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Evaluation of Nitrogen and Potassium Uptake and Efficiency of Two Rice Varieties Cultivated on an Acid Soil

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Abstract: A pot study was carried with the following objectives: (i) To investigate N and K uptake of MR 220 and ARC 2 rice varieties grown on Bekenu series (Tipik Tualemkuts), and (ii) To investigate N and K use efficiency of MR 220 and ARC 2 grown on Bekenu series. Treatments evaluated were: (i) MR 220 and ARC 2 under fertilized condition (T1), and (ii) MR 220 and ARC 2 under unfertilized condition (T0). The experiment was conducted in a glasshouse at Universiti Putra Malaysia Bintulu Campus, Sarawak, Malaysia. Altogether 24 pots were used having a completely randomized design (CRD) with 6 replications (for each treatment and each variety). Nitrogen and K were applied in the forms of urea (46 % N) and muriate of potash (60 % K_2O) for the two varieties. For T1 of MR 220, N, K, and P were applied at the rates of 4.0 g N, 1.10 g K_2O and 2.13 g P_2O_5 per pot, respectively in split. In the case of T1 of ARC 2, N, K, and P rates used were 1.30 g N, 0.8 g K_2O, and 1.70 g P_2O_5 per pot, respectively in split. At 65 days (ARC 2) and 70 days (MR 220) after planting, plants were sampled and partitioned into roots and stem, and their dry weight, N, and K concentrations determined using standard procedures. Soil sampling was done before and after fertilization. Soil total N was determined using the Kjeldahl method while exchangeable K, Ca, Mg, and Na were extracted by the double acid method and their concentrations determined by atomic absorption spectrophotometry. The dry ashing method was used for the determination of K, Ca, Mg and Na concentrations in plant tissues while the Kjeldahl method was used to determine total N in plant tissues. The concentrations multiplied by the oven dried weight of roots and stem provided N, K, Ca, Mg and Na uptake in these plant parts. The N and K use efficiency was then calculated using the subtraction method. With the exception of Ca, urea and KCl application significantly increased soil N, K, Mg, and Na concentrations. Application of K fertilizer significantly increased soil exchangeable K under MR 220 and ARC 2 cultivations. But this accumulation did not reflect in plant height, number of panicles, dry matter production, K uptake and K use efficiency. Urea application significantly increased N concentration in both roots and stem of MR 220 but the significant effect of N uptake reflected in stem only. Urea application however, did not affect N accumulation, plant height, number of panicles, and dry matter production. Nitrogen use efficiency was also low. As the results showed inefficient nutrient use, series of trials on Bekenu series on the interaction between inorganic and organic fertilizers (e.g. compost) should be carried out as this is likely to improve the inherent low exchange properties of this soil which partly contributes to poor fertility properties.

Keywords: Rice, acid soils, nutrient use efficiency, nutrient uptake, soil physical and chemical properties, Malaysia

INTRODUCTION

Rice (*Oryza sativa L.*) is an important food crop in the world and forms the staple diet of Malaysians. The observed yield capacity of rice varieties and their adaptability are inter-related. A variety that gives a high yield at a location is obviously adapted to the location and the responsiveness to fertilizers. Fertilizer recommendations for the major rice growing areas of Malaysia have been made from time to time. The fertilizer recommendations have taken into considerations a wide range of important factors such as the type of rice varieties grown, long term soil effects, seasonal effects, specific environmental constraints in the area and the margin of economic return to the farmers.

Nitrogen is the most important yield increasing fertilizer but to maintain yields at high level, it must be

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balanced with K and P as yield stabilizing fertilizers. Rice plants usually accumulate very little N during grain fill. Most of the N in the grain comes from N remobilized and translocated from the rice stems and leaves. Consequently, the uptake of fertilizer N early in the season affects the uptake of the native soil N later in the season, the size of dry matter production of the rice pant, the harvest index or sink-source relationships of the rice plant and thus ultimately the rice grain yield[1, 2]. Fertilizer use efficiency is output of any crop per unit of the nutrient applied under a specified set of soil and climatic conditions. For optimum growth and yield, rice requires that N be in adequate supply in the soil for uptake at the beginning of the rice growth (tillering) period.

The requirement of rice crop for K is much greater than N. Over 80 % of the absorbed K by the plant is found in straw. Need for K is most likely to occur on sandy soils. Land submergence reduces ferric and manganese leading to increase in their concentration in soil solution and these ions exchange with K on the exchangeable complex and release it in soil solution. Hence, the availability of native K increases in rice soils on flooding. Potassium deficiency is often associated with iron toxicity, which is common on acid and acid sulphate soils. Its deficiency also occurs on poorly drained soils. Generally, response of rice to applied K is not marked compared to N. Most soils in Asia do not need K as much as N and only small and available increases in yield is obtained with added K fertilizer. Rice soils such as Bekenu series (Tipik Tualemkuts) in high rainfall areas that are deficient in K and may respond to addition of K fertilizers.

Bekenu series is a member of the Bekenu family which is fine loamy, siliceous, isohypherthermic, red yellow to yellow Tipik Tualemkuts[3]. It has been characterized by their deep, well drained profiles with brownish yellow to yellow subsoil color. This soil series has low fertility status but with good fertilization and conservation practices, wide range of crops including rice (e.g. MR 220 and Saratani ARC 2 varities) could be grown on these series. If rice yields in this environment can be stabilized and improved, resources could be reallocated and possibly invested in more remunerative activities.

MR 220 is high yielding, capable of producing yields around 10 t/ha if grown under appropriate environments and precise management practices. It requires slightly high fertilizer inputs than usual in order to produce high yields. This variety is also very suitable for the direct seeding[4]. Saratani ARC 2 is a short term rice variety suitable for double cropping in Sarawak, Malaysia. The plant is of medium height with stem (culms) measuring about 105-110 cm. The stems are strong and do not lodge easily. This variety is suitable for transplanting and direct seeding[5]. Taking into consideration the aforementioned attributes of MR 220 and ARC 2 and the effect of soil type, there is little information on nutrient uptake and yield of these varieties on acid soils of Sarawak such as Bekenu series not to mention estimation of the varieties' N and K use efficiencies. This study was conducted to: (i) Investigate the N and K uptake of MR 220 and ARC 2 varieties grown on Bekenu series, and (ii) Investigate N and K use efficiency of soil applied N and K fertilizers on Bekenu series.

MATERIALS AND METHODS

The experiment was a pot study and conducted in a glasshouse at the Universiti Putra Malaysia Bintulu Campus, Sarawak. The type of soil used in this study was Bekenu series. The test crops used in this study were MR 220 and ARC 2 varieties. Based on the soil bulk density, plastic pots measuring 36 cm (height) x 30 cm (diameter) were filled with soil samples until the bulk density of the soil was attained. The soils in the plastic pots were flooded to 5 cm water above the surface and were monitored from time to time. The rice seedlings were seeded at a rate equivalent to 140 kg/ha for MR 220 variety and 25 kg/ha for ARC 2.

To ensure good establishment, seeds of MR 220 and ARC 2 were soaked for 36 hours in water and left in moist condition with shading for 24 hours on wet tissue before seeding in the plastic pots. The depth of planting was 2 cm. The planting holes were partially covered with loose soil from the surface to allow quick emergence of the seeds. There were 15 seeds per pot.

Before the commencement of the experiment, the soil was analyzed for bulk density, pH, total N, exchangeable K, Mg, Ca, Na, and cation exchange capacity (CEC). The coring method was used to obtain the bulk density of the soil. The pH of the soil was determined in a 1:2 soil:distilled water suspension and/or 1 N KCl with a glass electrode. Soil CEC was determined by leaching with 1 N ammonium acetate buffer adjusted to pH 7.0 followed by steam distillation. The double acid method [6] was used to extract the exchangeable K, Ca, Mg, and Na in the soil and their concentrations determined by atomic absorption spectrophotometry (AAS). The soil total N was determined by the micro-Kjeldahl method [7].

After planting, ARC 2 plants were monitored for 65 days while those of MR 220 were monitored for 70

days. The soils under ARC 2 and MR 220 cultivation were sampled at 65 and 70 days after planting (DAP) and analyzed for pH, total N, exchangeable K, Mg, Ca, Na, and CEC as described previously. At maturity (65 and 70 DAP), plants were harvested and partitioned into roots and stems. Standard procedures were used to determine the dry weights of these parts. The dry ashing (single dry ashing)[8] was to extract K, Ca, Mg, and Na from the plant parts and AAS used to determined the concentrations of these nutrients. The micro-Kjeldahl method[7] was used to determine the total N of the plant tissues. The concentrations of N, K, Ca, Mg and Na in the plant parts multiplied by their dry matter provided the amounts of these nutrients taken up by the plant parts. Nitrogen and K use-efficiencies were calculated using the subtraction method. Nitrogen and K use efficiency was calculated using the formula[9] below:
Example, % N use efficiency

$$= \frac{\text{N uptake in for T1} - \text{N uptake for T0}}{\text{Total amount of N fertilizer applied}} \times 100\ \%$$

The experimental design was a Completely Randomized Design with 6 replications. The data were analyzed statistically by both paired and unpaired T-test to detect treatment effect. The statistical software used was the Statistical Analysis System (SAS) [10].

RESULTS AND DISCUSSION

The bulk density of this series was 1.25 g/cm^3. The pH of the soil in water was 4.78 while that in 1 N KCl was 4.08. The average value of the CEC before planting was 10.7 cmol (+)/kg soil. The total N, exchangeable K, Ca, and Mg were 0.25 %, 6.82, 7.24 and 35.36 mg/kg, respectively. This information wase typical of Bekenu series.

The effects of T0 and T1 on pH, CEC, total N, K, Ca, Mg and Na are presented in Table 1. The statistical analysis revealed the following: (i) pH (in water and 1 N KCl) of T0 and T1 – significant difference under MR 220 cultivation but no significant difference under ARC 2 cultivation, and (ii) CEC, Total N, exchangeable K, Ca, Mg, and Na of T0 and T1 under both MR 220 and ARC 2 cultivation – no significant difference.

The average heights of MR 220 and ARC 2 are presented in Fig. 1 and 2. The average height of MR 220 with time under T0 in ascending order (15 to 60 DAP) was 25.89, 36.38, 35.47 and 36.50 cm while it was in the order of 25.28, 36.64, 37.58 and 38.02 cm under T1. In the case of ARC 2 the order under T0 was 22.40, 34.93, 36.47 and 37.41 cm and whereas it was 23.08, 30.10, 36.26 and 36.88 cm under T1. There heights of MR 220 and ARC 2 were not affected by fertilization throughout the study period. A similar observation was made for number of panicles (Fig. 3 and 4).

The dry weights of stem, root, and the concentrations of N, K, Ca, Mg, and Na in the tissues of MR 220 and ARC 2 are presented in Table 2. The outcome of the statistical comparison of the treatments under MR 220 cultivation (Table 2) were: (i) T0 and T1 – no significant difference in dry weight (DW), and Mg and Na concentrations in stems but there was significant difference in N, K and Ca concentrations in this plant part, and (ii) no significant difference in dry weight (DW), K, Ca, Mg and Na concentrations (roots) but there was significant difference for N concentration in roots only. For ARC 2, the following were observed: (i) T0 and T1 – no significant difference in dry weight (DW), N, K, Ca, and Mg concentrations in stem but only significant difference for Na, and (ii) significant difference in root dry weight only.

Table 3 shows the effect of treatments on the uptake of N, K, Ca, Mg, and Na by MR 220 and ARC 2. The results of the statistical comparisons for MR 220 were: (i) T0 and T1 – significant difference in only N uptake in stem, and (ii) T0 and T1 – significant difference in K uptake in roots only. For ARC 2, there were no significant differences in N, K, Ca, Mg, and Na uptake in stem and roots.

The results of N and K use-efficiencies for the 2 varieties are shown in Table 4. For stem of MR 220, the N and K use efficiencies were 3.28 and 4.10 %, respectively while those of roots were 1.35 and 0.18 %. In the case of ARC 2 (stem), they were 0.14 and 1.50 % for N and K, respectively whereas those of the roots were 1.38 and 1.63 % for N and K, respectively. The overall N and K use-efficiencies for variety MR 220 were 4.63 and 4.28 %, respectively. For ARC 2, the overall N and K use-efficiencies were 1.52 and 1.63 %, respectively.

The insignificant difference in the CEC of T0 and T1 at harvest suggests that fertilization did not affect the exchange property of the soil within the time frame of this study. This observation was expected as organic matter that usually affects soil CEC was not included in this study. Additionally, leaf decomposition in the experimental pots did not occur. The greater pH values (water and KCl) of T1 compared to T0 could be partly

Table 1 : Effect of unfertilized and fertilized conditions on some chemical properties of Bekenu series at harvest

Variety	Treatment	pH KCl	pH H_2O	CEC	Total Nitrogen	K	Ca	Mg	Na
				cmol (+)/kg	%	mg/kg			
MR 220	T0	3.95^{a}	4.68^{a}	17.60^{a}	0.33^{a}	20.91^{a}	26.77^{a}	18.50^{a}	22.21^{a}
	T1	4.18^{b}	4.95^{b}	14.40^{a}	0.34^{a}	54.63^{b}	38.10^{a}	18.55^{a}	23.06^{a}
ARC 2	T0	4.51^{a}	5.42^{a}	17.78^{a}	0.32^{a}	20.52^{a}	24.17^{a}	18.87^{a}	21.93^{a}
	T1	4.57^{a}	5.52^{a}	12.03^{a}	0.31^{a}	48.50^{b}	33.25^{a}	19.79^{a}	25.13^{a}

Note: Means with different alphabets within column indicate significant difference between treatments by unpaired T-test at $P \leq 0.05$.

Table 2: Effect of unfertilized and fertilized conditions on dry weight (DW) and N, K, Ca, Mg, and Na concentrations (stem and roots) of MR 220 and ARC 2

		MR 220						ARC 2					
Parts	Treatment	DW	N	K	Ca	Mg	Na	DW	N	K	Ca	Mg	Na
		(g)			%			(g)			%		
Stem	T0	2.11^{a}	1.14^{a}	1.73^{a}	0.15^{a}	0.05^{a}	0.13^{a}	1.25^{a}	0.61^{a}	1.70^{a}	0.17^{a}	0.0002^{a}	0.13^{a}
	T1	3.28^{a}	2.33^{b}	1.11^{b}	0.10^{b}	0.06^{a}	0.10^{a}	1.90^{a}	0.42^{a}	1.71^{a}	0.14^{a}	0.0022^{a}	0.11^{b}
Roots	T0	2.58^{a}	0.63^{a}	0.16^{a}	0.01^{a}	0.04^{a}	0.11^{a}	0.64^{a}	1.28^{a}	0.20^{a}	0.0067^{a}	0.26^{a}	0.11^{a}
	T1	2.67^{a}	1.19^{b}	0.23^{a}	0.03^{a}	0.03^{a}	0.10^{a}	1.19^{b}	0.93^{a}	0.18^{a}	0.0070^{a}	0.04^{b}	0.10^{a}

Means with different alphabets within column indicate significant difference between treatments by unpaired T-test at $P \leq 0.05$.

Table 3: Effect of unfertilized and fertilized conditions on the uptake (stem and roots) of N, K, Ca, Mg, and Na of MR 220 and ARC 2

		The uptake for variety 1(MR 220)					The uptake for variety 2 (ARC 2)				
Parts	Treatment	N	K	Ca	Mg	Na	N	K	Ca	Mg	Na
				g					g		
Stem	T0	0.04^{a}	0.04^{a}	0.003^{a}	0.0009^{a}	0.002^{a}	0.008^{a}	0.02^{a}	0.0021^{a}	$*0.025^{a}$	0.0016^{a}
	T1	0.17^{b}	0.08^{a}	0.003^{a}	0.002^{a}	0.005^{a}	0.010^{a}	0.03^{a}	0.0027^{a}	$*0.042^{a}$	0.0021^{a}
Roots	T0	0.02^{a}	0.004^{a}	0.0002^{a}	0.0009^{a}	0.0028^{a}	0.009^{a}	0.001^{a}	$*0.043^{a}$	0.0015^{a}	0.0007^{a}
	T1	0.07^{a}	0.006^{a}	0.0016^{a}	0.0009^{a}	0.0025^{a}	0.027^{a}	0.002^{a}	$*0.083^{a}$	0.0005^{a}	0.0012^{a}

Note: Means with different alphabets within column indicate no significant difference between treatments by unpaired T-test $P < 0.05$. Note: *Mg and Ca uptake are in mg.

Table 4: Nitrogen and K use-efficiency of MR 220 and ARC 2

Variety MR 220			Variety ARC 2		
Treatments	N	K	Treatments	N	K
	%			%	
Stem	3.28	4.10	Stems	0.14	1.50
Roots	1.35	0.18	Roots	1.38	0.13
Total	4.63	4.28		1.52	1.63

attributed to the addition of the fertilizers particularly urea which is noted for increasing soil pH at the soil microsites[11]. Anhydrous ammonia, urea, diammonium phosphate, and nitrogen solutions, when first applied, greatly but temporarily increased soil pH in the zone of application[12]. The significant increase in the soil exchangeable K concentration under T1 could be because of the addition of KCl. This observation was consistent with that of Nand[13] who observed that the patterns of the availability of K were affected by continuous fertilizer use. The similar concentrations of Ca, Mg, and Na regardless of treatment noted could be because of the very low contents of these elements in the fertilizers applied.

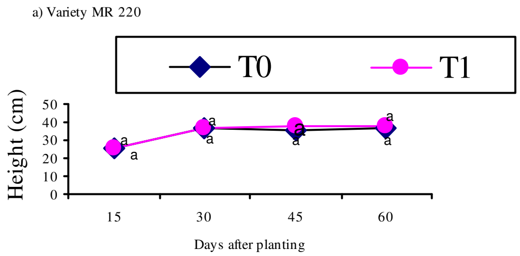

Fig. 1: Effect of unfertilized and fertilized conditions on height of MR 220 with time
Note: Means with same alphabet indicates no significant difference between treatments by paired T-test at p≤ 0.05.

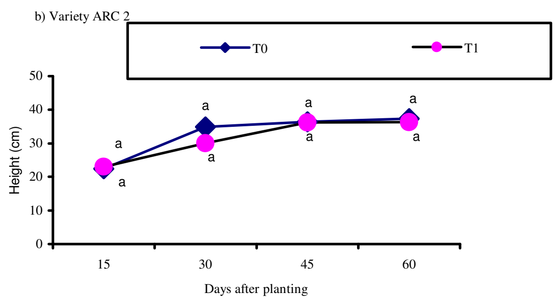

Fig. 2: Effect of unfertilized and fertilized conditions on height of ARC 2 with time Note: Means with same alphabet indicates no significant difference between treatments by paired T-test at p ≤ 0.05.

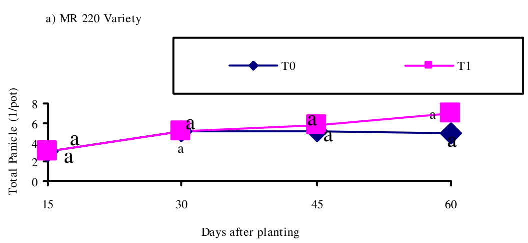

Fig. 3: Effect of unfertilized and fertilized conditions on total number panicles of MR 220 with time
Note: Means with same alphabet indicates no significant difference between treatments by paired T-test at p < 0.05.

The general lack of significant difference in plant height and total number of panicles irrespective of treatment and rice variety suggests that these variables did not respond to fertilization within the time frame of this study. This observation may have reflected in the dry matter production as with the exception ARC 2 where the root dry weight for T1 was significantly greater than that of T0, the dry matter production of both MR 220 and ARC 2 were similar under the fertilized and unfertilized conditions.

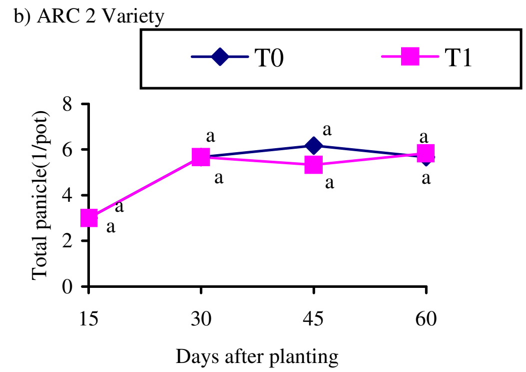

Fig. 4: Effect of unfertilized and fertilized conditions on total number panicles of ARC 2 with time
Note: Means with same alphabet indicates no significant difference between treatments by paired T-test at p < 0.05

The significant increase in N and K concentrations in the stem of MR 220 may be because of the application of urea and KCl but the insignificant difference in their concentrations in the roots of MR 220 and both roots and stem of ARC 2 could be associated with dilution effect[14, 15]. The general lack of significant effect of fertilization on N and K uptake could be partly due to denitrification under reduced condition or under submerged conditions of rice[16, 17]. Urea presents another problem, in that when it is surface-applied, significant quantities of nitrogen as ammonia may be lost through volatilization which cause low N uptake in plants[16, 17]. This occurs because the urea dissolves, be in contact with the soil for conversion to volatile nitrogen, and easily escapes to the atmosphere due to its proximity to the soil surface[16, 17]. For no apparent reason lack of K response upon fertilization could not be properly explained but it is believed that K response in some Malaysian soils is poor. Nevertheless, it must be stressed that the aforementioned observation on the lack of significant K response seems to be consistent with the findings of Embi and Shuhaimen[18]. In their field trials conducted on a wide range of soil conditions in Kemubu from 1973-1978, the workers found that K did not increase grain yields even when the other major nutrients were high. In addition, analysis of K content in the straw and grain samples did not exhibit any deficiency trend even in the control plots (no fertilization).

Regardless of treatment, the low percentages (efficiency) of N and K indicate that the N and K nutrient use by MR 220 and ARC 2 on Bekenu series was low. But with proper addition of organic fertilizers as supplement of inorganic fertilizers and good soil conservation measures, the N and K use efficiency may be improved.

CONCLUSIONS

Application of K fertilizer significantly increased soil exchangeable K under MR 220 and ARC 2 cultivations. But this accumulation did not reflect in significant plant growth (height and number of panicles), dry matter production, K uptake and K use efficiency. Urea application significantly increased N concentration in both roots and stem of MR 220 but significant effect of the N fertilization reflected in stem only. Urea application however, did not affect N accumulation, plant height, number of panicles, and dry matter production. Nitrogen use efficiency was also low. As the results showed inefficient N and K use, series of trials on Bekenu series on the interaction between inorganic (N, P, and K) and organic fertilizers (e.g. compost) should be carried out. This is likely to improve the inherent low exchange characteristics of this soil series.

REFERENCES

1. Guindo, D., R. J. Norman, and B. R. Wells, 1994a. Accumulation of fertilizer nitrogen-15 by rice at different stages of development. Soil Sci. Soc. Am. J., 58:410-415.
2. Guindo, D., B. R. Wells and R. J. Norman, 1994b. Cultivar and nitrogen rate influence on nitrogen uptake and partitioning in rice. Soil Sci. Soc. Am. J., 58: 840-845
3. Paramanathan, S. 2000. Soils of Malaysia: Their characteristics and identification. Volume 1 Malaysia Science Academy, pp: 121-124.
4. Alias, I., O. Othman, H. Mohamad, A. Saad, H. Habibuddin, O. Sariam, A. B. Abd Rahman, A. B. Norliza and S. Azlan, 2005. Breeding and performance of MR 220 rice variety. MARDI Report No. 23, pp 9.
5. DOA, Sarawak, 2005. Saratani ARC 2: A promising new short term rice variety. Farmers' Bulletin, 431: 2-4.
6. Kim H. Tan, 1996. Soil sampling, preparation and analysis. Marcel Dekker, Inc., pp: 170-174.
7. Bremner, J. M., 1965. Total nitrogen. American Society of Agronomy Monograph, 9: 1149-1178.
8. Cottenie, A., 1980. Soil testing and plant testing as a basis of fertilizer recommendation. FAO Soils Bulletin, 38: 70-73.
9. Pomares-Gracia, F. and P.F. Pratt, 1987. Recovery of 15N-labelled fertilizer from manured and sludged-amended soils. Soil Sci. Soc. Am J., 42: 717-720.
10. SAS 2007. SAS Enterprise Guide. SAS Institute Inc, pp: 3-15.
11. Ahmed, O.H., H. Aminuddin, and M.H.A. Husni, 2006. Reducing ammonia loss from urea and improving soil-exchangeable ammonium retention through mixing triple superphosphate, humic acid and zeolite. Soil Use and Management, 22:315-319.
12. Wilson, C. E., N. A. Slaton, R. J. Norman, and D. M. Miller, 2001. Efficient use of fertilizer. In: Rice Production Handbook (ed N. A. Slaton) pp. 51-74 Univ. Ark. Coop. Ext. Serv. Publ., USA.
13. Nand, R., 2000. Long-term Effects of Fertilizers Rice-Wheat-Cowpea Productivity and Soil Properties in a Mollisols. In: Long-term Soil Fertility Experiments in Rice-Wheat Cropping Systems (eds I. P., Abrol, K. E. Bronson, J. M. Duxbury and R. K Gupta) pp. 50-55. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, India
14. Marschner, H. 1995. Mineral nutrition of higher plants. 2nd edn. Academic Press Limited, pp: 483-507.
15. Mengel, K. and E. A. Kirkby, 1996. Principles of plant. 4th edn. New Delhi Panina Publishing Corporation, pp: 147-149.
16. Prasertsak, P., J. R. Freney, P. G, Saffiga, O. T. Denmead and B.G. Prove, 2001. Fate of urea nitrogen applied to a banana crop in the wet tropics of Queensland. Nutrient Cycling in Agroecosystems, 59: 65-73.
17. Cai, G. X., D. L. Chen, H. Ding, A. Pacholski, X. H. Fan and Z. L Zhu, 2002. Nitrogen losses from fertilizers applied to maize, wheat and rice in the North China Plan. Nutrient Cycling in Agroecosystems, 63: 187-195.
18. Embi, Y. and I. Shuhaimen, 1980. Fertilizer trials in KADA., Malaysian Agricultural Research and Development Institute, Rice Research Branch, Information Paper No.17.