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Levels and times of artificial defoliation on performance of second cycle cassava

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Abstract

The information on behavior of crop linked to defoliation is essential to determine the management of herbivore pests. The aim of this study was to evaluate the performance of cassava as a function of the time and level of defoliation applied in the second cycle of cultivation, that is, after the first year of cultivation in which the crop was naturally submitted to the physiological rest period, caused by low temperatures and pluviometric precipitation typical of the southern Brazilian region. We used a randomized block design in factorial 5 x 5.in which 5 levels of defoliation (0, 25, 50, 75 or 100% of defoliation) were applied at 5 different times of 45, 90, 135, 180, or 225 days after sprouting (DAS) of the stems. The following variables were measured: plant height, stem diameter, number of roots per plant, root mass and amount of starch in the roots. The means were submitted to the F test at 5% of probability and analyzed by the regression test using the Sisvar software. Plant height and diameter were inversely proportional to the degree of defoliation when subjected to treatments, especially when subjected to 100% defoliation at 90 DAS. For the root mass, the more drastic defoliation treatments (100 %), when applied at 132 DAS, led to a low production, whereas only the defoliation levels induced a meaningful reduction in the deposition of starch in roots, showing a linear effect and decreasing according to the increase in defoliation. It can be concluded that defoliation between 90 and 135 DAS at the more drastic levels resulted in a greater root mass loss, regardless of the time of defoliation, caused the greatest losses in the amount of starch, therefore, it is recommended to the producer to control this pest before the 90 days of sprouting of the stems at the beginning of the defoliation.

Keywords: *Manihot esculenta*; productivity; root; starch.

Introduction

Due to tolerance to different water regimes, adverse (mainly high) temperatures, and low fertility soils, cassava (*Manihot esculenta* Crantz.) is cultivated in practically all regions of the world with a tropical climate, mainly by small producers (Aguiar et al., 2011). The root has excellent nutritional value, is inexpensive, and depends excessively on the shoot, more precisely the leaves, due to the production of photoassimilates that will be converted into sugars and accumulated in the roots as starch (Furlaneto et al., 2007).
In more technical properties, the farmer is able to harvest when the starch price is higher, allowing a higher income (Fagundes et al., 2010); therefore, it is very common for many varieties of cassava to be harvested within 18 to 22 months after planting. This is called second-crop cassava. However, not all varieties show dry root and starch gains, which are therefore a characteristic of the crop material. Some varieties when harvested more than 12 months after planting, do not provide economic gains and their roots can easily deteriorate in the field.
Abiotic factors, such as phytotoxicity of pesticides or fertilizers, sleet, and certain mechanical injuries and biotic factors such as some diseases and pests, are events of common occurrence in cultivation areas, which may cause losses of leaf area in these cultured plants (Fazolin & Estrela, 2003; Glier et al., 2015). Depending on the level of defoliation, i.e., the intensity and time of plant development, significant defoliation may reduce the photosynthetic potential and productivity (Silva et al., 2012). Therefore, the artificial defoliation of crops of economic importance is a useful methodology to simulate this damage, allowing measurement of the extent of defoliation supported by a culture at a specific phenological stage, and quantification of the loss of productivity at different levels of defoliation (Bertoncello et al., 2011).

Research on levels and times of artificial defoliation in cassava is, therefore, necessary. The effect of different levels of defoliation and stages of development of the culture, may not be the same, as described in the work of Barrigossi et al. (2002) testing caterpillars of *E. ello* in the early stages. Based on this work, the current study focused on the cultivation of cassava, which may tolerate artificial defoliation, even a high percentage of defoliation, with minimal losses to the crop, depending on the stage of crop development.
Studies on defoliation levels at different times of crop development, such as in cassava, provide information on the behavior of the respective crop with regard to its ability to support defoliation. Therefore, the aim of this work was to evaluate the agronomic performance of second cycle cassava crop as a function of time and levels of artificial defoliation.

Results and discussion

The analysis of variance of the regression showed a significant p-value ($p < 0.05$) for the isolated factors, levels and times of defoliation, and on the interaction of defoliation factors for height, stem diameter, number of roots per plant, mass of roots, and starch content during the second cycle of the cassava crop, which indicates that increases in defoliation levels caused reductions in the observed responses, and that the intensity of this effect depends on the stage at which the defoliation occurs.
An unequal effect on plant height was observed in the early stages (45 and 90 DAS) of the defoliation tested (Figure 1 A). The defoliation at 90 DAS produced the greatest reduction in height, particularly at the 100% level of defoliation. This can be explained by the fact that in this period, the cassava plant is investing the photoassimilates produced in the leaves and also its reserves from the tuberous roots, in the growth of aerial part, especially in the formation of new leaves, coinciding with its development of second cycle, when almost every structural part is already formed.
Defoliations at 180 and 225 DAS were almost unaffected by the different levels of defoliation, since the cassava plant already stabilized its aerial part growth in this period, investing, almost in its totality, in the growth of its tuberous roots. According to the mathematical model of the regression equation at the 100% level of defoliation, 205 DAS is the time when the cassava plant would suffer the least damage in this variable for this defoliation level, resulting in a height of 1.79 m. According to Viecelli et al. (2011), the stage of development in which the plant is under stress, may affect tolerance to it. In the case of this work, the cassava crop did show any changes in this variable after the defoliation at 90 DAS, since its growth had stabilized.
For the culture of cassava, the higher the height of the stem and branches, the better the performance of these structures as drains, damaging the accumulation of carbohydrates in the roots. Tall plants are also susceptible to strong winds, which can topple the plants, exposing the roots and causing them to deteriorate.
By evaluating the effect of defoliation levels on the height variable, it is possible to observe differences in the size of the plants for the most drastic levels of defoliation (50, 75 and 100%). Defoliation of less than 50% was not sufficient to reduce this variable in the initial times of defoliation in this second cycle (Figure 1 B). Defoliations at 45 and 90 DAS showed a linear adjustment, decreasing due to the defoliation levels, that is, the higher the level of defoliation, the greater the effect on this variable, with an emphasis on defoliation of 75 and 100%.
Bertulio (2008) and Cantarelli et al. (2008), who evaluated a simulation of defoliation by leaf cutting ants in eucalyptus, verified that the defoliation in the first three months and with more drastic defoliation affected the growth of the tree species and that defoliation after twelve months did not interfere with this variable. Although the development cycle of cassava is different from that of tree species, the shoot growth is defined at the beginning of plant cycle for both. As cassava in this case is already in the second cycle of development and the plants were not pruned, this difference in the first two periods of defoliation may be due to the defoliation carried out in these same periods; however, in the first cycle, it was carried out when the aerial part was growing.
Analyzing the stem diameter variable, differences in the plants would be observed for all the defoliation seasons (Figure 2A). As for height, defoliation performed at 45 and 90 DAS induced the greatest reduction of stem diameter (8.96%), especially when there was 100% defoliation. It can be inferred that the cassava plant is investing the photoassimilates produced in the leaves and storing them in its tuberous roots for the reestablishment of aerial part (leaves), which coincides with the beginning of its budding. Defoliations performed at 180 and 225 DAS were not affected by the different levels of defoliation, as for height, and these results are probably due to the defoliation carried out in the first cycle of cultivation. According to the mathematical model of the regression, defoliation at 220 DAS at the 100% level was the time of the lowest loss for the variable stem diameter, presenting a value of 27.8 mm.
The greater sensitivity of the diameter in relation to time is explained in the experiment of Matrangolo et al. (2010) where tree species were subjected to defoliations; the authors reported that the diameter growth is more dependent on photosynthesis than on the reserves accumulated in the tree, while the growth with respect to height is more dependent on the reserves of the tree than on photosynthesis.
The diameter of the base of the cassava stem showed reduction at several defoliation levels applied (Figure 2 B). The defoliation at the 75 and 100% levels influenced this variable the most, especially when performed at 45 and 90 DAS, as for height, which presented the greatest reduction. Defoliation near zero (4.5%) resulted in less damage to stem diameter (30.27 mm) according to the regression equation at 45 DAS.
No significant effect was observed on the length and diameter of the root after the plant had undergone the different levels of defoliation at different time periods as well as the interaction of these two factors in the second cycle of development. This result is due to these two variables being defined at the beginning of culture development; therefore, they would be more influenced by defoliations when the producer grows in a second cycle.
The number of roots per plant was influenced significantly by the time of defoliation (Figure 3A), where as in the equation of regression mathematical model, the plant when defoliated to 150 DAS had 3.8 roots on average, which was, therefore, the more damaging to the culture.

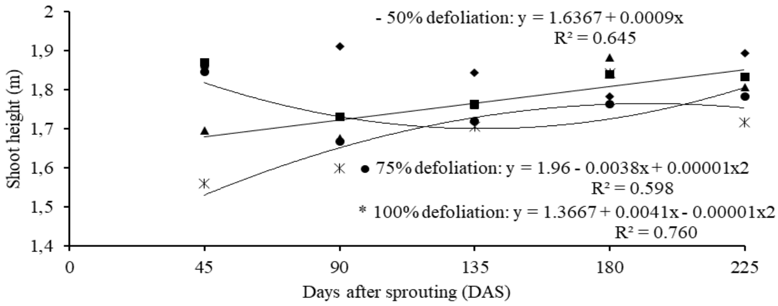

Fig 1 A. Average height of second cycle cassava plants, cultivated in Guaíra - PR, crop 2013/2014, submitted to different periods of artificial defoliation.

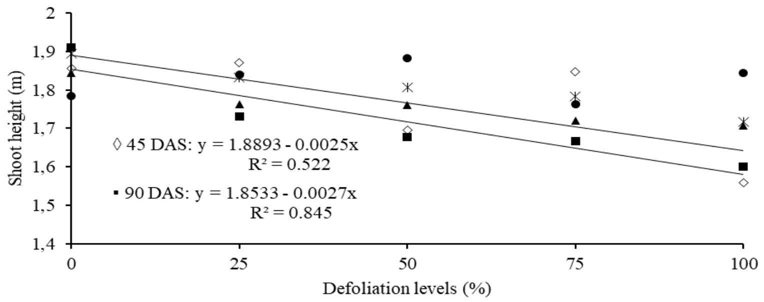

Fig 1 B. Average height of second cycle cassava plants, cultivated in Guaíra - PR, crop 2013/2014, submitted to different levels of artificial defoliation.

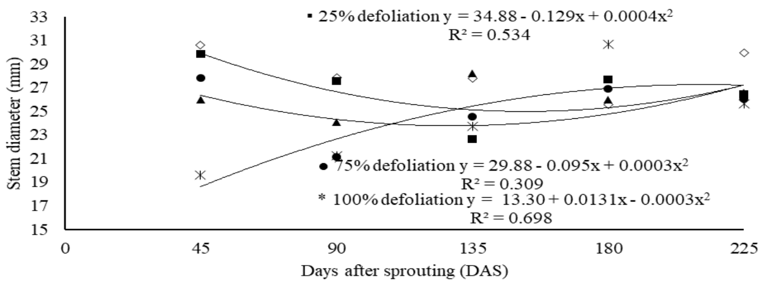

Fig 2 A. Mean diameter of the stem base of second cycle cassava plants, cultivated in Guaíra - PR, crop 2013/2014, submitted to different periods of artificial defoliation.

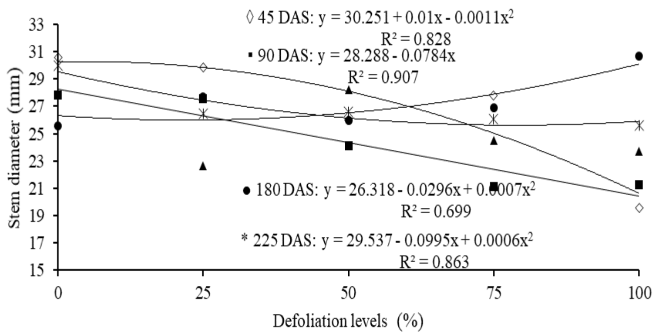

Fig 2 B. Average diameter of stem base of second cycle cassava plants, cultivated in Guaíra - PR, crop 2013/2014, submitted to different levels of defoliation.

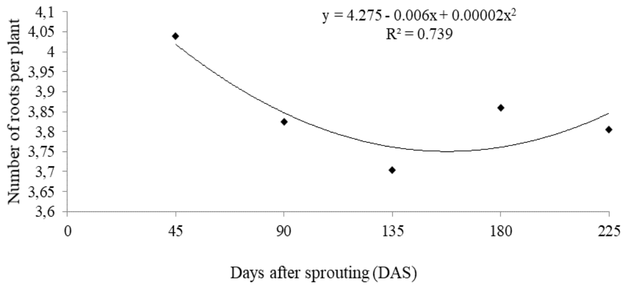

Fig 3 A. Number of roots per second cycle cassava plant, cultivated in Guaíra - PR, crop 2013/2014, submitted to different periods of artificial defoliation.

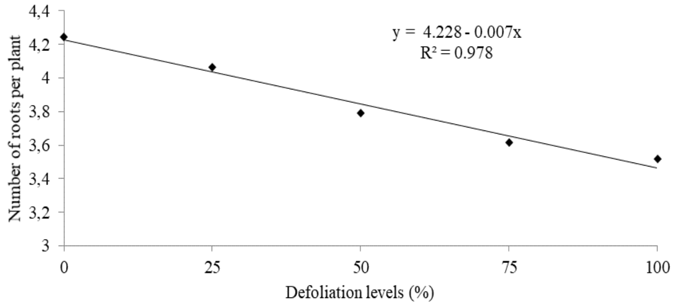

Fig 3 B. Number of roots per second cycle cassava plant, cultivated in Guaíra - PR, crop 2013/2014, submitted to different levels of artificial defoliation.

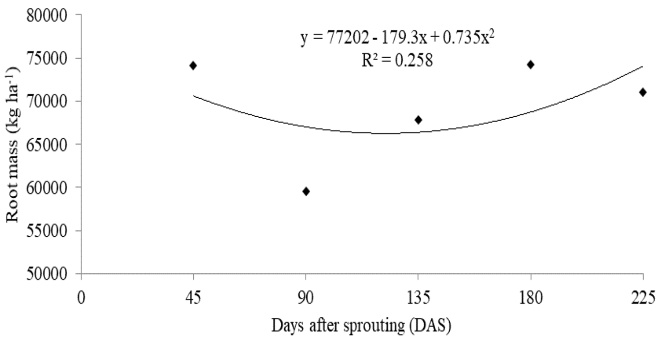

Fig 4 A. Mass of second cycle cassava roots, cultivated in Guaíra - PR, crop 2013/2014 submitted to different periods of artificial defoliation.

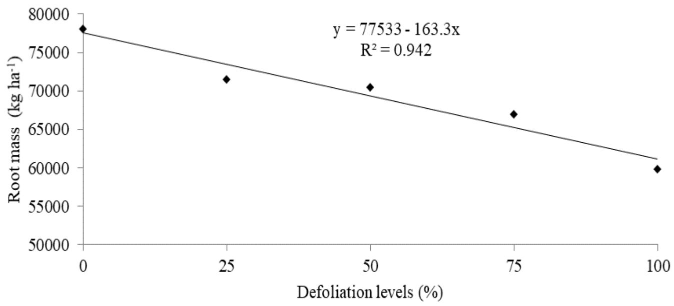

Fig 4 B. Mass of cassava roots of second cycle cultivated in Guaíra - PR, crop 2013/2014, submitted to different levels of artificial defoliation.

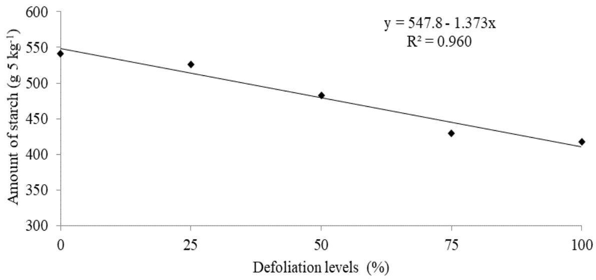

Fig 5. Amount of starch present in 5 kg of second cycle cassava roots, cultivated in Guaíra - PR, crop 2013/2014, submitted to different levels of artificial defoliation.

The number of roots was not influenced by the season or level of defoliation, during the first cycle of development of culture of cassava, and is necessarily set during the first seasons of this cycle (up to approximately 120 days after planting (DAP)) and not in a second cycle, in which the roots formed may usually change in size, mass and starch content, and not in number.

This result suggests that there were internal and/or external factors that influenced the decrease in the number of roots per plant. This may have been due to the fact that the genetic strain used, the "cascudinha" variety, is not usually cultivated in a second cycle, being widely used by producers who need income in the short term, harvesting it normally at 10 months after emergence. According to many producers, it is a strain that presents good yields in this period and that after a year in the field suffers great losses of roots by deterioration. This was observed in the harvest during the second cycle in this experiment, and may be, therefore, the main contributing factor for the reduction of the number of roots in this work, which entailed this statistical difference. The high population density adopted in the experiment, together with the high rainfall from March and the clayey texture of the soil, probably contributed to the occurrence of a large number of deteriorated roots

According to Andrade (2010) and Oliveira et al. (2010), harvesting with one or two cycles does not significantly influence the number of tuberous roots per plant, as it is fundamentally determined in the second and third month after planting, or until approximately 120 days after planting (Alves, 2006). However, depending on the variety, there may be an increase in the mass of tuberous roots as well as in starch content.

As shown in Figure 3B, the number of roots per plant was influenced significantly by levels of defoliation; however, levels of defoliation presented no direct effect on this variable because it is determined up to 120 DAP as mentioned above.

As cassava plants have not been pruned after the end of the first cycle, the shoot mass (SM) of cassava plants was not significantly influenced by the levels and times of artificial defoliation. Sganzerla et al. (2011) reported that the stem/leaf ratio is not influenced by phenological stage, because it did not differ between the intensities of defoliation as observed in this work.

The regression analysis (Figure 4 A) showed a quadratic adjustment for the variable root mass (RM) according to the periods of artificial defoliation. The lowest RM, according to the mathematical model of the equation, occurs during defoliation at 122 DAS, providing in only 66088 kg ha^{-1} of roots, possibly because less photoassimilate translocation occurred due to the decrease in the photosynthetically active area reducing height, diameter of stem and, consequently, less accumulation of reserves in the tuberous roots.

According to Aguiar et al. (2011), there is a reduction in dry matter yield of roots with pruning after September, due to the reduction in the average mass and dry matter contents of roots, as well as the extraction of reserves, mobilized from the roots to the aerial part, with removal after the beginning of the shoots in the second vegetative cycle. In this work, the second and third leaf strips in this second cycle were carried out in the months of November and January, during which high starch extraction occurs, to be mobilized to the aerial part in order to form new leaves.

The regression analysis (Figure 4B) showed a linear decreasing adjustment for the variable root mass according to the levels of artificial defoliation, making it possible to infer that the foliar loss of 100% was the most damaging, especially when performed between 90 and 135 DAS, resulting in greater damage in the root mass. The low value for this variable in the most drastic levels of defoliation is possibly due to the greater expense of the reserves stored in the tuberous roots for the reestablishment of the leaf area to return to produce photoassimilates for the maintenance of the plant.

Defoliation level in grain and fiber crops is highly significant and detrimental as crop defoliation increases. Thus, Pratissoli et al. (2012), evaluating the effect of defoliation levels at different stages of bean crop development, found a significant effect on grain mass in the interaction of these two factors in which the defoliation of 100% in the R6 and R7 stages produced a marked loss in grain mass. In the cotton crop, Silva et al. (2012), evaluating the same factors, found that there was a reduction in the mass of buds when the plants were defoliated from 50 to 100%, especially in the first flower stage (F1). With this work, it can be verified that crops producing underground reserve organs, such as the decline of cassava, also suffer from the same damages as grain and fiber producing crops.

The variable amount of starch had a linear adjustment according to regression analysis (Figure 5) to the influence of artificial defoliation levels, which suggests that the cassava responded largely to leaf loss. This result makes it possible to infer that the reduction of the quantity of starch that was stored was used for the formation of new shoots to make up for the absence of leaves due to defoliation in the first cycle of development.

According to Andrade (2010), the excessive production of new leaves, mainly by means of new branches, that is very common in the cassava crop, can lead to a reduction in the root yield, an effect that was observed in this work with the increase of the levels of defoliation. The reduction of the amount of starch in the defoliated cassava plants is probably due to the consumption of the root reserves by the plant, for the recovery of the leafy aerial part. With the defoliation, in this specific case the most drastic a 75 and 100%, the reserves of the tuberous roots were transferred to new shoots of the plant, causing a reduction of the amount of starch in the tuberous roots.

Andrade (2010) verified that when pruning was performed between the months of June and January, there was a tendency towards balance in the period between physiological rest and vegetative growth. When performed from February to April, there was a tendency for a more severe reduction due to the proximity of the harvest, due to insufficient time for the plants to recover the lost reserves. In this work, the defoliation season did not significantly affect with the amount of starch stored in the roots.

In industrial root production systems, such indices (amount of starch stored in tuberous roots) are of great importance to the producer because it is possible to predict the quality of the product and to set the prices for commercialization. The flexibility of the harvesting season of the tuberous roots, together with these starch indices, allow the producer to evaluate the cost/benefit ratio between the duration of the crop cycle and the starch productivity (Oliveira et al., 2010). In general, a longer time of permanence of the tuberous roots in the field allows a greater accumulation of starch, although this was not observed in this work possibly due to the climatic conditions and the characteristics of the cultivar.

Materials and methods

Location of the experimental area and installation

The experiment was carried out under field conditions, in a rural property in the municipality of Guaíra, west of Paraná, located between the coordinates 24º 51 'S, 54º 12' W and an altitude of 264 meters.

The soil is classified as Red Eutroferric Latosol of clayey texture and the local climate according to Köppen's is Cfa, in which the average annual temperatures vary between 22 and 23 °C and average annual precipitation in the region varies between 882 and 2344 mm.

Before the installation of the experiment, soil sampling was carried out at two depths (0-0.20 m and 0.21-0.40 m) with the aid of a Dutch Auger, for the characterization of chemical attributes. The results were respectively: pH: 5,5 and 5; P (20,5 and 11,7 mg dm^{-3}); MO (20,5 and 7,4 g dm^{-3}), K, Ca, Mg, Al, SB, CTC, H+Al (0,8 and 0,6; 7,9 and 5,8; 1,6 and 1,1; 0,0 and 0,0; 10,4 and 7,5; 14,6 and 11,9; 4,3 and 4,4 $cmol_c$ dm^{-3}); V = 70,7 and 63%.

Subsequent to the soil analysis, conventional soil preparation was carried out by means of a disk plow followed by two leveling grids. The planting was carried out on October 02, 2012 with the help of a planter (Planti Center, model Bazuca 1), with the regulation of maniva cut of approximately 15 cm, spacing between plants of 0.55 m between rows of 0.65 m, using the variety known as "cascudinha", considered to be a 'brava' cassava due to the presence of hydrocyanic acid (HCN).

On August 25, 2013, more than 50% of cassava plants which had not undergone pruning had already started the process of sprouting, i.e., issuance of new leaves which characterizes the plant exiting the physiological rest period and starting a second growing cycle. Therefore, the timing of defoliation was based from this date of sprouting.

Experimental design of treatments

Five levels of artificial defoliation (0, 25, 50, 75, and 100%) were evaluated in order to simulate attack by the major crop pest, *E. ello* in five growing seasons. The five levels of artificial defoliation were carried out at 45, 90, 135, 180, and 225 days after sprouting (DAS) of the stem, that is, the plots that had already passed through a defoliation in the first cycle, were subjected to the same levels of defoliation in the second cycle at the time from the start of budding of stems, in exactly the same plot subjected to the treatments during the first crop cycle.

The experimental design used was the randomized block in factorial 5 x 5, with 5 levels of defoliation and 5 timings, with 3 repetitions, totaling 25 treatments.

Each plot was 20.8 m^2, consisting of 5 lines each 8 m long, providing around 14 to 15 manivas per line in the plot (72). The total experimental area was therefore 2268 m^2 and the population 27972 plants per hectare.

The defoliation levels were performed with the aid of scissors to the stated proportions and all the leaves of the plant were cut.

Features evaluated

At the time of the last defoliation (225 DAS), morphological parameters such as shoot height and stem diameter were measured. The height was measured from the soil surface to the apical meristem with a plot and the diameter of the main stem was determined by means of a digital caliper at a height from the soil surface of approximately 5 cm.

The useful area of the plot comprised the fourth planting line, with 10 plants being harvested, excluding two plants at each end of the line, with the third and fifth lines as a border for the second cycle cassava harvest on July 19, 2014. The plants were in the period called "physiological rest" where all leaves fall naturally, leaving only the stem (ramifications).

The following variables were evaluated: shoot mass, root mass, root length, root diameter, number of roots per plant, and starch content.

All these variables were evaluated in 10 plants in the same line of planting. In these lines, initially the plants were pruned by using a machete to 0.30 m from the surface of the soil, and the stems (branches-aerial part) weighed in a balance with a capacity of 15 kg. Afterwards, the plants were manually removed and left in the planting line for the measurement of number of roots per plant (made by manual counting), root length (by means of a tape measure in all roots of the plant), and diameter (performed by means of a digital caliper in the middle part of the same). Once these measurements were taken, the roots were separated from the strains to weigh them in the same scale used for the shoot according to the same order, that is, the aerial part of the plants according to the roots of the same plant.

To determine the cassava starch content, approximately 7 kg of cassava root was collected at random in the useful plot and the variables were measured by a starch manufacturer through the hydrostatic balance method, using a 5 kg sample of tuberous roots (Rimoldi et al., 2003). This measurement was carried out at the starch Agricola Horizonte in Novo Três Passos, district of Marechal Cândido Rondon PR.

Statistical analysis

The results of production variables were tabulated and submitted to analysis of variance in function with a 5% level of significance by F-test, and the quantitative averages were subject to regression test of 5% probability, using the software SISVAR-5.4 system to analysis of variance (Ferreira, 2011).

Conclusion

The mass of the aerial part of the cassava was not influenced by the different levels and times of defoliation. The levels and times of defoliation in the second crop cycle did not affect the size of the roots. The difference in the number of roots per plant submitted to the treatments was due to the characteristic of the variety. Defoliation between 90 and 135 days after planting and sprouting of the stem resulted in greater damage to the root mass. The more drastic defoliation levels, such as 75 and 100%, caused the greatest losses in the amount of starch stored in the tuberous roots, regardless of the time of defoliation.

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