Research Article

NEED BASED NITROGEN MANAGEMENT IN HYBRID AND IMPROVED RICE VARIETIES UNDER DRY DIRECT SEEDED CONDITION

P. Subedi[1]*, S. K. Sah[1], S. Marahatta[1] and A. P. Regmi[2]

[1]Agriculture and Forestry University, Rampur, Chitwan, Nepal

[2]Cereal System Initiative for South Asia (CSISA), Nepal

ABSTRACT

Nitrogen is one of the most limiting elements in almost all soils. Thus, proper application of nitrogen fertilizers is vital to improve crop growth and grain yields. Insufficient and/or inappropriate nitrogen fertilizer management is highly damaging to the crops. Optimal nitrogen management strategies aim at matching the nitrogen fertilizer supply to the actual crop demand. The Leaf Color Chart (LCC) is a tool for real time, or need based nitrogen management in rice. LCC based nitrogen management without its basal application assisted to save significant amount of nitrogen (30 to 37.5 Kg N ha^{-1}) in case of inbred varieties (Radha-4 and Sukkha-5) as compared to recommended practice with 120 Kg N ha^{-1} applied in three equal splits. On the other hand, the requirement of nitrogen for hybrid US-312 was remarkably higher than that of inbred varieties. However, pure LCC based nitrogen management significantly decreased the amount of excess nitrogen application as compared to the all other LCC based treatments. All the nitrogen management treatments including LCC were similar to each other in respect of grain yield formation (4695 – 4891 Kgha^{-1}), but significantly superior over recommended practice (4408 Kg ha^{-1}). The hybrid rice US-312 was significantly more productive (4695 Kgha^{-1}) than inbred varieties, i.e Radha-4 (4089 Kgha^{-1}) and Sukkha-5 (4315 Kgha^{-1}) which differed insignificantly. Thus, pure LCC based nitrogen management was the most economic practice for both inbred and hybrid varieties of rice.

Key words: grain yield, nitrogen saving, limiting element, superior

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most popular cereal crops in the world. It is a staple food for nearly half of the world's population. The global rice production is 745 M tons (FAOSTAT, 2013) and its global consumption is estimated at 581 M tons in 2015 (IRRI, 2006). More than 90% of this rice is produced and consumed in Asia (Pathak, Tiwari, Sankhyan, Dubey, Mina, Singh, Jain, & Bhatia, 2011). In Nepal, rice stands first position in terms of area (0.14 M ha) and production (0.45 M tones) with an average productivity of 3.21 t ha^{-1} (MoAD, 2012/13). Rice contributes nearly 20% to the agricultural gross domestic product (AGDP) and more than 50% in food grains production as well as in the total calories requirement of the Nepalese people (Basnet, 2014).

Puddled rice transplanting is the burdensome and time consuming crop establishment method with more labor and water requirement which are becoming scarce too. It destroys the soil physical properties by dismantling the soil aggregates and ultimately affects the growth and productivity of succeeding wheat crop as there is formation of hard pan at shallow depths (Bhurer, Yadav, Ladha,

* Corresponding author: purushottam.afu@gmail.com

Thapa, & Pandey, 2013).

Pathak et al., (2011) reported that climate change may cause the variability of monsoon rainfall and also the risks of early season drought. There may be delayed transplanting by 1-3 weeks due to waiting for ponded water in the field for puddling which ultimately reduces the crop yield (Ladha, Kumar, Alam, Sharma, Gathala,Chandan, Sharawat, & Balasubramanian, 2009). So, dry direct seeded rice (DDSR) can be an alternative method to conventional transplanted rice as it avoids puddling and transplanting of young seedlings and requires less water, labor, time, drudgery and cultivation cost (Ali, Ladha, Rickman, Lales, & Alam, 2012). The direct seeded rice matures 7-10 days earlier than the transplanted rice and thus allows timely sowing of succeeding wheat crop (Giri, 1998) which assists to improve the system productivity. Moreover, the grain yield obtained from the DSR is found comparable to that of the transplanted rice if managed properly (Gill, Walia, & Gill, 2014).

Some of the major challenges found in dry direct seeded rice are high weed infestation (Joshi, Kumar, Lal, Nepalia, Gautam, & Vyas, 2013) and more nitrogen loss through denitrification, volatilization, leaching and runoff than in conventional transplanted rice (Kumar & Ladha, 2011). Therefore, nitrogen management is considered as one of the most challenging parts of the direct seeded rice to achieve higher grain yield and nitrogen use efficiency (Ali et al,.2012). Moreover, a real time N management requires periodic assessment of nitrogen status in standing crop and its application according to the need of the crop (Witt, Buresh, Balasubramanian, Dawe, & Dobermann, 2004). In this context, Chlorophyll meter (SPAD) or Leaf Color Chart (LCC) can be used to assess the actual plant nitrogen status (Balasubramanian, Morales, Cruz, & Abdulrachman, 1999). LCC provides the guideline for effective nitrogen management by giving the idea of when and how much nitrogen fertilizer to apply for maintaining and optimizing nitrogen status in rice plants to ensure high grain yield (Sathiya & Ramesh, 2009).

Nitrogen demand and synchronization differ with inbred and hybrid rice varieties. Hybrid varieties having genetically high yield potential require higher amount of nitrogen as compared to inbred varieties (Ravi, Ramesh, & Chandrasekaran, 2007). Considering these facts, an experiment was carried out to evaluate the impact of leaf color chart based N management on the performance of improved and hybrid rice varieties under dry direct seeded condition.

MATERIALS AND METHODS

A field experiment was conducted at Agronomy research block of Agriculture and Forestry University (AFU), Rampur Chitwan from June to October 2014. The experimental soil was sandy loam with the following characteristics in the top 20 cm profile; clay 5.1 %, silt 22.8 %, sand 72.1 % and pH 5.4. Similarly, the soil had 3.18 % SOM, 0.16 % total N, 41.45 Kg ha^{-1} available P and 98.40 Kg ha^{-1} available K which were under the medium category based on rating chart (Jaishy, 2000).

A total rainfall of 2014.95 mm was received during the entire period of experimentation (from May to October).At the time of intensive growth period (up to 90 DAS), the crop received an average rainfall of 282.64 mm per fortnight with 1695.85 mm in total. The relative humidity (RH) ranged from 84.21% in June to 85.43% during harvesting (October) with average of 85.88%. The mean maximum and minimum temperatures were 33.76 ^{0}C and 25.25 ^{0}C, respectively.

The experiment was arranged in Split plot design with four replications. There were 15 treatments including three rice varieties (Radha-4, US-312 and Sukkha-5) as main plot factor and five nitrogen management practices {0 Kg N ha^{-1}, 120 Kg N ha^{-1}(applied in three equal splits; as basal, at tillering and panicle initiation stages), 30 Kg N ha^{-1}as basal followed by its topdressing @30 Kg N ha^{-1} based on LCC critical value four, 30 Kg N ha^{-1} at 15 days after sowing (DAS) followed by LCC based top dressing @30 Kg N ha^{-1} and pure LCC (without basal N dose) based N application} as sub plot factor. The crop was sown continuously in line with the seed rate of 40 Kg ha^{-1}maintaining row to row spacing of 20 cm. Radha-4 and Sukkha-5 were high yielding inbreds with productivity of 3.5 and 3.2-4.2 t ha^{-1} , respectively whereas US-312 was Indian hybrid released for Terai of Nepal in 2012 with productivity of 5.46 t ha^{-1}. In LCC based treatments, nitrogen was applied through urea according to average LCC reading taken from 21 DAS to heading stage at every 10 days interval. The readings were taken from upper healthy leaves of 10 randomly selected plants. In each reading, the plots showing average lower LCC values in comparison to critical value, received nitrogen at the rate of 30 Kgha^{-1}through urea. The grain yield (t ha^{-1}) adjusted at 14 % moisture level was calculated by using formula as prescribed by (Shahidullah et al., 2009):

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Plot yield (Kg) X (100- grain moisture content \%) X 10000 m}^2}{\text{(100-14) X net plot area (m}^2\text{) X 1000}}$$

RESULTS

Nitrogen saving

The total amount of N applied and its saving owing to LCC based N management in comparison to the recommended practice is presented in the Table 1. On an average, the amount of N applied (Kgha^{-1})in the LCC based treatments ranged from 100 to 130 Kgha^{-1} and was remarkably lower (100 Kg ha^{-1}) in the pure LCC based N management. Further, the data presented in the Table 1 indicate that both inbred varieties Radha-4 and Sukkha-5 did not differ statistically in respect of the total N received by them in all LCC based treatments. However, it was significantly higher in hybrid US-312. Similarly, all inbred varieties as well as hybrid rice utilized significantly lower amount of N in the pure LCC treatment as compared to other LCC based treatments. Further, significantly maximum N saving (30 to 37.5 N Kg ha^{-1}) and insignificantly minimum excess N application were recorded with inbred varieties (Radha-4 and Sukkha-5) and hybrid (US-312) respectively with pure LCC based N management treatment in comparison to recommended practice.

Table 1: Effect of N management and rice varieties on amount of total N applied and N saving in DDSR at AFU, Chitwan, 2014

Treatments	Varieties (Factor A)			Grand mean (Factor A)
N management (Factor B)	Radha-4	US-312	Sukkha-5	
N_{120}	120	120	120	120
N_{30} (basal) + LCC	120 (0)	157.5 (-37.5)	112.5 (+7.5)	130
N_{30} (15DAS) + LCC	112.5 (+7.5)	157.5 (-37.5)	105 (+15)	125
Pure LCC	90 (+30)	127.5 (-7.5)	82.5 (+37.5)	100
LSD (0.05)		5.72**		10.95**
Grand mean (Factor B)	110.6	140.6	105	
A x B				
LSD (0.05)	17.01*			
SEm (±)	5.90			

Note: Figures in the parentheses indicate N saving (+) or excess (-) in Kg ha^{-1} in comparison to N_{120}.

*indicates significant at 5 % level of probability and **indicates significant at 1% level of probability

Yield attributes

The data presented in the Table 2 indicate that significant difference between inbred and hybrid varieties were observed in all yield attributing characters except in effective tillers per meter square. Thus, the improved variety Radha-4 was found significantly superior over hybrid US-312 and Sukkha-5 in respect of panicle weight, thousand grain weight and sterility percentage. However, panicle length and grains per panicle were significantly higher in hybrid US-312 (24.24 cm and 95.51) as compared to Radha-4 (20.89 cm and 77.94) and Sukkha-5 (20.60 cm and 76.01) respectively. This was also reflected in thousand grain weight. The thousand grain weight (18.12 g) obtained with hybrid US-312 was significantly lower than that of inbred varieties i.e Radha-4 ((23.38 g) and Sukkha-5 (22.35 g) which also differed significantly.’

Table 2: Yield attributing characters as influenced by varieties and N management in DDSR at Rampur, Chitwan, 2014

Treatments	Yield attributing characters					
	Effective tillers m^{-2}	Panicle length (cm)	Panicle weight (g)	Grains per panicle	TGW (g)	Sterility (%)
Varieties						
Radha-4	322.40	20.89^{b}	2.03^{a}	77.94^{b}	23.38^{a}	13.42^{a}
US-312	321.10	24.24^{a}	1.83^{b}	95.51^{a}	18.12^{c}	10.36^{b}
Sukhkha-5	319.70	20.60^{b}	1.77^{b}	76.01^{b}	22.35^{b}	9.72^{c}
SEm (±)	10.38	0.298	0.056	2.15	0.178	0.163
LSD (0.05)	Ns	1.03	0.195	7.44	0.616	0.564
N management						
N_0	248.3^{b}	19.72^{c}	1.38^{c}	62.33^{c}	20.00^{b}	14.42^{a}
N_{120}	337.6^{a}	21.98^{b}	1.85^{b}	81.81^{b}	21.46^{a}	10.67^{b}
N_{30} (basal) + LCC	335.6^{a}	22.74^{a}	2.13^{a}	89.43^{a}	21.69^{a}	9.84^{b}
N_{30} (15DAS) +LCC	337.3^{a}	22.43^{ab}	1.99^{ab}	90.26^{a}	21.29^{a}	10.52^{b}
Pure LCC	346.4^{a}	22.68^{ab}	2.04^{a}	91.96^{a}	21.97^{a}	10.38^{b}
SEm (±)	9.52	0.234	0.051	2.24	0.228	0.304
LSD (0.05)	27.29	0.672	0.147	6.41	0.654	0.872
CV, %	10.27	3.70	9.50	9.30	3.70	9.40
Grand mean	321.03	21.91	1.88	83.20	21.28	11.17

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

TGW = Thousand Grain Weight

Further, all LCC based N management treatments were found similar to each other in respect of all yield attributing characters presented in the Table 2. However, they were superior over recommended practice of N management with respect to only grains per panicle. Such trend was also recorded in panicle length and panicle weight when compared with the treatments receiving 30 Kg N ha^{-1} as basal and remaining through LCC reading.On the other hand, all LCC based treatments were found insignificantly different from recommended practice in effective tillers per meter square; thousand grain weight and sterility percentage. Finally, all yield attributing characters recorded in control were significantly lower than that of the other N management treatments but it showed its significant superiority in respect of sterility percentage.

Grain and straw yields and harvest index

The hybrid US-312 gave significantly higher grain yield (4695.23 Kg ha^{-1}) as compared to inbreds; Radha-4 (4089.39 Kg ha^{-1}) and Sukkha-5 (4315.43 Kg ha^{-1}) which were statistically at par with each other (Table 3). All LCC based N management treatments produced similar grain yields (4695.21 to 4891.23 Kg ha^{-1}) which were significantly higher than that of the recommended practice (4408.06 Kg ha^{-1}) and control (3094.15 Kg ha^{-1}). The grain yield obtained in control was significantly lower than that of all other N management treatments. Further, the interaction between varieties and N management practices did not show significant influence on grain yield. Significantly lower straw yields were produced by Sukkha-5 (4987.12 Kg ha^{-1}) as compared to hybrid US-312 (6631.03 Kgha^{-1}) and Radha-4 (6619.35 Kgha^{-1}) which remained at par with each other. Further, significantly lower straw yield was observed in control (3982.23 Kg ha^{-1}) as compared to all other N management treatments (6216.11to 6924.21 Kg ha^{-1}). The straw yields obtained in recommended practice (6216.11 Kg ha^{-1}) and LCC based N management with 30 Kg Nha^{-1}as basal (6352.04 Kg ha^{-1}) were similar to each other but significantly lower than that of the pure LCC based N management (6924.21 Kg ha^{-1}) and LCC based N management with 30 Kg Nha^{-1}applied at 15 DAS (6923.50 Kg ha^{-1}) which also remained at par with each other.

The harvest index (HI) was significantly influenced by rice varieties but not significant due to N management practices (Table 3). The HI recorded in Sukkha-5 (0.48) was significantly higher than US-312 (0.45) and Radha-4 (0.43) which also differed significantly.

Table 3: Grain and straw yields and HI as influenced by rice varieties and N management in DDSR at Rampur, Chitwan, 2014

	Parameters		
Treatments	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest Index (HI)
Varieties			
Radha-4	4089.39^{b}	6619.35^{a}	0.43^{c}
US-312	4695.23^{a}	6631.03^{a}	0.45^{b}
Sukhkha-5	4315.43^{b}	4987.12^{b}	0.48^{a}
SEm (±)	95.30	202.90	0.002
LSD (0.05)	329.80	702.00	0.007
N management			
N_0	3094.15^{c}	3982.23^{c}	0.45
N_{120}	4408.06^{b}	6216.11^{b}	0.45
N_{30} (basal) + LCC	4695.21^{a}	6352.04^{b}	0.45
N_{30} (15 DAS) + LCC	4746.08^{a}	6923.50^{a}	0.45
Pure LCC	4891.23^{a}	6924.21^{a}	0.46
SEm (±)	98.40	166.90	0.003
LSD (0.05)	282.10	478.70	Ns
CV, %	7.80	9.52	2.40
Grand mean	4367.35	6079.14	0.4533

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

DISCUSSION

The most common practice of nitrogen application in rice is three split applications at fixed time. At early stage, due to low crop need, most of the applied N is lost. Similarly, due to lack of synchrony between N supply and crop need, N applied in splits at fixed time or growth stages favors its higher loses. Yadav, Padre, Pandey and Sharma (2004) stated that more than 60% of applied N in blanket recommendation is lost due to lack of synchronization between crop N demand and N supply. This might be reason for obtaining significant saving of N in pure LCC based N management in comparison to recommended practice in case of inbred varieties (Radha-4 and Sukkha-5), as well as a significant reduction in the application of excess nitrogen as compared to the treatments with 30 Kg N ha^{-1} as basal followed by LCC based N application with hybrid US-312. Balasubramanian (2002) and Samson et al.(2005) also found saving of nitrogen in LCC based application than in fixed time split application indicating lower N losses in LCC usage.

Significantly higher grain yield (4695.23 Kg ha^{-1}) obtained with hybrid US-312 in comparison to inbred varieties (Radha-4 and Sukkha-5) was mainly related to its significantly higher number of grains per panicle owing to significant difference in panicle length (Table 2). In general, requirement of nitrogen for hybrids was higher than inbred varieties (Ravi et. al., 2007). This is also obvious from the results presented in the Table 1. The total N applied for hybrid US-312 was significantly higher than that of the inbred varieties in all treatments with LCC based N application. This might have helped in the formation of higher assimilating surfaces and consequently translation of assimilates in the formation of significantly higher number of grains per panicle.Hosain, Ahamed, Haque, Islam, Bari, Mahmud & Gholami, (2014) reported that hybrids show high heterosis for grains per panicle. The more grain yield of hybrids than that of inbreds was also reported by Yang, Peng, Laza, Visperas & Dionisio-Sese (2007). Likewise, Hosainet. al. (2014) reported that higher grain yield obtained with hybrid was related to its higher panicle length (3.4 %) and more number of grains per panicle (9.8 %) as compared to inbred variety.

Nitrogen is the constituent of amino acids, proteins, nucleic acids and chlorophyll and therefore both the source and sink development are dependent on sufficient supply of nitrogen (Mengel & Kirkby, 1987). This supports for the reasons why growth and grain yield are low in nitrogen control treatments presented in Table 3. The grain and straw yields were found significantly lower in nitrogen control as compared to other N management treatments.

Further, the grain yields obtained in all treatments with LCC based N management were similar to each other but significantly higher than that of the recommended practice. As in the case of varieties, it was also ascribed to significant difference in grains per panicle (Table 2). According to Manzoor, Awan, Zahid and Faiz(2006), the recovery efficiency of N is higher under LCC based N management which assists to increase chlorophyll content of leaves and rate of photosynthesis as a result of which plenty of photosynthates become available during grain development stage. When nitrogen is applied during crop demand through LCC, it is utilized more efficiently resulting in higher grain yield. Singh, Kumar, Singh & Singh (2010) also found a comparable or even higher grain yield in LCC based nitrogen application with 30 Kg N ha^{-1} as basal and critical value four receiving 30 Kg N ha^{-1} in comparison to recommended practice during 2008 and 2009.Jayanti, Gali, Angadi, and Chimmad (2007) also reported the similar results. Similarly, Alam, Ladha, Khan, and

Buresh (2005) found an increase in grain yield of Aman (by 400 Kg) and Boro (by 600 Kg) rice with LCC based nitrogen management as compared to recommended practice.

CONCLUSION

Pure LCC based nitrogen management was the most economic practice for both inbred and hybrid varieties of rice. The requirement of N was higher for hybrid as it was high yielder than inbred varieties.

ACKNOWLEDGEMENT

The authors acknowledge the Directorate of Research and Extension (DOREX), Agriculture and Forestry University, Chitwan, Nepal for the financial support in conducting the research work.

LITERATURE CITED

Alam, M. M., Ladha, J. K., Khan, S. R., Khan, A. H. & Buresh, R. J. (2005). Leaf color chart for managing nitrogen fertilizer in lowland rice in Bangladesh.*Agronomy Journal*. 97, 949-959. Available on: http://www.agron.scijournals.org [retrieved on 12th June 2014].

Ali, M. A., Ladha, J. K., Rickman, J., Lales, J. S., & Alam, M. M. (2012).Evaluation of drill seeding patterns and nitrogen management strategies for wet and dry land rice.*Bangladesh Journal of Agricultural Research,* 37 (4), 559-571.

Balasubramanian, V., Morales, A. C., Cruz, R. T. & Abdulrachman, S. (1999). On farm adaptation of knowledge-intensive nitrogen management technologies for rice systems.*Nutrients Cycle in Agro-ecosystems.* 53 (1), 59-69.

Balasubramanian, V. (2002).Real-time N management in rice by using Leaf Color Chart (LCC). Available at: https://www.knowledgebank.irri.org [retrieved on 2nd July, 2015].

Basnet, B.M.S. (2014). National rice day rice and food security.*Gorkhapatra Daily, (Retrieved on August 3, 2014 and available at: gorkhaptaraonline.com)*

Bhurer, K. P., Yadav, D. N., Ladha, J. K., Thapa, R. B., & Pandey, K. R. (2013). Efficacy of various herbicides to control weeds in dry direct seeded rice (*Oryza sativa* L.). *Global Journal of Biology, Agriculture and Health Sciences,* 2(4), 205-212.

FAOSTAT.(2013). Statistical data on agricultural production. (available at: www.fatostat.org)

Gill, J. S., Walia, S. S. & Gill, R. S. (2014). Direct seeded rice: An alternative rice establishment technique in north-west India – A review. *International Journal of Advanced Research,* 2(3), 575-386.

Giri, G. S. (1988). Effects of rice and wheat establishment techniques on wheat grain yield. In: Hobbs, P. R; Bhandari, R. (Eds.). Proceedings of rice-wheat research end of project workshop, India, pp. 65-68.

Hosain, M. T., Ahamed, K. U., Haque, M. M., Islam, M. M., Bari, A. F., Mahmud, J. A., &Gholami, E. (2014). Performance of Hybrid Rice (*Oryza sativa* L.)Varieties at Different Transplanting Dates in Aus Season.*Applied Science Reports,* 5 (1), 1-4.

International Rice Research Institute. (2006). Bringing Hope, Improving Lives-Strategies. Plan, 2007–2015, 61 pp.

Jaishy, S. N. (2000). Current fertility status of Nepal and IPNS. In: Jaishy, S. N., Mandal, S. N., Subedi, T. B., Subedi, K. S. & Weber, G. (Eds.) *Component of integrated plant*, pp.63-72.

Jayanthi, T., Gali, S. K., Angadi, V. V., & Chimmad, V. P. (2007). Effect of leaf colour chart based nitrogen management on growth and yield parameters of rainfed rice. *Karnataka Journal of Agricultural Sciences,* 20 (2), 272-275.

Joshi, E., Kumar, D., Lal, B., Nepalia, V., Gautam, P. &Vyas, A. K. (2013). Management of direct seeded rice for enhanced resource use efficiency. *Plant Knowledge Journal* 2(3), 119-134.

Kumar, V. &Ladha, J. K. (2011). Direct Seeding of Rice: Recent Developments and Future Research Needs. *Advances in Agronomy,* 11, 297-413.

Ladha J. K., Kumar, V., Alam M.M., Sharma, S., Gathala, M., Chandan, P., Saharawat, Y.S .& Balasubramanian, V. (2009). Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice-wheat system in South Asia.

Manzoor, Z., Awan, T. H., Zahid, M. A., & Faiz, F. A. (2006).Response of rice crop (super basmati) to different nitrogen levels. Journal of Animal & Plant Sciences, 16(1-2), 52-55.

Mengel, K. &Krikby, E.A. (1987).Principle of plant nutrition, 4th edition.Panima Publishing Corporation, New Delhi, India.

MoAD.(2012/13).Statistical information on Neplese Agriculture 2012/13.Ministry of Agriculture and Development, Agribusiness Promotion and Statistics Davison, Kathmandu, Nepal.

Pathak, H., Tiwari, A. N., Sankhyan, S., Dubey, D. S., Mina, U., Singh, V. K., Jain, N., & Bhatia, A. (2011). Direct-seeded rice: Potential, performance and problems – A review. *Current Advances in Agricultural Sciences,* 3(2), 77-88.

Ravi, S., Ramesh, S. & Chandrasekaran, B. (2007).Exploitation of hybrid vigor in rice hybrid (O*ryza sativa* L.) Through green manure and Leaf Color Chart (LCC) based N application. *Asian Journal of Plant science,* 6 (2), 282-287.

Samson, M. I., Laureles, E. V., Larazo, W. M., Gines, H. C., & Buresh, R. J. (2005), Benefits of Real-time N fertilizer management within 4 years in 2 long-term experiments (IRRI and PhilRice).*Philippines Journal of Crop Science,* 30, 37–51.

Sathiya, K. & Ramesh, T. (2009).Effect of split application of nitrogen on growth and yield aerobic rice.*Asian Journal of Experimental Science,* 23 (1), 303-306.

Shahidullah, S. M., Hanafi, Ashrafuzzaman, M., Ismail, M. R. & Salam, M. A. (2009).Tillering dynamics in aromatic rice genotypes.*International Journal of Agriculture & Biology,* 11(5), 509-515.

Singh, V., Kumar, D., Singh, B., & Singh, H. (2010).On-farm evaluation of real-time nitrogen management in rice.*Better Crop*, 94 (4), 26-28.

Witt, C., Buresh, R. J., Balasubramanian, V., Dawe, D., & Dobermann, A. (2004). Principles and promotion of site-specific nutrient management. p. 397-410. In: Dobermann*et al*. (Eds.) Increasing productivity of intensive rice systems through site-specific nutrient management. Science Publishers, Enfield, NH, USA and IRRI, Los Banos, Philippines, p. 410.

Yadav R. L., Padre A. T., Pandey P. S., & Sharma S. K. (2004).Calibrating the Leaf Color Chart for nitrogen management in different genotypes of rice and wheat in a system, *Agronomy Journal,* 98, 1606-1621.

Yang, W., Peng, S., Laza, R. C., Visperas, R. M., & Dionisio-Sese, M. L. (2007). Grain yield and yield attributes of new plant type and hybrid rice. Crop Science, 47(4), 1393-1400.