Original Research Article

Agronomic Evaluation of Amaranthus (*Amaranthus cruentus* cv. BRS Alegria) in Times and Seed Densities

ABSTRACT

The genus Amaranthus comprises several species of the Amaranthaceae family whose leaves and seeds are regularly consumed as food by populations in several countries, among which Brazil is not yet included. The objective of this work was to evaluate the productive potential of amaranth (*Amaranthus cruentus* cv. BRS Alegria) as a function of different seasons and sowing densities in succession to the soybean crop in the region of Lucas do Rio Verde, MT. The experimental design was a randomized block design, with four replications, in a 5x4 factorial scheme. The first factor refers to the five sowing seasons (16/02/2013; 02/26/2013; 05/03/2013; 03/20/2013 and 05/04/2013) and the second factor the four sowing densities (11.4, 20.0, 28.5 and 37.1 ppt m^{-2}). The evaluated characteristics were: plant height (AP, in meters); stem diameter (DC, in millimeters); panicle length (CP, in millimeters); dry panicle mass (MSP, in g); dry mass of stalk (MSC, in g); sheet dry mass (MSF, in g); total dry mass (MST, in g); final population of plants (POP, in plants ha^{-1}); productivity (PROD, in kg ha^{-1}). The experimental data were submitted to analysis if variance and when significant F was the Tukey test to compare the means. There was no difference in sowing density between the seasons, thus validating the variation of the desired sowing density between the seasons. The obtained real population and the different seasons of sowing were adopted as sources of variation of the other evaluated attributes. The later sows determined a longer time interval between sowing and panicle emission, as well as harvesting. The cumulative precipitation until the panicle and harvesting emission showed a great reduction as a function of the planting times. It is concluded that the productivity of the Amaranth crop is influenced directly by the number of plants per square meter and by the sowing season in succession the soybean crop.

Keywords: cover plant, soybean, succession.

.

1. INTRODUCTION

The genus Amaranthus comprises several species of the Amaranthaceae family whose leaves and seeds are regularly consumed as food by populations in several countries, among which Brazil is not yet included. The amaranth (*Amaranthus spp*) is a granífera adapted to produce in regions with high insolation and high temperature [1], conditions of saline stress [2] and hydric [3] and adapts also to altitudes that go from the level of the sea up to 3,500 m [4].

The use of new plant species is important to compose the diversity of productive systems for food purposes [5]. Amaranth is an interesting choice because it has fast growth, tolerates water deficiency, has high C/N ratio and diversity of use [6]. Amaranth can be used in the protection of the soil and as fodder, in the off-season, and its grains destined to human and animal feeding. Their cultivation may also be justified by their nutritional characteristics, such as high protein content in grains, ranging from 14 to 16.6% [7,8 and 9].

The ease of growth at high temperatures and low rainfall conditions, the presence of some varieties that express salt tolerance and aluminum toxicity in acid soil are important factors for the introduction of amaranth into the production system in cerrado soils [10]. In this sense, several genotypes of *Amaranthus cruentus* present high stability of production and adaptation to different environmental conditions [11]. The granifera species stand out due to the rapidity of growth and production, allowing the cultivation under conditions of moisture scarcity in the reproductive phase [12].

Another advantage of the cultivation of this Amaranthaceae lies in the fact that when belonging to another family of plants its introduction would be an alternative for crop rotation. In work under controlled conditions, resistance of the granitic amaranth was verified when sown in areas with high infestations of *Meloidogyne incognita* [13]. According to [14] the potential benefits of crop rotation contribute to increase crop productivity and production stability in the face of biotic and abiotic stresses, as well as to rationalize the use of inputs. Grain amaranth (*Amaranthus cruentus*) cultivation in the cerrado is recent. There is not enough information about the crop management, in relation to the plant population and sowing season, in succession to the soybean crop. Depending on cultivar and environmental conditions, yields between 1,000 and 2,359 kg ha^{-1} have been obtained under Brazilian cerrado soil conditions [15]. In the south of the country, yields of up to 4,500 kg ha-1 were obtained [16]. However, there is still little information on the adequate density of plants for the development of the crop, as well as its productivity [1]. [17] observed increased productivity and development of amaranth culture with increased plant density. Other researches, however, show that there was no effect of sowing density [18].

The cultivation of amaranth could replace that of maize in the productive system of crop of second crop and/or second harvest in those years in which there is water deficit. However, although the literature considers amaranth as a plant resistant to drought, information about its behavior in the second crop is scarce and this recommendation depends on studies that prove the potential of production of this pseudo cereal under conditions of water stress. To do so, it is necessary to develop experiments involving sowing times and population density, in crops of second harvest, in succession to soybean or corn.

The objective of this study was to evaluate the productive potential of amaranth (*Amaranthus cruentus* cv. BRS Alegria) as a function of different seasons and seed densities in succession to soybean cultivation in the region of Lucas do Rio Verde, MT.

2. MATERIAL AND METHODS

The experiment was installed at the Rio Verde Technological Research and Development Foundation, located at the geographical coordinates 12°59'49 "S and 55°57'47" W, with an altitude of 387 meters, in the municipality of Lucas do Rio Verde - MT. The experimental area had a Dystrophic Yellow Red Latosol and the sowing was done directly on residual straw from the soybean crop. The soil chemical analysis (0 to 0.2 m depth) allowed the following results to be obtained: pH in $CaCl_2$, equal to 5.5; P = 19.1 mg dm^{-3}; K = 109.0 mg dm^{-3}; Ca_2 + = 2.5 cmolc dm-3; Mg2+ = 1.1 cmolc $dm^{-3;}$ Al_3 + = 0.0 cmolc dm^{-3}; H + Al = 2.5 cmolc dm^{-3} and V%=61. The meteorological data of temperature, relative air humidity and rainfall during the execution of the experiment can be observed in Figure 1.

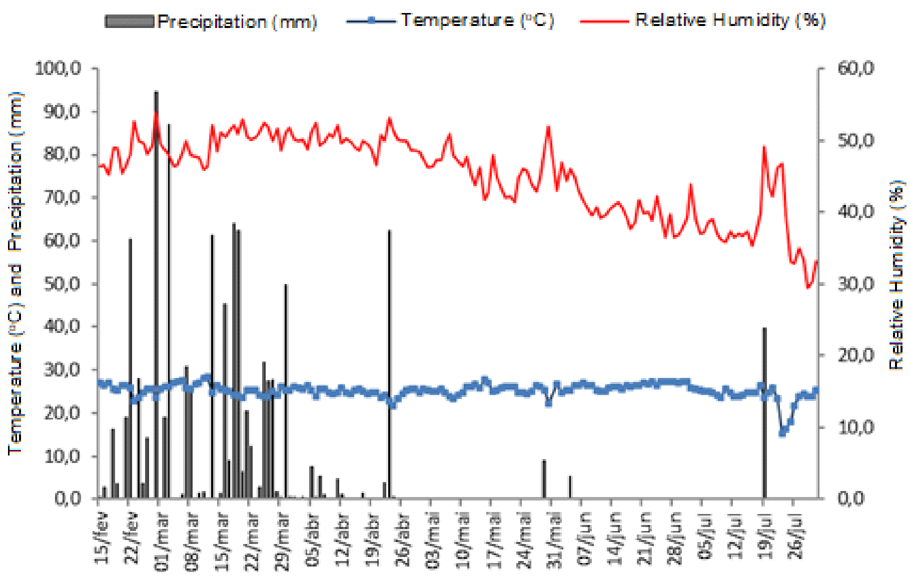

Fig. 1. Mean daily values of temperatures (°C), relative air humidity (%) and total daily precipitation (mm) occurred during the period from February 15 to July 26, 2013 in Lucas do Rio Verde, Mato Grosso, Brazil

The experimental design was a randomized block design, with four replications, in a 5x4 factorial scheme, with 5 sowing times, 4 sowing densities, totaling 80 plots. The sowing times (PE) of *Amaranthus cruentus* cv. BRS Alegria were: EP1 - 16/02/2013; EP2 - 26/02/2013; EP3 - 05/03/2013; EP4 - 20/03/2013 and EP5 - 05/04/2013. Seed densities were: 11.4 (114,000 plt ha^{-1}), 20,0 (200,000 plt ha^{-1}), 28,5 (285,000 plt ha^{-1}) and 37,1 (371,000 plt $ha^{-1)}$ plants per square meter. The experimental plot consisted of four rows of plants, 5.0 m long, spaced 0.35 m apart (Figure 2).

At the sowing stage, 60 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O were applied to the sowing furrow. The sowing was done manually using the mixture of 1 part of seed to 250 parts of fine sand, disposed in disposable bottles (PET) with a hole in the lid that allowed the sowing of the adequate amount of the mixture, by linear meter, aiming to achieve the necessary plant populations. Pest and disease control was performed as needed through periodic assessments. Weed control was performed by sowing desiccation with 2.0 L ha^{-1} glyphosate and a 0.5 L ha^{-1} application of Haloxifope® to control monocotyledonous plants at 25 days after sowing (DAS) and manual weeds for the control of dicotyledons. At 20 DAS of each season the manual thinning of the plants was carried out according to the desired population. At 25 DAS, fertilization was carried out with 60 and 50 kg ha^{-1} of N and K_2O in the form of urea and potassium chloride respectively.

Post-planting amaranth **Amaranth at 40 DAP and 25 DAP**

Panicle emission **Test overview**

Fig. 2. Amaranthus BRS Alegria in different vegetative and reproductive stages in Lucas do Rio Verde, Mato Grosso, Brazil

The evaluated characteristics were: panicle emission (EP, in days); harvest (CO, in days); plant height (AP, in meters); stem diameter (DC, in millimeters); panicle length (CP, in millimeters); dry panicle mass (MSP, in g); dry mass of stalk (MSC, in g); sheet dry mass (MSF, in g); total dry mass (MST, in g); final population of plants (POP, in plants ha^{-1}); productivity (PROD, in kg ha^{-1}).

For the evaluation of AP, DC, CP, MSP, MSC, MSF, five plants were sampled in the two central lines of each plot, being separated the agronomic components, dried in a forced ventilation oven at 65°C until reaching a constant mass. heavy. The MST was obtained from the sum of MSP, MSC and MSF. The evaluation of PE was performed through the difference of days between planting and PE when the plot presented about 50% of the plants with visible panicles. The number of days for CO was counted when the plots were at harvest point. For the POP and PROD evaluations all the plants of the two central lines of the plot were considered, the two lateral lines and 1.5 m of the edges were neglected. The harvested material was then manually harvested and the grain cleaning was carried out through a wind tunnel adapted to a domestic fan.

The experimental data were submitted to analysis of variance and regression through the SisVar software application v.4.2 [19]. In the significance of the analysis of variance and regression the probability level of 5% was considered by the F test.

3. RESULTS AND DISCUSSION

The initial plant density was 114,000, 200,000, 285,000 and 371,000 plants per hectare. However, the actual population obtained was 106,786, 187,143, 262,500 and 358,214,000 plants per hectare (Table 1). No statistical difference was observed for sowing density between the seasons, thus validating the variation of the desired sowing density between the seasons. Thus, the real population obtained and the different seasons of sowing were adopted as sources of variation of the other evaluated attributes.

Table 1. Final population of plants as a function of sowing season in *A. cruentus* cv. BRS Alegria, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Population (plt ha^{-1})				Average
	114,000	200,000	285,000	371,000	
EP1	105,357	173,214	257,142	353,571	222,312

EP2	112,500	196,428	266,071	360,714	233,928
EP3	105,357	189,285	260,714	362,500	229,464
EP4	107,142	189,090	260,714	357,142	228,571
EP5	103,571	187,500	267,785	357,142	229,464
Average	106,786 d	187,143 c	262,500 b	358,214 a	

** Averages followed by the same lowercase letter, in the row, do not differ by the Tukey Test at 5% probability. The coefficient of variation was 6.10%.*

The number of days for panicle emission and for harvesting was not influenced by the plant population. However, it was found that the sowing times employed in this experiment caused differences in the number of days for panicle emission and amaranth harvest (Table 2). The later sows determined a longer time interval between sowing and panicle emission, as well as harvesting. The cumulative precipitation up to panicle and harvesting showed a great reduction due to planting times, indicating that the late plantations had a smaller amount of water, which could have caused water restriction to the crop. This possible water restriction from EP4 may indicate the non-recommendation of amaranth planting as of the second decade of February.

Table 2. Time interval, in days, between sowing until panicle emission (EP) and amaranth (CO) harvest, according to sowing season and cumulative rainfall (H), in mm, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Time interval (days)		H (mm)		
	EP	CO	EP	CO	Accumulated
EP1	43.0 C	84.2 B	470.2	86.0	556.2
EP2	45.0 BC	84.2 B	432.2	43.4	475.6
EP3	48.0 AB	86.0 B	311.8	45.4	357.2
EP4	51.2 A	87.0 B	273.6	14.0	287.6
EP5	52.0 A	92.0 A	55.8	14.0	69.8
Average	47.9	86.7	308.72	40.56	349.28

**Averages followed by the same capital letter in the column do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 4.0% and 2.0% for EP and CO, respectively.*

The reaction of plants to external factors such as water stress and excessive population may be related to the intrinsic genetic characteristics of accessions for the same species of amaranth [20]. In this work, there was no influence of photoperiod on *Amaranthus cruenthus* BRS Alegria. The variations between the number of days of germination until the panicle emission and until the harvest were caused by the water deficiency on the crop, delaying the plant cycle. For the same region, the number of days between emergence and maturation may vary with latitude and sowing time, indicating that there is genetic variability in *Amaranthus cruentus* for response to photoperiod and demand for nutrients, especially nitrogen [21 and 22].

No differences were observed in PA as a function of plant population density, but the sowing season effect was observed for this evaluated characteristic (Table 3). The sowing in EP5 presented a lower AP in relation to the other treatments, indicating that the water restriction was intense shortly after the panicle emission. Despite the reduction of the size to EP4, there was little limitation in the average growth of the plants, indicating that it is a plant that actually supports severe water stresses after the panicle emission.

For cultivar BRS Alegria, [15] obtained maximum plant height at 60 days after plant emergence, between 1.0 and 1.3 m, depending on the amount of nutrients applied.

According to [10], plant height is an important parameter for mechanized harvesting of this crop, indicating that late sowing would not be recommended for mechanized harvesting.

Table 3. Plant height (AP), in (m) according to the plant population and the sowing time of the Amaranth, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	1.42	1.37	1.36	1.28	1.35 A
EP2	1.31	1.38	1.24	1.13	1.26 B
EP3	1.25	1.16	1.14	1.20	1.19 B
EP4	1.10	1.11	1.05	1.08	1.08 C
EP5	0.54	0.56	0.57	0.58	0.56 D
Average	1.12	1.12	1.07	1.05	

**Averages followed by the same capital letter in the column do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 8.20%.*

There was no significant interaction between the factors tested for CD, only effects of factors isolated from the populations and seasons of sowing (Table 4). Plant densities above 26.2 plt m^{-2} presented lower DC in relation to the smaller populations employed in this experiment, in this sense, high populations do not reduce the AP of the amaranth, but the DC. Evaluating the effect of sowing times on the DC, a reduction was verified as a function of the times used in this experiment. This fact was expected, since according to [23], the CD of amaranth is defined 40 days after emergence and allows inferences about the growth and reproduction of the culture. In this experiment, it was observed that sows from EP3 presented low volume of rainfall until the panicle emission, which occurred near the period of expression of maximum DC of amaranth. In general, the late sows presented lower DC and no cultivations were verified as a function of the reduction of DC during sowing seasons.

Table 4. Mean diameter of stem (mm) as a function of plant population and sowing time of soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	15.4	13.2	12.8	12.2	13.4 A
EP2	12.1	12.2	11.1	9.6	11.2 B
EP3	12.9	11.0	10.6	10.4	11.2 B
EP4	9.5	8.4	8.8	8.1	8.7 C
EP5	6.0	5.6	5.3	5.8	5.7 D
Average	11.2 a	10.1 ab	9.7 b	9.2 b	

*Averages followed by the same lowercase letter in the line and upper case in the column do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 16.70%.

Significant interaction was observed for panicle length (CP) as a function of sowing times and plant populations (Table 5). In general, CP decreased as a function of sowing times, regardless of plant density, except for the density of 10.6 plt m^{-2}, where there was no difference in CP between EP1 and EP2. The effect of the plant population on EP2 was observed only at the densities of 18.7 and 35.8 plt m^{-2} the lowest CP was obtained. The size of the panicle reflects the environment where the plant develops and depends on the population employed, soil fertility, water stress and sowing time [24].

Table 5. Panicle length (mm) according to the plant population and the sowing time of the Amaranth, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	360.0 Aa	375.0 Aa	368.0 Aa	356.0 Aa	365.0
EP2	353.0 Aa	326.0 Bbc	342.0 Bab	316.0 Bc	334.0
EP3	277.0 Ba	282.0 Ca	271.0 Ca	284.0 Ca	279.0
EP4	159.0 Ca	178.0 Da	177.0 Da	163.0 Da	169.0
EP5	90.0 Da	93.0 Ea	93.0 Ea	96.0 Ea	93.0
Average	248.0	250.0	250.0	243.0	

**Averages followed by the same lowercase letter in the line, and upper case in the column, do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 5.10%.*

It was observed a higher dry matter yield of stalk in EP1 and EP2 in relation to the other sowing times, with a marked decrease in the production of MSC in EP5, according to Table 6. When evaluating the effect of the population within the seasons of higher spore production was observed at sowing densities of 35.8 plt m^{-2} not differing from 26.2 and 10.6 plt m^{-2} and the lowest in the density of 18.7 plt m^{-2} within the EP2. The other sowing times did not differ in the MSC due to the increase in plant density per square meter. The increase in the number of plants per area has been shown to limit the dry weight of stem and leaves per plant in amaranth [24].

Table 6. Dry stalk mass (g plt^{-1}) as a function of plant population and sowing time of Amaranth, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	27.9 Aa	27.0 Aa	28.9 Aa	27.1 Aa	27.7
EP2	25.9 Aab	24.8 ABb	26.3 ABab	28.0 Aa	26.3
EP3	23.1 Ba	23.8 Ba	24.6 Ba	22.8 Ba	23.6
EP4	15.2 Ca	15.7 Ca	15.1 Ca	16.7 Ca	15.7
EP5	10.9 Da	9.1 Da	9.2 Da	8.8 Da	9.5
Average	20.6	20.1	20.8	20.7	

**Averages followed by the same lowercase letter, in the line, and upper case, in the column, do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 6.50%.*

For MSF data, there was a significant interaction between the factors tested (Table 7). The production of MSF showed a marked decrease from EP3, reaching the production of MSP of 4.51 g plt^{-1} in EP5. The low productivity of MSF in EP5 is directly related to the volume of rains accumulated at this time until the physiological maturity of amaranth. When we evaluated the effect of the population within the sowing season, we had higher SPS production at the seeding densities of 18.7 and 26.2 plt m^{-2} in EP1, and in EP2 the SPS was higher in the sowing density of 10 , 6, 18.7 and 26.2 plt m^{-2} relative to the density of 35.8 plt m^{-2}. In EP3, higher MSF was observed at densities of 18.7, 26.2 and 35.8 plt m^{-2}. The other sowing times did not differ in MSC due to the increase in plant density per linear meter. According to [23], in the last 30 days preceding the physiological maturation that occurs at 90 DAS the plants play their role of maximum leaf area production, that is, grain yield, influenced by growth parameters and leaf area, is defined in this short period.

Table 7. Dry leaf mass (g plt^{-1}) as a function of plant population and sowing time of Amaranth, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	13.7 Ab	15.4 Aa	14.0 Aab	13.4 Ab	14.1
EP2	11.5 Bab	10.8 Cab	12.1 Ba	10.5 Bb	11.2
EP3	11.8 Bb	13.5 Ba	13.5 ABa	12.9 Aab	12.9
EP4	8.6 Ca	9.9 Ca	8.5 Ca	9.4 Ba	9.1
EP5	4.4 Da	4.41 Da	4.6 Da	4.5 Ca	4.5
Average	10.0	10.8	10.6	10.2	

**Averages followed by the same lowercase letter, in the line, and upper case, in the column, do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 7.48%.*

When evaluating MSP as a function of sowing times, we observed a statistical difference in all sowing seasons, indicating that this is a highly sensitive variable to the water deficit found at different sowing times (Table 8). In EP1, EP4 and EP5 had no statistical difference as a function of the different sowing densities. In EP2 a lower MSP production was observed in the density of 35.8 plt m-2, not differing from the densities of 10.6 and 18.7 plt m^{-2}. In EP3 we had higher MSP production at densities of 18.6 plt m^{-2} compared to 10.6 plt m-2, not differing from 26.2 and 35.8 plt m^{-2}. The increase of the plant population between 30 and 62.5 plants per square meter in the spacing of 0.4 m between rows, in general, resulted in a decrease in the weight of the panicles [24], corroborating with that already found by [25]. This fact may be associated with greater competition for nutrients by plants in the sowing line.

Table 8. Dry matter of panicle (g plt^{-1}) as a function of plant population and sowing time of amaranth, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	15.9 Aa	15.9 Aa	16.5 Aa	16.8 Aa	16.2
EP2	13.7 Bab	13.8 Bab	14.8 Ba	13.1 Bb	13.8
EP3	9.3 Cb	11.9 Ca	10.7 Cab	10.3 Cab	10.5
EP4	6.5 Da	6.8 Da	7.8 Da	7.5 Da	7.1
EP5	4.6 Ea	4.9 Ea	4.0 Ea	4.9 Ea	4.6
Average	10.0	10.6	10.7	10.5	

**Averages followed by the same lowercase letter, in the line, and upper case, in the column, do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 7.60%.*

Significant interaction for MST was observed as a function of the factors tested (Table 9). It was observed a reduction of the MST as a function of sowing times in a progressive manner at densities of 10.6, 26.2 and 35.8 plants per square meter. At the density of 18.7 plt m^{-2} no differences were observed between EP2 and EP3 in the production of MST. In EP1, EP4 and EP5 there was no influence of plant density per square meter, however, in EP2 a higher MST was observed in the density of 26.2 plt m^{-2} in relation to 18.7 plt m^{-2}, did not differ from the densities of 10.6 and 35.8 plants per square meter. In the EP3, lower MST production was observed in the densities of 10.6 and 35.8 plt m^{-2}, with the best results being obtained in intermediate populations of 18.7 and 26.2 plants per square meter.

Table 9. Total dry mass (g plt ^{1}) according to the plant population and the sowing time of Amaranth, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	57.5 Aa	58.4 Aa	59.4 Aa	57.4 Aa	58.2

EP2	51.1 Bab	49.4 Bb	53.3 Ba	51.8 Bab	51.4
EP3	44.3 Cb	49.3 Ba	48.9 Ca	46.0 Cab	47.1
EP4	30.3 Da	32.4 Ca	31.5 Da	33.7 Da	31.9
EP5	19.9 Ea	18.3 Da	17.8 Ea	18.2 Ea	18.6
Average	40.6	41.6	42.2	41.4	

**Averages followed by the same lowercase letter, in the line, and upper case, in the column, do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 4.50%.*

The production of amaranth grains showed a significant interaction between the factors tested (Table 10). Sowing from EP4 did not show a productive gain due to the increase in population density. In the sowing carried out in EP1, a productivity of 2,521 kg ha^{-1} was observed in the density of 18.7 plt m^{-2}, not differing from the density of 26.2 plt m^{-2}, however, in the density of 10.6 and 35, 8 plt m^{-2} presented reduced productivity in relation to the intermediates. In the sowing performed EP2 at the density of 26.2 plt m^{-2} showed the highest productivity, with 2,327 kg ha^{-1}, in relation to the other populations employed. There was a trend of higher yields in sows after EP3 in treatments with densities above 18.7 plt m^{-2}.

Table 10. Amaranth productivity (kg ha^{-1}) as a function of plant population and sowing time, on soybean straw, in Lucas do Rio Verde, Mato Grosso, Brazil

Time	Density of plants (plt m^{-2})				Average
	10.6	18.7	26.2	35.8	
EP1	1,772.0 Ab	2,521.2 Aa	2,268.7 Aa	1,777.3 Ab	2,084.8
EP2	1,580.5 Ac	2,327.1 Aa	1,905.7 Bb	1,383.9 Bc	1,799.3
EP3	986.4 Bb	1,592.1 Ba	1,378.7 Ca	1,302.3 Ba	1,314.9
EP4	274.4 Ca	398.2 Ca	348.9 Da	436.8 Ca	364.5
EP5	218.4 Ca	301.9 Ca	325.0 Da	409.3 Ca	313.6
Average	966.3	1,428.1	1,245.4	1,061.9	

**Averages followed by the same lowercase letter, in the line, and upper case, in the column, do not differ from each other by the Tukey Test at 5% probability. The coefficient of variation was 13.30%.*

Amaranthus BRS Alegria productivity in the plantations carried out on 20/03 and 05/04/2013 increased linearly due to the increase in seed density, presenting a better response with 35.8 plt m^{-2} (Figure 3A and 3B). The low productivity observed at these times highlights the importance of the use of higher sowing density in late plantings.

In the plantations carried out on 16/02, 26/02 and 03/03/2013, the quadratic regression model was adjusted, where by the derived of the equation, the seed density of 24.0, 22.8 and 26 was calculated, 2 plants per square meter as responsible for the estimated maximum production of 2,470.3, 2,199.0 and 1,540.2 kg ha^{-1} of amaranth grains BRS Alegria (Figure 3E, 3D and 3C), respectively.

Several authors have obtained an increase in grain yield with increasing plant density [17] and this fact is usually affected by ambient conditions [26]. On the other hand, there are studies showing little change in productivity in different plant population ranges, or even no response to grain yield related to plant density [18]. The authors cited in the reference [1] suggest that the plant compensates for environmental variations, with the allocation of more energy to the plant reproductive organs, restricting stem diameter and minimizing the effect of competition for water and solar radiation.

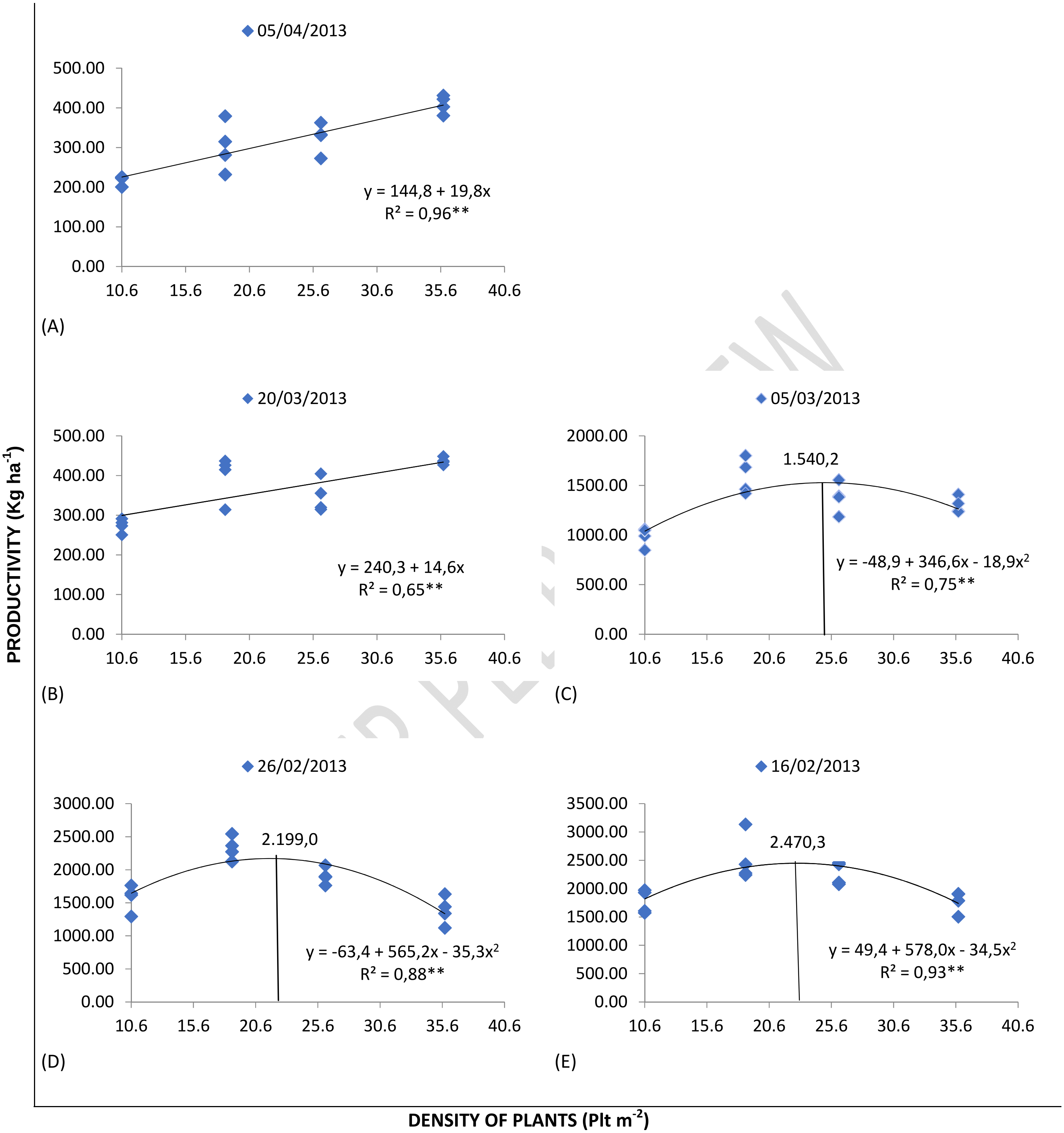

Fig. 3. Productivity of the BRS Alegria amaranth according to the season and the seed density, in Lucas do Rio Verde, Mato Grosso, Brazil. (A) – 05/04/2013; (B) – 20/03/2013; (C) – 05/03/2013; (D) – 26/02/2013 e (E) – 16/02/2013.

In a study carried out in Bolivia with A. caudatus, [27] observed that, with increasing plant density per unit area, an increase in yield was obtained. The authors cited in the reference [28] states that in excessively high populations, competition for moisture and nutrients reduces grain yield.

Results of research that determine the optimal spacing of the crop to achieve maximum productivity have been inconclusive [29]. The response of grain yield to plant density was influenced by the environment, species and cultivars [30, 31, and 32]. The authors cited in the reference [29] reported a decrease in production in a population greater than 210,000 pl ha^{-1}. However, [32] identified a much higher ideal plant density, between 323,000 and 360,000 ha^{-1} plt. According to [33] the low plant density can cause nitrate leaching or volatilization of ammonia, because the nitrogen changes in the soil are very fast and complex, increasing the losses of this nutrient in the system, reducing the productive potential in these low sowing densities.

4. CONCLUSION

The number of plants per square meter and the sowing time of Amaranth BRS Alegria directly influenced the productive parameters evaluated in the conditions of cultivation in succession to soybean.

The sowing density with greater productive potential of the BRS Alegria Amaranth was obtained with 24.2 and 22.8 plants per square meter for sowing performed on 16/02/2013 and 26/02/2013.

In the sowing carried out on 05/03/2013 it is recommended to use the density of 26.2 plants per square meter of Amaranth BRS Alegria.

Seeds from March 20, 2013 had low productive potential and linearly responded to the increase in plant density.

COMPETING INTERESTS

We declare that no competing interests exist.

REFERENCES

1. Guillen Portal, F.R., Baltensperger D.D, Nelson L.A. (1999): Plant population influence on yield and agronomic traits in Plainsman grain amaranth. In: Janick J. (Ed.): Perspectives on New Crops and New Uses. ASHS Press, Alexandria: 190 - 193.

2. Macler, B., Bamberg, E., Moffatt, E., Bui, H., Minor, E., & Nishioka, L. (1990). Effects of salinity and nitrogen on growth, productivity and food value of Amaranthus in controlled culture.

3. Omami, E. N. Response of amaranth to salinity stress. 2005. 255 f. Thesis (Ph.D. Horticulture). Department of Plant Production and Soils Science. Faculty of Natural and Agricultural Sciences. University of Pretoria. South Africa.

4. Teixeira, D. L .; Spehar, C.R .; Souza, L. A. C. Agronomic Characterization of Amaranth for Cultivation in the Cerrado. Pesquisa Agropecuária Brasileira, v.38, n.01, p.45-51, 2003.

5. Bianchini, M.G.A. Influence of thermal treatments on the physical, chemical, biological and technological properties of whole grain flours of Amaranthus cruenthus. Londrina, State University of Londrina, 2011. 125 p.

6. Spehar, C.R .; Santos, R. L. B .; Souza, P. I. M. New cover plants for the grain production system. In: International Seminar on the Direct Planting System, 2., 1997, Passo Fundo. Anais Passo Fundo: Embrapa / CNPT, 1997. p.169-172, 1997.

7. Bianchini, M.G.A .; Beléia, A.D.P .; Bianchini, A. Modification of the chemical composition of whole flours of amaranth grains after the application of different thermal treatments. Rural Science, v.44, p.167-173, 2014.

8. Capriles, V.D. et al. Effects of processing methods on amaranth starch digestibility and predicted glycemic index. J Food Sci, v.73, n.7, p.H161-H164, 2008.

9. Gamel, T.H. et al. Effect of seed treatments on the chemical composition of two amaranth species: oil, sugars, fibers, minerals and vitamins. Journal of the Science of Food and Agriculture, v.86, p.82-89, 2006.

10. Erasmo, E.A.L .; Domingos, V.D .; Spehar, C.R .; Didonet, J .; Sarmento, R.A .; Cunha, A.M. Evaluation of amaranth cultivars (Amaranthus spp.) Under no-tillage system in the south of Tocantins. Bioscience Journal, Uberlândia, v.20, n.1, p.171-176, 2004.

11. Garcia-Pereyra, J. Valdés-Lozano, C.G.S .; Alejandre-Iturbidse, G .; Fierro, I.V .; Gómez, O.G.A. Interaction genotype x environment and stability analysis in amaranth genotypes (Amaranthus spp.) Oyton, v.60, p. 167-173, 2011.

12. Spehar. C. R. Amaranth: option to diversify agriculture and food. Brasília, DF: Embrapa Information Technology, 30p., 2007.

13. Asmus, G.L., Inomoto, M.M., Sazaki, C. S. S., & Ferraz, M.A. (2005). Reaction of some cover crops used in the no-tillage system to Meloidogyne incognita. Nematologia Brasileira, 29 (1), 47-52.

14. Franchini, J.C., Costa, J.D., & Debiasi, H. (2011). Rotation of crops: practice that gives greater sustainability to agricultural production in Paraná. Inf. Agron, 134, 1-13.

15. Domingos, V.D .; Erasmo, E.A.L .; Silva, J.I.C .; Cavalcante, G.D .; Spehar, C.R. Growth, grain yield and biomass of amaranth cultivars (Amaranthus cruentus) as a function of fertilization with NPK. Bioscience Journal, Uberlândia, v.21, n.3, p.29-39, 2005.

16. Brambilla, T.R .; Constantino, A.P .; Oliveira, P.S. Effect of nitrogen fertilization on amaranth production. Semina: Agrarian Sciences, Londrina, v.29, n.4, p.761-768, 2008.

17. Peiretti, E. G., and J. J. Gesumaria. "Effect of interrow spacing on growth and yield of amaranth (Amaranthus spp.)." Agricultural Research. Production and Protection of Vegetables (Spain) (1998).

18. Myers, R.L. Amaranth: New crop opportunity. In: JANICK, J., ed. Progress in new crops. Alexandria, ASHS Press, 1996. p.207-220.

19. Ferreira, D.F. Sisvar: a computer statistical analysis system. Science and Agrotechnology (UFLA), v. 35, n.6, p. 1039-1042, 2011.

20. Bond, J.A .; Olivier, L.R. Comparative growth ol Palmer amaranth (Amaranthus Palmieri) accessions. Weed Science, v.54, p.121-126, 2006.

21. Gimplinger, D.M .; Dobos, G .; Schönlechner, R .; Kaul, H.P. Yield and quality of grain amaranth (Amaranthus sp.) In Eastern Austria. Plant Soil Enviroment, v.53, n.3, p.105-112, 2007.

22. Earley, G.S .; Kaul, H.P. Kruse, M; Aufhammer, W. Yield and nitrogen utilization efficiency of the pseudocereals amaranth, quinoa, and buckwheat under differinf nitrogen fertilization. European Journal of Agronomy, 22, p.95-100, 2005.

23. Teixeira, D.L. Growth, reproduction and effect of loss of leaf area on amaranth cv. BRS Joy. (Masters dissertation). University of Brasília, Brasília, DF, 86p., 2011.

24. Ferreira, C.C., 2012. Effect of plant density and nitrogen rates on yield, phenology and organomineral composition of amaranth in Cerrado Latosol (Master's Dissertation). University of Brasília, Brasília, DF, 61p. 2012.

25. Fitterer, S.A., Johnson, B.L., Schneiter, A.A., 1996. Grain amaranth harvest timeliness in eastern North Dakota. In: Janick, J. (Ed.), Progress in New Crops. ASHS Press, Alexandria, VA, p. 220-223.

26. Henderson, T.L .; Johnson, B.L .; Schneiter, A.A. Row spacing, plant population, and cultivar effects on grain amaranth in the northern Great Plains. Agronomy Journal, v.92, p.329-336, 2000.

27. Apaza-Gutierrez, V .; Romero-Saravia, A .; Guillen Portal, F.R .; Baltensperger, D.D. 2002. Response of grain amaranth production to density and fertilization in Tarija, Bolivia. p.107-109. In: Janick, J. and Whipkey, A. (Eds.), Trends in new crops and new uses. ASHS Press, Alexandria, VA, 599p.

28. Weber, L.E., Applegate, W.W., Johnson, D.L., Nelson, L.A., Putnam, D.H., Lehman, J.W., 1989. Amaranth Grain Production Guide. Rodale Press, Emmaus, PA.

29. Robinson, R.G. Amaranth, quinoa, ragi, tef and niger: tiny seeds of ancient history and modern interest. Station Bulletin. AD-SB-2949. Agricultural Experiment Station, University of Minnesota, St. Paul, 1986.

30. Putnam, D.H. Agronomic practices for amaranth, p. 151-162. In: Proc. 4th National Amaranth Symposium. Rodale Press, Emmaus, PA, 1990.

31. Edwards, A.D; Volak, B. Grain amaranth: optimization of field population density, p. 91-94. In: Proc. 2nd Amaranth Conference. Rodale Press, Emmaus, PA, 1980.

32. Haas, P.W. Amaranth density report. Rodale Research Center Report No. RRC / NC-83-8. Rodale Press, Emmaus, PA, 1983.

33. Moreira, F.M.S. & Siqueira, J.O. Microbiology and soil biochemistry. Lavras: UFLA publisher, 729p. 2006.