Weed Interference on Growth and Leaf Nutrient Accumulation in Two Cassava Varieties

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Abstract

The development of cassava varieties with more efficient nutrient absorption can prevent losses caused by weed competition. The objective of this study was to evaluate dry matter accumulation and leaf nutrient content in traditional and improved cassava varieties, with and without coexistence with weeds throughout the cycle. A randomized complete block design was used in a 2 x 2 x 11 factorial scheme with four replications. The first factor consisted of two varieties (Baianinha and Clone 56-03); the second factor was composed of the conditions with and without coexistence with weeds, and the third factor was 11 harvest periods. Coexistence with weeds reduced leaf contents of N (20.8% and 24.8%), P (26.7% and 4.6%) and K (27.1% and 12.6%) for 'Baianinha' and 'Clone 56-03', respectively. For coexistence with 'Baianinha', the period up to the maximum daily nutrient accumulation rate (N, P and K) ranged from 82 to 99 days after planting (DAP), while for 'Clone 56-03', coexistence in this period ranged from 80 to 88 DAP. The plants from the variety 'Clone 56-03' presented higher total dry mass and root dry mass accumulation, as well as higher leaf contents of N, P and K than the traditional cassava variety 'Baianinha', especially when in coexistence with weeds during the whole cycle.

Keywords: *Manihot esculenta*, NPK, crop-weed coexistence, genetic enhancement

1. Introduction

Cassava (*Manihot esculenta* Crantz) is cultivated in nearly 104 countries, in regions of Africa, Asia, Latin America, the Caribbean and even Oceania (Fao, 2018). In these regions, the cassava crop is the main source of staple food of about one billion people with low income (Latif & Muller, 2015). However, in addition to human consumption, cassava is also used in animal feed, as a raw material for the starch industry, products with a biologic basis (such as medicines, cosmetics and biopolymers) and as a source for production of biofuel (Anyanwu *et al*., 2015; Li *et al*., 2017; Ozoegwu *et al*., 2017).

Brazil stands out among the ten top cassava producers, and its production accounts for about 8% of world production (FAO, 2018; Conab, 2018). However, there is a limitation on the productive potential of the crop, owing to weed interference (Albuquerque *et al*., 2012); moreover, low soil fertility is a common problem in the main Brazilian regions where cassava is grown (Silva *et al*., 2018).

In general, because of the rusticity of cassava plants, producers do not apply fertilizers during the crop cycle; instead, cassava crops receive the remains from fertilizers used in previous crops in the same area (Ezui *et al*., 2016). This fact intensifies the effects of competition between weeds and the main crop for environmental resources, especially nutrients (Mortensen *et al*., 2012; A'ihi *et al*., 2017).

Weed competition for soil nutrients or fertilizers limits their absorption by crops and harms plant growth and development, as is the case of beans (Araújo *et al*., 2018), cotton (Cardoso *et al*., 2010), coffee (Carvalho *et al*., 2013), wheat (Maciel *et al*., 2017) and maize (Silva *et al*., 2015). There are negative consequences over their productive potential; however, for cassava crops, data on weed competition are still scarce in the literature, especially with new varieties.

Thus, researchers from the Brazilian Agricultural Research Corporation ("Embrapa") – Cassava and Fruticulture (Cruz das Almas/Bahia) have been selecting new clones of cassava, which have a faster and more vigorous initial growth when compared to the cultivars traditionally cultivated in the West of Paraná (e.g.: 'Baianinha'). The selection of new clones or varieties can contribute to the cultural management of weeds by providing fast closing of rows and limiting the passage of shading light, which consequently reduces the development of the soil seed bank.

Therefore, the objective of the present study was to evaluate dry mass accumulation and leaf contents of nutrients (N, P and K) in cassava plants, namely the variety 'Baianinha' (traditional) and the 'Clone 5-03' (improved), with and without coexistence with weeds during the whole cycle.

2. Material and Methods

2.1 Experimental Site

The experiment was conducted in only one crop cycle (year 2015/16 – 1st crop cycle/10 months) in field conditions on the following coordinates: 24º 42' 24' South, 54º 14' 36" West and 260 m of altitude. The varieties were planted on October 7, 2015 in a 0.90x0.60 m spacing, in a direct planting system under oat straw (5.89 t ha^{-1}).

No base fertilization was performed while the varieties were planted. The soil from the area was classified as an Oxisol with clayey texture (Santos *et al*., 2018), and it presented the following chemical characteristics: pHCaCl$_2$ = 5.95; Al^{3+} = 0.0 cmol$_c$ dm^{-3}; = 4.52 cmol$_c$ dm^{-3}; Mg^2+ = 3.42 cmol$_c$ dm^{-3}; P = 33.3 mg dm^{-3}; K = 0.88 cmol$_c$ dm^{-3}; Organic matter = 6.04 g dm^{-3}, V% = 76.1 %.

2.2 Treatments and Experimental Design

The experiment used a randomized block design in a factorial scheme 2 x 2 x 11, with four replicates. The first factor consisted of two varieties ('Baianinha' and Clone 56-03); the second factor was crop-weed coexistence conditions (with and without coexistence), and the third factor was 11 periods (20, 40, 60, 80, 100, 120, 140, 160, 180, 200 and 220 days after planting). Weed control was performed at the end of each coexistence period by means of manual hoes. Each experimental unit consisted of four rows eight-meter-long, totalizing an area of 28, 8 m².

2.3 Experiment Details

At the end of each period of with and without coexistence, two cassava plants were collected

from the central rows of the plot. The plants were similar and always surrounded by neighboring plants, i.e., avoiding areas in the plots with missing plants. The plants were taken to a laboratory to determine total dry mass and root mass (g plant^{-1}) and leaf contents (g kg^{-1}) of nitrogen (N), phosphorus (P) and potassium (K).

Weed biomass was estimated at the end of each coexistence period, by collecting the weeds present in a metal quadrat of 0.25m² (0.5 x 0.5 m) thrown at the center of each plot. The result was expressed as weed dry mass (g m^{-2}).

Total dry mass accumulation values of cassava plants (g plant^{-1}) and of weeds (g m^{-2}) were determined after they were dried in an air forced circulation oven for 72 hours at 65ºC, and weighed on a 0.1g precision scale. N, P and K contents were determined using leaf dry mass of the cassava varieties. Extraction was performed using the Kjeldahl method (N), the colorimetric method (P) and atomic absorption spectrometry (K), as adapted by Lana *et al*. (2010).

Percentage loss ratio was also determined for leaf contents of N, P and K found in the varieties of cassava plants with and without coexistence with weeds, on the basis of weed dry mass (g m^{-2}) throughout the cycle.

Following the methodology proposed by Greef et al. (1999), the first derivative of the adjusted equation was used to determine maximum accumulation rate (MAR), the period up to the maximum daily accumulation rate (PMDAR) and the duration of the maximum daily accumulation rate (DMDAR) of the total mass and root dry mass of cassava plants, as well as NPK accumulation in the leaves of cassava seedlings, where:

The MCR value of total dry mass and root dry mass of the plant and the leaf content of N-P-K were considered as being between 90 and 100% of the maximum value of total dry mass and root dry mass of the plant and leaf content of N-P-K. The PMCDR value of total dry mass and root dry mass of the plant and leaf content of N-P-K was defined as the number of days from planting until reaching 90% of the maximum value of total dry mass and root dry mass of the plant and leaf content of N-P-K. DMCDR was defined as the period in which the rate of total dry mass accumulation and the N-P-K content in the leaves and roots of the plants remained higher than 90% of the highest value.

$$MCR = \frac{\sum_{t_1}^{t_2} MCR}{t_2 - t_1} \ [g \ day^{-1}]$$

(1)

$$PMCDR = t_1 + \frac{(t_2 - t_1)}{2} \ [days]$$

(2)

$$DMCDR = t_2 - t_1 [days]$$

(3)

2.4 Statistical Analysis

The data underwent regression analysis, and the model was chosen considering the biologic phenomenon logic, normality, the regression significance and the high determination coefficient (R^2).

3. Results

In the absence of coexistence with weeds, the plants 'Clone 56-03' presented fast growth and higher total dry mass accumulation that that of the plants of the traditional variety 'Baianinha' (Figure 1A). This result is evidence of the highest competitive potential of 'Clone 56-03'. This fact can be confirmed by the result; total dry mass accumulation of 'Clone 56-03' plants in coexistence with weeds was similar to the value found for 'Baianinha' without coexistence. Also, when comparing plants in coexistence with the infesting community during all the cycle, reduction in total dry mass of cassava was greater for the 'Baianinha' plants (20.6%) than for 'Clone 56-03' plants (14.5%).

In general, coexistence with the infesting community can retard growth and/or the maximum biomass accumulation period of cassava plants in up to 11.8 and 5.4 days for 'Baianinha' and for 'Clone 56-03', respectively (Figure 1A). However, varieties with higher dry mass accumulation and fast growth are more competitive. Thus, despite coexistence with weeds during the whole cycle, the 'Clone 56-03' plants presented maximum total dry mass accumulation rate of 9.46 g day^{-1}, at 117 DAP, while for 'Baianinha', there was a maximum rate of 8.79 g day^{-1} at 118 DAP (Figure 1B and Table 1). In this situation, although the periods until the maximum daily dry mass accumulation rate of the varieties were similar (117 and 118 DAP), the duration of the maximum daily rate of total dry mass accumulation was 39 and 45 days for the 'Baianinha' and 'Clone 56-03', respectively, i.e., there were 6 more days for 'Clone 56-03'.

(A)

- Baianinha (without coexistence): $y = 1105.8359\exp(-0.5((x-191.5155)/69.4297)^2)$; $R^2 = 0.98$**
- Baianinha (with coexistence): $y = 877.9217\exp(-0.5((x-179.6791)/60.5876)^2)$; $R^2 = 0.98$**
- Clone 56-03 (without coexistence): $y = 1260.9338\exp(-0.5((x-192.6708)/71.8480)^2)$; $R^2 = 0.99$**
- Clone 56-03 (with coexistence): $y = 1078.1645\exp(-0.5((x-187.2565)/69.1058)^2)$; $R^2 = 0.98$**
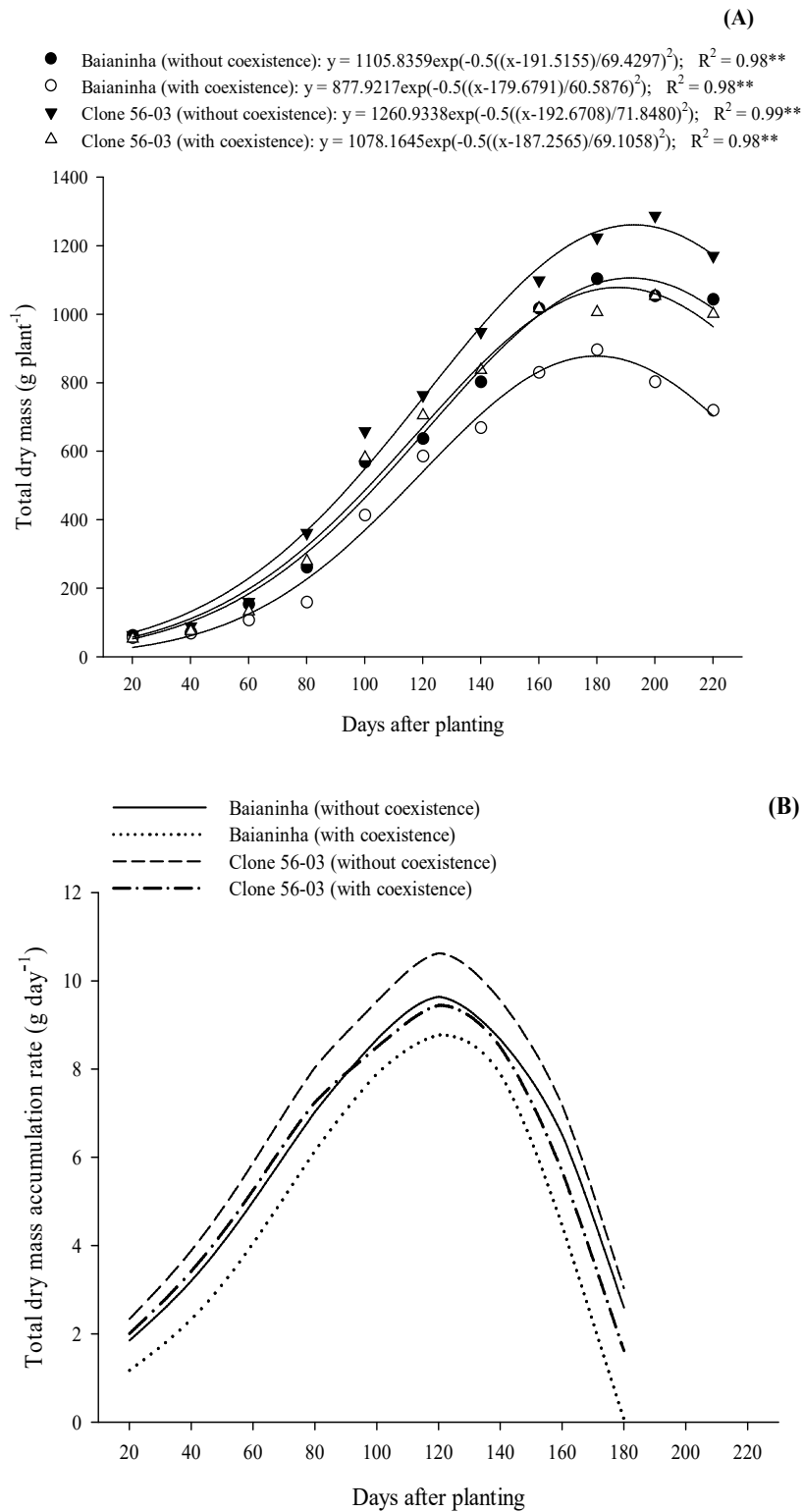

(B)

Figure 1. Accumulation (A) and accumulation rate (first derivative) (B) of total dry mass of cassava varieties 'Baianinha' and 'Clone 56-06', with and without coexistence with weeds throughout crop development (1st cycle)

Table 1. Maximum accumulation rate, period up to the maximum daily accumulation rate and duration of maximum daily rate of total dry mass accumulation of plants of cassava varieties without and with coexistence with weeds

Varieties		Maximum accumulation rate (g day^{-1})	Period up to maximum daily accumulation rate (days)	Duration of maximum daily accumulation rate (days)
Baianinha	Without coexistence	9.65	121	45
	With coexistence	8.79	118	39
Clone 56-03	Without coexistence	10.64	120	47
	With coexistence	9.46	117	45
First derivative equations				
Baianinha	Without coexistence	$1105.8359\exp(-0.5((x-191.5155)/69.4297)^2)$		
	With coexistence	$877.9217\exp(-0.5((x-179.6791)/60.5876)^2)$		
Clone 56-03	Without coexistence	$1260.9338\exp(-0.5((x-192.6708)/71.848)^2)$		
	With coexistence	$1078.1645\exp(-0.5((x-187.2565)/69.1058)^2)$		

Data collected from the first derivative of the equations, as proposed by Greef *et al.* (1999).

These results indicate that the photosynthetic apparatus of the 'Clone 56-03' remained active for longer and, consequently, increased root tuberization, in comparison to 'Baianinha', especially when in coexistence with weeds (Figure 2A). However, in the absence of coexistence with weeds, the 'Baianinha' plants accumulated 6.2% more dry mass in the roots than 'Clone 56-03'; moreover, they showed a longer duration of the maximum daily rate of total dry mass accumulation (Figure 2B and Table 2).
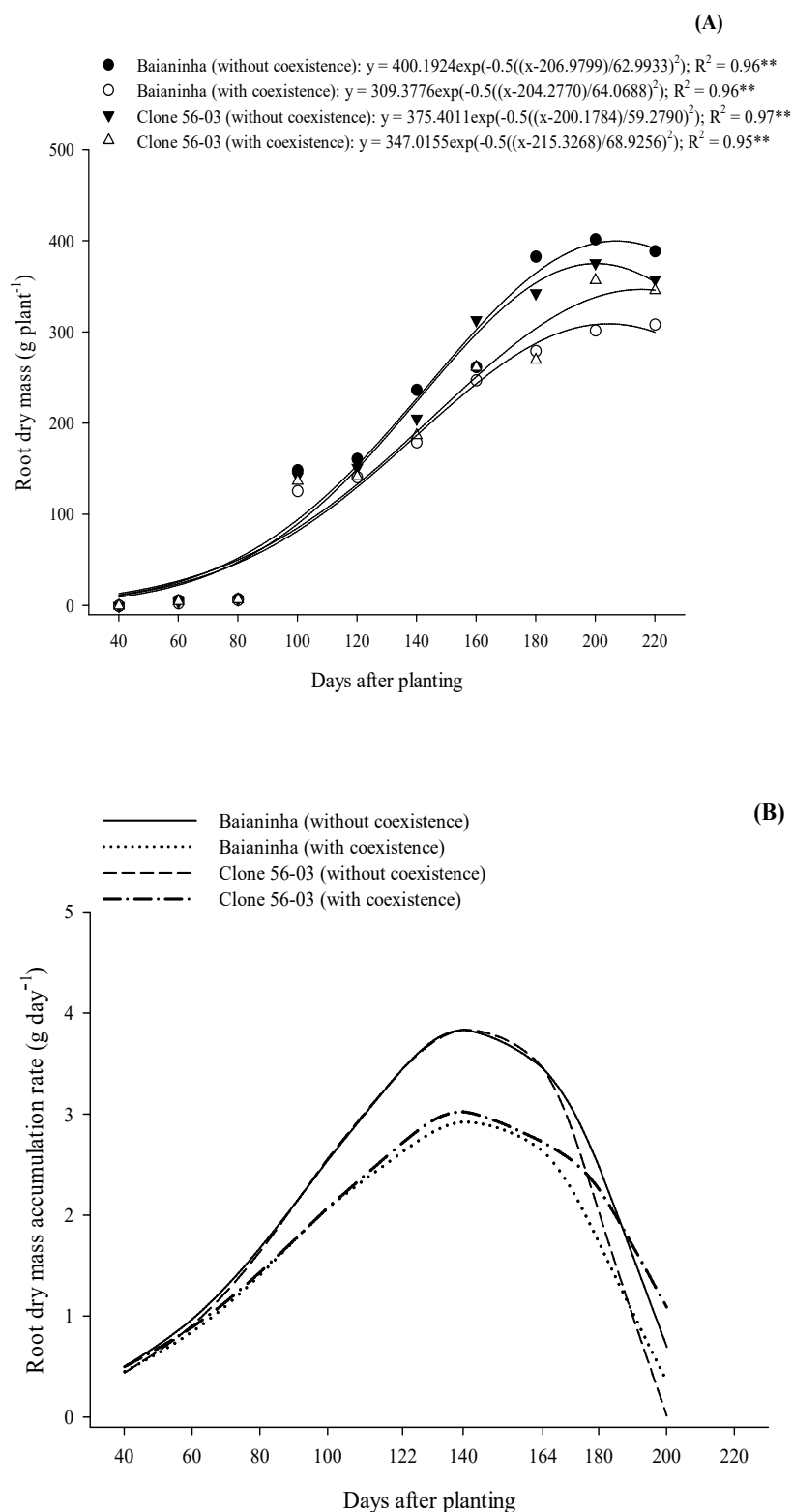
(A)

- ● Baianinha (without coexistence): $y = 400.1924\exp(-0.5((x-206.9799)/62.9933)^2)$; $R^2 = 0.96**$
- ○ Baianinha (with coexistence): $y = 309.3776\exp(-0.5((x-204.2770)/64.0688)^2)$; $R^2 = 0.96**$
- ▼ Clone 56-03 (without coexistence): $y = 375.4011\exp(-0.5((x-200.1784)/59.2790)^2)$; $R^2 = 0.97**$
- △ Clone 56-03 (with coexistence): $y = 347.0155\exp(-0.5((x-215.3268)/68.9256)^2)$; $R^2 = 0.95**$

(B)

- —— Baianinha (without coexistence)
- ········ Baianinha (with coexistence)
- – – – Clone 56-03 (without coexistence)
- –·–·– Clone 56-03 (with coexistence)

Figure 2. Accumulation (A) and accumulation rate (first derivative) (B) of root dry mass of cassava plants 'Baianinha' and 'Clone 56-03', with and without coexistence with weeds throughout crop development (1st cycle)

Table 2. Maximum accumulation rate, period up to the maximum daily accumulation rate and duration of maximum daily rate of root dry mass accumulation of cassava plants with and without coexistence with weeds

Varieties		Maximum accumulation rate (g day^{-1})	Period up to maximum daily accumulation rate (days)	Duration of maximum daily accumulation rate (days)
Baianinha	Without coexistence	3.84	143	41
	With coexistence	2.93	140	41
Clone 56-03	Without coexistence	3.84	140	38
	With coexistence	3.03	145	46
		First derivative equations		
Baianinha	Without coexistence	$400.1924\exp(-0.5((x-206.9799)/62.9933)^2)$		
	With coexistence	$309.3776\exp(-0.5((x-204.277)/64.0688)^2)$		
Clone 56-03	Without coexistence	$375.4011\exp(-0.5((x-200.1784)/59.2790)^2)$		
	With coexistence	$347.0155\exp(-0.5((x-215.3268)/68.9256)^2)$		

Data collected from the first derivative of the equations, as proposed by Greef et al. (1999).

More competitive varieties provide fast closing of the inter-row space, thus blocking the sunlight passage which stimulates seed bank germination and weed growth. This way, the potential of 'Clone 56-03' for suppression of weed development was more evident, according to the results shown in Figure 3. The 'Clone 56-03' had an average reduction of 55.7% in weeds dry mass throughout the crop cycle in comparison to 'Baianinha'. This result reinforces

the idea that the development of modern, more competitive and faster-growing varieties can be an excellent alternative for cultural management of the infesting community.
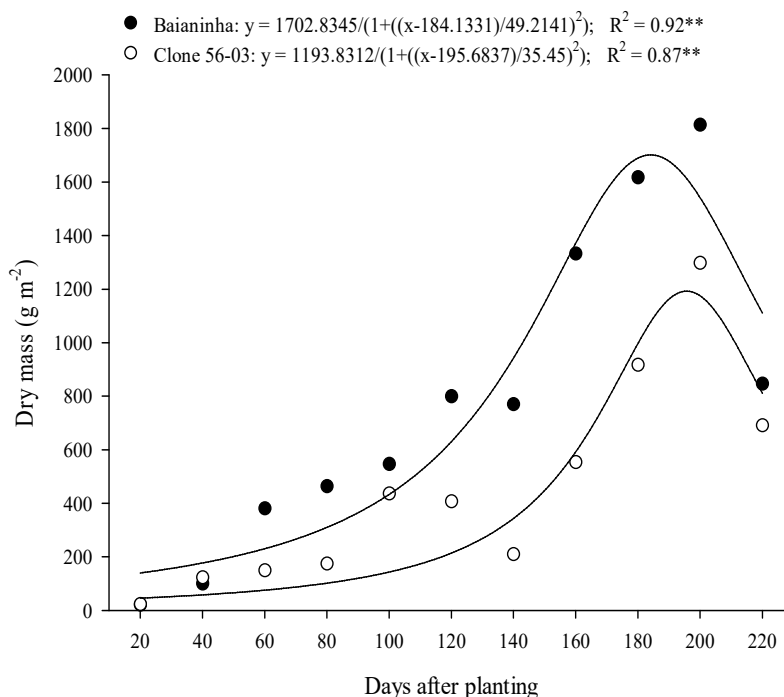

Figure 3. Weeds dry mass in coexistence with cassava plants 'Baianinha' and 'Clone 56-03' throughout the crop development (1st cycle)

Therefore, the results of leaf contents of N, P and K of the study cassava varieties, showed that the highest leaf contents of N in 'Baianinha' (44.7 g kg^{-1}) and 'Clone 56-03' (48.0 g kg^{-1}) without coexistence with weeds were recorded at 98.1 and 90.6 DAP, respectively (Figure 4A). However, when the varieties coexisted with weeds, the highest N content was found at 62.7 DAP for 'Baianinha' (35.4 g kg^{-1}) and at 75.7 DAP for 'Clone 56-03' (36.1 g kg^{-1}). This earlier occurrence of the maximum period of N accumulation in the leaves of the cassava varieties may indicate an adaptive response to the stress caused by weed competition.

The maximum P leaf content found for 'Baianinha' without coexistence with weeds occurred at 79.4 DAP, while for 'Clone 56-03', it occurred at 75.4 DAP (Figure 5A). When there was coexistence with weeds, the maximum P foliar contents in varieties 'Baianinha' and 'Clone 56-03' were found at 77.4 and 74.4 DAP, but they were 26.7% and 4.6% smaller, respectively, than those of the plants without coexistence.

The varieties 'Baianinha' and 'Clone 56-03' without coexistence with weeds presented foliar contents of about 22.5 g kg^{-1} of K at 84.2 and 87.2 DAP, respectively (Figure 6A). However, coexistence with the infesting community caused the anticipation of the maximum absorption point and reduced the K leaf contents, respectively, to 24 days and 27.1% for 'Baianinha' and to 12 days and 12.6% for 'Clone 56-03'.
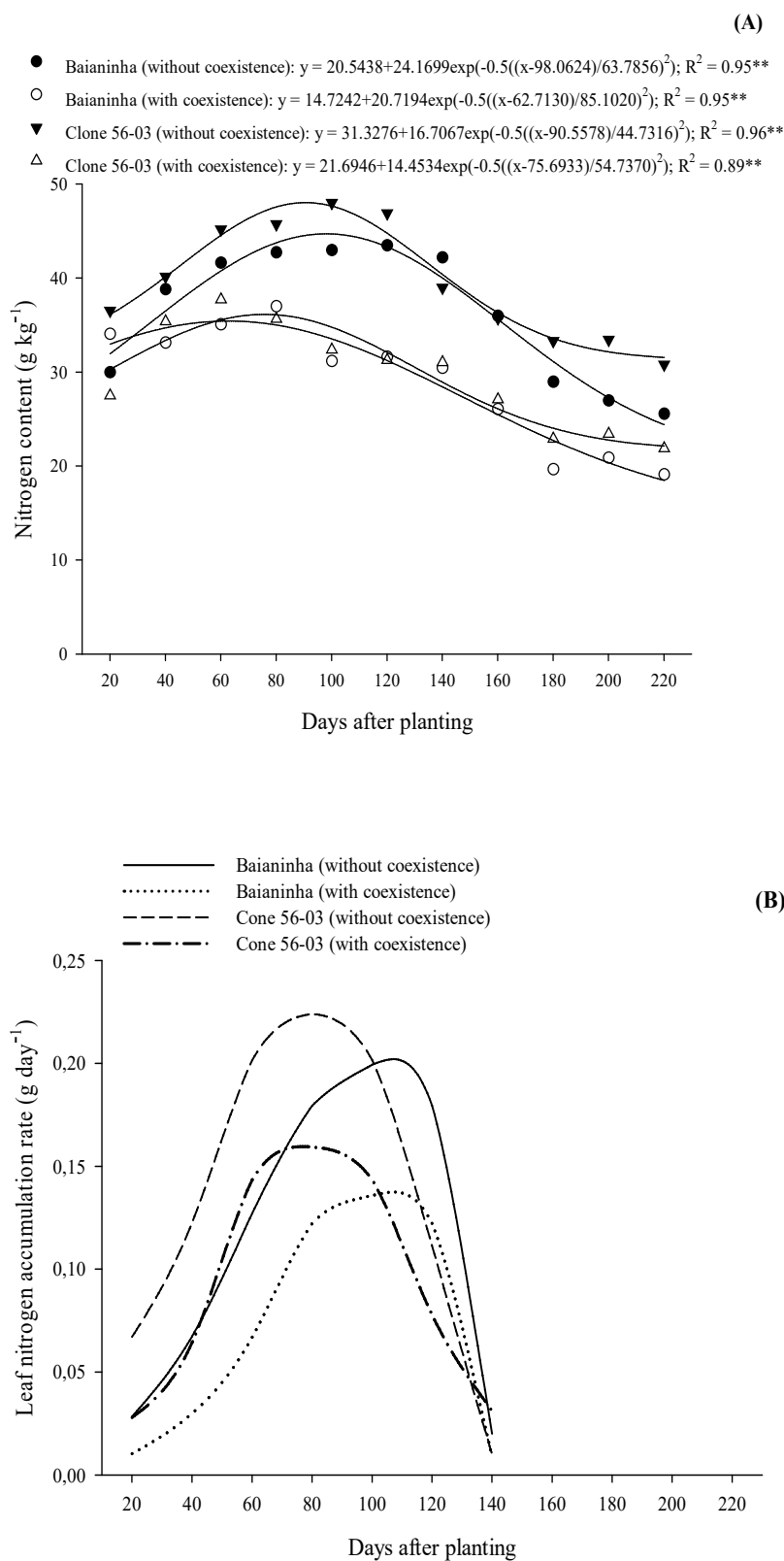
(A)

- ●   Baianinha (without coexistence): $y = 20.5438+24.1699\exp(-0.5((x-98.0624)/63.7856)^2)$; $R^2 = 0.95^{**}$
- ○   Baianinha (with coexistence): $y = 14.7242+20.7194\exp(-0.5((x-62.7130)/85.1020)^2)$; $R^2 = 0.95^{**}$
- ▼   Clone 56-03 (without coexistence): $y = 31.3276+16.7067\exp(-0.5((x-90.5578)/44.7316)^2)$; $R^2 = 0.96^{**}$
- △   Clone 56-03 (with coexistence): $y = 21.6946+14.4534\exp(-0.5((x-75.6933)/54.7370)^2)$; $R^2 = 0.89^{**}$

(B)

Figure 4. Contents (A) and accumulation rate (first derivative) (B) of nitrogen in the leaves of the 'Baianinha' and 'Clone 56-03' cassava plants, with and without weed coexistence throughout crop development (1st cycle)
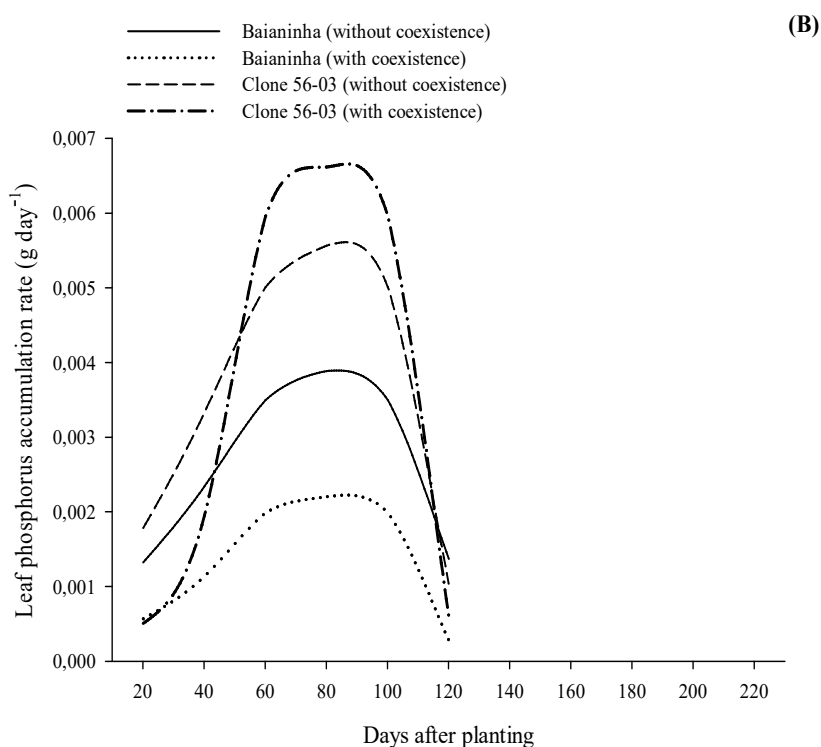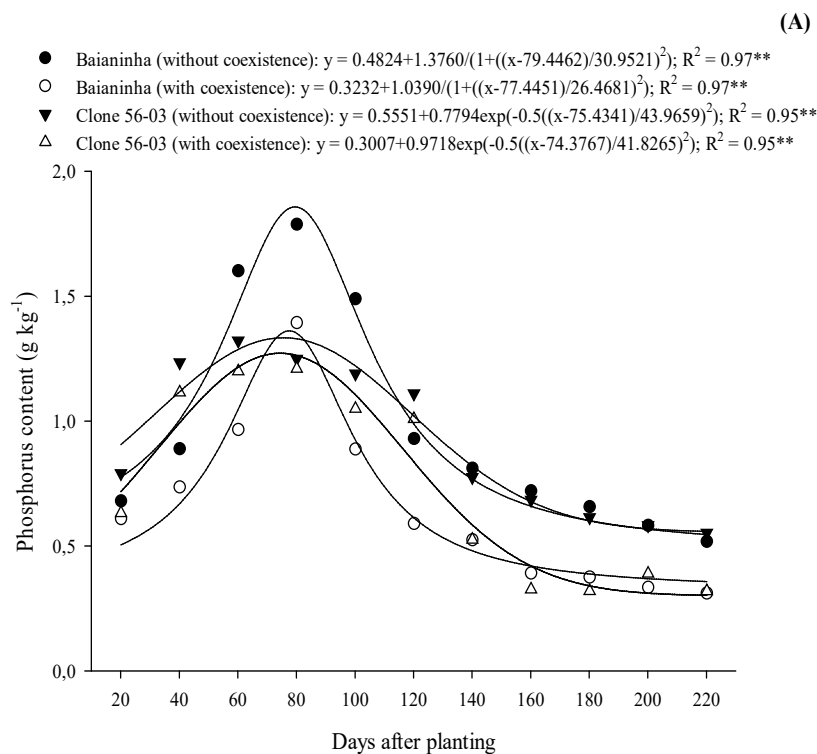
(A)

- ● Baianinha (without coexistence): $y = 0.4824 + 1.3760/(1+((x-79.4462)/30.9521)^2)$; $R^2 = 0.97**$
- ○ Baianinha (with coexistence): $y = 0.3232 + 1.0390/(1+((x-77.4451)/26.4681)^2)$; $R^2 = 0.97**$
- ▼ Clone 56-03 (without coexistence): $y = 0.5551 + 0.7794 \exp(-0.5((x-75.4341)/43.9659)^2)$; $R^2 = 0.95**$
- △ Clone 56-03 (with coexistence): $y = 0.3007 + 0.9718 \exp(-0.5((x-74.3767)/41.8265)^2)$; $R^2 = 0.95**$

(B)

Figure 5. Contents (A) and accumulation rate (first derivative) (B) of phosphorus in the leaves of the 'Baianinha' and 'Clone 56-03' cassava plants, with and without weed coexistence along the crop development (1st cycle)
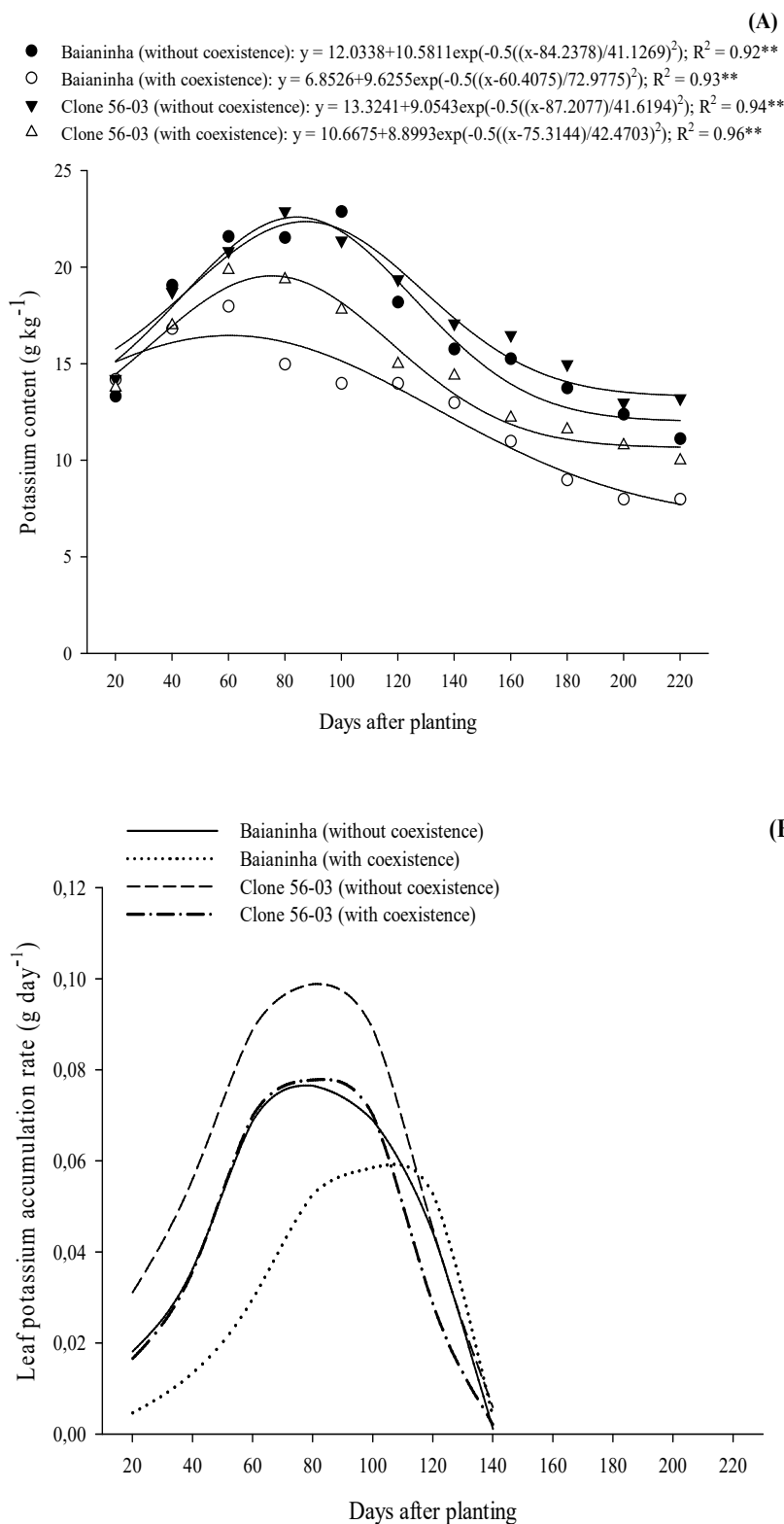
(A)

- ● Baianinha (without coexistence): $y = 12.0338 + 10.5811\exp(-0.5((x-84.2378)/41.1269)^2)$; $R^2 = 0.92$**
- ○ Baianinha (with coexistence): $y = 6.8526 + 9.6255\exp(-0.5((x-60.4075)/72.9775)^2)$; $R^2 = 0.93$**
- ▼ Clone 56-03 (without coexistence): $y = 13.3241 + 9.0543\exp(-0.5((x-87.2077)/41.6194)^2)$; $R^2 = 0.94$**
- △ Clone 56-03 (with coexistence): $y = 10.6675 + 8.8993\exp(-0.5((x-75.3144)/42.4703)^2)$; $R^2 = 0.96$**

(B)

Figure 6. Contents (A) and accumulation rate (first derivative) (B) of potassium in the leaves of the 'Baianinha' and 'Clone 56-03' cassava plants, with and without crop-weed coexistence along crop development (1st cycle)

Without coexistence with weeds, the 'Clone 56-03' presented the highest leaf accumulation rates of N, P and K; also, the period until maximum daily rate of nutrient accumulation occurred earlier than for 'Baianinha' (Figures 4 to 6 and Table 3). The period until maximum daily rate of N, P and K accumulation was 93.8 and 87 DAP for the 'Baianinha' leaves, respectively, while for 'Clone 56-03', it was 84, 77 and 82 DAP, respectively. After this period, there was a decline in the leaf contents in both varieties.

Coexistence with the infesting community changed the absorption physiology of the plants, causing reductions in the nutrient accumulation rates of N, P and K in the leaves of 'Baianinha' by 31.6%; 50.0% and 23.4%, respectively; for 'Clone 56-03', the rates were 29.0%; 0.0% and 21.2% respectively. Both varieties showed a longer period until reaching the maximum daily nutrient accumulation rates, but this period tended to be shorter for plants without coexistence.

The 'Clone 56-03' under coexistence conditions showed a slight increase in the maximum accumulation rate of P, as well as reduction of 10 days in the duration of the maximum daily accumulation rate (Table 3). These results indicate that there is a varietal difference regarding nutrient absorption efficiency and nutritional demands: the 'Clone 56-03' plants were more efficient in absorbing nutrients, especially P, than the 'Baianinha' plants.

The loss of nutrient in leaves from the cassava varieties may be correlated with weed dry mass (Figure 7). In 'Baianinha', there were losses in the order of 28.0%; 41.1% and 31.2% for N, P and K, respectively, at the end of the evaluation period, when the weeds accumulated about 1815 g m^{-2} of dry mass. During the same period, in the variety 'Clone 56-06', there were losses of 30.8%; 45.1% and 22.5% of N, P and K, respectively, and the weeds accumulated about 1300 g m^{-2} of dry mass.

The rate of total weed dry mass required to cause losses of 50% in the leaf contents found in 'Baianinha' and 'Clone 56-03' were 193 and 160 g m^{-2}, respectively. The data in Figure 3 show that the period for the weeds to accumulate an amount of biomass with potential to cause a 50% reduction in the leaf contents of the nutrients were of about 46 and 105 DAP for 'Baianinha' and 'Clone 56-03', respectively.

Table 3. Maximum cumulative content, period up to the maximum daily accumulation rate and duration of the maximum daily accumulation rate of Nitrogen, Phosphorus and Potassium (N-P-K) content in the leaves of cassava with and without crop-weed coexistence

Varieties		Maximum cumulative content (g day^{-1})			Period up to the maximum daily accumulation rate (days)			Duration of the maximum daily accumulation rate (days)		
		N	P	K	N	P	K	N	P	K
Baianinha	Without coexistence	0.199	0.004	0.077	93	79	87	32	33	36
	With coexistence	0.136	0.002	0.059	99	82	98	27	31	27
Clone 56-03	Without coexistence	0.226	0.006	0.099	84	77	82	33	31	34
	With coexistence	0.159	0.007	0.078	88	80	84	33	21	31

First derivative equations		
		N
Baianinha	Without coexistence	$15.3085\exp(-0.5((x-139.9580)/45.7920)^2)$
	With coexistence	$9.4714\exp(-0.5((x-141.6987)/42.2953)^2)$
Clone 56-03	Without coexistence	$19.2609\exp(-0.5((x-136.3108)/51.7852)^2)$
	With coexistence	$12.1747\exp(-0.5((x-133.3958)/44.7704)^2)$
		P
Baianinha	Without coexistence	$0.3289\exp(-0.5((x-131.2538)/51.3066)^2)$
	With coexistence	$0.1732\exp(-0.5((x-130.2199)/47.4168)^2)$
Clone 56-03	Without coexistence	$0.4401\exp(-0.5((x-125.4353)/47.8101)^2)$
	With coexistence	$0.3524\exp(-0.5((x-112.6693)/32.271)^2)$
		K
Baianinha	Without coexistence	$6.4420\exp(-0.5((x-138.0606)/49.6437)^2)$
	With coexistence	$4.0976\exp(-0.5((x-140.8728)/42.3603)^2)$
Clone 56-03	Without coexistence	$8.4884\exp(-0.5((x-134.8541)/51.8658)^2)$
	With coexistence	$5.9017\exp(-0.5((x-130.2653)/45.4963)^2)$

Data collected from the first derivative of the equations, as proposed by Greef et al. (1999).
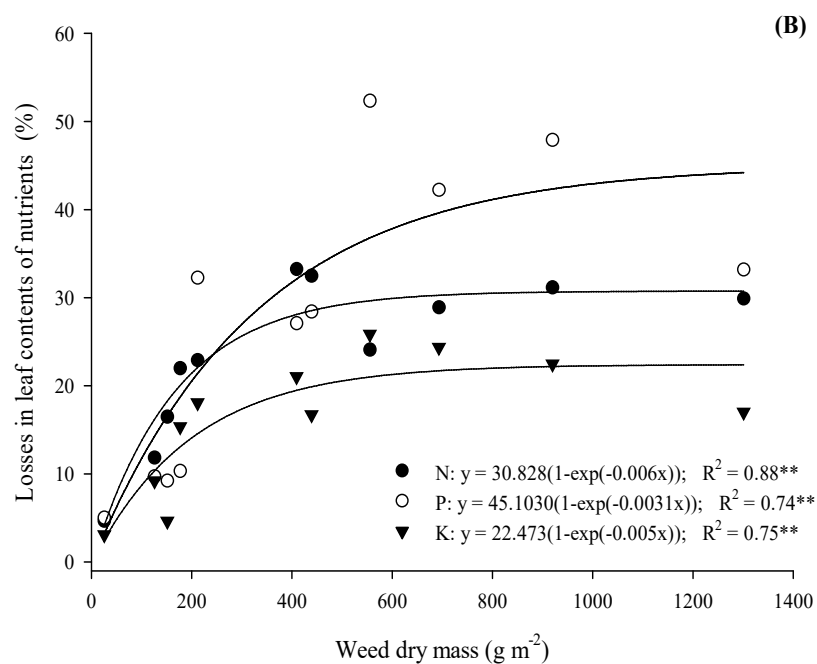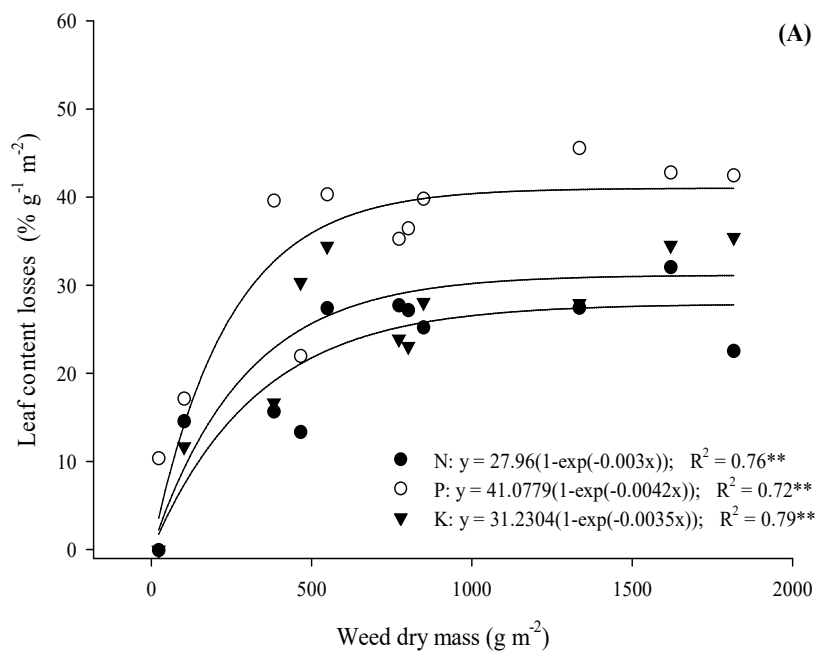
(A)

N: $y = 27.96(1-\exp(-0.003x))$; $R^2 = 0.76**$
P: $y = 41.0779(1-\exp(-0.0042x))$; $R^2 = 0.72**$
K: $y = 31.2304(1-\exp(-0.0035x))$; $R^2 = 0.79**$

(B)

N: $y = 30.828(1-\exp(-0.006x))$; $R^2 = 0.88**$
P: $y = 45.1030(1-\exp(-0.0031x))$; $R^2 = 0.74**$
K: $y = 22.473(1-\exp(-0.005x))$; $R^2 = 0.75**$

Figure 7. Losses in leaf contents of nutrients N, P and K in the cassava plants 'Baianinha' (A) and 'Clone 56-03' (B), on the basis of weed dry mas

4. Discussion

According to Greef *et al*. (1999), the maximum dry mass accumulation rate of maize was negatively correlated with duration of the dry mass maximum accumulation rate. However, in this study, there was a higher accumulation rate, combined with a longer duration of the total dry mass maximum accumulation period for 'Clone 56-03', in comparison to 'Baianinha' both with and without coexistence with weeds.

Sangoi & Krause (1993) argued that the variety with the fastest growth and highest dry mass production is not always the most productive one from an economic perspective. These authors found that the cassava variety 'Aipim-gigante' presented greater total dry mass production than 'Mico'; however, at the end of the cycle, the tuberous roots accounted for 50% of the 'Aipim-gigante' biomass while for 'Mico', the tuberous roots accounted for 70%. A similar behavior also found by Rós *et al*. (2011) when they evaluated nine cassava varieties.

More competitive varieties provide fast closing of the inter-rows space, blocking the passage of sunlight, which stimulates seed bank germination and weed growth. Thus, Silva *et al*. (2013), found that plants from the variety 'Periquita' in coexistence for 75 DAP with weeds *Bidens pilosa, Cenchrus echinatus* and *Amaranthus spinosus* presented 60.9%; 32.6% and 48.6% more total dry mass than the plants from the variety 'IAC-12'. The authors also found that the cassava varieties presented lower dry mass accumulation when in competition with weed species, and the roots were the organs most affected by competition. These results can also be found in the present study.

The fast growth and higher dry mass accumulation in 'Clone 56-03' plants can also indicate higher efficiency in absorbing the nutrients available in the soil, even under competition with weeds.

The decline in the leaf contents coincides with the period when the plant transforms the fibrous roots into tuberous roots, which increases translocation of photoassimilates, produced on the leaves, to the reserve roots (Lorenzi *et al*., 1981; Rós *et al*., 2011; Silva *et al*., 2014).

Another important point to be considered for understanding the interference mechanisms of the infesting community over the productive potential of cassava plants, is the fact that the period until the maximum daily rate of leaf nutrient accumulation of the varieties (77 to 93 DAP) also coincides with the critical period of weed control, which may range from 25 up to 100 DAP, depending on each variety, infesting community and edaphoclimatic conditions (Moura, 2000; Albuquerque *et al*., 2008; Biffe *et al*., 2010). This indicates that crop-weed competition for nutrients can explain the drastic reductions in root production in the cassava varieties (Figure 2).

Non-fertilization of the crop at planting time is a common practice among cassava producers to reduce production costs. Thus, the use of efficient varieties in terms of nutrient absorption may be an economic advantage to farmers planting in low fertility soils, especially those with a deficit of P. On the other hand, the use of fertilizers at planting or on cover could minimize the effects of weed competition on nutrient absorption and, consequently, on crop yield.

According to Fidalski (1999), root production for the cassava variety 'Fibra' did not present responses to nitrogen and potassium fertilization; however, phosphorus fertilization significantly increased root production by up to 39% using the dose of 120 kg ha^{-1} of P_2O_5, in low-fertility sandy soils in northwestern Paraná. By contrast, Cardoso Júnior *et al*. (2005) found that for each 1 kg of N applied in the soil, 11 kg of tuberous roots, on average, were produced by the varieties 'Sergipe' and 'Lisona'.

In general, it was found that the smallest accumulation of nutrients in the leaves indicate the need for cassava plants to anticipate the development cycle, which leads to a shorter tuberization period and, consequently, a lower final crop yield. Thus, it is evident that despite the rusticity of the cassava crop, there is a need to manage the weed community, at least in the critical period of the crop, so as not to cause damage to the tuber root production, owing to the competition for soil nutrients (Albuquerque *et al*., 2012, Costa *et al*., 2013, A'ihi *et al*., 2017).

The correlation of weed biomass with damage to nutrient absorption can be used to support the development of specific weed control strategies, especially at post-emergence, according to the level of tolerance to the competition of the variety used in planting. It can also be used as a criterion to determine the need (dose or rate) and / or the strategy (leaf or soil) for crop nutrient replacement after planting.

In general, there was higher sensitivity in the 'Baianinha' variety in coexistence with weeds, because it presented lower shoot dry mass and leaf nutrient accumulation rates. The 'Clone 56-06', in coexistence with weeds, was more tolerant to such coexistence. Therefore, the choice of varieties tolerant to weed competition may contribute to Integrated Weed Management, owing to the cultural control of weeds by fast closure of inter-rows.

5. Conclusion

Plants from the 'Clone 56-03' presented higher biomass accumulation and root dry mass, as well as higher leaf contents of N, P and K than the traditional cassava variety 'Baianinha', especially in coexistence with weeds during the whole cycle.

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