Srinivasagam Krishnakumar and Stephan Haefele

Integrated nutrient management and LCC based nitrogen management on soil fertility and yield of rice (Oryza Sativa L.)

Scientific Research and Essays, 2013; 8(41):2059-2067 academicJournals

Vol. 8(41), pp. 2059-2067, 4 November, 2013
DOI 10.5897/SRE2013.5643
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Integrated nutrient management and LCC based nitrogen management on soil fertility and yield of rice (*Oryza Sativa* L.)

Srinivasagam Krishnakumar[1]* and Stephan Haefele[2]

[1]Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi – 642 103, Tamil Nadu, India.
[2]Soil Science/Agronomy, Crop and Environmental Sciences Division, IRRI, Philippines.

Accepted 26 September, 2013

The experiment was conducted at lowland series of wet lands, International Rice Research Institute (IRRI) Farm, Los Banos, Laguna, Philippines. The rice variety PSBRc 82 was raised during wet season (June – October), and the experiment was laid out in randomized block design with four replications. There were eleven treatments viz., control, recommended NPK fertilizer, -N, -P, -K, LCC 3, LCC 4, LCC 5, 100% N as fresh rice straw, 50% N through rice straw compost and 50% N as poultry manure and 50% N as combined organic manures (RSC + PM). The P and K were applied to all the treatments except -P and –K treatments, respectively. The fertilizer N @ 90 kg ha^{-1}, P_2O_5 @ 40 kg ha^{-1} and K_2O @ 60 kg ha^{-1} were applied in the form of urea, super phosphate and muriate of potash respectively. The application of N at 90 kg level as 50% through RSC + 50% N as PM registered higher available N, P and K contents of soil during different growth stages as compared to the other treatment combinations including recommended NPK fertilizers. The growth and yield attributes were also found to be improved by the above treatment resulting in more grain and straw yield. With regard to N management, LCC 4 and 5 based N applications recorded higher grain yield as a result of higher soil available nutrients during the critical growth stages.

Key words: Nutrient management, soil fertility, fertilizer, Rice variety, yield.

INTRODUCTION

Rice is the most vital food crop and a major food grain for more than a third of the world's population (Zhao et al., 2011). Its most important and essential plant nutrient is nitrogen and will increase the crop yield positively (Dastan et al., 2012). Chlorophyll, a green pigment present in plants, captures the sunlight that is used in photo synthesis (Swain and Jagtap, 2010). Rice plant needs a sufficient supply of nutrients from several sources for optimal growth. These nutrients are supplied by indigenous sources such as soil minerals, soil organic matter, rice straw, manure, and water (rain, irrigation), but the amount supplied is usually insufficient to achieve high and sustainable yields. However, the use of organic manures alone might not meet the plant requirement due to presence of relatively low levels of nutrients. Therefore, in order to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields (Rama Lakshmi et al., 2012). Many of our problems on declining productivity (increasing cost, declining yield) can be traced to imbalanced and inefficient use of nutrients. Improper nutrient management has resulted in the nutrient imbalances in

*Corresponding author. E-mail: drkrishnakumar76@gmail.com.

Table 1. Intercultural operations.

S.No	Character/cultural operation	Details
1.	Variety	PSBRc 82
2.	Duration (days)	115 - 117
3.	Plot size (m^2)	3 × 5 = 15
4.	Date of sowing	01-06-2004
5.	Date of transplanting	15-06-2004
6.	Spacing (cm)	20 × 20
7.	Date of harvesting	05-10-2004

Table 2. Treatment details.

Treatments	Details
T_1	Control
T_2	RD of NPK (90:40:60 N P_2O_5: K_2O ha^{-1})
T_3	0 N (RD of P & K)
T_4	0 P (RD of N & K)
T_5	0 K (RD of N & P)
T_6	N as per LCC 3 (P&K as per RD)
T_7	N as per LCC 4 (P&K as per RD)
T_8	N as per LCC 5 (P&K as per RD)
T_9	100% N FRS + RD of P & K
T_{10}	50% N RSC + 50% N PM + RD P&K
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K

the soil with nutrients in excess while other nutrients depleted. Integrated nutrient management (INM) is very important in rice production. Through this, farmers can increase agricultural productivity and safeguard the environment as they efficiently use fertilizer (Rice Technology Bulletin Series, 2002). Awareness about crop quality and soil health increased the attention of people towards organic farming (Sharma et al., 2008).

Plant based tools for real time nitrogen management in rice through use of Leaf Color Chart (LCC) is becoming progressively popular in South and South East Asian rice farming. Leaf color chart (LCC) is made of high quality plastic material. It consists of six colour ranging from light yellowish green (NO1) to dark green (NO6) colour strips fabricated with veins resembling those of rice leaves (Nachimuthu et al., 2007). It has been observed that more than 60% of applied nitrogen is lost due to lack of harmonization between the nitrogen demand and nitrogen supply (Yadav et al., 2004) Farmers normally apply nitrogen fertilizer in fixed time advocated N split schedule (Pillai et al., 1993) in 1:2:1 or 2:1:1 ratio at basal, extreme tillering and panicle initiation phases respectively, without taking into account whether the plant really requires N at that time which may lead to loss or may not be found sufficient enough to harmonize nitrogen supply with actual crop nitrogen demand (Ladha et al., 2000).

MATERIALS AND METHODS

Location

The experiment was conducted in low land series of wet lands of International Rice Research Institute (IRRI) Farm, Los Banos, Laguna, Philippines.

Crop and variety

Rice variety PSBRc 82 was raised during wet season (June to October 2004). The details of important cultural operations are shown in Table 1, such as sowing, transplanting and harvesting are as furnished below.

Treatment details

The field experiment was conducted in Randomized Block Design with 11 treatment combinations replicated thrice and treatment details are as follows (Table 2).

Layout of the field experiment

The field was divided into 44 plots of 15 m^2 size with adequate

Table 3. Amount of Nitrogen added through treatments.

Treatment	N (kg)
T_1	0
T_2	90
T_3	0
T_4	90
T_5	90
T_6	90 (Four splits viz., 15, 25, 25, 25)
T_7	115 (Five splits viz., 15, 25, 25, 25, 25)
T_8	140 (Six splits viz., 15, 25, 25, 25, 25, 25)
T_9	90 kg N as FRS
T_{10}	45 kg N as RSC + 45kg N as PM
T_{11}	45 kg N as RSC+ PM + 45kg N as urea

irrigation and drainage channels with clear demarcation of boundary for the four replications. The treatments were allotted to plots using Fisher's random numbers in each replication.

Application of organic manures and fertilizers

There are three treatments involving various sources of organic manures such as fresh rice straw (FRS), rice straw compost (RSC) and poultry manure (PM) applied on equal N basis. These manures were analyzed for N, P and K contents and the quantity of organic manures used to supply 90 kg ha^{-1} were calculated and applied at ten days prior to transplanting. The treatment that received fertilizer N @ 90 kg ha^{-1}, P_2O_5 @ 40 kg ha^{-1} and K_2O @ 60 kg ha^{-1} received the nutrients in the form of urea, super phosphate and muriate of potash. Half the dose of N and K_2O and full dose of P_2O_5 were applied basally and the remaining half of the N and K_2O were applied in 2 equal splits at tillering and panicle initiation stages. The absolute control treatment received no manures or fertilizers.

Amount of N added through treatments

The amount of nitrogen added through treatments are as shown in Table 3.

Biometrical observations

Five plants were selected at random and tagged for recording biometric observations.

Plant height

Plant height was recorded from ground level to the tip of the top most leaf or panicle and the mean height was worked out and expressed in centimeter.

Number of tillers and productive tillers m^{-2}

Number of tillers was counted at tillering and flowering stages and productive tillers m^{-2} was counted at harvest stage.

Panicle length

Five panicles were taken from each plot and the length was measured from the scar of the panicle to the tip of the panicle and the mean panicle length was expressed in centimeter.

Number of grains per panicle

Five panicles were taken from each plot and the number of grains per panicles was counted and the mean number of grains of panicle was worked out.

Thousand grain weight

One thousand grains from each treatment were counted and the weight was recorded in gram.

Grain and straw yield

Grain and straw yields were recorded separately for each plot and expressed at 14% moisture level.

RESULTS AND DISCUSSION

Effect on nutrient availability

Available N

The available N status of soil was increased up to the tillering stage and there was a gradual decrease in N availability status at harvest stage (Tables 4 and 5). This might be due to the release of N from organic manures and simultaneous uptake by rice. Soil application of 50% N as RSC + 50% N as PM + RD P and K @ 90 kg N ha^{-1} gave significantly higher available N compared to control treatment. The per cent increase in 50% N as RSC + 50% N as PM + RD P and K @ 90 kg N ha^{-1}, 50% N through combined organics (RSC + PM) + 50% N as inorganic + RD P and K and 100% N FRS + RD P and K over recommended NPK fertilizer treatment (T_2) was 7.1, 7.0 and 6.3 respectively at tillering stage and 22.3, 19.2 and 9.3 respectively at post harvest stage of crop growth. This might be due to direct effect of decomposition and mineralization of nitrogen from various organic manures and indirectly due to rhizosphere effect in increasing the microbial activity and its impact on available N content in flooded soil. Ramesh (1998) reported that application of poultry manure increased the total as well as available N content of soil, besides increasing ammonical and nitrate N concentration in soil as compared to other organic sources. The available N content of soil decreased with stages of advancement of crop growth stages.

As could be expected, application of 140 kg N ha^{-1} in six splits (LCC 5) showed highest available N at different stages of plant growth compared to other LCC treatments. The higher N availability obtained due to the application of110 kg N ha^{-1} applied at different stages of crop growth was also reported by Michael and Behringer (1980). The lowest available N was observed in control treatment. Though the N management treatments viz., LCC 3, LCC 4 and LCC 5 did not show significant

Table 4. Available NPK content of soil at tillering stage of PSBRc 82 rice as influenced by organic manures and LCC based N management.

Treatments		Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Control	244	26.9	233
T_2	RD of NPK	247	31.5	240
T_3	0 N (RD of P & K)	257	32.8	242
T_4	0 P (RD of N & K)	235	24.4	239
T_5	0 K (RD of N & P)	225	31.1	243
T_6	LCC 3 (P&K as per RD)	240	29.7	237
T_7	LCC 4 (P&K as per RD)	240	32.2	242
T_8	LCC 5 (P&K as per RD)	242	27.5	241
T_9	100% N FRS + RD of P & K	263	31.2	260
T_{10}	50% N RSC + 50% N PM + RD P&K	265	58.0	302
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K	265	45.0	285
SEd		8.04	1.73	8.56
CD (p = 0.05)		16	3.5	18

FRS– Fresh rice straw; RSC– Rice straw compost; PM– Poultry manure; LCC – Leaf colour chart.

Table 5. Available NPK content of soil at post harvest stage of PSBRc 82 rice as influenced by organic manures and LCC based N management.

Treatments		Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Control	241	24.1	228
T_2	RD of NPK	279	38.8	250
T_3	0 N (RD of P & K)	284	47.5	248
T_4	0 P (RD of N & K)	276	33.4	245
T_5	0 K (RD of N & P)	271	44.9	253
T_6	LCC 3 (P&K as per RD)	277	38.9	244
T_7	LCC 4 (P&K as per RD)	278	39.2	255
T_8	LCC 5 (P&K as per RD)	288	39.8	250
T_9	100% N FRS + RD of P & K	307	42.1	315
T_{10}	50% N RSC + 50% N PM + RD P&K	359	56.5	331
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K	345	53.9	318
SEd		6.34	2.08	5.32
CD (p = 0.05)		13	4.2	11

FRS– Fresh rice straw; RSC– Rice straw compost; PM– Poultry manure; LCC – Leaf colour chart.

variation in soil available N during initial stages after transplanting. The LCC 5 had 3% increase in soil available N at post harvest stage. The probable reason might be the addition of higher quantity of N.

Available P

Significant difference in the available P status of the soil was observed during different stages of crop growth. The available P was observed to be higher at tillering stage and progressively decreased at the flowering and maturity stages of crop growth. The plant uptake of P was probably lower during the tillering stage and the amount of uptake increased due to increased biomass production towards maturity stage (Tables 4 and 5). The available P content of the soil was found to be significantly higher in the treatment that received 90 kg N ha^{-1} as 50% N through RSC + 50% N as PM + RD P and K than control treatment. The per cent increase in 50% N RSC + 50% N PM + RD P and K @ 90 kg N ha^{-1} and 50% N through combined organics (RSC + PM) + 50% N as inorganic + RD P and K over recommended NPK fertilizer treatment (T_2) was 45.7 and 30% respectively at active tillering stage and 31.3 and 28.0 respectively at post harvest stage of crop growth. Organic manures on decomposition in soil might release organic acid which would have solubilized the soil P as reported by Sripriya (1993). Among LCC treatments, LCC 4 and LCC 5 were found to give higher available P content of the soil. Johnkutty et al.

Table 6. Height of PSBRc 82 rice as influenced by organic manures and LCC based N management.

Treatments (T)		Plant height (cm)			
		Active Tillering (S_1)	Panicle initiation (S_2)	Post harvest (S_3)	Mean
T_1	Control	36.8	70.1	91.4	66.1
T_2	RD of NPK	42.4	78.3	98.5	73.1
T_3	0 N (RD of P & K)	39.7	72.6	88.7	67.0
T_4	0 P (RD of N & K)	39.7	83.1	104.9	75.9
T_5	0 K (RD of N & P)	44	79.9	100.5	74.8
T_6	LCC 3 (P&K as per RD)	41.8	80	96.3	72.7
T_7	LCC 4 (P&K as per RD)	42.4	77	98.6	72.7
T_8	LCC 5 (P&K as per RD)	42.6	80.1	97.9	73.5
T_9	100% N FRS + RD of P & K	27.4	71.4	96.7	65.2
T_{10}	50% N RSC + 50% N PM + RD P&K	41.9	86.3	103.7	77.3
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K	42.1	80.9	98.5	73.8
	Mean	**40.1**	**78.1**	**97.8**	**-**

	SEd	CD (p = 0.05)
T	1.06	2.1
S	0.55	1.1
T × S	1.83	3.7

FRS– Fresh rice straw; RSC– Rice straw compost; PM– Poultry manure; LCC – Leaf colour chart.

(2000) also brought out similar results for increased P availability due to higher N applications. The recommended NPK fertilizer treatment gave lowest available P than organic manures treatment.

Available K

Significant variation in the available K content of the soil was observed due to the application of various sources of organic manures. The reduction in available K content from tillering to harvest stage might be due to the uptake of K by the crop and retention in clay complex (Tables 4 and 5). Application of N @ 90 kg ha^{-1}as 50% RSC + 50% N PM + RD P and K recorded the highest soil available K in all the stages of crop growth. The per cent increase in 50% N through RSC + 50% N as PM @ 90 kg N ha^{-1}, 50% N through combined organics (RSC + PM) + 50% N as inorganic fertilizer and 100% N as FRS over recommended NPK fertilizer treatment (T_2) was 20.6, 15.6 and 7.5 respectively at active tillering stage and 24.3, 20.7 and 20.6 respectively at post harvest stage of crop growth. The increased available K in this treatment might be due to the abundant release of K from poultry manure as well as its effects on release of soil K. Among all LCC treatments, LCC 4 showed highest available potassium. The recommended NPK fertilizer treatment showed lowest available K than organic manure treatment.

The LCC 4 (115 kg N ha^{-1}) treatment showed higher available potassium at all the growth stages of rice crop which might be due to the synergetic effect of N on potassium.

Effect on growth and yield attributes

Plant height

Soil application of various sources of organic manures @ 90 kg N ha^{-1} significantly influenced the plant height at different growth stages of the plant. Among various sources of organic manures, soil application of 90 kg N ha^{-1} in the form of 50% N as RSC + 50% N as PM + RD P and K showed significantly highest plant height than absolute control (Table 6). This might be due to higher available nutrients as a result of RSC and PM (Ramesh, 1998). Application of 90 kg N ha^{-1} in the form of 50% N as RSC + 50% N as PM + RD P and K showed significantly higher plant height of 5.4% more than the recommended dose of NPK fertilizer (T_2). Application of 140 kg N ha^{-1} in six splits under LCC 5 treatment increased the plant height which was attributed to higher amount of N addition. Positive correlation between plant height and N levels have been earlier reported by Balasubramanian et al. (2000).

Number of tillers

Soil application of 90 kg N ha^{-1} in the form of 50% N through RSC + 50% N as PM + RD P and K showed significantly higher number of tillers than absolute control treatment (Table 7). Increase in tiller production with the

Table 7. Number of tillers of PSBRc 82 rice as influenced by organic manures and LCC based N management.

Treatments (T)		Tiller number m^{-2}			
		Active tillering (S_1)	Panicle initiation (S_2)	Post harvest (S_3)	Mean
T_1	Control	148	261	253	223.3
T_2	RD of NPK	270	413	450	377.6
T_3	0 N (RD of P & K)	177	238	257	223.6
T_4	0 P (RD of N & K)	209	417	450	358.9
T_5	0 K (RD of N & P)	294	406	418	372.5
T_6	LCC 3 (P&K as per RD)	219	319	319	285.6
T_7	LCC 4 (P&K as per RD)	283	388	427	365.7
T_8	LCC 5 (P&K as per RD)	234	366	426	342.1
T_9	100% N FRS + RD of P & K	94	323	324	247.0
T_{10}	50% N RSC + 50% N PM + RD P&K	308	425	481	404.7
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K	241	427	475	380.7
	Mean	**225.1**	**361.9**	**389.8**	**-**

	SEd	CD (p = 0.05)
T	20.3	40
S	10.6	21
T × S	35.2	70

FRS– Fresh rice straw; RSC– Rice straw compost; PM– Poultry manure; LCC – Leaf colour chart.

Table 8. Panicle number and length of PSBRc 82 rice as influenced by organic manures and LCC based N management.

Treatments		Panicle No. hill^{-1}	Panicle length (cm)
T_1	Control	9	23.0
T_2	RD of NPK	10	25.5
T_3	0 N (RD of P & K)	9	24.2
T_4	0 P (RD of N & K)	12	25.4
T_5	0 K (RD of N & P)	11	24.9
T_6	LCC 3 (P&K as per RD)	11	24.2
T_7	LCC 4 (P&K as per RD)	12	25.3
T_8	LCC 5 (P&K as per RD)	11	25.8
T_9	100% N FRS + RD of P & K	10	25.4
T_{10}	50% N RSC + 50% N PM + RD P&K	13	25.7
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K	11	26.1
SEd		0.61	0.33
CD (p = 0.05)		1	0.7

FRS– Fresh rice straw; RSC– Rice straw compost; PM– Poultry manure; LCC – Leaf colour chart.

poultry manure application might be due to the dual benefits of improving the physical environment of rzhiosphere region and supplying plant nutrients. LCC 4 gave significantly highest number of tillers compared to LCC 3 treatment, but was on par with LCC 5. More number of early formed tillers under favourable N nutrition tends to bear more number of panicles. It may be due to higher availability and uptake of N, which is a substrate for synthesis of organic compounds, which constitute protoplasm and chlorophyll (Hatwar et al., 1992). This was the reason for the production of higher number of tillers in treatments LCC 4 and LCC 5 over the no fertilizer applied treatment.

Panicle number hill^{-1}

Among the various treatments, application of 90 kg N ha^{-1} in the form of 50% N as RSC + 50% N as PM + RD P and K showed significantly higher number of panicles and also lengthier panicles (Table 8). Besides, higher

Table 9. Filled, unfilled grains and thousand grain weight of PSBRc 82 rice as influenced by organic manures and LCC based N management.

Treatments		Filled Grain/Panicle	Unfilled Grains/Panicle	1000 Gr. Wt. (g)
T_1	Control	71	28	26.1
T_2	RD of NPK	83	22	27.0
T_3	0 N (RD of P & K)	84	22	26.0
T_4	0 P (RD of N & K)	91	26	27.5
T_5	0 K (RD of N & P)	74	26	27.3
T_6	LCC 3 (P&K as per RD)	81	17	26.2
T_7	LCC 4 (P&K as per RD)	94	15	27.2
T_8	LCC 5 (P&K as per RD)	92	16	27.5
T_9	100% N FRS + RD of P & K	92	20	25.3
T_{10}	50% N RSC + 50% N PM + RD P&K	89	10	27.3
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K	90	12	27.3
SEd		3.5	2.7	0.31
CD (p = 0.05)		7	6	0.6

FRS– Fresh rice straw; RSC– Rice straw compost; PM– Poultry manure; LCC – Leaf colour chart.

nutritional status helped the production of panicle number and lengthier panicles too, with more number of filled grains and grain weight (Arumugaperumal, 2000). The treatments receiving higher N dose namely, LCC 4 and LCC 5 produced higher panicle number and lengthier panicle respectively, over no fertilizer applied treatment. Increased levels of N application in splits synchronized with the nutritional demand of rice at all the stages resulted in longer panicles.

Application of 90 kg N ha^{-1} in the form of 50% N as RSC + 50% N as PM + RD P and K showed significantly higher number of panicles (23.1%) and 50% N combined organics (RSC + PM) + 50% N inorganic + RD P and K recorded significantly lengthier panicles (16.7%) than recommended dose of NPK fertilizer (T_2). The per cent increase number of panicles in treatments LCC 3 (90 kg N ha^{-1}), LCC 4 (115 kg N ha^{-1}) and LCC 5 (140 kg N ha^{-1}) over was 9.1, 16.7 and 9.1 and LCC 5 (145 kg N ha^{-1}) gave lengthier panicles than T_2 treatment.

Among various treatments, 100% N as FRS showed significantly higher filled grains panicle^{-1} and application of 90 kg N ha^{-1} in the form of 50% N as RSC + 50% N as PM + RD P and K showed lower unfilled grains panicle^{-1} (Table 9). Among LCC treatments, LCC 4 showed highest filled grains panicle^{-1} and lowest unfilled grains panicle^{-1}. This was due to the higher nutrient uptake and higher plant assimilation with adequate supply of photosynthates to grains, as explained by Morales et al. (2000).

Among organic manure treatments, 50% N as RSC + 50% N as PM + RD P and K (T_{10}) showed highest thousand grain weight and 140 kg N ha^{-1} (LCC 5) gave significantly higher thousand grain weight as compared to other LCC treatments. Asif et al. (1999) reported that the split application of nitrogen sustained the supply of N throughout the vegetative and reproductive development of plant, particularly during grain filling and ripening (Table 9). Nayak and Patra (2000) reported that the increased thousand grain weight due to N application at flowering could be attributed to the increased filled grains. The highest thousand grain weight was recorded in the 50% N as RSC + 50% N as PM + RD P and K and LCC 5 (140 kg N ha^{-1}) treatments compared to recommended dose of NPK fertilizer treatment.

Yield of rice

The grain yield, straw yield and dry matter production of rice were significantly influenced by application of various sources of organic manures and other treatments. The results revealed that application of 90 kg N ha^{-1} in the form of 50% N through RSC + 50% N as PM + RD P and K recorded significantly higher grain and straw yield than other treatments (Table 10). High yield obtained for the application of rice straw compost and poultry manure may be attributed to the growth parameters and yield attributes viz., productive tillers, lengthier and more number of panicles besides thousand grain weight. The higher soil available nutrients as observed under this treatment would have contributed to more nutrient uptake ultimately resulting in high yield.

Among LCC treatments, LCC 4 gave highest grain yield, DMP and LCC 5 showed higher straw yield. The grain filling can be one prime reason for the yield differences. The LCC 4 had the highest filled grains and reduced unfilled grains. Due to this reason the increased grain yield was noted in LCC 4. The consumed level of

Table 10. Grain yield and straw yield of PSBRc 82 rice as influenced by organic manures and LCC based N management.

Treatments		Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})
T_1	Control	3340	3159
T_2	RD of NPK	4524	5260
T_3	0 N (RD of P & K)	3582	3432
T_4	0 P (RD of N & K)	5142	5327
T_5	0 K (RD of N & P)	4344	5268
T_6	LCC 3 (P&K as per RD)	4590	4843
T_7	LCC 4 (P&K as per RD)	5003	5684
T_8	LCC 5 (P&K as per RD)	4804	5775
T_9	100% N FRS + RD of P & K	4544	5538
T_{10}	50% N RSC + 50% N PM + RD P&K	5360	6155
T_{11}	50% N Combined organic (RSC +PM) + 50% N inorganic +RD P& K	5120	5513
SEd		291	375
CD (p = 0.05)		595	765

FRS– Fresh rice straw; RSC– Rice straw compost; PM– Poultry manure; LCC – Leaf colour chart.

fertilizer application (115 kg N ha^{-1}) had recorded the highest grain yield in LCC 4 which was much higher when compared to no fertilizer treatment. Stalin et al. (2000) also got the best yield of rice in the dose of 115 kg N ha^{-1}. Peng et al. (1993) ascribed the increased grain yield to the favourable effects of improved leaf N concentration, photosynthetic rate of flag leaves and increased filled grain percentage. A better response for N dose up to 130 kg N ha^{-1} in rice was reported by Stalin et al. (2000) who reported that the N doses have to be applied only after careful assessment of plant requirement through LCC and not by predetermined crop calender timings, because the need based application help in increased filled – grain per cent and thousand grain weight. Effect of different split application N-fertilizer was significantly on LCC values each of the time (Yoseftabar, 2013). Fertilizer N is applied whenever the leaves are less greenish than a threshold LCC value, which corresponds to a critical leaf N content (Singh et al., 2010). Application of nitrogen in split according to the crop needs was the reason for better rice growth parameter (Sathiya and Ramesh, 2009).

LCC is easy to use and is an inexpensive diagnostic tool for monitoring the relative greenness of rice leaf as an indicator for the plant N status and can be used as an alternative to chlorophyll meter (Sen et al., 2011).

The treatment receiving 90 kg N ha^{-1} in the form of 50% N through combined organics (RSC + PM) + 50% N as inorganic + RD P and K showed next best organic treatment and 100% N through FRS + RD of P and K gave lowest grain yield compared to other organic treatments. But 100% N as FRS + RD of P and K gave higher yield than absolute control as could be expected. Interestingly, it was on par with recommended NPK which may be ascribed due to the nutrient release from rice straw under lowland situations. Sodhi et al., (2009) did a study of continuous application of rice straw compost to soil properties. They apply rice straw compost either alone or in conjunction with inorganic fertilizers and studied the impacts on aggregate stability and distribution of carbon and nitrogen on a sandy loam soil.

The benefit gained by farmers is seen as the reduction of using chemical fertilizer based on the associate chemical components of the compost. According to (FAO, 2005), the recommended rate of nitrogen for rice is 95-145 kg/ha. If the straw compost contains 1.86% (Isroi, 2009) of nitrogen, about 26 kg of nitrogen is available from 1.4 ton of compost. Farmers can use this source of nitrogen and can save about one quarter of the nitrogen needs. For example, as mentioned earlier that 1 ton of rice straw compost is equivalent with 41.3 kg urea. Organic manures were often superior to inorganic fertilizer as they exhibit dual benefits of improving the physical environment of soil and also supply the plant nutrients, which might have contributed to the increased nutrient uptake and ultimately the higher grain yield. Application of 90 kg N ha^{-1} in the form of 50% N through RSC + 50% N as PM + RD P and K recorded significantly higher grain yield (15.6%) and straw yield (17.0%) over recommended dose of NPK fertilizer (T_2) treatment. The integrated nutrient management technique resulted in a positive influx of nutrients by increasing organic carbon content, available nitrogen, phosphorus, and potassium. It was found that the application of enriched poultry manure compost on equal N basis (2.3 t·ha^{-1}) recorded higher yield attributes and grain yield of rice (4675 kg·ha^{-1} in 2007 and 4953 kg·ha^{-1} in 2008), which was however comparable with composted poultry manure (Sangeetha et al., 2013).

Conclusion

Application of nitrogen at 90 kg level as 50% through

Rice straw compost + 50% nitrogen as poultry manure registered higher available N, P and K contents of soil during different growth stages as compared to the other treatment combinations. The growth and yield attributes were also found to be enhanced by the above treatment resulting in more grain and straw yield. With regard to N management, LCC 4 and 5 based N applications recorded higher grain yield as a result of higher soil available nutrients during the critical growth stages.

ACKNOWLEDGEMENT

Authors are grateful to Jawaharlal Nehru Memorial Fund (JNMF), New Delhi for allowing this research to be carried out at International Rice Research Institute, Philippines.

REFERENCES

Abichandani CT, Patnaik S (1958). Nitrogen changes and fertilizer losses in lowland and waterlogged soils. J. Indian Soc. Soil Sci. 6:87-93.

Acharya CL, Bishnoi SK, Yaduvanshi HS (1988). Effect of long term application of fertilizers and organic amendments under continuous cropping on soil physical and chemical properties in an *Alfisol*. Indian J. Agric. Sci. 58:509-516.

Arumugaperumal N (2000). Studies on plant density and nitrogen management in hybrid rice (CORH 2) under Thambiraparani Command area. M.Sc. (Ag.) Thesis, TNAU, Coimbatore.

Asif M, Chaudhary FM, Saeed M (1999). Influence of NPK levels and split N application on grain filling and yield of fine rice. IRRN 24:30-31.

Balasubramanian V, Morales AC, Cruz RT, Thiyagarajan TM (2000). Adaptation of the chlorophyll meter (SPAD) technology for real-time N management in rice: A review. IRRN 25(1):4-8.

Dastan S, Siavoshi M, Zakavi D, Ghanbaria-Malidarreh A, Yadi R, Ghorbannia Delavar E, Nasiri AR (2012). Application of nitrogen and silicon rates on morphological and chemical lodging related characteristics in rice (Oryza sativa L.) north of Iran. J. Agric. Sci. 4(6).

FAO (2005). Fertilizer use by crop in Egypt. FAO, Rome.

Hatwar KG, Rahaste VT, Thakare JT (1992). Nitrogen uptake behaviour of summer rice as influence by sowing date and N levels. Ann. Plant Physiol. 6(2):252-257.

Integrated Nutrient Management for Rice Production. Rice Technology Bulletin Series, 2002 No. 5, IRRI, Philippines.

Isroi (2009). Hasil analisa kompos jerami dan nilai haranya [Online]. Available by isroi.wordpress.com http://isroi.wordpress.com/2009/05/13/hasil-analisakompos- jerami-dan-nilai-haranya/ (verified May, 29).

Johnkutty L, Kandawamy OS, Palaniappan SP (2000). Time course Leaf N concentration in rice under different nitrogen application strategies and development of simulation models. J. Trop. Agric. 37:40-45.

Ladha JK, Fischer KS, Hossain M, Hobbs PR, Hardy B Eds. (2000). Improving the Productivity and Sustainability of Rice-Wheat Systems of the Indo-Gangetic Plains. A Synthesis of NARS-IRRI Partnership Research Discussion Paper 40, IRRI, Los Banos, 2000.

Michael G, Behringer H (1980). The role of hormones in yield formation. In: Physiological aspects of crop productivity, pp. 85-116. International Potash Institute, Berne, Switzerland.

Morales AC, Agustin EO, Lucas MP, Marcos TF, Chlanay DA (2000). Comparative efficiency of N management practices on the performance of upland rice. Oryza 29:234-239.

Nayak BC, Patra AK (2000). Effect of nursery seeding density on seedlings vigour and yield of summer rice (*Oryza sativa*) under varying seedlings rates. Indian J. Agron. 45(3):555-559.

Nchimuthu G, Velu V, Malarvizhi P, Ramasamy S, Gurusamy L (2007). Standardisation of leaf colour chart based nitrogen management in direct wet seeded rice (*Oryza sativa* L.). J. Agron. 6(2):338-343.

Peng S, Garcia FV, Laza RC, Cassman KG (1993). Adjustment for specific leaf weight improves chlorophyll meter estimate of leaf nitrogen concentration. Agron. J. 85:987-990.

Pillai KG, Kundu DK (1993). Fertilizer Management in Rice, In: H. L. S. Tandon, Ed., *Fertilizer Management in Food Crops*, Fertilizer Development and Consultation Organization, New Delhi, pp. 1-26.

Rama Lakshmi ChS, Rao PC, Sreelatha M, Madhavi G, Padmaja PV, Rao PV, Sireesha A (2012). Nitrogen Use Efficiency and Production Efficiency of Rice UnderRice-Pulse Cropping System with Integrated Nutrient Management. J. Rice Res. 5(1&2):42-51.

Ramesh S (1998). Substitution of inorganic N through poultry manure and livestock wastes in low land rice. M.Sc. (Ag.) Thesis, TNAU, Coimbatore.

Sangeetha SP, Balakrishnan A, Devasenapathy P (2013). Influence of Organic Manures on Yield and Quality of Rice (*Oryza sativa* L.) and Blackgram (*Vigna mungo* L.) in Rice-Blackgram Cropping Sequence. Am. J. Plant Sci. 4:1151-1157.

Sathiya K, Ramesh T (2009). Effect of split application of nitrogen on growth and yield aerobic rice. Asian J. Exp. Sci. 23(1):303-306.

Sharma M, Pandey CS, Mahapatra BS (2008). Effect of Biofertilizers on Yield and Nutrient Uptake by Rice and Wheat in Rice-Wheat Cropping System under Organic Mode of Cultivation. J. Eco-friendly Agric. 3(1):19-23.

Singh H, Sharma KN, Dhillon GS, Singh T, Singh V, Kumar D, Singh H (2010). On-farm evaluation of real-time nitrogen management in rice. Better Crop 94(4):26-28.

Sodhi GPS, Beri V, Benbi DK (2009). Soil aggregation and distribution of carbon and nitrogen in different fractions under long-term application of compost in rice-wheat system. Soil Till. Res. 103:412-418.

Sripriya S (1993). Studies on the efficacy of humic acid on soil fertility attributes and response of ADT 36 rice. M.Sc. (Ag.) Thesis, TNAU, Coimbatore.

Stalin P, Thiyagarajan TM, Ramanathan S, Subramanian M (2000). Comparing management techniques to optimize fertilizer N application in rice in the Cauvery Delta of Tamil Nadu, India. IRRN 25(2):25-26.

Subbaiah SV (2006). Rice Meeting Challenges. The Hindu Survey of Indian Agriculture, pp. 50-54.

Swain DK, Jagtap SS (2010). Development of spad values of medium- and long duration rice variety for site-specific nitrogen management. J. Agron. 9(2):38-44.

Yadav RL, Padre AT, Pandey PS, Sharma SK (2004). Calibrating the Leaf Color Chart for Nitrogen Manage-ment in Different Genotypes of Rice and Wheat in a System, Agron. J. 98:1606-1621.

Yoseftabar S (2013). Effect of split application of nitrogen fertilizer on leaf color chart values in hybrid rice (grh1). Int. J. Biol. 5(1):79-84.

Zhao L, Wu L, Wu M, Li Y (2011). Nutrient uptake and water use efficiency as affected by modified rice cultivation methods with irrigation. Paddy Water Environ. 9:25-32.