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Scientific Article

Efficient and responsive table cassava cultivars to the use of phosphorus

Cultivares de mandioca de mesa eficientes e responsivas ao uso do fósforo

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ABSTRACT - Table cassava cultivars efficient in the use of phosphorus (P) and responsive to phosphate fertilization represent a crop option for regions with low availability of the nutrient and for crops using technological packages, such as investment in fertilization. The objective of the study was to classify table cassava cultivars regarding efficiency and responsiveness to P application in two agricultural crops. For this, four table cassava cultivars (Água Morna, BRS Gema de Ovo, Recife and Venâncio) were evaluated under conditions of low P availability (and without phosphate fertilization) and high availability (and fertilized with 240 kg ha^{-1} of P_2O_5). The Água Morna cultivar proved to be efficient and responsive in the two harvests evaluated. Only the Venâncio cultivar was classified as non-efficient. There was variation in the response of the Recife cultivar between the crops evaluated.

Keywords: *Manihot esculenta* Cranz. Phosphate fertilizer. Efficiency. Responsiveness.

RESUMO - Cultivares de mandioca de mesa eficientes no uso do fósforo (P) e responsivas à adubação fosfatada representam opção de cultura para regiões com baixa disponibilidade do nutriente e para cultivos com emprego de pacotes tecnológicos, como investimento em adubação. O objetivo da pesquisa foi classificar cultivares de mandioca de mesa quanto à eficiência e responsividade à aplicação de P em duas safras agrícolas. Para isso, foram avaliadas quatro cultivares de mandioca de mesa (Água Morna, BRS Gema de Ovo, Recife e Venâncio) em condições de baixa disponibilidade de P (e sem adubação fosfatada) e alta disponibilidade (e adubada com 240 kg ha^{-1} de P_2O_5). A cultivar Água Morna mostrou-se eficiente e responsiva nas duas safras avaliadas. Apenas a cultivar Venâncio foi classificada como não-eficiente. Houve variação na resposta da cultivar Recife entre as safras avaliadas.

Palavras-chave: *Manihot esculenta* Cranz. Adubação fosfatada. Eficiência. Responsividade.

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INTRODUCTION

Cassava is a plant native to Brazil, more specifically to the tropical Amazon basin region (FOLEGATTI; MATSUURA; FERREIRA FILHO, 2005). It is a tuberous species capable of developing in environments with low water availability and soils with low fertility (HOWELER, 2002). These characteristics make it a crop widely cultivated by small producers in different regions of Brazil, often without significant use of technology, resulting in low productivity (MARTINS et al., 2018), with emphasis on the semi-arid region, where the crop has a strong social and economic appeal.

Soils in the semi-arid region have wide variability in chemical, physical and mineralogical attributes, significantly affecting the adsorption and precipitation reactions of phosphorus (P); thus, the soil can become a strong sink of this element (VIEIRA et al., 2021), consequently making it difficult for plants to absorb it. Even so, cassava can develop under conditions of low availability of this nutrient (HOWELER, 2002). P absorption occurs depending on the amount available in the soil solution, on the population and association with mycorrhizal fungi and on the cassava genotype used.

In soils deficient in P, the application of phosphate fertilizers, organic fertilizers and the use of plant residues are options to overcome this limitation, maintaining the appropriate level without harming the yield of agricultural crops (BALEMI; NEGISHO, 2012). In situations where the use of these resources is not possible, the adoption of efficient cultivars, which produce reasonably well, even under low nutrient availability, represents another option.

Genetic variability in the efficiency and response of agricultural crops to P has been observed not only for species, but also for genotypes within the same species, as observed by Fidelis et al. (2015) with rice cultivars, Almeida et al. (2019) with cowpea cultivars, Jesus et al. (2021) with carrot cultivars, and Soares, Sediyama and Matsuo (2020) and Ardon et al. (2022) with soybean cultivars.

Identifying table cassava cultivars that are efficient in the use of P in the soil and responsive to phosphate fertilization can help technicians and producers in adequate fertilization programming and environmental sustainability, besides supporting agricultural research to select genotypes with potential for application for genetic enhancement.

Thus, the use of genotypes efficient in the absorption and use of P represents a strategy for agricultural cultivation in soils with nutrient deficiency (FAGERIA, 1998).

Information of this nature confirms important aspects of the crop and its relationship with P, in addition to expressing the ability of different materials, available for cultivation, to absorb and use the nutrient for their development. In addition, no research work was found in the literature that carried out this classification for cassava cultivation with the nutrient P and in different agricultural crops. In this context, the objective of this study was to classify table cassava cultivars in terms of efficiency and response to P application in two agricultural crops.

MATERIAL AND METHODS

Table cassava was grown at the Rafael Fernandes Experimental Farm (5°03'31.00"S, 37°23'47.57"W and 80 m altitude), belonging to the Universidade Federal Rural do Semi-Árido (UFERSA), located in the district of Alagoinha, rural area of the municipality of Mossoró, Rio Grande do Norte, Brazil, in the 2018/19 and 2019/20 agricultural harvests.

The local climate, according to Köppen's classification, is of the BSh type (ALVARES et al., 2013), characterized as being dry and very hot, with two climatic seasons: a rainy season that covers the months of February to May, and a dry season, which runs from June to January. The meteorological variables were collected at a station on the Experimental Farm, during the period in which the experiments were carried out (Figure 1).

The local soil was classified as *Argissolo Vermelho Distrófico Típico* (Ultisol) (RÊGO et al., 2016). The chemical and physical characterizations of the soil in the areas where the experiments were carried out, following the methodologies of Silva (2009) and Donagema et al. (2011), respectively, are presented in Table 1.

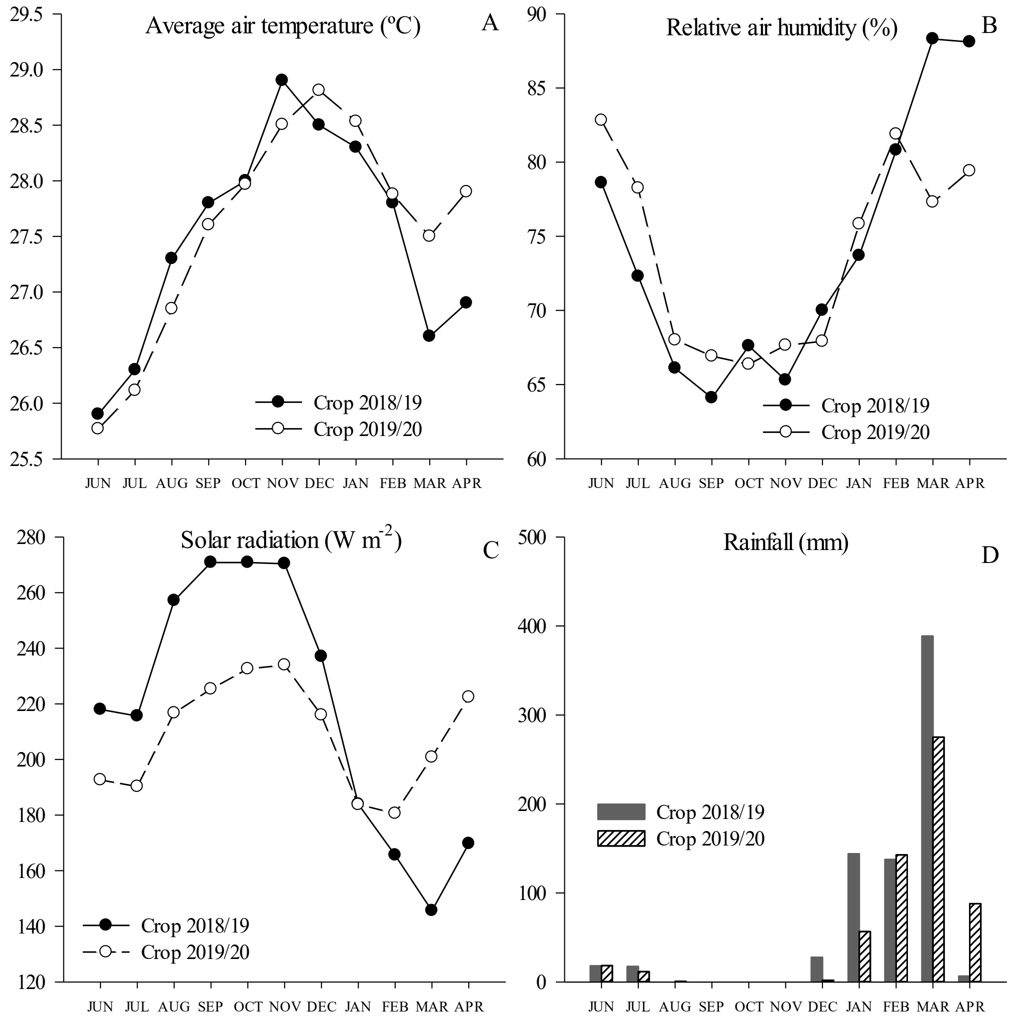

Figure 1. Average values of average air temperature (A), relative humidity (B), solar radiation (C) and accumulated rainfall (D) in the two agricultural crops of table cassava (2018/19 and 2019/20).

Table 1. Chemical and physical analysis of the soil in the experimental areas (depths 0-0.20 m and 0.20-0.40 m) in agricultural crops 2018/19 and 2019/20.

Depth	pH	P*	K^+	Na^+	Ca^{2+}	Mg^{2+}	Sand	Silt	Clay
m		mg dm^{-3}			cmolc dm^{-3}		kg kg^{-1}		
1st Crop (2018/19)									
0-0.20	5.90	8.3	38.9	1.2	0.80	0.50	0.91	0.02	0.07
0.20-0.40	5.50	2.0	50.8	1.2	0.70	0.20	0.88	0.03	0.09
2nd Crop (2019/20)									
0-0.20	5.90	3.7	41.1	9.3	0.60	0.20	0.91	0.02	0.07
0.20-0.40	4.90	0.9	24.3	8.3	0.50	0.10	---	---	---

*Extractor: $Mehlich^{-1}$.

The table cassava cultivars studied were Água Morna, BRS Gema de Ovo, Recife and Venâncio. The efficiency and response of these cultivars were evaluated at doses of 0 and 240 kg ha^{-1} of P_2O_5.

Each experimental unit consisted of four 6-m-long rows, spaced 1.0 m apart, totaling an area of 24 m^2 (6 m x 4 m). The two central rows, disregarding one plant at each end, were considered the usable area of the experimental unit (9.6 m^2).

Soil preparation was carried out with heavy harrowing to incorporate the remaining plant material in the area, in addition to a leveling harrowing to homogenize the soil surface before setting up the experiments. Fertilization was carried out following the recommendations of Silva and Gomes (2008) based on soil analysis, with the exception of P, for which the treatments were taken into account. In each harvest, 30 kg ha^{-1} of N and 40 kg ha^{-1} of K_2O were applied. Urea (45% N), single superphosphate (18% P_2O_5) and potassium chloride (60% K_2O) were used as sources of nitrogen (N), phosphorus (P) and potassium (K), respectively. Phosphate fertilizer was applied entirely during planting. Half of the recommended dose of N was applied at 30 days after plant emergence (DAE), together with the total dose of K, and the second half of nitrogen fertilization was applied at 60 DAE. Both N and K were applied via an irrigation system, through a bypass tank.

The propagative material was obtained from a multiplication area installed at the Rafael Fernandes Experimental Farm, planted ten months before off setting up the experiments, with cultivation conditions similar to those used in the study. Planting was done manually, with 0.10-0.15 m long cuttings and 5-7 buds per hole, at a depth of 0.10 m, with a spacing of 1.00 m between rows by 0.60 m between holes, accounting for a population density of 16,666.7 plants ha^{-1}.

The crop was irrigated using a drip system, with emitters spaced 0.30 m apart and a flow rate of 1.6 L h^{-1}, applying an average daily water depth of 4.8 mm, with irrigation suspended eight months after planting. The crop coefficient (Kc) was used for each cassava phenological stage. Three manual weeding operations were necessary to control weeds and, due to the occurrence of mites, a commercial product with the active ingredient spiromesifen was used to control the infestation.

Using the methodology proposed by Fageria and Kluthcouski (1980), the table cassava cultivars were grouped according to efficiency and response to P application.

The efficiency of P use was determined by the average productivity of table cassava roots in soil without phosphate fertilization. And the response to P use was obtained by the difference between root productivity in an environment with the maximum dose of the nutrient (240 kg ha^{-1} P_2O_5) and in the absence of phosphate fertilizer (0 kg ha^{-1} P_2O_5), divided by the difference between doses, using the following formula:

$$RI = (ROOTPROD\_240 - ROOTPROD\_0) / DP$$

Where:
RI: Response index; ROOTPROD_240: Root productivity (kg ha^{-1}) with high dose of phosphorus (240 kg ha^{-1} P_2O_5); ROOTPROD_0: Root productivity (kg ha^{-1}) in the absence of phosphate fertilizer (0 kg ha^{-1} P_2O_5); DP: Difference between phosphorus doses (kg ha^{-1}).

Based on these data, a graph was created in the Cartesian plane to group the cultivars according to their efficiency and response to the application of P. P use efficiency was represented on the abscissa axis, and the index of response to its application was represented on the ordinate axis. The efficiency and average response of the cultivars determined the point of origin. From this, the four quadrants were categorized as follows: quadrant I – efficient and responsive cultivars; quadrant II - non-efficient and responsive cultivars; quadrant III - non-efficient and non-responsive cultivars; quadrant IV - efficient and non-responsive cultivars.

Table 2 shows the productivity values of the table cassava genotypes studied at the minimum and maximum dose of phosphate fertilizer in each harvest evaluated (SILVEIRA et al., 2023).

Table 2. Productivity of table cassava cultivars fertilized with doses of 0 and 240 kg P_2O_5 ha^{-1} in two agricultural seasons.

Season	Cultivar	Root productivity	
		0 kg P_2O_5 ha^{-1}	240 kg P_2O_5 ha^{-1}
		kg ha^{-1}	
2018/2019	Água Morna	48,498	47,153
	BRS Gema de Ovo	48,965	39,885
	Recife	56,960	42,685
	Venâncio	10,160	21,388
Media		41,146	37,778
2019/2020	Água Morna	44,185	64,253
	BRS Gema de Ovo	47,865	40,688
	Recife	45,088	53,220
	Venâncio	20,630	39,715
Media		39,442	49,469

RESULTS AND DISCUSSION

According to the grouping of the four table cassava cultivars regarding their classification in efficiency and response to P fertilization in two agricultural harvests, it was found that, of the four cultivars evaluated, three repeated the same response pattern in both harvests (Água Morna, BRS Gema de Ovo and Venâncio), and only one cultivar (Recife) showed a change in behavior between the crops evaluated (Figures 2A and 2B).

The cultivar Água Morna was classified as “efficient and responsive” in the two harvests evaluated (Figures 2A and 2B), expressing above-average productivity (41146 and 39442 kg ha^{-1} in the 2018/19 and 2019/20 harvests, respectively) in soils with low available P content and without application of phosphate fertilizer, indicating the efficiency of its root system in absorbing and using this nutrient. Furthermore, with the supply of the nutrient, application of a dose of 240 kg ha^{-1} of P_2O_5, the plant responded and increased its root production. It is a cultivar recommended for environments with low P availability and for crops using phosphate fertilizer.

The Venâncio cultivar proved to be “non-efficient and responsive” (Figures 2A and 2B). This implies that, in the absence of phosphate fertilizer and under conditions of low available P in the soil, the cultivar had below-average productivity. However, when the nutrient was supplied, the cultivar responded and achieved an increase in productivity. In the 2018/19 harvest, in the absence of phosphate fertilizer, the cultivar had a productivity of just over 10000 kg ha^{-1}, reaching 21,388 kg ha^{-1} with a dose of 240 kg ha^{-1} of P_2O_5, a percentage increase of 110%. In the 2019/20 harvest, productivity went from 20630 kg ha^{-1} (0 kg ha^{-1} of P_2O_5) to 39715 kg ha^{-1} (240 kg ha^{-1} of P_2O_5), an increase of 92.5%, highlighting the capacity of response to phosphate fertilization of this cultivar.

Therefore, this same cultivar was the one that obtained the highest Response Index value in the first harvest, 47.00 kg kg^{-1} (Figure 2A), and the second highest in the second harvest, 80.00 kg kg^{-1} (Figure 2B). Thus, for each kg of P_2O_5 applied, the plant produced 47 and 80 kg more roots, respectively in the 2018/19 and 2019/20 harvests.

The BRS Gema de Ovo cultivar maintained the same pattern in the two agricultural crops evaluated, behaving as “efficient and non-responsive” (Figures 2A and 2B), suggesting that it is a genetic material that has an efficient root system in absorbing P in the soil, as even in situations of low availability, it managed to obtain productivity above the observed average (Table 2). At the same time, it signals that it is a cultivar that requires little P to have high productivity, since the supply of a high dose of the nutrient did not necessarily result in an increase in productivity. It is an interesting feature for producers considering all the complexity that exists involving the availability, cost and acquisition of fertilizers, being an option for planting planning with low demand for phosphate fertilizers. Soares, Sediyama and Matsuo (2020) emphasize that efficient and non-responsive cultivars should be prioritized in conventional genetic improvement programs.

The Recife cultivar showed “efficient and non-responsive” behavior in the 2018/19 harvest and “efficient and responsive” behavior in the 2019/20 harvest (Figures 2A and 2B). In other words, it is a cultivar, like Água Morna and BRS Gema de Ovo, that produced above average even with low P availability in the soil, but that changed its behavior pattern in according to the supply of the nutrient between harvests. In the 2018/19 harvest, it did not respond to the application of P, but achieved productivity gains of almost 20% with the supply in the 2019/20 harvest. According to the analysis, before cultivation, it was observed that the P available in the soil in the 2019/20 harvest area represented less than half of the amount available in the first harvest (Table 2), which may justify this responsive aspect in the 2019/20 harvest for this specific cultivar.

The Recife cultivar showed a different classification pattern between the two crops evaluated, as shown previously (Figures 2A and 2B). The difference observed in P content between the two environments (Table 1) possibly justifies this distinction. In areas cultivated with cassava with levels between 3.88 and 9.33 mg dm^{-3}, similar to this study, Sarr et al. (2019) observed variation in the composition of mycorrhizal fungi. This composition is also influenced by the cultivars used (BEGOUDE et al., 2016), highlighting the fact that this variation was observed for only one cultivar.

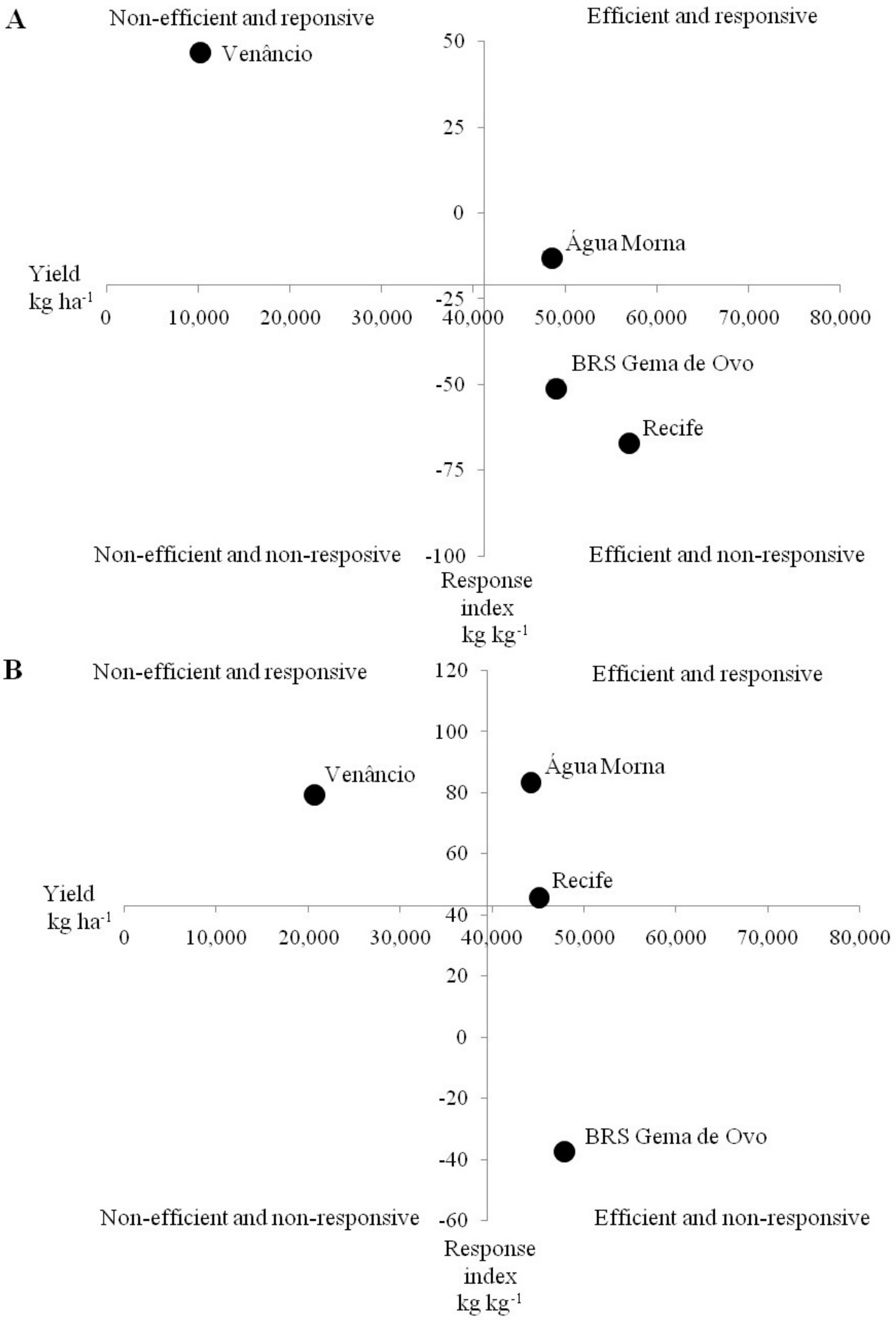

Figure 2. Classification of table cassava cultivars based on efficiency in use and response to phosphorus application on root productivity in two agricultural harvests, (A) 2018/19 and (B) 2019/20.

None of the table cassava cultivars evaluated were classified as non-efficient and non-responsive (Figures 2A and 2B). This finding is relevant, as it suggests that such materials can be cultivated in regions with low P availability in the soil and/or can respond positively to the supply of this nutrient, resulting in increased productivity.

Results of research that evaluated the use of P in different crops have shown that cultivars of the same species showed different performances in terms of efficiency and response to the use of this nutrient. Among these results, the following stood out: Almeida et al. (2019), working with five cowpea cultivars (Paulistinha, BRS Xiquexique, Pingo de Ouro, Corujinha and Costela de Vaca) and doses of 0 and 60 kg ha^{-1} P_2O_5; and Jesus et al. (2021), evaluating carrot cultivars (Brasília, Planalto, Suprema and Nativa) at doses of 0 and 180 kg ha^{-1} P_2O_5.

Cultivars classified as efficient in the use of P are recommended for environments with low availability of the nutrient and for producers who use a low technological package in their crops (FIDELIS et al., 2015). These are cultivars that have a low demand for P to carry out their metabolic activities (JESUS et al., 2021), representing a strategic action in the efficiency of phosphate fertilization in areas of low natural fertility of this nutrient (ARDON et al., 2022) and obtaining high productivity even under nutrient limitation (BALEMI; NEGISHO, 2012). In turn, cultivars classified as responsive are recommended for producers who adopt high technological packages, since the crop will respond to the application of the nutrient.

The classification of the genotypes Água Morna, BRS Gema de Ovo and Recife as efficient allows them to be recommended for locations with P-deficient soils.

Efficient cultivars exploit a greater volume of soil to absorb P through modifications in the architecture and growth of the root system, such as producing a larger root system, longer root hairs or through association with mycorrhizal fungi (BALEMI; NEGISHO, 2012). In addition to making P adsorbed in the soil available through the exudation of organic anions and protons, these cultivars have low internal demand for the nutrient.

CONCLUSIONS

The cultivar Água Morna was classified as efficient and responsive in terms of P use, while BRS Gema de Ovo was efficient and non-responsive, and Venâncio, non-efficient and responsive.

The Recife cultivar was classified as efficient and non-responsive in terms of P use in the 2018/19 harvest, and efficient and responsive in the 2019/20 harvest, showing that the performance of a genotype can vary between harvests depending on the chemical characteristics of the soil.

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