# RICE CULTIVARS RESPONSE TO PHOSPHORUS IN NUTRIENT SOLUTION[1]

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ABSTRACT - Due to widespread deficiency of phosphorus in acid soils in various parts of the world, germplasm screening for identification of less susceptible cultivars of crop plants has become as essential as recommendation of proper methods and levels of P fertilization. To study the relationship between differential susceptibility to P deficiency, four cultivars of rice (*Oryza sativa* L.) were grown in nutrient solution at 8.06, 32.25, 322.58 μM (0.25, 1 and 10 $\mu gP.ml^{-1}$) of applied P. After 54 days of growth in nutrient solution, dry matter yield of roots and shoots and P and K uptake were measured. Rice cultivars did not differ widely in dry matter production and P uptake. Among the growth parameters, shoot dry weight was the best parameter for classifying cultivars as to P efficiency. Based on this parameter, cultivars were classified for P efficiency in the order: IRAT 104 > Beira Campo > Bico Torto > Quatro Meses. Phosphorus uptake was increased with increasing concentrations of P in the growth medium. This study suggests that this methodology can be used for identification of P efficient rice cultivars.

Index terms. *Oryza sativa,* P uptake, P-efficient cultivar.

## RESPOSTA DAS CULTIVARES DE ARROZ AO FÓSFORO EM SOLUÇÃO NUTRITIVA

RESUMO - Devido à ampla deficiência de fósforo no solo ácido em várias partes do mundo, a identificação de cultivares menos susceptíveis é tão essencial quanto as recomendações de métodos e níveis de fertilizante P adequados. Para estudar a variabilidade das cultivares em relação à deficiência de P, quatro cultivares de arroz (*Oryza sativa* L.) foram cultivadas em solução nutritiva com a 8,06; 32; 25; 322; 58 μM (0,25, 1 e 10 μg P $ml^{-1}$) de P aplicado. Após 54 dias de crescimento em solução nutritiva, foram medidas a produção de matéria seca da parte aérea e raiz, e a absorção de P. As cultivares de arroz não diferem largamente na produção de matéria seca e absorção de P. Entre os parâmetros de crescimento, o peso de matéria seca da parte aérea foi o melhor parâmetro para classificação das cultivares quanto à eficiência do P. Com base neste parâmetro, as cultivares foram classificadas quanto à eficiência de P, na ordem: IRAT 104 > Beira Campo > Bico Torto > Quatro Meses. A absorção de P aumentou com o aumento de concentração de P no meio de crescimento. Este estudo sugere que esta metodologia pode ser usada para identificação das cultivares de arroz eficientes na absorção de P.

Termos para indexação: *Oryza sativa,* absorção de P, cultivar eficiente em P.

## INTRODUCTION

Meeting the future food needs of the world can be accomplished by increasing productivity in traditional areas and by occupation of new areas not yet cultivated. Tropical areas which cover over 3 billion hectares in various parts of the world, present both alternatives (Goedert et al. 1982). The tropical areas are mostly covered by rain forest and savanna vegetation. The predominant soils in these regions are Oxisols and Ultisols. These soils have good physical properties but are highly acid and very low in nutrients, especially phosphorus.

Moreover, appropriate levels, sources and methods of P fertilizations, and use of P efficient cultivars of important field crops can be a complimentary solutions for improvement of production in these soils. A considerable amount of genetic diversity is present in plants for the efficient and inefficient uptake and utilization of P (Baker et al. 1970, Baligar & Barber 1979, Fageria & Barbosa Filho 1981, Nielson & Barber 1978). The objective of this study was to determine rice cultivar response to P using a methodology of screening for P efficiency in nutrient solution.

## MATERIALS AND METHODS

An experiment was conducted in a greenhouse to study rice cultivar response to P in nutrient solution. The nutrient solution used was that developed by the International Rice Research Institute in the Philippines for rice (Yoshida et al. 1976). Its macronutrient composition in mM was: 2.85 N as $NH_4NO_3$; 1.03 K as $K_2SO_4$; 1 Ca as $CaCl_2$ and 1.64 Mg as $MgSO_4.7H_2O$. The micronutrients composition in μM was: 9.1 Mn as $MnCl_2.4H_2O$; 0.52 Mo as $(NH_4)_6Mo_7O_{24}.4H_2O$; 18.48 B as $H_3BO_3$; 0.15 Zn as $ZnSO_4.7H_2O$; 0.16 Cu as $CuSO_4.5H_2O$ and 36 Fe as FeEDTA. Phosphorus was supplied as $NaH_2PO_4$ in amounts required for P concentrations of 8.06, 32.25 and 322.58 μM as low, optimum, and high concentrations. The nutrient solutions were changed once a week. The pH of the solution was adjusted to 4 ± 0.2 initially and once every two days

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thereafter with .1 M NaOH or 1 M HCl. Maximum and minimum air temperature means during the experiment were 28 ± 2°C and 18 ± 2°C, respectively.

Seeds of 4 rice cultivars (IRAT 104, Quatro Meses, Beira Campo and Bico Torto) were germinated in nutrient solutions using four plastic pots of two - liter capacity. When seedlings attained and age of 14 days, four uniform seedlings were transplanted to acrylic discs with holes in the center. The seedlings were held in place with cotton. These discs were then transferred to plastic pots containing about eight liters of nutrient solution with different P treatments. Each pot had three discs with 12 plants. Each treatment was replicated four times.

After 54 days of growth in P treated solutions, plant tops and roots were harvested separately and washed in distilled water. The plant material was dried to a constant weight at about 80°C and dry matter was determined. Ground material was digested with a 2:1 mixture of nitric and perchloric acids. The P concentration in the digest was determined colorimetrically.

## RESULTS AND DISCUSSION

Results related to thew influence of different P concentrations on growth parameters of four rice cultivars are presented in Tables 1 and 2. There was a general tendency for the shoot-parameters (height, tiller number, dry weight) to be highest at the 32.25 µM P level although they were not significantly different from those at the 322.58 µM P level. Root length and dry weight of roots were higher at low concentrations of P and a minimum at the highest P concentration in all four cultivars. The reason for high growth of roots at low levels of P is that there is a close association between the translocation of P and that of photosynthate, the direction of movement being governed by the supply and

**TABLE 1. Influence of phosphorus on growth parameters of rice cultivars.**

| Cultivar | P levels µM | Plant height (cm) | Tiller number | Root length (cm) | Shoot dry wt. (g/12 plants) | Root dry wt. (g/12 plants) |
|---|---|---|---|---|---|---|
| | 8.06 | 69 b | 16.50 a | 38 a | 12.58 a | 5.12 a |
| IRAT | 32.25 | 72 a | 19.25 a | 38 a | 12.73 a | 3.00 b |
| | 322.58 | 82 a | 18.25 a | 35 b | 13.58 a | 3.20 b |
| | 8.06 | 78 b | 13.75 b | 37 a | 11.07 ab | 3.75 a |
| Quatro Meses | 32.05 | 87 a | 17.25 a | 36 a | 14.31 a | 3.20 ab |
| | 322.58 | 81 ab | 13.75 b | 36 a | 10.49 b | 2.73 b |
| | 8.06 | 85 b | 14.75 b | 39 a | 12.41 b | 5.05 a |
| Beira Campo | 32.25 | 89 a | 20.25 a | 38 ab | 13.77 a | 3.11 b |
| | 322.58 | 88 ab | 13.75 b | 37 b | 11.87 b | 3.15 c |
| | 8.06 | 80 b | 16.00 a | 36 a | 11.65 a | 4.26 a |
| Bico Torto | 32.25 | 87 a | 20.50 a | 36 a | 13.15 a | 3.22 b |
| | 322.58 | 84 ab | 15.75 a | 35 a | 11.35 a | 2.57 c |

For a given cultivar means within a column followed by the same letter are not significantly different at 0.05 level of probability using Duncan's Multiple Range Test.

**TABLE 2. Influence of P on growth parameters of four rice cultivars.**

| P levels µM | Plant height (cm) | Tiller number | Root length (cm) | Shoot dry wt. (g/12 plants) | Root dry wt. (g/12 plants) |
|---|---|---|---|---|---|
| 8.06 | 77.88 b | 15.25 b | 37.38 a | 11.95 b | 4.54 a |
| 32.25 | 84.88 a | 19.31 a | 37.13 a | 13.49 a | 3.33b |
| 322.58 | 83.69 a | 15.38 b | 35.81 b | 11.96 b | 2.91 c |

Values in the table represent an average across all four cultivars. Means within a column followed by the same letter are not significantly different at 0.05 level of probability using Duncan's Multiple Range Test.

demand for carbohydrates and not specifically by phosphate levels (Evan & Wardlow 1976). Thus, if shoot growth is reduced by P deficiency, there will be less movement of carbohydrate to the deficient shoot and more to the roots, with consequently remobilized from the leaves will be preferentially transported to the roots. This is an additional reason why roots, which have first access to the external nutrient supply, will grow more actively than shoots under P-deficient conditions (Evan & Wardlow 1976). The similarity in distribution patterns suggests that N behaves in much the same way as P. Results obtained by Fageria in nutrient solutions showed that K and Ca behave differently in relation to root development (Fageria 1984). In other words, root development under increasing concentrations of K and Ca increased in rice cultivars.

The plant height and dry weight of tops increased in the 32.25 μM P solution but decreased in three rice cultivars in the solution containing the highest P concentration. In case of IRAT 104, plant height and dry weight of shoot increased was to the maximum level of P applied. On average, 32.25 μM (1 μg $P.ml^{-1}$) P can be considered as the optimum level of P in nutrient solution for growth of rice cultivars. Therefore, for this experiment and for the sake of comparing contrasts, two levels of P were chosen i.e. 8.06 μM (0.25 μg $P.ml^{-1}$) and 32.25 μM (1 μg $P.ml^{-1}$) as a low and optimum level, respectively.

To identify which growth parameter is most sensitive to P deficiency, values of plant height, root length, shoot and root weight were transformed into relative values (Table 3). Root and shoot weight parameters were more sensitive to P-deficiency. Relative values of height and root length were more or less constant for all four cultivars. Root weight can not be used as a parameter, because under field conditions root weight does not behave as it does in nutrient solution (Fageria 1984). In other words, root growth increased with increasing levels of P up to certain point and then remained constant and/or decreased. This means that shoot is the desirable growth parameter for screening cultivars for P-efficiency in nutrient solution under greenhouse conditions. Based on this growth parameter, cultivar IRAT 104 was most and Quatro Meses least efficient with regard to P.

Results related to P concentrations and contents are presented in Table 4. Phosphorus concentrations and contents increased with increasing levels of P in the growth medium in all four cultivars. Phosphorus concentration and content was higher in the tops as compared to roots. An average of four cultivars showed that 17% of the total P uptake was retained in the roots while 83% was translocated to the shoots. When P content was compared among cultivars, IRAT 104 had the highest values at all three levels of P applied (Table 4). When values were transformed into P-utilization efficiency (Table 5) at the 8.06 μM P level, the cultivars IRAT 104, Quatro Meses and Beira Campo showed the same shoot dry weight/mg P absorbed and IRAT 104, Beira Campo and Bico Torto showed about the same root dry weight/mg P absorbed. At the highest concentration of P, Beira Campo produced the highest dry matter of roots as compared to the other three cultivars. There was practically no difference in phosphorus utilization efficiency of shoot by four cultivars at the highest P level.

**TABLE 3 The effect of low P on growth parameters of four rice cultivars. Values are for plants grown with low P (8.06) μM expressed relative to those of plants grown with optimum P (32.25 μM).**

| Cultivar | Relative height | Relative root length | Relative shoot wt. | Relative root wt. |
|---|---|---|---|---|
| IRAT 104 | 90 | 100 | 99 | 171 |
| Quatro Meses | 90 | 103 | 77 | 117 |
| Beira Campo | 96 | 100 | 91 | 162 |
| Bico Torto | 92 | 100 | 88 | 132 |

Relative values = $\frac{Yb}{Ya}$ x 100, where Ya = value of optimum P level and Yb = value of low level of P.

**TABLE 4. Concentration and content of phosphorus in the shoots and roots of four rice cultivars under three levels of phosphorus.**

| Cultivar | P levels µM | Shoots | | Roots | |
|---|---|---|---|---|---|
| | | P conc. (%) | P content (mg/12 plants) | P conc. (%) | P content (mg/12 plants) |
| | 8.06 | 0.13 | 16.35 | 0.09 | 4.61 |
| IRAT | 32.25 | 0.34 | 43.28 | 0.28 | 8.40 |
| | 322.58 | 1.07 | 145.31 | 1.01 | 32.32 |
| | 8.06 | 0.13 | 14.39 | 0.12 | 4.50 |
| Quatro Meses | 32.25 | 0.29 | 41.49 | 0.25 | 8.00 |
| | 322.58 | 1.07 | 112.24 | 0.94 | 25.65 |
| | 8.06 | 0.13 | 16.26 | 0.10 | 5.05 |
| Beira Campo | 32.25 | 0.28 | 38.55 | 0.27 | 8.39 |
| | 322.58 | 1.09 | 129.38 | 0.77 | 24.25 |
| | 8.06 | 0.14 | 16.31 | 0.09 | 3.83 |
| Bico Torto | 32.25 | 0.28 | 36.82 | 0.22 | 7.08 |
| | 322.58 | 1.14 | 129.16 | 0.82 | 21.07 |

**TABLE 5. Phosphorus utilization efficiency by roots and tops of four rice cultivars.**

| Cultivar | P levels µM | mg dry weight/mg P absorbed | |
|---|---|---|---|
| | | Shoots | Roots |
| | 8.06 | 769.42 | 1110.62 |
| IRAT 104 | 32.25 | 294.13 | 357.14 |
| | 322.58 | 93.45 | 99.00 |
| | 8.06 | 769.28 | 833.33 |
| Quatro Meses | 32.25 | 344.90 | 400.00 |
| | 322.58 | 93.46 | 106.39 |
| | 8.06 | 769.37 | 1000.00 |
| Beira Campo | 32.25 | 357.19 | 370.67 |
| | 322.58 | 91.74 | 129.89 |
| | 8.06 | 714.28 | 1112.27 |
| Bico Torto | 32.25 | 357.14 | 454.80 |
| | 322.58 | 87.72 | 121.97 |

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