Original Research Article

Phosphate Fertilization in Amaranth Culture cv. BRS Alegria in Second Harvest in the Cerrado

ABSTRACT

Vegetable species, capable of diversifying production in the second crop of the Cerrado, producing grains rich in protein and providing dry matter for off-season, are most welcome. The amaranth presents these characteristics, however its cultivation is little known in Brazil. The adequate availability of nutrients for this plant, under cerrado conditions, has not yet been defined and these soils, in turn, are of low natural fertility, deficient, mainly, in phosphorus. Before this senary, the present work was developed with the objective of evaluating agronomic and productive aspects of amaranth cv. BRS Alegria, cultivated in succession to soybean, underwent increasing doses of phosphorus. The experimental design was a randomized complete block design with five levels of phosphorus (0, 30, 60, 100 and 150 kg.ha^{-1} of phosphorus - triple superphosphate) applied in the sowing furrow, with four replications. Plant height was evaluated; stem diameter; panicle length; final population of plants; phosphorus content in leaf tissue; mass of dry matter of panicle, stem, leaf and total and; grain yield. The model with higher R^2 in the regression analysis was selected to express the behavior of the phosphorus doses on the evaluated characteristics. The phosphorus applied in the sowing furrow increases productivity and phosphorus content in the amaranth foliar tissue in succession to the soybean crop. The highest estimated productivity of amaranth grains was obtained with 98.7 kg ha^{-1} of P_2O_5, with values close to the level of economic response to the application of the input.

Keywords: Amaranthus cruentus, biomass and grain yield, phosphate.

1. INTRODUCTION

The agricultural exploration in the Brazilian Cerrado is structured in the cultivation of soybean, corn and cotton in succession crop/second crop. The insertion of new plant species producing high aggregate and residual value of straw in appreciable quantity and quality, aiming the maintenance of the system throughout the agricultural years is a necessity. In this sense, the amaranth culture presents favorable development under conditions of high temperatures and low precipitation [1], with biomass production and forage potential [2 and 3].

The cultivation of amaranth, still incipient in Brazil, presents the perspective of establishing itself as an alternative for the rotation of crops, diversifying the productive systems and creating opportunity for healthier diets [4].

In Brazil, Embrapa Cerrados (DF) tested several amaranth genetic materials for food production, grain diversification and green manuring in the off-season, as well as no-till use [5, 6 and 7]. The cultivar BRS Alegria is available for seed commercialization [3]. Early sowing and the occurrence of rainfall in April and May contribute to the development of cover crops in the off season [8].

Grains and leaves of amaranth have high crude protein levels ranging from 18.88% [9] to 21.92% [10], allied to the high biological quality measured by the essential amino acids, also supplying fibers and minerals, mainly calcium. Therefore, the demand for and insertion of this pseudocereal in foods for healthy eating grows [11, 12 and 13]. With the greater demand for healthier diets, especially for people with gluten intolerance, amaranth grain can be used in the manufacture of flour, breakfast cereals, pasta and biscuits [11,12 and 14].

The Brazilian soils are of low natural fertility, especially in phosphorus (P), because the clay fraction has minerals with high adsorption capacity of this element and the strong interaction of the element with the soil [15 and 16]. Phosphorus is found at low concentrations in the soil solution, causing limitation of biomass productivity in tropical soils [15]. In the literature, the reported cases where the effect of P doses on amaranth culture [17 and 18] were studied under field conditions. Therefore, the information on residual P, after soybean cultivation, is not sufficient for a correct positioning on its management in the amaranth culture in succession, when aiming at economic yield.

The objective of this work was to evaluate the agronomic and productive aspects of amaranth cv. 'BRS Alegria' cultivated in succession to soybean cultivation under increasing doses of P in Dystrophic Yellow Red Latosol in Lucas do Rio Verde, Mato Grosso, Brasil.

2. MATERIALS AND METHODS

The experiment was installed at the Rio Verde Technological Research and Development Foundation, located at the geographical coordinates 12°59'48 "S and 55°57'49" W, with an altitude of 387 meters, in the municipality of Lucas do Rio Verde – Mato Grosso, Brasil, on a dystrophic Yellow Red Latosol [19], in no-till sowing of the soybean crop. Chemical and granulometric analysis (0 to 0.2m depth) revealed the following results: pH in $CaCl_2$ = 5.5; P = 12.1 mg dm^{-3}; K = 109.0 mg dm^{-3}; Ca_2 + = 2.5 cmolc dm^{-3}; Mg 2 + = 1.1 cmolc dm-3; Al_3 + = 0.0 cmolc dm^{-3}; H + Al = 2.5 cmolc dm^{-3}; V% = 61; Sand = 571 g kg^{-1}; Silt = 104 g kg^{-1} and Clay = 325 g kg^{-1}.

The experimental design was in randomized complete blocks, with five treatments and four replications. The treatments consisted of five doses of P applied in the pre-sowing groove (0, 30, 60, 100 and 150 kg ha^{-1} of P_2O_5, in the form of triple superphosphate) after demarcation of plots and rows of sowing. The experimental plot consisted of five rows of sowing, 5.0 m long and spaced 0.45 m apart. The meteorological data of temperature, atmospheric relative humidity and rainfall during the execution of the experiment are in Figure 1.

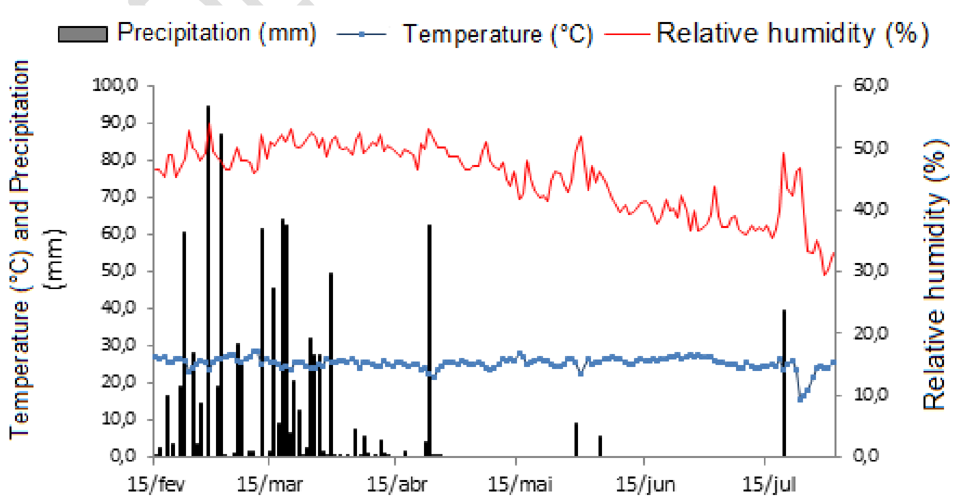

Figure 1. Mean daily temperature (°C), atmospheric relative humidity (%) and total daily rainfall (mm) between 15/02 and 26/07/2013 in Lucas do Rio Verde, Mato Grosso, Brazil

Seeding was performed on 05/03/2013 manually by adopting the seed mix with sand, in the proportion of 1:250, and a device made with disposable bottles (PET) with a hole in the lid (Figure 2). allowing sowing in the appropriate quantity of the mixture aiming to reach the population of 180,000 plants per hectare.

Figure 2. Apparatus developed for sowing amaranth using PET bottle in Lucas do Rio Verde, Mato Grosso, Brazil

Pest and disease control was performed as needed through periodic assessments. Weed control was performed by desiccation before sowing with 2.0 L ha^{-1} glyphosate. They were applied from 0.5 L ha^{-1} of haloxifope® to the control of monocotyledonous plants at 25 days after emergence (DAE) and manual weeding to control dicotyledons. At 20 DAE, manual thinning of the plants was performed aiming at plant density of 180,000 plants per hectare. At 25 DAE, 60 and 60 kg ha^{-1} of N and K_2O in the form of urea and potassium chloride, respectively, were applied.

The evaluated characteristics were: plant height (AP, in meters); stem diameter (DC, in millimeters); panicle length (CP, in millimeters); mass of panicle dry matter (MSP, in g); mass of the stem dry matter (MSC, in g); mass of leaf dry matter (MSF, in g); mass of the total dry matter (MST, in g); final population of plants (POP, in plants ha^{-1}); phosphorus content in leaf tissue (P content in mg kg^{-1}) and productivity (PROD, in kg ha^{-1}).

For the evaluation of the P content in the leaf tissue, sampling was performed at 55 DAE, according to Figure 3. The collected material was ground (Willey, sieve with a mesh of 0.33 mm) for laboratory determinations. The concentration of phosphorus (P) was determined according to [20]. For the evaluation of AP, DC, CP, MSP, MSC, MSF, five plants were sampled in the two central lines of each plot at 90 DAE. The agronomic components were separated and subjected to drying in a forced ventilation oven at 65°C until reaching a constant mass and then weighed. MST was obtained from the sum of MSP, MSC and MSF.

Figure 3. Leaf sampling in *Amaranthus cruentus* cv. 'BRS Alegria' in Lucas do Rio Verde, Mato Grosso, Brazil

RESULTS AND DISCUSSION

The plant population remained within the expected range in all experimental plots (Figure 4), with 177,000 plants.ha^{-1} or 17.7 plants.m^{-2}, justified by coefficients of variation below 10%.

32 DAE 47 DAE

85 DAE Post harvest

Figure 4. Plants of *A. cruentus* cv. BRS Alegria in the test with different doses of P at different stages in Lucas do Rio Verde, Mato Grosso, Brazil

No significant effects were observed on plant height, stem diameter, panicle length and dry matter of the panicle as a function of the application of different doses of P in 'BRS Alegria' amaranth (Table 1). There was, however, a tendency to increase plant height and stem diameter from the 30 kg ha^{-1} dose of P relative to the control. The effects on these parameters can also be explained by the decomposition of the soybean residues and the fertilizations used in previous years, resulting in the P content in soil of 12.1 mg dm^{-3}, which is considered as a compliant medium [23].

Table 1. Effect of different doses of phosphorus (P_2O_5) on the agronomic characteristics of *A. cruentus* cv. 'BRS Alegria'. Lucas do Rio Verde, Mato Grosso, Brazil

Doses of P_2O_5	AP	DC	CP	MSP
(kg ha^{-1})	--- m ---	--------- mm ---------		-- g pl^{-1} --
0	1.26	10.8	318.7	4.46
30	1.34	11.4	337.7	4.77
60	1.39	12.0	329.2	4.80
100	1.41	12.3	322.0	5.47
150	1.34	12.3	348.5	5.28
Média	1.35	11.7	331.2	5.15
C.V. (%)	5.7	7.6	7.7	21.6

AP - plant height; DC - stem diameter; CP - panicle length; MSP - panicle dry matter mass. C.V.(%) coefficient of variation.

A linear increase of leaf dry mass was observed as the P doses, with a maximum value of 6.88 g pl^{-1} for 150 kg ha^{-1} of P (Figure 5), were increased. This value did not result in higher plant height and amaranth stem diameter as a function of the P doses. This fact may be associated with the initial nutrient contents in the soil, supplying the need for the initial development of the plant.

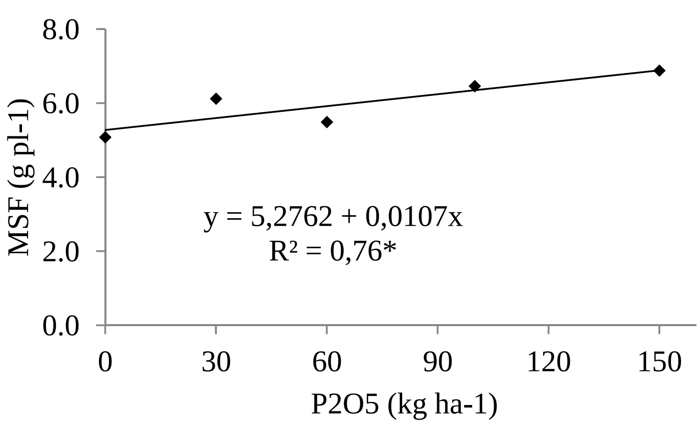

Figure 5. Plants of A. cruentus cv. BRS Alegria in the test with different doses of P at different stages in Lucas do Rio Verde, Mato Grosso, Brazil

The mass yields of the dry matter of the stem and total dry matter adjusted to the quadratic model of response to the increase of P, where the dose of 84.2 and 103.5 kg ha^{-1} of P_2O_5 presented the maximum estimated yields of 13, 8 and 26.0 g plt^{-1} of amaranth cv. 'BRS Alegria', respectively (Figure 6). According to [24] in areas under no-tillage with the use of soil cover plants in succession, the increase in organic matter contents can reduce the adsorption of phosphorus to the soil, which is one of the major problems with phosphate fertilization in soils of the Cerrado.

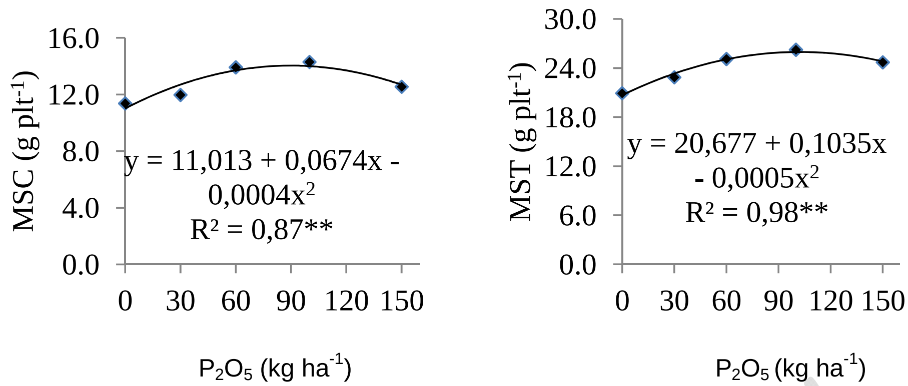

Figure 6. Mass of the dry matter of stalk (MSC) and mass of the total dry matter (MST) as a function of different doses of P_2O_5 in the culture of *A. cruentus* cv. BRS Alegria in Lucas do Rio Verde, Mato Grosso, Brazil. *Coefficient of Variation of 7.5 and 7.7% for MSC and MST, respectively.

P content in leaf tissue increased linearly as P doses increased, reaching 4.06 mg kg^{-1} for application of 150 kg ha^{-1} of P_2O_5 (Figure 7). However, this dose was not enough to reach the highest level of phosphorus in the leaf tissue of this study. According to [25], phosphate fertilization increased linearly the P concentrations in the leaf tissue and the yield of the soybean crop in two consecutive harvests up to the dose of 160 kg ha^{-1} reaching a content of 6.0 mg dm^{-3}. In legumes, P deficiency decreased the yield potential by lower flower production and seed pods with lower mass [26,27 and 28].

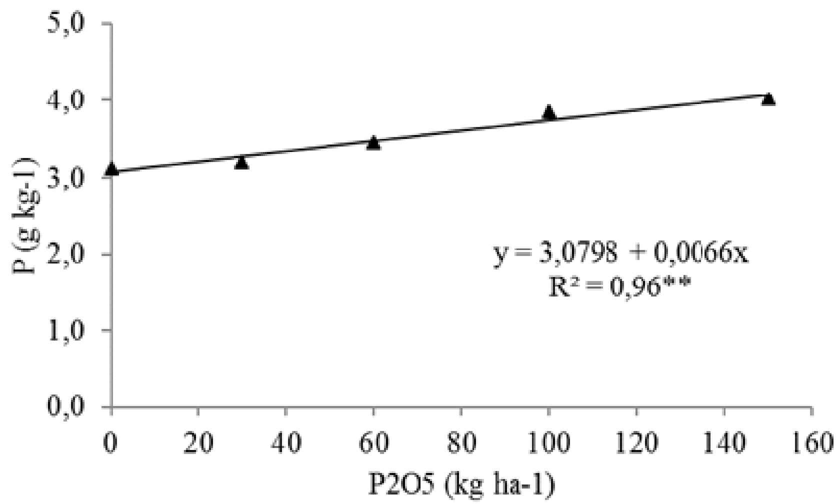

Figure 7. Phosphorus content in the leaf tissue of *A. cruentus* cv. BRS Alegria due to different doses of P_2O_5 in Lucas do Rio Verde, Mato Grosso, Brazil

The grain yield averages were adjusted to the quadratic model of regression (Figure 8), where the derivative of the equation calculated the dose of 98.7 kg ha^{-1} of P_2O_5, for a maximum estimated productivity of 1690.14 kg ha^{-1} of amaranth grains 'BRS Alegria'. The productivity drop beyond this value may have occurred due to a zinc deficiency, induced by the high concentration of phosphorus in the sowing furrow as observed [29] in soybean. In addition, the nutritional imbalance in the crop can reduce the initial growth of the roots [30].

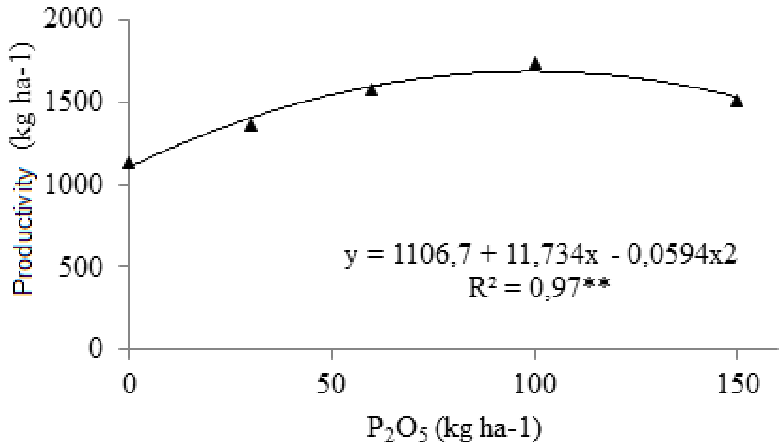

Figure 8. Productivity of A. cruentus cv. BRS Alegria due to increasing doses of P_2O_5 in Lucas do Rio Verde, Mato Grosso, Brazil

The formula obtained for the dose of maximum economic efficiency was:

$$Dose\ P_2O_5 = \frac{11{,}734 - Y}{0{,}1188}$$

where Y is the relationship between input and output prices. Thus, the most economical dose of P_2O_5 was 94.8 kg ha^{-1}, for Y = 0.46, with yield of 1,686.1 kg ha^{-1} of amaranth grains, representing an increase of 579.4 kg ha^{-1} in relation to the absence of the input. This dose represented 96% of that responsible for maximum productivity, indicating that amaranth responds economically to the use of P_2O_5, even in areas where the level of P is high.

In a study carried out in Sorriso, MT, with the BRS Alegria sour amaranth seeded in succession to the soybean crop without the use of phosphate fertilization in different soil management systems, the average yield was 923.0 kg ha^{-1} [31]. According to [3] in work performed with amaranth cv. BRS Alegria seeded in succession to soybean in Goiás, obtained 2,000 kg ha^{-1} of grain yield with application of 60 and 80 kg ha^{-1} of P_2O_5 and K_2O, respectively. In a study conducted in Malaysia, [17] in Malaysia, they concluded, for the purpose of fertilizer recommendation, that 50 kg of P ha^{-1} (114.57 kg.ha^{-1} of P_2O_5) was the most adequate for the production of leaves and grains of amaranth. In another experiment, with phosphorus doses, conducted in hot and humid Nigerian regions, similar to the Brazilian Cerrado, [18] obtained the best grain yield using 100 kg ha^{-1} of P_2O_5. According to the results obtained in other studies, it can be verified that the doses of maximum productivity, as a function of phosphorus content, are close to those found in this study, regardless of the location and pre-existing phosphorus levels.

The search for new species of cover crops in the Cerrado region and the correct technical positioning, aiming at high production of dry biomass and high grain yield in the second crop should be constant. Thus, greater diversification of grain yield and nutrient intake by plants of different species in the soil-plant system over the agricultural years is expected.

4. CONCLUSION

The phosphorus applied in the sowing furrow increased yield and P content in leaf tissue in amaranth cv. BRS Alegria, in succession the soybean crop, even with medium to high levels of soil phosphorus.

The highest estimated total dry mass of the plant (26.2 $g.plant^{-1}$) and grain (1,700 $kg.ha^{-1}$) of amaranth was obtained with 98.7 kg ha^{-1} of P_2O_5.

The higher estimated productivity of amaranth grains was obtained with values very close to the level of economic response to the application of the input.

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