Madras Agric. J., 101 (7-9): 251-256, September 2014
https://doi.org/10.29321/MAJ.10.001192

Effect of Calcium Silicate on Nitrogen Management by Adopting LCC in Aerobic Rice (*Oryza sativa* L.)

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Nitrogen (N) fertility is an important component of rice cultivation systems, especially where rice growing under aerobic condition. This study examined the effects of silicon (Si) and leaf colour chart (LCC) based N management on yield and N use efficiency under aerobic rice. A field experiment was conducted in sandy loam soils at Bangalore-north with split plot design. The treatments consist of four main plots *viz*., control (No N), 60 kg Nha $^{-1}$(No basal + LCC-3), 90 kg Nha^{-1}(Urea at 30 kg Nha $^{-1}$as basal + LCC-3) and 100 kg Nha $^{-1}$as urea (RDF) and two sub plots *viz*., with (calcium silicate at 2 tha^{-1}) and without Si treated plots. Periodical LCC readings were taken and N was applied if the LCC value falls below the prescribed critical value. The results revealed that the highest grain yield was noticed with the application calcium silicate at 2 t ha^{-1}and with 90 kg Nha^{-1}(Urea at 30 kg Nha^{-1}as basal + LCC-3) and it was on par with 60 kg Nha^{-1}(no basal + LCC-3) compared to recommended N (100 kg Nha $^{-1}$) under aerobic rice. Higher fertilizer N-use efficiency was recorded with the application of Si and need-based N management using LCC-3 rather than recommended dose of fertilizer over control.

Key words*:* Nitrogen, LCC, NUE, Silicon and Aerobic rice.

Aerobic method is a new concept of growing rice. It is a production system, which concentrates in direct seeding and irrigation intermittently in contrast to the practices, such as, raising nursery, puddling, transplantation and submergence. N has been and will continue to be the key input in augmenting India's food grain production, particularly the rice. For most soils of the country, nitrogen use efficiency (NUE) by rice is only about 30 to 40%. About one-third of applied N is lost by different N losses process (Abrol *et al*., 2007). Application of N can be done at right time with required quantity by making use of LCC, which reduces the leaching loss and enhances the nutrients uptake of crop (Bala subramanian and Morales, 2000). The use of LCC based fertilizer N management in wetland rice helped to save 27-56 kg Nha $^{-1}$in Punjab, 19-39 kg Nha^{-1}in Haryana, 30-40 kg Nha $^{-1}$in Bihar and 42-50 kg Nha^{-1}in West Bengal as compared to fixed-time blanket N recommendation or farmers practice without compromising grain yield (Bijay-singh *et al*., 2006). The NUE in rice was low due to the inefficient management of fertilizer N by farmers. Application of N fertilizer whenever leaf greenness was less than shade 4 on the LCC (the critical LCC value) produced rice grain yields on par with blanket recommendation in three equal splits in different years. It resulted in an average saving of 26% fertilizer N across season and site. In most situations, there was no significant advantage of applying 20 kg N ha^{-1}as basal N at transplanting on grain yield and NUE of rice compared with no basal N (Yadvinder Singh *et al*., 2007).

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Rice is considered to be a silicon (Si) accumulator plant and tends to actively accumulate Si to tissue concentrations of 5 per cent or higher (Epstein, 1994). Application of N fertilizers is an important practice for increasing rice yields. However, when applied in excess may limit yield because of lodging, promote shading and susceptibility to insects and diseases. These effects could be minimized by the use of Si (Munir *et al*., 2003). Information on the importance of Si in Indian rice farming system is limited (Prakash, 2002). Rice is prone to various stresses if the available soil silicon is low for absorption. Production of 5 tha $^{-1}$of grain yield of rice is estimated to remove about 230-470 kg elemental Si from soil, depending upon soil and plant factors. Absorption will be about 108 % more than the nitrogen content. Adequate supply of silicon to rice from tillering to elongation stage increases the number of grains per panicle and the percentage of ripening (Korndorfer *et al*., 2001). Silicon has been reported to raise the optimal level of nitrogen in rice. However, adoption of any real-time N management studies in aerobic rice is very limited and also information on Si and need-based N management in aerobic rice is not available.

Materials and Methods

A field experiment was conducted at eastern dry zone soils of Bengaluru north, Karnataka, India. The soil reaction was slightly acidic (6.6), with medium organic carbon (6.5 g/kg) and available N content (331.6 kg ha^{-1}). Similarly, available soil K_2O and P_2O_5 values were low (115 kg ha^{-1}) and medium (35.8 kg ha^{-1}), respectively. The aerobic rice cultivar BI-34 was sown in 30 X 20 cm spacing with two seeds per hill, the experiment was conducted in the split plot design with three replications. The treatments consisted of four main plots viz., control (No N), 60 kg N ha^{-1}(No basal + LCC-3), 90 kg N ha^{-1}(30 kg N ha^{-1}as basal + LCC-3) and 100 kg N ha^{-1}as urea (RDF) and two sub plots viz., with (calcium silicate at 2 tha^{-1}) and without silicon (Si) treated plots. The recommended N (RDF) was 100 kg N ha^{-1}applied in three splits with 50 % at sowing and 25 % each at maximum tillering stage and before flowering stages. Periodically LCC readings were taken in ten top most fully expanded leaves randomly and N was applied based on the LCC-3 critical values if the LCC values falls below the LCC-3 30 kg N ha^{-1} was applied on the same day. The recommended dose of P (SSP) and K (MOP) were applied at the time of sowing. Grain and straw samples were analyzed by using CHNS analyzer for total N content. Nitrogen use efficiency (NUE) in rice was calculated by using different efficiency formulae (Cassman *et al.,* 1998) *viz.*, agronomic efficiency (AE_N), apparent recovery efficiency (RE_N) and Partial factor productivity (PFE_N). The time and amount of N applied at different growth stages of aerobic rice is given in Table 1.

Determination of N in plant samples

The total nitrogen was determined using CHNS analyzer, (LECO, USA). For the analysis, crushed samples were weighed (5-10 mg) and mixed with an oxidizer (vanadium pentoxide [V_2O_5] in a tin capsule, which was then combusted in a reactor at 1000°C. The sample and container melt and the tin promote a violent reaction (flash combustion) in a temporarily enriched oxygen atmosphere. The combustion products $CO_2$and NO_2were carried by a constant flow of carrier gas (helium) that passes through a glass column packed with an oxidation catalyst of tungsten trioxide (WO_3) and a copper reducer, both kept at 1000°C. At this temperature, the nitrogen oxide was reduced to N_2. The $CO_2$and N_2were then transported by the helium and separated by a 2m long packed column (Poropak Q/S 50/80 mesh) and quantified with a Thermal Conductive Dictators (TCD) (set at 290°C.).

Method of application of N based on LCC

Leaf colour chart procured from Nitrogen parameter, Adambakkam, Chennai -600088. India, (e-mail:lccenquiry@gmail.com) was used in the present investigation. LCC is a simple, cheap, and easy-to-use tool that can help farmers manage N judiciously. The critical or threshold value of the LCC is defined as the intensity of green colour that must be maintained in the uppermost fully opened leaf of the rice plant and fertilizer N needs to be applied whenever leaf greenness is below the critical LCC value. Leaf greenness or leaf N content is closely related to photosynthesis rate and biomass production and is a sensitive indicator of changes in crop N demand during the growing season. Thus, maintaining the leaf greenness just above the LCC critical value ensures high yields with need-based N application thereby leading to high fertilizer N use efficiency.

Results and Discussion

The data pertaining to grain yield are depicted in the Table 2. There was a significant increase in the grain yield of aerobic rice with LCC-3 based N application over RDF. The highest grain yield (5.3 tha^{-1}) was noticed with application of 90 kg Nha^{-1} (urea at 30 kg Nha^{-1}as basal + LCC-3) over control (3.7 tha^{-1}). The comparisons between different amounts of N *i.e.,* the treatment with 90 kg Nha^{-1}(30 kg Nha^{-1}as basal + LCC-3) and 60 kg Nha^{-1}(No basal + LCC-3) were on par with each other.

Table 1. The time and amount of N applied at different growth stages of aerobic rice

Treatment	Basal	Maximum tillering stage	Before flowering stage	Total (kg N ha^{-1})
0 kg Nha^{-1}(Control)	-	-	-	-
60 kg Nha^{-1}(No basal + LCC-3)	-	30	30	60
90 kg Nha^{-1}(30 kg Nha-1 as basal + LCC-3)	30	30	30	90
100 kg Nha^{-1}as (RDF)	50	25	25	100

There was significant increase in grain yield in sub plots with the application of calcium silicate at 2 tha^{-1}(5.0 tha^{-1}) over control (4.3 tha^{-1}). The highest grain yield of (5.6 tha^{-1}) was noticed with the application of Si as calcium silicate at 2 $tha^{-1}$with 90 kg Nha^{-1}(30 kg N ha^{-1}as basal + LCC-3) and on par with 60 kg Nha^{-1}(No basal + LCC-3).

The highest straw yield (6.2 tha^{-1}) was recorded in the treatment with 100 kg Nha^{-1}(RDF) over control (4.6 tha^{-1}). Among the treatments with different amounts of N, the treatment with 90 kg Nha^{-1}(urea at 30 kg Nha^{-1}as basal + LCC-3) and 60 kg Nha^{-1} (No basal + LCC-3) recorded 5.7 and 5.5 tha^{-1} of straw yield respectively and found to be on par with each other. The components for producing higher grain are number of productive tillers, number of filled grain per panicle and 1000 grain weight. The higher number of productive tillers, number of filled grain per panicle and test weight were noticed in the treatment with 90 kg N ha^{-1}(30 kg N ha^{-1}+ LCC-3) and it was on par with 60 kg N ha^{-1}(No basal + LCC-3). The N absorbed by the plant from tillering to panicle initiation helped to increase the number of productive tillers and that absorbed during panicle initiation to flowering increased the number of filled spiklets per panicles (Budhar, 2005). In the present study also, enhanced number of productive tillers and filled grain per panicles were observed

Table 2. Effect of Si and N on grain and straw yield of aerobic rice

Treatment		Grain yield ($t ha^{-1}$)			Straw yield ($t ha^{-1}$)		
		-Si	+Si	Mean	-Si	+Si	Mean
0 kg Nha^{-1}(Control)		3.2	4.3	3.7	4.8	5.1	4.9
60 kg Nha^{-1}(No basal + LCC-3)		4.7	5.5	5.1	5.3	5.8	5.6
90 kg Nha^{-1} (30 kg Nha-1 as basal + LCC-3)		4.9	5.6	5.3	5.5	5.8	5.7
100 kg Nha^{-1}as (RDF)		4.4	4.5	4.5	6.2	6.2	6.2
Mean		4.3	5.0		5.5	5.7	
SEM ±	Main (N)			0.08			0.04
	Sub (Si)			0.05			0.03
CD (5%)	Main (N)			0.25			0.16
	Sub (Si)			0.48			012
Interaction	N x Si			0.16			0.25

wherever N was top dressed based on LCC at active tillering and panicle initiation stages. Inefficient and imbalance use of N fertilizer particularly at high levels of 100 kg N ha^{-1}(RDF), could reduce yield due to crop lodging, increased chaffy grains, increased disease and pest incidence and reduced profitability for farmers. This makes blanket recommendation of 100 kg N ha^{-1}could be highly inefficient for most of aerobic rice situations.

Application of calcium silicate at 2 tha^{-1}along with 100 kg Nha^{-1} (RDF) recorded highest straw yield (6.2 tha^{-1}) and the treatments with 60 kg Nha^{-1}(No basal + LCC-3) and 90 kg Nha^{-1}(30 kg Nha^{-1}as basal + LCC-3) were on par with each other. The LCC-guided N management with no other change in package of practices (RDF) for aerobic rice resulted in a total N fertilizer application of 60 kg N ha^{-1}compared with 100 kg N ha^{-1}in package of practices (RDF) of applying fixed-time N with two split doses. Application of N fertilizer whenever leaf greenness less than three on the LCC (the critical value) produced on par grain yield with 60 kg N ha^{-1} (without basal N) and 90 kg N ha^{-1}(with 30 kg N ha^{-1}as basal) of urea applying in two equal split doses, resulted in saving of 10 to 40 kg N $ha^{-1}$of fertilizer N. Plant growth reflects total N supply from all sources. Plant N presumably is the best indicator of N availability to crops at any given time. Adequate N supply is needed throughout the active growing period of rice.Thus, proper N management is very crucial for successful rice production. Excessive N application lead to an inefficient N acquisition by the rice crop and contribute to contamination of surface and ground water, volatilization of ammonia and emission of greenhouse gasses *viz*., nitrous and nitric oxides to atmosphere. There is enormous variability in soil nutrient status or supply from the field. The results indicated that the fixed split N (25 kg N ha^{-1}) approach as well as real-time N management using LCC-3 performed well in respect of increasing the grain yield at this site in aerobic rice. In the present study, the LCC critical value three based N (30 kg N ha^{-1} as basal) and two splits of 30 kg N ha^{-1} each time matched the crop demand at different physiological stages and reduced the losses through nitrification, leaching and volatilization and resulted in the highest grain yield. It was also on par with 60 kg N ha^{-1}(No basal + LCC-3).

Table 3. Effect of Si and N on N content (%) in grain and straw of aerobic rice

Treatment		Grain N (%)			Straw N (%)		
		-Si	+Si	Mean	-Si	+Si	Mean
0 kg Nha^{-1}(Control)		1.14	1.21	1.18	0.49	0.44	0.46
60 kg Nha^{-1}(No basal + LCC-3)		1.28	1.23	1.25	0.84	0.82	0.83
90 kg Nha^{-1}(30 kg Nha-1 as basal + LCC-3)		1.39	1.30	1.34	0.93	0.90	0.92
100 kg Nha^{-1}as (RDF)		1.23	1.33	1.28	0.99	0.82	0.91
Mean		1.26	1.27		0.81	0.75	
SEM ±	Main (N)			0.03			0.02
	Sub (Si)			0.02			0.01
CD (5 %)	Main (N)			0.08			0.02
	Sub (Si)			0.07			0.01
Interaction	NxSi			0.05			0.01

There was significant increase in grain yield with the application of Si as calcium silicate at 2 t ha^{-1} (4.9 t ha^{-1}). However, the highest grain yield (5.6 t ha^{-1}) was noticed with the application of Si as calcium silicate at 2 t ha^{-1}along with 90 kg N ha^{-1}(Urea at 30 kg N ha^{-1}+ LCC-3). This may be attributed to the reduction in per cent spikelet sterility as noticed in the present investigation, increased rate of photosynthesis, increased number of productive tillers. The highest grain yield (5.6 t ha^{-1}) was noticed in the treatments with 90 kg N ha^{-1}(Urea at 30 kg N ha^{-1}+ LCC-3) along with Si as calcium silicate at 2 t ha^{-1} followed by 90 kg N ha^{-1}(DAP at 30 kg N ha^{-1}+ LCC-3) and 90 kg N ha^{-1}(calcium nitrate at 30 kg N ha^{-1}+ LCC-3). Higher grain yield with Si treated plots are in agreement with the findings of Munir *et al.* (2003), Singh and Singh (2005), and Singh *et al.* (2006).

Synder *et al.* (1986) demonstrated that calcium silicate application increased rice yield on histosols

Table 3a. Effect of Si and N on grain and straw uptake of N (kg ha^{-1}) in aerobic rice

Treatment		Grain N (kg ha^{-1})			Straw N (kg ha^{-1})		
		-Si	+Si	Mean	-Si	+Si	Mean
0 kg Nha^{-1}(Control)		36.5	52.0	44.3	23.5	22.4	23.0
60 kg Nha^{-1}(No basal + LCC-3)		60.2	67.7	63.9	44.5	47.6	46.0
90 kg Nha^{-1}(30 kg Nha $^{-1}$as basal + LCC-3)		68.1	72.8	70.5	51.2	52.2	51.7
100 kg Nha^{-1}as (RDF)		54.1	59.9	57.0	61.4	50.8	56.1
Mean		54.7	63.1		45.1	43.3	
SEM ±	Main (N)			0.4			2
	Sub (Si)			0.2			1.8
CD (5 %)	Main (N)			1			2.7
	Sub (Si)			0.7			1.8
Interaction	NxSi			0.7			2.3

mainly due to the supply of plant available Si and not due to supply of other nutrients. Increased application of N (100 kg N ha^{-1}) decreased the grain yield due to production of lower 1000-grain weight, filled spikelets panicle^{-1}and higher spikelet sterility. This was mainly attributed to the reduction in photosynthesis rate due to self shading and increased number of tillers and decreased production of assimilates and there by reduction in grain yield (Munir *et al.*, 2003 and Ma *et al*., 1989). The enhanced straw yield with Si at higher N levels may be attributed to leaf erectness, which facilitated better penetration of sunlight leading to higher photosynthetic activity of plant and higher production of carbohydrates. Similar results were also noticed by Rodrigues *et al*. (2003) and Singh *et al*. (2006). It was thus concluded that the level of physiological activity increased during vegetative and early reproductive stage, but started declining at seed filling stage. The results were also in agreement with the findings of Agarie *et al.* (1992) and Korndorfer *et al.* (2001).

N content and uptake in grain and straw

The N content in grain was higher than that of straw in all the silicon applied treatments. Application of calcium silicate as Si source, resulted in significant increase in per cent N in grain and decrease in per cent N in straw in Table 3 and 3a. This may be due to the application of Si on dilution effect of N in straw and translocation effect of N in grain. The per cent N content increased with increased application of N alone in both straw as well as grain. Increased application of N up to 90 kg N ha^{-1}increased the per cent N in both straw as well as grain. Application of calcium silicate at 2 t ha^{-1} along with of 90 kg N ha $^{-1}$(30 kg N ha $^{-1}$+ LCC-3) recorded highest per cent N content in grain.

Application of amide form of N increased the N content in grain and straw in the present investigation. The results are corroborating with the findings of Singh *et al.* (2006). Savant *et al*. (1997) noticed a positive interaction between Si and N in rice for higher per cent Si and its uptake in straw as well as grain and grain yield. A strong relationship between grain yield and N uptake at harvest was observed with r^2=O.709 (Fig. 1). Among different amount of N, application of 90 kg Nha^{-1}(30 kg Nha $^{-1}$as basal + LCC-3) recorded significantly higher total N uptake at harvest than all the other treatment. However, N uptake in case of no basal with leaf colour chart based N management was next only to RDF practice and in fact remained on par with RDF, which suggests that higher N uptake in rice could be achieved with smaller amounts of N provided as top dressed at appropriate time as and when observed with leaf colour chart based N management under the present investigation. The higher N uptake thus contributed to higher grain yield in case of leaf colour chart based N management treatment.

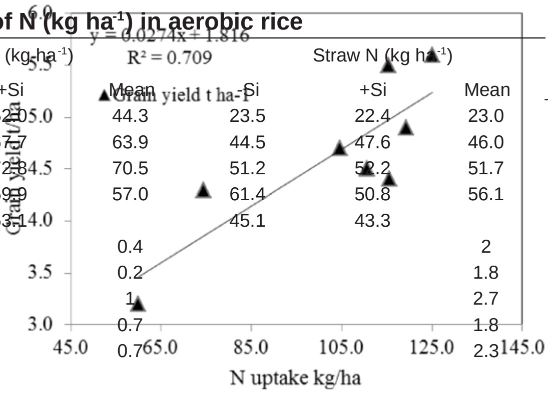

Fig 1. Relation between N uptake and grain yield of aerobic rice

Nitrogen Use Efficiency

The highest AE_N(28.3), RE_N(75.6) and PFP_N (86.0) values were noticed with 60 kg Nha^{-1}(No basal + LCC-3) (Table 4). The AE_N(19.2), RE_N(66.3) and PFP_N(63.4) values were due to the effect of calcium silicate at 2 t ha $^{-1}$under aerobic rice (Table 4). The $AE_N$is a function of both physiological efficiency and $RE_N$of applied N. Application of N using LCC resulted in increased leaf N concentration which might have promoted photosynthetic efficiency of the plant. The agronomic efficiency was greater when less N fertilizer was used, but this was achieved with the LCC without sacrificing the yield. When need based N management using LCC-3 as the critical value was followed along with a basal application of 30kg N ha^{-1}, grain yield of aerobic rice was similar to those of treatments with no basal application. In the interaction between Si and LCC based N management, the highest AE_N(31.8), RE_N(77.1) and

Table 4. Effect of Si and N on Nitrogen Use Efficiency (NUE) in aerobic rice

Treatment		AE_N			RE_N(%)			PFP_N		
		- Si	+ Si	Mean	- Si	+ Si	Mean	- Si	+ Si	Mean
0 kg N ha^{-1}(Control)		-	-	-	-	-	-	-	-	-
60 kg N ha^{-1}(No basal + LCC-3)		24.9	31.8	28.3	74.1	77.1	75.6	78.8	93.2	86.0
90 kg N ha^{-1}(30 kg N ha^{-1}+ LCC-3)		18.6	21.8	20.2	52.6	65.2	58.9	54.5	62.7	58.6
100 kg N ha^{-1}as (RDF)		11.8	8.3	10.1	50.1	57.0	53.5	44.1	45.2	44.7
Mean		18.4	20.6		58.9	66.4		59.1	67.0	
SEM ±	Main (N)			0.8			0.7			0.9
	Sub (Si)			0.7			0.1			0.9
CD (5 %)	Main (N)			2.3			1.9			2.6
	Sub (Si)			2.7			0.2			3.8
Interaction	N x Si			1.6			1.4			1.8

AE_N= Agronomic efficiency of N ; RE_N= Recovery efficiency of N ; PFP_N= Partial factor productivity of N

PFP_N(93.2) values were noticed in 60 kg N ha^{-1} (No basal + LCC-3) with calcium silicate at 2 tha^{-1}under aerobic rice. It reflects both agronomic efficiency and balance between the indigenous soil N supply and applied N. Soil in most intensive, irrigated rice domains can support grain yields of 3 to 5 t ha^{-l} without N application when weeds and insect pests do not limit rice growth. For example, mean yield in unfertilized plots from 11 long-term experiments in five Asian countries was 3.9 t ha^{-l}, it was 3.9 and 4.4 t ha^{-1}from replicated plots without applied N established in farmers' fields of Central Luzon in the 1992 and the 1994 dry seasons, respectively (Cassman *et al*., 1996). Cassman and Pingali, (1995) reported AE_Nvalues of 24 to 30 in rice by improved timing and further revealed that crop demand of applied N could improve the $AE_N$to some extent.

The N fertilization is the major agronomic practice that affects the yield and quality of rice crop, which requires as much as possible at maximum tillering and before flowering stage to maximize panicle number and during reproductive stage to produce optimum spikelets per panicles and per cent filled spikelets. These results are in agreement with the findings of Murthy *et al*. (1992) and Cassman *et al.* (1996). Availability of adequate quantity of N during critical stages of plant growth might have resulted in better growth characters and yield components at various phenological stages. Half of the 100 kg N ha^{-1}for aerobic rice has been recommended to be applied basally before sowing. The LCC guided N management in aerobic rice starts 21 or 30 days after sowing. The usefulness of applying a dose of N basally at lower dose is sufficient or at about 30 days after sowing need to be examined in aerobic rice. These results suggest that basal dose of 30 kg N ha^{-1}was not efficiently used by the crop and possibly prone to leaching and other losses.

The agronomic efficiency in the LCC guided N management treatment without basal N was significantly higher than the other treatments. Alam *et al*. (2005) observed that not only higher NUE, but also higher grain yields through LCC-based N management. The aerobic rice yield in zero-N plots (control) was more than 3 t ha^{-1}which indicates that basal N application had no added effect. The results of different sources of N indicated that the environmental loss potential of N is strongly influenced by amount of fertilizer and time of application. Results of the present investigation support the hypothesis of Balasubramanian *et al*. (1999), who revealed that the soil producing grain yield of more than 3 t ha^{-1}in the plots without any fertilizer application do not need basal N application. These results are also in accordance with the findings of Budhar (2005) and Stalin *et al*. (2008).

The use of LCC with a critical value of three with or without basal N application resulted in a significantly higher yield than the recommended N treatments. The LCC-guided N management with no other change in package of practices (RDF) for aerobic rice resulted in a total N fertilizer application of 60 kg Nha^{-1}compared to 100 kg Nha^{-1}in package of practices (RDF) of applying fixed-time N with three split doses. It further increased in yield and NUE of aerobic rice due to the interaction effect of Si as calcium silicate at 2 t ha^{-1} along with LCC based N (time demand and sufficient amount). Thus, the leaf colour chart would be helpful to avoid the under or over fertilizing, besides applying at appropriate time when the crop needs nitrogen so as to increase the productivity in aerobic rice. Leaf colour chart based N management could adequately take care of location to location and temporal variation in N supply and holds promise in increasing fertilizer N use efficiency in aerobic rice.

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Received: July 28, 2013; Accepted: May 23, 2014