

## Full Length Research Paper

## Weed dry mass accumulation in response to the application of NPK fertilizers in cassava crop

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Fertilizers can be used to change competition relationships between crop and weed by promoting crop species growth, since rival species has a differentiated response to nutrients. We aimed to evaluate weed dry mass accumulation when or not NPK (nitrogen, phosphorus and potassium) fertilizers were applied to cassava crop. Therefore, weed samples were collected every 35 days, from 35 to 525 days after cassava planting, by randomly throwing a 0.25 m<sup>2</sup> metal square (0.5 m × 0.5 m) within useful area of the plots with and without fertilization. After each throw, it was removed weed shoot, separated by species, then counted and weighed to determine number of plants and shoot dry mass. Fertilization did not influenced the weed population during most part of the crop cycle; however, promoted greater weed dry mass accumulation in the second crop year, 350 days after planting. *Panicum maximum*, *Brachiaria plantaginea*, *Sida rhombifolia*, *Pavonia cancellata*, *Setaria parviflora* and *Cynodon dactylon*, which were the most abundant weeds, had different responses to fertilization. *P. maximum* and *B. plantaginea* have outstood because of their shoot dry mass increase of 41.59 and 36.25%, respectively, when comparing fertilized and non-fertilized treatments.

**Key words:** *Manihot esculenta*, weed community, biomass, fertilizers.

### INTRODUCTION

Cassava (*Manihot esculenta* Crantz) has great importance for tropical regions, wherein it is one of the major sources of carbohydrates for needy communities. The tuberous roots are the most important part of the plant, being rich in starch, which is used for human and animal nutrition or as raw material for several industrial

derivatives (Albuquerque et al., 2012). It plays a crucial role in job and income growth especially for small and medium farmers (Albuquerque et al., 2008), being among the most important food harvested in Brazil, and outnumbered only by soybean, wheat, rice and corn (IBGE, 2014).

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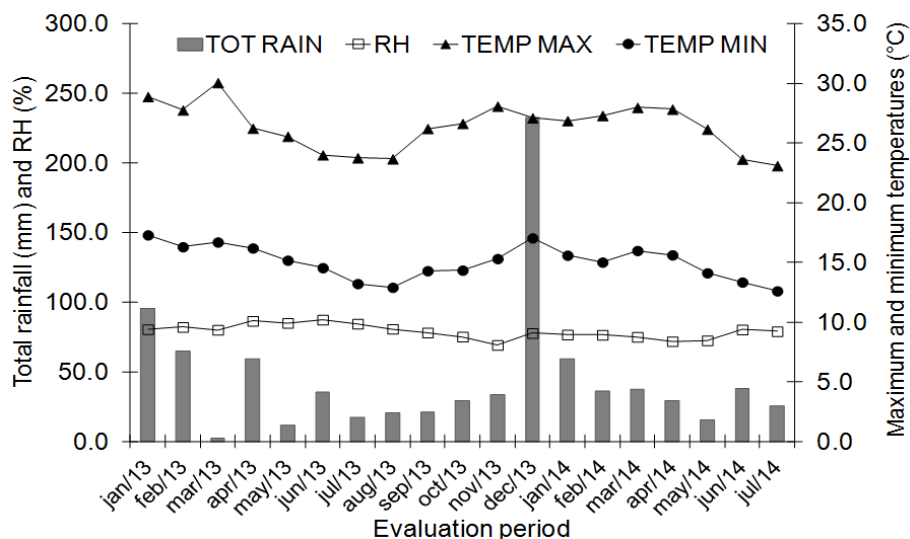


**Figure 1.** Monthly average of rainfall, air relative humidity and maximum and minimum temperature, in Vitória da Conquista-BA, Brazil. From January 2013 to July 2014. \*Source: National Institute of Meteorology - INMET/ Vitória da Conquista, BA, Brazil, 2014.

On national scenario, Bahia is one of the main producing states, generating around 8.7% of the 21.22 million tons of national production. Cassava yield averages 13.91 tons ha<sup>-1</sup> (IBGE, 2014). Vitória da Conquista city is a prominent micro region of cassava production, accounting for approximately 10% of the state production (IBGE, 2008). However, despite its importance, the root yield is considered low when compared with the crop production potential of up to about 90 t ha<sup>-1</sup> of roots (Cock, 1979).

Cassava cultivation is largely concentrated on small farming, which is characterized by low use of feedstock. It occurs because of the cassava ability to be grown on low-fertility soils (Carvalho et al., 2007b). Nonetheless, it is also one of the reasons of the short Brazilian root production in the last decades. Additionally, Cardoso et al. (2013) complemented that such small production is due to low adoption of agricultural techniques, little productive varieties and/ or adapted the region, and mainly competition with weed.

Weed in cassava cultivation has been reported as one of the main factors affecting crop yield. According Albuquerque et al. (2008), root yield can be reduced by more than 90% in absence of weed control. This is due mainly to a slow initial growth of cassava plants, which facilitates weed species development, favoring the competition for water, light, nutrients, carbon dioxide and physical space (Azevêdo et al., 2000). In addition, cassava harvest can occur up to two years after planting, when roots are delivered to processing industry (Silva et al., 2012). Because of long cultivation and the soil partial covering by the plant, several weed infestations can

occur within the planting area, what might increase crop yield losses (Johanns and Contiero, 2006).

Among resources liable to weed and crop competition, nutrient extraction and accumulation appear to be a crucial feature when studying the entire weed community in competition with intermediate cycle crops, such as cassava (Albuquerque et al., 2012).

Fertilizers can be used to alter competitive relationships between crop and weed, favoring crop plants by changing weed community composition and density, since the species have different responses to nutrient inputs (Armstrong et al., 1993). Even though a large amount of knowledge and technological advances on crop mineral nutrition are available, there is a lack of that regarding infesting communities, what impairs the understanding of interfering factors in competition for nutrients between weed and crop plants (Procópio et al., 2005).

Based on the above considerations, the current research aimed to assess weed dry mass accumulation in response to NPK fertilization in cassava crop.

## MATERIALS AND METHODS

The study was carried at experimental area from the State University of Southwestern Bahia, campus in Vitória da Conquista – BA, Brazil, from January 2013 through July 2014. The campus is located at 14° 51'S latitude and 40° 50' W longitude, in average altitude of 941 m. According to Köppen classification, climate is Cwa type (high altitude tropical), with average annual rainfall of 717 mm. Figure 1 displays weather data of the assessed period related to rainfall, relative humidity, maximum and minimum temperature. Soil is classified as dystrophic Yellow Latosol (Oxisol) (EMBRAPA,

**Table 1.** Particle size and chemical analyses of topsoil (0-20 cm), belonging to a dystrophic Yellow (Oxisol) from the experimental area<sup>1/</sup>. Vitória da Conquista - BA, Brazil, UESB (2015).

| Particle size analysis (dag kg <sup>-1</sup> ) |                          |                   |                      |                                         |                     |                     |                      |                 |    |                      |
|------------------------------------------------|--------------------------|-------------------|----------------------|-----------------------------------------|---------------------|---------------------|----------------------|-----------------|----|----------------------|
| Clay                                           |                          | Silt              |                      | Coarse sand                             |                     | Fine sand           |                      | Texture         |    |                      |
| 29                                             |                          | 1                 |                      | 56                                      |                     | 14                  |                      | Sandy clay loam |    |                      |
| Chemical analysis                              |                          |                   |                      |                                         |                     |                     |                      |                 |    |                      |
| pH                                             | P <sup>2/</sup>          | K <sup>+ 2/</sup> | H + Al <sup>3/</sup> | Al <sup>+3 4/</sup>                     | Ca <sup>+2 4/</sup> | Mg <sup>+2 4/</sup> | CEC <sub>total</sub> | V               | m  | OM                   |
| H <sub>2</sub> O                               | .....mg dm <sup>-3</sup> | .....             | .....                | .....cmol <sub>c</sub> dm <sup>-3</sup> |                     |                     | .....                | .....%          |    | dag kg <sup>-1</sup> |
| 5.2                                            | 10.0                     | 0.11              | 3.4                  | 0.3                                     | 0.9                 | 0.5                 | 4.9                  | 31              | 17 | 19.0                 |

<sup>1/</sup>Data generated by the Laboratory of Soil Analyses from the UESB; by various extractants: <sup>2/</sup> Mehlich-1; <sup>3/</sup> 0.5 mol L<sup>-1</sup> Ca (OAC) 2 at pH 7.0; <sup>4/</sup> mol L<sup>-1</sup> KCl<sup>1</sup>.

2006), whose main physical and chemical characteristics are shown in Table 1.

Soil tilling consisted of plowing, harrowing and grooving. Fertilization of treatments was based on soil analysis and recommendation for cassava crop proposed by Nogueira and Gomes (1999). It was applied 17.5 kg ha<sup>-1</sup> P, directly into planting groove; and 70 kg ha<sup>-1</sup> N and 25 kg ha<sup>-1</sup> K as topdressing, sixty days after planting. In the second year, 60 Kg ha<sup>-1</sup> N and 50 Kg ha<sup>-1</sup> K were applied as topdressing at the beginning of rainy season (December 2013). For treatments without fertilizer application (control), it was considered soil natural fertility (Table 1).

Planting was manually performed in January 2013, using 'Caitité' variety with approximately 2 to 3 cm stem diameter, 20 cm length and seven buds. Plant spacing was 1.0 m between rows and 0.6 m between plants, totaling 16,666 plants ha<sup>-1</sup>. Each plot consisted of four rows within an area of 8.4 m length per 4.0 m width, totaling 33.6 m<sup>2</sup>. The plot useful area of 14.4 m<sup>2</sup> was composed of the two central lines, leaving a 0.6 m border at each edge.

The experiment was set up in an entirely randomized block design comprising two treatment groups evaluated with and without fertilizer application and three replications. In the first group, it was evaluated six growing periods of convival between crop and weed, starting from planting time (DAP): 35, 70, 105, 140, 175 and 540 days (control with weed). After the interaction period, crop remained out of competition with weed by manual weeding. In the second group, we evaluated six growing periods of control, starting from planting time (DAP): 35, 70, 105, 140, 175 and 540 days (control without weed). After the end of each period, weed were left to emerge freely.

Weed evaluations were performed at 35, 70, 105, 140, 175, 210, 245, 280, 315, 350, 385, 420, 455, 490 and 525 days after cassava planting (DAP). During these evaluations, weed samples were collected for measurements. Samples were made by throwing randomly a metal square of 0.5 × 0.5 m (0.25 m<sup>2</sup>) within the plot useful area. Thirty-six samplings were carried at each period, totaling 540 samplings.

Weeds from sampled areas were cut close to ground and then taken to the laboratory, where they were counted and separated by species, to determine their number and shoot dry mass, dried in a forced-air oven at 70°C, up to constant weight.

Unprocessed data underwent variance analysis; and the treatments were set in a 15x3 factorial scheme (fifteen evaluation periods and two fertilization conditions). The F test compared mean squares, and means were compared by the Scott-Knott test at 5% probability. Each species dry mass of fertilized and non-fertilized treatments were compared by the Tukey test at 5% probability.

## RESULTS AND DISCUSSION

Fifty weed species were identified during inventories, which are distributed into 39 genera and 15 botanical families. Regarding species number, Malvaceae (14), Asteraceae (08), Poaceae (07) and Fabaceae (05) are the most notable and account for 68% of all species (Table 2). Otsubo et al. (2002), Albuquerque et al. (2008) and Guglieri et al. (2009), who have highlighted the same families as the richest in weed species for cassava fields, observed similar findings.

Weed community composition was considered heterogeneous when compared to results from Albuquerque et al. (2014), who evaluated 27 species distributed into 21 genera and 8 families in cassava plantations in Roraima savannah (Boa Vista – RR, Brazil). In addition, Huziwarra et al. (2009) found 10 species belonging to nine genera and 9 families in cassava field located in Campos de Goytacazes – RJ, Brazil.

Cassava fertilization promoted an increase of 23% in weed dry mass accumulation, compared to non-fertilized treatments (Table 2). This results show that fertilization also promotes weed growth; thus, there are major losses of cassava root yield due to weed and crop competition. As reported by Cruz and Pelacani (1993), among the effects of weed presence within crops, shading promoted by fast growth species seems to be the most important one, that is, as long as shading area increases, cassava plant height increases and its leaf area decreases, without biomass accumulation. These authors also concluded that as cassava plants are less exposed to light, stem and leaf dry matter as well as root yield become compromised. Consequently, shading promotes formation delay and decreases the growth rate of tuberous roots.

*Panicum maximum* (31.88%), *Brachiaria plantaginea* (15.98%), *Sida rhombifolia* (12.03%), *Pavonia cancellata* (5.43%), *Setaria parviflora* (4.16%) and *Cynodon dactylon* (4.03%) were the weed species that had the highest dry mass accumulation. Regarding the total dry

**Table 2.** Weed species found in cassava field, organized by family, scientific name, Brazilian common name and dry mass of treatments with and without fertilization. Vitória da Conquista - BA, Brazil, UESB (2015).

| Family/ species                   | Brazilian common name  | Dry mass (gha <sup>-1</sup> ) |                      |          |
|-----------------------------------|------------------------|-------------------------------|----------------------|----------|
|                                   |                        | F <sup>1/</sup>               | NF <sup>2/</sup>     | Total    |
| Amaranthaceae                     |                        |                               |                      |          |
| <i>Amaranthus retroflexus</i>     | Caruru-gigante         | 76.72 <sup>A*</sup>           | 8.43 <sup>B</sup>    | 85.15    |
| <i>Chenopodium carinatum</i>      | Anserina-rendada       | 105.98 <sup>B</sup>           | 358.95 <sup>A</sup>  | 464.94   |
| Asteraceae                        |                        |                               |                      |          |
| <i>Acanthospermum australe</i>    | Carrapicho-rasteiro    | 1296.60 <sup>A</sup>          | 1470.86 <sup>A</sup> | 2767.46  |
| <i>Acanthospermum hispidum</i>    | Carrapicho-de-carneiro | 11.74 <sup>A</sup>            | 2.15 <sup>B</sup>    | 13.89    |
| <i>Bidens pilosa</i>              | Picão-preto            | 28.11 <sup>B</sup>            | 52.58 <sup>A</sup>   | 80.69    |
| <i>Blainvillea rhomboidea</i>     | Picão-grande           | 521.15 <sup>B</sup>           | 1038.17 <sup>A</sup> | 1559.32  |
| <i>Emilia fosbergii</i>           | Falsa-serralha         | 208.82 <sup>A</sup>           | 122.52 <sup>B</sup>  | 331.34   |
| <i>Eupatorium ballotifolium</i>   | Picão-roxo             | 1696.22 <sup>A</sup>          | 1827.67 <sup>A</sup> | 3523.89  |
| <i>Siegesbeckia orientalis</i>    | Botão-de-ouro          | 2.15 <sup>A</sup>             | 2.48 <sup>A</sup>    | 4.63     |
| <i>Synedrellopsis grisebachii</i> | Agrião-do-pasto        | 15.54 <sup>A</sup>            | 3.14 <sup>B</sup>    | 18.68    |
| Boraginaceae                      |                        |                               |                      |          |
| <i>Heliotropium indicum</i>       | Crista-de-galo         | 8.10 <sup>A</sup>             | 12.07 <sup>A</sup>   | 20.17    |
| Brassicaceae                      |                        |                               |                      |          |
| <i>Lepidium virginicum</i>        | Mentrueto              | 12.57 <sup>A</sup>            | 0.99 <sup>B</sup>    | 13.56    |
| Commelinaceae                     |                        |                               |                      |          |
| <i>Commelina benghalensis</i>     | Trapoeiraba            | 997.17 <sup>A</sup>           | 7.27 <sup>B</sup>    | 1004.44  |
| Euphorbiaceae                     |                        |                               |                      |          |
| <i>Chamaesyce hyssopifolia</i>    | Burra-leiteira         | 20.83 <sup>A</sup>            | 7.94 <sup>B</sup>    | 28.77    |
| <i>Euphorbia prostrata</i>        | Quebra-pedra-rasteira  | 15.05 <sup>A</sup>            | -                    | 15.05    |
| Fabaceae                          |                        |                               |                      |          |
| <i>Aeschynomene denticulata</i>   | Angiquinho             | 17.03 <sup>A</sup>            | 9.09 <sup>B</sup>    | 26.12    |
| <i>Crotalaria incana</i>          | Chocalho-de-cascavel   | -                             | 76.22 <sup>A</sup>   | 76.22    |
| <i>Senna obtusifolia</i>          | Fedegoso               | 335.47 <sup>A</sup>           | 323.90 <sup>A</sup>  | 659.38   |
| <i>Stylosanthes viscosa</i>       | Vassourinha            | -                             | 1.98 <sup>A</sup>    | 1.98     |
| <i>Zornia reticulata</i>          | Alfafa-do-campo        | -                             | 60.68 <sup>A</sup>   | 60.68    |
| Malvaceae                         |                        |                               |                      |          |
| <i>Gaya pilosa</i>                | Guanxuma               | -                             | 126.98 <sup>A</sup>  | 126.98   |
| <i>Herissantia crispa</i>         | Mela-bode              | -                             | 9.42 <sup>A</sup>    | 9.42     |
| <i>Herissantia tiubae</i>         | Malva-de-bode          | 4.30 <sup>A</sup>             | -                    | 4.30     |
| <i>Malvastrum coromandelianum</i> | Falsa-guanxuma         | 502.14 <sup>A</sup>           | 242.55 <sup>B</sup>  | 744.69   |
| <i>Pavonia cancellata</i>         | Malva-rasteira         | 2883.03 <sup>A</sup>          | 3272.91 <sup>A</sup> | 6155.94  |
| <i>Pavonia sidifolia</i>          | Vassoura               | 297.45 <sup>B</sup>           | 928.22 <sup>A</sup>  | 1225.67  |
| <i>Sida carpinifolia</i>          | Malva-baixa            | 387.06 <sup>A</sup>           | 75.73 <sup>B</sup>   | 462.79   |
| <i>Sida cordifolia</i>            | Malva-branca           | 2395.61 <sup>A</sup>          | 1640.17 <sup>A</sup> | 4035.78  |
| <i>Sida glaziovii</i>             | Guanxuma-branca        | 10.09 <sup>A</sup>            | -                    | 10.09    |
| <i>Sida rhombifolia</i>           | Guanxuma (vassourinha) | 6372.37 <sup>A</sup>          | 7265.54 <sup>A</sup> | 13637.90 |
| <i>Sida santaremnensis</i>        | Guanxuma               | 9.76 <sup>A</sup>             | -                    | 9.76     |
| <i>Sida spinosa</i>               | Guanxuma-de-espinho    | 886.72 <sup>A</sup>           | 892.51 <sup>A</sup>  | 1779.22  |
| <i>Sida urens</i>                 | Guanxuma-dourada       | 190.14 <sup>A</sup>           | 41.00 <sup>B</sup>   | 231.15   |
| <i>Waltheria indica</i>           | Malva-branca           | 1.16 <sup>B</sup>             | 8.60 <sup>A</sup>    | 9.76     |
| Molluginaceae                     |                        |                               |                      |          |
| <i>Mollugo verticillata</i>       | Molugo                 | 29.93 <sup>A</sup>            | 19.51 <sup>A</sup>   | 49.44    |

Table 2. (Contd).

|                               |                      |                       |                       |                  |
|-------------------------------|----------------------|-----------------------|-----------------------|------------------|
| <b>Nyctaginaceae</b>          |                      |                       |                       |                  |
| <i>Boerhavia diffusa</i>      | Agarra-pinto         | 103.34 <sup>A</sup>   | 37.20 <sup>B</sup>    | 140.54           |
| <b>Passifloraceae</b>         |                      |                       |                       |                  |
| <i>Passiflora cincinnata</i>  | Maracujá-do-mato     | 30.09 <sup>A</sup>    | -                     | 30.09            |
| <b>Poaceae</b>                |                      |                       |                       |                  |
| <i>Brachiaria plantaginea</i> | Capim-marmelada      | 11059.43 <sup>A</sup> | 7049.60 <sup>B</sup>  | 18109.03         |
| <i>Cenchrus echinatus</i>     | Capim-carrapicho     | 1924.72 <sup>A</sup>  | 1480.62 <sup>A</sup>  | 3405.34          |
| <i>Cynodon dactylon</i>       | Gramma-seda          | 3031.01 <sup>A</sup>  | 1540.97 <sup>B</sup>  | 4571.98          |
| <i>Digitaria horizontalis</i> | Capim-colchão        | 29.43 <sup>B</sup>    | 108.13 <sup>A</sup>   | 137.56           |
| <i>Panicum maximum</i>        | Capim-colonião       | 22807.99 <sup>A</sup> | 13321.11 <sup>B</sup> | 36129.10         |
| <i>Rhynchelytrum repens</i>   | Capim-favorito       | 1813.78 <sup>A</sup>  | 917.80 <sup>B</sup>   | 2731.58          |
| <i>Setaria parviflora</i>     | Capim-rabo-de-raposa | 1772.11 <sup>B</sup>  | 3019.27 <sup>A</sup>  | 4791.39          |
| <b>Portulacaceae</b>          |                      |                       |                       |                  |
| <i>Portulaca oleracea</i>     | Beldroega            | 1253.28 <sup>A</sup>  | 724.35 <sup>B</sup>   | 1977.63          |
| <i>Portulaca mucronata</i>    | Onze-horas           | 2.15 <sup>B</sup>     | 11.74 <sup>A</sup>    | 13.89            |
| <b>Rubiaceae</b>              |                      |                       |                       |                  |
| <i>Diodia teres</i>           | Mata-pasto           | 640.53 <sup>A</sup>   | 387.56 <sup>B</sup>   | 1028.08          |
| <i>Richardia scabra</i>       | Poaia-do-cerrado     | 155.92 <sup>A</sup>   | 175.10 <sup>A</sup>   | 331.01           |
| <b>Solanaceae</b>             |                      |                       |                       |                  |
| <i>Solanum americanum</i>     | Maria-pretinha       | 143.18 <sup>A</sup>   | 50.76 <sup>B</sup>    | 193.94           |
| <i>Solanum erianthum</i>      | Caiçara              | 1.32 <sup>B</sup>     | 458.65 <sup>A</sup>   | 459.98           |
| <b>Total</b>                  |                      | <b>64107.28</b>       | <b>49193.11</b>       | <b>113300.39</b> |

\*Means followed by the same letter in the line do not differ from each other by the Tukey test at 5% probability. <sup>1/</sup> and <sup>2/</sup> Crop with and without fertilization, respectively.

mass accumulation for treatments with and without fertilizer application, these species comprised 74.69 and 71.99%, respectively (Table 2).

Concerning the responses of these species to fertilization, *P. maximum*, *B. plantaginea* and *C. dactylon* (Poaceae) had significant dry mass accumulation when fertilizer was applied, representing 41.59; 36.25 and 49.15%, respectively. Contrarily, *S. parviflora* had higher accumulation of dry mass in non-fertilized treatments, reducing this rate in 41.3% for fertilized ones. However, *S. rhombifolia* and *P. cancellata* (Malvaceae) had no significant results about fertilization, with slightly reduction of crop dry mass in treatments with fertilizer application (12.29 and 11.91%, respectively), although not differing from non-fertilized treatments (Table 2). Such results demonstrate that weed responses to fertilizers are variable with regards to shoot dry mass accumulation. According to Brighenti and Oliveira (2011), some weed species have greater efficiency to use fertilizers to grow faster, increasing the competition against crop.

With respect to number of plants, it was found a total number of 192,968 weed individuals per hectare, being 93,813 from fertilized treatments and 99,154 from non-fertilized ones (Figure 2); therefore, plant number did not

differ from fertilized to unfertilized treatments.

Number of individuals has reduced considerably from 105 DAP on, having less than 10,000 individuals per hectare; the lowest number was observed starting from 455 DAP (Figure 2). Yet the highest number was checked at 35 DAP due to a lower growth of cassava plants, which favored weed emergency during this period. Biffe et al. (2010) reported similar results; the authors also noted that weed interference on cassava crop is major from 18 to 100 DAP. Thus, weed control strategies should be taken within this time, aiming to preserve the maximum root yield.

According to Lorenzi and Dias (1993), cassava has a slow initial growth, which combined with a wide row spacing results in low competitive ability against weed population. It is mainly related to soil shading, enabling weed emergence for a longer period, what explains the elevated number of weeds up to 105 DAP.

Cassava fertilization increased significantly the amount of weed individuals at 105 days after crop implementation, being around 3,000 more individuals than non-fertilized ones. While, at 70 and 385 DAP, non-fertilized treatments increased in 20.1 and 36% the number of weed individuals, respectively, if compared to fertilized ones. However, in the other evaluation periods,

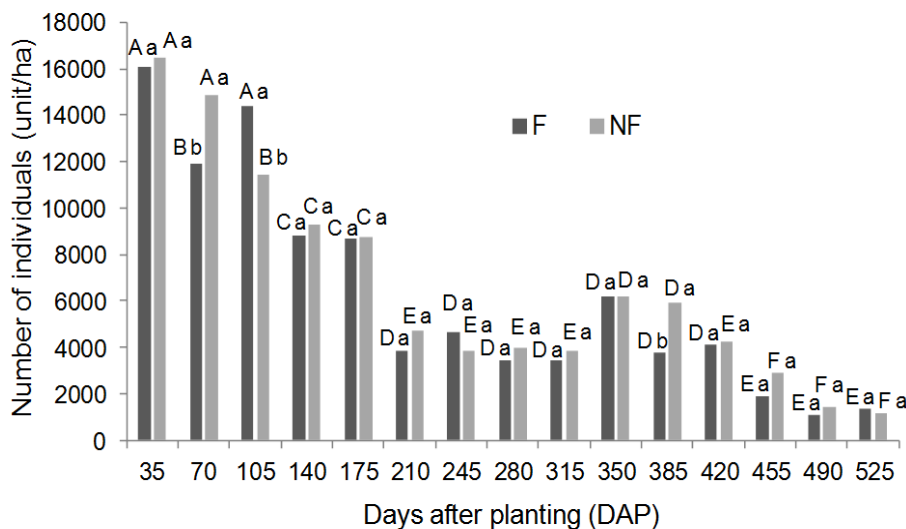


**Figure 2.** Number of weed individuals in cassava crop from 35 to 525 days after planting (DAP) of treatments with (F) and without (NF) fertilization. Vitória da Conquista – BA, Brazil, UESB (2015). \*Columns followed by the same lowercase letter (fertilized treatments at each evaluation time) and uppercase letter (evaluation times in fertilized and non-fertilized treatments) do not differ from each other by the Scott-Knott test at 5% probability.

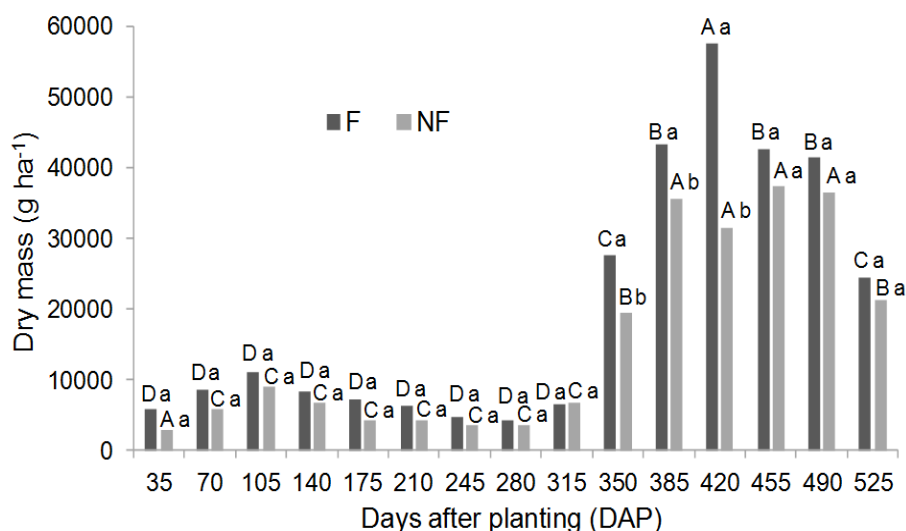


**Figure 3.** Weed shoot dry mass ( $\text{g ha}^{-1}$ ) from 35 to 525 days after planting (DAP) of treatments with (F) and without (NF) fertilization. Vitória da Conquista – BA, Brazil, UESB (2015). \*Columns followed by the same lowercase letter (fertilized treatments at each evaluation time) and uppercase letter (evaluation times in fertilized and non-fertilized treatments) do not differ from each other by the Scott-Knott test at 5% probability.

no differences have been found between fertilized and non-fertilized treatments (Figure 2).

Figure 3 shows the results of dry mass accumulation of weed shoot within cassava cultivation areas with and without fertilization. Dry mass accumulation was observed from 350 DAP on, in which fertilized treatments stood out. This treatment had a maximum buildup at 420

DAP, having 45% more weed dry mass compared to non-fertilized ones (Figure 3). Therefore, cassava fertilizations increased weed dry mass accumulation, notably during the second cropping year; time when nutrient competition might not be harmful to cassava plants, since they already have well-formed shoot and root.

According to Radosevich et al. (1996), as density and

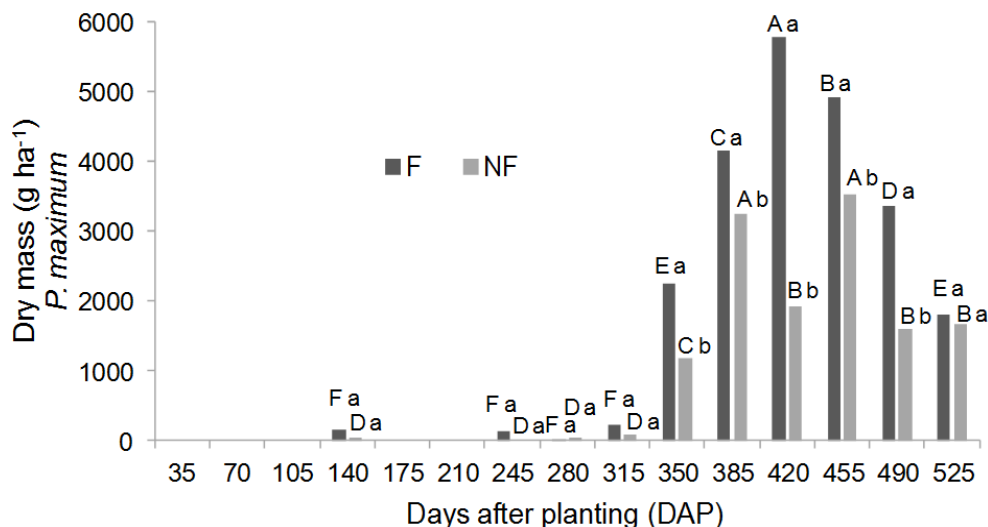


**Figure 4.** Shoot dry mass of *Panicum maximum* plants (g ha<sup>-1</sup>) infesting cassava crop from 35 to 525 days after planting (DAP) of the treatments with (F) and without (NF) fertilization. Vitória da Conquista - BA, Brazil, UESB (2015). \*Columns followed by the same lowercase letter (fertilized treatments at each evaluation time) and uppercase letter (evaluation times in fertilized and non-fertilized treatments) do not differ from each other by the Scott-Knott test at 5% probability.

development of weeds increase, especially at the beginning of the crop cycle, intraspecific and interspecific competition is enhanced; thus, higher and well-developed weed plants become dominant, while small and weak are suppressed or come to death. This scenario explains the reduction in weed individuals from 105 DAP, also the increase of weed shoot dry mass after 350 DAP (Figures 2 and 3).

Despite being less expensive, weed control during second year can be difficult, because crop shoot has already been formed, which makes it difficult to enter into the field (Peressin and Carvalho, 2002). In this case, between the two cycles, the crop is in physiological rest. Falling leaves and plant reduced metabolic activity characterize this phase and its duration is related to environmental conditions especially. Therefore, it is during this period that a new infestation starts, which was also observed in this study, mainly in fertilized treatments from 350 DAP. It is therefore necessary to control these plants, to avoid possible losses and to facilitate crop harvesting (Silva et al., 2012).

Evaluating cassava growth (Cacau UFV cultivar) and weeds due to phosphate fertilizing (0, 80, 800 and 4,000 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub>), Pereira et al. (2012) found that cassava showed greater shoot growth with increasing phosphorus availability; while weeds showed higher responses to lower phosphorus levels. Complementary effect was observed by Fidalski (1999), when evaluating cassava growing with NPK fertilization in sandy soils in Northwestern Paraná. This author noted that root production (Fibra cultivar) showed no response to nitrogen (0, 20, 40 and 60 kg ha<sup>-1</sup> N) and potassium (0,

40, 80 and 120 kg ha<sup>-1</sup> K<sub>2</sub>O). On the other hand, Alves et al. (2012), evaluating NPK doses (10:28:20 commercial formula) on cassava yield in Moju – PA, Brazil; they concluded that Paulozinho variety responded linearly with increasing doses in sandy and low fertility soils.

In general, fertilization carried to favor cassava development against weed community, had also benefited shoot dry matter accumulation of these plants in the second year. Therefore, depending on the level of competition at this stage, the crop may be adversely affected. As stated by Procópio et al. (2005), depending on crop management, the application of nutrients can most benefit weeds to the detriment of the crop.

As aforementioned, *P. maximum*, *B. plantaginea* and *S. rhombifolia* rose to predominance at the experimental area, which have stood out along infesting community evaluations of fertilized and non-fertilized treatments (Figures 4 to 6).

*P. maximum*, popularly known as capim-colonião in Brazil, had elevated values of shoot dry mass, accounting for 35.57% of the total dry weed mass recorded in fertilized cultivation and 27.07% in the cultivation without fertilization (Table 2); showing a great competitive potential as function of its high production capacity of biomass compared to the other species. This weed occurrence was recorded in some periods of the first year; though reduced dry mass accumulation. However, from 350 DAP, which matched to the rainy season (Figure 1), there was a significant increase in the dry mass accumulation of *P. maximum* in fertilized treatments, reaching a maximum dry mass accumulation at 420 DAP of 66.5% compared to treatments without

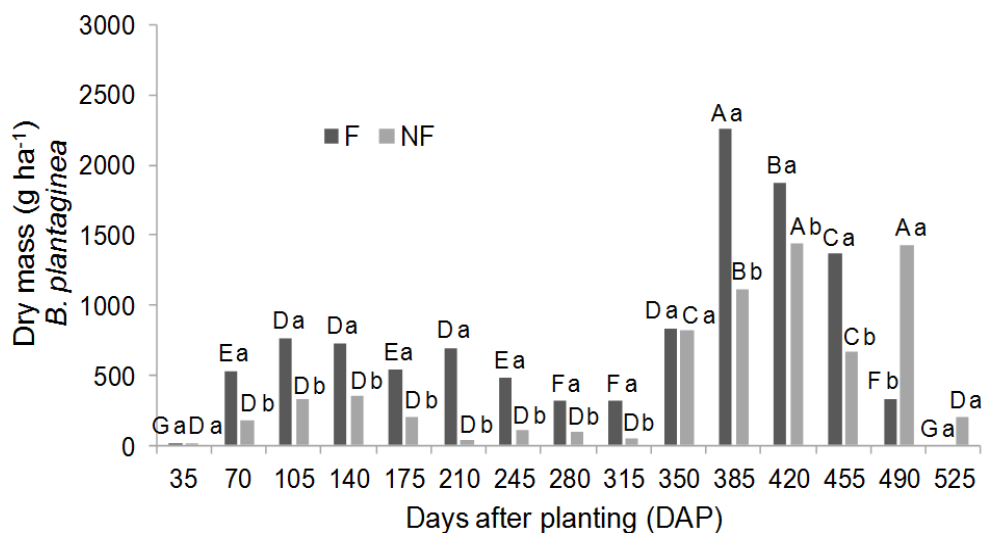


**Figure 5.** Shoot dry mass of *Brachiaria plantaginea* ( $\text{g ha}^{-1}$ ) infesting cassava crop from 35 to 525 days after planting (DAP) of the treatments with (F) and without (NF) fertilization. Vitória da Conquista - BA, Brazil, UESB (2015). \*Columns followed by the same lowercase letter (fertilized treatments at each evaluation time) and uppercase letter (evaluation times in fertilized and non-fertilized treatments) do not differ from each other by the Scott-Knott test at 5% probability.

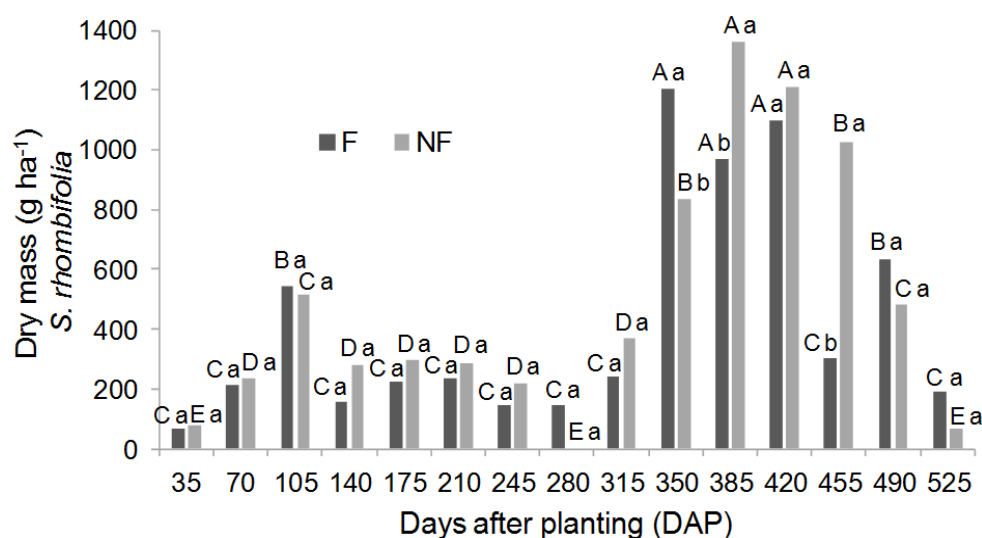


**Figure 6.** Shoot dry mass of *Sida rhombifolia* ( $\text{g ha}^{-1}$ ) infesting cassava crop from 35 to 525 days after planting (DAP) of the treatments with (F) and without (NF) fertilization. Vitória da Conquista - BA, Brazil, UESB (2015). \*Columns followed by the same lowercase letter (fertilized treatments at each evaluation time) and uppercase letter (evaluation times in fertilized and non-fertilized treatments) do not differ from each other by the Scott-Knott test at 5% probability.

fertilization (Figure 4).

Among the reasons of *P. maximum* dry mass accumulation, it can be listed its presence in neighboring areas, cassava defoliation at maturation, weed seed dispersal, crop fertilization and early rainy season. Such conditions certainly favored this weed establishment and development over the area, once it is quite demanding in

light, fertility and soil moisture.

Since *P. maximum* is a fierce and competitive plant, it can generate significant losses during peak infestations in the first crop year. Cruz et al. (2010), who evaluated the effect of *P. maximum* on initial growth of eucalyptus clones, found that all studied clones showed negative influence of the coexistence with variations on leaf area,

dry weight of leaves and stem. Moreover, some studies had proved *P. maximum* efficiency to produce shoot dry mass. For example, Ferreira et al. (2008), who assessed the effect of increasing phosphorus doses ( $P_2O_5$ ) (30, 60, 90, 120 and 150 kg ha<sup>-1</sup>) on *P. maximum* growth, checked a linear raise of shoot dry mass production up to the dose of 103 kg ha<sup>-1</sup> de  $P_2O_5$ . Nevertheless, Lugão et al. (2003), studying nitrogen fertilization (0, 150, 300 and 450 kg/ ha/ year) efficiency on shoot dry mass accumulation of *P. maximum*, observed high rates with nitrogen use, having the greatest efficiency at 150 kg nitrogen/ ha /year.

Commonly known as capim-marmelada in Brazil, *B. plantaginea* demonstrated good adaptation and aggressiveness, being logged at all evaluations, representing 17.25% of total dry mass in fertilized treatments and 14.32% in non-fertilized ones (Table 2). This Poaceae, originally from Africa, has as main means of spread, the seeds, which are characterized by presenting primary dormancy during maturation stage (Lorenzi, 2008); thus, germination is distributed over time, which makes its control difficult (Kissmann, 1997).

The greatest dry mass values are checked for the second year between 350 and 490 DAP (Figure 5), matching local rainy season (Figure 1).

Cassava fertilization enhanced *B. plantaginea* production of shoot dry mass, especially from 385 to 455 DAP, increasing it more than 50% compared to non-fertilization. Nevertheless, at the end of the crop cycle, 490 and 525 DAP; dry mass values of the fertilized treatments decreased and represented 76.5 and 12.05% of those of unfertilized treatments, respectively (Figure 5). Weeds as *B. plantaginea*, at the final crop stage, could hamper cassava root harvest, in addition to the occurrence of venomous animals as much reported by Brazilian farmers, and mainly in weed infested areas (Albuquerque et al., 2014).

In a comparative study of dry mass accumulation and macronutrients with corn and *B. plantaginea*, Carvalho et al. (2007a) concluded that maximum competition for macronutrients occurs at 100 days after emergence (DAE), during which corn plants begin physiological maturity, which could cause serious damage to final production. Agostinetto et al. (2009), evaluating competitive ability of soybean against *B. plantaginea*, found antagonism between them without competitive dominance of one over the other, and in both, intraspecific competition was more important than interspecific. For the cassava crop, Aspiazú et al. (2010), evaluating the water use efficiency by cassava in competitive conditions with weeds, they found that *B. plantaginea* is very efficient in water use, primarily due to its C4 metabolism, and remains competitive even under temporary low water availability.

Poaceae family has a major space among the infesting plants; it is considered one of the most important in cassava crops. Pinotti et al. (2010) identified *B.*

*decumbens* and *D. horizontalis* as the most important species in Pompéia – SP, Brazil. Albuquerque et al. (2014), still studying cassava crop in Roraima, observed the highest dry mass accumulation for *D. sanguinalis*, *B. brizantha*, *B. decumbens* and *B. humidicola*. According to Maciel et al. (2010), several species from Poaceae family are perennial and produce a great amount of seed, fact that enhance their spread and colonization at different environments.

*S. rhombifolia*, popularly known as guanxuma in Brazil, had widespread distribution within experimental area, being recorded in all evaluations; it accounted for 9.94% of accumulated total dry mass in fertilized cultivation and 14.76% in non-fertilized crop (Table 2). Such an occurrence could have been attributed to their high potential infestation, since it presents high seed yield and ease of dispersion.

Higher shoot dry mass accumulation was seen in the second year, starting from 350 days after cassava planting. It noteworthy to highlight non-fertilized treatments at 385 and 455 DAP, promoting an increase of 28 and 70% respectively, compared to the fertilized ones. However, in other evaluations, it was found no significant differences between cultivation with and without fertilization; demonstrating that, in general, dry mass accumulation of that weed do not depend on fertilizer supply (Figure 6).

*S. rhombifolia* is found in annual and perennial crops, being highly competitive because of its root system that can reach 50 cm depth (Lorenzi, 2008; Kissmann and Groth, 2000). There are reports showing that this plant is able to produce up to 28.2 thousand seeds m<sup>-2</sup> in a single summer season infesting soybean crop (Fleck et al., 2003). Among “guanxuma” species found in Brazil, this is considered most widely spread and hard to be controlled at various farming environments (Constantin et al., 2007). It was also reported as infesting plant in cassava field by Azevêdo et al. (2000) and Albuquerque et al. (2008), besides corn (Macedo et al., 2003), sugarcane (Oliveira and Freitas, 2008) and soybean (Voll et al., 2005).

Concerning *S. rhombifolia* dry mass accumulation, Bianco et al. (2014) reported that N and K are the most required macronutrients; macronutrient accumulation daily rate is cumulative until 94 DAE; and periods of increased accumulation of dry mass and macronutrients occur after 122 DAE.

Although *S. rhombifolia* is present in all evaluations with a high number of individuals, *P. maximum* and *B. plantaginea* showed greater efficiency in using fertilizers and environmental resources, and therefore a greater accumulation of dry weight. Both species are widely exploited for local cattle raising, and, like other species from Poaceae family used in animal husbandry, they should be eliminated from cassava plantations, since they are perennials, produce large amounts of seeds, has high biomass production and ease to adapt to various environments.

## Conclusions

Fertilizers applied into cassava crops did not influenced the number of individuals of the weed community during most part of the cassava cycle. *P. maximum*, *B. plantaginea*, *S. rhombifolia*, *P. cancellata*, *S. parviflora* and *C. dactylon* showed the highest accumulation of shoot dry mass, which also presented varied responses to NPK fertilization in cassava crop. Generally, cassava fertilization promoted weed dry mass accumulation during the second year of the cassava cycle, mainly from 350 days after planting on, and being more significant for the grasses *P. maximum* and *B. plantaginea*.

## Conflict of Interest

The authors have not declared any conflict of interest.

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