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PHOSPHORUS USE EFFICIENCY BY BRAZILIAN UPLAND RICE GENOTYPES EVALUATED BY THE ^{32}P DILUTION TECHNIQUE

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Abstract

The objectives of this work were to identify the most efficient upland rice genotypes in phosphorus (P) utilization, and to verify if P from the seed affects the classification of upland rice genotypes on P uptake efficiency. The experiment was conducted in a greenhouse of the Center for Nuclear Energy in Agriculture (CENA/USP), Piracicaba, São Paulo, Brazil, using the ^{32}P isotope technique, and plants were grown in pots with samples of dystrophic Typic Haplustox (Oxisol). The experimental design was completely randomized with four replications. The treatments consisted of 47 upland rice genotypes and two standard plant species, efficient or inefficient in P uptake. The results were assessed through correlation and cluster analysis (multivariate). The Carisma upland rice genotype was the most efficient in P uptake, and Caripuna was the most efficient on P utilization. The P derived from seed does not influence the identification of upland rice genotypes in P uptake efficiency.

1. INTRODUCTION

In low input farming systems, phosphorus (P) is one of the most important factors worldwide limiting crop yields. In Brazil, upland rice is typically grown in P deficient soils with high P-fixing capacity [1] and without fertilization in agricultural frontier areas, mainly in the Cerrado region. Low P input as fertilizer is one of the main factors that explain low upland rice grain yields in Brazil, on average 2 t ha^{-1} [2], compared to lowland rice of 4.5 t ha^{-1} [3]. Furthermore, upland rice is an important crop in Brazil, because it is grown by resource poor farmers as a subsistence crop, representing a minimum input production system.

There is a large natural inter- and intra-specific genetic variation for plant traits that are associated with P uptake efficiency, and development of transgenic plants can be used as a strategy for improving P uptake efficiency of crops that may represent a sustainable solution to increase yields [4]. Although success in developing nutrient efficient crop genotypes has been limited, this strategy should continue to receive top priority during the 21st century [5].

Upland rice genotypes differ in P use efficiency and efficient rice genotypes can be used in breeding programs [1, 6]. Identifying rice genotypes more efficient in P uptake is the first step to a successful breeding program, and is a strategy to reach high economic yields in low input systems. High P content in rice grains (the majority as phytate) contributes little to human nutrition because micronutrients such as iron and zinc are binding to phytate [7]. In addition, continued removal of P from the fields in rice grain at harvest results in depletion of soil P reserves in low input agricultural systems [8].

There are several definitions and calculation methods for P use efficiency (divided into P uptake efficiency and P utilization efficiency). Here we define P uptake efficiency as the ability of upland rice genotypes to take up P from soil assessed by the ^{32}P dilution technique [9], and P utilization efficiency as the ability to produce grain yield under low available P supply [10]. The advantage of the ^{32}P isotopic dilution method compared to others is the possibility of eliminating the influence of seed derived P when comparing P uptake efficiency by crop species or genotypes, by the L-value [9, 11, 12].

The ability of different plant species (canola, white lupin, pigeon pea, soybean, sunflower and wheat) for absorbing less available forms of soil P was compared using the ^{32}P isotope dilution technique, and it was observed that the white lupin was more efficient [9]. Using this same technique in a study of 22 plant species [13], it was observed that white lupin, upland rice, eucalyptus, cotton and pigeon pea were the most efficient in P uptake, while sunhemp, cowpea and soybean were classified as less efficient species. An important factor usually not considered in studies assessing genotypic variation for P uptake efficiency is the P content present in seeds. Genotypes that have seeds with higher P content can be classified, by mistake, as more efficient in P uptake than others with less P content of seeds. Comparing wheat genotypes for their efficiency in P uptake, it was found that the tolerance to P deficiency was higher in genotypes of durum wheat (*Triticum durum* L.) in relation to wheat (*Triticum aestivum* L.) [14, 15]. In this study, the greater tolerance of durum wheat genotypes was attributed to higher P content in seeds in relation to wheat.

The objectives of this study were to identify upland rice genotypes more efficient in P uptake using the ^{32}P isotope dilution technique and upland rice genotypes more efficient in P utilization. Furthermore, we aim to verify if P from the seed affects the classification of upland rice genotypes on P uptake efficiency.

2. MATERIALS AND METHODS

2.1. Experimental

The experiment was conducted in the greenhouse at Center for Nuclear Energy in Agriculture (CENA/USP), located at latitude 22°42'30" S, longitude 47°38'01" W and 554 m altitude, in Piracicaba, São Paulo, Brazil. The study were performed in 3.0 l plastic pots, lined with polyethylene bags, containing 2.5 kg of air-dried soil, collected from the 0 to 0.20 m of a dystrophic Typic Haplustox [16]. The soil samples were dried, sieved in a 2 mm mesh sieve and homogenized. The soil had 280, 70 and 650 g kg^{-1} content of clay, silt and sand, respectively, and the following chemical characteristics: pH (0.01 mol l^{-1} $CaCl_2$, 4.5; organic matter, 18.0 g dm^{-3}; resin extracted P, 5 mg dm^{-3}; K, 0.6 $mmol_c$ dm^{-3}; Ca, 11.5 $mmol_c$ dm^{-3}; Mg, 5.2 $mmol_c$ dm^{-3}; H + Al, 35.4 $mmol_c$ dm^{-3}; CEC, 52.7 $mmol_c$ dm^{-3}; sum of bases, 17.3 $mmol_c$ dm^{-3}; base saturation, 32.8%, according to methodology described by [17]; and P by Mehlich-1, 3 mg dm^{-3} [18].

After application of lime (Calcium Carbonate Equivalent = 110%) to raise the base saturation to 50% for the upland rice, according to the official recommendation of Bulletin 100 [19], the soil was incubated for 30 days and the moisture content was maintained at approximately 70% of water holding capacity.

To evaluate the efficiency of genotypes of upland rice for P uptake, a mixture of triple superphosphate (20 mg P kg^{-1} soil) as a source of readily available P to plants, and Patos phosphate rock (150 mg P kg^{-1} soil) were applied to raise the total P content of soil to 170 mg P kg^{-1} in each pot. N and K were applied at rates of 200 mg N kg^{-1} as urea and 200 mg K kg^{-1} as potassium sulphate. Fertilization with micronutrients, in the three experiments was done applying nutrient solution in all treatments at rates of 0.5 mg B kg^{-1}, 1.5 mg Cu kg^{-1}, 3.0 mg Fe kg^{-1}, 2.0 mg Mn kg^{-1}, 3.0 mg Zn kg^{-1} and 0.1 mg Mo kg^{-1}.

The experimental design was completely randomized with four replications. The treatments consisted of 47 upland rice genotypes and two standard species described in the literature as efficient or inefficient in P uptake: Sunhemp (*Crotalaria juncea* L.) as inefficient in absorbing P [12] and white lupin (*Lupinus albus* L.) as efficient [19, 12].

The upland rice genotypes evaluated were: Araguaia, Arroz Preto, Beira Campo, Bico Ganga, BRS Aimoré, BRS Apinajé, BRS Aroma, BRS Bonança, BRS Caripuma, BRS Colosso, BRS Curinga, BRS Monarca, BRS Pepita, BRS Primavera, BRS Sertaneja, BRS Soberana, BRS Talento, BRSMG Conai, BRSMG Relâmpago, Cabaçu, Cambará, Canastra, Carajás, Carisma, Cateto Seda, Centro América, Cuiabana, Douradão, Guanai, Guape, Guaporé, IAC 25, IAC 47, IAC 60 dias, IAC 202, IAC 1246, Ipê, Jaguary, Maravilha, Maranhão, Montaninha 90 dias, Progresso, Rio Paranaíba, Rio Verde, Tangará, Xingú and Zebu.

The soil was labeled with ^{32}P by applying a solution with 9.25 MBq of ^{32}P and 0.2 mg P kg^{-1} carrier. Eight seeds of the upland rice varieties or five seeds of the two standards were sown in each pot, and the final population was thinned to three plants pot^{-1}. Soil moisture was maintained at approximately 70% of water retention capacity during the experiment.

The above-ground part of the plant of each genotype was taken at two samplings: (i) first, two plants, from the total of three cultivated in each plot, were harvested at 40 days after emergence, and (ii) the one remaining plant at the stage of panicle full maturity. The plant samples were separated into shoots (leaves, stems, rachis and rice husks) and grain.

The seed-contained P was discounted for calculating the L-value, which was used to compare the efficiency of P uptake among the genotypes, considering that from the total P stored in the seeds of rice genotypes, 60% is used for plant growth [11], i.e., 40% of seed P is not used by the plant (remains in the cotyledon).

2.2. Calculations of phosphorus and ^{32}P

With shoot dry matter (Sdm), grain weight (Gw), P concentration in Sdm and Gw, the P contents in the shoot and in grain were calculated:

$P\,uptake = \text{Pconcentration}\, x\, \text{Sdm}$, where Sdm is shoot dry matter.

$P\,content = \text{Pconcentration}\, x\, Gw$, where Gw is grain weight.

With the data of plant P content and the ^{32}P activity of the plant, the specific activity (SA), the L-value, and the L-value subtracting the amount of seed-derived P from the total P content of the shoot were calculated [9, 10].

$$SA = \frac{^{32}P}{^{31}P}$$

where SA is specific activity (dpm µg^{-1} P); ^{32}P is radioisotope activity in the plant (dpm); ^{31}P is plant P content (µg P plant^{-1});

$$Lvalue = X\left(\frac{SA_0}{SA_p} - 1\right)$$

where L-value (mg P kg^{-1} soil); SA_0 is specific activity of the applied solution (dpm µg^{-1} P); SA_p is specific activity of plant (dpm µg^{-1} P); X is amount of applied P;

$$L - s\,value = \left(Y\frac{(X_T - Z)}{Y_T} - X\right)$$

where: L-s value is L-value subtracting P in the plant derived from the seed (mg of P kg^{-1} soil); Y is the ^{32}P activity in the applied solution (dpm); X_T is plant P uptake (mg); Y_T is ^{32}P activity in the plant shoot dry matter (dpm); X is the rate of ^{31}P carrier applied pot^{-1} (mg); Z is the total P content derived from seed (mg).

2.3. Statistical analysis

The results of Sdm, Gw, P concentration and P content in the shoot or in the grain, specific activity (SA), L-value and L-value subtracting the P derived from the seed (L-s value) were submitted to analysis of Pearson linear correlation and hierarchical cluster analysis with the objective for grouping the similar genotypes. Cluster analysis of upland rice genotypes was carried out with the SAS 9.1 - "Statistical Analysis System" [20] and SYSTAT version 10.2 software programs, using the UPGMA (un-weighed pair group arithmetic average clustering) The cluster analysis was preceded by the standardization of data before the Euclidian distances calculation, as the variables presented different scales. After standardization, all the variables were equally important in the determination of these distances. Final results of the groups were presented as dendrograms. The P uptake efficiency by plants is inversely proportional to SA and directly proportional to L-value and L-s value.

The upland rice genotypes were grouped into four or five groups, aiming at achieving greater homogeneity within each group and greater heterogeneity among the different groups. The results are presented and discussed in three parts: (1) first sampling - shoot; (2) second sampling - shoot, and (3) second sampling - grain. The term shoot dry matter (Sdm) refers to all above ground plant organs (leaves, stalks, husks and rachis) except the grain.

3. RESULTS AND DISCUSSION

3.1. First sampling - shoot

Plant data for the first sampling are given in Table 1.

TABLE 1. MEAN SHOOT DM YIELD (SDM) OF 47 UPLAND RICE GENOTYPES, P CONCENTRATION (P CONC), P UPTAKE, SPECIFIC ACTIVITY (SA), L-VALUE AND L-VALUE DISCOUNTING THE P FROM THE SEED (L-S VALUE) IN THE FIRST SAMPLING

Genotype	Sdm ($g\ pot^{-1}$)	P conc ($g\ kg^{-1}$)	P uptake ($mg\ pot^{-1}$)	SA ($dpm\ \mu g^{-1}\ P$)	L-value ($mg\ kg^{-1}$ soil)	L-s value ($mg\ kg^{-1}$ soil)
Cuiabana	2.07	1.53	3.16	137.29	12.34	12.18
Caripuna	2.50	1.45	3.63	213.81	7.86	7.87
Relâmpago	2.63	1.44	3.77	200.52	8.39	8.38
Maravilha	2.66	1.58	4.20	103.04	16.81	16.75
Xingú	2.69	1.44	3.88	119.29	14.25	14.12
Ipê	2.75	1.60	4.39	152.76	11.08	10.98
Aroma	2.78	1.46	4.06	173.75	9.71	9.72
Canastra	2.80	1.34	3.76	136.66	12.40	12.32
Carisma	2.81	1.72	4.81	80.37	21.24	21.16
Carajás	2.91	1.49	4.32	158.15	10.69	10.66
IAC 202	2.95	1.48	4.38	140.00	12.10	12.09
Colosso	2.95	1.64	4.83	135.93	12.47	12.46
Progresso	2.95	1.52	4.49	105.28	16.17	16.09
Araguaia	2.99	1.55	4.63	129.26	13.14	13.12
Rio Verde	3.00	1.47	4.41	160.72	10.61	10.57
Arroz Preto	3.02	1.25	3.77	95.90	17.67	17.50
Bonança	3.05	1.46	4.44	152.64	11.11	11.10
Zebu	3.05	1.55	4.73	106.84	15.95	15.81
Guaporé	3.10	1.58	4.88	152.11	11.13	11.11
Talento	3.10	1.47	4.55	105.13	16.20	16.09
Pepita	3.10	1.72	5.33	130.04	13.05	12.95
Sertaneja	3.11	1.43	4.41	97.20	17.53	17.50
Primavera	3.14	1.53	4.78	126.48	13.43	13.36
Tangará	3.15	1.26	3.95	214.96	7.81	7.77
Apinajé	3.20	1.56	4.99	122.64	13.85	13.80
Montanhinha 90 dias	3.21	1.43	4.61	171.16	9.86	9.85
Guanai	3.23	1.34	4.32	153.87	10.99	10.99
Conai	3.24	1.60	5.18	138.10	12.27	12.27
Cambará	3.27	1.54	5.03	127.68	13.29	13.23
Monarca	3.28	1.25	4.11	164.62	10.27	10.25
Curinga	3.29	1.48	4.88	162.81	10.38	10.45
Douradão	3.39	1.49	5.02	154.87	10.96	10.92
IAC 47	3.42	1.37	4.68	132.41	12.81	12.73
Beira Campo	3.45	1.34	4.59	218.79	7.67	7.65
Aimoré	3.50	1.59	5.57	173.49	9.73	9.70
Soberana	3.51	1.51	5.28	169.53	9.96	9.95
Rio Paranaíba	3.52	1.27	4.48	102.31	16.71	16.58
Cateto Seda	3.54	1.30	4.60	186.54	9.03	9.01
Centro América	3.66	1.44	5.28	97.96	17.38	17.29
IAC 1246	3.73	1.28	4.78	158.50	10.67	10.57
Cabaçu	3.80	1.35	5.14	157.02	10.77	10.76
Maranhão	3.82	1.31	5.00	134.41	12.62	12.62
Bico Ganga	3.87	1.45	5.61	109.53	15.52	15.48
IAC 25	3.92	1.47	5.77	142.28	11.91	11.88
IAC 60 dias	3.94	1.26	4.94	145.46	11.76	11.75
Jaguary	4.04	1.33	5.39	195.96	8.61	8.60
Guape	4.36	1.29	5.63	187.21	8.96	8.91
Average	3.22	1.45	4.65	145.43	12.32	12.27
CV (%)	10.90	10.22	10.38	12.21	12.78	12.65

The results obtained with the two standard species were: (i) White lupin - Sdm = 1.15 g pot^{-1}, P in Sdm = 2.03 mg pot^{-1}, SA = 39.06 dpm mg^{-1} P, L-value = 43.99 mg P kg^{-1} soil and L-s value = 2.6 mg P kg^{-1} soil, (ii) Sunhemp - Sdm = 5.16 g pot^{-1}, P content in Sdm = 5.77 mg pot^{-1}, SA = 193.32 dpm mg $^{-1}$ P, L-value = 6.88 mg P kg^{-1} soil and L-s value = 6.67 mg P kg^{-1} soil. The white lupin plant was, as expected, more efficient in absorbing P (the lowest SA, and highest L-value L and L-s value) than all upland rice genotypes evaluated in this study. The Sdm of rice is one of the main parameters related to grain yield of this crop, and P increases due to an increase in the number of tillers and leaf area [21]. The values of Sdm of 47 upland rice genotypes correlated significantly and negatively with Sdm P concentrations (–0.466***) and positively with Sdm P contents (0.785***). Therefore, the dilution effect was observed in Sdm P, i.e., increasing Sdm decreased the Sdm P concentrations, although the total P uptake was higher. From these three variables, the cluster analysis identified the following five groups of upland rice genotypes (Fig. 1):

1st: Aimoré, Soberana, Centro América, Bico Ganga, IAC 25, Jaguary and Guape;
2nd: Cabaçu, Maranhão, IAC 1246, IAC 60 dias, Rio Paranaíba, Cateto Seda, Beira Campo, IAC 47 and Guanai;
3rd: Monarca, Tangará, Arroz Preto, Canastra, Aroma, Xingú, Relâmpago and Caripuna;
4th: Maravilha, Ipê, Progresso, Carajás, IAC 202, Rio Verde, Bonança, Talento, Sertaneja, Montaninha 90 dias, Douradão, Curinga, Araguaia, Zebu, Primavera, Guaporé, Apinajé, Cambará, Conai, Colosso, Carisma and Pepita;
5th: Cuiabana.

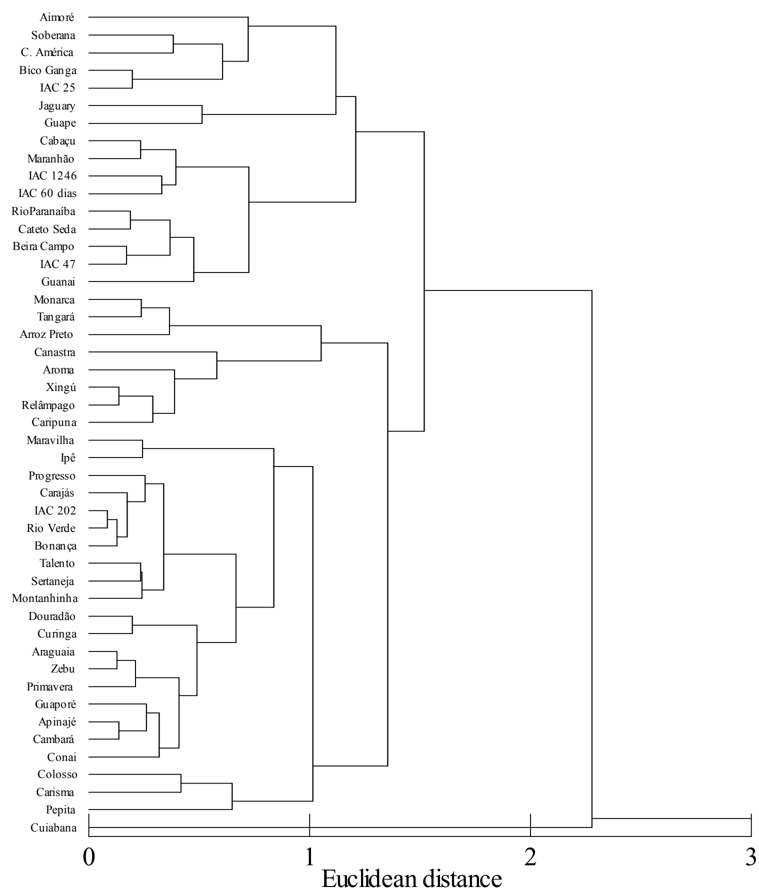

FIG. 1. Dendrogram resulting from the hierarchical cluster analysis of 47 genotypes of upland rice, based on the variables of shoot dry matter (Sdm), concentration and accumulation of P in Sdm. First plant sampling.

Among all the correlations between variables of upland rice genotypes, taken in the first sampling, the SA and L-value (–0.962 ***) x the L-s value (–0.960***), and L-value x the L-s value (0.999***) were the variables that showed higher Pearson correlation coefficients. By hierarchical cluster analysis with both variables SA and L-value (Fig. 2) as with the SA and L-s value (Fig. 3), upland rice genotypes were classified for the P uptake efficiency in the following four groups:

1st: very efficient, Carisma;
2nd: efficient, Arroz Preto, Sertaneja, Centro América, Maravilha, Rio Paranaíba, Talento, Progresso, Zebu and Bico Ganga;
3rd: medium efficiency, Xingú, Apinajé, Primavera, Cambará, Araguaia, Pepita, IAC 47, Maranhão, Colosso, Canastra, Cuiabana, Conai, IAC 202, IAC 25, IAC 60 dias, Guaporé, Bonança, Ipê, Guanai, Douradão, Cabaçu, Carajás, IAC 1246, Rio Verde, Curinga, Monarca, Soberana, Montaninha 90 dias, Aimoré and Aroma;
4th: less efficient, Cateto Seda, Guape, Jaguary, Relâmpago, Caripuna, Tangará and Beira Campo.

The Carisma genotype was the best for P uptake efficiency, and did not form a group with any other genotype (Figs. 2 and 3). Furthermore, we observed that the two dendrograms (Figs. 2 and 3) are similar, meaning that there was no difference in P uptake efficiency among groups of upland rice genotypes based on L-values or P in the plant derived from seed, because the genotypes grouped by SA, L-value and L-s value were similar.

3.2. Second sampling - shoot

The Sdm values correlated significantly and positively with Sdm P concentrations (0.486***) and P content in Sdm P (0.884***). Therefore, there was a response in shoot production to an increase of P concentration in plant tissue. The dendrogram obtained by grouping these three variables, in the second sampling, is shown in Fig. 4. The 47 upland rice genotypes were classified into four groups:

1st: Cuiabana, Ipê, Cabaçu and Zebu (genotypes with higher values of Sdm, Sdm P concentration and P uptake);
2nd: Cateto Seda, Beira Campo, Guaporé, Xingú, Sertaneja, Araguaia, Caripuna, Rio Parnaíba, IAC 47, Maranhão, IAC 1246, Arroz Preto, Guape, Monarca, Canastra, Maravilha, Rio Verde, Progresso, Curinga, Bonança, Pepita, Montaninha 90 dias, Carisma, Jaguary, Carajás, Aroma, IAC 202, Talento, Cambará, IAC 25 and Soberana;
3rd: Tangará, Relâmpago, Aimoré, Conai, Douradão, Centro América, Colosso, Primavera, Apinajé, Guanai and IAC 60 dias (genotypes with lower values of Sdm, P concentration and content in Sdm);
4th: Bico Ganga. It did not group with any other genotypes, because although it had high Sdm production, P concentration and P uptake were low (Fig. 4).

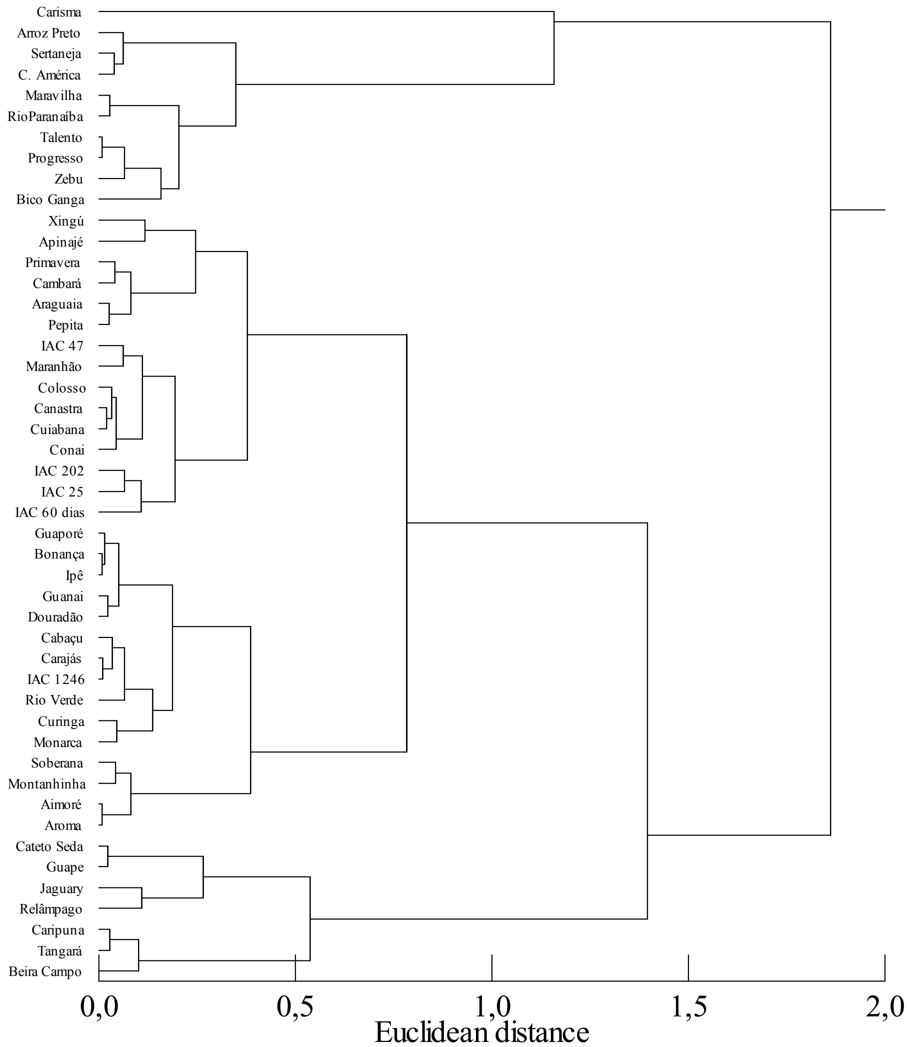

FIG. 2. Dendrogram resulting from hierarchical cluster analysis of 47 genotypes of upland rice, based on specific activity (SA) and L-value. First plant sampling.

3.3. Second sampling – grain

The grain dry matter, P concentration and P content of grain are given in Table 2. The Gw values correlated significantly and negatively with its P concentrations (–0.512***) and positively with its P contents (0.711***). The grain P concentration decreased with increasing Gw due to the dilution effect of P in vegetal tissue. The positive correlation between grain yield and its P content indicates that it is possible to increase grain production of upland rice with increasing plant P content, as observed by [23] for common bean, suggesting the use of bean genotypes more efficient in P utilization to increase grain yield.

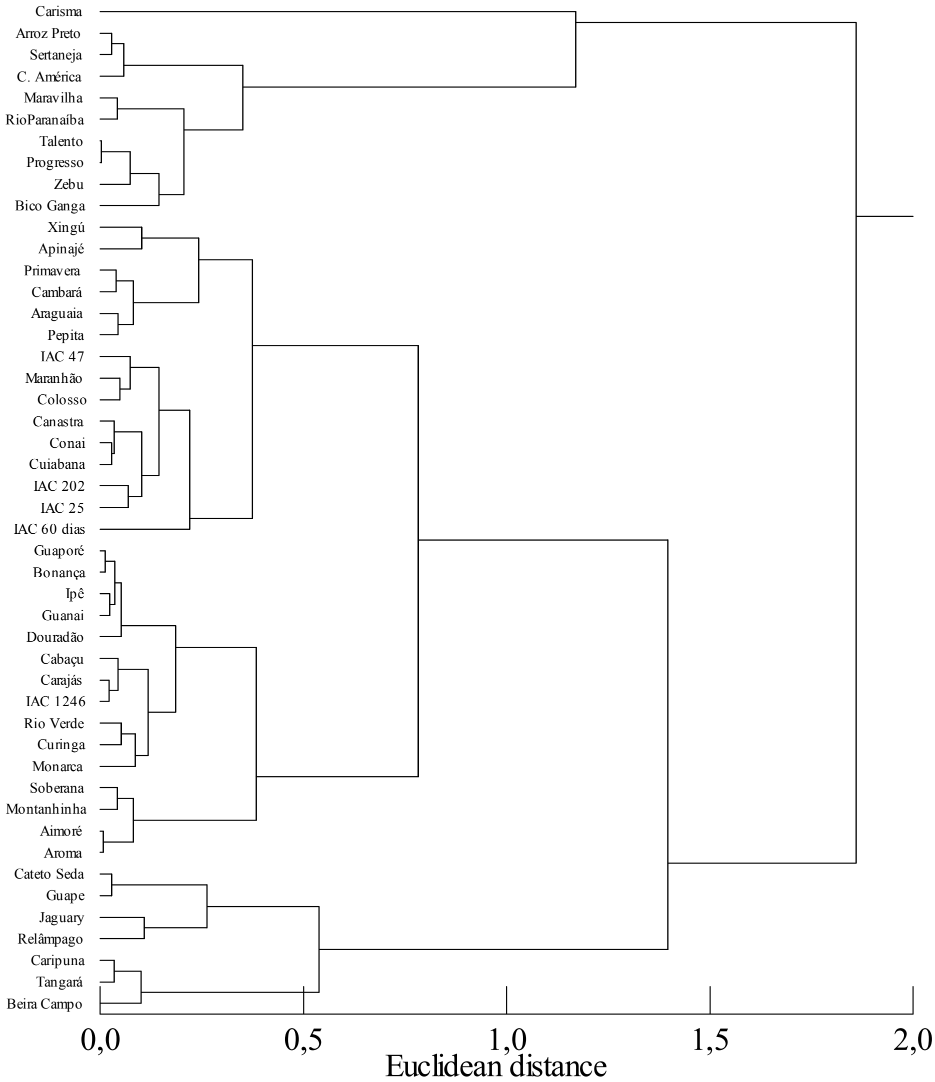

FIG. 3. Dendrogram resulting from hierarchical cluster analysis of 47 genotypes of upland rice, based on specific activity (SA) and L-value discounting the P in plant derived from seed (L-s value). First plant sampling.

From the analysis of hierarchical clustering of variables Gw concentration and content of P, the following five groups were identified, homogeneous and distinct from varieties of upland rice genotypes (Fig. 5) and were classified as:

1st: highly productive and highly rich in grain P content (genotype Caripuna);
2nd: very productive and very rich in grain P content (genotypes Bico Ganga, Sertaneja, IAC 202, Colosso and Rio Parnaíba);
3rd: productive and rich in grain P (genotypes Cambará, Relâmpago, Tangará, Aroma, Monarca, Guanai, Progresso, Cuiabana, Aimoré, Arroz Preto, Rio Verde, Xingú, Zebu, Cabaçu, Araguaia, Douradão, Centro América, Maravilha, IAC 25, IAC 60 dias, Primavera, Bonança, IAC 1246, Ipê, Montaninha 90 dias, IAC 47, Talento, Carisma, Conai, Pepita, Beira Campo, Apinajé, Guaporé, Maranhão, Jaguary, Curinga, Canastra and Cateto Seda);
4th: moderately productive and moderately rich in P in the grains (genotype Guape);
5th: less productive and low grain P (genotypes Soberana and Carajás).

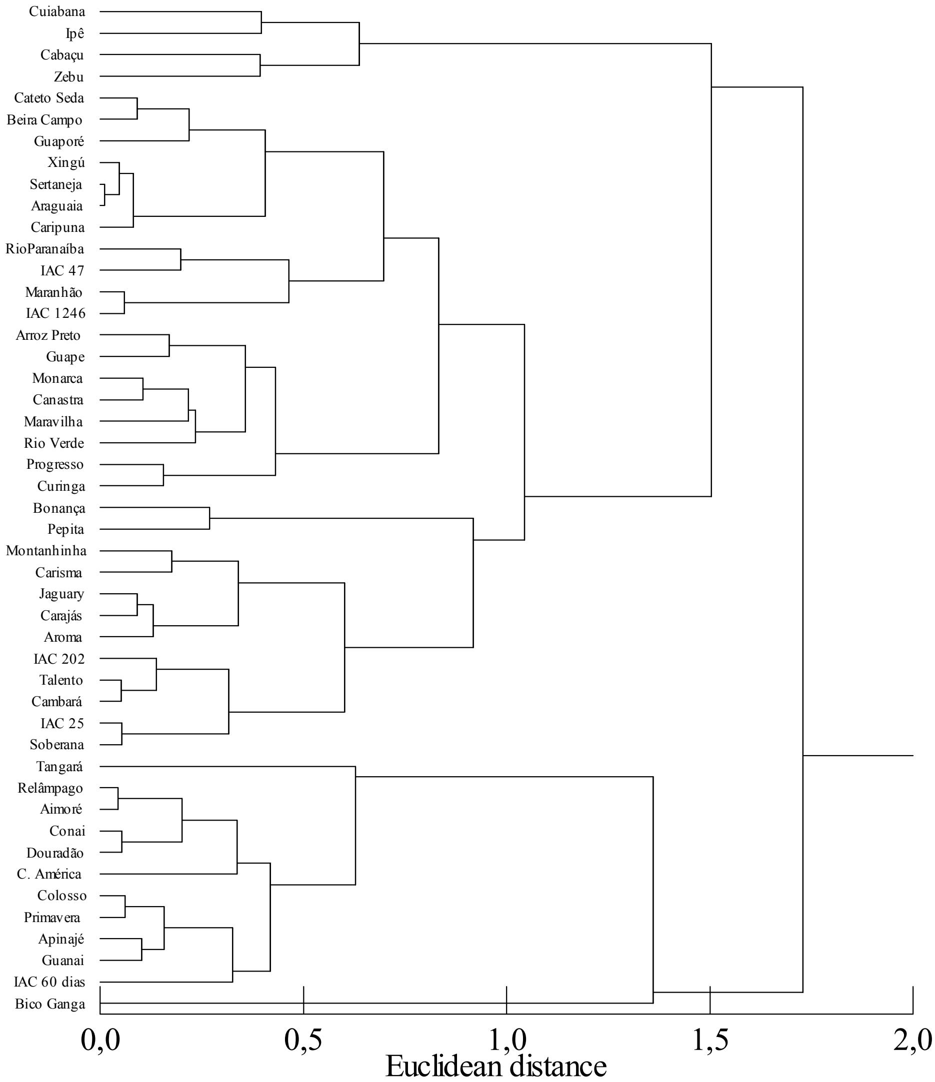

FIG. 4. Dendrogram resulting from hierarchical cluster analysis of 47 genotypes of upland rice, based on shoot dry matter (Sdm), concentration and accumulation of P in Sdm. Second plant sampling.

The Guape genotype was not grouped with any other genotype due to its low yield, but high accumulation of P in the grain, indicating that this genotype was not efficient in converting the plant accumulated P. Caripuna showed Gw similar to other genotypes, but was not grouped with any other, as the accumulation of P in the plant was higher than of other upland rice genotypes. In this experiment, we observed higher Gw and its P content in Rio Parnaíba compared to Araguaia, and these genotypes were classified as very productive and productive, respectively. Differences in P uptake and grain yield among upland rice genotypes grown in soil with low available P (P Mehlich-1 = 2.2 mg kg^{-1}) were also observed in the field [24].

TABLE 2. MEAN GRAIN DRY MATTER YIELD 47 UPLAND RICE GENOTYPES, P CONCENTRATION AND P CONTENT IN GRAIN IN THE SECOND SAMPLING

Genotype	Grain yield (g plant^{-1})	P concentration (g kg^{-1})	P content (mg plant^{-1})
Soberana	10.66	2.01	21.35
Guape	11.21	2.45	27.47
Carajás	11.47	1.88	21.45
Zebu	12.43	2.24	27.77
Cabaçu	12.46	2.10	26.21
Xingú	12.64	2.22	28.06
Araguaia	12.83	2.04	26.12
Centro América	12.88	1.92	24.73
Douradão	12.88	2.03	26.12
Arroz Preto	13.25	2.29	30.34
IAC 60 dias	13.51	1.98	26.75
Rio Verde	13.61	2.22	30.18
Primavera	13.64	2.02	27.56
IAC 25	14.04	1.97	27.69
Montanhinha 90 dias	14.10	2.12	29.89
Progresso	14.15	1.82	25.68
Bonança	14.17	2.02	28.65
IAC 1246	14.25	2.05	29.21
Ipê	14.34	2.08	29.85
Maravilha	14.48	1.94	28.11
Cuiabana	14.74	1.84	27.02
Aimoré	14.81	1.87	27.59
Jaguary	14.81	2.15	31.83
Guanai	14.96	1.71	25.52
Monarca	15.18	1.72	26.00
Carisma	15.25	1.95	29.80
Conai	15.35	1.94	29.71
Relâmpago	15.41	1.76	27.00
Tangará	15.47	1.73	26.78
Aroma	15.49	1.70	26.38
Pepita	15.60	1.93	30.03
Curinga	15.72	2.27	35.60
Beira Campo	15.78	1.91	30.09
Maranhão	15.88	2.09	33.15
Apinajé	16.15	1.94	31.38
Guaporé	16.36	2.00	32.70
Cambará	16.61	1.67	27.68
Canastra	16.79	2.11	35.41
Cateto Seda	17.37	2.20	38.31
Talento	17.60	1.95	34.26
Rio Paranaíba	17.69	1.79	31.63
IAC 47	17.79	1.99	35.44
Caripuna	18.18	2.39	43.34
Colosso	18.52	1.65	30.50
Sertaneja	20.20	1.88	37.91
IAC 202	20.39	1.69	34.43
Bico Ganga	20.59	2.04	41.87
Average	15.14	1.98	29.88
CV (%)	12.32	12.19	12.15

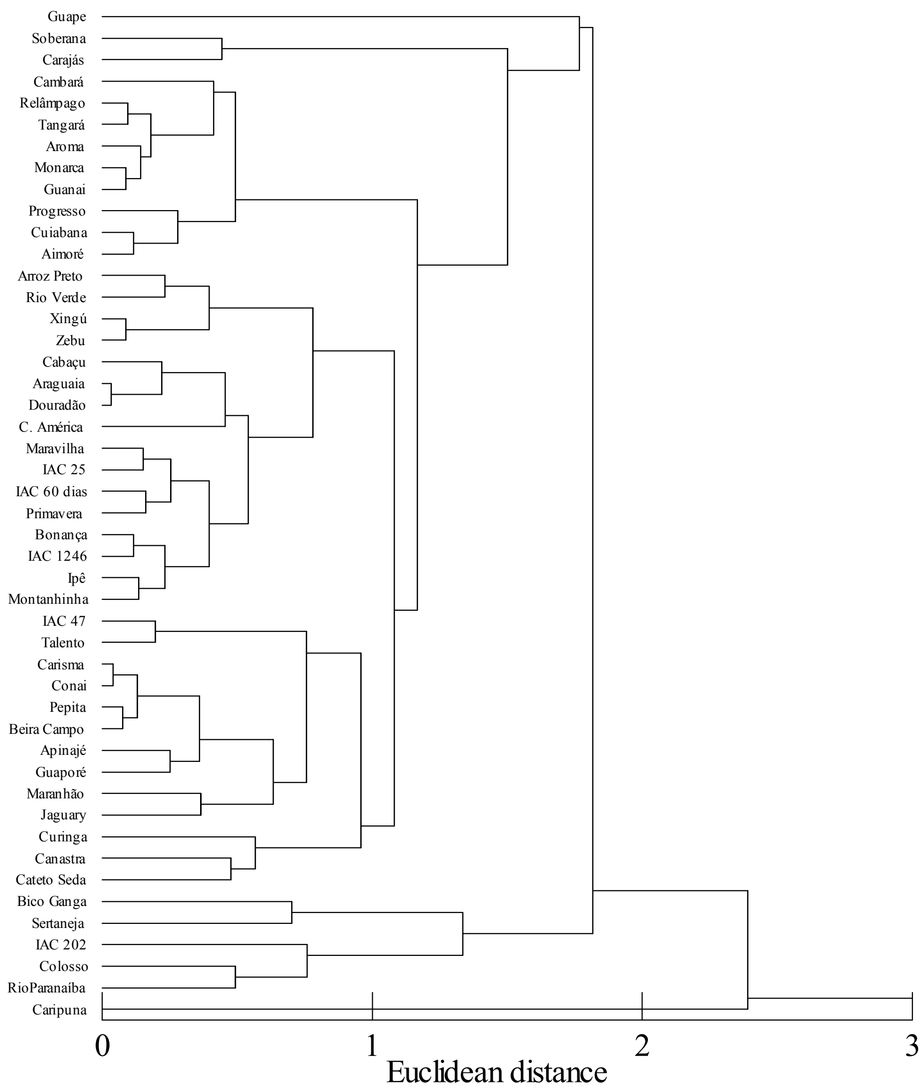

FIG. 5. Dendrogram resulting from hierarchical cluster analysis of 47 genotypes of upland rice, based on grain dry matter yield (Gw), and accumulated P concentration in Gw. Second plant sampling.

Although Carisma was the most efficient upland rice genotype in P uptake (Figs. 2 and 3), it was not classified in the group of the genotypes most productive in grain. Therefore, considering the definition of efficiency on P utilization by crops [10], Carisma was not the most efficient in P utilization.

In the second group of upland genotypes Arroz Preto, Sertaneja, Centro América, Maravilha, Rio Paranaíba, Talento, Progresso, Zebu and Bico Ganga were more efficient in P uptake (Figs. 2 and 3). Bico Ganga, Sertaneja and Rio Parnaíba were the highlighted genotypes, because these genotypes were classified in the second group that produced more grain (Fig. 5).

There was no significant correlation between SA, L-value and L-s value of 47 upland rice genotypes (measured in the first sampling) with Gw, P concentration and P content in the grain (measured in the second sampling). This indicates that upland rice genotypes more efficient in P uptake are not necessarily the most efficient in converting P taken up into grain.

The P amount required by plants can be reduced by using efficient upland rice genotypes in P use [25]. The identification of upland rice genotypes more efficient in P uptake and P utilization is a strategy to reduce P fertilizer rates besides allowing its cultivation in soils poor in P, and yet obtain high economic grain yields.

4. CONCLUSIONS

- The upland rice genotype Carisma was the most efficient in P uptake;
- The Caripuna upland rice genotype was the most productive in grain yield under conditions of low available soil P (genotype more efficient in P utilization);
- The P derived from seed in the plant, when the ^{32}P L-value technique is used, did not affect the identification and classification of upland rice genotypes.

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