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SOIL PHOSPHORUS AVAILABILITY TESTS FOR IRRIGATED LOWLAND RICE IN CANTHO, VIETNAM

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ABSTRACT

Phosphorus (P) fertilizer use efficiency in irrigated lowland rice could be improved if fertilizer recommendations were based on the native soil fertility currently defined in field as plant P uptake. Soil P availability indices were not significantly correlated with crop performance in all four cropping cycles based on either simple or multiple linear regression analysis, except for a moderate simple positive correlation between PPU and soil P availability extracted by HCl and H_2 SO_4 solution in 2001 WS and GPU and soil P availability extracted by HCl and NH_4F solution in 2002 WS. For plant P uptake, the best fitting multiple equations predicted 0.39%, 0.42%, 0.42%, and 0.58% during four seasons, respectively. The 0.025 N HCl and 0.03 N NH_4F solutions should be recommended.

The goal of optimal scheduling and quantities of applied fertilizer P can be based on the assumption that greastest P use efficiency is achieved by efficient utilization of both applied and the soil P availability. In order to identify less laborious laboratory methods that could adequately predict the soil P availability, 6 soil P availability indices were correlated with plant P uptake in four cropping periods. Secondary objectives were to identify any relationships between these soil analysises and crop measurements and to examine whether soil-sampling time affects the prediction of plant P uptake.

Keywords: Phosphorus availability tests, plant phosphorus uptake, soil fertility.

MATERIALS AND METHODS

Time and location of experiment

Experiment was conducted in experimental farm of the Cuu Long Rice Research Institute, Omon district, Cantho province, Vietnam. This experimental plot was tested by some of fertilizer kinds of companies (e.g Con Co or Dau Trau...) in Fluvaquentic Humaquept soil beeing representative of much of the double-cropped rice areas in the Mekong Delta. It is a clayey soil with very slow infiltration, high water holding capacity and easy to puddle. Soil texture does not change with depth. The whole area is naturally flooded from September to November, when deposition of fresh sediment occurs. Following 1986 soil analysis data, the texture was 57% clay, 42.5% silt and 0.5% sand, with pH 5.2 (1:1 H_20). The experiment commenced from 2000 wet season (WS) to 2002 WS, but this study was restricted from 2000-2001 dry season (DS), 2001 WS, 2001- 2002 DS to 2002 WS.

Experimental design

The experiment was designes as latin square with four replications. Plot size was 40 m^2. Phosphurus fertilizer treatments were P_2O_5 at the following rates in kg ha^{-1} as 00, 40, 80 and 120. These trements were mixed to nitrogen fertilizer at the following rates in kg element ha^{-1} as 80 for dry seasons and 60 in wet seasons. Potassium fertilizer at the following rates in kg K_2O ha^{-1} was applied 30 for both DS and WS. Nitrogen was applied as three split doses of urea: 1/3 at transplanting, 1/3 at tillering and 1/3 at panicle initiation. Phosphorus was applied as two split doses: 40 kg P_2O_5 at transplanting and the rest at 15 days after transplanting (DAT). Potassium chloride was applied at transplating.

Soil sampling

Samples were taken from the 0-15 cm depth at before transplanting (BT) and at 25- 30 DAT. All P availability analyses were conducted in the all crop samplings. Air-dry soils were ground and passed through a 2mm sieve.

Plant sampling

Samples were taken at 25-30 DAT and at harvesting. Plant phosphorus uptake (PPU) was measured in all treatments at two those stages in order to test for any correlations between soil P indices and PPU. Crop phosphorus uptake was determined by Olsen method (Olsen et al. 1982) after Kjeldahl digestion (Varley 1966).

Soil P availability analyses

- Adams Extraction (Adams. 1974): Phosphorus was extracted by distilled water.
- Oniani Extraction (Vien Tho Nhuong Nong Hoa. 1998): Phosphorus was extracted by 0.1 N H_2SO_4.
- Nelson Extraction (Nelson et al. 1953): Phosphorus was extracted by 0.05 N HCl and 0.025 N H_2SO_4.
- Olsen Extraction (Olsen et al. 1982): Phosphorus was extracted by 0.5 M $NaHCO_3$ at pH 8.5.
- Bray 1 Extraction (Bray and Kurtz 1945): Phosphorus was extracted by 0.025 N HCl and 0.03 N NH_4F.
- Bray 2 Extraction (Bray and Kurtz 1945): Phophorus was extracted by 0.1 N HCl and 0.03 N NH_4F.

Statistical analysis

Simple correlation coefficients among soil P availability indices were determined for the 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS. Soil P availability indices were compared to crop measurements of the all treatments for each crop. Statistical relationships between factors were determined to identify the one or more analyses that best predict (s) crop performance and soil P availability through simple linear regression and multiple linear regressions, using the Statistical Analysis System.

RESULTS

Plant phosphorus uptake at 25 DAT

Plant phosphorus uptake (PPU) varied from 0.37- 0.47%, 0.33- 0.58%, 0.23- 0.39% and 0.16- 0.42% in 2001- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Plant phosphorus dried weight per 16 hills (PPDW) of all treatments varied from 0.23- 0.34 gram, 0.15- 0.31 gram, 0.20- 0.42 gram and 0.09- 0.31 gram in 2001- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively.

Coefficients of variation were generally higher for plant phosohorus dried weight than for PPU (data not shown). Plant phosphorus dried weight and PPU of treatments were not significantly different in all cropping seasons except in 2001 WS.

Plant phosphorus uptake at harvesting

Plant phosphorus uptake varied from 0.12- 0.15%, 0.22- 0.37%, 0.11- 0.29% and 0.10- 0.16% in 2001- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively.

Plant phosphorus dried weight per 16 hills (PPDW) of all treatments varied from 0.24- 0.44 gram, 0.42- 1 gram, 0.20- 0.80 gram and 0.17- 0.44 gram in 2001- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively.

Coefficients of variation were generally higher for plant phophorus dried weight than for PPU (data not shown). Plant phosphorus dried weight and PPU of treatments were not different significantly in all cropping seasons except PPU in 2001 WS.

Grain phosphorus uptake at harvesting

Grain phosphorus uptake (GPU) varied from 0.16- 0.29%, 0.33- 0.54%, 0.17- 0.400.17- 0.40% and 0.17- 0.24 in 2001- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively.

Grain phosphorus dried weight per 16 hills (GPDW) of all treatments varied from 0.36- 0.71 gram, 0.47- 0.82 gram, 0.70- 1.55 gram and 0.24- 0.47 gram in 2001- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively.

Coefficients of variation were generally higher for GPDW than for GPU except GPU in 2001- 2002 DS (data not shown). Grain phosphorus dried weight and PPU of treatments were not different significantly in all cropping seasons.

Soil P availability indices at before transplanting

Olsen extraction: Soil phosphorus extracted by this analysis varied from 1.79- 9.74 mg/kg soil, 2.5- 16 mg/kg soil, 11.8- 34.5 mg/kg soil and 1.61- 9.18 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were not significantly different in all cropping seasons, except 2001 WS.

Nelson extraction: Soil phosphorus extracted by this analysis varied from 29- 47 mg/kg soil, 39- 79 mg/kg soil, 50- 90 mg/kg soil and 2.5- 22.7 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were not significantly different in all cropping seasons.

Oniani extraction: Soil phosphorus extracted by this analysis varied from 32- 86 mg/kg soil, 36- 76 mg/kg soil, 63- 94 mg/kg soil and 2.5- 23.5 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were not significantly different in all cropping seasons.

Bray 2 extraction: Soil phosphorus extracted by this analysis varied from 6.2- 14 mg/kg soil, 5- 18 mg/kg soil, 2.9- 18 mg/kg soil and 0.34- 4.13 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were not significantly different in 2000- 2001 DS and 2002 WS, but significantly different in 2001 WS and 2001- 2002 DS.

Bray 1 extraction: Soil phosphorus extracted by this analysis varied from 0.6- 2.2 mg/kg soil in 2001 WS. Soil P availability of all treatments was significantly different. Soil phosphorus extracted by this analysis varied from 0.39- 4.59 mg/kg soil in 2002 WS and soil P availability of all treatments were not significantly different.

Adams extraction: Soil phosphorus extracted by this analysis varied from –7.59- 0.81 mg/kg soil in 2002 WS and soil P availability of all treatments were not significantly different. Soil P availability was not extracted by this analysis in 2000- 2001 DS, 2001 WS and 2001- 2002 DS.

Generally, Olsen Bray 1 and Bray 2 varied more than Nelson and Oniani among all treatments in all cropping seasons (data not shown).

Soil P availability indices at 25- 30 DAT

Olsen extraction: Soil phosphorus extracted by this analysis varied from 0- 191 mg/kg soil, 13.5- 27.5 mg/kg soil, 5- 44 mg/kg soil and 0.5- 3.2 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were significantly different in 2001 WS and 2002 DS, but in 2001 DS and 2002 WS they wre not different significantly.

Nelson extraction: Soil phosphorus extracted by this analysis varied from 414- 1451 mg/kg soil, 38- 91 mg/kg soil, 5.8- 60 mg/kg soil and 5.6- 31.4 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were different significantly in 2001 WS and 2001- 2002 DS, but in 2000- 2001 DS and 2002 WS they wre not different significantly.

Oniani extraction: Soil phosphorus extracted by this analysis varied from 430- 1403 mg/kg soil, 62- 93 mg/kg soil, 14- 75 mg/kg soil and 8.3- 32.9 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were different significantly in all cropping seasons except in 2001 WS.

Bray 2 extraction: Soil phosphorus extracted by this analysis varied from 106- 47.4 mg/kg soil, 10- 23 mg/kg soil, 5.1- 25 mg/kg soil and 0.11- 6.32 mg/kg soil in 2000- 2001 DS, 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were different significantly in all cropping seasons except in 2002 WS.

Bray 1 extraction: Soil phosphorus extracted by this analysis varied from 1- 49 mg/kg soil, 1.5- 7.2 mg/kg soil and 0.11- 0.92 mg/kg soil in 2001 WS, 2001- 2002 DS and 2002 WS, respectively. Soil P availability of all treatments were different significantly in all cropping seasons.

Adams extraction: Soil phosphorus extracted by this analysis varied from –0.16- 0.93 mg/kg soil in 2002 WS. Soil P availability of all treatments were not different significantly.

Soil P availability was not extracted by this analysis in 2001 DS, 2001 WS and 2002 DS.

Generally, Olsen varied more than the other among all treatments in all cropping seasons (data not shown).

Correlations among soil P availability indices

2001 DS

To determine whether related analyses provided comparable results and to identify the degree of cross-correlation for each parameter to be regressed against crop parameters, simple correlation coefficients were computed among all soil availability indices for all cropping seasons. Parameters that correlated to three parameters were Olsen, Nelson, Oniani and Bray 2 at BT and at 25- 30 DAT. Here we only show the representative data for correlations among soil P availability indices (Table 1).

Table 1: Simple correlation coefficients among soil P availability indices for all treatments at before transplanting, 2001 DS.

	Olsen	Nelson	Oniani	Bray 2
Olsen	1			
Nelson	0.68**	1		
Oniani	0.79**	0.83**	1	
Bray 2	0.81**	0.74**	0.83**	1

** Significant at P< 0.01

2001 WS

Parameters that correlated to at least three of the other four parameters were Olsen, Nelson, Oniani and Bray 2 at BT and at 25- 30 DAT. Parameter that was correlated fewer was Bray 1 at transplanting. Here we only show the representative data for correlations among soil P availability indices (Table 2).

Table 2: Simple correlation coefficients among soil P availability indices for all treatments at before transplanting, 2001 WS.

	Olsen	Nelson	Oniani	Bray 2	Bray 1
Olsen	1				
Nelson	0.85**	1			
Oniani	0.73**	0.83**	1		
Bray 2	0.93**	0.89**	0.70**	1	
Bray 1	0.62**	0.45^{ns}	0.40^{ns}	0.53*	1

** significant at P< 0.01; * significant at P< 0.05; ns: not significant.

2002 DS

Parameters that correlated to at least three of the other three parameters at BT and with at least four of the other four parameters at 25 DAT were Olsen, Nelson, Oniani, Bray 2 and Bray 1 at 25 DAT. Here we only show the representative data for correlations among soil P availability indices (Table 3).

Table 3: Simple correlation coefficients among soil P availability indices for all treatments at 25 DAT, 2002 DS.

	Olsen	Nelson	Oniani	Bray 2	Bray 1
Olsen	1				
Nelson	0.91**	1			
Oniani	0.78**	0.87**	1		
Bray 2	0.91**	0.93**	0.90**	1	
Bray 1	0.97**	0.86**	0.78**	0.91**	1

** Significant at $P < 0.01$

2002 WS

Parameters that correlated to at least two of the other five parameters at BT were Olsen, Nelson and Oniani. Parameters that correlated to at least three of the other five parameters at 25 DAT were Olsen, Nelson, Oniani, Bray 2 and Bray 1. Here we only show the representative data for correlations among soil P availability indices (Table 4).

Table 4: Simple correlation coefficients among soil P availability indices for all treatments at 25 DAT, 2002 WS.

	Olsen	Nelson	Oniani	Bray 2	Bray 1	Adams
Olsen	1					
Nelson	0.73**	1				
Oniani	0.49*	0.71**	1			
Bray 2	0.32^{ns}	0.69**	0.62*	1		
Bray 1	0.70**	0.82**	0.60*	0.59*	1	
Adams	0.18^{ns}	0.00^{ns}	-0.07^{ns}	0.00^{ns}	0.04^{ns}	1

** significant at $P < 0.01$; * significant at $P < 0.05$; ns: not significant.

Generally, parameters had positive correlations with other parameters in all cropping seasons.

Simple correlation between plant phosphorus uptake and soil P availability indices

2001 DS

All soil phosphorus availability indices at BT and 25 DAT had simple correlation with PPU at 25 DAT and at harvesting and were weak. Of all phosphorus availability indices, only Olsen at BT was the highest correlated with PPU at harvesting but their correlation was only at $R^2 = 0.19$.

2001 WS

All soil phosphorus availability indices at BT and at 25 DAT had simple correlation with PPU at 25 DAT and at harvesting and were not clear. The correlations between PPU at 25 DAT and phosphorus availability indices at 25 DAT varied from $R^2 = 0.11$- 0.48 (Table 5).

Table 5: Simple correlation between plant phosphorus uptake at 25 DAT and soil P availability indices at 25 DAT.

P index	**PPU**	**PPDW**
Olsen	$R^2 = 0.30$	$R^2 = 0.44$
Nelson	$R^2 = 0.48$	$R^2 = 0.45$
Oniani	$R^2 = 0.34$	$R^2 = 0.34$
Bray 1	$R^2 = 0.20$	$R^2 = 0.11$
Bray 2	$R^2 = 0.29$	$R^2 = 0.29$

2002 DS

All soil phosphorus availability indices at BT and at 25 DAT had simple correlation with PPU at 25 DAT and harvesting and were not clearly. Of all phosphorus availability indices, only Bray 1 at 25 DAT was the highest correlated with PPU at 25 DAT but their correlation was only at R^2= 0.11 (Table not shown).

2002 WS

All soil phosphorus availability indices at BT and at 25 DAT had simple correlation with PPU at 25 DAT and at harvesting and were not clear. The correlations between GPU at harvesting and phosphorus availability indices at 25 DAT varied with R^2= -0.07- 0.42 (Table 6).

Table 6: Simple correlation between grain phosphorus uptake at harvesting and soil P availability indices at 25 DAT.

P index	GPU
Olsen	R^2= 0.21
Nelson	R^2= 0.25
Oniani	R^2= 0.23
Bray 2	R^2= 0.20
Bray 1	R^2= 0.42
Adams	R^2= -0.07

Multiple regression analysis between plant phosphorus uptake and soil P availability indices.

Due to the poor simple correlations between soil P availability indices with crop data, stepwise multiple linear regressions was attempted between PPU, GPU, PPDW or GPDW with soil P availability indices.

2001 DS

In multiple regression analysis, the best fitting equation for PPU at 25 DAT in soil P availability indices was:

PPU= 0.402** - 0.003* $Nelson_1$ R^2= 0.39

Where * represent significance of the parameter coefficient at P< 0.05, ** represent significance of the parameter coefficient at P< 0.01 and $Nelson_1$ is P availability that is extracted by 0.05 N HCl and 0.025 N H_2SO_4 at before transplanting.

2001 WS

In multiple regression analysis, the best fitting equation for plant P uptake at harvesting was:

PPU= 0.409** - 0.009*$Bray2_1$ R^2= 0.42

The best fitting equation for plant P uptake at 25 DAT in soil P availability indices was:

GPDW= 0.452** - 0.008**$Bray2_2$ R^2= 0.42

Where * represent significance of the parameter coefficient at P< 0.05, ** represent significance of the parameter coefficient at P< 0.01, $Bray2_1$ and $Bray2_2$ are P availability that are extracted by 0.1 N HCl and 0.03 N NH_4F at BT and at 25 - 30 DAT, respectively.

2002 DS

In multiple regression analysis, the best fitting equation for plant P uptake at 25 DAT was:

GPDW= 0.666** - 0.045* $Olsen_2$ + 0.395* $Bray1_2$ R^2= 0.42

where * represent significance of the parameter coefficient at P< 0.05, ** represent significance of the parameter coefficient at P< 0.01, $Olsen_2$ and $Bray1_2$ are P availability that are extracted by 0.5 M $NaHCO_3$ at pH 8.5 at 25- 30 DAT and 0.025 N HCl and 0.03 N NH_4F at 25- 30 DAT, respectively.

2002 WS

In multiple regression analysis, the best fitting equation for plant P uptake as total of GPDW and PPDW at harvesting was:

GPDW + PPDW= 1.097** + 0.011^{ns} $Oniani_2$ + 0.083* $Bray2_2$ - 0.692* $Bray1_2$
R^2= 0.58

or:

PPDW= 0.223** + 0.030** $Bray2_2$ - 0.096^{ns} $Bray1_2$ R^2= 0.53

and:

GPU= 0.226** - 0.055** $Bray1_2$ R^2= 0.45

Where * represent significance of the parameter coefficient at P< 0.05, ** represent significance of the parameter coefficient at P< 0.01, ns is not significant, $Oniani_2$, $Bray2_2$, $Bray1_2$ are P availability that are extracted by 0.1 N H_2SO_4, 0.1 N HCl and 0.03 N NH_4F and 0.025 N HCl and 0.03 N NH_4F at 25- 30 DAT, respectively.

Correlations between seasons for plant phosphorus uptake and soil P availability indices

To evaluate the reproducibility of plant and soil measurements, correlations between seasons were computed for PPU, GPU, PPDW, GPDW and soil P availability indices.

Plant phosphorus uptake: Correlations between seasons for plant phosphorus uptake of individual treatments were significant and varied from 0.51*- 0.58* at the following in 2001 DS *vs* 2002 WS for only GPDW, 2000/2001 DS vs 2001/2002 DS for PPDW at harvesting and 2002 DS *vs* 2002 WS for only PPU at 25 DAT.

Soil P availability indices: Correlations between 2001 WS and 2001 DS, 2001 WS and 2002 DS for soil P availability indices were significant at before transplanting and at 25 DAT. Correlations between 2002 DS and 2002 WS for soil P availability indices were significant at 25 DAT (Table 7). Table 10 also showed that correlations between 2001 DS and 2002 DS for soil P availability indices that were significant at 25 DAT were Nelson, Oniani and Bray 2.

Generally, correlations between seasons for soil P availability indices varied from high to low at before transplanting in the following tests Olsen, Oniani, Nelson and Bray 2. At 25 DAT correlations between seasons for soil P availability indices varied from high to low in the following tests Oniani, Nelson, Bray 2, Olsen and Bray 1.

Table 7: Correlation coefficients between seasons and soil P availability indices at before transplanting and at 25 DAT.

	01 DS vs 01 WS	01 DS vs 02 DS	01 DS vs 02 WS	01 WS vs 02 DS	01 WS vs 02 WS	02 DS vs 02 WS
Olsen	0.52*[a] 0.56*[b]	0.40ns 0.38ns	0.42ns 0.04ns	0.81** 0.77**	-0.03ns 0.38ns	-0.11ns 0.54*
Nelson	0.47ns 0.53*	0.35ns 0.70**	0.41ns 0.30ns	0.63** 0.63**	0.14ns 0.36ns	0.01ns 0.56*
Oniani	0.51* 0.54*	0.41ns 0.79**	0.14ns 0.64**	0.63** 0.58*	0.43ns 0.38ns	0.01ns 0.78**
Bray 2	0.52* 0.85**	0.00ns 0.81**	0.25ns 0.37ns	0.29ns 0.73**	-0.20ns 0.29ns	-0.37ns 0.59*
Bray 1	- -	- -	- -	- 0.66**	-0.18ns 0.58*	- 0.75**

[a] At before transplanting ; [b] At 25 days after transplanting.
** significant at P< 0.01; * significant at P< 0.05; ns: not significant

Correlations between two sampling times for parameters were only significant in the 2001 WS and 2002 DS (Table 8).

Table 8: Correlation coefficients between two sampling times and soil P availability indices.

	2001 DS[a] vs 2001 DS[b]	2001 WS[a] vs 2001 WS[b]	2002 DS[a] vs 2002 DS[b]	2002 WS[a] vs 2002 WS[b]
Olsen	0.18	0.96**	0.62*	-0.01
Nelson	0.32	0.94**	0.67*	0.19
Oniani	0.12	0.79**	0.74**	0.16
Bray 2	0.18	0.97**	0.38	-0.10
Bray 1	-	0.54*	-	0.16

[a] Early sampling (at befpore transplanting); [b] Later sampling (at 25 days after transplanting).

DISCUSSION

The quantities of applied fertilizer P can be based on the greatest P use efficiency that is achieved by the available phosphorus in soil. In lowland rice of the Mekong delta, phosphorus plays a very important role to increases rice yield, particularly in wet season. The need for simple laboratory tests that satisfactorily estimate the available P in lowland rice then becomes eviden.

Methods to evaluate phosphorus available in soild and plant under lowland rice, with submerged soils are reviewed by Chang (1978). In pot experiments, all soil P availability indices only by Olsen extraction gave high correlation (0.76). However, in field experiments none of eight extractions used such as Spurway, Truog, Bray 1, Bray 2, Dyer, McGeorge, Morgan and Olsen, gave good correlation between available soil P and rice response to phosphorus. Recently, Indian workers confirmed good correlation of Olsen extraction. Goswami et al. (1971) found that the Olsen extraction was satisfactory in correlating soil phosphorus with rice response, based on 489 trials representing diverse soil and climatic conditions. Nambiar et al. (1973) also found available soil phosphorus extracted by Olsen that correlated highly with rice response to phosphorus in pot experiments, but not in field experiments. It is generally accepted that plant analyses for phosphorus was less reliable.

Chang (1978) reported a low correlation between available soil P and rice yield in the field experiment with eight soil types. However, in the green house of all phosphorus availability indices, only Olsen more correlated with rice yield than the others did. Dabin (1980) found that with rice grown in pots with soils dominated by Fe-P, alkaline extractants gave the best correlation with crop response to P fertilizer.

The treatments of above studies were likely to result in strong relationship because they studied certainly more prearranged treatment differences in growing conditions than here.

The results in this study do not promote use of any soil P availability indices for quantitative predictions of soil available P quantity. First, the correlations of the simple regressions that were not consistenly strong varied from 0.11-0.19 in DS and 0.42-0.48 in WS.

The correlations between soil P availability indices with crop data in DS is low that can be explained by previously published studies. Tan et al. (1995) reported in long-term experiment, phosphorus played a main role that affected to rice yield and rice yield components, particularly in the wet seasons, mean WS yields of plots with P were 72% more than corresponding plots without P, but in DS the improvement due to P averaged only 16%. The greater DS yields may be partly due to improved soil conditions. Mean pH increased from 5.2 in 1986 DS to 5.7 in 1993 DS. This change may be due to tillage and puddling following submergence for 2 to 3 months.

As compared to the DS, soil P availability indices should be more tightly correlated with PPU measurements in the WS but their correlations here were not enough strong for recommendation. This problem may be due to residual P fertilizer was released by the accumulated fertilizer residues in previously crops. Palmer et al (1990) found in Indonesia P deficiency is decreased in lowland rice due to the results of accumulated fertilizer residues. Fertilizer P recovery by rice ranges from 8-20% and 80–90% of applied P remaining in the soil for the succeeding crops (De Datta et al 1966; Goswami and Banerjee 1978).

Lin et al (1973) analyzed P content of soil samples was applied in 48 consecutive years and found that 58% of the applied phosphorus was retained in the surface soil and subsoil. The results of accumulated P fertilizer residues throught 4 previously crops can affect to rice yield after the third crop onwards. Diep et al (1992) the higher the rate of P application, the longer the residual effect on rice would be. Xuan et al (1992) confirmed this observation.

A second obstacle to on- farm use of the studied soil P availability indices was raised by the finding in that according to the best-fitting multiple regression equations, multiple soil parameters would have to be performed in order to accurately predict soil P availability. The best-fitting multiple regression equations for all four cropping seasons predicted at most half of the variation in crop measurements. Ideal would have been the identification of one parameter that had a simple correlation with plant P uptake of at least 0.8-0.9 and in all cropping periods.

A third problem in transferring these results to on-farm use is that the correlations between seasons for crop measurements were not high except GPDW in 2002 WS *vs* 2001 DS, PPDW at harvesting in 2002 DS vs 2001 DS and PPU at 25 DAT in 2002 WS vs 2002 DS. But they varied only from 0.51*- 0.58*.

It addressed no correlation of each crop measurement between seasons, whether for wet seasons or for all soil parameters of two sampling times in DS and WS, and among seasons. The concept of this study presumed the quantities of applied phosphorus, which could be based on the correlations between available soil P and response of rice to phosphorus. While correlations between seasons of two sampling times (at before transplanting and at 25 DAT) and among seasons between two sampling times for soil P availability indices were noticed in 2001 WS and 2001 DS. Under field conditions, P availability changed throughout the cropping period. In this case, stronger correlations of soil P availability indices with the PPU might be possible if the optimal sampling time was identified.

If the results in dry seasons are deleted, then significant relationship will be found in WS, which became more noteworthy, such as the significance of the Nelson, Olsen and Bray 1.

Overall, the best predicting P availability index in this study was solution of strong acid containing complexing radicals for Fe and Al (Bray 1 and Bray 2). They appeared in eight of the seven multiple regression equation for crop measurements (four for the Bray 2 and four for the Bray 1). In all seven equations, they were significantly correlated with the primary contributors.

Although quantitative estimation of the crop measurements might not be possible with any single analysis, the results of this study still appear to have on-farm applicability. Multiple regression equations involving Bray 1 and Bray 2 supported prediction of 45% or more 50% of crop measurements. Such a semi-quantitative estimate of P availability should suffice for supporting reasonably efficient fertilizer application: a field manager possesses some flexibility in applying P fertilizer. Regular crop monitoring will allow adjustment of fertilizer applications in case of soil P availability estimate is slightly inaccurate. Because soil P availabilty is though to change slowly, it need not to be measured in every cropping period, particularly in wet season, and hence measurement of multiple parameters as dictated by multiple regression equations may be economical.

The primary objectives of this study addressed correlations with crop parameters, but the results also provided insights into behavior of the tested soil P availability indices. Almost the tested soil P availability indices such as strong acid solutions, alkaline solutions and solution of strong acid containing complexing radicals for Fe and Al tended to be significantly correlated with each other as well as with another parameters. The Nelson, Oniani and Olsen tended to less (or more) correlate slightly to another than Bray 1 and Bray 2. The Adams showed the poorest correlation to another.

Phosphorus was applied in two times in order to limit the fixation of applied fertilizer P. Lower yield response to P applied at 7 days after transplanting than from basal application in Vertisol in India (Kytyal 1978, and Patrick et al. 1974).

Patrick et al (1974) also showed that rice yield reduced its response to P applied at 2, 4 and 6 weeks after transplanting. Split P application has not been effective because of high mobility of P from old to young leaves, increased availability of soil P with time during submergence, and low leaching losses (De Datta 1981). Early phosphate application benefits rice yields, with basal application giving a better yield response than split applications (Chang 1978).

In Mekong Delta of Vietnam, experiment on P application methods for rice from 1983 to 1987 showed that P applied at 15-30 days after transplanting it is leading to decrease rice yield from 6 to 15% (Tan et al. 1991).

Following formal studies and this, we can explain why no significant differences among applied P treatments of plant P uptake in almost cropping seasons.

Optimal timing and rates of applied P to irrigated rice could be based on accurate estimates of soil P availability. Hence, the primary objective of this study was to identify simple laboratory tests that reasonably approximate soil P availability in the field when plant P uptake was defined. In general, the results of this study do not support on-farm application of any single laboratory analysis to predict soil P availability. No soil measurement was significantly correlated to crop measurements in all four cropping periods. Stepwise multiple linear regression analysis identified better predictions of crop P uptake that included some soil P availability indices. However, the multiple regression equations were either weak or they contained several parameters. The Bray1 and Bray2 indices appeared in four and four respectively of the seven multiple regression equations for all four cropping periods. These indices also had high number of significant correlations with all indices in all four growing cycles. It suggested their relationship to plant P uptake could be causal in nature. Nevertheless, the results of this study suggest that soil P was extracted by 0.025 N HCl. Then 0.03 N NH_4F solution can be used to provide semi-quantitative estimates of P availability under irrigated rice field condition in Omon area.

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SUMMARY IN VIETNAMESE

Mối quan hệ giữa hàm lượng lân hấp thu trong cây lúa và lượng lân dễ tiêu trong đất lúa tưới bằng các phương pháp phân tích lân dễ tiêu

Trong điều kiện lúa có nước tưới, hiệu quả phân lân có thể được nâng lên nếu như lượng lân khuyến cáo được tính toán dựa vào lượng lân dễ tiêu trong đất. Các chỉ tiêu lân dễ tiêu của đất đều không có mối tương quan đủ với hàm lượng lân hấp thu của cây qua cả 4 vụ lúa trong cả phương trình hồi quy đơn tuyến hay đa tuyến, ngoại trừ mối tương quan ở mức trung bình giữa PPU và P dễ tiêu được trích từ phương pháp Nelson ở vụ hè thu 2001 và giữa GPU với P dễ tiêu được trích từ phương pháp Bray 1 trong vụ hè thu 2002. Công thức thích hợp nhất thông qua phương trình đa tuyến cho kết quả đạt được là 39, 42, 42 và 58% lần lượt cho cả 4 vụ. Phương pháp xử lý bằng hỗn hợp dung dịch HCl và NH_4F ở 2 nồng độ khác nhau cho kết quả đáng tin cậy hơn các phương pháp khác.