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RESEARCH ARTICLE

Nitrogen Use Efficiency - A Tool for Varietal Selection

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ABSTRACT

Field experiment was conducted during *pishanam*, 2017 (October to January) with 32 numbers of short duration rice varieties / cultures grown in Tamil Nadu province as main plot and N levels (0, 50, 100 and 150% recommended N) as subplot in split plot design replicated twice at Rice Research Station, Tamil Nadu Agricultural University, Ambasamudram to delineate and classify rice varieties into N utilization and responsive classes. The experimental soil was sandy loam in texture with acidic pH (4.16) had 0.35% organic matter, available nitrogen - 270 kg ha^{-1}, available phosphorus - 10 kg ha^{-1} and available potassium - 63 kg ha^{-1}. The 32 short duration rice varieties used under this study were delineated and classified into highly responsive (10), moderately responsive (5), low responsive (7) and non-responsive cultures (10) based on the responsiveness and utilization of applied nitrogen by the variety. The technique of selection of highly efficient and responsive rice variety / cultures under low nitrogen input can be used as a tool for crop improvement programme to evolve better crop variety.

Keywords: *Rice; Nitrogen use efficiency; Classification; Organic farming*

INTRODUCTION

The population in India may cross 1.69 billion by 2050 and may overtake China by 2035 itself. The total food grain production in our country has to be increased from the present level of 291.95 million tonnes during 2019 -20 to 333 million tonnes by the year 2050. To meet this challenge, India would need to increase supply of nutrient to over 45 million tonnes. Out of this, 35 million tonnes should come from chemical fertilizer sources and 10 million tonnes from organic sources (NAAS, 2009). Rice is an important world food security crop which relies on chemical fertilizer to sustain high yields (Dobermann, 2007).

In order to achieve the full yield potential of rice, increased fertilize nitrogen application is compulsory (Roberts, 2009) and estimated that about 250 million tonnes of fertilizer nitrogen may be needed by 2050 (Tilman *et al*., 2011). India is the second largest producer and consumer of nitrogenous fertilizer in the world. In the event of high input agriculture, more emphasis on fertilizer use efficiency, especially nitrogen use efficiency (NUE) has to be given to safeguard the economic as well as environmental resources under rice production system. Though the nutrient use efficiency mainly depends on the efficient fertilizer management practices, the existing N use efficiency pattern under varied doses and the factors responsible for N use efficiency in existing fertilizer application methods in various soil and crop varieties need to be studied for further improvement in N use efficiency by determining nitrogen use efficiency of N fertilizer at different levels and classifying the rice genotypes based on nitrogen use efficiency (NUE) of promising rice varieties/genotypes of Tamil Nadu.

MATERIALS AND METHODS

A field experiment was conducted during 2017 (*Pishanam*) at RRS, Ambasamudram, Tirunelveli to screen thirty two short duration rice genotypes cultivated in all rice growing areas of Tamil Nadu for identifying nitrogen efficient and responsive cultures in split plot design with four nitrogen levels of N *viz*., control, 50, 100 and 150 % recommended dose of nitrogen. The details of main plot and sub-plot factors are as follows.

S. No	Factors	Number	Details
1.	Level of Nitrogen	4	N0 - Absolute control N1-50 % recommended N N2- 100 % recommended N N3- 150 % recommended N
2.	Genotype	32	ASD16, ADT39, ADT43, ADT45, CO51, TPS5, MDU5, ANNA4, AS12051, AS12104, AD09206, AD10034, ACK14001, ACK14004, CB06803, CB08702, CB13539, CB14508, CB14533, TR0927, TR0531, TR13069, TR13083, TM1307, TM07335, TM09135 , TM10085, TM12059, TM12061, TM12077, PM12009, EC725224

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The grain yield from each plot was recorded as kg plot^{-1} and converted to kg ha^{-1}. The moisture content of the grain was maintained at 14 percent by oven drying at 80^{0}C. The grain yields for the plants removed for sampling purposes from each plot were computed based on the number of hills and added to the harvested yields of their respective plots. The efficiency is the maximum economic yield produced per unit of nitrogen applied, absorbed and utilized by the plant was calculated as agronomic efficiency, physiological efficiency, apparent recovery efficiency and utilization efficiency. (Cassman *et al*., 1996).

The incremental efficiency of applied N is often called as agronomic efficiency and computed as

$$\text{ANUE (kg (kg N)}^{-1}) = \Delta GY/N_t$$

Where, ΔGY is the incremental grain yield (kg ha^{-1}) for N applied.

Apparent recovery efficiency (RE) is the efficiency with which the crop utilizes the acquired N from the applied N and computed as follows.

$$\text{ARE} = \frac{\text{(Total plant N uptake with N application)} - \text{(Total plant N uptake without N application)}}{\text{Total N application}} \times 100$$

Physiological efficiency (PE) is the efficiency with which the crop utilizes the acquired N to produce more grains and computed as

$$\text{PE} = \frac{\text{Grain yield with N application} - \text{Grain yield without application}}{\text{Total plant N uptake with N application} - \text{Total plant N uptake without N application}} \times 100$$

Classification system of rice genotypes

A number of methods and parameters have been proposed for classifying genotypes for their N use efficiency. The graphical methods and the parameters used to classify the genotype in to various groups under normal scatter diagram are listed below.

Table 1. Various methods and parameters used for N use efficiency

Sl. No.	X axis	Y axis	Author
1.	Grain yield at low nitrogen level	Nitrogen use efficiency	Fageria (2003)
2.	Grain yield at low nitrogen level	Physiological N use efficiency	Kosar *et al*. (2003)
3.	Dry matter yield at low level of nitrogen	Efficiency index	Siddiqi and Glass (1981)
4.	Dry matter yield at low level of nitrogen	Dry matter yield at high level of nitrogen	Gill *et al*. (2011)
5.	Grain yield at low level of nitrogen	Total uptake of nitrogen at high level nitrogen application	
6.	Efficiency Index	N utilization efficiency	Fageria (2007)

In all the above method, genotypes can be delineated at low N conditions and may not classify the genotypes responded to higher N level. Since the agronomic N use efficiency reflects the nutrient absorption efficiency and Physiological efficiency indicate the utilization efficiency, these parameters are used in this study to classify and delineate rice varieties.

RESULTS AND DISCUSSION

Agronomic N use efficiency

The ANUE for rice genotypes varied from 1.52 to 22.73 kg (kg N)$^{-1}$ with an average value of 12.09 kg of grain produced per kg of N applied (Fig. 1). The genotypes namely ASD16, ADT39, ADT45, TPS5, AD09206, ACK14001, CB06803, TR05031, TM10085, PM12009 and EC725224 registered agronomic N use efficiency of more than 15 kg (kg N)$^{-1}$. The variation in agronomic N use efficiency among the genotypes indicates the difference in biochemical and physiological characteristics, nutrient uptake, remobilization and translocation of absorbed N (Ladha *et al*., 1998). Similar results were obtained by Samonte *et al*. (2006) who stated that the large genotypic variation in agronomic nitrogen use efficiency was probably due to low yield potential.

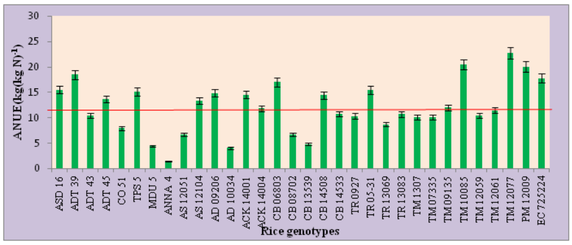

Fig 1. Agronomic N use efficiency as influenced by rice genotypes

The lowest agronomic nitrogen use efficiency was observed under higher dose of 150 % recommended dose of nitrogen (Fig. 1). This is in agreement with results of Ohnishi *et al*. (1999) and Peng *et al*. (2007). The agronomic nitrogen use efficiency showed a decreased linear response to applied N because there was no increase in utilization efficiency but increase in production of grain yield with enhanced N fertilization in rice can only be achieved by higher N uptake (Jothimani, 2012). The reason for decreased nitrogen use efficiency with N application is not clear (Artacho *et al*., 2009).

Among the interaction between rice genotypes and nitrogen levels, the decreasing trend of ANUE with increasing N level was noticed with ADT39, TPS5, AS12051, AS12104, AD09206, AD10034, ACK14001, ACK14004, CB06803, CB08702, CB13539, TR05031, TM13007, TM09135, TM10085, TM12059, TM12077, PM12009 and

EC725224 due to non response of variety to higher level of nitrogen application as observed by Noureldin *et al*. (2013). Low agronomic N use efficiency reflect limited yield response to fertilizer N application because of high indigenous soil N levels (Peng *et al*., 2006).

The genotypes ASD16, ADT45, CO51, MDU5, CB14533, CB14508, TR13069, TM07335 and TM12061 showed increasing trend of ANUE with increasing N levels from 50% to 150% recommended dose of nitrogen due to responsiveness of genotypes to high level of N addition with less utilization efficiency. The similar results were derived by Tirol-Padre *et al*. (1996). Therefore, it is necessary to develop cultivars that have more efficient in absorption of applied N to minimize leaching loss of N from soil to nearby water bodies and make more economic use of applied fertilizer with higher utilization efficiency, which not only increase rice grain yield but also prevent environmental pollution (Singh *et al*., 1998).

Physiological N use efficiency

In general the physiological efficiency decreased with increased level of N application (Fig. 2). However, application of N @ 120 and 180 kg ha^{-1} were on par with each other on mean physiological efficiency. Among the genotypes, the higher mean physiological efficiency of 71.71 kg (kg N)$^{-1}$ was observed under CB 14533 and PM 12009 (62.95 kg (kg N)$^{-1}$). Gauer *et al*. (1992) reported that the physiological nitrogen use efficiency depends on genotypic character. Dobermann (2007) concluded that the varieties with higher mean physiological efficiency may have more physiological efficiency at the lower N than the higher N application and as such both these varieties (CB 14533 and PM 12009) registered highest physiological efficiency at the lower N application. These varieties are suitable to cultivate under low input system.

There were three types of trend followed in PNUE.

Group-I: The PNUE increased with increased nitrogen application in ASD 16, ADT43, CO51, MDU 5, ANNA 4, CB08702, CB14508, TR0927, TR13069, TM07335, and TM12061. But the physiological efficiency of these varieties / cultures was not more than the mean physiological efficiency, 30 kg (kg N)$^{-1}$ which implies the applied N was effectively utilized by these varieties. Lopez and Lopez (2001) suggested that the increased physiological N use efficiency with nitrogen application reflect the efficient utilization of absorbed nitrogen by rice plant.

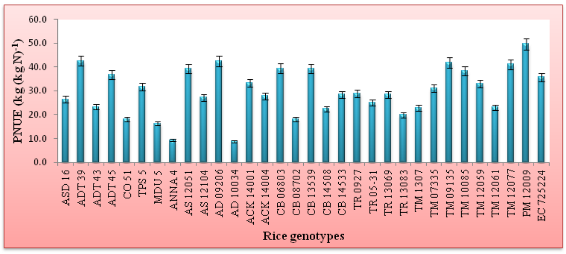

Fig 2. Physiological N use efficiency (kg (kg N)$^{-1}$) as influenced by rice genotypes

Group-II: The PNUE decreased with increased N doses in ADT 39, ADT45, TPS5, AS12051, AS12104, AD09206, AD10034, ACK14001, CB06803, CB13539, TR0531, TR13083, TM1307, TM12059 and TM12077. In most of the varieties / cultures the physiological efficiency exceeded the mean value which implies that absorbed nitrogen has been effectively utilized and converted into grain (Jothimani and Thiyagarajan, 2005). The capability of increase in yield per kg nitrogen declined remarkably with increasing nitrogen application (Devika *et al*., 2018).

Group – III: Intermediate genotypes such as ACK 14001, CB14533, TM09135, TM10085, EC725224 and PM12009 which recorded highest PNUE at 180 kg ha^{-1} (N_3) with little bit decrease at 120 kg ha^{-1} (N_2) than lowest N application of 60 kg ha^{-1} (N_1). The N efficiency culture EC 725224 registered a mean physiological efficiency of 35.74 kg (kg N)$^{-1}$ and an almost equal physiological efficiency was recorded in all the N doses. An ideal genotype which absorbs relatively high amounts of N from soil and fertilizer, produces a high grain yield per unit of absorbed N and stores relatively little N in the straw (Isfan, 1993).

Classification

A scattered diagram was drawn by taking agronomic N use efficiency in X axis and physiological N use efficiency in Y axis. An intercept line was drawn at the mean agronomic and physiological efficiencies with perpendicular and parallel line on the scattered diagram respectively which divided the graph into four equal quadrants. The top left quadrant represent the non efficient and responsive varieties, the top right quadrant represent the efficient and responsive group of rice varieties, the bottom left quadrant indicate non-efficient and non responsive varieties and the bottom right quadrant represent non efficient and responsive varieties (Sivasabari and Jothimani, 2019).

Fig. 3 showed all the groups of N efficiency. The genotypes such as ADT39, ADT45, TPS5, ACK14001, AD09206, CB06803, TM10085, TM12077, PM12009 and EC725224 were classified under Efficient and Responsive (ER) category and ASD16, AS12104, CB14508 and TR05031 were grouped under Efficient and Non-responsive (ENR) category. The genotypes such as AS12051, CB13539, CB14533, TM12059 and TM09135 were classified under Non-efficient and responsive (NER) and ADT43, CO51, MDU5, ANNA4, AD10034, ACK14004, CB08702, TR09027, TM13007, TM07335, TM12061, TR13083 and TR13069 were classified as Non- efficient and non-responsive (NENR) category.

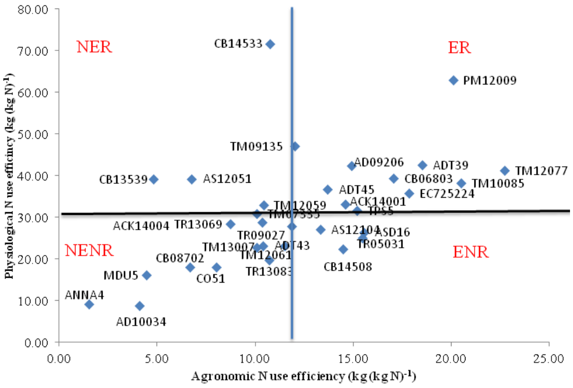

Fig 3. AE vs PE model of delineating rice genotypes

CONCLUSION

It is necessary to develop cultivars that have more efficient in absorption of applied N and utilization of absorbed nitrogen to obtained enhanced grain yield with less dose of nitrogen to minimize leaching loss of N from soil to nearby water bodies and pollute the environment besides increasing rice grain yield of rice. Among 32 varieties popular in Tamil Nadu, the genotypes such as ADT39, ADT45, TPS5, ACK14001, AD09206, CB06803, TM10085, TM12077, PM12009 and EC725224 were identified as highly efficient and responsive rice variety / cultures under low nitrogen input. So these varieties can be used as a donor under rice improvement programme to evolve better crop variety and prevent nitrate pollution in soil, ground water and atmosphere.

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