EXTERNAL PHOSPHORUS REQUIREMENT OF SOME PHILIPPINE LOWLAND RICE SOILS

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ABSTRACT

Experiments were conducted to determine the external P requirements of lowland rice using five P-deficient Philippine soils belonging to different textural classes. Of the five soils, Quingua soil did not respond to added P, probably because of the comparatively high available P. Observed data indicated that the external P requirement of the soils was 0.07 ppm for maximum tillering and, 0.08 — 0.10 ppm P for shoot dry matter production at flowering and for grain production. Based on relative yield curves, external P requirement under pot culture for 95% of the maximum shoot dry matter yield at flowering and maximum grain yield were 0.071 and 0.064 ppm P respectively.

KEY WORDS : External P requirement, Lowland rice

INTRODUCTION

Phosphorus is one of the major nutrient elements required by the rice plant and it is involved in the supply and energy transfer needed for biochemical processes. The effects of phosphorus on plant growth are stimulation of root development, early flowering and ripening, encouragement of active tillering and promotion of good grain development and quality (De Datta, 1981).

Phosphorus deficiency is an important nutritional problem in tropical soils. However, all soils in tropics are not phosphorus deficient and those that are deficient do not always require large amount of phosphorus fertilizer (Fox and Searle, 1978). There is an abundant evidence that soil solution is the immediate source of phosphorus for growing rice. It bears a close relationship to sorbed state and involves phosphorus desorption (Syers *et al.*, 1970).

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Phosphorus requirement of crops can be expressed in several ways. The internal phosphorus requirement may mean the minimum uptake of phosphorus associated with a specific yield. Due to its association near maximal growth, the internal phosphorus requirement is often referred to as the "critical concentration". In addition, the crops have also an external phosphorus requirement which is defined as the quantity of phosphorus that constitute the minimal pool for adequate crop nutrition, It is the concentration of phosphorus in soil solution associated with adequate nutrition, which is also referred to as intensity of nutrition.

The nutrient pool concept and its evaluation have been worked out by several researchers in the past. The "soil solution" concept has also been around for many years, even though only few investigations have been carried out. During the past decade efforts have been made to determine the external phosphorus requirement of cultivated crops. This paper reports on the external phosphorus requirement of some Philippine lowland rice soils.

MATERIALS AND METHODS

Soils

Five P deficient soils, Prensa (sandy loam), Quingua (silty loam), Pili (clay loam), Luisiana (silty clay) and Binangonan (clay) were used in the study (Table 1).

Greenhouse experiment

A pot experiment was carried out in the greenhouse of the Department of Agronomy, IRRI, Los Banos, Philippines, during the 1982 wet season in a randomized complete block design replicated three times. Ten kg oven-dried soil was transferred into pots and the soil solution P concentration was adjusted to a pre-determined level (Table 2), using phosphorus adsorption isotherm data. The phosphorus source used was $Ca(H_2PO_4)_2$. Rice cultivar, IR 36 which is susceptible to P deficiency, was used as the test crop. Seven-day old seedlings raised in P-free culture solution, were transplanted with 3 seedlings per pot. Fertilizer potassium (KCl) was added at the

Table 1. Physico-chemical characteristics of the experimental soils

Soil property	*Location*				
	Gen. Natividad (Nueva Ecija)	*Talavera (Nueva Ecija)*	*Bo. Pamukid (Bicol)*	*Lucban (Quezon)*	*Teresa (Rizal)*
pH	5.3	5.4	5.4	4.6	6.1
CEC (me/100g)	8	29	21	16	35
Total N (%)	0.06	0.12	0.14	0.17	0.12
Organic matter (%)	0.9	2.1	2.0	2.4	2.3
Total P (ppm)	93	406	276	577	236
Available P					
Bray—2	1.8	2.5	0.9	0.6	0.9
Olsen	2.9	7.3	4.9	5.0	2.6
Exchangeable cation (me/100g)					
K	0.03	0.14	0.09	0.13	0.50
Ca	3.14	17.6	10.7	3.42	25.9
Total Fe (%)	2.1	5.0	4.9	9.0	6.2
Total Mn (ppm)	297	840	1630	809	1310
Particle size analysis (%)					
Clay	11	34	40	44	56
Silt	24	54	37	47	39
Sand	65	12	23	9	5
Texture	Sandy Loam	Silty Loam	Clay Loam	Silty Clay	Clay
Soil series	Prensa	Quingua	Pili	Luisiana	Binangonan

Table 2. Details of the treatments tested — IRRI 1982, wet season

Treatment	*Soil solution P concentration (ppm)*				
	Prensa	*Quingua*	*Pili*	*Luisiana*	*Binangonan*
T_1	0.01 (3)	0.01 (6)	0.01 (10)	0.03 (73)	0.01 (40)
T_2	0.03 (9)	0.03 (38)	0.03 (40)	0.05 (145)	0.03 (65)
T_3	0.05 (15)	0.05 (68)	0.05 (123)	0.07 (359)	0.05 (95)
T_4	0.07 (29)	0.07 (90)	0.07 (175)	0.09 (452)	0.07 (115)
T_5	0.09 (42)	0.09 (102)	0.09 (205)	0.11 (523)	0.09 (130)
T_6	0.11 (51)	0.11 (114)	0.11 (232)	0.13 (545)	0.11 (140)
T_7	0.13 (54)	0.13 (130)	0.13 (252)	0.15 (572)	0.13 (150)
T_8 (control)*	0.007	0.007	0.003	0.01	0.01

*Soil solution P concentration in the unfertilized soil was monitored by the peizometers installed; Figure within brackets refers to the amount of P in ppm added to each treatment rate of 100 ppm K as basal application. Nitrogen (ammonium sulphate) was split applied at the rate of 50 ppm N as basal and 50 ppm N at 5—7 days before PI. Demineralized water was used throughout for irrigation.

Phosphorus treatments as shown in Table 2 were imposed as basal dressing. The lower soil solution P concentrations were obtained by extrapolating the curve to the soil solution P concentration of unfertilized soil.

Plant growth and tiller count were monitored at 10, 20, 30 days after planting, PI stage and at final harvest as described by Gomez (1972). One plant each, was sampled at maximum tillering and flowering stages to determine the shoot dry matter production and yield components at harvest. Correlation analysis was conducted on the above characteristics with soil solution P concentration.

RESULTS AND DISCUSSION

Soil characteristics

The physico-chemical properties of the five soils studied are given in Table 1. Most soils were acidic except Binangonan. They belong to five different textural classes ranging from sandy loam to clay. Their total P content vary, with the highest P content in Luisiana and the lowest in Prensa. The P availability indices do not indicate any relationship to total P. However, Olsen P indicated a higher value for Luisiana even though it was not proportionate to its total phosphorus content.

Plant growth

Test variety IR 36 with an average growth duration of 106 days matured in 98 days after germination with adequate P, probably due to high temperature inside the greenhouse. In all soils except Quingua, the control and 0.01 ppm P treatments showed P deficiency symptoms with erect dark green leaves after the PI stage. However, the above symptoms did not appear in treatments where tillering of rice was drastically reduced. Furthermore, the maturity was delayed by 10 days.

Tillering

Tiller number at PI stage indicated that the minimal soil solution P concentration for maximum tiller production is 0.07 ppm. Another feature observed was that in the control treatments (no P) the tiller number increased even after PI stage indicating that plant's vegetative growth was extended under phosphorus deficiency; consequently the maturity was also delayed.

Dry matter yield

The data indicated that the minimum soil solution P concentration for maximum dry matter production at maximum tillering was 0.07 ppm for Prensa and Luisiana, 0.05 ppm for Pili, and 0.03 ppm for Binangonan and Quingua soils (Fig. 1).

At flowering stage, which is the most critical stage for P nutrition of rice, regression analysis for soil solution P concentration gave a range of 0.08—0.10 ppm (Binangonan, 0.08; Prensa, Quingua and Pili, 0.09; and Luisiana, 0.10 ppm). The high P requirement of Luisiana soil could be attributed to iron toxicity (Roy, 1981).

When dry matter production (grain plus straw) at harvest was considered, maximum total dry matter yield occurred at 0.07 ppm P for Prensa, Quingua and Pili soils and 0.11 ppm P for Luisiana and Binangonan soils. In the Binangonan soil, plants in the two treatments, 0.07 and 0.09 ppm, were damaged by strong winds resulting in lower dry matter and grain yields than in the other treatments.

Composite dry matter yield response curve developed by plotting relative dry matter yield percentage against soil solution P concentration indicated that 95% of the shoot dry matter yield at flowering could be obtained at 0.071 ppm (Fig. 2). Yield data indicated that except in Binangonan soil, the minimum pool of soil solution P concentration for maximum grain yield was 0.07 ppm (Fig. 3).

Regression analysis of grain yield data (Fig. 4) indicated that the external P requirement to obtain maximum yields ranges from 0.08 to 0.10 ppm (Pili 0.080; Prensa and Binangonan 0.087; Luisiana

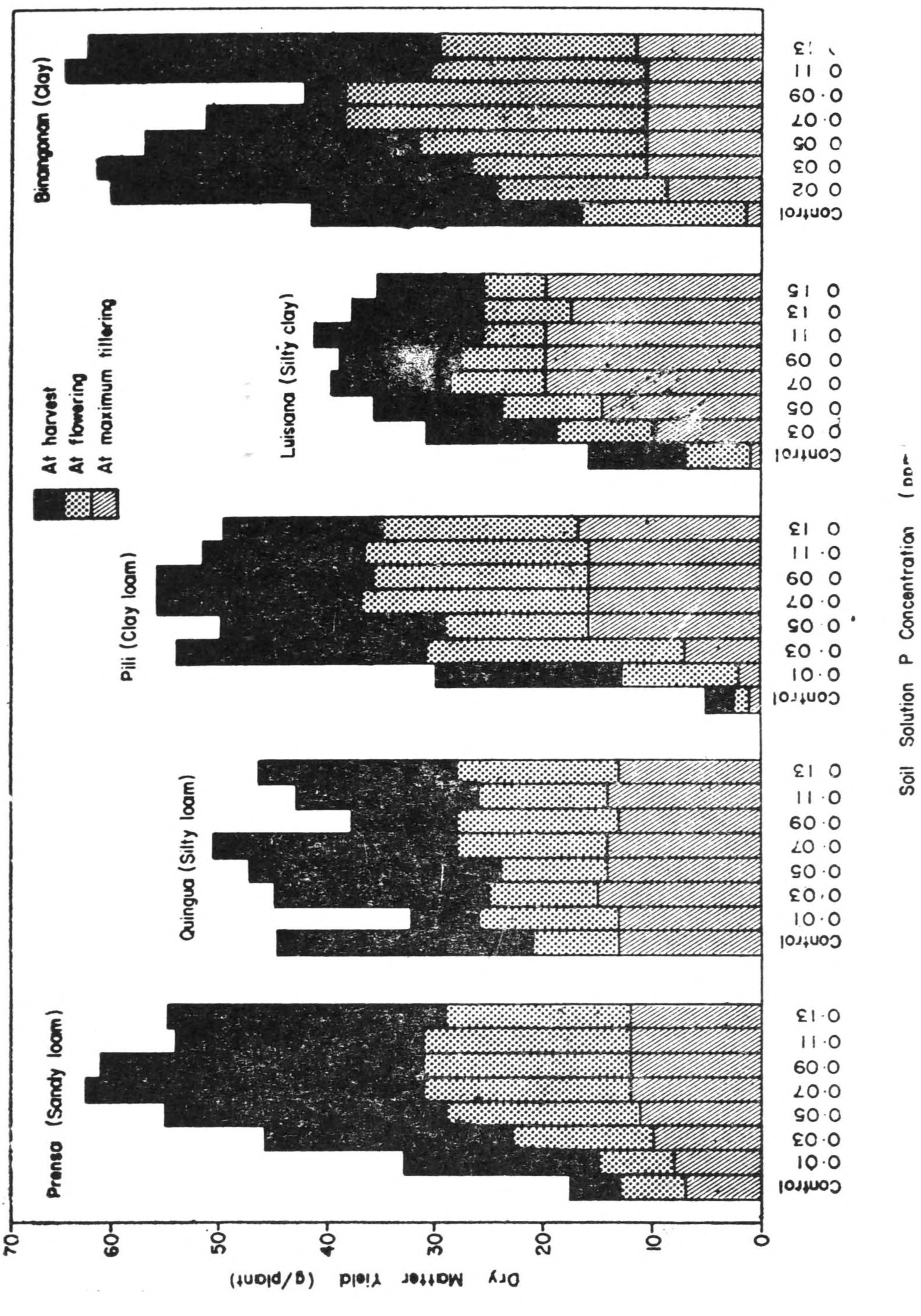

Fig. 1. Dry matter yield of IR 36 at maximum tillering, flowering and final harvest under varying soil solution P concentrations in the different soils – IRRI, 1982 wet season

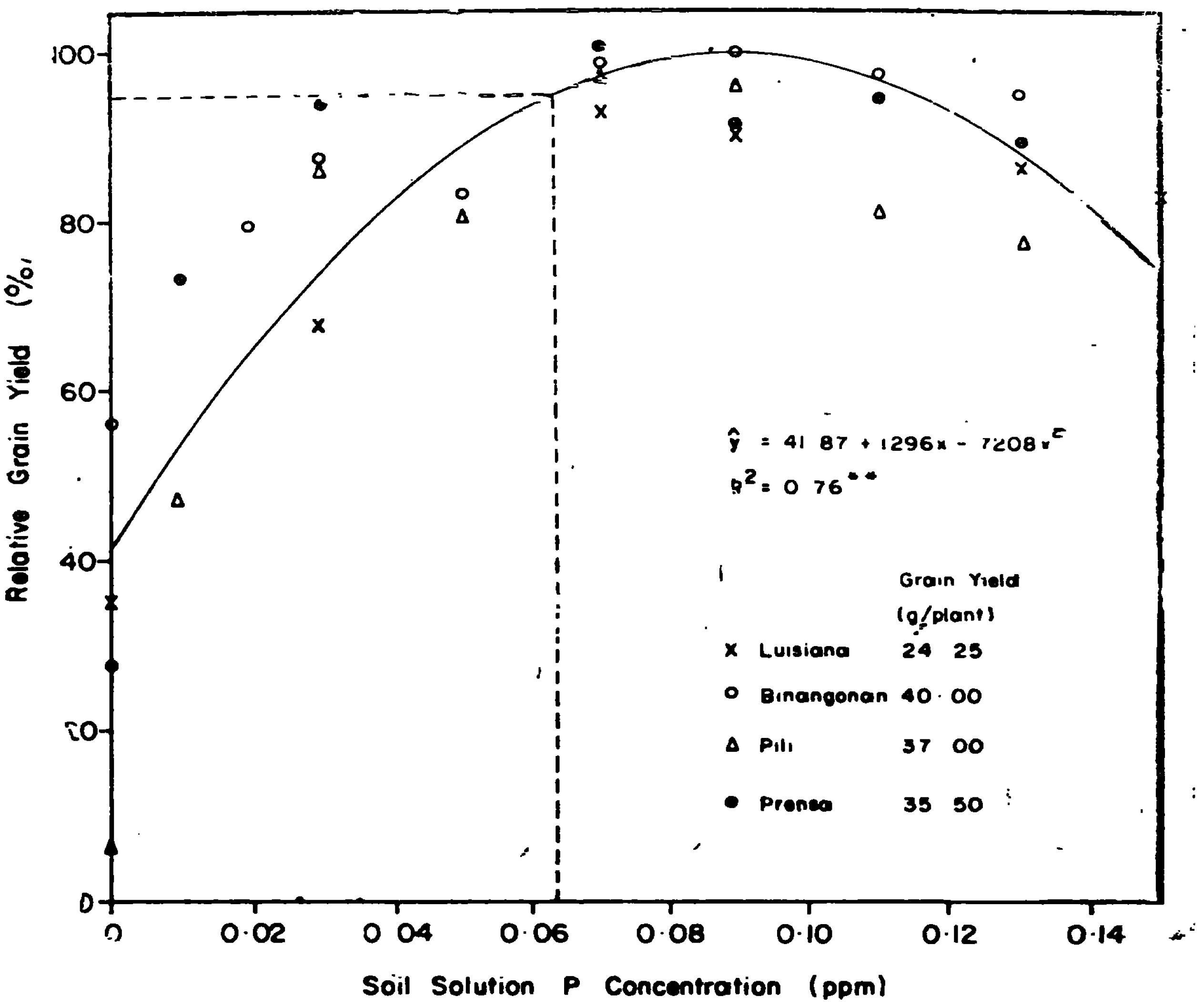

Fig. 2. Relationship between soil solution P concentration of 4 soils and relative dry matter yield - IRRI, 1982 wet season

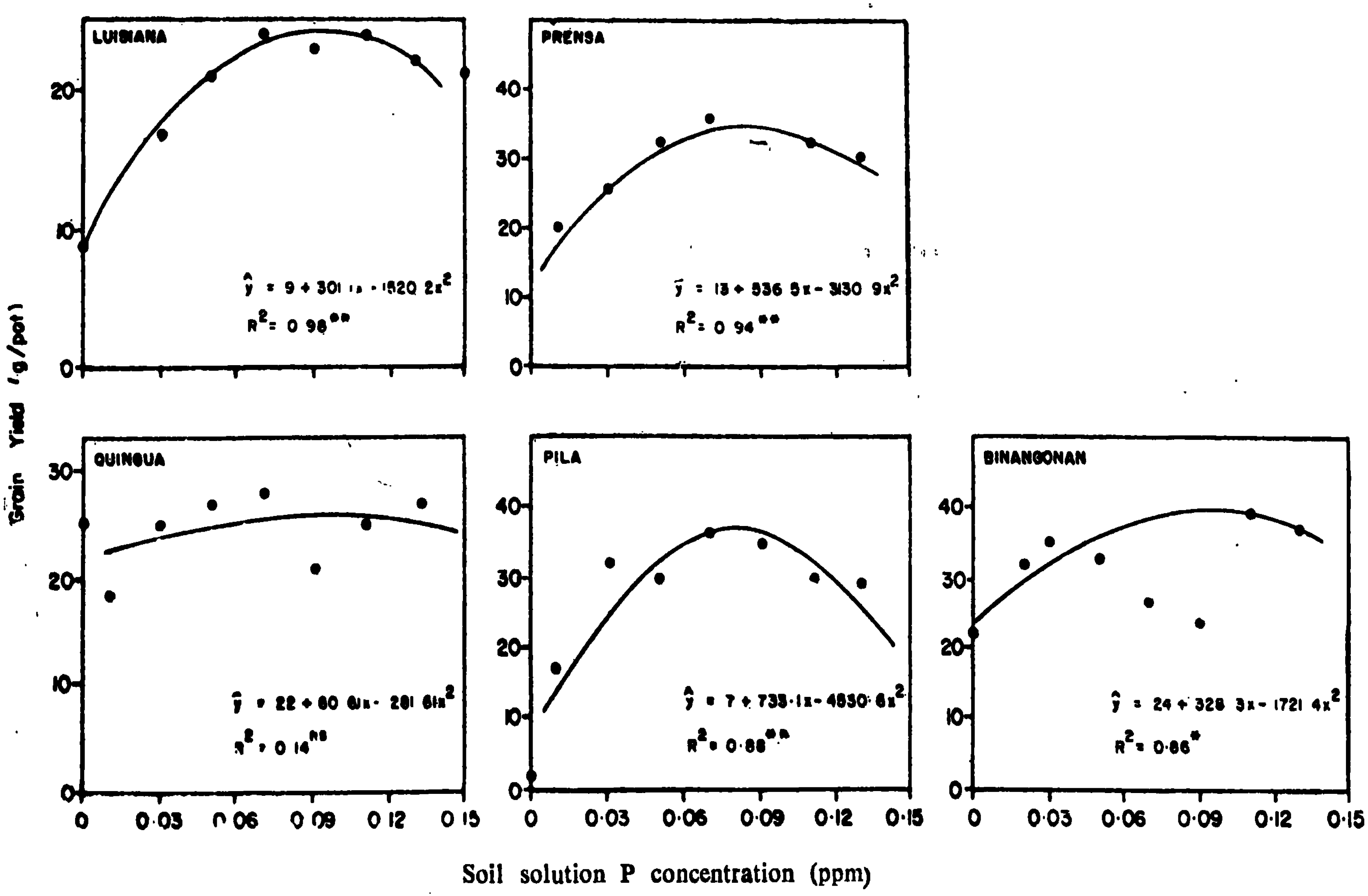

Fig. 3. Relationship between soil solution P concentration in different soils and grain yield of rice – IRRI, 1982 wet season. ns = not significant; * significant at 5% level; ** significant at 1% level

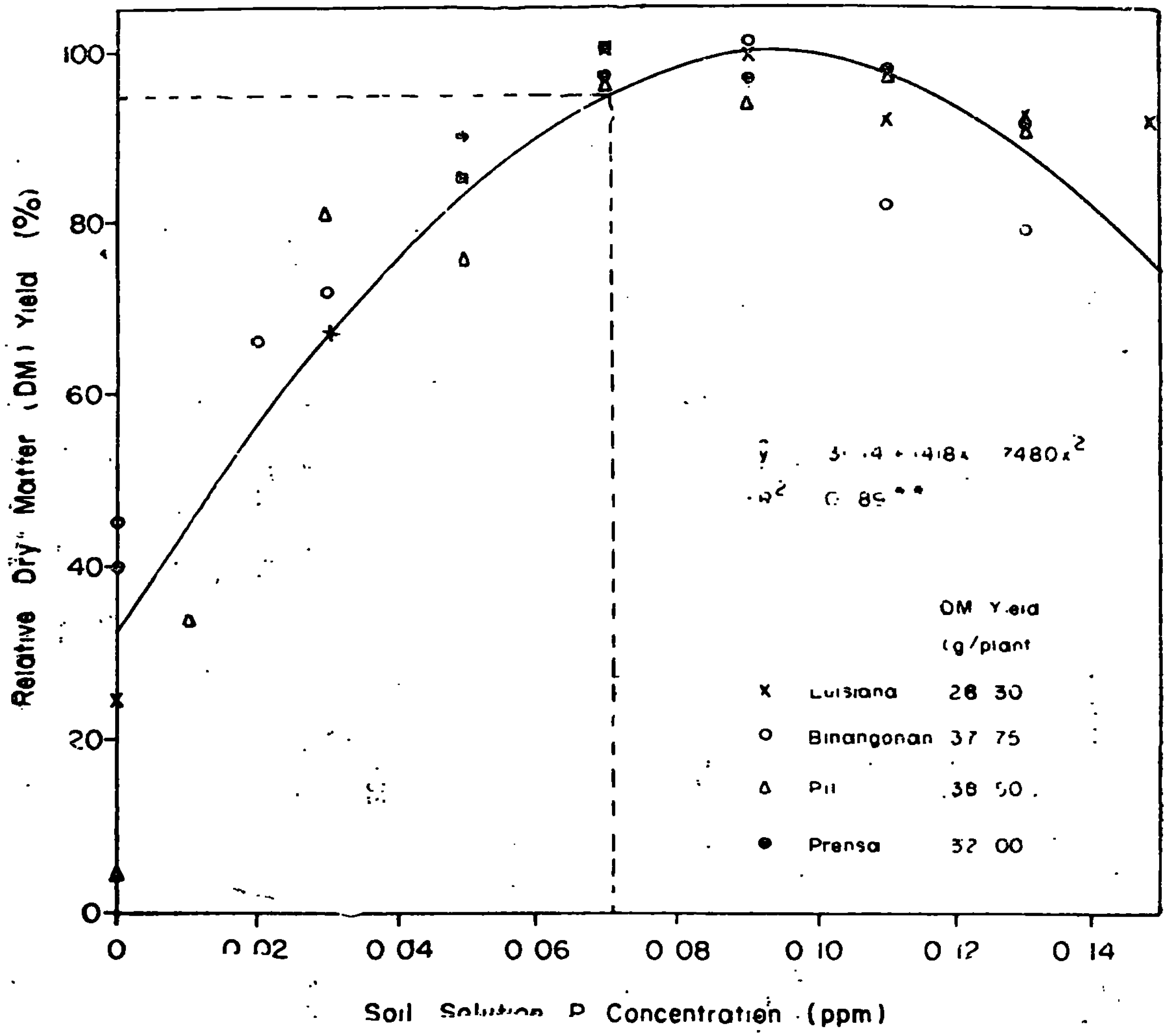

Fig. 4. Relationship between soil solution P concentration of 4 soils and relative grain yield — IRRI, 1982 wet season

0.099; and Quingua 0.100 ppm). Regression analysis was significant except for Quingua soil. The significant relationship could be attributed to the comparatively higher availability of native P which further increased with soil reduction. Furthermore, the higher P requirement for Luisiana soil could be attributed to the iron toxicity problem associated with this soil. Vander Zaag *et al.* (1979) working on potato (*Solanum tuberosum* L.) used data from several countries to plot composite yield response curve, where percentage relative yield was plotted against the soil solution P concentration. He concluded that 95% of the maximum yield of potato could be obtained at a soil solution P concentration of 0.2 ppm which he termed as the standard value for potato. Similar relationship was adopted for rice using 4 soils, since Quingua soil did not respond to added P (Fig. 4). The data indicated that 95% of the maximum yield of rice could be obtained at a soil solution P concentration of 0.064 ppm in these Philippine soils.

REFERENCES

De Datta, S. K. 1981. Principles and practices of rice production. John Wiley and Sons, New York, USA. 618 p.

Fox, R. L. and P. G. E. Searle. 1978. Phosphate adsorption by soils of the tropics. USA Special Publ. 34, Madison, Wisconsin, USA.

Gomez, K. A. 1972. Techniques for field experiments with rice. International Rice Research Institute, P. O. Box 933, Manila, Philippines.

Syers, J. K., J. T. Murdock and J. D. H. Williams, 1970. Adsorption and desorption of phosphate by soils. Comm. Soil Sci. Plant Anal. 1:57—61.

Roy, A. C. 1981. Phosphate sorption isotherms for evaluating phosphate requirements of submerged rice soils and rice yields in relation to sorbed phosphate and inorganic phosphate fraction under varied levels of residual phosphate. Terminal Report. International Rice Research Institute, P. O. Box 933, Manila, Philippines.

Vander Zaag *et al.* 1979. The utility of phosphate sorption curves for transferring soil management information. Trop. Agri. (Trinidad) 56: 150—160.