

EFFECTS OF PLANTING POSITION AND *Azospirillum brasilense* APPLICATION ON THE INITIAL GROWTH OF CASSAVA (*Manihot esculenta* Crantz)

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ABSTRACT

This work aimed to evaluate the effect of the strick planting position and *Azospirillum brasilense* application on the initial growth of cassava. The assay was carried out following a completely randomized experimental design, with factorial arrangement (planting positions [horizontal (HP) and vertical (PV)] and the *A. brasilense* [with (+Azos) and without (-Azos)]). The sprouting percentage (SP) was evaluated from 11 to 35 days after planting (DAP). After 30 DAP, the following variables were evaluated: sprouts number (SN), sprouts height (SH), number of leaflets (NL), length of leaflets (LL), and vegetative vigor (VV). Cassava plants positioning significantly influenced the initial growth. PV promotes a greater sprouting, 63% in 17 DAP, over the PH which was only 3% of the visible shoots during the same period. Here we show for the first time that PV promoted the highest values combined with -Azos in the variables SH (an increase of 17%) and VV (an increase of 61%). The PH, in combination with +Azos, stimulated the NL in 20%. The sub-division into three VV groups allowed identify the existence of differences among the treatments which were not seen in an independent ANOVA being VV an important variable for the initial growth evaluation in cassava.

Keywords: initial development, production technology, vegetal vigor.

INTRODUCTION

The culture of cassava (*Manihot esculenta* Crantz) is of great importance worldwide, constituting a subsistence food (FAO, 2019). The largest cassava producers all over the world are Nigeria, Congo, Ghana, Thailand, Indonesia, and Brazil; with a production that exceeds the 292 million tons produced in 2017 (FAO, 2019). In Brazil, cassava is produced in almost all regions, emphasizing Bahia, Mato Grosso do Sul and Pará. According to the latest update from the Brazilian Institute of Geography and Statistics (IBGE), the estimate of the Brazilian production of cassava root in 2020 is of 18.92 million tons, harvested in an area of 1.26 million hectares (CONAB, 2020). Brazil constitutes the largest center of diversity of the genus *Manihot* (Allem, 2002) and it is considered the probable center of the cultivated species origin all over the world (Olsen, 2004). In Brazil, although cassava crops have shown adaptation to different agroecosystems, and the specific adaptation to edaphoclimatic conditions in some regions (Otsubo *et al.*, 2009), this crop is considered unresponsive to fertilization management (Vieira *et al.* 2007), encouraging farmers to plant it without fertilizers.

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Nutritional management is one of the main aspects to be considered for a better performance of the cassava culture. An adequate supply of macronutrients nitrogen (N), phosphorus (P), and potassium (K) has been instrumental in obtaining increased yields in the crop (Soares *et al.*, 2016). Among them, nitrogen management influences hydrocyanic acid (dos Santos *et al.*, 2005) and productive performance (Santos *et al.*, 2014; Oliveira *et al.*, 2017). Along with this performance associated with N, the use of bacteria and its contribution to culture was tested (Balota *et al.*, 1999; Ferreira *et al.*, 2018). The successful performance in employing bacteria of the genus *Azospirillum* has been confirmed by Balota *et al.* (1999), Nascimento *et al.* (2014) and Lopes *et al.* (2019) in cassava, where research has shown the bacteria's ability to fix nitrogen and stimulate plant development. However, the planting time is also essential for obtaining good yields.

The seedlings quality is determined by the size, diameter, conservation period after collection, and planting positioning of the stricks. Generally, farmers plant cassava horizontally in the soil, often with little or no slope, which partly facilitates planting (Normanha and Pereira, 1950; Gabriel Filho *et al.*, 2003). Physiologically, the positioning can stimulate the hormonal balance (auxins and gibberellins) on the other hand when triggering the buds germinating process. As a response, it can also contribute to a fast field closing, avoiding weeds emergency and water losses by evaporation. Studies have shown that vertical planting can contribute to a better agronomic performance of cassava, especially in sandy soils (Viana *et al.*, 2000; Ospina *et al.*, 2002; Cerqueira *et al.*, 2016). In this case, when cassava is planted in vertical planting, there is a greater root deepening. However, no reports show that the growth of sprouting and cassava depends on the planting position and on the association with *A. braziliense*.

Therefore, the present work aimed to evaluate the effects of the strick planting position and the application of *A. braziliense* on the initial growth of cassava.

MATERIAL AND METHODS

Experimental conditions

The experiment was carried out under field conditions. According to Koppen's classification, the region's climate is of tropical rainy type (Aw), with dry winter and rainy summer, with precipitation, average temperature and annual relative humidity of 1,261 mm, 23.97 ° C, 64.23%, respectively (Alvares *et al.*, 2014).

The soil was previously classified as a Dystric Ferralsol (WRB 2015), and Latossolo Vermelho distrófico típico for the Brazilian Soil Survey (Santos *et al.*, 2018), with a clay texture. The soil was sampled at a 0.0-0.20 m and 0.20 – 0.40 m depth before installing the experiment by collecting 30 simple samples to form a composite sample, which was subsequently physical-chemically analyzed. Soil samples were air-dried, crushed, and sieved through a 2.0 mm mesh for physicochemical analysis.

The following parameters were determined: pH in CaCl₂ (0.01 mol L⁻¹); the potential acidity (H+Al), extracted in calcium acetate buffered at pH 7.0, quantified by titration with NaOH; phosphorus (P) and potassium (K⁺), extracted with Mehlich⁻¹ and determined by

colorimetry and flame photometry, respectively; calcium (Ca^{2+}), magnesium (Mg^{2+}) and aluminum (Al^{3+}), extracted with KCl 1 mol L^{-1} and determined by atomic absorption spectrophotometry. These results permitted the calculation of the following parameters: sum of bases (SB) = $\text{Ca} + \text{Mg} + \text{K}$; cation exchange capacity (CEC) = $\text{SB} + \text{H} + \text{Al}$; and base saturation (BS) = $\text{CEC}/\text{SB} \times 100$). The chemical properties of the soil are shown in Table 1.

The soil acidity was mitigated with the superficial application 513 kg ha^{-1} of the limestone (CaO : 29%; MgO : 20%; total relative neutralizing value: 90.1%, compared to calcium carbonate). The liming was carried out 60 days before the implementation of the experiment.

Irrigation was carried out using a drip irrigation system with Streamline Model Netafim hoses, the spacing between emitters of 0.30 m. Irrigation provided a 1.3 L h^{-1} , at intervals of 24 h in the first two weeks, and then applied every 48 h to guarantee the good development of the culture.

Plant material

Cassava sticks used in the experiment were obtained from a producer of the region. A selection was carried out using those plants with approximately 0.02 m in diameter. The sticks were cut at a length of 0.20 m to standardize the plant material. The verification of the material's homogeneity was proven from the initial evaluation of descriptors suggested by Fukuda and Guevara, (1998), measured in all sprouted plants. This evaluation was carried out according to: color evaluation of the apical leaf (notes of 3 - light green, 5 - dark green, 7 - purplish green, and 9 - purple), apical bud pubescence (notes of 0 - absent and 1 - present) and petiole color (notes of 1 - yellowish-green, 2 - green, 3 - reddish-green, 5 - greenish-red, 7 - red, 9 - purple).

Experimental design and treatments

The experimental design used was completely randomized, with 20 repetitions per treatment, in subdivided plots. The treatments consisted of two positions [planting position: horizontal (PH) and vertical (PV)] in the plots and *Azospirillum brasilense* application [with (+Azos) and without (-Azos)] in the subplots. Each plot consisted in two rows spaced 0.6 m apart and 0.5 m between plants.

Table 1. Chemical properties of the soil used in the experiment.

Depth (m)	pH CaCl_2	OM ¹ (g dm^{-3})	P (mg dm^{-3})	H+Al	Al^{3+}	Ca^{2+}	Mg^{2+}	K^+	CEC ²	BS ³ %
					cmol dm^{-3}					
0.00 – 0.20	5.2	27.5	6.0	3.8	0.12	3.20	1.10	0.25	8.4	54.5
0.20 – 0.40	4.8	30.1	5.5	4.8	0.07	2.70	0.80	0.20	8.5	43.5

¹OM: Organic matter; ²CEC: Cation exchange capacity at pH 7.0; ³BS: Base saturation.

The treatments associated to planting position were carried out at the time of planting by placing the seedbed approximately 0.20m long in the pits done with a hoe and leaving the seedlings in the PV with approximately half of its length buried in the soil. PH was wholly buried, maintaining the same spacing for both treatments (Figure 1). *A. brasilense* was applied 15 days after planting with the aid of a 20 L costal pump using doses of 500 ml ha⁻¹. The commercial product used was AZOS containing the liquid inoculant *A. brasilense* Ab-V5 in a concentration of 1 x 10⁸ CFU ml⁻¹. Weed was controlled manually when necessary.

Measured variables

Sprouting percentage (SP) was initially assessed at 11 days after planting (DAP) and at 2-day intervals until 35 DAP. SP was obtained by the average number of sprouts found during the evaluated period.

After 30 DAP, the following variables were evaluated: the sprouts number (SN), when counting sprouts over 0.01m in length in each seedling; sprout height (SH), using a millimeter ruler, the length of the plant base was measured up to the apex of all shoots with a length above 0.01m; the number of leaflets (NL), performed by counting the number of leaflets in the longest sprout per hand and the length of the leaflets (LL), measured on the leaf but developed in the longest bud per hand. Vegetative vigour (VV) was obtained by the product of the four measured variables (SN, SH, NL, and LL) as an indicator of the more significant development of the evaluated plant. The VV values would be grouped into three groups [low VV (66-312), moderate VV (313-482), and superior VV (483-2145)].

Statistic analysis

After collecting data for the measured variables, analysis of variation (ANOVA) of double classification based on a linear model of fixed effects were performed. Also, Pearson's correlation analysis between variables were determined. For the VV variable, three groups

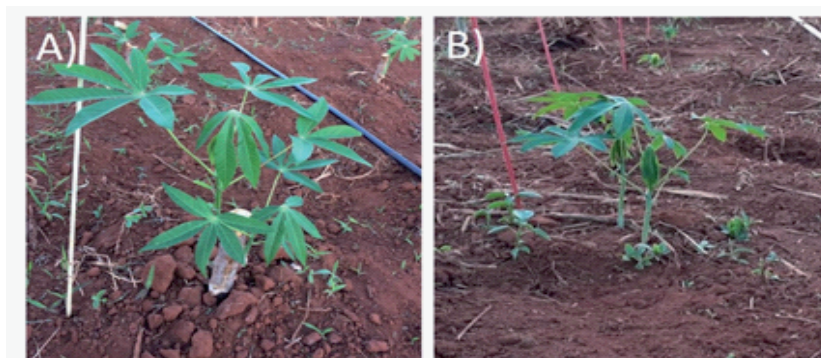


Figure 1. Detail of initial cassava growth at different strick planting position [A) vertical position and B) horizontal position].

of plants were established (grouping the treatments with plants that showed different performance), and after the selection, the comparison of treatments among the three established groups was performed, and cassava performance among those groups of VV was thus evaluated. All analysis were performed using the RBio program (Bhering, 2017), and the Sigma Plot version 11.0 program was used to construct the graphics.

RESULTS AND DISCUSSION

Changes in the sprouting pattern considering the stricks planting position

As a management practice, but common in the cassava culture, planting is usually done horizontally (Gabriel Filho *et al.*, 2003). However, PV accelerated the sprouting in the first 35 DAP in the present assay (Figure 2). The PV promoted the highest sprouting time if we consider that at 17 DAP for this treatment, 63% of the seedlings had sprouted (at least one visible bud). In the PH treatment, a 66% of the plants sprouted at 29 DAP (Figure 3). Viana *et al.* (2000) found, when evaluating the effects of the plants size and planting position on the cassava harvest, that the plants sprouting planted vertically took place at 15 days and had 50% of the plants sprouted; also, this process occurred faster than the inclined planting concerning those planted horizontally (26 days). This study corroborates the previously obtained result, where 14 days were enough to have 50% of the sprouted plants in the PV (Figure 2).

The fastest emergence occurred in the treatments vertically positioned, guaranteeing a rapid development of shoots, which is one advantage of these planting system. In this initial phase, carbohydrate reserves determine the initial development (first 30 DAP), according to Alves, (2006). For cassava in PV, sprouting induction is being stimulated,

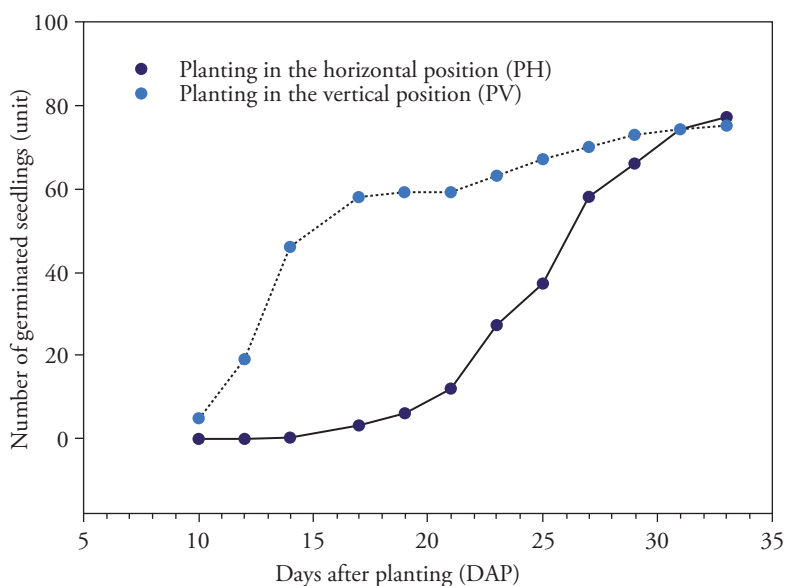


Figure 2. Number of germinated seedlings of cassava at different days after planting, (n = 92).

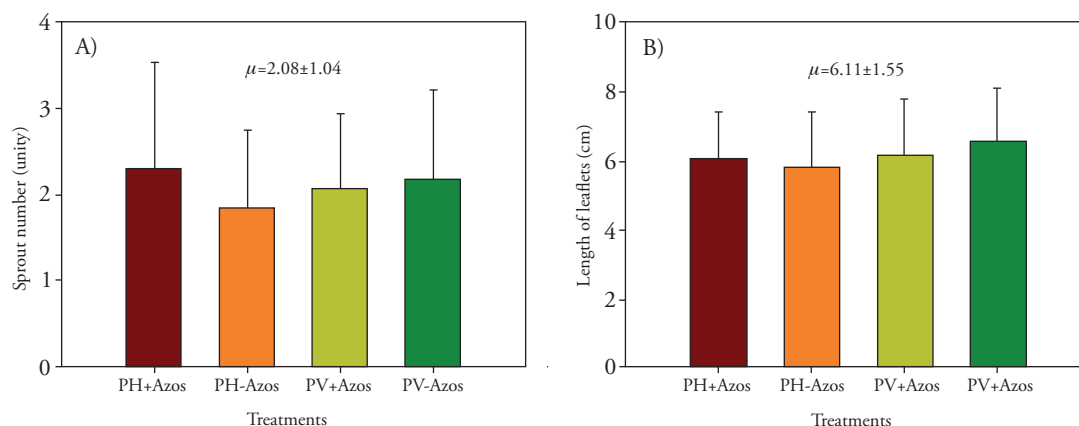


Figure 3. Sprout number (A) and length of leaflets (B) obtained when measuring the effects of the stricks positioning of cassava [horizontal (PH) and vertical (PV)] and the application of *Azospirillum brasilense* [with (+Azos) and without (-Azos)] in experiments conducted in Chapadão de Sul, MS. (n = 46).

possibly due to the better distribution of assimilates associated with the employed position. The rapid sprouting of the plants and growth is also important to prevent the emergence of weed, which reduces herbicide application or use of machinery for weed control during the early growth stages. Simultaneously, it promotes a quick closure of the field, reducing the surface exposed to solar radiation and contributing to the soil moisture maintenance. Ospina *et al.* (2002) recommend the PV under the conditions of Colombia. However, they comment that the disposition of cassava roots when planting the roots horizontally are spacious and with that, the harvest of PV or inclined is easier.

Effect of planting positioning and application of *A. brasilense* on initial growth

When evaluating the stricks positioning and the combination with the absence of the presence of *A. brasilense* applied in the soil, the results showed significant effects of the interaction of both factors for the variables SH ($p < 0.05$), NL and VV ($p < 0.01$) in cassava plants (Table 2). For the variables NS and LL, no significant differences were found in any of the two factors evaluated, showing that for these two variables, regardless of the position of the handles and the presence or absence of *A. brasilense*, the response remains equal (Figure 3). The CVs in most of the variables were of medium to moderate magnitude, except the variables NS (CV=49.92) and VV (CV=70.7), which manifested wide variation in data, thereby influencing the CV values and the accuracy of the data collected in the field.

Figure 3, shows the means of the variables NS and LL, with general averages of 2.8 and 6.11 cm, respectively. The PH associated with +Azos promoted the largest number of shoots (2.29) with respect to the other treatments. The NS formed depends on the soil moisture conditions after planting, with the first roots being produced and then the emerging shoots. The first bud generally develops better due to the stem apical dominance, although this does not prevent the others from showing a specific development, as was shown in Figure 3.

Table 2. Summary of ANOVA when evaluating the effects of stricks positioning at different planting time and the applying *Azospirillum brasilense*.

SV ¹	DF	Medium Squares				
		NS ²	SH	NL	LL	VV
Positioning (P)	1	0.16	7.70	2.86*	6.61	198,718
<i>Azospirillum</i> (A)	1	1.24	0.03	0.02	0.11	273
P x A	1	2.16	20.61*	5.70**	3.23	816,692**
CV (%)		49.92	26.78	16.00	25.17	70.07
Overall Average		2.08	7.93	4.61	6.11	482.00

¹SV: the source of variation, DF: the degree of freedom. ²NS: number of shoots, SH: shoot height, NL: number of leaflets, LL: leaflets length, and VV: vegetative vigor. ³CV: coefficient of variation. *p <0.05, **p <0.01 significant by Tukey post-hoc comparison.

The LL showed the highest values in the treatment with PV and -*Azos* with 6.58 cm, values above the general average of the experiment (6.11 cm); however, without differing PH and +*Azos* (Figure 3b). The largest photosynthetic area in plants can be related to the variable LL, which directly influences the leaf index (LI). Thus, plants with higher LL and LI have a better product performance, of great practical interest for cassava producers.

Comparing the evaluated factors' interactions (Table 3), for the variables SH, NL, and VV. The SH showed significant differences only when comparing the two positions in -*Azos*, emphasizing the PV (8.66 cm) that increased the bud's height by 17% with the PH (Table 3). The results are in agreement with those obtained by Cerqueira *et al.* (2016) when comparing the initial development of 'cocoa' cassava under different stricks positions. The same authors observed a higher plant height in the PV with a 32% difference to the PH ($p < 0.01$), in addition to promoting a larger diameter of the neck, number of leaves, dry mass of leaves and dry mass of the stem.

The NL, among the measured variables, showed significant differences at 1% probability (Table 2) in favor of the combination of +*Azos* with PH (4.94 with a 20% increase) about +*Azos* with PV (Table 3). When observing the same variable, the comparisons

Table 3. Result of the effects of stricks positioning at the time of planting and the application of *Azospirillum brasilense* when measuring the sprout height (SH), number of leaflets (NL), and vegetative vigor (VV).

Positioning	<i>Azospirillum brasilense</i>					
	SH (cm)		NL		VV	
	+ <i>Azos</i>	- <i>Azos</i>	+ <i>Azos</i>	- <i>Azos</i>	+ <i>Azos</i>	- <i>Azos</i>
Horizontal (PH)	8.08 Aa	7.39 Ab	4.94 Aa	4.58 Aa	524.96 Aa	379.14 Ab
Vertical (PV)	7.62 Aa	8.66 Aa	4.10 Bb	4.66 Aa	413.37 Ba	611.11 Aa

+*Azos*: with the application of *A. brasilense*, -*Azos*: without application of *A. brasilense*. Lower case letters in the column and uppercase letters in the row represent significant differences by Tukey post-hoc comparison for $p < 0.01$.

between the positions, the PV showed highly significant differences ($P < 0.01$) with the best performance in *-Azos* (4.66), which represents an increase of 14% concerning *+Azos* with 4.10 (Table 3). NL is associated with plant development and directly related to a larger leaf area, desired characteristic for crop and positively correlated with yield of the reserve roots. Cerqueira *et al.* (2016) found that PV stimulated the largest number of leaves in 'cacao' cassava, with values very close to the inclined position, both of which are higher than HP.

Bacteria of the genus *Azospirillum* can promote plant growth and increase productivity mainly by producing stimulant substances, which contribute to roots development and increase in the rate of water and mineral uptake (El Zembrany *et al.*, 2007; Díaz-Zorita and Fernández-Canigia, 2009). Results showed that when using *+Azos* when combined with the PHs (completely buried in the soil), the effect under the variable NL was higher compared with the PV, showing the positive effect of this bacteria on cassava for this characteristic (Table 3). Other studies have shown good results in cassava culture with the application of bacteria of the genus *Azospirillum* (Nascimento *et al.*, 2014; Lopes *et al.*, 2019). However, the effect of the strick positioning and the combination of these bacteria's application had not been reported.

For the VV variable (Table 3) only in *-Azos* the striks positions differ with the PV providing the most massive increase of 61% in the VV of the plants about the PH. Simultaneously, when observing the comparison in the other direction (among the positions), only differences in PV with better performance in combination with *-Azos*, and an increase for the variable of 48%, were obtained. The results showed that regardless of the direction of the comparison for this variable VV, the combination PV and *-Azos* promoted the plant best quality, considering that the highest values are associated with plants that showed the most significant magnitude for the four characteristics evaluated.

When analyzing the correlations network among the evaluated variables and the VV evaluated at 35 after the beginning of sprouting, the most significant contribution was between SN x VV > SH x VV > LL x VV > NL x VV in the same order (Figure 4). Vegetal vigor, as a variable indicating biomass gain in the initial stages of plant development, can be an indicator of the quality of the seedling (associated with sprouting power of sprouting energy) and water availability, although some plant species do not need high percentages of moisture in the soil to germinate, such as cassava (Pacheco *et al.*, 2020). A high VV represents a satisfactory plant condition to have better development and productivity (Santos *et al.*, 2014).

VV contribution to the total variability in an integrated way

For that, the classification of the original values VV was made by obtaining the three groups [low (66-312), moderate (313-482), and superior (483-2145)] and verified the from a new ANOVA the hypothesis proposed for all measured variables (Table 4).

The ANOVA results confirmed that the effect of the evaluated factors was variable between the three groups formed when considering different groups for the VV values (Table 4). It was observed that in the group of low VV (66-312), the treatments did not influence

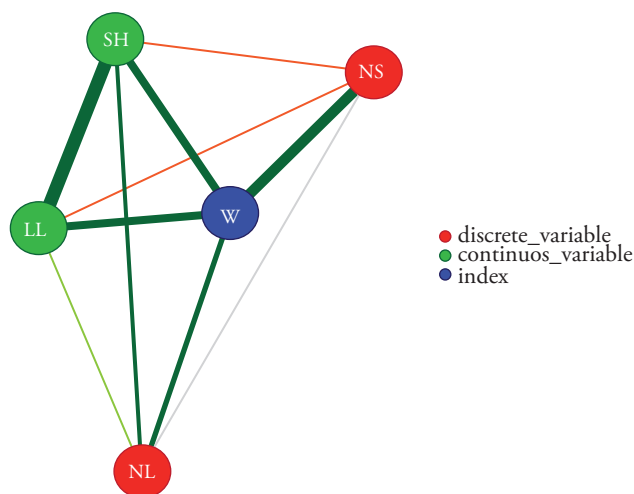


Figure 4. Correlations network between discrete variables [sprout number (SN) and number of leaflets (NL)], continuous variables [shoot height (SH) and length of leaflets (LL)] and the vegetative vigor index (VV) obtained by measuring the effects of the positioning of cassava plants and the application of *Azospirillum brasilense*. (n = 92).

the responses of the plants, whereas for the medium VV (313-482) and superior VV (483-2145), there was only an effect of positioning for the variables NL ($P < 0.01$) and LL ($P < 0.05$), respectively (Figure 5).

The results show that only the strick positioning factor influenced in the general response. However, the same treatment was not always superior among the variables that showed significant differences. The response varied between the two variables, with PH being more favorable for NL and PV but more favorable for LL.

Here we show that vertical strick positioning has a beneficial effect on the initial germination of cassava plants. We show the combination of positioning as the application of *A. brasilense* in the soil influences the development of plants.

CONCLUSIONS

The vertical stricks positioning of cassava promotes sprouting with 63% of seedlings 17 days after planting about 3% of horizontal positioning. Vertical positioning in the absence of *A. brasilense* promotes the highest values in shoot height (an increase of 17%) and vegetative vigor (an increase of 61%) variables. However, horizontal positioning in the presence of *A. brasilense* stimulates the number of leaflets (an increase of 20%).

The evaluation of vegetative vigor was the most precise variable to establish the differences between the treatments that were not observed in isolated way by means of ANOVAs analyses. Given that cassava is a crop that feeds many people daily, the results obtained show a better growth efficiency promoted by the vertical positioning of the plant, thus representing an excellent management option for agriculture.

Table 4. Summary of ANOVA when evaluating the effects of the pliers' positioning at the time of planting and the application of *Azospirillum brasilense* for subgroups formed among the variable vegetative vigor.

SV ¹	DF	Medium Squares				
		SN ²	SH	NL	LL	VV
Groups low VV (66-312)						
Positioning (P)	1	0.68	1.13	0.59	0.42	177
Azospirillum (A)	1	2.21	0.03	0.08	0.62	11,634
P x A	1	0.08	0.69	1.22	1.13	363
CV ³ (%)		49.26	30.87	15.52	24.39	34.78
Overall Average		1.63	6.44	4.09	4.95	188.14
Groups moderate VV (313-482)						
Positioning (P)	1	0.02	1.43	4.07**	0.12	2,467
Azospirillum (A)	1	0.19	4.54	0.14	0.11	24
P x A	1	0.01	1.16	0.16	1.22	495
CV ³ (%)		39.27	19.87	14.56	19.00	13.57
Overall Average		1.71	8.35	4.77	6.50	395.83
Groups superior VV (483-2145)						
Positioning (P)	1	0.54	5.76	1.15	8.14*	169,262
Azospirillum (A)	1	0.31	0.04	0.02	0.02	22,978
P x A	1	0.54	0.00	0.47	0.29	50,122
CV ³ (%)		39.62	20.03	11.79	19.10	37.19
Overall Average		2.81	9.15	5.02	7.03	846.47

¹SV: the source of variation, DF: the degree of freedom. ²SN: sprout number, SH: shoot height, NL: number of leaflets, LL: length of leaflets, and VV: vegetative vigor. ³CV: coefficient of variation. *p <0.05 and **p <0.01 by Tukey post-hoc comparison.

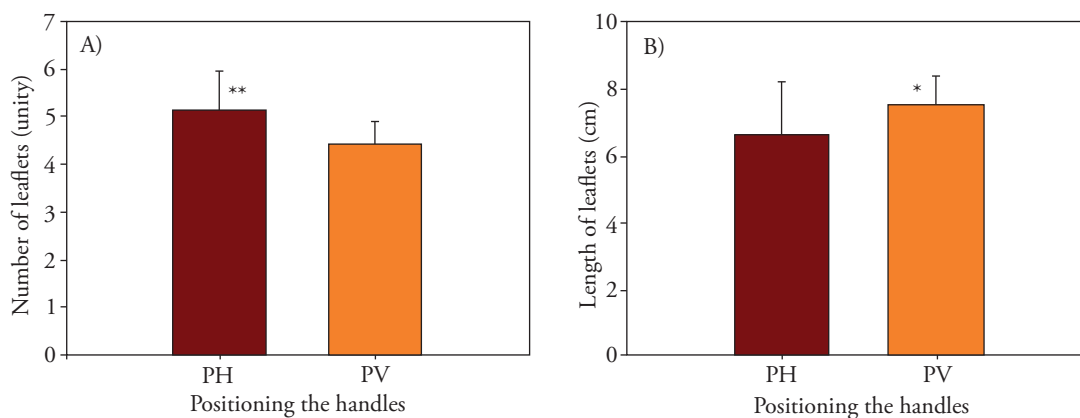


Figure 5. The number of leaflets (A) and length of leaflets (B) obtained when measuring the effects of the positioning of cassava [horizontal (PH) and vertical (PV)] positions for subgroups formed among the variable vegetative vigor [moderate VV (313-482) (A) and superior VV (483-2145) (B)] in experiments conducted in Chapadão de Sul, MS. *P<0.05 and **P<0.01 significant by Tukey post- hoc comparison. (n = 20)

REFERENCES

- Allem AC. 2002. The Origins and Taxonomy of Cassava. In: Hillocks, R. J. and Tresh, J. C. (eds), Cassava: Biology, Production, and Utilization. CAB International, Wallingford, UK. 1-16. 10.1079/9780851995243.0000
- Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek G. 2014. Köppen's Climate Classification Map for Brazil. *Meteorologische Zeitschrift*. <http://dx.doi.org/10.1127/0941-2948/2013/0507>
- Balota EL, Lopes ES, Hungria M, Döbereiner J. 1997. Inoculação de bactérias diazotróficas e fungos micorrízico-arbusculares na cultura da mandioca. *Pesquisa Agropecuária Brasileira* 32(6), 627-639.
- Bhering LL. 2017. Rbio: A Tool For Biometric And Statistical Analysis Using The R Platform. *Crop Breeding and Applied Biotechnology* 17(2): 187-190. <https://doi.org/10.1590/1984-70332017v17n2s29>
- Cerqueira FB, Faria AJG, Santos PF, Carneiro JJS, de Freitas JA, Ribeiro FC. 2016. Desenvolvimento inicial da mandioca 'cacau' sob diferentes posições da maniva. *Tecnologia & Ciência Agropecuária* 10(5): 16-21.
- CONAB (Companhia Nacional de Abastecimento). 2020. Análise mensal, Mandioca, junho de 2020. Companhia Nacional De Abastecimento. Recuperado el 30 de Agosto del 2020, de <https://www.conab.gov.br/info-agro/analises-do-mercado-agropecuario-e-extrativista/analises-do-mercado/historico-mensal-de-mandioca> (accessed 30 August 2020).
- Díaz-Zorita M, Fernández-Canigia MV. 2009. Field performance of a liquid formulation of *Azospirillum brasilense* on dryland wheat productivity. *European Journal of Soil Biology* 45(1):3-11. <http://dx.doi.org/10.1016/j.ejsobi.2008.07.001>
- El Zembrany H, Czarnes S, Hallett PD, Alamercury S, Bally R, Jocteur Monrozier L. 2007. Early changes in root characteristics of maize (*Zea mays*) following seed inoculation with the PGPR *Azospirillum lipoferum* CRT1. *Plant and Soil* 291: 109-118. <http://dx.doi.org/10.1007/s11104-006-9178-0>
- FAO (Food and Agriculture Organization of the United Nations). 2019. Production crops. FAO-Food and Agriculture Organization of the United Nations. Recuperado el 20 de enero del 2020, de: <http://www.fao.org/faostat/en/#data/QC>.
- Ferreira RS, Silva NS, Lima CP, Silva NM, Silva JG, Farias LA, Lopes EP. 2018. Diversidade de bactérias dofiticas associadas à Mandioca (*Manihot esculenta* Crantz). *Revista Craibeiras de Agroecologia* 3 (1), e6707.
- Gabriel Filho A, Strohhaecker L, Fey E. 2003. Profundidade e espaçamento da mandioca no plantio direto na palha. *Ciência Rural* 33(3): 461-467. <http://dx.doi.org/10.1590/S0103-84782003000300011>.
- Kolmogorov AT. 1933. Basic Concepts of Probability Theory. Berlin: Julius Springer. 62.
- Lopes EAP, Silva ADA, Mergulhão ACES, Silva EVN, Santiago AD, Figueiredo MVB. 2019. Co-inoculation of growth promoting bacteria and *Glomus clarum* in micropropagated cassava plants. *Revista Caatinga* 32(1): 152-166. <http://dx.doi.org/10.1590/1983-21252019v32n116rc>.
- Nascimento JML, Santos MRB, Queiroz MAÁ, Yano-Melo AM. 2014. Desenvolvimento vegetativo e associação micorrízica em plantas de mandioca adubadas com resíduo agroindustrial. *Semina: Ciências Agrárias* 35(2): 727-734. <http://dx.doi.org/10.5433/1679-0359.2014v35n2p727>
- Oliveira NT, Uchôa SCP, Alves JMA, Albuquerque JAA, Rodrigues GS. 2017. Effect of harvest time and nitrogen doses on cassava root yield and quality. *Revista Brasileira de Ciência do Solo* 41: e0150204. <http://dx.doi.org/10.1590/18069657rbc20150204>.
- Olsen KM. 2004. SNPs, SSRs, and inferences on cassava's origin. *Plant Molecular Biology* 56: 517-526. <http://dx.doi.org/10.1007/s11103-004-5043-9>.
- Ospina PB, García GML, Alcalde TCA. 2002. Sistemas mecanizados de siembra y cosecha para el cultivo de la yuca. In: Ospina PB, Ceballos H. (eds), La yuca del tercer milenio: sistemas modernos de producción, procesamiento, utilización y comercialización. Centro Internacional de Agricultura Tropical, Consorcio Latinoamericano y del Caribe de Apoyo a la Investigación y Desarrollo de la Yuca, Proyecto IP-3 Mejoramiento de Yuca. pp: 326-340.
- Otsubo AA, Brito OR, Mercante FM, Otsubo VHN, Gonçalves, MA, Telles TS. 2009. Desempenho de cultivares elites de mandioca industrial em área de cerrado do Mato Grosso do Sul. *Semina: Ciências Agrárias* 30 (suplemento 1), 1155-1162.
- Pacheco RIL, Macías MP, Campos FCF, Izquierdo AJR, Izquierdo GAR. 2020. Agronomic and physiological evaluation of eight cassava clones under water deficit conditions. *Revista Facultad Nacional de Agronomía Medellín* 73(1): 9109-9119. <http://dx.doi.org/10.15446/rfnam.v73n1.75402>.
- Santos HG, Jacomine PKT, Anjos LHC, Oliveira VA, Lumberras JF, Coelho MG, Almeida JA, Araújo-Filho J,

- Oliveira JB, Cunha T. 2018. Brazilian Soil Classification System, 5th ed. Rio de Janeiro: Embrapa. 303p.
- Santos, N. S., Alves, J. M. A., Uchôa, S. C. P., Oliveira, N. T., and Albuquerque, J. A. A. 2014. Absorption of macronutrients by cassava in different harvest dates and dosages of nitrogen. *Revista Ciência Agronômica* 45(4): 633-640. <http://dx.doi.org/10.1590/S1806-66902014000400001>.
- Soares MRS, Neto ACA, José ARS, Lima RS, Moreira ES, Prado TR, Silva RA, Moreira GLP. 2016. Effect of weeds on yield loss of cassava plants in response to NPK fertilization. *African Journal of Agricultural Research* 11(5): 356-370. <http://dx.doi.org/10.5897/AJAR2015.10551>.
- Viana AES, Sedyama T, Lopes SC, Sedyama CS, Rocha VS. 2000. Effects of length in stem cutting and its planting position on cassava yield. *Acta Scientiarum* 22(4), 1011-1015.
- Vieira EA, Fialho JF, Silva MS. 2007. Desempenho de variedades de mandioca de mesa no Distrito Federal. Planaltina – DF: Embrapa Cerrados. Boletim de Pesquisa e Desenvolvimento 180. 16 p.