (Fe) and zinc (Zn), which are reported to be widely deficient in rice eating population. In order to identify promising and stable rice germplasm for high Fe and Zn content in the endosperm and assess the influence of environment on the accumulation of micronutrients in the grain this trial was conducted during *kharif* 2010 at 11 locations (Aduthurai, Chinsurah, Faizabad, Kanpur, Karaikal, Khudwani, Mandya, Maruteru, Moncompu, Raipur and Titabar) of diverse environments and productivity potential. About 185 cultures including common set of 4 promising cultures (Aghonibora, Profulla, TKM 9 and Vasumathi) were screened at these locations for studying the influence of location environment on the nutrient contents in brown rice. Dehusked (brown rice) samples from all the centres were analyzed for Fe and Zn concentration by atomic absorption spectrophotometry at DRR and results presented in Tables 5.4.1 to 5.4.7 are discussed briefly.

Grain yield

Grain yields of common set of cultures received from 10 locations showed significant genotype variation in productivity between the locations. Mean yields of the cultures varied from 2.5 to 4.8 t/ha across locations (Table 5.4.2). Low yielding environments were at Faizabad and Raipur where few cultures like TKM 9 and Aghonibora yielded well (~4.0 t/ha) compared to other cultures. Comparatively the yields were higher in neutral alluvial, and medium textured acid soils at Aduthurai, Kanpur, Bankura, Moncompu and Titabar. Among the cultures Aghonibora at Moncompu, Bankura and Aduthurai, Profulla at Kanpur, and TKM 9 at Moncompu recorded high grain yields of 5.8 to 6.9 t/ha, while Vasumathi yielded low between 1.4 to 4.8 t/ha (average – 3.6 t/ha). Cultures like TKM 9 and Aghonibora showed some stability in yields among the test locations.

Micronutrient (Zn, Fe) accumulation in brown rice

The accumulation of zinc and iron in the brown rice (dehusked, unpolished) was analyzed in the common set of cultures, where at ten locations complete data set was available to study the influence of environment on the nutrient contents as mediated through variation in rice productivity. With few exceptions the zinc and iron contents ranged from 17 – 51 ppm and 7- 61 ppm, respectively (Table 5.4.2). Variety wise Zn content ranged from 21 – 33, 17 – 31, 24 – 51 and 22 – 39 ppm in Aghonibora, Profulla, TKM 9 and Vasumathi, respectively while Fe content varied from 18 – 28, 10 – 25, 13 – 61 and 9 – 37 indicating apparent influence of environment on grain Fe content. The Zn contents in brown rice were relatively stable compared to that of iron concentration.

The micronutrient accumulation in brown rice and grain yields were further analyzed for assessing the relationship with rice productivity. The influence of location and varietal effects on grain yield and Zn content, and of location effects on Fe content in grain were significant with strong interaction effects of locations and varieties on Fe content indicating differential accumulation of Fe in brown rice in the test locations. On the other hand data on total uptake of Fe and Zn in the dry matter (Table 5.4.3) indicated significant location, genotype and interaction effects on Zn uptake, while Fe uptake varied only with the locations. Correlation analysis of iron and zinc contents with the grain yields of each variety across the locations, however, was non significant (Table 5.4.2) for all the genotypes.

Promising cultures for zinc and iron content in brown rice

About 185 germ plasm and improved lines besides the common entries were screened for their relative potential to accumulate iron and zinc in the rice grain. The data presented in the Table 5.4.4

indicated mean zinc and iron content in brown rice across the test locations ranged from 20 – 32 ppm Zn and 15 – 35 ppm of Fe. Higher zinc and iron contents were recorded at Moncompu and Aduthurai, respectively. Promising cultures showing higher Zn and Fe contents (> mean + SD) were specific to locations. Among the four check varieties cultures TKM 9 and Profulla showed promise in many southern and eastern India locations for higher Fe and / or Zn contents while cultures like Aghonibora and Vasumathi were promising at Mandya, Maruteru and Moncompu (Tables 5.4.5 to 5.4.7). In addition to the above, among the test cultures few location specific traditional cultures like Njavara group at Moncompu, Pathani 23 and Jodumani at from Karaikal, swarna sub 1 at Kanpur, few NDR and scented cultures at Faizabad and Khudwani, resectively and Bhutmuri at Bankura were promising for high zinc and / or iron content. Cultures identified for high contents of both Fe and Zn in the brown rice (listed in the Table 5.4.7) were MDR 6311, Swarna sub 1, Sughand pusa – 5, Pathani 23, Jodumani' BR 2655 and Bhutmuri.

Summarising, the study was conducted at 11 locations screening about 185 cultures which also included four varieties (checks) to study the influence of environment on rice productivity and micronutrient contents was significant. The influence of location and varietal effects on grain yields and concentration and uptake of Zn and of location effects on Fe contents / accumulation in grain were significant with strong interaction effects. However, the relationship between Fe and zinc contents in brown rice and grain yield was not significant despite observed variations in grain yields and micronutrient contents for all the common set of genotypes evaluated. Several location specific promising cultures for high Fe and Zn content were identified which included the Njavara group at Moncompu, Pathani 23 and Jodumani at Karaikal, Swarna sub 1 at Kanpur, few NDR and scented cultures at Faizabad and Khudwani, respectively and Bhutmuri at Bankura.

Table 5.4.1 Screening of rice germplasm for high iron and zinc contents, *kharif* 2010
Site characteristics

Parameters	BNK	FZB	KNP	KRK	KDW	MND	MTU	MCP	RPR	ADT	TTB
% clay	-	23	19.8	18.4	-	9.8	-	29.9	39	-	45
% silt	-	21	23.6	5	-	20.2	-	21.3	36	-	32
% sand	-	56	56.4	71.25	-	70.0	-	41.8	25	-	23
Texture	-	Sa. loam	Sa. loam	Sa. loam	Si. Cl. loam	Sandy loam	-	Si. clay	Cl. loam	Clay loam	Silty clay
pH	-	7.5	7.9	7.6	-	6.68	7.2	6.35	7.8	7.85	5.5
OC (%)	-	0.42	0.49	0.43	-	0.38	0.65	-	0.51	0.54	1.15
CEC [c mol (p^+)/kg]	-	13.82	14.7	20.65	-	-	-	15.12	38	36	11.85
EC (dSm^{-1})	-	1.02	0.45	0.22	-	--	0.49	0.12	0.17	O,24	0,15
Avail.Zn (ppm)	-	-	0.78	-	-	0.50	-	-	1.3	0.8	0.88
Avail.Fe (ppm)	-	-	8.15	-	-	-	-	-	21.03	12.4	26.5
No. of entries	13	20	13	17	21	3	2	17	23	1	16
Common entries	4	4	4	3	-	4	4	4	4	4	4
Total	17	24	17	20	21	7	6	21	27	5	20

Table 5.4.2 Screening of rice germplasm for high iron and zinc contents, *kharif* 2010

Relationship between grain yield and Zn & Fe content (mg/kg) in BR of common entries

Cultures	ADT	BNK	FZB	KNP	KRK	MND	MTU	MCP	RPR	TTB
Grain yield (kg/ha) of common varieties										
Aghonibora	5978	6000	3986	4556	4609	2607	4367	6850	3264	5410
Profulla	3960	3357	2966	6111	-	4663	4090	1760	1389	4783
TKM-9	5088	4183	3329	3444	4388	4233	3938	5833	4025	4133
Vasumathi	4315	4750	3392	4667	2783	3435	3390	4575	1389	3517
Mean	4565	4573	3418	4695	3927	3735	3946	4755	2517	4461
CD (0.05)	338	343	175	1328	432	774	398	1224	839	489
CV (%)	3.9	4.5	2.6	15.6	9.2	9.2	5.0	12.9	17.6	34.5
Zinc content (ppm) in brown rice of common varieties										
Aghonibora	30.3	26.4	24.0	25.0	23.9	33.2	20.9	32.5	29.3	25.0
Profulla	20.6	20.0	17.1	26.1	-	27.0	25.7	30.8	25.5	19.4
TKM-9	42.6	25.7	26.9	23.6	26.9	29.5	29.0	40.0	28.3	50.9
Vasumathi	24.1	21.9	26.7	25.6	23.0	26.9	38.8	30.3	26.7	26.1
CD (0.05) - Zn	Loc.	6.4	Var.	4.4	L x V	NS	CV (%)	23.5	-	-
Iron content (ppm) in brown rice of common varieties										
Aghonibora	29.1	23.4	13.6	27.8	20.8	21.4	24.4	22.5	18.4	7.2
Profulla	25.4	22.8	9.5	44.5	-	13.0	17.8	25.9	22.9	9.7
TKM-9	60.8	19.1	13.2	22.5	23.6	20.6	16.0	23.4	46.3	27.0
Vasumathi	21.2	17.6	21.7	25.5	27.1	20.5	15.2	20.5	36.8	8.9
CD (0.05) - Fe	Loc.	26.2	Var.	NS	L x V	45.5	CV (%)	79.3	-	-

Correlation coefficients (grain yield Vs micronutrient contents in BR)

Variety	Iron	Zinc
Aghonibora	0.3247	0.2113
Profulla	0.1851	0.3205
TKM-9	0.3058	0.2636
Vasumathi	-0.0888	0.0655
CD (0.05)	NS*	NS*

* *Non significant for all the varieties*

Table 5.4.3 Screening of rice germplasm for high iron and zinc contents, *kharif* 2010

Location and genotype effects on accumulation of Fe and Zn in the total dry matter

Cultures	ADT	BNK	FZB	KNP	KRK	MND	MTU	MCP	RPR	TTB
Zinc uptake (g/ha) in common varieties										
Aghonibora	433	507	291	-	-	-	307	660	320	-
Profulla	193	363	197	-	-	-	234	305	179	-
TKM-9	419	472	352	-	-	-	232	997	345	-
Vasumathi	227	708	345	-	-	-	405	632	367	-
Mean Zn	318	512	296	-	-	-	295	649	302	-
CD (0.05) - Zn	Loc.	83	Var.	40.4	L x V	99	CV (%)	15.1	-	-
Iron uptake (g/ha) in common varieties										
Aghonibora	1454	679	406	-	-	-	1270	3139	514	-
Profulla	812	746	363	-	-	-	1607	1718	743	-
TKM-9	1966	714	330	-	-	-	903	2827	527	-
Vasumathi	885	1202	490	-	-	-	888	1829	602	-
Mean Fe	1279	835	397	-	-	-	1167	2378	597	-
CD (0.05) - Fe	Loc.	320	Var.	NS	L x V	NS	CV (%)	60.8	-	-

Table 5.4.4 Screening of rice germplasm for high iron and zinc contents, *kharif* 2010

Zinc and iron content (mg/kg) in brown rice of genotypes grown at different locations

Genotypes	Fe	Zn	Genotypes	Fe	Zn	Genotypes	Fe	Zn	Genotypes	Fe	Zn	Genotypes	Fe	Zn
Bankura			Faizabad			Kanpur			Khudwani			Maruteru		
Aghonibora	23.4	24.4	Aghonibora	13.6	24.0	Aghonibora	27.8	25.0	SKAU-23	21.5	20.6	Aghonibora	16.9	20.9
Prafulla	22.8	20.0	Prafulla	9.5	17.1	Prafulla	44.5	26.1	SugandhiPusa-5	49.3	25.7	TKM-9	21.8	25.7
TKM-9	19.1	25.7	TKM-9	13.2	26.9	TKM-9	22.5	23.6	K-116	27.8	24.5	Prafulla	24.4	29.0
Vasumathi	17.6	21.9	Vasumathi	21.7	26.7	Vasumathi	25.5	25.6	SKAU-382	14.3	20.6	Vasumathi	30.5	38.8
Netadhan	26.3	29.6	MDR-6311	48.0	34.9	Jaya	20.2	21.7	SKAU-405	13.6	14.8	MTU-7029	27.5	24.9
Bhutmuri	40.0	34.8	MDR-6239	20.4	28.1	Plant-10	23.9	24.2	SKAU-389	19.3	21.0	BPT-5204	31.4	34.0
Davan sail	56.3	30.1	MDR-3512	31.0	28.9	Narendra-118	17.9	25.4	China-988	13.6	19.5			
IET 19886	29.0	22.8	MDR-3408	64.4	29.1	NDR-2008	41.6	22.2	Kamad	8.3	12.7	Mean	25.4	28.9
IET 20761	22.1	27.8	MDR-3539	13.5	20.8	User-3	27.6	29.6	China-1039	10.9	17.6	SD	5.5	6.6
IET 20760	18.5	28.1	MDR-5088	13.2	20.6	User-2	28.7	29.7	SKAU-98	16.7	16.7			
Bhadabhog	22.9	29.9	MDR-3105	19.4	22.7	PB-1	40.0	28.2	SKAU-337	13.7	20.1			
Danaguri	26.6	31.4	MDR-3112	11.7	21.2	Swarna sub-1	44.8	46.1	SKAU-341	16.1	15.9			
Moti	26.4	26.1	MDR-2062	13.7	21.3	CSR-23	26.1	29.8	Jehlum	8.7	15.3			
Sabitri	18.2	23.2	MDR-2026	14.8	22.8	CSR-36	24.3	25.7	Shalimar Rice-1	11.0	18.7			
Gayatri	20.1	24.6	MDR-359	13.0	22.4	Sarjoo-53	21.2	27.4	China-1007	9.8	21.1			
Varsadhan	14.8	22.7	MDR-274-52	12.3	22.5	PA-644	21.2	24.4	SKAU-5	12.5	26.1			
Durga	19.5	28.3	MDR-Mlalmat	36.7	34.7	Ramraj	23.7	26.7	SKAU-292	8.9	19.0			
			MDR-susksm2	53.1	45.0				SKAU-334	14.9	23.7			
			MDR-Baranidee	16.8	25.2	Mean	28.3	27.1	SKAU-338	15.3	24.3			
Mean	24.9	26.5	MDR-118	20.7	26.0	SD	8.8	5.5	SKAU-336	13.4	21.7			
SD	9.9	3.9	MDR-97	27.8	26.9				SKAU-339	13.0	17.5			
			MDR-2064	18.6	23.9									
			MDR-2084	18.7	23.2				Mean	15.8	19.9			
			MDR2065-	19.7	28.1				SD	8.9	3.7			
			Mean	22.7	26.0									
			SD	14.3	5.8									

Table 5.4.4 (contd.) Screening of rice germplasm for high iron and zinc contents, *kharif* 2010
Zinc and iron content (mg/kg) in brown rice of genotypes grown at different locations

Genotypes	Fe	Zn	Genotypes	Fe	Zn	Genotypes	Fe	Zn	Genotypes	Fe	Zn	Genotypes	Fe	Zn
Mandya			Karaikal			Moncompu			Raipur			Titabar		
KCP-1	11.9	27.5	Aghonibora	20.8	23.9	Aghonibora	22.5	32.5	IR-36	16.7	25.4	Aghonibora	19.9	25.0
TKM-9	13.0	29.5	TKM-9	23.6	26.9	Prafulla	23.6	30.8	Khitish	9.4	44.6	Prafulla	34.4	19.4
Aghonibora	21.4	33.2	Vasumathi	27.1	23.0	TKM-9	23.4	40.0	ADT-43	18.1	29.1	TKM-9	30.9	50.9
Prafulla	13.0	27.0	NDR-6279	22.7	23.1	Vasumathi	21.9	30.3	NDR-6279	21.3	42.7	Vasumathi	17.8	26.1
Vasumathi	20.5	26.9	Ormanyoor Anakodam	28.8	24.0	Vyttila-1	14.5	29.0	Jehlum	26.7	28.1	WL-9	9.5	21.5
Vikas	13.3	26.9	Chittivirippu Kannamali	24.2	29.6	Vyttila-2	13.4	28.0	Aghonibora	18.4	29.6	Bahadur	26.4	31.2
Thanu	11.8	24.8	Chilrakin Pokkali	28.6	24.0	Vyttila-3	11.1	29.6	NDR-359	24.3	31.6	Kushal	11.5	22.7
			Ponnarayan	32.5	24.9	Vyttila-4	10.5	26.9	MTU-1001	23.9	33.3	WL-2	13.7	21.9
Mean	16.0	27.8	Edavankadu Pokkali	41.6	35.1	Vyttila-5	13.6	32.5	MTU-3626	38.2	28.4	WL-13	13.1	22.4
SD	4.6	3.2	Kadamakuady Pokkali	23.2	21.0	Vyttila-8	8.7	26.8	Prafulla	23.1	25.5	WL-3	11.3	17.3
			Pathani-23	39.5	37.0	Bhagya	11.0	26.7	Shalimar Rice-1	26.2	30.9	WL-10	14.7	20.4
			Jodumani	57.0	38.2	Onam	12.4	26.4	ADT-45	37.7	23.6	WL-12	14.3	21.6
			Gouri	17.8	27.8	Chingam	9.2	30.9	ADT-a7	40.2	24.4	WL-4	19.3	18.7
Aduthurai			Chittanai	17.5	22.3	Manupriya	9.2	24.9	Gouri	35.3	29.3	WL-7	26.0	20.8
			Njavara	19.7	19.9	Njavara-1	13.3	33.8	Pavizham	33.6	31.4	Gitesh	16.9	31.7
Aghonibora	29.1	30.3	K.Vedarantam	16.4	20.4	Njavara-7	9.0	36.9	Vasumathi	36.4	26.7	WL-6	25.4	30.6
Prafulla	25.4	20.6	MTU-3626	13.0	22.3	Njavara-15-2	9.3	35.3	Thanu	29.4	27.7	WL-1	22.4	21.8
TKM-9	60.8	42.6	Sivappu Kompalain	14.7	24.2	Njavara-16-b1	13.5	30.3	BR-2655	47.7	42.1	Bankisali(L)	23.2	24.1
Vasumathi	21.2	24.1	Chityan Kottai	15.3	24.8	Njavara-16-b2	14.6	36.4	ADT-36	41.6	27.0	Baishmuti(L)	22.2	20.2
ADT 45	40.0	34.0	Vattan	14.0	26.1	Njavara-16-e3	29.0	35.1	ADT-37	33.0	31.0	WL-11	11.5	12.5
						Njavara-16-f2-2	16.9	32.8	TKM-9	46.3	28.3			
Mean	35.3	30.3	Mean	24.9	25.9	Njavara-17-7	28.2	32.4	Chandrahasini	44.6	26.6	Mean	19.2	24.0
SD	15.8	8.6	SD	11.0	5.3	Njavara-18-1-2	13.7	33.6	Karmamahshuri	54.6	29.2	SD	7.0	7.9
						Njavara-22	15.8	33.9	Karhanni	35.6	36.2			
						Njavara-23	13.2	32.3	Mainpuri	21.4	41.2			
									Mahamaya	21.3	25.3			
						Mean	15.3	31.5	Dubraj	16.6	26.1			
						SD	6.0	3.7	Mean	30.4	30.6			
									SD	11.3	5.9			

Table 5.4.5 Screening of rice germplasm for high iron and zinc contents, *kharif* 2010

Promising cultures with higher concentration of Zn in brown rice

Location	Zn content in BR (ppm)	Cultures
Faizabad	35.0 – 45.0	MDR-6311, MDR-susksm2
Kanpur	46.0	Swarna sub-1
Karaikal	37.0 - 38.0	Pathani-23, Jodumani,
Khudwani	24.0 - 26.0	SugandhiPusa-5, K-116, SKAU-5, SKAU-334, SKAU-338
Mandya	21.5	Aghonibora
Maruteru	39.0	Vasumathi
Moncompu	35.0 - 40.0	TKM-9, Njavara-7, Njavara-15-2, Njavara-16-B2
Raipur	41.0 – 42.0	BR-2655, Mainpuri
Titabar	51.0	TKM-9
Bankura	35.0	Bhutmuri
Aduthurai	42.5	TKM-9

Table 5.4.6 Screening of rice germplasm for high iron and zinc contents, *kharif* 2010

Promising cultures with higher concentration of Fe in brown rice

Location	Fe content in BR (ppm)	Cultures
Faizabad	48.0 – 64.0	MDR-6311, MDR-susksm2, MDR-3408,
Kanpur	40.0 – 45.0	NDR-2008, Prafulla, PB-1, Swarna sub-1
Karaikal	40.0 - 57.0	Edavankadu Pokkali, Pathani-23, Jodumani
Khudwani	28.0 – 49.0	SugandhiPusa-5, K-116
Mandya	33.0	Aghonibora
Maruteru	31.5	BPT-5204
Moncompu	22.0 – 29.0	Aghonibora, Prafulla, TKM-9, Vasumathi, Njavara-16-E3, Njavara-17-7
Raipur	45.0 – 55.0	BR-2655, TKM-9, Chandrahasini, Karmamahshuri
Titabar	31.0 - 34.5	TKM-9, Prafulla, Bahadur
Bankura	40.0 - 56.0	Davan sail, Bhutmuri
Aduthurai	61.0	TKM-9

Table 5.4.7: Screening of rice germplasm for high iron and zinc contents, *kharif* 2010

Promising cultures with higher concentration of both Zn and Fe in brown rice

Location	Cultures
Faizabad	MDR-6311, MDR-susksm2
Kanpur	Swarna sub-1
Karaikal	Pathani-23, Jodumani,
Khudwani	SugandhiPusa-5, K-116,
Mandya	Aghonibora
Raipur	BR-2655
Titabar	TKM-9
Bankura	Bhutmuri
Aduthurai	TKM-9

5.5 Nutrient and water requirement for aerobic rice cultivation

Irrigated or shallow lowland rice, depending on the season and the site characteristics, consumes about 1500 - 2500 mm water, and much of it is lost through deep percolation and seepage. In the wake of declining availability of water (due to other sectoral demands) rice is one crop that is affected most. Aerobic rice, an evolving system of rice cultivation, aims at optimizing irrigation water use up to 70-100% of maximum water holding capacity of the soil under controlled conditions and involving improved and water efficient rice varieties without penalty on yield levels equivalent to that of irrigated wetland rice. Nutrients, which have strong interaction effects with water, also contribute to the overall productivity of water. Keeping this in view, a trial has been initiated in kharif 2010 at two sites representing Indogangetic plains (Kanpur, UP) and Deccan Plateau (DRR) to assess relative efficiency of utilizing water and nutrient requirements under aerobic rice cultivation (non-puddled, direct sown and near saturated field water regime). The trial has also been extended to several locations under Agronomy program. Data of *kharif* 2010 received from the two centres are presented in Tables 5.5.1 to 5.5.5 and summarized hereunder briefly. The treatments consisted of three water regimes (irrigation equivalent to CPE 150, 100 and 75 per cent) with combination of nutrient (NPK) applications having 4 N levels, and 3 each of P and K. The soils at the test sites were of near neutral pH (7.8 – 8.0), sandy loam and clay textured, low to medium in organic carbon content (0.4 – 0.7%) and available N status, and low to medium in P and K status (Table 5.5.1).

Data presented in Table 5.5.2 show non significant effect of water regimes on grain and straw yields except for straw yield at DRR where irrigation equivalent to 100% of cumulative pan evaporation (CPE) recorded highest straw production of 6.9 t / ha to the aerobic crop. Average rice productivity was 4.1 and 3.5 t/ha, respectively at DRR and Kanpur. Response to applied nutrients (based on mean yield) was significant for only N at DRR up to 60 kg N/ha, and for N and P at Kanpur up to 120 kgN/ha and 60 kg P2O5 /ha, respectively increasing the yield by 1.2 t / ha at DRR with N application and by about 1.2 and 0.3 – 0.6 t/ha, respectively with N and P application in the IGP (Kanpur).The response K application was, however, low (non -significant) ranging from 0.25 to 0.4 t/ha increase

Data on the nutrient uptake (Tables 5.5.4 and 5.5.5) indicate non significant effect of water regimes for all the major nutrients at both locations possibly due to interference of rainfall during the season which was about 715 and 800 mm at Kanpur and DRR during the cropping season although irrigation was regulated based on pan evaporation data. Application of nutrients influenced positively with significant improvement in N and K accumulation in dry matter up to 60 kg N and 100 kg K / ha at DRR, while at Kanpur the effects were significant for the uptake of all nutrients increasing uptakes up to 120, 60 and 50 kg/ha of NPK application. Maximum uptake of nutrients was recorded with 180, 60 and 100 kg NPK levels at both the locations. At the highest yield level of 5.2 and 4.0 t / ha at DRR and Kanpur, the crop accumulated respectively 105, 40 and 136 kg/ha of NPK, and 75, 22 and 85 kg NPK/ha. This works out to a nutrient uptake requirement of 20.3, 7.6 and 25.9 Kg NPK / t of grain at DRR, and 18.4, 5.4 and 21 kg of NPK /t grain production at Kanpur indicating low utilization efficiency of K.

The productivity of irrigation water including rainfall was estimated by measuring the quantum of water used and effective rainfall (70% under aerobic conditions) besides including about 50 mm irrigation water required for land preparation of aerobic rice field (Table 5.5.6). About 970, 1073 and 1227 mm at DRR and 737, 770 and 920 mm of water (including effective rainfall) was used during the season at DRR and Kanpur, respectively imposing the three water regimes. Water productivity (kg grain/mm water used) ranged from 4.0 – 4.6 at Kanpur and 3.9 to 4.8 kg grain / mm water at DRR depending on the water regime. This works out to a water requirement of 2066 - 2160 l/kg with irrigation equivalent to 75% CPE, compared to 2165 to 2545 l/kg grain yield at these locations with other two water regimes. Comparatively lesser water requirement recorded at Kanpur perhaps indicates the influence of ground water table on the percolation of irrigation water. Although grain yield with different water regimes did not differ much, based on the recorded water productivity, irrigation equivalent to 100% of cumulative pan evaporation appeared to be optimum for aerobic rice system at both these locations with no yield loss, while saving about 16.3 and 12.5 per cent of irrigation water at Kanpur and DRR, respectively.

Summarizing the results, the study indicated no effect of water regimes on the performance of aerobic rice (non-puddled, direct sown and near saturated field water regime) at DRR and Kanpur. Response to applied nutrients (based on mean yield) was significant for N at DRR and for N and P at Kanpur increasing grain yield by 1.2 t / ha at DRR, and by about 1.2 and 0.3 – 0.6 t/ha, respectively with N and P application in the IGP (Kanpur). Application of nutrients improved N and K accumulation up to 60 and 100 kg / ha, respectively at DRR and increased uptake of all the nutrients up to 120, 60 and 50 kg/ha of NPK application at Kanpur. At the highest yield level of 5.2 and 4.0 t / ha at DRR and Kanpur, the nutrient uptake requirement was estimated to be 20.3, 7.6 and 25.9 Kg and 18.4, 5.4 and 21 kg NPK /t grain at DRR and Kanpur. Water productivity (kg grain/mm water used) ranged from 4.0 – 4.6 at Kanpur and 3.9 to 4.8 kg grain / mm water at DRR depending on the water regime, based on which irrigation equivalent to 100% of cumulative pan evaporation (CPE) appeared to be optimum for aerobic rice system at the test locations without yield loss and saving, respectively 16.3 and 12.5 per cent of irrigation water.

Table: 5.5.1 Nutrient and water requirement for aerobic rice cultivation, *Kharif* 2010

Soil, Crop and Weather data

Parameter	Kanpur	DRR
Crop		
Variety	NDR 359	PA 6444
Crop growth	Good	Good
Rec. fert. Dose (KgNPK/ha)	As per treatments	As per treatments
Soil		
% Clay	20.1	52
% Silt	23.8	22
% Sand	56.1	24
Soil texture	Sandy loam	Clay
pH(1:2)	7.8	8.0
Org.carbon (%)	0.4	0.72
CEC (me/100g)	-	-
EC (dS/m)	0.6	-
Avail.N (kg/ha)	232	265
Avail. P_2O_5 (kg/ha)	54	24.0
Avail. K_2O (kg/ha)	335	402

Table 5.5.2 Nutrient and water requirement for aerobic rice cultivation, *kharif 2010*

Yield and yield parameters

Treatments	Grain yield (t/ha)		Straw yield (t/ha)	
	DRR	Kanpur	DRR	Kanpur
Water regimes				
IW/CPE-150%	4824	3636	5792	4691
IW/CPE-100%	4834	3509	6858	4549
IW/CPE-75%	4691	3413	5951	4415
CD(0.05)	NS	NS	733	NS
CV (%)	28.1	10.3	14.7	9.3
Nutrient application				
$N_0P_{60}K_{100}$	3619	2638	3613	3637
$N_{120}P_0K_{100}$	4786	3290	6933	4275
$N_{120}P_{60}K_0$	4993	3638	6485	4694
$N_{60}P_{60}K_{100}$	4869	3317	5714	4253
$N_{120}P_{30}K_{100}$	4748	3565	6453	4651
$N_{120}P_{60}K_{50}$	4831	3897	6732	4935
$N_{120}P_{60}K_{100}$	5226	3762	6185	4798
$N_{180}P_{60}K_{100}$	5191	4046	7485	5169
Expt. Mean	4116	3519	6200	4552
Nutrients	875	189	1269	214
M in S	NS	NS	NS	NS
S in M	NS	NS	NS	NS
CV (%)	19.2	5.6	21.5	4.9

Table 5.5.4 Nutrient and water requirement for aerobic rice cultivation, *Kharif* 2010

Nutrient uptake (kg/ha) (location: DRR)

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%	99.3	41.3	119.3	49.5	118.3	40.5	20.7	8.6	24.6
IW/CPE-100%	95.1	40.0	146.2	52.0	123.1	36.0	20.9	8.4	21.9
IW/CPE-75%	101.7	39.0	123.3	48.0	120.8	40.6	22.6	8.5	24.6
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	1.0
CV (%)	25.1	11.1	36.2	25.4	19.2	28.7	33.8	18.9	14.5
$N_0P_{60}K_{100}$	59.7	29.6	75.3	61.9	124.6	49.2	17.0	8.2	20.3
$N_{120}P_0K_{100}$	90.5	40.9	126.9	52.3	120.1	37.6	19.9	8.6	26.5
$N_{120}P_{60}K_0$	109.3	44.5	127.1	45.8	111.5	40.6	22.8	9.0	24.6
$N_{60}P_{60}K_{100}$	103.2	42.4	123.5	48.6	116.0	40.9	21.8	8.9	24.4
$N_{120}P_{30}K_{100}$	97.9	40.1	163.6	49.1	120.2	32.9	20.8	8.4	30.3
$N_{120}P_{60}K_{50}$	103.6	40.1	121.2	46.5	121.8	38.9	23.7	8.6	25.7
$N_{120}P_{60}K_{100}$	104.6	40.3	135.9	50.0	133.1	38.6	20.3	7.6	25.9
$N_{180}P_{60}K_{100}$	120.5	43.3	163.2	44.5	118.7	33.3	24.8	8.6	30.0
Expt. Mean	98.7	40.1	129.6	49.8	120.7	39.0	21.4	8.5	23.7
Nutrients	22.9	8.1	40.3	10.1	NS	NS	NS	NS	NS
M in S	NS	NS	NS	NS	NS	NS	NS	NS	NS
S in M	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	24.4	21.2	32.7	21.2	15.0	27.7	25.7	14.8	29.2

Table 5.5.5 Nutrient and water requirement for aerobic rice cultivation, *Kharif* 2010
Nutrient uptake (kg/ha) (location: Kanpur)

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%	67.1	19.6	74.8	54.3	187.2	48.7	18.4	5.4	20.6
IW/CPE-100%	63.9	18.4	71.8	55.0	192.6	48.9	18.2	5.2	20.5
IW/CPE-75%	61.7	17.4	69.0	55.5	198.2	49.5	18.0	5.1	20.2
CD(0.05)	NS	NS	NS	0.8	4.0	NS	0.3	0.1	NS
CV (%)	9.9	12.1	10.5	1.9	2.6	2.0	1.8	2.6	2.2
$N_0P_{60}K_{100}$	46.8	13.3	55.2	56.4	200.0	47.8	17.7	5.0	20.9
$N_{120}P_0K_{100}$	59.3	15.1	67.4	55.5	218.9	48.8	18.0	4.6	20.5
$N_{120}P_{60}K_0$	67.3	20.0	69.4	54.1	182.6	52.4	18.5	5.5	19.1
$N_{60}P_{60}K_{100}$	59.3	17.3	66.2	55.9	192.1	50.2	17.9	5.2	20.0
$N_{120}P_{30}K_{100}$	65.5	18.2	74.6	54.4	196.4	47.8	18.4	5.1	21.0
$N_{120}P_{60}K_{50}$	72.4	22.1	78.5	53.9	177.4	49.7	18.6	5.7	20.1
$N_{120}P_{60}K_{100}$	68.7	20.0	78.3	54.8	188.9	48.1	18.3	5.3	20.8
$N_{180}P_{60}K_{100}$	74.5	21.9	85.1	54.4	185.1	47.6	18.4	5.4	21.0
Expt. Mean	64.2	18.5	71.9	54.9	192.7	49.0	18.2	5.2	20.4
Nutrients	3.7	1.2	3.7	1.0	7.5	1.6	0.3	0.2	0.7
M in S	NS	NS	NS	NS	NS	NS	NS	NS	NS
S in M	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	6.1	6.9	5.4	1.9	4.1	3.4	1.9	3.9	3.5

Table 5.5.6 Nutrient and water requirement for aerobic rice cultivation, *Kharif* 2010
Water productivity under different water regimes

Water regimes	Water input including rainfall*(mm)		Mean yield (kg/ha)		Water productivity (kg grain/mm)		Water requirement (litres/kg grain)	
	Kanpur	DRR	Kanpur	DRR	Kanpur	DRR	Kanpur	DRR
IW/CPE-150%	920	1227	3636	4824	3.95	3.93	2532	2545
IW/CPE-100%	770	1073	3509	4834	4.62	4.51	2165	2217
IW/CPE-75%	737	970	3413	4691	4.63	4.84	2160	2066

** Includes water applied through irrigation, effective rainfall during the crop growth and about 50 mm used for land preparation. Figures in parentheses are per cent water saved and requirement. **Rainfall ~715 and 800mm at Kanpur and DRR, respectively,*

5.6 Management of crop residues in rice based cropping systems

Crop residues of cereals and N-fixing legumes and green manures are good sources of plant nutrients and are important components for sustainable agricultural productivity. About 400 M. tons of crop residues are produced in the country annually which can contribute more than 6 M. tons of plant nutrients. With the advent of mechanized harvesting, substantial quantities of these residues are being burnt *in situ* to facilitate seeding operations of the next crop, which cause loss of nutrients, organic matter and biological activity in the soil. In the rice-wheat cropping system alone about 12-16 M. tons of crop residues are burnt. Unlike removal or burning, recycling of straw can build up soil organic matter, and improve soil nutrient (N, P, K, S and Si) status upon its mineralization which, however, is generally slow due to wide C/N ratio, residue characteristics and soil edaphic conditions. Mineralization of cereal residues can be enhanced by mixing with green manures, fertilizer N or inoculation with microbial (fungal) cultures. An experiment was, therefore, initiated in *kharif* 2007 to evaluate management options for utilizing crop residues involving microbial cultures, N application and complementation with green manures in rice based cropping systems.

The trial was proposed for 7 locations and data received from these centres were compiled, analysed and presented in Tables 5.6.1 to 5.6.15.

Productivity of *Rabi* 2009-10 crop

Grain and straw yield data of *rabi* season crops (rice in Chinsurah, Karaikal and Maruteru and wheat in Faizabad, Ghaghraghat, Kanpur and Raipur) presented in Table 5.6.2 indicate significant differences in grain yield due to residue treatments at all centres except Karaikal, Maruteru and Raipur. Straw incorporation with green manure recorded the highest yields at Faizabad (3.91 t/ha), Ghaghraghat (2.31 t/h) and Kanpur (4.93 t/ha). Straw yields also followed similar trends as grain yields at Ghaghraghat and Kanpur. At Faizabad, the highest straw yield was recorded with straw burning and ash incorporation (7.82t/ha). The lowest yields were observed when straw removal at Faizabad (2.85t/ha) and Kanpur (3.51t/ha) while at Ghaghraghat it was with straw incorporation alone (1.78 t/ha). At Chinsurah, the highest grain and straw yields were recorded with straw and microbial incorporation (4.92 and 5.12 t/ha respectively) and the lowest yields were observed with straw removal (4.13 and 4.43 t/ha respectively).

Nutrient uptakes

Residue treatments were observed to contribute to increase in the uptake of major nutrients (NPK) in total dry matter (Table 5.6.3). N accumulation at Kanpur and Maruteru were highest with straw + green manure incorporation (133.8 and 63.7 kg/ha respectively) and with straw + microbial inoculum (106.5 kg/ha) at Chinsurah. N uptake at Karaikal did not show any significant differences between treatments. Lowest N uptake at all these locations were observed in treatments where straw was removed. Straw + microbial inoculum at Chinsurah (45.9 kg/ha) and Karaikal (69.6kg/ha), and straw + green manure incorporation at Maruteru (29.9 kg/ha) recorded the highest P uptake. No significant differences were observed for P uptake at Kanpur. K uptake did not differ significantly between treatments at Karaikal. Straw + green manure and straw + microbial culture incorporation recorded highest K uptake at Kanpur (111.3 kg/ha), Maruteru (123.7 kg/ha) and Chinsurah (116.9 kg/ha) respectively. Straw removal in general, reduced uptake of all the nutrients (NPK) at most of the locations while P uptake was lowest with application of straw at Karaikal.

Nutrient use efficiencies (Internal efficiency IE)

Nutrient use efficiencies of N, P and K were observed to be influenced by residue treatments at all the centers (Table 5.6.4). Straw + green manure incorporation and straw removal recorded the highest nitrogen use efficiency (NUE) at Chinsurah (52.7 kg/ka) and Maruteru (129.8 kg/kg) respectively while no treatment differences were observed for nitrogen use efficiency at Kanpur and Karaikal. A significant treatment difference for phosphorus use efficiency (PUE) was observed only at Karaikal; the highest PUE was recorded with straw burning and ash incorporation (62.5 kg/kg) perhaps due to the very low yield levels at this location. Highest potassium use efficiency (KUE) was obtained with straw removal treatment at Kanpur and Maruteru (49.4 kg/kg and 67.1 kg/kg respectively) and with straw incorporation at Chinsurah (51.5 kg/kg).

Nutrient requirements

Nitrogen, Phosphorus and Potassium requirement (NR, PR and KR respectively) was found to be affected by residue treatments (Table 5.6.5). Straw + green manure incorporation at Chinsurah and straw + 25% RDF-N at Maruteru were the most efficient treatments with the lowest NR (19.0 and 8.7 kg/t grain respectively). The highest NR at these centres was observed with straw + microbial inoculation at Chinsurah (21.7 kg/t grain) and straw + green manure at Maruteru (11.1kg/t grain). At Kanpur and Karaikal, no differences were observed between treatments for NR. Significant differences in PR were observed only at Chinsurah and Karaikal. PR was lowest with straw + green manure (7.7 kg/t grain) at Chinsurah and was highest with straw + microbial inoculum at Chinsurah (9.3 kg/t grain) and straw + green manure at Karaikal (47.1 kg/t grain). Residue treatments were found to have an influence on KR at Chinsurah, Kanpur and Maruteru. Incorporation of straw alone at Chinsurah (19.5 kg/t grain), removal of straw at Kanpur (20.2 kg/t grain) and Maruteru (14.9 kg/t grain) were the treatments that recorded the lowest KR.

Soil fertility status (Post *rabi* crop) 2009-10

Post harvest analysis of soils indicated significant differences in the soil nutrient status (Table 5.6.6). Available N increased in all treatments over straw removal was recorded at Kanpur and Maruteru which ranged from 5.0 kg/ha to 2 2 kg/ha at Kanpur and from 18.7 kg to 97 kg/ha at Maruteru. The highest increase in available N was observed with straw + green manure incorporation at both the centres. N balance was negative at Chinsurah with straw + 25% RDF-N incorporation (-17.5 kg/ha) , straw + green manure incorporation (-7.5 kg/ha) and straw + microbial inoculum (-16.2 kg/ha) over residue removal treatment. At Karaikal, positive increase in soil available N over straw removal was observed with straw + green manure incorporation (11.4 kg/ha) and straw + microbial inoculum (6.3 kg/ha). Available P increased over straw removal with straw incorporation treatments by 3.3 – 16.1 kg/ha at Kanpur, 1-14 kg/ha Karaikal and 2.4-12.3 kg/ha at Maruteru. Incorporation of straw alone was the only treatment that showed a positive P balance (4 kg/ha) over straw removal at Chinsurah. An increase of 20.5 kg/ha – 38.0 kg/ha at Chinsurah, 5.0 kg/ha -50 kg/ha at Kanpur and 25.0 -103.6 kg/ha at Kanpur was observed as the contribution of residue treatments to soil available K content. At Karaikal all treatments except straw + MB incorporation recorded positive K balance over straw removal (11.7 – 43.4 kg/ha).

Significant increase in soil organic matter due to residue treatments was observed at Kanpur, Karaikal and Maruteru (Table 5.6.7). At all the three centers, straw incorporation along with green manure resulted in maximum increase in soil organic carbon content among all the treatments. Straw + green manure incorporation also increased the soil pH at Karaikal with, no significant changes in EC, and CEC.

Crop productivity of *kharif* rice

Straw incorporation in combination with N and green manure recorded significant increase in grain yield over straw removal by 1.6 t/ha, 1.7-1.9 t/ha and 1.2 1.5 t/ha at Faizabad, Ghaghraghat and (Table 5.6.9). Straw yields at Ghaghraghat and Kanpur followed the yield trends. Yield parameters *viz*., panicles/ sq m was highest with straw + 25% RDF –N incorporation (467) and straw + green manure incorporation (461) at Ghaghraghat and with straw + green manure incorporation (436) and straw + microbial inoculum (428) at Kanpur (Table 5.6.8). The treatment effects on production were not significant at Chinsurah, Karaikal, Maruteru and Raipur.

Nutrient uptake and use efficiencies

Residue treatments were found the influence the uptakes of N, P and K at all the centres except Karaikal (Table 5.6.10). Straw + microbial inoculum recorded the highest NPK uptake of (82.8, 35.3 and 97.2 kg/ha respectively) at Chinsurah. Straw incorporation in combination with 25% RDF –N recorded higher N (149.9 kg/ha) and P uptake (41.3 kg/ha) at Faizabad, and that of K with straw + green manure incorporation (107.7 kg/ha). Nutrient uptakes were observed to follow trends similar to yields at Ghaghraghat with straw + green manure incorporation recording the highest NPK (111.0, 56.6 and 179.9 kg/ha respectively) uptakes, which also resulted in the highest N uptake (129.4 kg/ha) at Kanpur. Lowest nutrient uptake was recorded with straw removal at all the locations.

Treatments recording highest nitrogen use efficiencies differed with locations (Table 5.6.11). Straw incorporation alone at Chinsurah and Faizabad (43-58 kg/kg), straw burning and ash incorporation (43.3 - 67.1 kg/kg) at Kanpur and Faizabad and straw removal (55.5 kg/kg) at Ghaghraghat recorded highest nitrogen use efficiencies. Significant differences in P use efficiencies were observed only at Chinsurah and Faizabad with highest PUE recorded with only straw incorporation (165.1 kg/kg) and straw burning (160.4 kg/kg), respectively. Chinsurah and Ghaghraghat recorded highest potassium use efficiencies with straw incorporation alone (49.2 and 36.3 kg/ha respectively) or with straw + 25% RDF-N incorporation (57.3 kg/kg) at Faizabad. Nutrient use efficiencies of all the three nutrients were non significant at Karaikal.

Nutrient requirements

The data on nutrient requirements at different locations are presented in Table 5.6.12. The lowest quantity of nitrogen required to produce one ton of yield was 17. 2 kg with incorporation of straw alone at Chinsurah, with straw burning and ash incorporation at Faizabad and Kanpur (23.1 kg and 15.0 kg respectively) and with straw removal (18.0 kg) at Ghaghraghat . The highest NR was recorded with straw + microbial inoculum (19.2 kg/t) at Chinsurah, straw + 25% RDF-N incorporation (24.4 kg/t) at Faizabad and with straw + green manure incorporation at Ghaghraghat and Kanpur (19.5 kg/t and (18.5 kg/t respectively). P requirement was least with straw incorporation alone and straw at Chinsurah and Faizabad respectively while KR was lowest with straw removal at Chinsurah (19.7 kg/t), with straw + green manure incorporation at Faizabad (18.1 kg/t) and with straw incorporation alone at Ghaghraghat (27.4 kg/t).

Soil fertility status

The fertility status of the soil after harvest of *kharif* rice is presented in Table 5.6.13. An increase in available N status over straw removal ranging from 0.3 to 11.8 kg/ha at Faizabad, 7-18 kg/ha at Kanpur and 1.5 – 10.5 kg/ha at Karaikal was observed. At Chinsurah, a positive N balance over straw removal was observed only with straw incorporation (1.2 kg/ha). Increases in available P over residue removal was observed in all straw incorporation treatments at Faizabad (3.2-5.2 kg/ha), Kanpur (4.3-

11.2 kg/ha) and Karaikal (0.9-14 kg/ha). Straw incorporation + 25% RDF-N was the only treatment which recorded a positive increase of 3.3 kg/ha in available P over straw removal at Chinsurah. Positive K balances due to straw incorporation ranging from 6-57 kg/ha and 9-41 kg/ha was observed at Faizabad and Kanpur respectively. At Chinsurah, increase in available K was observed with straw burning and ash incorporation (10 kg/ha increase over straw removal) and straw + microbial inoculum treatments (2.5 kg/ha increase over straw removal). At Karaikal, a reduction in soil available K content by 1.2 kg/ha, 4.7 kg/ha and 8.2 kg/ha over straw removal was recorded in treatments with straw + 25% RDF-N, straw burning and ash incorporation and straw incorporation alone while straw + green manure and straw + microbial inoculum increased available K by 47 kg/ha and 4.7 kg/ha respectively. Straw + green manure incorporation at Kanpur resulted in the highest soil organic carbon content (0.61%). At Karaikal, straw + green manure was observed to increase the soil pH to 6.2 while no significant changes were recorded for organic C, EC and CEC due to the incorporation of straw (Table 5.6.14).

To summarize, straw + green manure incorporation was observed to produce the highest increase in yields of *rabi* and *kharif* crop at Kanpur, Ghaghraghat and Faizabad. At Chinsurah, maximum yields were observed with straw + microbial inoculum. Increased nutrient uptakes, use efficiencies and increase in available nutrient status of soil and positive changes in soil organic carbon has also been observed at a few locations due to straw incorporation either alone or along with inorganic nitrogen, green manure or microbial culture.

Table: 5.6.1 Management of crop residues in rice based cropping system
Site characteristics

Parameter	CHN	FZB	GGT	KNP	KKL	MTU	RPR
Cropping system	R - R	R - W	R - W	R - W	R - R	R - R	R - W
Variety							
Kharif	Satabdi	NDR 359	NDR 359	NDR 359	ADT 43	MTU 1061	Mahamaya
Rabi	Satabdi	HUW 234	PBW 373	PBW 343	ADT 46	MTU 1010	GW 273
RFD (Kg/NPK/ha)							
Kharif	60:30:30	120:60:60	120:60:40	120:60:60	150:50:50	90:60:60	100:60:40
Rabi	120:60:60	-	120:60:40		150:50:50	180:90:60	100:60:40
Crop growth							
Kharif	Good	Good	Good		Good		Good
Rabi	Good	-	Good		Good		Good
Soil data							
% clay		23	28	19.98			39
% silt		21	31	24.20	6		36
% sand		56	41	55.81	73		25
Soil Texture	Silty clay	Sandy loam	Sandy loam	Sandy loam	Sandy clay loam	Clay	Clay loam
pH (1:1)	7.4	-	8.2	7.5	6.7	6.49	7.48
Org.carbon (%)	0.72	0.42	0.42	0.48	0.34	1.33	0.51
CEC [c mol (p+)/kg]	15	13.82	-	13.6	33.5	-	38
EC (ds/m)	0.28	1.02	-	0.34	0.06	0.72	0.17
Avail.N (kg/ha)	425	200	228	225	111	132	177
Avail. P_2O_5 (kg/ha)	85	24	14.6	48.80	37	14.3	13
Avail. K_2O (kg/ha)	272	234	203	288	131	261	424

CHN: Chinsurah; FZB: Faizabad: GGT: Ghaghraghat: KNP: Kanpur; KRK: Karaikal; MTU: Maruteru; RPR: Raipur

Table: 5.6.2 Management of crop residues in rice based cropping system, *Rabi* 2009-10

Grain and Straw yields

Location	Grain yield (t/ha)							Straw yield (t/ha)						
	CHN	FZB	GGT	KNP	KKL	MTU	RPR	CHN	FZB	GGT	KNP	KKL	MTU	RPR
Rabi crop	Rice	Wheat	Wheat	Wheat	Rice	Rice	Wheat	Rice	Wheat	Wheat	Wheat	Rice	Rice	Wheat
Treatments														
Straw removed	4.13	2.85	1.94	3.51	1.43	4.99	2.02	4.43	6.04	3.02	4.25	5.89	7.56	4.34
Straw burning (5 t/ha) ash incorporation	4.57	2.93	1.96	3.69	1.78	5.44	2.47	4.71	7.82	3.08	4.45	5.09	7.54	4.72
Straw (5 t/ha) incorporated (20 DBT)	4.51	3.12	1.78	4.17	1.34	5.62	2.19	4.79	7.46	2.75	5.12	5.59	8.15	4.67
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	4.73	3.27	2.17	4.44	1.74	5.34	2.50	4.91	7.33	3.33	5.42	5.63	8.29	5.11
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	4.69	3.91	2.31	4.93	1.43	5.74	2.46	4.86	6.76	3.57	6.05	5.57	8.82	2.80
Straw (5 t/ha) + MB culture incorporated (20 DBT)	4.92	3.74	2.10	4.59	1.78	5.57	2.21	5.12	6.36	3.33	5.61	6.16	8.49	4.81
Expt. Mean	4.59	3.30	2.04	4.22	1.58	5.45	2.31	4.80	6.92	3.18	5.15	5.65	8.14	4.41
CD (0.05)	167	0.15	0.06	0.451	NS	NS	NS	273	0.86	0.14	0.521	NS	0.79	1.37
CV (%)	2.00	3.10	1.98	7.08	20.24	12.26	10.68	4.00	8.17	2.91	6.72	13.60	6.42	20.57

Table: 5.6.3 Management of crop residues in rice based cropping system, *Rabi* 2009-10

Nutrient uptakes (Kg/ha)

Treatments	N uptake (Kg/ha)				P uptake (Kg/ha)				K uptake (Kg/ha)			
	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU
Straw removed	86.3	86.4	12.6	38.4	33.6	54.6	39.3	22.9	91.6	71.1	204.6	74.6
Straw burning (5 t/ha) ash incorporation	94.2	91.9	11.0	49.0	38.0	29.6	28.7	25.8	98.9	78.7	257.8	91.0
Straw (5 t/ha) incorporated (20 DBT)	88.3	108.2	10.8	52.5	35.2	34.7	33.2	26.6	87.8	90.7	238.5	106.4
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	95.4	92.9	13.8	46.2	40.2	37.0	48.2	25.7	104.9	97.1	229.3	106.3
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	89.1	133.8	12.0	63.7	35.9	44.5	67.5	29.9	93.3	111.3	280.5	123.7
Straw (5 t/ha) + MB culture incorporated (20 DBT)	106.5	122.1	13.6	58.8	45.9	39.8	69.6	25.4	116.9	101.9	267.3	114.7
Expt. Mean	93.3	105.9	12.3	51.4	38.1	39.9	47.7	26.1	98.9	91.8	246.3	102.8
CD (0.05)	4.4	26.7	NS	11.3	4.8	NS	22.8	2.6	6.7	8.9	NS	13.9
CV (%)	3.2	16.7	23.1	14.5	8.4	61.8	31.7	6.7	4.5	6.40	21.9	8.9

Table: 5.6.4 Management of crop residues in rice based cropping system, *Rabi* 2009-10

Nutrient Use Efficiencies (Kg/kg)

Treatments	NUE (Kg/kg)				PUE (Kg/kg)				KUE (Kg/kg)			
	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU
Straw removed	47.9	40.7	114.6	129.8	123.1	111.2	38.2	217.0	45.2	49.4	7.4	67.1
Straw burning (5 t/ha) ash incorporation	48.6	40.2	172.6	111.3	120.3	125.3	62.5	209.8	46.3	46.9	7.1	59.6
Straw (5 t/ha) incorporated (20 DBT)	51.1	38.5	130.2	110.5	129.1	122.1	41.9	212.0	51.5	45.9	5.8	53.1
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	49.6	72.4	131.1	116.2	117.7	120.1	41.3	207.7	45.2	45.8	7.7	50.3
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	52.7	36.8	128.3	90.13	132.0	110.6	21.3	191.2	50.5	44.2	5.3	46.7
Straw (5 t/ha) + MB culture incorporated (20 DBT)	46.2	37.6	136.7	95.23	107.7	115.2	26.4	220.1	42.1	45.0	6.7	48.7
Expt. Mean	49.4	44.4	135.6	108.9	121.7	117.4	38.6	209.6	46.8	46.2	6.7	54.2
CD (0.05)	2.4	NS	NS	18.8	NS	NS	14.9	NS	3.4	1.1	NS	9.4
CV (%)	3.2	63.3	30.7	11.5	8.5	20.1	25.6	9.0	4.8	1.6	23.6	11.5

Table: 5.6.5 Management of crop residues in rice based cropping system, *Rabi* 2009-10

Nutrient requirements (kg/t)

Treatments	NR				PR				KR			
	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU
Straw removed	20.9	24.6	9.2	7.7	8.1	14.7	29.0	4.6	22.1	20.2	152.6	14.9
Straw burning (5 t/ha) ash incorporation	20.6	24.9	6.7	9.0	8.3	7.9	16.8	4.7	21.6	21.3	145.4	16.9
Straw (5 t/ha) incorporated (20 DBT)	19.6	25.9	8.2	9.3	7.8	8.2	24.5	4.7	19.5	21.7	176.6	19.0
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	20.2	21.1	7.9	8.7	8.5	8.3	26.8	4.8	22.2	21.8	132.2	20.1
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	19.0	27.2	8.4	11.1	7.7	9.0	47.1	5.2	19.9	22.6	199.8	21.8
Straw (5 t/ha) + MB culture incorporated (20 DBT)	21.7	26.6	8.2	10.5	9.3	8.7	38.4	4.5	23.8	22.2	156.3	20.6
Expt. Mean	20.3	25.0	8.1	9.40	8.3	9.5	30.4	4.8	21.5	21.6	160.5	18.9
CD (0.05)	1.0	NS	NS	1.4	1.0	NS	10.5	NS	1.4	0.5	NS	3.6
CV (%)	3.2	16.9	29.8	10.1	8.0	64.9	23.0	9.2	4.4	1.6	25.5	12.6

Table: 5.6.6 Management of crop residues in rice based cropping system, *Rabi* 2009-10

Post harvest soil nutrient status

Treatments	Avail. N (Kg/ha)				Avail. P (Kg/ha)				Avail. K (Kg/ha)			
	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU	CHN	KNP	KKL	MTU
Straw removed	431.2	210.0	87.8	238.5	82.9	49.2	39.6	27.4	273.2	280.0	84.3	291.2
Straw burning (5 t/ha) ash incorporation	433.7	215.0	82.7	257.2	79.6	53.1	44.0	29.8	311.2	285.0	96.0	316.4
Straw (5 t/ha) incorporated (20 DBT)	432.5	218.0	86.6	269.7	86.9	60.4	40.4	31.1	295.0	310.0	121.8	339.7
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	413.7	220.0	70.6	310.7	81.5	61.5	53.5	33.8	300.0	315.0	104.2	356.3
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	423.7	232.0	99.2	335.5	81.2	65.3	46.5	39.7	293.7	330.0	127.7	394.8
Straw (5 t/ha) + MB culture incorporated (20 DBT)	415.0	225.6	94.1	307.5	73.1	64.6	44.2	32.5	293.7	328.0	83.2	386.3
Expt. Mean	425	220.1	86.8	286.5	80.9	59.0	44.7	32.4	294.5	308.0	102.9	347.4
CD (0.05)	12.5	4.3	NS	46.9	6.8	3.8	NS	3.8	16.1	4.4	20.6	47.01
CV (%)	1.9	1.3	15.9	10.8	5.6	4.3	30.2	7.8	3.6	0.93	13.3	8.97

Table: 5.6.7 Management of crop residues in rice based cropping system, *Rabi* 2009-10

Post harvest soil characteristics

Treatments	SOC%		pH		EC (dS m-1)	CEC cmol(p+) kg-1	
	KNP	KKL	MTU	KKL	MTU	KKL	KKL
Straw removed	0.46	0.36	1.25	5.5	6.5	0.05	38.03
Straw burning (5 t/ha) ash incorporation	0.48	0.49	1.28	5.2	6.6	0.08	39.80
Straw (5 t/ha) incorporated (20 DBT)	0.52	0.48	1.36	5.3	6.5	0.07	37.18
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	0.52	0.54	1.38	5.3	6.6	0.09	38.80
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	0.65	0.89	1.4	6.0	6.7	0.32	37.75
Straw (5 t/ha) + MB culture incorporated (20 DBT)	0.62	0.82	1.37	5.5	6.7	0.09	37.10
Expt. Mean	0.54	0.60	3.64	5.5	6.6	0.12	38.11
CD (0.05)	0.02	0.28	1.35	0.4	NS	NS	NS
CV (%)	2.97	30.97	0.074	5.3	2.6	156.46	8.23

Table: 5.6.8 Management of crop residues in rice based cropping system, *Kharif* 2010

Yield Characteristics

Treatments	Panicles /sq. m						Pan. Weight (g)	
	FZB	GGT	KNP	KKL	MTU	RPR	FZB	KNP
Straw removed	290	415	338	132	274	315	3.40	3.78
Straw burning (5 t/ha) ash incorporation	294	421	375	157	283	353	3.53	3.99
Straw (5 t/ha) incorporated (20 DBT)	298	437	399	129	291	295	3.50	4.10
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	308	467	415	166	292	256	3.60	4.15
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	310	461	436	152	308	331	3.60	4.58
Straw (5 t/ha) + MB culture incorporated (20 DBT)	297	453	428	194	298	302	3.60	4.45
Expt. Mean	300	442	398	155	291	309	3.54	4.17
CD (0.05)	8.20	19	23.06	NS	15.11	16.31	0.12	0.52
CV (%)	1.82	3	3.83	19.32	3.45	3.50	2.34	8.26

Table: 5.6.9 Management of crop residues in rice based cropping system, *Kharif* 2010

Grain and Straw yields

Treatments	Grain yield (t/ha)							Straw yield (t/ha)						
	CHN	FZB	GGT	KNP	KKL	MTU	RPR	CHN	FZB	GGT	KNP	KKL	MTU	RPR
Straw removed	3.70	4.41	3.80	5.53	1.58	4.95	5.14	3.91	7.87	5.54	7.52	3.74	7.29	5.85
Straw burning (5 t/ha) ash incorporation	4.12	5.44	3.93	5.97	1.55	4.71	5.54	4.29	8.25	5.67	8.06	3.14	6.95	6.05
Straw (5 t/ha) incorporated (20 DBT)	4.00	5.59	4.28	6.58	1.58	4.78	5.29	4.22	8.43	5.98	8.55	3.43	8.16	6.11
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	4.21	6.03	5.51	6.68	1.42	5.07	5.44	4.44	7.98	7.79	8.75	2.96	7.82	6.19
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	4.21	5.95	5.68	7.02	1.75	5.52	6.09	4.50	8.55	8.13	9.25	3.63	8.29	6.92
Straw (5 t/ha) + MB culture incorporated (20 DBT)	4.30	5.73	4.65	6.76	1.75	5.38	5.49	4.62	8.73	6.77	8.92	3.25	8.06	6.09
Expt. Mean	4.09	5.53	4.64	6.43	1.60	5.07	5.49	4.33	8.30	6.65	8.51	3.36	7.76	6.21
CD (0.05)	NS	0.11	0.81	0.380	NS	NS	NS	0.37	0.092	1.21	0.348	NS	NS	0.055
CV (%)	6.27	1.35	11.64	3.92	23.07	7.89	9.40	5.74	0.73	12.13	2.71	22.19	8.58	5.92

Table: 5.6.10 Management of crop residues in rice based cropping system, *Kharif* 2010

Nutrient uptakes (Kg/ha)

Treatments	N uptake (Kg/ha)					P uptake (Kg/ha)					K uptake (Kg/ha)				
	CHN	FZB	GGT	KNP	KKL	CHN	FZB	GGT	KNP	KKL	CHN	FZB	GGT	KNP	KKL
Straw removed	65.5	103.8	68.4	83.0	17.2	24.6	26.8	37.1	29.9	29.1	72.9	90.1	107.7	27.7	32.1
Straw burning (5 t/ha) ash incorporation	74.1	125.5	72.2	89.4	15.0	26.8	33.9	38.8	33.7	27.5	85.2	100.2	122.4	33.7	32.9
Straw (5 t/ha) incorporated (20 DBT)	68.6	129.6	77.9	99.8	16.0	24.3	37.0	41.4	37.4	25.9	81.3	105.5	117.2	36.1	35.7
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	77.0	146.9	102.1	117.2	11.2	30.7	41.3	53.9	53.5	20.7	91.3	105.3	155.8	52.8	32.4
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	76.5	140.1	111.0	129.4	15.4	30.0	39.9	56.6	41.7	24.4	86.9	107.7	179.9	42.4	38.8
Straw (5 t/ha) + MB culture incorporated (20 DBT)	82.8	135.0	88.1	109.6	12.5	35.3	35.8	46.3	40.9	22.9	97.2	105.8	141.6	38.9	37.5
Expt. Mean	74.1	130.2	86.6	104.7	14.6	28.6	35.8	45.7	39.5	25.1	85.8	102.4	137.4	38.6	34.9
CD (0.05)	6.2	2.1	15.1	10.55	NS	4.13	1.13	8.3	NS	NS	6.8	1.88	24.1	NS	NS
CV (%)	5.5	1.0	11.6	5.69	32.3	9.57	2.10	12.1	33.1	20.6	5.3	1.22	11.62	31.1	16.0

Table: 5.6.11 Management of crop residues in rice based cropping system, *Kharif* 2010

Nutrient Use Efficiencies (Kg/kg)

Treatments	NUE (Kg/kg)					PUE (Kg/kg)					KUE (Kg/kg)				
	CHN	FZB	GGT	KNP	KKL	CHN	FZB	GGT	KNP	KKL	CHN	FZB	GGT	KNP	KKL
Straw removed	56.5	42.5	55.5	66.9	98.8	150.2	164.8	102.4	185.0	54.2	50.7	48.9	35.2	199.9	48.4
Straw burning (5 t/ha) ash incorporation	55.7	43.3	54.4	67.1	109.0	154.3	160.4	101.0	177.1	57.6	48.4	54.3	32.1	177.1	46.8
Straw (5 t/ha) incorporated (20 DBT)	58.2	43.2	54.8	66.1	111.4	165.1	151.3	103.5	175.8	61.4	49.2	53.1	36.3	182.3	44.6
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	54.6	41.0	53.9	57.2	131.0	138.2	145.9	102.1	149.2	69.0	46.1	57.3	35.2	148.9	44.0
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	55.0	42.5	51.1	54.4	113.7	140.2	149.3	100.3	168.4	71.5	48.5	55.2	31.6	165.5	44.9
Straw (5 t/ha) + MB culture incorporated (20 DBT)	51.9	42.5	52.7	61.8	142.3	122.6	160.1	100.2	165.2	78.6	44.2	54.2	32.8	173.9	47.9
Expt. Mean	55.3	42.5	53.8	62.23	117.7	145.1	155.3	101.6	170.1	65.4	47.8	53.8	33.9	174.6	46.1
CD (0.05)	2.74	1.0	0.9	6.79	NS	15.9	5.5	NS	NS	NS	2.0	1.3	1.8	NS	NS
CV (%)	3.3	1.6	1.1	7.24	31.0	7.3	2.3	2.3	13.6	18.3	2.8	1.6	3.6	12.1	16.8

Table: 5.6.12 Management of crop residues in rice based cropping system, *Kharif* 2010

Nutrient requirements (kg/t)

Treatments	NR					PR					KR				
	CHN	FZB	GGT	KNP	KKL	CHN	FZB	GGT	KNP	KKL	CHN	FZB	GGT	KNP	KKL
Straw removed	17.7	23.5	18.0	15.1	11.9	6.7	6.1	9.8	5.4	18.6	19.7	20.4	28.4	5.0	21.2
Straw burning (5 t/ha) ash incorporation	17.9	23.1	18.4	15.0	10.0	6.5	6.2	9.9	5.6	18.0	20.7	18.4	31.2	5.6	21.5
Straw (5 t/ha) incorporated (20 DBT)	17.2	23.2	18.2	15.2	10.0	6.1	6.6	9.7	5.7	16.5	20.3	18.8	27.4	5.5	22.6
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	18.3	24.4	18.5	17.5	7.8	7.3	6.8	9.8	7.9	14.6	21.7	17.57	28.3	7.8	23.3
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	18.2	23.5	19.5	18.5	8.8	7.1	6.7	9.9	5.9	14.1	20.7	18.1	31.6	6.0	22.5
Straw (5 t/ha) + MB culture incorporated (20 DBT)	19.2	23.5	18.9	16.2	7.3	8.2	6.2	9.9	6.0	13.8	22.6	18.4	30.5	5.7	22.4
Expt. Mean	18.1	23.5	18.6	16.2	9.3	6.9	6.4	9.8	6.1	15.9	20.9	18.6	29.6	5.9	22.2
CD (0.05)	0.89	0.56	0.30	1.72	NS	0.79	0.23	NS	NS	NS	0.89	0.44	1.38	NS	NS
CV (%)	3.2	1.6	1.1	7.01	31.0	7.5	2.4	2.2	30.3	20.7	2.8	1.6	3.1	28.4	19.4

Table: 5.6.13 Management of crop residues in rice based cropping system, *Kharif* 2010
Post harvest soil nutrient status

Treatments	Avail. N (Kg/ha)				Avail. P (Kg/ha)				Avail. K (Kg/ha)			
	CHN	FZB	KNP	KKL	CHN	FZB	KNP	KKL	CHN	FZB	KNP	KKL
Straw removed	435.0	209.2	208.0	84.3	77.2	20.0	48.8	39.5	307.5	234.7	280.0	112.4
Straw burning (5 t/ha) ash incorporation	433.7	215.0	211.0	86.2	73.2	23.2	53.1	44.0	317.5	249.7	289.0	107.7
Straw (5 t/ha) incorporated (20 DBT)	436.2	221.0	215.0	94.8	73.5	24.5	56.8	40.4	302.5	256.0	306.0	104.2
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	406.2	220.7	218.0	85.8	80.5	25.2	57.2	53.5	304.2	291.5	310.0	111.2
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	403.7	210.0	226.0	89.8	75.0	24.2	60.0	46.5	293.7	240.7	321.0	159.3
Straw (5 t/ha) + MB culture incorporated (20 DBT)	397.5	209.5	221.0	78.8	62.1	23.5	59.1	44.2	310.0	245.5	318.0	117.1
Expt. Mean	418.7	214.2	216.5	86.6	73.6	23.4	55.8	44.7	305.9	253.0	304	118.6
CD (0.05)	10.39	1.54	3.61	NS	6.51	0.69	5.77	NS	13.06	2.34	4.48	16.72
CV (%)	1.64	0.48	1.11	13.21	5.87	1.95	6.86	30.24	2.83	0.61	0.98	9.35

Table: 5.6.14 Management of crop residues in rice based cropping system, *Kharif* 2010
Post harvest soil characteristics

Treatments	SOC%	pH	EC (dS m-1)	CEC cmol(p+) kg-1	
	KNP	KKL	KKL	KKL	KKL
Straw removed	0.44	0.08	5.5	0.09	37.23
Straw burning (5 t/ha) ash incorporation	0.46	0.07	5.8	0.08	38.73
Straw (5 t/ha) incorporated (20 DBT)	0.52	0.11	5.5	0.07	40.78
Straw (5 t/ha) incorporated (20 DBT) + 25% RDF – N	0.53	0.03	5.8	0.08	35.60
Straw (5 t/ha) + GM (5 t/ha) incorporation (20 DBT)	0.61	0.08	6.2	0.21	39.65
Straw (5 t/ha) + MB culture incorporated (20 DBT)	0.58	0.08	5.8	0.08	40.23
Expt. Mean	0.52	0.08	5.8	0.10	38.70
CD (0.05)	0.02	NS	0.3	0.06	NS
CV (%)	3.66	72.36	3.7	38.09	12.20

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

Rice is widely grown in India in about 15 major soils groups of which acid soils occupy more than 15 million ha. These are widely spread in Eastern, North Eastern and coastal regions of the Peninsula. The soils are highly leached, have poor soil fertility and water-holding capacity. These soils are associated with toxicity of iron in rice lowlands and of aluminum in uplands, depletion of bases like Ca, Mg and K, deficiency of micronutrients like B, Mo and fix large quantities of soluble P. These constraints lead to sub optimal productivity of crops in acid soils.

Amelioration practices for such soils include liming to correct soil acidity, application of sufficient quantities 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. This trial was, therefore, conducted at Titabar (Assam) in soils of pH 5.1 to evaluate the performance of 16 rice genotypes and at Ranchi (Jharkhand) with 10 genotypes under lowland conditions with and without liming and by doubling the P and K dose along with lime. Lime was applied @ 2.5t/ha.The soil was highly acidic (pH 5.1) with high organic carbon content (0.88%); medium N content (468 kg /ha), low P_2O_5 (14.5 kg/ha) and K_2O (123 kg / ha) status, and high in exchangeable Fe (360 mg/kg). Observations on dry matter yield (grain and straw), nutrient uptake and iron toxicity scoring were recorded (Tables 5.7.1 – 5.7.3).

At Titabar, the grain yield of rice ranged from 2.4 to 4.1 t/ha and straw yield from 2.2 to 3.5 t/ha with an average of 3.3 and 3.1 t/ha, respectively. IET 10016 recorded the highest grain yield (4.1 t/ha) followed by WL 21 (3.7 t/ha), IET 20974 (3.7 t/ha), Jaya (3.6 t/ha) and IET 21519 (3.5 t/ha) which were on par with IET 10016. These were superior to majority of other test entries like WL 9, WL 24, IET 21510, IET 21531, TKM 9, IET 21006, IET 21009 and IET 21523. Similar trend was also observed in case of straw yield with cultures Jaya, IET 10016 and IET 21513 and IET 21519 producing higher straw yields. Lowest grain as well as straw yield (2.16 t/ha) was recorded by IET 21007 producing 2.4 and– 2.2 t/ha, respectively.

The rice yields recorded at Ranchi were higher as compared to those at Titabar. The grain yield varied from 3.4 to 5.0 t/ha while that of straw was unusually high ranging from 10.7 to 16.1 t/ha. IET 21528 recorded the highest grain yield which was at par with IET 21531 and IET21519 followed by IET 21009, MTU 7029 and IET 21510. Lowest grain as well as straw yield was recorded by IET 21523.

Though, liming significantly influenced the grain yields at both the locations, the response at Titabar was higher with an average increase of 35% over recommended NPK while at Ranchi it was 13%. Addition of double dose of PK did not give any yield advantage at either location. Scoring of iron toxicity stress indicated moderate level of stress with recommended NPK which ranged from 4 to 6 even in limed soils and from 5 to 7 without liming. Doubling the dose of PK lowered the Fe toxicity stress to a score of 3 - 4.

Accumulation of N, P_2O_5 and K_2O in grain was highest in the genotype IET 10016 (28.72, 4.85 and 4.80 kg/ha) closely followed by WL 21. Liming significantly increased the grain NPK uptake over no-liming. Further, doubling the PK dose significantly increased P and K uptake by 15 – 31% though this did not improve rice productivity of any of the cultures. Based on the observations on crop productivity, uptake of major nutrients and response to lime and nutrient management, IET 10016, WL 21, Jaya and IET 20974 were observed to be promising for acid soils.

To summarise, the results indicated genotype dependent response to lime application and tolerance to Fe toxicity. Liming influenced the productivity of rice under lowland conditions significantly in soils of pH ~5.0. Doubling P and K application did not give any yield advantage though it improved P and K uptake in grain. Considering crop response to management in low pH soils, the genotype IET 10016 was most promising for higher productivity and better N P K nutrition at Titabar, and IET 21528, IET 21531 and IET21519 at Ranchi for higher yields, while IET 21519 was found to be tolerant to Fe toxicity.

Table 5.7.1 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2010)

Grain and straw yields

Variety	Location - Titabar								Location - Ranchi		
	Grain yield (t/ha)				Straw yield (t/ha)				Treatment	Grain yield (t/ha)	Straw yield (t/ha)
	T1*	T2	T3	Mean	T1*	T2	T3	Mean			
Jaya	3.23	3.85	3.78	3.62	3.40	3.60	3.70	3.57	Amendment		
IET 21009	2.40	3.33	3.50	3.08	2.97	3.40	3.40	3.26	*T1	3.92	12.05
IET 21510	2.77	3.50	3.50	3.26	2.43	3.52	3.52	3.16	T2	4.43	13.95
IET 21513	3.05	3.63	3.63	3.44	3.10	3.53	3.77	3.47	T3	4.49	14.08
IET 21519	3.27	3.60	3.60	3.49	2.77	3.62	3.65	3.34	CD (0.05)	0.19	0.62
IET 21523	2.60	3.20	3.13	2.98	2.37	3.35	3.28	3.00	CV (%)	6.16	6.44
IET 21531	2.90	3.37	3.40	3.22	2.57	3.38	3.28	3.08	Variety		
IET 10016	3.07	4.63	4.63	4.11	2.63	3.73	4.03	3.47	JAYA	4.03	14.41
WL 21	3.43	3.77	3.90	3.70	2.73	3.60	3.60	3.31	IET 21009	4.48	12.99
WL 9	2.20	3.80	3.80	3.27	1.63	3.37	3.63	2.88	IET 21510	4.26	11.26
IET 20974	2.97	3.83	4.17	3.66	2.70	3.63	3.63	3.32	IET 21513	3.70	10.93
WL 24	2.50	3.63	3.67	3.27	2.03	3.43	3.43	2.97	IET 21519	4.73	14.37
TKM 9	2.53	3.50	3.50	3.18	2.43	3.37	3.37	3.06	IET 21523	3.40	10.73
Vasumathi	1.67	3.30	3.30	2.76	1.47	3.37	3.37	2.73	IET 21528	4.96	13.50
IET 21006	2.23	3.63	3.63	3.17	1.80	3.50	3.50	2.93	IET 21531	4.84	14.94
IET 21007	1.60	2.73	2.90	2.41	1.34	2.57	2.57	2.16	LALAT	3.93	16.06
Mean	2.65	3.58	3.63		2.40	3.44	3.48	-	MTU 7029	4.44	14.42
CD_Main	-	0.26	-	-	-	0.24	-	-	Mean	4.28	13.36
CD_Sub	-	0.29	-	-	-	0.24	-	-	CD (0.05)	0.35	1.08
CD_MinS		0.53				0.45			CV (%)	8.69	8.54
CD_SinM		0.50				0.42					
CV_Main		14.06				13.40					
CV_Sub		9.41				8.35					

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

Table 5.7.2 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2010) (Location- Titabar)

Nutrient uptake in Grain

Treatment	Nitrogen (kg N /ha)	Phosphorus (kg P_2O_5/ha)	Potassium (kg K_2O /ha)
Amendment			
Recommended NPK	15.31	2.54	2.77
Recommended NPK + Lime	25.24	4.20	3.95
Recommended N + double PK + lime	26.38	4.85	5.19
CD (0.05)	2.02	0.40	0.28
CV (%)	15.95	18.12	12.41
Variety			
Jaya	25.12	4.71	4.60
IET 21009	22.75	3.75	3.87
IET 21510	22.25	4.14	3.74
IET 21513	22.90	3.94	4.03
IET 21519	22.03	3.81	4.17
IET 21523	20.40	3.46	3.55
IET 21531	21.97	3.74	3.94
IET 10016	28.72	4.85	4.80
WL 21	27.09	4.26	4.53
WL 9	22.30	3.92	4.09
IET 20974	24.88	4.12	4.42
WL 24	21.19	3.80	4.02
TKM 9	20.57	3.82	3.72
Vasumathi	18.61	3.10	3.42
IET 21006	20.05	3.61	3.67
IET 21007	16.14	2.79	2.94
Expt. Mean	22.31	3.86	3.97
CD (0.05)	2.41	0.54	0.56
CV (%)	11.52	14.86	15.00

Table 5.7.3 Screening of rice genotypes for soil acidity and related nutritional constraints in low land rice (*kharif* 2010) (Location- Titabar)

Fe Toxicity scores

Variety	Recommended NPK	Recommended NPK + lime	Recommended N + double PK + lime
Jaya	6	5	3
IET 21009	6	5	4
IET 21510	6	5	3
IET 21513	5	6	4
IET 21519	5	5	4
IET 21523	7	5	4
IET 21531	7	5	3
IET 10016	7	4	3
WL 21	6	4	4
WL 9	7	4	4
IET 20974	6	5	3
WL 24	6	5	4
TKM 9	6	5	3
Vasumathi	7	6	4
IET 21006	6	5	3
IET 21007	7	4	4

5.8 Nutritional status of rice in farmers' fields in relation to productivity

Fertilizer nutrient management not matching with the temporal and spatial variability in the availability of major nutrients in the farmers' fields and nutrient requirements of the crop variety besides other crop related management are among the important factors responsible for the low realization of productivity potential of the variety, imbalanced nutrition and unsustainability of the production system. A study was, therefore, conducted in *kharif* 2010 at five locations representing major rice growing agro ecosystems to assess the nutritional status and productivity of the crop under farmers' current management practices. The study involved survey and record of all the package of fertilizer and crop management practices followed by the farmer, besides information about the nutrient availability status of the soils before cropping, nutritional status of the crop at maximum tillering stage including crop productivity and dry matter yield at harvest. Simultaneously the nutrient supply potential of the soil was also assessed at the research farm representing the study area. Data collected in *kharif* 2010 from 30 farm sites around Ghagraghat, 25 from Mandya, 30 from Titabar,18 from Maruteru and 45 from Karaikal representing Indo Gangetic and Brahamputra plains, the plateau region and Godavari and Cauvery delta are presented in the Tables 5.8.1 to 5.8.4 and briefly discussed. The farmers in the study area around Ghagraghat, UP (IGP) cultivated HP 71 and Samba Mahsuri applying a range of nutrient (NPK) levels of 120:60:40, 80:60:0 and 60:40:0; varieties BR2655, MTU 1001, KMP 101, JGL,KRH-2, Jaya and applying nutrient levels of 100:50:40 to a maximum of 350:70:40 in Mandya (Karnataka); varieties Bahadur, Ranjit, Mah50, Swarna Mahsuri, Monohar Sali, Gitesh, TTB303-18-3, TTB303-2-23,IR70153-TTB9-3-3-1-2 with nutrient management levels of 9:5:4 kg / ha NPK to maximum of 60:20:10 at Titabar,Assam; varieties Andhra ponni, White Ponni, CO 43, ADT 38,BPT 5204, ADT 46, KKL (R) 1, ADT 39, CR 1009, CR 1010, CR 1009 following a range of nutrient management levels of 2.6:0.5:0.5 kg NPK / ha to a maximum of 145:59:76.5 kg NPK/ha in the Cauvery delta region, while at Maruteru the nutrient management levels applied ranged from 28 :57:37 to 56:57:75 kgNPK/ha.

Soil characteristics

Important soil fertility characteristics (pH, SOC, available N, P and K) analysed from samples collected prior to planting from the farmers' fields are presented in the Table 5.8.1.The parameters showed a fairly wide range of variability. Soils at Ghagraghat were sandy loam in texture with pH 7.0 to 8.7, 0.4-0.6% soil organic carbon, 110- 220 kg/ha available N, 7.5-25 kg/ha available P and 135 to 236 kg/ha available K. Similarly the soils in the farmers' fields around Mandya(Karnataka) were sandy loam in texture with pH 6.14 to 7.54, 0.33-0.55% soil organic carbon, 175-3544kg/ha available N, 18.75-36.84 kg/ha available P and 138 to 286 kg/ha available K. The soils in the farmers' fields around Maruteru varied in pH from 5.11 to 7.1, 0.73-1.17% soil organic carbon, 213-464 kg/ha available N, 8.2-30.26 kg/ha available P and 206 to 927 kg/ha available K. The soils in the farmers' fields around Titabar varied in pH from 5.3 to 5.7, 0.75-1.35% soil organic carbon, 310-520 kg/ha available N, 5.8-15 kg/ha available P and 68 to 137 kg/ha available K and the soils around Karaikal varied in pH from 6.12 to 8.27, 0.14-3.39% soil organic carbon, 39-201 kg/ha available N, 1.85-183 kg/ha available P and 82 to 1142 kg/ha available K.

Rice productivity in the farmers' fields

Average rice productivity across different agro ecosystems varied as follows – Titabar > Maruteru > Karaikal > Ghagraghat > Mandya reflecting, in general, soil organic carbon and nitrogen status which was Titabar > Maruteru > Mandya > Ghagraghat > Karaikal. The yields were unusually very high to low at certain farm sites, probably due to error in assessment. Hybrids, in general, recorded higher yields than HYVs. The yields ranged from 2.46 t/ha to 3.81t/ha at Ghaghraghat, 1.56 to 4.68 t/ha at Mandya, 3.37 t/ha to 5.25 t/ha at Maruteru, 0.57 t/ha to 9.6 t/ha at Titabar and 1.26 t/ha to 7.2 t/ha at Karaikal indicating substantial variability among the farm sites (5.8.2).

Nutrient concentration in grain and straw

Grain and straw nutrient concentration varied considerably at the test locations. Higher nutrient concentration in grain and straw were recorded in the samples at Ghagraghat. The nutrient contents particularly that of N were much lower at Mandya, Titabar and Karaikal compared to that in Ghagraghat Similar trend was observed for P accumulation in the grain in farm sites around Mandya and Titabar centres. Except for very high K content in the straw at Titabar (Table 5.8.3) N, P content in grain and K content in straw at all other centres were substantially low, indicating poor nutritional status of the crop as reflected by low soil nutrient availability and highly imbalanced fertilizer use by the farmers mismatching with the soil nutrient status. However, at Karaikal, high P and K content was recorded in grain compared to other places and unusually low N content in the crop

Nutrient accumulation and translocation efficiency

Nutrient accumulation in grain indicating average harvest index (translocation) was 72, 68 and 18 per cent at Ghagraghat and at Mandya it averaged 48, 52 and 47 per cent. At Titabar, the average harvest index of nutrients was 48, 40 and 24 per cent, while at Karaikal it was 63, 56 and 52 per cent, respectively broadly reflecting the dry matter yields at these locations (5.8.4). Nutrient harvest index calculated across farmers' fields at Ghaghraghat, Mandya, Titabar and Karaikal indicated steep variation for all the nutrients. Low nutrient harvest index was recorded for N and K at Titabar and Mandya due to poor nutrient concentration in the grain and straw, which is a deviation from the reported values and did not reflect the management practices being followed. Unlike the grain yields, the nutrient harvest index recorded at Karaikal was substantially higher and was found to be lower at Mandya and Titabar as compared to that in Ghagraghat.

Utilization efficiency of soil and fertilizer nutrients and nutrient requirement

Internal efficiency (IE, kg grain/kg nutrient accumulation) of nutrients varied between the sites and genotypes. Average IE for hybrids at Ghaghraghat was 76.2, 221.6 and 207.3 kg grain/kg N, P_2O_5 and K_2O respectively and correspondingly averaged 212.8, 357.4 and 169 kg grain at Mandya (Table 5.8.5). Similarly at Karaikal, it was 116,120 and 263 kg grain/kg N, P_2O_5 and K_2O respectively. This works out to a nutrient accumulation ratio of 4.69 at Mandya to 12.6 kg N at Ghagraghat, 2.79 kg P_2O_5 at Mandya to 8.29 kg P_2O_5 at Karaikal and acutely low requirement of potassium (3.79-5.89 kg K_2O) per ton of grain. The results suggest a highly imbalanced uptake of K relation to N at Ghaghraghat.

Soil efficiency worked out at Ghagraghat varied from 40.3% for nitrogen to 13.4% for phosphorus and 60.13% for potassium.At Mandya the same varied as 12.41, 61.1 and 16.5% respectively for the three major nutrients. At Titabar, it ranged from 13.9, 21.2 and 33.25 for the major nutrients repectivcely.At Karaikal, the same varied from 16.5, 12.6 and 9.93% for the major nutrients. Fertilizer use efficiencies calculated for all these centres gave a highly skewed picture. At Ghagraghat FUE was found to be 71.6% for N, 22.1% for P_2O_5 and 88% for K_2O respectively. At Mandya, FUE was found to be 33.76% for N, 16.26% for P_2O_5 and 35% for K_2O respectively. At Titabar, FUE was found to be 59% for N, 18.9% for P_2O_5 and 33% for K_2O respectively. At Karaikal FUE was found to be 19.4% for N, 43.84% for P_2O_5 and 49.6% for K_2O respectively. To find out the contribution of a single fertilizer factor in the productivity of rice, the partial factor factor protucitvity was calculated. At Ghagraghat PFP was found to be 41.9% for N, 83.9% for P_2O_5. At Mandya, PFP was found to be 12.6% for N, 61.6% for P_2O_5 and 68.6% for K_2O respectively. At Titabar, PFP was found to be 21.7% for N, 47.4% for P_2O_5 and

65.6% for K_2O respectively. At Karaikal PFP was found to be 47.5% for N, 79.8% for P_2O_5 and 81.8% for K_2O, respectively

The values of IE and nutrient ratios (Table 5.8.5) indicated sharp differences among farm sites with regard to nutrient uptake, genotypes indicating highly imbalanced nutrition which do not match with the crop nutrient requirements. This suggests for refinement of the current fertilizer practice being followed by the farmer.

Summarising, this exploratory study organized in representative farm sites (148) around Ghagraghat, Mandya, Titabar, Maruteru and Karaikal representing Indo-gangetic plains, Brahamputra basin, southern plateau region and Godavari / Cauvery delta the results indicated wide variability among farm sites in rice productivity, soil nutrient supply and nutrient use efficiency by genotypes. Average rice productivity was highest at Titabar, Assam followed by Maruteru, Karaikal, Ghaghraghat and Mandya reflecting broadly the soil quality status. Nutrient harvest index calculated across farmers' fields at these sites indicated steep variation for all the nutrients and low nutrient harvest index at Mandya and Titabar due to poor nutrient concentration in the grain and straw

Table 5.8.1 Nutritional status of rice in farmers' fields in relation to productivity, *Kharif 2010*
Soil characteristics in the farmers field prior to planting during *kharif* 2010

Parameters	Min	Max	Average	Sd
Ghaghraghat, UP*				
pH	7.0	8.7	8.01	0.42
SOC%	0.4	0.6	0.49	0.05
Avail. N(kg/ha)	110	220	179	22.47
Avail.P_2O_5 (kg/ha)	7.5	25	16.68	4.66
Avail.K_2O (kg/ha)	135	236	183	26.08
Mandya, Karnataka**				
pH	6.14	7.54	6.85	0.41
SOC%	0.33	0.55	0.42	0.07
Avail. N(kg/ha)	175	344	273	49.03
Avail.P_2O_5 (kg/ha)	18.75	36.84	26.94	5.28
Avail.K_2O (kg/ha)	138	286	217	40.78
Maruteru ,Andhra Pradesh***				
pH	5.11	7.1	5.96	0.54
SOC%	0.726	1.117	0.92	0.13
Avail. N(kg/ha)	213	464	354	86.8
Avail.P_2O_5 (kg/ha)	8.2	30.26	14.18	6.82
Avail.K_2O (kg/ha)	206	927	523	238.6
Titabar,Assam****				
pH	5.3	5.7	5.4	0.08
SOC%	0.75	1.35	0.98	0.13
Avail. N(kg/ha)	310	520	425	48.9
Avail.P_2O_5 (kg/ha)	5.8	15	9.1	2.3
Avail.K_2O (kg/ha)	68	138	102	13.7
Karaikal,Tamil Nadu*****				
pH	6.12	8.27	7.0	0.5
SOC%	0.14	3.39	0.6	0.6
Avail. N(kg/ha)	39	201	119	28.6
Avail.P_2O_5 (kg/ha)	1.85	183	36	43.5
Avail.K_2O (kg/ha)	82	1142	512	273

** Mean of 30 farmer fields ** Mean of 25 farmer fields*** Mean of 18 farmer fields*
***** Mean of 30 farmer fields***** Mean of 45 farmer fields*

Table 5.8.2 Nutritional status of rice in farmers' fields in relation to productivity, *Kharif 2010*
Grain and straw yield variations during *kharif* 2010

Parameters	Min	Max	Average	Sd
Ghaghraghat,UP*				
Grain(t/ha)	2.46	3.81	3.35	0.32
Straw(t/ha)	3.77	5.01	4.48	0.3
Mandya,Karnataka**				
Grain(t/ha)	1.56	4.68	3.02	1.1
Straw(t/ha)	1.67	4.83	3.18	0.99
Maruteru ,Andhra Pradesh***				
Grain(t/ha)	3.37	5.25	4.34	0.55
Straw(t/ha)	NA	NA	NA	NA
Titabar,Assam****				
Grain(t/ha)	0.57	9.6	4.8	2.8
Straw(t/ha)	0.75	19.1	6.5	4.6
Karaikal,Tamil Nadu*****				
Grain(t/ha)	1.26	7.2	3.54	1.5
Straw(t/ha)	1.0	7.76	3.7	1.2

** Mean of 30 farmer fields ** Mean of 25 farmer fields*** Mean of 18 farmer fields*
***** Mean of 30 farmer fields***** Mean of 45 farmer fields*

Table 5.8.3 Nutritional status of rice in farmers' fields in relation to productivity, *Kharif 2010*
Nutrient concentration among the genotypes

Parameters	N(%)	P(%)	K(%)	Sd
Ghaghraghat,UP*				
Grain	1.55	0.46	0.47	0.02
Straw	0.45	0.16	2.04	0.11
Mandya,Karnataka**				
Grain	0.47	0.28	0.56	0.07
Straw	0.54	0.24	0.62	0.07
Titabar,Assam****				
Grain	0.6	0.16	0.2	0.1
Straw	0.47	0.17	4.01	0.9
Karaikal,Tamil Nadu*****				
Grain	0.4	0.7	0.8	0.2
Straw	0.3	0.7	0.9	0.1
Maruteru ,Andhra Pradesh***				
Grain	NA	NA	NA	NA
Straw	NA	NA	NA	NA

** Mean of 30 farmer fields ** Mean of 25 farmer fields*** Mean of 18 farmer fields*
***** Mean of 30 farmer fields***** Mean of 45 farmer fields*

Table 5.8.4 Nutritional status of rice in farmers' fields in relation to productivity, *Kharif 2010*
Nutrient uptake and harvest index

Parameters	Grain	Straw	NHI	Sd
Ghaghraghat,UP*				
N(kg/ha)	52.33	20.14	72.21	22.8
P_2O_5 (kg/ha)	15.31	7.04	68.5	5.8
K_2O (kg/ha)	21.22	91.39	18.84	49.6
Mandya,Karnataka**				
N(kg/ha)	16.5	17.4	48.67	0.6
P_2O_5 (kg/ha)	8.7	7.9	52.41	0.6
K_2O (kg/ha)	17.1	18.9	47.5	1.3
Titabar,Assam****				
N(kg/ha)	28.8	30.7	48.8	1.3
P_2O_5 (kg/ha)	7.8	11.3	40.83	2.5
K_2O (kg/ha)	10.4	32.2	24.42	15.4
Karaikal,Tamil Nadu*****				
N(kg/ha)	12.48	7.23	63.32	3.7
P_2O_5 (kg/ha)	25.39	19.47	56.59	4.2
K_2O (kg/ha)	26.86	23.93	52.88	2.1
Maruteru ,Andhra Pradesh***				
N(kg/ha)	NA	NA	NA	NA
P_2O_5 (kg/ha)	NA	NA	NA	NA
K_2O (kg/ha)	NA	NA	NA	NA

** Mean of 30 farmer fields ** Mean of 25 farmer fields*** Mean of 18 farmer fields*
***** Mean of 30 farmer fields***** Mean of 45 farmer fields*

Table 5.8.5 Nutritional status of rice in farmers' fields in relation to productivity, *Kharif 2010*
Internal efficiency of nutrients in hybrids and HYVs *kharif* 2010

Parameters	Internal efficiency	Soil efficiency (%)	Fertilizer use efficiency (%)	Partial factor productivity	Nutrient requirement
Ghaghraghat,UP*					
N	46.3	40.3	71.6	41.9	2.2
P_2O_5	150	13.4	22.1	83.9	0.7
K_2O	29.8	61.5	88	NA	3.4
SD	65.2	24.1	34.3	42.0	1.4
Mandya,Karnataka**					
N	88	12.41	33.78	12.6	1.1
P_2O_5	18.1	61.1	16.26	61.6	0.6
K_2O	83.9	16.5	35	68.6	1.2
SD	39.2	27.0	10.5	30.5	0.3
Titabar,Assam****					
N	80.6	13.9	59	21.7	1.24
P_2O_5	250.0	21.2	18.9	47.4	0.4
K_2O	14.3	33.2	33	65.6	7.0
SD	121.6	9.7	20.3	22.1	3.6
Karaikal,Tamil Nadu*****					
N	179	16.5	19.4	47.5	0.8
P_2O_5	78	12.6	43.84	79.8	1.27
K_2O	69	9.93	49.6	81.8	1.43
SD	61.1	3.3	16.0	19.3	0.3
Maruteru ,Andhra Pradesh***					
N	NA	NA	NA	NA	NA
P_2O_5	NA	NA	NA	NA	NA
K_2O	NA	NA	NA	NA	NA

** Mean of 30 farmer fields ** Mean of 25 farmer fields*** Mean of 18 farmer fields*
***** Mean of 30 farmer fields***** Mean of 45 farmer fields*

Table 5.8.6 Nutritional status of rice in farmers' fields in relation to productivity, *Kharif 2010*
Grain yield, content and nutrient uptake pattern among different nutrient omission plots

Treatments	Grain Yield(t/ha)	Straw yield	UN kg/ha	UP kg/ha	UK kg/ha
	Ghaghraghat,UP*				
(-N)+100% RDF P,K	3.47	4.52	59.16	24.6	112.7
(-P)+100% RDF N,K	3.67	5.4	71.8	25.3	124.6
(-K)+100% RDF N,P	3.82	5.6	75.3	28.5	125.1
100% RDF NPK	4.35	6.31	87.35	33.3	152.1
Sd	0.4	0.5	8.2	4.0	15.7
	Mandya,Karnataka**				
(-N)+100% RDF P,K	2.34	2.44	14.33	10.04	30.79
(-P)+100% RDF N,K	2.57	2.65	19.05	9.65	34.43
(-K)+100% RDF N,P	3.38	3.47	22.11	15.41	42.2
100% RDF NPK	3.89	4.05	27.9	19.2	54.9
FFP	3.75	3.81	29.05	19.3	51.4
SD	0.7	0.7	6.1	4.7	10.4
	Karaikal,Tamil Nadu***				
(-N)+100% RDF P,K	6.0	6.17	50.93	52.0	44.3
(-P)+100% RDF N,K	7.17	6.34	78.53	48.03	48.08
(-K)+100% RDF N,P	6.5	6.17	103.83	59.82	189.73
100% RDF NPK	NA	NA	NA	NA	NA
FFP	NA	NA	NA	NA	NA
SD	0.6	0.1	15.1	2.1	3.1

UN- 'N' uptake; UP- 'P_2O_5' uptake; UK- 'K_2O' uptake

** * Mean of 30farmer fields ** Mean of 25 farmer fields*** Mean of 45 farmer fields*

5.9 Nutrient requirements of recently released rice varieties and hybrids of different duration groups

Nutrients have played a vital role in realising the yield potential of modern high yielding varieties. Release of varieties and hybrids with higher yield potential and varied yield expression under different environments warrants precise assessment of the nutrient requirements of these varieties for different environments for optimizing the inputs to be applied. The trial was, therefore, constituted to assess the requirements of major nutrients (NPK) of recently released varieties and hybrids (two each) of mid early to mid late duration group grown under different environments at five locations (DRR, Karaikal, Faizabad, Maruteru and Chinsurah) in *kharif* 2010. The varietal responses and nutrient accumulation under standard cultural practices and combination of nutrient levels were recorded. The nutrient levels were 0, 60,120 and 180 kg N (4), 0, 30 and 60 kg P (3) and 0, 50 and 100 kg K (3). The genotypes selected for the study were IET 20419 (Hybrid), IET19795, MTU 1075 and GK 5003 (Hybrid) which have been released recently based on their high yielding potential and resistance to biotic stresses. Results received from the 5 locations are presented in the Tables 5.9.1 to 5.9.5 and briefly discussed hereunder. Site characteristics with regard to soil and weather are presented in the Table 5.9.1.

Rice productivity

The data on rice and straw yields, presented in the Table 5.9.2, show a very low CV (1.5%) recorded at Faizabad and hence not been considered for reporting. Average productivity of rice at the other test locations ranged from 2.5 – 5.1 t/ha with significant effects of genotypes, nutrients and their interaction except at Karaikal for grain yield. Hybrids yielded more than the HYVs only at Maruteru by about 27%. Response to nutrient application was significant up to different nutrient levels which was location specific recording highest mean yields of 4.8 t/ha with 120, 0, and 50kg NPK/ha at Chinsurah (high soil P content), and 6.0 and 3.6 t/ha with the application of 120, 60, and 50 or 100kg NPK/ha, respectively at Maruteru and Karaikal. The interaction effects were significant at all the locations with MTU 1075 recording highest yields of 5.5 and 3.7 t/ha, respectively at Chinsurah and Karaikal with N optimum of 120,0,50 and 120,60,100 kg NPK/ha. The highest yielding treatment for each genotype and at each 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

Information on nutrient accumulation in the dry matter at harvest was collected from all the locations where yield responses to nutrient application were significant (Table 5.9.3). Mean N uptake ranged from 40 -98 kg/ha and that of P and K were, respectively 24-37 and 68 - 87 kg/ha. The uptake values were low at Karaikal because of low productivity levels recorded at this location. Varietal variations for nutrient accumulation were not significant for all nutrients at Karaikal and for only N at DRR. Among the varieties IET 20419 (Hybrid) accumulated significantly more nutrients at Chinsurah, while MTU 1075 at DRR took up large quantities of K compared to all other cultures. Uptake of nutrients varied with the nutrient application levels and combinations recording highest uptake at 120 kg N/ha without P application at Chinsurah, and with P and K application at other locations. Similarly P uptake improved up to 30 kg/ha at DRR and up to 60 kg/ha at Karaikal, while maximum K uptake was recorded with 100 kg/ha level at all locations. Very low CV was recorded at Faizabad and hence not discussed.

Nutrient requirement

Based on the uptake of nutrients recorded at highest yields of each variety at these locations nutrient requirement (kg nutrient uptake/ton grain) were estimated (Table 5.9.4). The test genotypes accumulated nutrients differentially depending on the location and broadly varied from 15 – 25 kg N, 5 – 11 kg P_2O_5, and 17 - 43 kg K_2O/t grain. K accumulation per ton of grain was unusually high at DRR particularly in HYVs and at Karaikal for both the genotype groups. Among the test cultures hybrids accumulated (requirement) less of nutrients compared to HYVs at DRR, while the nutrient requirement for hybrids was relatively high at Chinsurah for expressing comparatively low productivity levels indicating mismatch of the hybrids and also location effects on nutrient uptake requirements. Such information is essential to arrive at optimum level of fertilizer doses for achieving realizable productivity of the varieties.

Nutrient requirement (NR) for each variety and location was also estimated following regression analysis between grain yields and nutrient uptake (Table 5.9.5). A strong correlation was recorded between yields and nutrient uptake except for N and K uptake at DRR. The test genotypes accumulated nutrients differentially for each ton of grain production at the locations which ranged from 14 - 30 kg N, 3 – 10 kg P_2O_5, and 9 – 28 kg K_2O/t grain. Unlike the high estimate of NR based on actual uptake, statistical method estimated K requirement to be optimum per ton of grain at DRR, while at Karaikal it followed the same trend as that of actual uptake for both the genotype groups. Among the test cultures the nutrient uptake requirement per ton of grain was less for hybrids compared to HYVs at both DRR and Karaikal.

In summary, the results indicate differential response of genotypes to nutrient application which was specific to different test environments. On an average the yield response was significant up to 120, 60, 50 kg NPK /ha for HYVs at most of the locations, while there was no response to P application at Chinsurah. Based on the nutrient accumulation and yield response to fertilizer application, the estimated nutrient uptake requirements for hybrids and HYVs across the locations ranged from 15 – 24 kg N, 5-11 kg P2O5 and 15 – 43 kg K2O per ton of grain production. By regression analysis the nutrient requirement of the test cultures ranged from 14 - 30 kg N, 3 – 10 kg P_2O_5, and 9 – 28 kg K_2O/t grain. K requirement was high for both the genotype groups at Karaikal.

Table 5.9.1 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2010
Soil and crop data

Parameters	Chinsurah	DRR	Faizabad	Karaikal	Maruteru
Variety	As per treatments	As per treatments	As per treatments	As per treatments	As per treatments
Crop growth	Good	Satisfactory	Good	Satisfactory	Satisfactory
Rec. fert. Dose (KgNPK/ha)	As per treatments	As per treatments	As per treatments	As per treatments	As per treatments
Soil					
% Clay	-	52	23	13.3	64.0
% Silt	-	22	21	10.5	22.6
% Sand	-	24	56	72.1	12.5
Soil texture	Silty clay	Clay	Sandy loam	Sandy loam	Clay
pH(1:2)	7.1	8.1	7.5	7.48	6.9
Org.carbon (%)	0.68	0.72	0.42	0.64	0.54
CEC (me/100g)	13.0	-	13.8	14.6	-
EC (dS/m)	0.27	-	1.0	0.21	0.62
Avail.N (kg/ha)	400	270	200	110	188
Avail. P_2O_5 (kg/ha)	70	24.0	24	13.1	27.8
Avail. K_2O (kg/ha)	240	402	234	332	348

Table 5.9.2 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2010

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										
IET 20419	4579	5026	5869	2438	5718	5517	8454	6893	3590	7005
IET19795	4470	3924	6297	2308	4206	4859	9269	7941	3379	5765
MTU 1075	4659	4301	4540	2546	4869	5019	11481	5872	3729	6224
GK 5003	3644	5147	4243	2550	5802	4213	7413	5051	3742	7047
CD (0.05)	373	868	56	NS	161	364	743	105	NS	283
CV (%)	12.2	26.7	1.5	23.3	4.4	10.5	11.5	2.3	22.8	6.1
$N_0P_{60}K_{100}$	3642	3486	3255	2358	3914	4039	6656	4859	3438	5118
$N_{120}P_0K_{100}$	4826	4836	4791	2458	4646	5575	10018	5849	3625	5808
$N_{120}P_{60}K_0$	4093	4921	4913	2242	5066	4572	9728	6354	3283	6358
$N_{60}P_{60}K_{100}$	4159	4139	5033	2700	4863	4695	7795	6796	4067	5964
$N_{120}P_{30}K_{100}$	4660	4920	5466	2000	5246	5239	10412	6409	2958	6575
$N_{120}P_{60}K_{50}$	4479	4971	6364	2442	5976	5050	9228	7133	3567	7883
$N_{120}P_{60}K_{100}$	4537	5002	5862	3550	5759	5131	9572	6959	5108	7249
$N_{180}P_{60}K_{100}$	4306	4523	6213	1933	5721	4915	9826	7155	2833	7126
Expt. Mean	4338	4600	5237	2461	5149	4902	9154	6439	3610	6510
CD(0.05) Nutrients	227	626	68	265	177	283	1384	104	370	257
Interaction – M in S	488	NS	139	565	364	595	NS	215	794	534
-S in M	454	NS	135	529	353	565	NS	208	741	513
CV (%)	6.4	16.6	1.6	13.1	4.2	7.0	18.5	2.0	12.5	4.8

Table 5.9.3 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2010
Nutrient uptake (kg/ha)

Treatment	Nitrogen (N)				Phosphorus (P2O5)				Potassium (K2O)			
	Chinsurah	DRR	Faizabad	Karaikal	Chinsurah	DRR	Faizabad	Karaikal	Chinsurah	DRR	Faizabad	Karaikal
Varieties												
IET 20419	103.1	105.8	134.5	40.4	35.8	39.8	37.1	25.4	105.7	136.1	91.8	67.7
IET19795	75.4	97.0	148.5	38.3	22.3	37.2	40.5	19.5	81.3	108.0	104.1	63.6
MTU 1075	79.3	95.3	107.8	42.9	24.9	36.8	29.2	24.2	78.9	179.8	75.0	70.1
GK 5003	72.1	94.4	97.1	38.5	26.9	32.8	26.9	24.9	80.9	106.0	67.5	71.7
CD (0.05)	5.9	NS	0.9	NS	3.8	4.1	0.4	NS	7.6	30.5	1.4	NS
CV (%)	10.1	30.5	1.0	23.1	19.6	16.0	1.9	27.1	12.5	32.6	2.4	24.5
$N_0P_{60}K_{100}$	60.5	66.2	74.9	39.0	22.5	27.5	18.6	22.4	72.0	103.8	58.5	66.0
$N_{120}P_0K_{100}$	94.0	102.5	107.5	43.0	27.6	39.7	24.5	20.8	100.9	140.8	75.4	68.1
$N_{120}P_{60}K_0$	79.0	109.2	114.4	36.0	27.3	39.9	29.2	22.4	70.1	133.1	76.6	59.7
$N_{60}P_{60}K_{100}$	75.5	86.2	121.9	45.3	26.8	32.4	31.2	27.5	87.2	116.3	86.3	77.2
$N_{120}P_{30}K_{100}$	90.5	113.8	129.4	33.8	28.6	42.7	32.9	19.9	93.1	148.1	85.6	56.0
$N_{120}P_{60}K_{50}$	86.0	101.9	147.9	36.7	28.8	36.0	42.8	22.1	91.5	140.0	94.7	68.7
$N_{120}P_{60}K_{100}$	85.8	103.8	140.3	57.7	29.0	39.6	41.7	33.7	84.9	132.7	96.9	96.2
$N_{180}P_{60}K_{100}$	88.5	101.4	139.9	28.8	29.3	35.6	46.6	19.0	94.0	145.2	103.0	54.3
Expt. Mean	82.5	98.1	122.0	40.0	27.5	36.6	33.4	23.5	86.7	132.5	84.6	68.3
CD(0.05) Nutrients	5.2	15.2	1.6	5.2	2.7	6.1	0.6	2.8	7.5	25.6	1.2	7.2
Interaction – M in S	10.8	NS	3.2	10.9	5.7	NS	1.2	6.1	15.6	NS	2.6	15.6
-S in M	10.3	NS	3.2	10.4	5.4	NS	1.1	5.7	15.1	NS	2.5	14.5
CV (%)	7.7	19.0	1.6	15.8	11.9	20.5	2.1	14.8	10.6	23.6	1.8	13.0

Table 5.9.4 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2010

Nutrient requirement of test varieties (kg/ha)

Location	Variety	Maximum yield (kg/ha)	NPK level (kg/ha)	Nutrient uptake (kg/ha)			NR (kg uptake / ton grain)		
				N	P2O5	K2O	N	P2O5	K2O
Chinsurah	V1 IET 20419 (H)	4938	$N_{120}P_{60}K_{50}$	110.8	36.7	112.8	22.4	7.4	22.9
	V2 IET19795	4861	$N_{120}P_{0}K_{100}$	85.6	23.8	92.2	17.6	4.9	19.0
	V3 MTU 1075	5494	$N_{120}P_{0}K_{100}$	97.3	28.1	96.1	17.7	5.1	17.4
	V4 GK 5003 (H)	4136	$N_{180}P_{60}K_{100}$	89.9	34.2	101.8	21.7	8.3	24.7
	Hybrids	4537	$N_{120-180}P_{60}K_{50}$	100.4	35.5	107.3	22.1	7.9	23.8
	HYVs	5178	$N_{120}P_{0}K_{100}$	91.5	26.0	94.2	17.7	5.0	18.2
Faizabad	V1 IET 20419 (H)	8059	$N_{180}P_{60}K_{100}$	167.2	58.1	107.7	20.7	7.2	13.4
	V2 IET19795	7527	$N_{120}P_{60}K_{50}$	179.0	51.8	117.8	23.8	6.9	15.7
	V3 MTU 1075	5385	$N_{120}P_{60}K_{50}$	124.6	37.0	75.6	23.1	6.9	14.0
	V4 GK 5003 (H)	5383	$N_{180}P_{60}K_{100}$	120.9	39.8	82.6	22.5	7.4	15.3
	Hybrids	6721	$N_{180}P_{60}K_{100}$	144.1	49.0	95.2	21.6	7.3	14.4
	HYVs	6456	$N_{120}P_{60}K_{50}$	151.8	44.4	96.7	23.5	6.9	14.9
Karaikal	V1 IET 20419 (H)	3600	$N_{120}P_{60}K_{100}$	55.9	33.5	93.2	15.5	9.3	25.9
	V2 IET19795	3367	$N_{120}P_{60}K_{100}$	55.6	26.0	90.2	16.5	7.7	26.7
	V3 MTU 1075	3667	$N_{120}P_{60}K_{100}$	66.5	39.0	99.0	18.0	10.5	27.0
	V4 GK 5003 (H)	3567	$N_{120}P_{60}K_{100}$	52.8	36.4	102.5	14.7	10.1	28.8
	Hybrids	3584	$N_{120}P_{60}K_{100}$	54.4	35.0	97.9	15.1	9.7	27.4
	HYVs	3517	$N_{120}P_{60}K_{100}$	61.1	32.5	94.6	17.3	9.1	26.9
DRR	V1 IET 20419 (H)	5860	$N_{120}P_{60}K_{0}$	105.8	39.8	136.1	21.3	8.0	27.5
	V2 IET19795	5053	$N_{120}P_{60}K_{100}$	97.0	37.2	108.0	25.4	9.9	29.7
	V3 MTU 1075	5004	$N_{120}P_{0}K_{100}$	95.3	36.8	179.8	22.5	8.7	43.0
	V4 GK 5003 (H)	5700	$N_{120}P_{60}K_{0}$	94.4	32.8	106.0	18.7	6.4	20.9
	Hybrids	5780	$N_{120}P_{60}K_{0}$	100.1	36.3	121.1	20.0	7.2	24.2
	HYVs	5029	$N_{120}P_{0-60}K_{100}$	96.2	37.0	143.9	24.0	9.3	36.4
Maruteru	V1 IET 20419 (H)	6508	$N_{120}P_{60}K_{50}$	-	-	-	-	-	-
	V2 IET19795	5027	$N_{120}P_{60}K_{50}$	-	-	-	-	-	-
	V3 MTU 1075	5659	$N_{120}P_{60}K_{50}$	-	-	-	-	-	-
	V4 GK 5003 (H)	6711	$N_{120}P_{60}K_{50}$	-	-	-	-	-	-
	Hybrids	6609	$N_{120}P_{60}K_{50}$	-	-	-	-	-	-
	HYVs	5343	$N_{120}P_{60}K_{50}$	-	-	-	-	-	-

Table 5.9.5 Nutrient requirements of recently released rice varieties and hybrids, *kharif* 2010
Nutrient requirement of test varieties at different locations by regression analysis (kg/ha)

Location	Variety	Corr. Coeff. (GY vs Nutr. Upt)			Regr. Coefficient (GY vs Nutr. Upt)			NR (kg uptake / ton grain)		
		N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
Chinsurah	V1 IET 20419 (H)	0.934	0.673	0.497	0.885	0.454	0.248	29.5	7.4	21.1
	V2 IET19795	0.944	0.646	0.732	0.625	0.299	0.536	22.6	6.3	-
	V3 MTU 1075	0.864	0.533	0.826	0.746	0.284	0.682	18.7	3.3	21.7
	V4 GK 5003 (H)	0.967	0.703	0.921	0.935	0.494	0.849	23.6	6.3	26.5
	Hybrids	-	-	-	-	-	-	26.6	6.9	23.8
	HYVs	-	-	-	-	-	-	20.7	6.9	21.7
Faizabad	V1 IET 20419 (H)	0.975	0.971	0.846	0.953	0.707	0.935	20.0	8.3	8.9
	V2 IET19795	0.958	0.904	0.910	0.892	0.833	0.762	23.9	8.3	15.6
	V3 MTU 1075	0.959	0.863	NS	0.920	0.745	0.076	20.6	9.0	-
	V4 GK 5003 (H)	0.914	0.945	0.736	0.835	0.893	0.541	22,1	8.5	12.8
	Hybrids	-	-	-	-	-	-	21.1	8.4	10.9
	HYVs	-	-	-	-	-	-	22.3	8.7	15.6
Karaikal	V1 IET 20419 (H)	0.907	0.895	0.929	0.814	0.792	0.858	16.3	9.2	22.7
	V2 IET19795	0.940	0.881	0.992	0.887	0.768	0.985	15.9	8.6	27.6
	V3 MTU 1075	0.966	0.883	0.995	0.934	0.780	0.989	19.3	10.1	26.2
	V4 GK 5003 (H)	0.894	0.868	0.991	0.799	0.754	0.982	14.8	9.0	28.4
	Hybrids	-	-	-	-	-	-	15.6	9.1	25.6
	HYVs	-	-	-	-	-	-	17.6	9.4	26.9
DRR	V1 IET 20419 (H)	0.580	0.757	0.431	0.331	0.577	0.169	14.1	5.9	15.1
	V2 IET19795	0.684	0.612	NS	0.469	0.375	NS	15.7	5.1	-
	V3 MTU 1075	NS	0.444	NS	NS	0.197	NS	-	5.1	-
	V4 GK 5003 (H)	0.616	0.837	0.570	-	0.732	0.319	-	5.2	17.7
	Hybrids	-	-	-	-	-	-	14.1	5.6	15.1
	HYVs	-	-	-	-	-	-	15.7	5.1	-

5.10 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 biofortification 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 the above in view the trial was intiated in *kharif* 2010 at 4 locations (Aduthurai, Karaikal, Maruteru, and DRR) of diverse soil and climatic conditions and productivity potentials. Three rice cultures Aghonibora and location specific promising genotypes for high Zn and Fe content in grains, and a non promising one were grown at these locations with a set of treatments to supply zinc and iron through soil and spray schedules. The partitioning of micronutrients during the crop growth in different plant parts (root, stem and leaf) and between vegetative and reproductive parts was analysed in relation to treatments imposed in the test cultures. The samples were analysed for Fe and Zn concentration by atomic absorption spectrophotometry at DRR and results receiced from four locations and presented in Tables 5.10.1 to 5.10.6 are discussed briefly.

Grain yield

Rice productivity on an average ranged from 2.5 to 4.6 t/ha with significant varietal and nutrient effects. The test variety Aghonibora grown at all the locations was most productive at DRR and Aduthurai (4.3 – 5.1 t/ha), while the yield levels were very low at Karaikal (2.0 – 3.0 t/ha) (Table 5.10.2). Among the location specific check varieties (IR 64 and ADT43) at Aduthurai, Vytilla and ADT 43 at Karaikal, Vasumathi and BPT 5204 at DRR and MTU 1061 at Maruteru, only MTU 1061 and ADR 43 at Karaikal were superior to others. The response to soil application of zinc was significant at Aduthurai, DRR and Karaikal, while spray application of iron did not influence yields at most of the locations except at Maruteru where combined application of iron and zinc significantly improved rice productivity. Integration of organic manures (@5 t/ha) along with micronutrients was most productive at Aduthurai, Karakal and Maruteru which was superior to all other treatments in the cauverry delta region. Straw yields more or less followed the similar trend as that of grain production recording highest dry matter with integrated use of organic manures and all fertilizer nutrients except at DRR the treatment effects including varietal responses were not significant.

Uptake and partitioning of micronutrients

Plant samples drawn at grain maturity were analysed for micronutrient (Zn, Fe) contents in different plant parts (leaf, stem, root and grain). At Aduthurai samples were also drawn at PI stage when the crop accumulated about 70 - 240 g/ha of zinc in the dry matter and 300 - 710 g/ha of iron. Concentration of the micronutrients varied with the genotypes with Aghonibora recording highest zinc content in all the plant parts at harvest time at Karaikal, while it was second best next to ADT43 at Aduthurai for both zinc and iron contents in leaf, stem and roots at PI stage (Table 5.10.3). However, the variety accumulated more of the micronutrients by harvest time compared to other two varieties (IR 64, ADT 43) at Aduthurai. At both the locations concentration of zinc and iron, in general, was highest in the stem followed by root and leaf. Data on uptake and partitioning of micronutrients at harvest time (Table 5.10.3) indicate non significant effects of varieties on accumulation of both the micronutrients in the leaves, roots and grain at Karaikal and that of iron uptake in grain and straw at DRR, while at Aduthurai culture Aghonibora accumulated significantly higher quantity of micronutrients in the biomass including grain and straw. Application of micronutrients though influenced the uptake of iron and zinc significantly at Aduthurai and Karaikal no definite trend could be observed except improvement in the uptake of iron in grain at Karaikal and both the nutrients in all the parts including grain with the nutrient treatments at Aduthurai. The total accumulation of zinc and iron were very high at Aduthurai and Karaikal which ranged from 2000-3222 g/ha of iron and 520 – 670 g/ha of zinc as compared to 422 and 302 g/ha, respectively at DRR. Of this total uptake in the dry matter (including grain), nearly 67 - 96% of Fe and 54 - 68% of Zn was distributed in the stem portion at Karaikal and Aduthurai, while the translocation of iron into the grain was only 6 – 13% and that of zinc ranged from 18 -20%. However, at DRR the mobilization of micronutrients into the grain was relatively high (22 and 16%) for Zn and Fe, respectively probably due to climatic conditions for better harvest index. Among the varieties Aghonibora was most promising improving accumulation of zinc and iron in grain in proportion to total uptake in dry matter with micronutrient application at Aduthurai and and that of iron at Karaikal where the interaction effects were significant.

Summarising the results of the first year study variety Aghonibora grown at all the locations was most productive at DRR and Aduthurai, and the location specific check varieties MTU 1061 at Maruteru and ADT 43 at Karaikal. Response to zinc application was significant at Aduthurai, DRR and Karaikal, while spray application of iron influenced the yields at Maruteru. Integration of organic manures (@5 t/ha) along with micronutrients was most productive at most of the locations. Concentration of the micronutrients varied with the genotypes with Aghonibora recording highest zinc content in all the plant parts at harvest time at Karaikal and was second best next to ADT43 at Aduthurai for both zinc and iron contents at PI stage. Varietal variations for micronutrient accumulation were not significant at Karaikal and DRR, while at Aduthurai culture Aghonibora accumulated maximum in the biomass. Application of micronutrients improved uptake of iron in grain at Karaikal and of both the nutrients at Aduthurai. Of the total uptake nearly 67 - 96% of Fe and 54 - 68% of Zn was distributed in the stem portion and translocation into the grain was only 6 – 16% and 18 -22% of Fe and Zn. Among the varieties Aghonibora was most promising improving accumulation of zinc and iron in grain with micronutrient application at Aduthurai and and that of iron at Karaikal.

Table 5.10.1 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2010

Soil and crop data

Parameters	Aduthurai	DRR	Karaikal	Maruteru
Variety	Aghonibora IR 64 ADT 43	Aghonibora Vasumathi BPT 5204	Aghonibora Vytilla Anakodan DT 43	MTU 1061 Aghonibora
Crop growth	Good	Satisfactory	Satisfactory	Satisfactory
Rec. fert. Dose (KgNPK/ha)	As per treatments	As per treatments	As per treatments	As per treatments
Soil				
% Clay	-	52	-	64.0
% Silt	-	22	-	22.6
% Sand	-	24	-	12.5
Soil texture	Silty clay	Clay	Sandy clay loam	Clay
pH(1:2)	7.1	8.1	7.48	7.3
Org.carbon (%)	0.68	0.72	0.64	0.7
CEC (me/100g)	13.0	-	14.6	-
EC (dS/m)	0.27	-	0.21	0.62
Avail.N (kg/ha)	400	270	189	220
Avail. P_2O_5 (kg/ha)	70	24.0	26	21
Avail. K_2O (kg/ha)	240	402	144	346

Table 5.10.2 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2010

Grain and straw yield (kg / ha)

Treatment	Grain yield (kg/ha)				Straw yield (kg/ha)			
	Aduthurai	DRR	Karaikal	Maruteru	Aduthurai	DRR	Karaikal	Maruteru
Varieties								
V1 Aghonibora	5141	4331	2047	4334	7411	9111	3093	5734
V2 Local check 1	3743	3387	2600	4770	5219	7322	3873	6128
V3 Local check 2	2729	4015	3073	-	4733	7917	4540	-
CD (0.05)	104	523	122.8	206	122	NS	345.6	NS
CV (%)	2.6	13.2	4.7	2.9	2.1	21.4	8.9	8.0
Micronutrients								
NPK	3374	3637	1844	4116	5501	7812	3044	5147
NPK + Zinc @ 10kg Zn / ha	4118	4477	2344	4327	5908	8494	3289	6169
NPK + Fe spray @ 0.5%	3395	3663	2667	4318	5518	7513	3933	5798
NPK + Zn + Fe	4123	3568	2767	4855	5913	8507	4200	6049
OM + NPK+ Zn + Fe	4345	4209	3244	5143	6097	8258	4711	6494
Expt. Mean	3871	3911	2573	4552	5788	8117	3835	5931
CD(0.05) Nutrients	66	425	182.3	302	86	NS	386.5	558
Interaction – M in S	128	802	NS	NS	165	NS	NS	NS
-S in M	114	736	NS	NS	149	NS	NS	NS
CV (%)	1.7	11.2	7.3	5.4	1.5	14.7	10.4	7.7

Table 5.10.3 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2010

Micro - nutrient contents in dry matter (ppm)

Treatment	Leaf at HST		Root at HST		Stem at HST		Grain		Grain		Straw	
	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
	Karaikal								DRR			
Aghonibora	34	19	51.1	over	81	465	39	105	27	28	30	42
Local check 1	28	34	35.1	over	60	626	34	38	20	9	23	38
Local check 2	33	101	28.6	over	23	335	36	79	21	16	26	48
CD (0.05)	NS	NS	NS	-	30	136	NS	NS	3.7	NS	NS	NS
CV (%)	50.0	139.9	50.7	-	54.0	28.1	58.8	107.0	15.9	149.0	29.7	37.6
NPK	30	46	49.8	over	71	516	29	70	19	9	30	52
NPK + Zinc @ 10kg Zn / ha	29	81	52.4	over	62	498	34	72	21	22	33	44
NPK + Fe spray @ 0.5%	43	34	29.6	over	49	436	49	27	26	10	24	39
NPK + Zn + Fe	30	43	20.9	over	40	441	39	137	28	35	23	48
OM + NPK+ Zn + Fe	27	53	38.7	over	51	486	32	65	21	13	23	31
CD(0.05) Nutrients	NS	NS	15	-	15	NS	NS	65	NS	NS	NS	NS
Interaction – M in S	NS	67	28	-	30	269	NS	123	NS	NS	NS	40.7
-S in M	NS	57	26	-	25	254	NS	113	NS	NS	NS	39.3
CV (%)	40.9	65.3	39.9	-	27.5	31.8	53.7	90.6	43.6	129.9	54.4	54.5

Table 5.10.4 Studies on partitioning of zinc and iron and prospects for enrichment in rice, *kharif* 2010 (contd.)
Micro - nutrient contents in dry matter (ppm)

Treatment	Aduthurai							
	Leaf at HST		Root at HST		Stem at HST		Grain	
	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
Varieties								
Aghonibora	19.9	69.1	64.6	136.9	35.0	178.4	37.7	71.1
Local check 1	18.9	51.7	52.2	116.0	33.3	74.1	26.3	52.9
Local check 2	22.0	75.4	95.2	176.7	41.4	120.9	38.4	79.0
CD (0.05)	1.2	0.8	3.9	6.6	1.6	NS	0.72	0.9
CV (%)	5.6	1.2	5.4	4.6	4.3	124.0	2.07	1.4
NPK	18.6	62.9	55.2	125.6	33.9	97.0	30.5	66.0
NPK + Zinc @ 10kg Zn / ha	21.0	64.5	75.2	149.3	38.0	100.8	35.6	67.8
NPK + Fe spray @ 0.5%	19.7	64.8	60.6	126.3	34.4	99.3	31.8	67.9
NPK + Zn + Fe	20.8	65.8	77.6	152.6	37.4	101.9	36.0	68.1
OM + NPK+ Zn + Fe	21.2	69.0	84.6	162.1	39.0	223.5	36.8	68.6
CD(0.05) Nutrients	1.4	1.6	3.2	5.6	1.4	NS	0.64	1.7
Interaction – M in S	NS	2.8	NS	NS	NS	NS	1.20	NS
-S in M	NS	2.7	NS	NS	NS	NS	1.11	NS
CV (%)	7.2	2.5	4.6	4.0	4.1	123.3	1.94	2.6

Table 5.10.5 Studies on partitioning of zinc and iron and prospects for enrichment in rice, kharif 2010
Micro - nutrient uptake and partitioning in rice varieties at harvest

Treatment	Leaf at HST		Root at HST		Stem at HST		Grain		Total		Grain		Straw		Total	
	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
Varieties	Karaikal										DRR					
Aghonibora	80	43	113	-	526	3014	78	213	719	3057	111	107	282	387	393	494
Local check 1	78	98	75	-	388	4032	90	96	541	4130	68	30	167	287	236	317
Local check 2	90	286	71	-	152	2194	114	246	313	2480	85	64	205	392	290	456
CD (0.05)	NS	NS	NS	-	215	1121	NS	NS	-	-	20.9	NS	64.1	NS	83.1	126
CV (%)	41.2	141.2	50.4	-	59.6	35.9	54.6	117.8	-	-	23.3	131.2	29.0	37.0	26.8	29.6
NPK	81	127	113	-	456	3340	54	118	650	3467	85	40	233	430	318	470
NPK + Zinc @ 10kg Zn / ha	76	229	116	-	399	3151	78	150	591	3280	76	79	285	368	362	447
NPK + Fe spray @ 0.5%	100	79	67	-	325	2901	122	66	492	2980	96	35	185	291	280	327
NPK + Zn + Fe	78	115	45	-	258	2935	113	397	381	3050	98	126	198	427	296	554
OM + NPK+ Zn + Fe	79	162	89	-	339	3072	104	194	507	3234	87	55	189	258	276	313
Expt. Mean	83	142	86	-	355	3080	94	185	524	3222	68	67	218	355	306	422
CD(0.05) Nutrients	NS	91	34	-	109	NS	43	179	-	-	NS	NS	NS	NS	NS	NS
Interaction – M in S	55	187	65	-	220	1876	NS	337	-	-	NS	NS	NS	339.0	NS	376
-S in M	50	158	59	-	189	1742	NS	309	-	-	NS	NS	NS	327.4	NS	367
CV (%)	36.1	65.7	40.6	-	31.6	33.6	46.6	99.3	-	-	40.6	120.9	60.3	54.7	46.0	51.6

Table 5.10.6 Studies on partitioning of zinc and iron and prospects for enrichment in rice, kharif 2010 (contd.)

Micro - nutrient uptake and partitioning in rice varieties

Treatment	Aduthurai									
	Leaf at HST		Root at HST		Stem at HST		Grain		Total	
	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
Varieties										
Aghonibora	37	129	195	409	432	2351	195	366	859	3255
Local check 1	25	67	104	229	312	693	99	198	540	1187
Local check 2	20	69	148	274	343	1004	106	216	618	1563
CD (0.05)	2.8	6.0	12.1	23.1	29.8	NS	3.7	8.8	39.7	NS
CV (%)	10.1	6.7	8.0	7.5	8.1	168.1	2.7	3.3	5.8	113.6
NPK	21	70	97	227	287	832	103	218	508	1348
NPK + Zinc @ 10kg Zn / ha	28	86	154	309	369	985	147	276	698	1656
NPK + Fe spray @ 0.5%	24	79	110	234	302	883	108	228	544	1425
NPK + Zn + Fe	30	97	175	347	398	1096	148	279	751	1818
OM + NPK+ Zn + Fe	34	110	209	404	457	2950	160	298	860	3763
Expt. Mean	27	88	149	304	362	1349	133	260	672	2002
CD(0.05) Nutrients	1.7	3.8	7.4	17.4	16.7	NS	2.7	6.1	20.6	NS
Interaction – M in S	3.4	7.4	14.6	33.1	33.2	NS	5.2	11.7	41.3	NS
-S in M	3.0	6.6	12.9	30.1	29.0	NS	4.8	10.5	35.6	NS
CV (%)	6.5	4.4	5.1	5.9	4.7	165.2	2.1	2.4	3.1	111.5

Table 5.10.6 Studies on partitioning of zinc and iron and prospects for enrichment in rice, kharif 2010 (contd.)

Micro - nutrient uptake and partitioning in rice varieties

Treatment	Aduthurai									
	Leaf at HST		Root at HST		Stem at HST		Grain		Total	
	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe
Varieties										
Aghonibora	37	129	195	409	432	2351	195	366	859	3255
Local check 1	25	67	104	229	312	693	99	198	540	1187
Local check 2	20	69	148	274	343	1004	106	216	618	1563
CD (0.05)	2.8	6.0	12.1	23.1	29.8	NS	3.7	8.8	39.7	NS
CV (%)	10.1	6.7	8.0	7.5	8.1	168.1	2.7	3.3	5.8	113.6
NPK	21	70	97	227	287	832	103	218	508	1348
NPK + Zinc @ 10kg Zn / ha	28	86	154	309	369	985	147	276	698	1656
NPK + Fe spray @ 0.5%	24	79	110	234	302	883	108	228	544	1425
NPK + Zn + Fe	30	97	175	347	398	1096	148	279	751	1818
OM + NPK+ Zn + Fe	34	110	209	404	457	2950	160	298	860	3763
Expt. Mean	27	88	149	304	362	1349	133	260	672	2002
CD(0.05) Nutrients	1.7	3.8	7.4	17.4	16.7	NS	2.7	6.1	20.6	NS
Interaction – M in S	3.4	7.4	14.6	33.1	33.2	NS	5.2	11.7	41.3	NS
-S in M	3.0	6.6	12.9	30.1	29.0	NS	4.8	10.5	35.6	NS
CV (%)	6.5	4.4	5.1	5.9	4.7	165.2	2.1	2.4	3.1	111.5

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Performance of Soil Science Centers during 2010

Sl.No	Location	Trial 1	Trial 1	Trial 2	Trial.3	Trial 4	Trial 5.	Trial 6	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Total allotted	Conducted	Not conducted
		Kharif	Rabi	Kharif	Kharif	Kharif	Kharif	Kharif	Rabi	Kharif	Kharif	Kharif	Kharif			
	DRR (Hq)	--	----	----	----	----	x	-----	-----	----	----	x	X	3	3	0
1	KANPUR	--	----	-----	x	X	x	x	x	----	NC	---	-	6	5	1
2	MARUTERU	x	x	x	----	X	----	x	x	----	x	x	X	9	9	0
3	TITABAR	x	x	x	----	X	----	----	----	x	x	--	NC	7	6	1
4	ADUTHURAI	----	----	----	----	x	--	----	---	----	NC	--	X	3	2	1
5	CHINSURAH	----	----	NC	----	--	--	x	x	----	----	x	--	4	3	1
6	FAIZABAD	---	---	----	----	X	--	x	x	----	--	x	--	4	4	--
7	GAGHRAGHAT	----	----	--	----	--	--	x	x	----	-----	--	--	2	2	----
8	KARAIKAL	----	----	NC	----	X	--	x	x	----	x	x	X	7	6	1
9	KHUDWANI	----	----	----	----	X	--	-----	--	----	----	--	--	1	1	0
10	MANDYA	x	X	x	----	X	--	----	----	----	x	--	--	5	5	--
11	MONCOMPU	----	----	----	----	X	--	----	----	----	----	--	--	1	1	----
12	RAIPUR	----	----	------	-----	x	--	X	x	----	---	--	--	3	3	--
13	SIRSI	---	---	NC	CNR	---	--	----	----	----	-----	--	--	2	0	2
14	BANKURA	---	---	-----	-----	X	--	----	----	----	-----	--	--	1	1	0
15	RANCHI	----	----	----	----	--	--	----	----	--	----	--	--	1	1	0
x	Total allotted	3	3	6	2	11	2	7	7	2	6	5	5	59	----	----
x	Conducted	3	3	3	1	11	2	7	7	1	4	5	4	--	51	----
NC	Not conducted	---	---	3	1	0	0	0	0	1	2	0	1	--	----	7

Trial No.1 Long-term soil fertility management in rice based cropping systems (RBCS) (Kharif and Rabi)
Trial No.2 Rice productivity in relation to internal supply capacity of nutrients in farmer's fields
Trial No.3 Integrated management for enhancing rice productivity in sodic soils (Kharif and Rabi)
Trial No.4 Screening of rice germplasms 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 Management of crop residues in rice based cropping systems (Kharif and Rabi)
Trial No.7 Screening of genotypes for acidity and related nutritional constraints (Kharif)
Trial No.8 Nutritional status of rice in farmers' field in relation to productivity (Kharif)
Trial No. 9 Nutrient requirements of recently released rice varieties and hybrids
Trial No.10 Partitioning and enrichment of Zn and Fe in rice

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