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Article

Period of Weed Interference in Guarana Crop

Período de Interferência das Plantas Daninhas na Cultura do Guaranazeiro

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ABSTRACT - Guarana is a plant native to the Amazon region that produces the fruit known as guarana. Guarana production is carried out by small farmers and is a source of income for thousands of people in rural and urban areas. The interference caused by the competition between weeds and guarana is an important limiting factor of its production. Despite its economic and social importance, there are few studies on the management of weeds in this species. Thus, this research aimed to study the effects of weed interference on guarana yield in different periods. This study was performed in Maués, AM, in the 2014 and 2015 seasons. The experimental design was a randomized block design with eight treatments and four blocks. Treatments consisted of a combination of four different periods of control or coexistence with weeds (March to May, June to August, September to November, and December to February). Weed community was composed of 23 weed species belonging to 12 botanical families, with *Paspalum virgatum* being the species with the highest importance value index (55.74%). Weed coexistence with guarana from June to August provided the lowest yields (156.16 kg ha^{-1} of grains) when compared to weed control in the same period (309.05 kg ha^{-1} of grains). Weed interference from June to August reduced guarana yield by 50%.

Keywords: critical period, weeds, competition, *Paullinia cupana*.

RESUMO - O guaranazeiro é uma planta nativa da região amazônica, cujo fruto é conhecido como guaraná. A produção de guaraná envolve pequenos agricultores e é fonte de renda para milhares de pessoas nos meios rural e urbano. A interferência causada pelas plantas daninhas na cultura constitui um importante fator que limita sua produção. Apesar da importância econômica e social do guaranazeiro, ainda são escassos estudos sobre o manejo das plantas daninhas em seu cultivo. Diante do exposto, o presente trabalho teve por objetivo estudar os efeitos da interferência das plantas daninhas sobre a produtividade do guaranazeiro em diferentes períodos. O estudo foi conduzido em Maués, AM, nas safras de 2014 e 2015. O delineamento experimental adotado foi em blocos casualizados com oito tratamentos e quatro blocos. Os tratamentos foram a combinação de quatro períodos diferentes de controle ou de convivência das plantas daninhas (março a maio; junho a agosto; setembro a novembro; dezembro a fevereiro). A comunidade infestante foi composta por 23 espécies de plantas daninhas, pertencentes a 12 famílias botânicas, sendo Paspalum virgatum a espécie com o maior índice de valor de importância (55,74%). O convívio das plantas daninhas com o guaranazeiro durante o período de junho a agosto proporcionou as menores produtividades (156,16 kg ha^{-1} de grãos), em comparação ao mesmo período com controle das plantas daninhas (309,05 kg ha^{-1} de grãos). A interferência das plantas daninhas de junho a agosto reduziu em 50% a produtividade do guaranazeiro.

Palavras-chave: período crítico, plantas daninhas, competição, *Paullinia cupana*.

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INTRODUCTION

Guarana is a plant native to the Amazon, known for its medicinal and energy properties related to the high natural caffeine content in its seeds, which may be four times higher than that of coffee (Tfouni et al., 2007) or 30 times higher than that found in cocoa (Edwards et al., 2005). Thus, it has the potential for use in the soft drink, pharmaceutical, and cosmetic industry.

In 2016, Brazil had a harvested area of 11,465 hectares, reaching a production of 3,726 tons of grains, being considered the only commercial producer of guarana, serving the domestic and international markets. The municipality of Maués is the main producer in the State of Amazonas (IBGE, 2016). In this scenario, guarana production has gained economic and social importance for the Amazon region, where plantations are mainly carried out by family farming.

The interference caused by weeds constitutes an important factor limiting guarana production, besides promoting significant changes in the physiology of cultivated plants, which may compromise its growth, yield, and quality of fruits. Despite its economic and social importance, studies on weed management in the guarana crop are still scarce. Thus, research plays an important role in creating alternatives to make it an economically viable agricultural activity. Considering that, the aim of this research was to study the effects of weed interference on guarana yield in different periods.

MATERIAL AND METHODS

The experiment was installed and conducted during the 2014 and 2015 seasons at the Santa Helena Farm, a guarana production area of the Companhia de Bebidas das Américas (Ambev) located in Maués, AM, at the geographical coordinates 03°27'00" S and 57°38'60" W.

The regional climate is classified as Af according to the Köppen classification, i.e. a rainy tropical climate with mean annual temperature above 26 °C, relative humidity from 80 to 85%, and mean annual precipitation from 2,080 to 2,837 mm (Prosaimaués, 2012). The analysis of soil samples at a depth of 0 to 20 cm presented a high content of exchangeable aluminum and low contents of organic matter, phosphorus, calcium, and magnesium (Table 1).

Table 1 - Results of soil chemical analyses of the experimental area at a depth of 0 to 20 cm. Maués, AM, 2014/2015

pH	OM	P	K	Ca	Mg	Al	H+Al	SB	T	t	V	M
	($g\ kg^{-1}$)	($mg\ dm^{-3}$)		($cmol_c\ dm^{-3}$)							(%)	
3.7	2.0	4.0	56.0	0.65	0.55	1.6	8.0	1.34	9.34	2.94	14.4	54.4

Guarana orchard presented plants with a good phytosanitary aspect, formed by the cultivar BRS-Maués, with approximately five years of age, spaced 5.0 x 4.0 m from each other, and 15 plants per plot, the three of the central row being considered useful plants, totaling 300 m^2 per plot and 9,600 m^2 of experimental area.

For the study of interference periods, the experimental design was a randomized block design with eight treatments and four replications. Treatments consisted of the combination of different periods of control and/or coexistence with weeds (Table 2), defined based on the precipitation data collected at the experiment site (Figure 1).

Weed control was performed according to the method adopted by the company: a monthly application of the herbicide Gramoxone® (200 g L^{-1}) at a dose of 1.5 L ha^{-1} with the adjuvant Agral® at 0.05% v/v in a directed application on the guarana planting rows.

Studies on floristic and phytosociological compositions of weeds were performed using the inventory square method (Braun-Blanquet, 1950) using samplers with an area of 0.12 m^2 randomly placed twice at each plot, totaling 7.68 m^2 of sampling area. The calculated phytosociological

Table 2 - Periods of control (Control) and coexistence (X) of weeds with the guarana crop. Maués, AM, 2014/2015

Treatment	Period (months)			
	March to May	June to August	Sept. to Nov.	Dec. to Feb.
	P1	P2	P3	P4
T1	X	Control		
T2	Control			X
T3	Control	X	Control	X
T4	X	Control	X	Control
T5	Control		X	
T6	X		Control	
T7	Control			
T8	X			

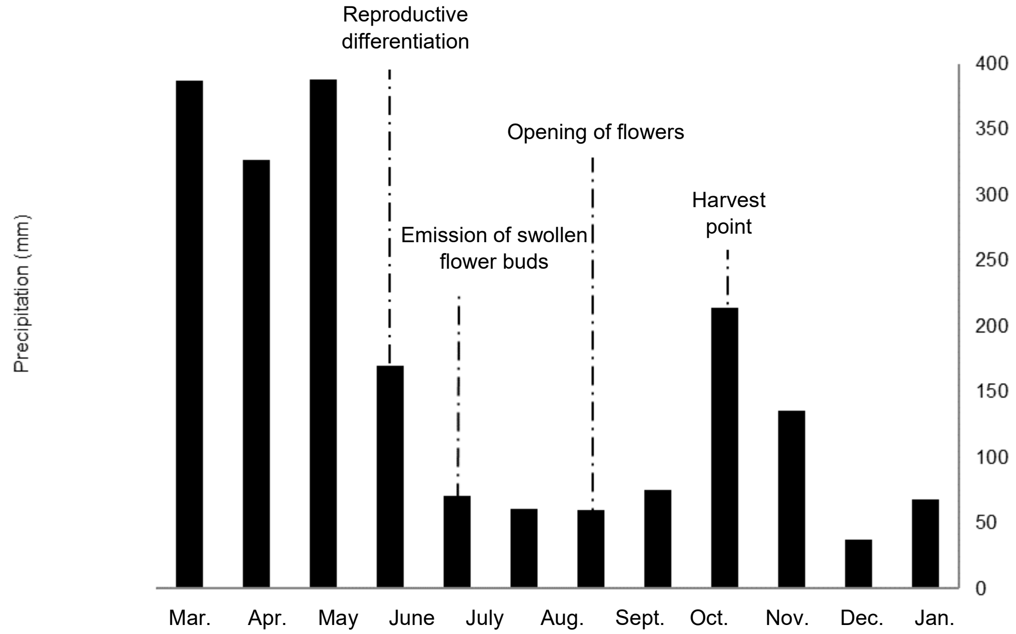

Figure 1 - Precipitation data of the experimental area and reproductive evolution of guarana. Maués, AM, 2014.

parameters were frequency, density, abundance, and importance value index, according to the equations proposed by Mueller-Dombois and Ellenberg (1974).

Guarana yield was quantified in the 2014 and 2015 seasons. Harvest was manually carried out from November to December of each year. The yield data of both agricultural years were submitted to the joint analysis according to Banzatto and Kronka (1992) for analysis of variance and subsequent mean comparison by the Scott-Knott test ($p<0.05$) using the software Assistat version 7.7.

RESULTS AND DISCUSSION

Twenty-three weed species belonging to 12 botanical families were identified in the experimental area, totaling 3,093 individuals. Among the identified species, 11 were monocots and 12 dicots. The most important families in the number of species were Poaceae (6) and Cyperaceae (4) (Table 3). Albertino et al. (2004) and Souza et al. (2003) found similar results in guarana plantations, where the dicot class also had the highest number of families.

Monocots had the lowest number of species, but the highest number of individuals (2,508), representing 80% of the total of individuals of the two classes, while the Poaceae family presented

Table 3 **-** Weeds identified in the guarana plantation. Maués, AM, 2014/2015

Family	Species		
	Scientific name	Code	Common name
Amaranthaceae	*Alternanthera tenella* Colla.	ALRTE	Calicoplant
	Alternanthera sessilis (L.) R. Br. ex DC.	ALRSE	Sessile joyweed
Commelinaceae	*Commelina erecta* L.	COMER	Whitemouth dayflower
Cyperaceae	*Cyperus aggregatus* (Willd.) Endl.	CYPAG	Inflatedscale flatsedge
	Cyperus diffusus Vahl.	CYPDF	Diffused flatsedge
	Cyperus esculentus L.	CYPES	Yellow nutsedge
	Cyperus sesquiflorus L.	CYPSS	Fragrant spikesedge
Euphorbiaceae	*Euphorbia heterophylla* L.	EPHHL	Wild poinsettia
Fabaceae	*Zornia latifolia* Sm.	ZORLA	Zornia
	Pueraria phaseoloides (Roxb.) Benth.	PUEPH	Tropical kudzu
Melastomataceae	*Clidemia rubra* (Aubl.) Mart.	CXARU	Clidemia
Nyctaginaceae	*Boerhavia diffusa* L.	BOEDI	Red spiderling
Piperaceae	*Peperomia pellucida* (L.) Kunth	PEOPE	Man to man
Poaceae	*Andropogon leucostachyus* Kunth	ANOLE	Matojillo bluestem
	Brachiaria decumbens Stapf	BRADC	Spreading liverseed grass
	Digitaria horizontalis Willd.	DIGHO	Jamaican crabgrass
	Eleusine indica (L.) Gaertn.	ELEIN	Goosegrass
	Homolepis aturensis (H.B.K.) Chase	HOMAT	Panicgrass
	Paspalum virgatum L.	PASVI	Talquezal
Rubiaceae	*Spermacoce latifolia* Aubl.	BOILF	Oval-leaf false buttonweed
	Spermacoce verticillata L.	SPEVE	Shrubby false buttonweed
Solanaceae	*Solanum stramoniifolium* Jacq.	SOLST	Coconilla
Verbenaceae	*Stachytarpheta cayennensis* (Rich.) Vahl.	STACA	Cayenne porterweed

approximately 57% of the total of individuals found in the experimental area, which is in accordance with Albertino et al. (2004) and Souza et al. (2003).

Talquezal (*Paspalum virgatum*), belonging to the Poaceae family, was the most prominent species in the weed community, with the highest number of individuals (986), the highest values of relative density (31.88%) and, consequently, the highest importance value (IVI = 55.74%) (Table 4). Some studies have concluded that species of the genus *Paspalum* present mechanisms of survival to water deficit and adaptive characteristics for water loss, such as that of Beloni et al. (2017).

Moreover, this species has been cited in researches carried out in Amazonian agro-systems, such as that of Tavares (2005), who studied a guarana production system in the State of Amazonas and considered as a situation of highly weed infestation the presence of aggressive species, such as *P. virgatum*. Some species of the Poaceae family in guarana plantations are recognized by their efficiency in extracting water from the soil during the period of higher water restriction (Melo et al., 2007). Such characteristics give advantages to these species under conditions of lower water availability, which may hinder guarana development.

Commelina erecta, which presented the second highest importance value index (Table 4), is a species that competes with several agricultural crops for nutrients, water, and light, causing significant losses to producers (Krolikowski, 2015). In addition, this species may hinder grain harvest due to its high water content in the stem (Penckowski and Rocha, 2006). Despite a good development in light and rich soils, with good moisture conditions, plants of the Commelinaceae family, when well established, may withstand long periods of water stress (Krolikowski, 2015).

For 2014 and 2015 seasons, the highest yields were registered when weeds were controlled from June to August (T1, T2, T4, T5, and T7) when compared to the treatments without control during the same period (T3, T6, and T8) (Table 5). The coexistence with weeds during this period showed a reduction of approximately 50% in guarana yield. This period corresponded to the crop

Table 4 **-** Phytosociological parameters of the weed community in a Guarana plantation. Maués, AM, 2014/2015

Class	Scientific name	TNI	FRE	DEN	ABU	FRR	DER	ABR	IVI
M	*Paspalum virgatum* L.	986	0.72	128.39	42.87	15.33	31.88	8.53	55.74
M	*Commelina erecta* L.	491	0.75	63.93	20.46	16.00	15.87	4.07	35.95
D	*Pueraria phaseoloides* (Roxb.) Benth	368	0.78	47.92	14.72	16.67	11.90	2.93	31.49
M	*Digitaria horizontalis* Willd.	383	0.22	49.87	54.71	4.67	12.38	10.89	27.94
M	*Andropogon leucostachyus* Kunth	117	0.03	15.23	117.00	0.67	3.78	23.29	27.74
M	*Brachiaria decumbens* Stapf	225	0.16	29.30	45.00	3.33	7.27	8.96	19.56
M	*Cyperus aggregatus* (Willd.) Endl.	95	0.34	12.37	8.64	7.33	3.07	1.72	12.12
M	*Cyperus esculentus* L.	63	0.03	8.20	63.00	0.67	2.04	12.54	15.24
M	*Eleusine indica* (L.) Gaertn.	61	0.03	7.94	61.00	0.67	1.97	12.14	14.78
D	*Boerhavia diffusa* Willd.	55	0.25	7.16	6.88	5.33	1.78	1.37	8.48
M	*Cyperus diffusus* Vahl	44	0.22	5.73	6.29	4.67	1.42	1.25	7.34
D	*Stachytarpheta cayennensis* (Rich.) Vahl	37	0.19	4.82	6.17	4.00	1.20	1.23	6.42
M	*Cyperus sesquiflorus* L.	40	0.13	5.21	10.00	2.67	1.29	1.99	5.95
D	*Spermacoce latifolia* Aubl.	36	0.16	4.69	7.20	3.33	1.16	1.43	5.93
D	*Peperomia pellucida* (L.) Kunth	9	0.19	1.17	1.50	4.00	0.29	0.30	4.59
D	*Alternanthera sessilis* (L.) R. Br. ex DC.	30	0.09	3.91	10.00	2.00	0.97	1.99	4.96
D	*Zornia latifolia* Sm.	15	0.09	1.95	5.00	2.00	0.48	1.00	3.48
D	*Alternanthera tenella* Colla.	13	0.09	1.69	4.33	2.00	0.42	0.86	3.28
D	*Spermacoce verticillata* L.	11	0.09	1.43	3.67	2.00	0.36	0.73	3.09
D	*Clidemia rubra* Aubl. Mart.	6	0.03	0.78	6.00	0.67	0.19	1.19	2.05
D	*Euphorbia heterophylla* L.	3	0.03	0.39	3.00	0.67	0.10	0.60	1.36
M	*Homolepis aturensis* (H.B.K.) Chase	3	0.03	0.39	3.00	0.67	0.10	0.60	1.36
D	*Solanum stramoniifolium* Jacq.	2	0.03	0.26	2.00	0.67	0.06	0.40	1.13
TOTAL		3093	4.69	402.73	502.43	100.00	100.00	100.00	300.00

M = monocot; D = dicot; TNI = total number of individuals; FRE = absolute frequency; DEN = absolute density; ABU = absolute abundance; FRR = relative frequency; DER = relative density; ABR = relative abundance; IVI = importance value index.

Table 5 **-** Guarana yield submitted to periods of control (Control) and coexistence (X) with weeds. Maués, AM, 2014/2015

Treatment	Period (months)				Yield ($t\ ha^{-1}$)
	March to May	June to August	Sept. to Nov.	Dec. to Feb.	
	P1	P2	P3	P4	
T1	X	Control			281.52 a
T2	Control			X	309.55 a
T3	Control	X	Control	X	156,16 b
T4	X	Control	X	Control	279.32 a
T5	Control		X		309.05 a
T6	X		Control		177.12 b
T7	Control				337.39 a
T8	X				120.26 b

pre-flowering and coincided with the abrupt reduction of water availability in the experimental area (Figure 1).

Guarana flowering in the studied agricultural years was observed from September to October and harvest from November to December. The observations carried out in this research, in agreement with the known data on guarana phenology, indicate a relationship between precipitation and its reproductive evolution (Figure 1).

Although the externalization of the reproductive stage begins with the emission of the first swollen flower buds, complex physiological changes occur internally before this, stimulated mainly by the marked reduction of precipitation. Besides denoting a possible influence of hydroperiodism on the crop, it indicates that guarana sensitivity to weed competition can occur even at the reproductive differentiation stage, i.e. even before the first visible reproduction signs.

Another factor that may be related to the lowest guarana yields during weed coexistence from June to August (Table 5) refers to the intensification of plant demand for water and nutrients at the differentiation of reproductive tissues. Thus, the technical recommendations of fertilization for the most diverse agricultural crops propose the supply of nutrients at pre-flowering in order to maximize the formation of specific structures of this stage, which justifies the recommendation of topdressing fertilization for guarana plants until May, i.e. before the beginning of flowering (Tavares, 2005).

Researches on guarana fertilization are scarce and no studies have been found in the literature relating nutritional requirements of this species to its phenological stages. However, the competition for water and nutrients during guarana reproductive evolution probably has affected its yield due to the loss in the formation of reproductive structures.

Another factor to be considered in this study is the condition of the soil cultivated with guarana, which presented low values of pH and organic matter, high contents of exchangeable aluminum, and nutritional deficiency (Table 1). This soil condition may have favored the establishment of more aggressive weeds, promoting a decrease in crop yield. In this case, the ability of weeds to develop and extract nutrients from acid soils (a common condition of tropical soils) contributes to successful competition for this factor, thus reducing its availability to the crop of agronomic interest (Souza Filho et al., 2000).

Guarana yield free from weed coexistence during the entire cycle was 337.39 kg ha^{-1} and decreased to 120.26 kg ha^{-1} when it coexisted with weeds during the entire cycle, representing a loss of approximately 65% (Table 5).

Therefore, weed interference on guarana yield may be a result of the combination of two main factors: one related to the crop phenological stage by means of physiological changes and high nutritional demand during the differentiation of reproductive tissues, and another related to the competition for water since the scarcity of this resource directly compromises nutrient absorption from the soil solution and, consequently, the growth and development of guarana plants. These facts allow us to conclude that weed interference in guarana from June to August reduced its yield.

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