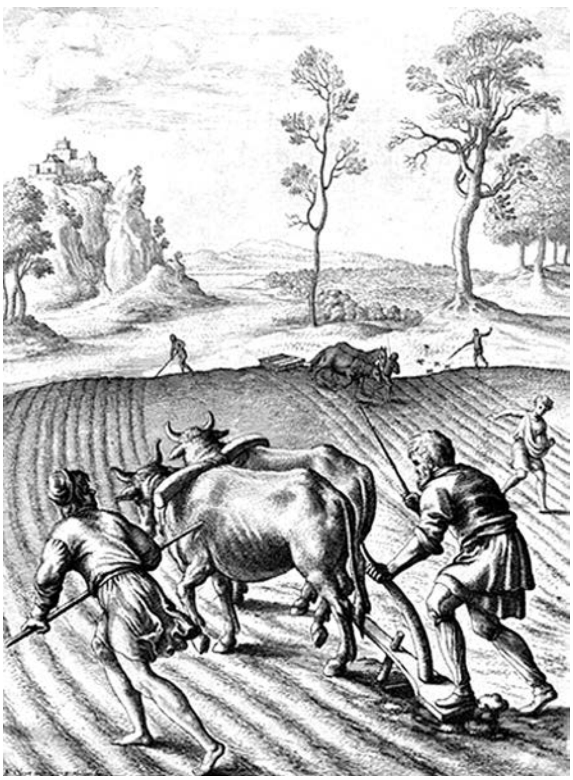
ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY



ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS

Journal of Agronomy

ISSN 1812-5379
DOI: 10.3923/ja.2017.168.173

Research Article
Evaluating Multi-split Topdressing as an Option for Improving Nitrogen Management in Lowland Rice

[1]Ofori Joseph, [2]Anning Dominic Kwadwo, [2]Anim Jerry Jacob and [1]Wristberg Joseph NiiKotey

[1]Soil and Irrigation Research Centre, School of Agriculture, University of Ghana, P.O. Box LG 68, Legon, Ghana
[2]School of Graduate Studies, University of Ghana, P.O. Box LG 571, Legon, Ghana

Abstract

Background and Objective: The contribution of nitrogen fertilizer to grain yield of irrigated rice is phenomenal in Ghana. However; the expected yield level based on the crop potential in this cultivation system is yet to be realized, despite the systematic increase in nitrogen fertilizer rate of application. This could be mainly attributed to inappropriate timing of fertilizer application. Fertilizer management strategy is therefore needed to ensure effective utilization by the rice crop for improved yield. **Materials and Methods:** The field experiment was conducted at the University of Ghana's Soil and Irrigation Research Centre-Kpong during 2014 and 2015 cropping seasons to evaluate the influence of N fertilizer rates and timing of application on rice yield. A 3×2 factorial experiment was laid out in a randomized complete block design and replicated three times. Fertilizer rate and time of nitrogen application were the factors involved. The levels of fertilizer rate were: 0, 75, 90 and 120 kg N ha^{-1}, while time of the nitrogen application included; conventional practice (2 times, basal and top dress) and multi-split (weekly application till booting stage) and determined using two-way analysis of variance (ANOVA) using GenStat statistical software (12th edition). **Results:** High N fertilization rates increased growth and yield components, grain yield. However, better grain yield was obtained when N was multi-split for topdressing (eg. 90 kg N; 5.0 t ha^{-1}) than the conventional method (90 kg N; 4.6 t ha^{-1}). **Conclusion:** The study revealed that, the generally followed blanket nitrogen application rate and two-split traditional practice, was not adequate to obtain higher yields. Rice response to fertilizer was better at 120 kg N ha^{-1} than the other lower N rates. However, 120 kg N ha^{-1} applied at seven splits performed better (5.4 t ha^{-1}) than 120 kg ha^{-1} applied at the conventional (5.0 t ha^{-1}) application of basal and top-dress at panicle initiation stage.

Key words: Irrigatedrice, nitrogen management, multi-split top dressing, conventional practice, blanket recommendation

Received: January 17, 2017 Accepted: June 14, 2017 Published: September 15, 2017

Citation: Ofori Joseph, Anning Dominic Kwadwo, Anim Jerry Jacob and Wristberg Joseph NiiKotey, 2017. Evaluating multi-split topdressing as an option for improving nitrogen management in lowland rice. J. Agron., 16: 168-173.

Corresponding Author: Ofori Joseph, Soil and Irrigation Research Centre, School of Agriculture, University of Ghana, P.O. Box LG 68, Legon, Ghana Tel: +233-50-042-66-04

Copyright: © 2017 Ofori Joseph *et al*. This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The application of nitrogen fertilizer has contributed to an enormous grain yield increase for irrigated rice production in Ghana in recent years[1,2]. However, studies have shown that, there was a stagnation of this trend of yields increase despite the increasing rate of fertilizer application[3]. This mainly attributed to the excessive and inappropriate timing of fertilizer application[4].

The conventional application of N fertilizer where 50-70% of the total fertilizer was applied at sowing or transplanting as basal dressing and the remaining applied as top-dress at booting stages did not consider the dynamic soil N supply and crop N requirements. This therefore led to untimely application of higher percentage of N fertilizer at a time where the plant was not ready physiologically to take up that quantum of applied N fertilizer[5]. This resulted in very little uptake of the applied N and the remaining was lost from the soil-plant system.

The generally followed conventional practice of excessive fertilizer N applications as basal to avoid the risk of N deficiency rather reduced N use efficiency of rice[5]. Excessive N application caused nutrient imbalances and produced plants that were disease and pest-susceptible. Low recovery of N was not only responsible for higher cost of crop production, but also resulted in environmental pollution and eutrophication[6].

Splitting N fertilizer applications less than 3-4 times within a rice growth cycle, led to the production of greater ammonia concentration peaked in paddy soil. Studies have proven that, higher ammonia concentration led to a large amount of N loss through leaching and volatilization[7,8]. Ohnishi *et al.*[9] reported that top dressing of urea 6 times to rice throughout the whole growing season resulted in a significant ($p<0.05$) increase in the nitrogen recovery efficiency compared with the one-time application. However, Varinderpal-Singh *et al.*[10] observed no yield benefit when fertilizer N was applied at more than four growth stages of rice. Another innovative multi-split approach for efficient N utilization in rice, is the use of Leaf Color Chart (LCC) to estimate plant nitrogen demand in real time for efficient fertilizer use. Islam *et al.*[11] reported that need-based application of N fertilizer aided by LCC revealed substantial gains to farmers through reduction of N application, cost of fertilizer and insecticides use and a marginal increase in grain yields over farmers' practice.

Previous strategies to improve N-use efficiency have been deep placement of fertilizer, the use of slow released fertilizers such as coated urea, urea super granule etc.[12]. Controlled and slowly released fertilizer could control nutrients release rate so that nutrient availability to the plant lasted significantly ($p<0.05$) longer than with traditional fertilizers[12] and thus resulted in significant increases ($p<0.05$) in grain yield and NUE in rice[13]. However, the controlled-release fertilizer was not satisfactory to rice farmers due to its scarcity and high cost. For this reason, an alternative approach or technology needed to be considered to serve the same purpose.

Studies on efficient nitrogen management in irrigated rice cultivation in Ghana is limited, particularly concerning the effects of multi-split topdressing N fertilizer (MST) on rice growth and grain yield. The objective of this study was therefore to compare the differences in rice growth and grain yield between MST and conventional N management practice.

MATERIALS AND METHODS

Study area description: A field experiment was conducted at the Soil and Irrigation Research Centre, University of Ghana, Kpong during the major seasons of 2014 and 2015. The center is located at an altitude of 22 m a.s.l. and lies at latitude 6°09' N and longitude 00°04' E. The experimental site lies within the lower Volta basin of the Coastal Savannah agro-ecological zone with annual precipitation of 1200 mm, mean minimum temperature of 22.1°C and mean maximum temperature of 33.3°C. The soil at the experimental site is tropical black clay and it belongs to the Akuse series[14]. The chemical characteristic of the soil at the depth of 0-15 cm is as follows: pH (7.88), total nitrogen (0.07%), available phosphorus (2.09%), available potassium (4.72 mg kg^{-1}), calcium (22.8 mg kg^{-1}), magnesium (1.26 mg kg^{-1}) and organic matter (2.81%).

Experimental design and treatments: A 3×2 factorial experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Fertilizer rate and time of nitrogen application were the factors involved. The levels of fertilizer rate included: 0, 75, 90 and 120 kg N ha^{-1} while the methods of nitrogen application were; conversional (2 times, basal at a week after transplanting and top dress at maximum tillering stage 55 days after sowing (DAS) and weekly application at 7 equal portions (12.8 kg ha^{-1}) from a week after transplantingtill seven days before booting (84 DAS). The levels of the factors were combined to form six treatments as shown in Table 1.

Field layout and crop establishment: The field was ploughed and puddle to reduce percolation of water. Experimental units of 4×4 m were measured out with 2 m interval between plots and 3 m between replications. Twenty one days old seedlings of rice variety Ex-Baika were transplanted at spacing of 20 cm by 20 cm. All the experimental units received 45 kg P_2O_5 and 45 kg K_2O per hectarethrough Triple superphosphate and muriate of potash, respectively, at transplanting. The field was sprayed with a pre-emergence herbicide (Stomp) and a post-emergence herbicide (Propanil+2, 4 D). The fields were submerged until 10 days to harvest.

Data collection: Plant height, biomass accumulation and days to 50% flowering were recorded as growth parameters. Biomass accumulation was determined by cutting five plants randomly from each plot at maximum tillering, booting and harvest stages and oven dried at 70°C to a constant weight. The samples from each plot at the various growth stages were then weighed with electronic balance and recorded as biomass accumulation. Days to 50% flowering was recorded by counting the number of days from seeds emergence to the day half of the plants in each experimental plot flowered. Panicles per meter square, grains per panicle, percentage of filled grains, harvest index, test weight and grain yield were recorded as yield parameters. Grain yield was determined from an area of 9 m^2 without the border rows expressed as t ha^{-1} at 14% grain moisture. Twenty five plants were selected at the center of the plot and used to determine the yield components: test weight, percentage of filled grains, grains per panicle and panicles per meter square. Harvest index was calculated as the ratio of grain weight to grain and straw weight.

Statistical analysis: Averages for the data set of the two seasons were computed and the significant differences(5%) between the treatments were determined using two-way analysis of variance (ANOVA) using GenStat statistical software (12th edition)[15]. Treatment means were separated using the least significant difference (5%).

RESULTS

Plants height was significantly ($p<0.05$) influenced by N fertilizer rate at harvest (Table 2). The N120 produced the tallest plants (92.4 cm), followed by N90 (92.0 cm) while N75 significantly ($p<0.05$) produced the shortest plants (84.5 cm). The interaction between N fertilizer rate and method of N application had a significant ($p<0.05$) effect on plant height. M1×N120 produced the tallest plants (93.2 cm) while M1×N75 produced the short plants (83.1 cm). The main effects of N fertilizer rate and method of application did not significantly ($p>0.05$) influence days to 50% flowering as well as their interaction effect. Chlorophyll content was affected significantly ($p<0.05$) by N fertilizer rate and method of application at both mid-tillering and booting stages. M1 and M2 produced the highest chlorophyll content at mid-tillering and booting stages, respectively. The N120 produced the highest chlorophyll content at both stages while N75 recorded the lowest. The interaction between N fertilizer rate and method of application also significantly ($p<0.05$) influenced chlorophyll content at both stages. M1×N120 and M2×N75 produced the highest and lowest chlorophyll content at mid-tillering stage, respectively while M2×N120 and M1×N75 had the highest and lowest chlorophyll content at booting, respectively.

The main effects of N fertilizer rate and method of application affected dry matter accumulation significantly ($p<0.05$) at mid tillering, booting and harvest (Table 3). As N rate increases, dry matter accumulation also increases. The M1

Table 1: Description of rate and method of N application treatments

N rate (kg ha^{-1})	Application methods	Treatment combinations
75	Conventional practice (M1)	M1×N75
	Multi split (M2)	M2×N75
90	Conventional practice (M1)	M1×N90 (control)
	Multi split (M2)	M2×N90
120	Conventional practice (M1)	M1×N120
	Multi split (M2)	M2×N120

Table 2: Effect of N fertilizer rate and method of application on plant height, chlorophyll content at mid tillering and chlorophyll content at booting and days to 50% flowering of rice

Nitrogen rate (kg ha^{-1})	Application methods	Plant height (cm)	Chlorophyll content at MT (µmol m^{-2})	Chlorophyll content at BT (µmol m^{-2})	Days to 50% flowering
75	Conventional	83.1^{b}	39.3^{d}	37.8^{d}	94^{a}
	Multi split	86.0^{b}	38.8^{d}	40.4^{c}	93^{a}
	Average	84.5^{b}	39.1^{C}	39.1^{C}	93^{A}
90	Conventional	91.3^{a}	42.0^{bc}	40.1^{c}	93^{a}
	Multi split	92.7^{a}	40.3^{cd}	43.1^{b}	93^{a}
	Average	92.0^{a}	41.1^{B}	41.6^{A}	93^{A}
120	Conventional	93.2^{a}	45.5^{a}	42.9^{b}	93^{a}
	Multi split	91.5^{a}	43.9^{ab}	45.6^{a}	94^{a}
	Average	92.4^{A}	44.7^{A}	44.3^{B}	93^{A}

Means followed by the same small letter in a column are not significantly different from each other at 5% significant level. Means followed by the same capital letter in a column are not significantly different from each other at 5% significant level, MT: Mid tillering stage, BT: Booting stage

Table 3: Effect of N fertilizer rate and method of application on dry matter accumulation at mid tillering, booting and harvest

Nitrogen rate (kg ha^{-1})	Application methods	Dry matter at mid tillering (kg m^{-2})	Dry matter at booting (kg m^{-2})	Dry matter at harvest (kg m^{-2})
75	Conventional	0.9^{c}	4.3^{d}	8.8^{f}
	Multi split	0.7^{c}	4.8^{d}	9.2^{e}
	Average	0.8^{AB}	4.5^{C}	9.0^{C}
90	Conventional	1.8^{ab}	5.2^{c}	10.8^{d}
	Multi split	1.6^{b}	6.5^{b}	11.3^{c}
	Average	1.7^{B}	5.8^{B}	11.0^{B}
120	Conventional	2.0^{a}	6.7^{ab}	11.9^{b}
	Multi split	1.8^{ab}	6.8^{a}	12.3^{a}
	Average	1.9^{A}	6.7^{A}	12.1^{A}

Means followed by the same small letter in a column are not significantly different from each other at 5% significant level. Means followed by the same capital letter in a column are not significantly different from each other at 5% significant level

Table 4: Effect of N fertilizer rate and method of application on grain per panicle, panicles per meter square, grain yield (t ha^{-1}), test weight (g), harvest index and panicle length of rice

Nitrogen rate (kg ha^{-1})	Application methods	Grains per panicle	Panicles per m^{2}	Grain yield (t ha^{-1})	Test weight (g)	Harvest index	Panicle length (cm)
75	Conventional	113^{c}	251^{c}	3.8^{e}	25.3^{a}	0.44^{a}	22.8^{b}
	Multi split	123^{c}	268^{c}	4.0^{d}	26.0^{a}	0.44^{a}	24.1^{a}
	Average	118^{C}	259^{B}	3.9^{C}	25.7^{A}	0.44^{A}	23.4^{B}
90	Conventional	135^{b}	302^{b}	4.6^{c}	25.7^{a}	0.42^{b}	24.9^{a}
	Multi split	140^{ab}	313^{a}	5.0^{b}	25.3^{a}	0.45^{a}	24.6^{a}
	Average	138^{B}	308^{A}	4.8^{B}	25.5^{A}	0.44^{A}	24.8^{A}
120	Conventional	143^{ab}	311^{ab}	4.9^{b}	25.3^{a}	0.41^{b}	24.2^{a}
	Multi split	149^{a}	316^{a}	5.4^{a}	25.7^{a}	0.44^{a}	24.8^{a}
	Average	146^{A}	314^{A}	5.2^{A}	25.5^{A}	0.43^{A}	24.5^{A}

Means followed by the same letter in a column are not significantly different from each other at 5% significant level. Means followed by the same capital letter in a column are not significantly different from each other at 5% significant level

produced higher dry matter than M2 at mid tillering however, the latter produced higher dry matter than the former from booting to harvest. The interaction between N fertilizer rate and method of application was statistically significant ($p<0.05$) from mid tillering stage to harvest. The M1×N120 produced the highest dry matter accumulation (2.0 kg m^{-2}) at mid tillering stage while M2×N120 produced the highest dry matter from booting (6.8 kg m^{-2}) to harvest (12.3 kg m^{-2}). The M1×N75 produced the lowest dry matter from booting (4.3 kg m^{-2}) to harvest (8.8 kg m^{-2}).

Grain yield was significantly ($p<0.05$) influenced by N fertilizer rate as well as method of application (Table 4). Grain yield increased with N rate. N120 and N75 produced significantly ($p<0.05$) the highest and lowest grain yield with 5.2 and 3.9 t ha^{-1}, respectively. The M2 produced higher grain yield than M1. The interaction between N fertilizer rate and method of application also had a significant ($p<0.05$) effect on grain yield. The M2×N120 produced significantly ($p<0.05$) the highest grain yield (5.4 t ha^{-1}) while M1×N75 produced the lowest yield (3.8 t ha^{-1}). The main effects of N fertilizer rate and method of application significantly ($p<0.05$) influenced grains per panicle, panicles per meter square and panicle length (Table 4). The N120 produced the highest grains per panicle (146) and panicles per m^{2} (314). The N75 produced significantly ($p<0.05$) the lowest grains per panicle (113), panicles per meter square (251) and panicle length (22.8 cm). The interaction between N fertilizer rate and method of application also influenced grains per panicle, panicles per meter square and panicle length. The M2×N120 produced the highest grains per panicle (149) and panicles per meter square (316) while M1×N75 had the lowest grains per panicle (113), panicles per meter square (251) and panicle length (22.8 cm). The main effects of N fertilizer rate and method of application did not significantly ($p>0.05$) influence test weight as well as their interaction (Table 4). Harvest index was significantly ($p<0.05$) influenced by the main effect of method of application as well as the interaction effect between N fertilizer rate and method of application. The M2 produced higher harvest index than M1. The M2×N90 produced the highest harvest index (0.45) while M1×N120 produced the lowest (0.41).

DISCUSSION

The application of 120 kg N ha^{-1} applied in seven splits topdressing was most effective for the performance of the rice crop in terms of growth and yield. The high yield response observed with the application of 120 kg N ha^{-1} in seven split topdressing as compared to the lower rates of N in this study, might be ascribed to higher N uptake, higher biomass accumulation longer panicle length as well as higher grains per panicle[16].

Conventional application of 120 kg N ha^{-1} and multi-split application of 90 kg N ha^{-1} in seven splitshad similar yields. This shows that there is waste of N when it is applied at 120 kg N ha^{-1} in only 2 split as in conventional practice, which could be attributed to due to leaching, volatilization and runoff. This finding agrees with the findings of Islam *et al.*[11], who reported that application of N in multi-split yield higher than applying same amount in just two split.

All the rice growth and yield attributes, except percentage filled grain and test weight, were observed to be better influenced by multi-split application of N, particularly at 90 and 120 kg ha^{-1} N^{-1} rates. Chen *et al.*[17] observed that the individual grain weight is usually a stable varietal character and the management practice has less effect on its variation. Dry matter accumulation increased rapidly from maximum-tillering 55 Days After Sowing (DAS) through the various growth stages to harvest when 90 and 120 kg N ha^{-1} was multi-split and when 120 kg N ha^{-1} was applied conventionally. Tiller and dry matter increased proportionally with the increase of nitrogen levels and number of topdressings[18,19]. The accumulation of dry matter observed at the various stages up to booting stage and beyond might have enhanced the partitioning of more stored assimilates into the sink (grain) and thus influence the grain yield.

Chlorophyll content measured at booting stage was highest when 120 kg N ha^{-1} was split-applied seven, this is an indication of high photosynthetic rate and therefore high stored photosynthatewhich enhances remobilization during grain filling. This is in conformity with Mae[20], who reported that remobilization of N from the vegetative organs during grain filling accounted for 70% of the panicle N.

It was observed in the study that conventional application of N as basal and top-dress at panicle initiation stage (65 DAS) is less effective. Rather, application of N in seven multi-splittop-dressing (seven days after transplanting to a week before booting (84 DAS) enhanced growth and yield attributes which translated in higher grain yields. The finding in this study agrees with Chen *et al.*[17], who reported that splitting the N and applying it at different growth cycle in rice leads to increase yield as compared to the blanket application. Varinderpal-Singh *et al.*[10] however, observed in their studies that applying fertilizer N at more than four growth stages of rice does not lead to yield benefit. Bijay-Singh *et al.*[21] could not also observe yield benefit in rice even when fertilizer N was applied in 10 split doses rather than three.

There was interaction between fertilizer rate and number of split top dressings. Application of N fertilizer of 120 kg ha^{-1} at seven splits as top dress, proved superior to the rest of treatment combinations in terms of the grain yield. Even though many N applications would involve additional labor inputs, the results confirm that increasing number of splits of N applied could improve synchrony of the crop N demand and supply.

CONCLUSION

The study provides evidence that applying fertilizer N in several splits is very useful and leads to obtain high biomass production, leading to increased grain yield in rice. Application of 120 kg nitrogen per hectare out-yielded the lower rates of N, including the recommended rate of 90 kg ha^{-1} in Ghana.

SIGNIFICANCE STATEMENTS

In irrigated rice, applying nitrogen in seven equal splits, produces better yield than the conventional two-split nitrogen application. This indicates that increasing number of splits of N applied could improve synchrony of the crop N demand and supply.

REFERENCES

1. Moro, B.M., I.R. Nuhu, E. Ato and B. Nathanial, 2015. Effect of nitrogen rates on the growth and yield of three rice (*Oryza sativa* L.) varieties in rain-fed lowland in the forest agro-ecological zone of Ghana. Int. J. Agric. Sci., 5: 878-885.
2. Issaka, R.N., M.M. Buri and T. Wakatsuki, 2009. Effect of soil and water management practices on the growth and yield of rice in the forest agro-ecology of Ghana. J. Food Agric. Environ., 7: 214-218.
3. Moro, B.M., I.R. Nuhu and W. Toshiyuki, 2008. Determining optimum rates of mineral fertilizers for economic rice grain yields under the "Sawah" system in Ghana. West Afr. J. Applied Ecol., 12: 19-31.
4. Alam, M.M., J.K. Ladha, Foyjunnessa, Z. Rahman and S.R. Khan *et al.*, 2006. Nutrient management for increased productivity of rice-wheat cropping system in Bangladesh. Field Crops Res., 96: 374-386.
5. Ladha, J.K., H. Pathak, T.J. Krupnik, J. Six and C. van Kessel, 2005. Efficiency of fertilizer nitrogen in cereal production: Retrospects and prospects. Adv. Agron., 87: 85-156.
6. Baligar, V.C., N.K. Fageria and Z.L. He, 2001. Nutrient use efficiency in plants. Soil Sci. Plant Anal., 32: 921-950.

7. Tian, Y.H., B. Yin, L.Z. Yang, S.X. Yin and Z.L. Zhu, 2007. Nitrogen runoff and leaching losses during rice-wheat rotations in Taihu Lake region, China. Pedosphere, 17: 445-456.
8. Xu, J., S. Peng, S. Yang and W. Wang, 2012. Ammonia volatilization losses from a rice paddy with different irrigation and nitrogen managements. Agric. Water Manage., 104: 184-192.
9. Ohnishi, M., T. Horie, K. Homma, N. Supapoj, H. Takano and S. Yamamoto, 1999. Nitrogen management and cultivar effects on rice yield and nitrogen use efficiency in Northeast Thailand. Field Crops Res., 64: 109-120.
10. Varinderpal-Singh, Bijay-Singh, Yadvinder-Singh, H.S. Thind and R.K. Gupta, 2010. Need based nitrogen management using the chlorophyll meter and leaf colour chart in rice and wheat in South Asia: A review. Nutr. Cycling Agroecosyst., 88: 361-380.
11. Islam, Z., B. Bagchi and M. Hossain, 2007. Adoption of leaf color chart for nitrogen use efficiency in rice: Impact assessment of a farmer-participatory experiment in West Bengal, India. Field Crops Res., 103: 70-75.
12. Trenkel, M.E., 2010. Slow- and controlled-release and stabilized fertilizers: An option for enhancing nutrient use efficiency in agriculture. International Fertilizer Industry Association (IFA), October 2010, Paris, France, pp: 1-133.
13. Fu, J.R., Y.H. Zhu and L.N. Jiang, 2001. Use of controlled release fertilizer for increasing N efficiency of direct seeding rice. Pedosphere, 11: 333-339.
14. Amatekpor, J.K. and G.N.N. Dowuona, 1999. Site characterization. IBSRAM Vertisol Project, Department of Soil Science, University of Ghana, Accra, pp: 1-42.
15. VSN International, 2011. GenStat for Windows. 14th Edn., VSN International, Hemel Hempstead, UK.
16. Hirzel, J., A. Pedreros and K. Cordero, 2011. Effect of nitrogen rates and split nitrogen fertilization on grain yield and its components in flooded rice. Chilean J. Agric. Res., 71: 437-444.
17. Chen, Y., J. Peng, J. Wang, P. Fu and Y. Hou *et al*., 2015. Crop management based on multi-split topdressing enhances grain yield and nitrogen use efficiency in irrigated rice in China. Field Crops Res., 184: 50-57.
18. Anil, K., M. Yakadri and G. Jayasree, 2014. Influence of nitrogen levels and times of application on growth parameters of aerobic rice. Int. J. Plant Anim. Environ. Sci., 4: 231-234.
19. Kumar, G.S., S.N. Reddy and M. Ikramullah, 1995. Effect of age of seedling and nitrogen level on performance of rice (*Oryza sativa*) under late planting. Indian J. Agric. Sci., 65: 354-355.
20. Mae, T., 1986. Partitioning and utilization of nitrogen in rice plants. Jpn. Agric. Res. Quart., 20: 115-120.
21. Bijay-Singh, Yadvinder-Singh, C.S. Khind and O.P. Meelu, 1991. Leaching losses of urea-N applied to permeable soils under lowland rice. Fertil. Res., 28: 179-184.