Omonrice 10: 67-73 (2002)

Prediction of crop nitrogen uptake and grain yield by soil nitrogen availability tests for irrigated lowland rice- Correlations between seasons for grain yield, plant nitrogen uptake, soil properties and soil availability indices

Thach Thi Ngoc Anh[1], Daniel C. Olk[2]

ABSTRACT

Plant N uptake (PNU) and grain yield (GY) of the unfertilized (-F) plots varied considerably both across farms and across seasons. The CV was slightly higher for PNU than for GY in all three crops cycles. The correlation of each farmer's PNU or GY was insignificant between most pairs of seasons, for all plots and for those plots with crop growth limited solely by N, and even for all wet seasons from 1995-1998.

Keywords: Nitrogen availability tests, grain yield, plant nitrogen uptake, soil properties, seasons.

INTRODUCTION

Nitrogen (N) fertilizer use efficiency in irrigated lowland rice could be improved if fertilizer recommendations were based on the native soil fertility, or indigenous N supply (INS), currently defined in on-farm studies as grain yield or plant nitrogen uptake in unfertilized plots (Cassman et al., 1994, 1995, 1996a). In order to identify less laborious laboratory methods that could adequately predict the INS, 26 soil N availability indices and intrinsic soil properties were correlated with GY and PNU in –F plots of 27 farmers' fields in Nueva Ecija in three cropping periods that are presented (Anh et al., 2000). The second objective is to identify any relationships between these soil analyses and crop response to N fertilizer, correlations were computed between GY and PNU of the –F and the plots located within the same farmers' field that received adequate levels of N and K fertilizers (+NK) as well as in sections of immediately adjacent fields that received fertilizer rates estimated by other researchers as promoting improved fertilizer use efficiency for each field, the site-specific nutrient management (SSNM) treatments (Anh et al., 2001) and to examine whether soil sampling time affects the prediction of GY and PNU (Anh et al., 2001). The third objective is to identify any correlations between seasons for GY, PNU, soil properties and soil N availability.

MATERIALS AND METHODS

Soil samples were collected from nine farmers' fields that were located near each of three villages in PhilRice area (Bantug, Burgos, and Lagare) during the 1997 wet season (WS) and 1998 dry season (DS). They were used for evaluation of several N availability analyses and intrinsic soil properties. Both samplings were taken 25-40 days after sowing (DAS). To evaluate the effect of crop growth stage and sampling time, two samplings were collected in the 1998 WS (0-10 DAS and 25-40 DAS) for analysis by those N availability indices and intrinsic soil properties. Chemical indices of N availability evaluated were phosphate buffer, hot 2M KCl extraction, room temperature KCl extraction, ultraviolet light absorption at 200 and 260 nm, NaOH and $NaHCO_3$ extractions, alkaline permanganate, acidified $KMnO_4$, phosphate borate buffer, and autoclaving in $CaCl_2$ solution. Several properties of the mobile humic acid (MHA) fraction were evaluated, and a biological index was anaerobic

[1] Cuu Long Delta Rice Research Institute, Omon, Cantho, Vietnam
[2] International Rice Research Institute, Los Banos, Philippines

incubation with K-saturated cation exchange resin.

Crop performance in these fields had been monitored by other researchers during in every cropping period since the 1994-1995 dry season.

Recommended N fertilizer rates to the adjacent field under farmer's fertilizer management were determined by other researchers on a field-specific basis, based on earlier estimates of the INS. Nitrogen fertilizer rates to the +NK treatment were 180 kg N ha $^{-1}$ for the DS and 120 kg N ha $^{-1}$ for the WS in all farmer' fields.

To determine the reproducibility over time of all soil analyses, GY, and PNU, simple correlation coefficients were determined for each of these measurements among cropping seasons.

RESULTS

Correlations Between Seasons for Grain Yield, Plant Nitrogen Uptake, Soil Properties and Soil N Availability Indices

1. 1997 Wet Season and 1998 Dry Season

To evaluate the accuracy of GY and PNU measurements, correlations were computed between GY and PNU of the –F and the SSNM treatments in the 1997 WS and 1998 DS. As expected (Cassman et al., 1996b and Olk et al., 1999), the correlations between GY and PNU were highly significant in all cases except the SSNM treatment in the 1998 DS (Table 1), thus indicating that both the GY and PNU measurements were reasonably accurate. Both correlation coefficients for the SSNM treatment are lower than those previously reported for irrigated lowland rice.

Table 1. Simple correlation coefficients between grain yield and plant N uptake for the unfertilized (-F) treatment and the site specific nutrient management treatment (SSNM), 1997 wet season (WS) and 1998 dry season (DS).

	1997 WS		1998 DS		1998 WS
	-F	SSNM	-F	SSNM	-F
		GY		GY	GY
PNU	0.818***	0.563**	0.756***	0.349ns	0.745***

** Significant at P<0.01, *** Significant at P<0.001, ns : not significant at P<0.05

Correlations between seasons for GY and PNU response to N fertilizer for the SSNM and + NK treatments were insignificant in all cases (Table 2).

Table 2. Simple correlation coefficients between the 1997 wet season and 1998 dry season for grain yield (GY) and plant N uptake (PNU) response to N fertilizer for the site specific nutrient management (SSNM) treatment and the +NK fertilizer treatment

	SSNM	+NK
GY RESPONSE	0.211 ns	0.083 ns
PNU RESPONSE	-0.153 ns	-

ns Not significant at P<0.05

To evaluate the reproducibility of plant and soil measurements, correlations between seasons were computed for GY, PNU, indices for soil N availability and intrinsic soil properties. Correlations between the 1997 WS and 1998 DS for GY and PNU of individual farmers were both insignificant (Table 3). Correlation coefficients for soil N availability analyses varied from 0.0294 to 0.7757. Significant correlations were found in 15 of the 26 cases. Each group of N availability indices had some significant correlations between seasons, and the groups of light absorption and of oxidative, hydrolytic, and autoclaving analyses had the highest proportions of significant correlations.

Table 3. Simple correlation coefficients between seasons for grain yield (GY), plant N uptake (PNU), indices for soil N availability, and other soil properties in two replicates unfertilized plots in farmers' fields.

	1997 WS & 1998 DS	1998 DS & 1998 WS[a]	1998 WS 1998 WS[b]	1997 WS & 1998 WS[a]	1998 WS 1998 WS[b]	1998[a] WS & 1998[b] WS
GY	-0.038	-	0.051	-	0.056	-
PNU	-0.035	-	-0.098	-	0.305	-
PB[c]	0.330	-	-	-	-	-
TPB	0.296	-	-	-	-	-
HOTKCl	0.574**	-	-	-	-	-
THOTKCl	0.484*	-	-	-	-	-
KCl	0.602**	-	-	-	-	-
UV	0.519*	-	-	-	-	-
TUV	0.685**	-	-	-	-	-
NM260	0.775**	-	-	-	-	-
NaOH	0.668**	-	-	-	-	-
$NaHCO_3$	0.356	-	-	-	-	-
$KMnO_4$	0.384*	-	-	-	-	-
ACID	0.261	-	-	-	-	-
PBB	0.226	-	-	-	-	-
TPBB	0.128	0.077	0.229	0.264	0.556**	0.458**
AUTO	0.489**	0.240	0.068	0.306	0.442*	0.576**
TAUTO	0.487**	0.249	0.337	0.475*	0.711**	0.645**
MHA-C	0.655**	-	-	-	-	-
MHA-N	0.585**	-	-	-	-	-
MHA-CN	0.192	-	-	-	-	-
LIGHT	0.741**	-	-	-	-	-
N1	0.029	-	-	-	-	-
K1	0.136	-	-	-	-	-
K2	0.300	-	-	-	-	-
NET7	0.596**	-	-	-	-	-
NET21	0.309	-	-	-	-	-
NET63	0.521**	-	-	-	-	-
K	0.826**	0.806**	0.557**	0.749**	0.595**	0.806**
Mg	-	-	-	0.974**	0.970**	0.984**
SOC	0.679**	-	-	-	-	-
TN	0.748**	-0.052	-0.050	-0.034	-0.096	0.943**
pH	0.636**	-	-	-	-	-

a Early sampling (0-10 days after sowing); b Later sampling (25-40 days after sowing); *Significant at P<0.05;
** Significant at P<0.01; unmarked: not significant at P<0.05.
c PB: organic N extracted by phosphate buffer, TPP: total N extracted by phosphate buffer, HOTKCl: organic N extracted by hot 2M KCl, THOT KCl: total N extracted by hot 2M KCl, KCl: room temperature 2M KCl extraction, NI: total size of labile or readily mineralizable N pool in the anaerobic incubation with K saturated cation exchange resin, K1: rate constant of the labile or readily mineralizable N pool in the anaerobic incubation, K2: rate constant of the more stable recalcitrant mineralizable N pool in the anaerobic incubation, NET7: net NH_4-N at 7 day in the anaerobic incubation, NET22: net NH_4-N at 22 day in the anaerobic incubation, NET63: net NH_4-N at 63 day in the anaerobic incubation
Total soil organic C (SOC) and N (TN) contents, 1M NH_4- extractable K, Mg, and soil pH (1:1 water) for two replicated unfertilized plots in farmers' fields.

Correlation coefficients for the four soil properties measured in each season were somewhat higher than those of the soil N availability indices, varying from 0.64 to 0.83; all were significant (Table 3).

2. 1998 Dry and Wet Seasons

Correlations between the 1998 DS and 1998 WS for GY, PNU and soil N availability indices and other soil properties were all insignificant except at exchangeable K for either soil sampling time (Table 3).

3. 1997 and 1998 Wet Seasons

Correlations between the 1997 WS and 1998 WS for crop parameters were both insignificant. All soil N availability indices and soil properties had significant correlations between seasons for the second soil sampling in the 1998 WS (Table 3). Correlations between the 1997 WS and the first sampling in the 1998 WS were significant in only three of six soil measurements and were weaker than those of the second sampling in four of those six cases.

4. 1998 Wet Season at the First and Second Sampling

Correlations between two sampling times for all parameters varied from 0.4587 to 0.9846 and were all significant (P<0.05). Soil N availability indices had lower correlation coefficients than did soil properties.

5. 1995-1998 Wet Seasons

Grain yield and plant N uptake for the WS of 1995-1998 are presented in Table 4, and simple linear correlation coefficients between seasons for GY and PNU are presented in Tables 5-7. Correlations were insignificant for all possible pairs of years for both GY and PNU except for GY in 1995 and 1998.

Table 4: Grain yield and Plant N uptake for two or three replicated unfertilized plots in farmers' fields, 1995-1998 wet seasons.

	1995	1996	1997	1998
GY	963-3999 kg/ha	1827-4732 kg/ha	2344-5090 kg/ha	1563-4679 kg/ha
Overall Mean	2931	3637	3670	3482
Std. Dev.	790	759	677	827
CV(%)	27	21	18	24
PNU	23.0-72.8 kg/ha	41.8-99.4 kg/ha	43.1-101 kg/ha	21.3-88.9 kg/ha
Overall Mean	55.6	60.9	61.6	58.4
Std. Dev.	17.9	14.1	14.3	16.9
CV(%)	32	23	23	29

6. Correlations Between Seasons for Grain Yield and Plant N Uptake for those Plots with Crop Growth Limited Solely by N

Correlations were insignificant for all possible pairs of seasons for both GY and PNU in 2 of 6 cases (Table 7). Significant correlations were found only for GY between the 1998 DS and 1998 WS and PNU between the 1997 WS and 1998 WS. The GY correlation was negative, however.

Table 5: Simple correlation coefficients between seasons for grain yield for means of two or three replicated unfertilized plots in each farmers' field, 1995-1998 wet season (WS).

	1995 WS	1996 WS	1997 WS
1995 WS			
1996 WS	0.0031ns		
1997 WS	0.1329ns	0.2089ns	
1998 WS	0.4903**	0.1084ns	0.0569ns

*Significant at P<0.05; **Significant at P<0.01; ns Not significant at P<0.05

Table 6: Simple correlation coefficients between seasons for plant N uptake for mean of two or three replicated unfertilized plots in each farmers' field, 1995-1998 wet seasons (WS).

	1995 WS	1996 WS	1997 WS
1995 WS			
1996 WS	0.3058 ns		
1997 WS	0.2585 ns	0.4083 ns	
1998 WS	0.5056 ns	0.1195 ns	0.3059 ns

ns Not significant at P<0.05

Table 7: Simple correlation coefficients between seasons for grain yield (GY) and plant N uptake (PNU) for two replicated unfertilized plots where crop growth was limited solely by N deficiency.

	1997 WS and 1998 DS[a]	1997 WS and 1998 WS[b]	1998 DS and 1998 WS[c]
GY	-0.1508ns	-0.1457ns	-0.4441*
PNU	-0.1404ns	0.6127**	-0.1885ns

[a] Fifteen farmers' fields; [b] Nine farmers' fields; [c] Twelve farmers' fields
Significant at P<0.05; ** Significant at P<0.01; ns Not significant at P<0.05

DISCUSSION

Several N availability indices were found to have significant simple correlation with GY and PNU of the unfertilized plots in each season. However, no soil index was identified by multiple regression analysis in all three of the crop cycles evaluated here. Of all soil N availability indices, only phosphate borate buffer, autoclaving and total soil N appeared in more than one cropping period in the equations for plots where crops growth was sosely N-limited. If results from the 1998 DS are deleted, then significant relationships found in both WS crops became more noteworthy, such as the significance of the phosphate borate buffer, autoclaving, and total soil N analyses.

Overall, the best predicting N availability index in this study was total N extracted by autoclaving (TAUTO). It appeared in three of the four WS multiple regression equations for plots with crop growth limited sosely by N and was the primary contributor to each equation, having partial coefficients of determination ranging from 15-35% (data not shown). In all four equations, the primary contributing term had a positive correlation with GY or PNU, suggesting the relationship could be causal in nature. The TAUTO term was also significantly correlated with the majority of other soil N availability indices or intrinsic soil properties, indeed it had nearly the highest number of significant correlations of all tested indices in all three cropping seasons.

Soil N availability indices and intrinsic soil properties varied greatly on a proportional basis among all farmers' fields in all three crop cycles. However, all soils still shared some properties, e.g. modest soil organic matter (SOM) levels and moderate pH. Each soil N index and soil property was generally poorly or moderately correlated with itself across seasons. Soil N availability indices had lower correlation coefficients between seasons than did soil properties. Then results suggest that soil N availability is transient property and changes throughout the growing season.

Plant N uptake and GY of the –F plots varied considerably both across farms and across seasons. The CV was slightly higher for PNU than for GY in all three crop cycles. Accurate prediction of PNU and GY in the unfertilized plots was probably made more difficult by their high variation among seasons. The lack of significant correlation of each farmer's PNU or GY between most pairs of seasons, whether for wet seasons from 1995-1998 or for those plots where crop growth was limited sosely by N, is incongruent with the concept of the INS as being a measurable, reproducible soil property whose magnitude would serve as the starting point for efficient fertilizer recommendations for each field. In short, either the INS is not a valid concept, or PNU and GY are affected by factors other than the availability of soil N as measured by these indices, e.g., stand establishment, soil N availability at a crop growth stage earlier than the times of soil sampling conducted here, soil microbial activity, or some key characteristic of SOM-bound N not identifiable by the analyses performed here.

In summary, several factors might preclude fully quantitative estimation of the INS. The inconsistent trends in GY and PNU for individual farmers as noted above raises the concerns as to whether unfertilized plots are a valid measure of the INS and whether the INS even exists as a reproducible, measurable entity. Also, the large proportions of farmers who experienced crop-limiting problems other than N deficiency demonstrates the on-farm difficulty of providing ideal growing conditions. Further, soil N availability appears to be a transient property, as witnessed by the mediocre correlations for each soil N availability index between the two soil samplings in the 1998 WS, consistently lower than the corresponding correlations for intrinsic soil properties. Notable is that the magnitudes of all soil N availability changes throughout the cropping period. In this case, stronger correlations of soil N availability indices with the INS might be possible if the optimal sampling time were identified.

REFERENCES

Cassman KG, A Dobermann, PC StaCruz, MI Samson, JP Descalsota, JM Alcantara, M A Dizon, and DC Olk. 1996a. Soil organic matter and the indigenous nitrogen supply of intensive irrigated rice systems in the tropics. Plant and Soil 182:267-278.

Cassman KG, and PL Pingali. 1995. Intensification of irrigated rice systems: Learning from the past to meet future challenges. Geojournal 35:299-305.

Cassman KG, GC Gines, MA Dizon, MI Samson, and JM Alcantara. 1996b. Nitrogen-use efficiency in tropical lowland rice systems: contributions from indigenous and applied nitrogen. Fields Crops Res. 47:1-12.

Cassman KG, MJ Kropff and Y Zhen-De. 1994. A conceptual framework for nitrogen management of irrigated rice in high-yield environments. In S. S. Virmani (ed). Hybrid rice technology: new development and future prospects. Int. Rice Res. Inst. Philippines. pp. 81-96.

Olk DC, KG Cassman, G Simbahan, PC StaCruz, S Abdulrachman, R Nagarajan, PS Tan, and S Satawathananont. 1999. Interpreting fertilizer-use efficiency in relation to soil nutrient-supplying capacity, factor productivity, and agronomic efficiency. Nutrient Cycling in Agroecosystems 53:35-41.

Thach thi Ngoc Anh and DC Olk. 2001. Prediction of crop nitrogen uptake and grain yield response by soil nitrogen availability tests for irrigated lowland rice and comparision to laboratory indices. OMonRice 9: 46-54.

Thach thi Ngoc Anh., and DC Olk. 2000. Prediction of crop nitrogen uptake by soil nitrogen availability tests for irrigated lowland rice. OMonRice 8: 74-85.

SUMMARY IN VIETNAMESE

Mối quan hệ giữa hàm lượng đạm hấp thu trong cây lúa hoặc năng suất cây lúa và lượng đạm dễ tiêu trong đất trồng lúa có nước tưới, đã được ghi nhận bằng các phương pháp phân tích đạm dễ tiêu – Mối tương quan giữa các mùa vụ thể hiện qua năng suất, hàm lượng đạm hấp thu trong cây, các chỉ số đặc tính đất và các chỉ tiêu đạm dễ tiêu cũng được quan sát.

Hàm lượng đạm hấp thu trong cây lúa và năng suất cây lúa ở lô đất không có bón phân (-F) tại các hộ nông dân thì dao động lớn khi phân tích mối tương quan qua các mùa vụ. Độ biến động CV của hàm lượng đạm hấp thu thì cao hơn độ biến động CV của năng suất cây lúa trong cả 3 vụ lúa liên tiếp nhau. Mối tương quan của hàm lượng đạm hấp thu trong cây lúa ở các lô –F, các lô có bón phân N và K (+NK), các lô có bón phân theo mức khuyến cáo của các nhà nghiên cứu theo từng vùng đất riêng biệt (SSNM) và các lô không bị thiệt hại do những nguyên nhân khác, đã được ghi nhận, ngoài nghiệm thức phân N tại các hộ nông dân qua các mùa vụ không có tương quan với nhau, trong khi đó mối tương quan của năng suất cây lúa tại các hộ nông dân cũng cho kết quả phân tích tương tự như vậy. Không có mối tương quan nào của hàm lượng đạm hấp thu trong cây lúa với năng suất cây lúa ngay cả khi phân tích qua các vụ mùa mưa liên tiếp từ 1995-1998.