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Comparison of Nitrogen use Efficiency and its Variation among Rice Cultivars of Manipur, India

Joylata Laishram[1*], K.G. Saxena[1] and Ng. Piloo[2]

[1]*School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India*
[2]*College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, India*

Corresponding author

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ABSTRACT

Nitrogen use efficiency is considered as one of the most yield limiting factor for the rice production in all the rice growing regions of the world. This experiment was conducted to investigate the variation in nitrogen use efficiency of rice cultivars, the selection of rice cultivars with high nitrogen use efficiency, and the relationships of nitrogen use efficiency with the growth characteristics under non-limiting conditions of factors like water, fertilizer inputs. Variation in nitrogen use efficiency of rice cultivars was very low in 2010 (33.82 to 37.22) and in 2011 (34.38 to 38.33) but there were a high variation in nitrogen uptake efficiency was (0.55 to 0.79) and (0.56 to 0.68) for both the years and physiological utilization efficiency was (42.64 to 62.70) and (52.44 to 64.82) respectively. On average, nitrogen use efficiency of the 8 rice cultivars was 35.82 and 35.99, nitrogen uptake efficiency was 0.67 and 0.61 and physiological utilization efficiency was 54.29 and 59.45 respectively. For the year 2010, Nitrogen uptake efficiency was positively correlated with plant dry matter (0.846**) and leaf nitrogen content (0.943***) and for the year 2011, Nitrogen uptake efficiency was also positively correlated with plant dry matter (0.617) and leaf nitrogen content (0.820*). Therefore, the dry matter weight of rice plant was more important than leaf nitrogen content for characterizing nitrogen uptake efficiency and the result suggested that yield could be improved by optimizing the plant N uptake through improving the fertilizer N recovery efficiency.

Introduction

Nitrogen use efficiency (NUE) is defined as the ratio of grain yield to the supplied nitrogen (Shi *et al.*, 2010), it has composed of two primary components like the nitrogen uptake efficiency and nitrogen utilization efficiency (Haefele *et al.*, 2008). Nitrogen uptake efficiency (UE) is defined as the ratio of plant nitrogen content to the available nitrogen content, and nitrogen utilization efficiency is also defined as the ratio of grain yield to the available plant nitrogen content (Moll *et al.*, 1982). Also, nitrogen utilization efficiency was called physiological nitrogen utilization efficiency (PUE) (Singh *et al.*, 1998). Nitrogen fertility is an important component of rice (*Oryza sativa* L.) cultivation systems.

China accounts 32 % of the world's total consumption of synthetic nitrogen in the world, out of this 18 % (190 kg ha^{-1}) is applied to paddy cultivation and it is greater than the world average (Heffer, 2009). Most of the nitrogen fertilizer is lost due to gaseous emission, surface runoff volatilization, leaching and finally enters the environment. In China much of this loss is as the gaseous nitrogen in the form of N_2O, varying from 20-50 % of the total nitrogen input in irrigated rice cultivation (Zhu, 1997; Bao *et al*., 2006; Ju *et al*., 2009). Nitrogen losses during runoff generally happen throughout the drainage of the paddy field that occurs ten days after the tillering stage, and by the action of rainfall events (Qiao *et al*., 2012). The uptake of nitrogen is greatly affected by varietal characteristics, fertilizer application, soil condition and environmental factors (Bao *et al*., 2005). There is a strong influence of nitrogen on plant growth so farmers apply large amount of nitrogen fertilizer in order to get high productivity but plants generally consume less than half of the nitrogen applied in their fields and a major portion of it is lost to the environment or leached into several water bodies causing severe environmental pollution (Shi *et al*., 2010). Nitrogen use efficiency (NUE) is relatively low in irrigated lowland rice system because applied inorganic N is rapidly lost from the soil flood water system by volatilization and denitrification (De Datta *et al*., 1989). It was revealed that, agronomic nitrogen use efficiency (kg grain yield increase per kg of nitrogen applied) of rice was 15-18 kg N ha^{-1} in the dry season in Philippines (Cassman *et al*., 1996) but in China on average it was 10.2 kg N ha^{-1} (Zhang *et al*., 2008). It was estimated that reducing nitrogen fertilizer input could significantly improve nitrogen utilization efficiency (Cassman *et al*., 2002; Zhang *et al*., 2008; Peng *et al*., 2010). It was reported that there is higher Nitrogen use efficiency (NUE) in grain yield in hybrids varieties than the conventional varieties. It was estimated that, in South eastern China the economically optimum and ecologically optimum nitrogen rates for the rice production was 180-285 kg ha^{-1} and 90-150 kg ha^{-1} resulting to rice yields of 6.1-8.9 t ha^{-1} and 5.5-8.8 t ha^{-1} respectively (Chen *et al*., 2011). The N rate estimated here is considered as the economically optimum and ecologically optimum for the rice production in south-eastern China by saving 189 x 10^3 and 442 x 10^3 metric tons of N use per year and reducing N loss by 35% and 74% respectively. Ladha *et al.*, (1998) opined that desirable cultivars with high Nitrogen use efficiency (NUE) produces large yield irrespective of the nitrogen supply as grain yield and total N uptake were greatly affected by cultivars. To attain both high yield and efficiency of fertilizer application, it is suggested to optimize Nitrogen fertilizer management at crucial growing stages (Qiao *et al*., 2012). It was found that in Northeast Thailand, grain yield was 4 t ha^{-1} when nitrogen applied at the rate of 40, 80, 90 kg ha^{-1} at panicle initiation, heading and maturity respectively (Ohnishi *et al*., 1999). We have carried out this experiment to investigate the variation in Nitrogen use efficiency (NUE) of rice cultivars, the selection of rice cultivars with high nitrogen use efficiency, and the relationships of Nitrogen use efficiency (NUE) with the growth characteristics of rice cultivars under non-limiting conditions of factors like water, fertilizer inputs.

Materials and Methods

Site description

Field experiments were conducted in Wangkhem Village, Thoubal District, Manipur during the period 2010 - 2011. It is situated at a distance of 3.4 km from its district main city Thoubal and 25 km from Imphal, the capital city of Manipur (Figure 1). The experimental site is situated at 24^0 $40^/$ N latitude and 94^0 $10^/$ E longitude and at an altitude of 790 m above mean sea level (amsl). It is a plain area. The climate is sub-tropical with warm moist summer and cool dry winter. The soil of the village has clay loam soil type.

Plot design

Eight cultivars namely Norin, KD Chakanbi, Drumphou, Leima, Sanaphou, Tolen, Khuman and 24-Manao), were selected to compare their colour of grain, colour of husk, stickiness, taste quality, maturity period, yield kg/ha etc, Plot size was 2 m x 2 m, with three replicates of control, cowdung and fertilizer treatments respectively. Direct sowing of seeds was adopted as practiced locally in the village. Sowing was done on 25th July (2010) and 8th June (2011) at the rate of 500 seeds m^{-2}. There was no uniformity in sowing dates during the two years due to uneven distribution of rainfall patterns during monsoon season in the region. After 30-40 days, thinning was done such that density of mature plants was 20 hills m^{-2}.

Treatment

There were two treatments of cowdung and fertilizer and one check/control where neither fertilizer nor manure was applied. Fertilizers were applied at the rate of 120 kg/ha and 80 kg/ha of DAP were also applied. Fertilizer was applied top dressed in two split-dozes: 70 kg-urea and 50 kg DAP/ha at the time of early tillering stage and 50 kg urea and 30 kg DAP/ha.

Measurements

Time of formation of panicles and flowers in at least 50% plants and of maturity of all plants in different plots were recorded for all the cultivars in all years. At the harvest stage, plant component-wise crop biomass (husks, edible grains, leaves, weeds, stems and roots) were collected from all the sub-plots and fresh weight were recorded, air dried and then finally oven-dried in laboratory at 60-70°C for 48 hours and biomass was determined, After biomass determination all the biomass sample including husks, edible grains, leaves, weeds, stems and were ground and passed a 2 mm sieve for nitrogen estimation. Nitrogen was analyzed by using CHNS analyzer. It is an elemental analyzer used to determine the amount of Carbon, Hydrogen, Nitrogen and Sulphur in a given substance and gives the result as percentage amount of these atoms against the total weight. In this technique the substance under study is combusted under oxygen stream in a furnace at high temperatures (combustion temperature set at 1150^0C and reduction temperature was set at 850^0C). The end products of the combustion would be mostly the oxides of the concerned elements in the form of gases. These are then separated and carried to the detector using inert gases like helium or argon and finally N efficiency of rice cultivars in the terms of nitrogen use efficiency (yield/nitrogen application rate), uptake efficiency (plant nitrogen content/nitrogen application rate), and physiological utilization efficiency (yield/plant nitrogen content) were evaluated.

Statistical analysis

Data gathered in the experiment were statistically analyzed using Analysis of Variance (ANOVA) and least significant difference values ($P = 0.05$) were used to evaluate the significance of differences between varieties.

Results and Discussion

Nitrogen use efficiency was significantly varied among the cultivars in this particular village and it ranged from (33.82 to 38.33) mg grain produced per mg of N absorbed in both the years. Such differences might be related to genetic factors, physiological processes like absorption, translocation, assimilation, N remobilization and as well as during storage. Variation in nitrogen use efficiency of 8 cultivars in Wangkhem village was very low (33.82 to 37.22) (Table 1) and (34.38 to 38.33) (Table 2) when compared to Korean rice cultivars with (44.09 to 51.91) (Lee *et al.*, 2004) and there were also low variation in nitrogen uptake efficiency was (0.55 to 0.79) (Table 1) and (0.56 to 0.68) (Table 2) and physiological utilization efficiency was (42.64 to 62.70) (Table 1) and (52.44 to 64.82) (Table 2) when compared to Korean rice with nitrogen uptake efficiency of (0.51 to 0.90) and physiological utilization efficiency of (51.71 to 94.26) respectively (Lee *et al.*, 2004). On average, nitrogen use efficiency of the 8 rice cultivars was 35.82 (Table 1) and 35.99 (Table 2), nitrogen uptake efficiency was 0.67 (Table 1) and 0.61 (Table 2) and physiological utilization efficiency was 54.29 (Table 1) and 59.45 (Table 2) respectively. We have classified the cultivars in terms of nitrogen efficiency into two ranking groups, high and low. The highly efficient group with uptake efficiencies for the year 2010 and 2011 include Norin (0.79), Khuman (0.74) and Norin (0.62), K.D Chakanbi (0.60), Khuman (0.64), 24- Manao (0.68). while the low efficient group for both years include K.D Chakanbi (0.69), Drumphou (0.61), Leima (0.61), Sanaphou (0.67), Tolen (0.55), 24-Manao (0.67) and Drumphou (0.59), Leima (0.57), Sanaphou (0.59), Tolen (0.56) (Table 3) respectively. For physiological utilization efficiency Tolen (62.70) and K.D Chakanbi (60.86), Leima (60.66), Sanaphou (64.59), Tolen (64.82) were the more efficient cultivars, while Norin (42.64), K.D Chakanbi (54.00), Drumphou (55.87), Leima (59.18), Sanaphou (55.33), Khuman (50.57), 24-Manao (54.06) and Norin (55.91), Drumphou (58.06), Khuman (58.25), 24- Manao (52.44) in both the years were the least efficient cultivars (Table 3).

For the year 2010, Nitrogen uptake efficiency was positively correlated with plant dry matter (0.8397) and leaf nitrogen content (0.9437) (Table 4) and for the year 2011, Nitrogen uptake efficiency was also positively correlated with plant dry matter (0.5983), and leaf nitrogen content (0.8387) (Table 5).

Table 1. Variation in nitrogen use efficiency, uptake efficiency, physiological utilization efficiency, plant nitrogen content, and yield in rice cultivars for the year 2010

Maturity group	Cultivars	NUE(1)	UE(2)	PUE(3)	Plant N content (kg/ha)	Yield (kg/ha)
Early	Norin	33.82	0.79	42.64	95.17	4058.33
	K.D Chakanbi	37.22	0.69	54.00	82.71	4466.67
Medium	Tolen	34.44	0.55	62.70	65.93	4133.33
	Khuman	37.22	0.74	50.57	88.33	4466.67
	Sanaphou	36.94	0.67	55.33	80.12	4433.33
Late	Drumphou	34.10	0.61	55.87	73.24	4091.67
	Leima	36.32	0.61	59.18	73.65	4358.33
	24- Manao	36.46	0.67	54.06	80.93	4375.00
	Mean	35.82	0.67	54.29	80.01	4297.92
	SD	1.45	0.08	5.95	9.20	173.99
	CV%	4.05	11.49	10.96	11.49	4.05

Table.2 Variation in nitrogen use efficiency, uptake efficiency, physiological utilization efficiency, plant nitrogen content, and yield in rice cultivars for the year 2011

Maturity group	Cultivars	NUE(1)	UE(2)	PUE(3)	Plant N content (kg/ha)	Yield (kg/ha)
Early	Norin	34.58	0.62	55.91	74.23	4150.00
	K.D Chakanbi	36.60	0.60	60.86	72.16	4391.67
Medium	Tolen	36.46	0.56	64.82	67.49	4375.00
	Khuman	37.01	0.64	58.25	76.26	4441.67
	Sanaphou	38.33	0.59	64.59	71.21	4600.00
Late	Drumphou	34.38	0.59	58.06	71.05	4125.00
	Leima	34.72	0.57	60.66	68.69	4166.67
	24- Manao	35.83	0.68	52.44	82.00	4300.00
	Mean	35.99	0.61	59.45	72.88	4318.75
	SD	1.38	0.04	4.21	4.62	165.70
	CV%	3.84	6.34	7.08	6.34	3.84

(1) **NUE** (Nitrogen Use Efficiency): Yield/N application rate
(2) **UE** (Uptake Efficiency): Plant N content/N application rate
(3) **PUE** (Physiological Utilization Efficiency): Yield/Plant N content

Table.3 Rice cultivars classified into high and low groups in terms of nitrogen uptake efficiency and physiological utilization efficiency.

Groups	2010 cultivars	2011 cultivars
High nitrogen uptake efficiency	Norin (0.79), Khuman (0.74)	**Norin (0.62), K.D Chakanbi (0.60), Khuman (0.64), 24- Manao (0.68).**
Low nitrogen uptake efficiency	K.D Chakanbi (0.69), Drumphou (0.61), Leima (0.61), Sanaphou (0.67), Tolen (0.55), 24- Manao (0.67).	**Drumphou (0.59), Leima (0.57), Sanaphou (0.59), Tolen (0.56),**
High physiological efficiency	Tolen (62.70)	**K.D Chakanbi (60.86), Leima (60.66), Sanaphou (64.59), Tolen (64.82),**
Low physiological efficiency	**Norin (42.64), K.D Chakanbi (54.00), Drumphou (55.87), Leima (59.18), Sanaphou (55.33), Khuman (50.57), 24- Manao (54.06)**	**Norin (55.91), Drumphou (58.06), Khuman (58.25), 24- Manao (52.44).**

Table.4 Correlation relationships between uptake efficiency, physiological utilization efficiency, and growth characteristics of rice cultivars for the year 2010.

2010	Dry matter weight	Leaf N content	Yield
N uptake efficiency	0.846 **	0.943 ***	**0.160 NA**
N physiological utilization efficiency	**-0.762 ***	**-0.964 *****	**0.114 NA**

Table 5. Correlation relationships between uptake efficiency, physiological utilization efficiency, and growth characteristics of rice cultivars for the year 2011

2011	Dry matter weight	Leaf N content	Yield
N uptake efficiency	0.617 NA	0.820 *	**0.032 NA**
N physiological utilization efficiency	**-0.401 NA**	**-0.885 ****	**0.516 NA**

*significant at P<0.05, **significant at P<0.01, ***significant at P<0.001, NA- not significant

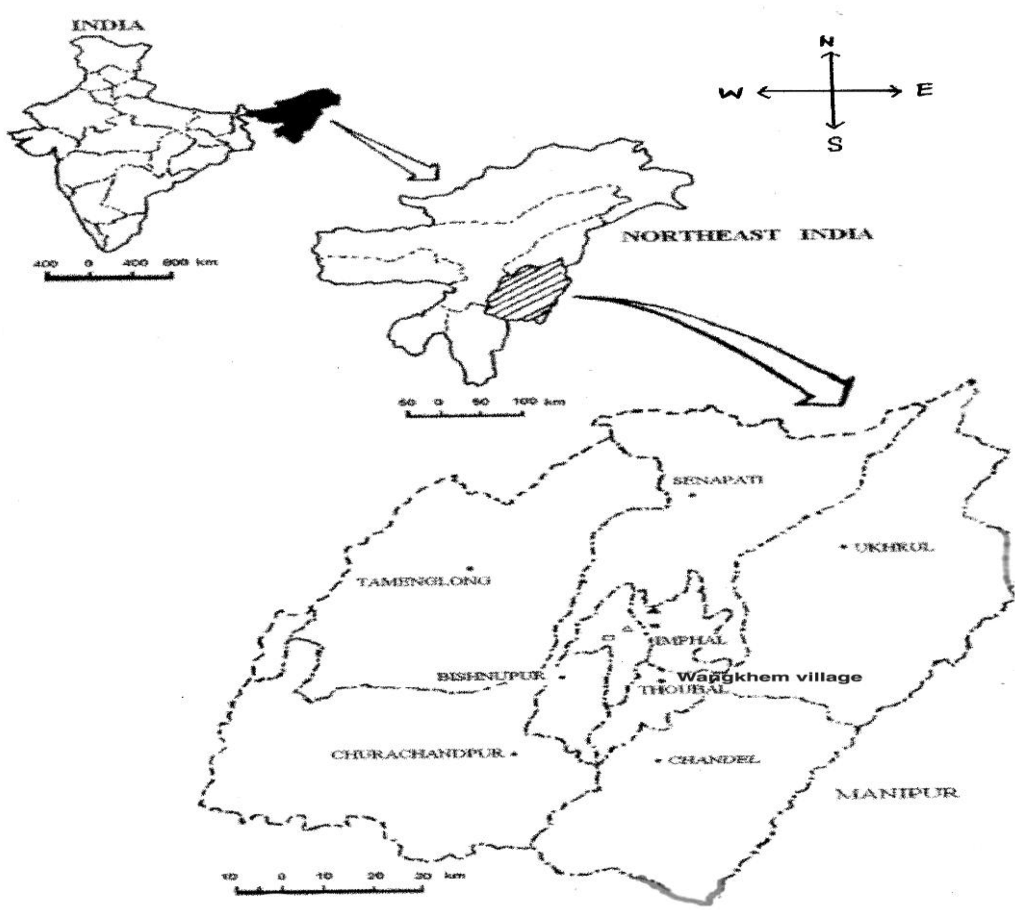

Figure.1 Map showing study site (Wangkhem village, Thoubal District, Manipur)

We investigated the reasons why Norin had a high nitrogen uptake efficiency, and why Tolen had a high physiological utilization efficiency for the year 2010 and for the year 2011, why 24- Manao had a high nitrogen uptake efficiency, and why Tolen had a high physiological utilization efficiency Nitrogen uptake efficiency was positively correlated with dry matter weight of plant and leaf nitrogen content. The regression coefficients between uptake efficiency and dry matter weight of plant and leaf nitrogen content were 0.846**, 0.943*** and 0.617NA, 0.820*, respectively. Therefore, the dry matter weight of rice plants was more important than leaf nitrogen content in characterizing N uptake efficiency. However, these two parameters had negative correlation coefficients with physiological utilization efficiency. Physiological utilization efficiency was positively correlated with yield (Table 4) and (Table 5.). Chakanbi and Khuman with 4467 (kg/ha) had larger grain yield and the nitrogen content absorbed from fertilizer was smaller than some other rice cultivars.

It is necessary to improve N use efficiency by understanding better knowledge about the physiological or biochemical mechanisms responsible for N use efficiency. The cultivars with high uptake efficiency can be used for sustainable environmental-friendly farming systems. It can be concluded that cultivars with high uptake efficiency had higher nitrogen contents than cultivars with low uptake efficiency from nitrogen application. Therefore, the cultivars with high uptake efficiency could reduce the contamination of water environments including river and sea on the other hand the low recovery of applied nitrogen in cultivars leads to losses of N through surface runoff, volatilization, denitrification and leaching, so it is advised to use adequate rate and timing of N application for achieving optimum yield production. Physiological utilization efficiency should be used for breeding of high-yielding rice to develop agronomically suitable cultivars for different rice producing regions. It is essential to use nitrogen efficient rice cultivars to generate high yields and lessen environmental contamination.

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