Weed dynamics in cover crop/Sillage maize succession under potassium fertilization

Dinâmica de plantas daninhas na sucessão planta de cobertura/milho silagem e adubação potássica

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Abstract: **Background**: Weeds compete with crops for resources, reducing agricultural productivity. Management practices involving cover crops and potassium fertilization can influence weed community dynamics.
Objective: To evaluate the weed community in a U*rochloa ruziziensis*-sillage maize (*Zea mays* L.) for silage succession system, considering different potassium fertilizer (K) rates applied to the cover crop.
Methods: During the fall-winter season, treatments included *U. ruziziensis* with six K rates (0, 30, 60, 90, 120, or 150 kg K_2O ha^{-1} as KCl) and a fallow control. In the summer, maize was cultivated with complementary K rates to total 150 kg K_2O ha^{-1} for the cover crop systems, and a conventional K application (60 + 90 kg K_2O ha^{-1}) for the fallow. Weed surveys were conducted using 0.50 m² metallic frame. Phytosociological indices, dry biomass, species count, and total weed density were determined.
Results: The weed community and phytosociological indices varied depending on the crop and season. The highest dry biomass of weeds was observed before cutting *U. ruziziensis*. Species richness and weed density were higher at the V_4 growth stage of maize, prior to herbicide application.
Conclusions: Management with *U. ruziziensis* and potassium fertilization affects weed community dynamics. The choice of succession system and K rates directly influences weed infestation and can contribute to integrated weed management strategies.

Resumo: **Introdução**: As plantas daninnhas competem com as culturas por recursos, reduzindo a produtividade agrícola. Práticas de manejo com plantas de cobertura e adubação potássica podem influenciar na dinamica da comunidade infestante.
Objetivo: Avaliar a comunidade de plantas daninhas em sistema de sucessão *Urochoa ruzizienis*- milho silage (Zea mays L.), considerando diferentes doses de fertilizante potássico (K) aplicadas na cultura de cobertura.
Métodos: No outono-inverno foram testados os tratamentos: U. ruziziensis com seis doses de K (0, 30, 60, 90, 120 ou 150 kg K_2O ha^{-1} na forma de KCl) e pousio. No verão, o milho recebeu doses complementares de K, totalizando 150 kg K_2O ha^{-1} nos sistemas com cobertura, e adubação convencional (60 + 90 kg K_2O ha^{-1}) no pousio. Realizou-se o levantamento populacional de plantas daninhas com quadros de 0,50 m, estimando-se índices fitossociológicos, massa seca, número e densidade das espécies.
Resultados: A comunidade de plantas daninhas e seus índices fitossociológicos variaram conforme a cultura e o período agrícola. A maior massa seca foi observada antes do corte da *U. ruziziensis*. O número de espécies e a densidade de plantas foram maiores no estádio V_4 do milho, antes da aplicação do herbicida.
Conclusões: O manejo com *U. ruziziensis* e a adubação potássica influenciam a dinâmica da comunidade de plantas daninhas. A escolha do sistema de sucessão e das doses de K afeta diretamente a infestação, podendo contribuir para estratégias integradas de manejo.

Keywords: *Zea mays L, Urochloa ruziziensis*, corn, succession, cover crops, potassium fertilization.

Palavras-chave: *Zea mays L, Urochloa ruziziensis*, milho, plantas de cobertura, fertilização potássica.

1. Introdução

Maize (*Zea mays* L.) is an annual grass with wide adaptation to different environments, and due to the ease of cultivation, nutritional quality and productivity, it is considered one of the most suitable plants for ensiling (Santos et al., 2018a). The use of maize for silage production is important as it ensures a quality feed source during the off-season (Calixto Junior et al., 2017). However, when harvesting maize for silage, all aerial parts of the plant are removed (Ueno et al., 2013) and in dry winter regions, the absence of rain makes it difficult to cultivate in succession, causing the soil to remain uncovered during this season (Moreira et al., 2014). The absence of a crop cover, promotes the occurrence and high incidence of weeds, thus resulting in an increase in the seed bank and infestation of subsequent crops (Lima et al., 2014).

Weed competition can significantly limit the profitability and productivity of agricultural crops. Many of the weed species have high seed production, high viability and germination, short growth cycle and are highly aggressive, which increases the complexity of control (Ávila et al., 2020). In addition to being hosts for pests and diseases, weeds compete for water, light, space and nutrients for crop development, negatively affect cultural practices and harvest, and raise production costs (Santos et al., 2018a). Thus, understanding the community of weeds within a crop production system is essential for choosing appropriate practices for their control, especially in crops with less capacity for competition (Concenço et al., 2013a).

The weed community of a given area is highly related to the particularity and management of the cropping system and to the interaction among several factors (Ulguim et al., 2018). Cover crops, for example, can suppress weeds by exerting competition for factors such as water, light, space and nutrients (Sturm et

al., 2018). The straw produced functions as a physical barrier acting directly on the amount of light reaching the soil surface and retention of soil moisture, which can affect the breaking of seed dormancy and the germination of seeds and/or propagules (Caratti et al., 2018). Some cover crop plants, either alive or decomposing, are able to inhibit the development of weeds through the exudation of allelopathic compounds (Jabran et al., 2015). Fertilizer use can affect the emergence, persistence, dormancy, dynamics, growth and dispersion of weeds (Bajwa et al., 2014). Excessive fertilization can promote the emergence of weeds at the beginning of the crop growing season, increasing competition with the crop and making weed management more difficult (Bulegon et al., 2014).

A phytosociological survey of weeds consists of a set of assessments that aim at a general knowledge of the composition and distribution of plant species present in a given community (Concenço et al., 2013b). The information obtained through phytosociological studies is of great relevance, since it allows the understanding of the iterations that occurred within an area and the identification of the species that are being selected by the practices and management used (Concenço et al., 2015). Additionally, the survey can be used to determine which species are harmful to crop yield, thereby directing more assertive control alternatives within each system (Silva et al., 2018; Teixeira

Júnior et al., 2020).

The objective of this work was to evaluate the weed community in a crop succession system of *Urochloa ruziziensis* / maize silage in which the cover crop, as well as the cash crop, received K fertilizer.

2. Materials and Methods

The experiment was conducted during the fall/winter season of 2020 and summer season of 2020/2021 at the (Local omitido por motivo de submissão). The region's climate is characterized as humid temperate (Cwa), with hot and humid summers and cold and dry winters, an average annual temperature of 19.4°C, and an average annual rainfall of 1,530 mm.

The climatic variations that occurred in the area during the experiment are shown in Figure 1. The soil in the region was classified as a dystrophic Red Yellow Latosol (LVAd) (Santos et al., 2018b). Soil analysis for the 0-20 cm layer prior to establishing the experiment was: pH H_2O: 6.9; Ca: 3.2 $cmol_c$ dm^{-3}; Mg: 0.60 $cmol_c$ dm^{-3}; Al: 0 $cmol_c$ dm^{-3}; H+Al: 1.8 $cmol_c$ dm^{-3}; effective CEC; 4.2 $cmol_c$ dm^{-3}; CEC at pH7: 6.0 $cmol_c$ dm^{-3}; P (Rem): 17.50 mg dm^{-3}; K: 142.2 mg dm^{-3}; Sum of Bases: 4.17 $cmol_c$ dm^{-3}; Base Saturation: 69.8%; Soil Organic Matter: 2.4%; Clay: 64%; Silt: 5%; Sand: 31%.
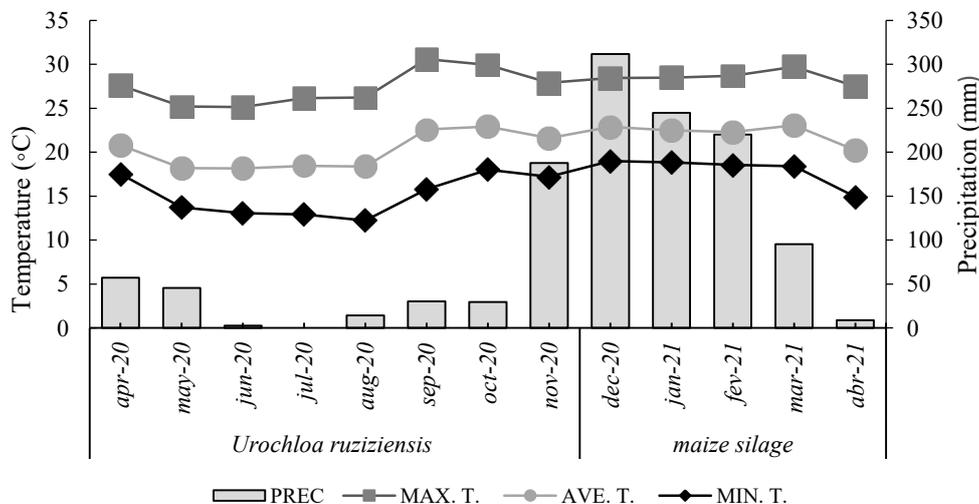

Figure 1. Accumulated precipitation (PREC) and maximum (MAX. T.), mean (AVE. T.) and minimum (MIN. T.) temperatures from April 2020 to April 2021 in the experimental area.

For the establishment of the experiment in the fall/winter crop of 2020, the soil was prepared with two harrows and then the furrows were opened with the aid of a furrower. Plots were ten rows by five meters long spaced 0.25 meters apart, totaling 12.5 m². In April of 2020, *Urochloa ruziziensis* from BR Seeds, cultural value: 62%, was sown by hand at 10 kg ha^{-1}. Forty-seven days after sowing, K fertilizer was broadcast applied as muriate of potash (KCl, 57% K_2O) at 0, 30, 60, 90, 120 and 150 kg K_2O ha^{-1} (Table 1). Experimental design was a completely randomized block with four replications.

In November 2020 (210 days after sowing), the

B. ruziziensis plants were cut close to the ground with a backpack brush-cutter and then the residues were distributed within each plot. In order to eliminate existing weeds and possible re-sprouting, all plots were desiccated using the herbicide Glyphosate (2.0 kg a.i. ha^{-1}).

In the summer crop of 2020/2021, the experimental plot consisted of five five-meter-long maize rows spaced 0.50 meters apart, totaling 12.5 m². Maize (R9082 PRO2 hybrid) was sown in December 2020. At seeding, 350 kg ha^{-1} of monoammonium phosphate (11% N, 50% P_2O_5) was applied at 5 cm below and to the side of the seed. Immediately after maize sowing, 30 kg K_2O ha^{-1} as KCl was manually broadcast

on the soil surface for all but two treatments the treatment that had previously received 150 kg K_2O ha^{-1} applied to the *U. ruziziensis* and the fallow treatment (Table 1). The fallow treatment received the standard recommendation for maize – 60 and 90 kg K_2O ha^{-1} applied at planting and the V_4 stage,

respectively (Sousa and Lobatto, 2004). Also, at V_4, 180 kg N ha^{-1} were broadcast by urea (46% N). Glyphosate (2.00 kg ai ha^{-1}) and atrazine (1.25 kg ai ha^{-1}) were broadcast applied at V_4 maize silage stage to all plots. Maize harvest for silage took place in April 2021 (112 days after sowing).

Table 1. Timing and rates of K treatments and N and P applied to *Urochloa ruziziensis* and maize.

Treat.	Crop	Fertilization – Fall/Winter 2020			Crop	Fertilization – Spring/Summer 2020/2021		
		At sowing	47 days after sowing			At sowing	At V_4 growth stage of maize	
		$N+P_2O_5$	K_2O	N		$N+P_2O_5+K_2O$	K_2O	N
		kg nutrient ha^{-1}				kg nutrient ha^{-1}		
0/120	*U. ruzi*	0	0	0	Maize	39 + 182 + 30	120	180
30/90	*U. ruzi*	0	30	0	Maize	39 + 182 + 30	90	180
60/60	*U. ruzi*	0	60	0	Maize	39 + 182 + 30	60	180
90/30	*U. ruzi*	0	90	0	Maize	39 + 182 + 30	30	180
120/0	*U. ruzi*	0	120	0	Maize	39 + 182 + 30	0	180
150/0	*U. ruzi*	0	150	0	Maize	39 + 182 + 0	0	180
F0/Re	Fallow	0	0	0	Maize	39 + 182 + 60	90	180

Weed community assessments were carried out in both seasons at three different periods: The 1st period, November 2020, was before cutting the *U. ruziziensis*; the 2nd period, January 2021, was at the maize V_4 growth stage and before herbicides were applied; and the 3rd period, April 2021, was just before maize silage harvest.

For the phytosociological survey of weeds, a metallic frame (0.5 x 0.5 m) was used randomly within the useful area of each plot. In each sampled frame, weeds were identified and quantified. Then, the frequency (total number of plots containing the species/number of plots used) was calculated; density (total number of individuals per species/total sampled area); the abundance (total number of individuals per species/total number of plots containing species), the relative frequency (RF) (frequency of the species*100/total frequency of all species), the relative density (RD) (density of the species *100/total species density) and relative abundance (RA) (species abundance*100/total abundance of all species), and finally the importance value index (IVI) (RF+RD+RA) as described by Ellenberg and Mueller-Dombois (1974). With the values obtained, the number of species m^{-2} and total weed density (number of weeds m^{-2}) were also calculated.

Dry mass, weed species and weed density data were subjected to analysis of variance (alpha=0.05), which allowed evaluation of the effects of the treatments (main plots) and of the evaluation periods (subplots) as well as the interaction between these factors. When significant, means were compared using orthogonal contrasts with SAS® software version 9.1.

3. Results and Discussion

Sixteen plant species belonging to eight different families were identified in the experimental area (Table 2). The family with the largest number of individuals was Asteraceae with eight species. Only one species was present in each of the other families (Commeliacea, Poaceae, Euphorbiaceae, Cyperaceae, Polulaceae, Rubiaceae, Amarantaceae and Malvaceae). Some small plants which

were not identifiable are listed as "others". Of the identified species, four appeared in two harvests and in three evaluation periods, namely *Acanthospermum hispidum* DC, *Commelina bengalensis* L., *Cenchrus echinatus* L. and *Richardia brasiliensis* Gomes.

Asteraceae was the second family with highest occurrence in an area under three management succession systems: cotton (*Gossypium hirsutum* L.) /soybean (*Glycine max* L.)/ *Urochoa decumbes*; millet/soybean/millet and millet/ soybean/*Crotalaria*, the surveys were carried out during the soybean crop and in cover crops during the soybean succession (Castro et al., 2021). Bulegon et al. (2014) also observed in a succession system oat (*Avena strigosa* cv. Comum)/maize under different poultry litter and nitrogen doses in Paraná, the highest number of plants for the Poaceae family. Otherwise, the Asteraceae was the most representative family in an area of crop-livestock integration with maize for silage with *U. ruziziensis* at different densities of grass (Batista et al., 2014). According to Hani et al. (2017), the Asteraceae family are mostly herbaceous plants that exist on all continents.

The constant presence of the species *A. hispidum*, *C. echinatus*, *C. benghalensis*, and *R. brasiliensis* over the evaluation periods may be related to the species ability to reproduce and adapt and their tolerance to glyphosate which is commonly used for weed control in the area. According to Grey and Prostko (2015) *A. hispidum* is a plant native to tropical America found in more than 40 countries, its control is essential to avoid dissemination since its seeds can cling to different surfaces such as animals and agricultural equipment. *C. echinatus* has the ability to develop well in soils over a wide range of nutrients levels and in stressful situations, being found in different regions and agricultural areas of Brazil (Silva et al., 2015). *C. benghalensis*, on the other hand, has a high propagation capacity either by vegetative parts or seeds, and it also can be successful in a wide range of environments (Sarmento et al., 2015). Both *C. benghalensis* and *R. brasiliensis* have developed tolerance to the herbicide glyphosate in some environments (Cerdeira et al., 2015).

Table 2. Weed species found in the experimental area at three evaluation periods; 1st period, before cutting the *Urochloa Ruziziensi*; 2nd period, at the maize V_4 growth stage and before herbicides were applied; and 3rd period, before maize silage harvest. An 'x' indicates the presence of a species.

Scientific name	Family	Evaluation period		
		1st	2nd	3rd
Acanthospermum hispidum DC.	Asteracea	x	x	x
Ageratum conyzoides L.	Asteracea		x	x
Amaranthus deflexus L.	Amarantaceae		x	
Bidens pilosa L.	Asteracea	x	x	
Commelina benghalensis L.	Commelinaceae	x	x	x
Cenchrus echinatus L.	Poaceae	x	x	x
Chamaesyce hirta (L.) Millsp.	Euphorbiaceae		x	
Cyperus rotundus L.	Cyperaceae	x		
Emilia fosbergii NICOLSON	Asteraceae			x
Galinsoga parviflora Cav.	Asteraceae		x	x
Gamochaeta coarctata (Willd.) Kerguélen	Asteraceae			x
Melampodium perfoliatum (Cav.) Kunth	Asteraceae		x	
Others	*		x	x
Portulaca oleraceae L.	Portulaceae	x	x	
Richardia brasiliensis Gomes	Rubiaceae	x	x	x
Sida glaziovii K. Schum.	Malvaceae		x	
Tridax procumbes L.	Asteraceae	x	x	

In commonly used phytosociological surveys, density (D) is related to the number of individuals per unit of area, which makes it possible to identify the largest population. Frequency (F) refers to the intensity of occurrence of a species in an area in relation to the total number of samples taken. Abundance (A) determines the concentration of certain species at certain points in the area. The RD, RF and RA indices are the percentage value for a species in relation to the total value of individuals in a weed community for D, F and A (Ferreira et al., 2019). The IVI, on the other hand, determines the most important species within an area, and according to Batista et al. (2017), plants with high IVIs need to have priority in management in order to reduce their population to avoid reducing crop productivity. The relative frequency (RF), relative density (RD), relative abundance (RA) and importance value index (IVI) for the main species found in the experimental area are shown in Table 3.

Table 3. Relative frequency, relative density, relative abundance and importance value index of the weed's species in different treatments at the three evaluation periods; 1st period, before cutting the *Urochloa ruziziensis*; 2nd period, at the maize V_4 growth stage and before herbicides were applied; and 3rd period, before maize silage harvest.

Treat	Specie	Relative Frequence (RF)			Relative Density (RD)			Relative Abundance (RA)			Indice of Value and Importance (IVI)		
		1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
0/120	*Acanthospermum hispidium* DC.	0.6	2.0	-	0.6	0.7	-	1.3	0.7	-	3.2	3.4	-
	Cammelina benghalensis	2.5	-	-	0.6	-	-	0.6	-	-	3.8	-	-
	Cenchrus echinatus	-	1.3	1.4	-	0.3	0.2	-	0.4	0.6	-	2.1	2.2
	Galinsoga parviflora Cav.	-	2.0	-	-	2.1	-	-	2.1	-	-	6.2	-
	Gamochaeta coarctata (Willd.)Kerguélen	-	-	1.4	-	-	0.9	-	-	2.3	-	-	4.7
	Melampodium perfoliatum (Cav.) Kunth	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
	Outros	-	0.7	2.9	-	0.7	4.5	-	2.2	5.8	-	3.6	13.2
	Portulaca oleraceae	-	2.7	-	-	4.2	-	-	3.1	-	-	10.0	-
	Richardia brasiliensis	2.5	1.3	4.3	0.9	1.3	1.8	1.0	1.9	1.6	4.4	4.58	7.65
	Tridax procumbes	-	0.7	-	-	0.2	-	-	0.7	-	-	1.5	-
30/90	*Acanthospermum hispidium* DC.	2.5	2.0	-	1.5	1.1	-	1.6	1.1	-	5.7	4.2	-
	Ageratum conyzoides L.	-	1.3	1.4	-	0.7	0.2	-	1.0	0.6	-	2.1	2.2
	Cammelina benghalensis	2.5	0.7	-	2.4	0.2	-	2.6	0.7	-	7.5	1.5	-
	Cenchrus echinatus	1.3	2.0	1.4	1.2	0.7	0.2	2.6	0.7	0.6	5.0	3.4	2.2
	Emilia fosbergii	-	-	1.4	-	-	0.2	-	-	0.6	-	-	2.2
	Galinsoga parviflora Cav.	-	1.3	-	-	0.7	-	-	1.0	-	-	3.0	-
	Gamochaeta coarctata (Willd.) Kerguélen	-	-	5.7	-	-	11.1	-	-	7.1	-	-	23.9
	Heliotropium indicum L.	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
	Outros	-	2.0	-	-	3.4	-	-	3.4	-	-	8.8	-
	Portulaca oleraceae	1.3	2.7	-	0.6	3.3	-	1.3	2.4	-	3.2	8.4	-
	Richardia brasiliensis	3.8	-	5.7	2.7	-	4.1	1.9	-	2.6	8.5	-	12.4
	Tridax procumbes	1.3	0.7	-	0.6	0.2	-	1.3	0.7	-	3.2	1.5	-

Table 3. Continuation.

Treat	Specie	Relative Frequence (RF)			Relative Density (RD)			Relative Abundance (RA)			Indice of Value and Importance (IVI)		
		1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
60/60	*Acanthospermum hispidium* DC.	2.5	3.3	-	1.5	1.2	-	1.6	0.7	-	5.7	5.2	-
	Ageratum conyzoides L.	-	-	2.9	-	-	0.7	-	-	0.9	-	-	4.4
	Cammelina benghalensis	2.5	-	-	0.9	-	-	1.0	-	-	4.4	-	-
	Cenchrus echinatus	1.3	0.7	2.9	0.6	1.0	0.7	1.3	3.0	0.9	3.2	4.7	4.4
	Galinsoga parviflora Cav.	-	0.7	1.4	-	0.4	0.2	-	1.1	0.6	-	2.1	2.2
	Gamochaeta coarctata (Willd.)Kerguélen	-	-	4.3	-	3	4.3	-	-	3.7	-	-	12.3
	Outros	-	1.3	-	-	2.0	-	-	3.0	-	-	6.4	-
	Portulaca oleraceae	-	2.7	-	-	6.0	-	-	4.5	-	-	13.2	-
	Richardia brasiliensis	-	2.0	5.7	-	1.2	2.7	-	1.2	1.7	-	4.5	10.2
	Tridax procumbes	1.3	-	-	0.3	-	-	0.6	-	-	2.2	-	-
90/30	*Acanthospermum hispidium* DC.	3.8	3.3	-	2.4	3.5	-	1.7	2.1	-	7.9	8.9	-
	Ageratum conyzoides L.	-	0.7	1.4	-	0.1	0.2	-	0.2	0.6	-	0.1	2.2
	Bidens pilosa	-	1.3	-	-	0.1	-	-	0.2	-	1.7	-	-
	Cammelina benghalensis	5.1	-	1.4	3.7	-	0.2	1.9	-	0.6	10.6	-	2.2
	Cenchrus echinatus	-	2.0	-	-	0.4	-	-	5.5	-	-	18.1	-
	Cyperus rotundus	1.3	-	-	9.2	-	-	19.2	-	-	29.6	-	-
	Galinsoga parviflora Cav.	1.3	-	-	-	0.7	-	-	1.1	-	3.1	-	-
	Gamochaeta coarctata (Willd.)Kerguélen	-	-	4.3	-	-	14.7	-	-	12.6	-	-	31.6
	Outros	-	1.3	1.4	-	2.6	1.8	-	3.9	4.6	-	7.8	7.9
	Portulaca oleraceae	1.3	3.3	-	0.3	9.3	-	0.6	5.5	-	2.2	18.1	-
	Richardia brasiliensis	3.8	3.3	5.7	2.1	2.0	1.8	1.2	1.2	1.2	7.4	6.5	8.7
	Tridax procumbes	1.3	-	-	0.3	-	-	0.6	-	-	2.2	-	-
120/0	*Acanthospermum hispidium* DC.	5.1	2.7	1.4	12.2	2.0	0.5	6.4	1.5	1.2	23.6	6.2	3.0
	Ageratum conyzoides L.	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
	Bidens pilosa	1.3	-	-	0.6	-	-	1.3	-	-	3.2	-	-
	Cammelina benghalensis	3.8	2.0	1.4	7.6	0.6	0.2	5.3	0.6	0.6	16.7	3.2	2.2
	Cenchrus echinatus	1.3	-	-	0.3	-	-	0.6	-	-	2.2	-	-
	Emilia fosbergii	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
	Galinsoga parviflora Cav.	-	2.7	-	-	1.7	-	-	1.2	-	-	5.6	-
	Gamochaeta coarctata (Willd.)Kerguélen	-	-	2.9	-	-	2.7	-	-	3.5	-	-	9.1
	Outros	-	1.3	1.4	-	3.3	2.3	-	4.9	5.8	-	9.5	9.5
	Portulaca oleraceae	1.3	2.7	-	0.3	10.4	-	0.6	6.2	-	2.2	20.0	-
	Richardia brasiliensis	3.8	2.7	5.7	0.9	1.0	2.0	0.6	0.8	1.3	5.4	4.4	9.1
	Tridax procumbes	1.3	0.7	-	0.3	0.3	-	0.6	0.9	-	2.2	1.8	-
150/0	*Acanthospermum hispidium* DC.	5.1	0.7	-	11.6	0.4	-	6.1	1.3	-	22.7	2.4	-
	Ageratum conyzoides L.	-	0.7	-	-	0.4	-	-	1.3	-	-	2.4	-
	Amaranthus deflexus L.	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
	Cammelina benghalensis	1.3	-	1.4	2.1	-	0.2	2.2	-	0.6	6.9	-	2.2
	Cenchrus echinatus	2.5	2.7	-	0.6	0.6	-	0.6	0.4	-	3.8	3.7	-
	Galinsoga parviflora Cav.	-	2.0	1.4	-	1.7	0.5	-	1.7	1.2	-	5.3	3.0
	Gamochaeta coarctata (Willd.)Kerguélen	-	-	5.7	-	-	12.7	-	-	8.1	-	-	26.5
	Outros	-	2.0	-	-	3.2	-	-	3.2	-	-	8.4	-
	Portulaca oleraceae	2.5	2.7	-	0.6	3.3	-	0.6	2.5	-	3.8	8.5	-
	Richardia brasiliensis	2.2	2.0	5.7	2.1	0.9	5.7	2.2	0.9	6.6	6.9	3.7	15.0
	Sida glaziovii K. Schum.	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
	Tridax procumbes	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
F0/Rec	*Acanthospermum hispidium* DC.	5.1	2.7	2.9	10.7	2.3	0.5	5.6	1.7	0.6	21.3	6.7	3.9
	Ageratum conyzoides L.	-	-	1.4	-	-	0.5	-	-	1.2	-	-	3.0
	Bidens pilosa	1.3	0.7	-	3.4	0.4	-	7.0	1.1	-	11.6	2.1	-
	Cammelina benghalensis	5.1	0.7	-	1.5	0.1	-	0.8	0.2	-	7.4	1.0	-
	Cenchrus echinatus	-	0.7	-	-	1.3	-	-	3.9	-	-	5.9	-
	Chamaesyce hirta (L.) Mill sp.	-	0.7	-	-	0.1	-	-	0.2	-	-	1.0	-
	Emilia fosbergii	1.3	7.0	-	0.3	-	-	0.6	-	-	2.2	-	-
	Galinsoga parviflora Cav.	-	1.3	-	-	1.1	-	-	1.6	-	-	4.0	-
	Gamochaeta coarctata (Willd.) Kerguélen	-	7	4.3	-	-	14.5	-	-	12.4	-	-	31.2
	Outros	-	2.0	1.4	-	2.0	2.7	-	2.0	7.0	-	6.1	11.1
	Portulaca oleraceae	1.3	2.3	3.0	0.3	7.5	-	0.6	5.6	-	2.2	15.7	-
	Richardia brasiliensis	5.1	2.0	4.3	7.0	3.0	4.1	3.7	3.0	3.5	15.8	7.9	11.9
	Tridax procumbes	1.3	-	1.4	0.6	-	0.2	1.3	-	0.6	3.2	-	2.2

[1] K_2O ha⁻¹ treatments applied at *Urochloa ruziziensis/* maize topdressing (e.g., 0/120= 0 kg K_2O ha⁻¹ to *Urochloa ruziziensis* and 120 kg K_2O ha⁻¹ to maize). All treatments also received 30 kg K_2O⁻¹ at maize sowing, except 150/0 (0 kg K_2O ha⁻¹ at maize sowing) and F0/Re. F0/Re = Fallow (0 kg K_2O ha⁻¹) plus 60 and 90 kg K_2O ha⁻¹ at maize sowing and topdressing, respectively. (-) absence of weeds.

For the 1st period of evaluation, *A. hispidium* species was identified in all treatments. The species showed high RF, RD, RA and IVI for 120/0 (5.1, 12.2, 6.4 and 23.6% respectively), and 150/0 (5.1, 11.6, 6.1 and 22.7%, respectively) (Table 3 and Figure 2). These results suggests that the absence of a cover crop, combined with high potassium levels, creates favorable conditions for *A. hispidium* proliferation (Figure 2A). *U.ruziziensis* seems somehow suppress *A. hispidum*. It can be seen comparing the IVI in the

Follow plot and the *U. ruziziensis* plot (Figure 2B). This supports the role of cover crops in weed management by limiting available space and resources for weed establishment. The competitive ability of *U. ruziziensis* might be due to its rapid canopy closure, which reduces light availability for weed germination and growth (Gama et al., 2020). By other hand, there is no evidence of research exanimating the effect of potassium fertilization on *A. hispidium*.
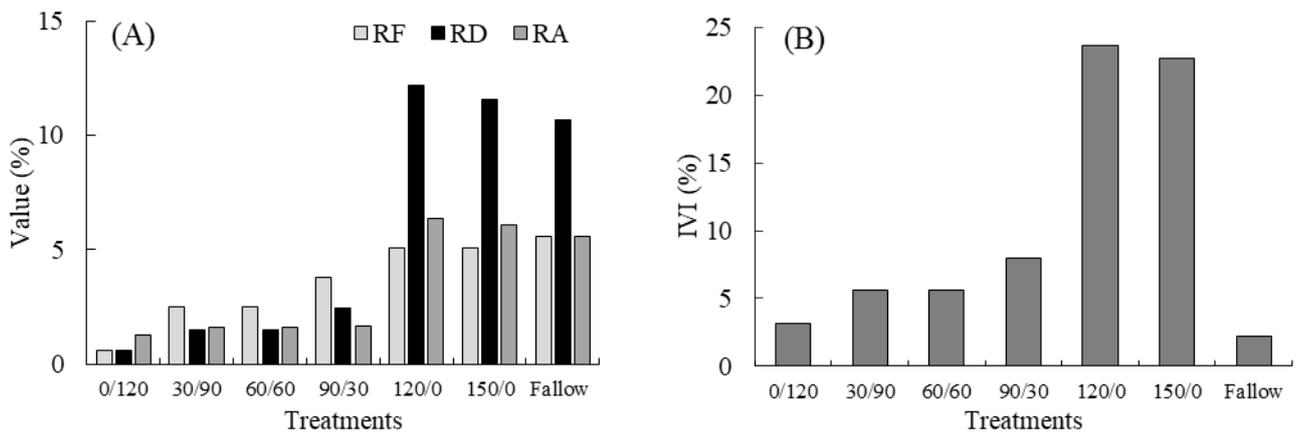

Figure 2. A) Relative frequency (RF), relative density (RD) and relative abundance (RA) and B) Importance Value Index (IVI) in the 1st period of evaluation, before cutting the *Urochloa ruziziensis* (November 2021) for *Acanthospermum hispidum* D.C. ^1K_2O ha^{-1} treatments applied at *Urochloa ruziziensis/*maize topdressing (e.g., 0/120= 0 kg K_2O ha^{-1} to *Urochloa ruziziensis* and 120 kg K_2O ha^{-1} to maize). All treatments also received 30 kg K_2O^{-1} at maize sowing, except 150/0 (0 kg K_2O ha^{-1} at maize sowing) and F0/Re. F0/Re = Fallow (0 kg K_2O ha^{-1}) plus 60 and 90 kg K_2O ha^{-1} at maize sowing and topdressing, respectively.

R. brasiliensis, absent only in the 60/60 treatment, showed higher RF, RD and IVI for 30/90 (3.8, 2.7 and 8.5%, respectively), and higher RD and IVI for 0/120 (0.9 and 4.4, respectively). Another species of high occurrence was *C. benghalensis*, the highest RF for the species was found in the treatments 30/90 (5.1%). The species *Cyperus rotundus* L. was present only in the treatment 90/30, where it obtained high RD, RA and IVI between species in the same plot. According to Concenço et al. (2013b) the most abundant species, those distributed throughout the area, should be managed with the use of pre-emergent herbicides. The species that are less frequent and appear in specific places in the field, should be controlled with localized herbicide applications.

In the 2nd period of evaluation, three plant species were found in all treatments: *R. brasiliensis*, *P. oleraceae* and *A. hispidium*. *P. oleracea* had the highest IVI in all treatments, ranging from 8.4% in the 30/90 treatment to 20.0% in the 120/0 treatment. The high IVI values of *P. oleracea* were related to the greater numbers of individuals distributed in the study area, considering that this species had high RD in all treatments, except for 30/90. This suggests that *P. oleracea* possesses a robust adaptative capacity, thriving particularly well in potassium-rich environments were competition is les intense. The RD and IVI for *A. hispidium* was higher in the 2nd period than in the 1st period in the 0/120 (0.7 and 3.4%, respectively) and 90/30 (3.5 and 8.9%, respectively) treatments. In the other treatments (30/90, 60/60, 120/0, 150/0 and F0/Rec) was observed decrease in these indices for this species. This variation suggests that *A.*

hispidium may respond positively to specific nutrient conditions but may also be outcompeted in environments where *P. oleracea* dominates. These finding emphasize the importance of integrated weed management strategies that synchronize nutrient management with species-specific responses. Future research should explore the physiological mechanisms underlying weed species and potassium fertilization responses and assess how interspecies competition influences weed proliferation. A comprehensive understanding of these dynamics is essential for developing sustainable weed management practices that preserve soil fertility while reducing weed crop competition.

In the 3rd period of evaluation, *Gamochaeta coarctata* (Willd.) Kerguélen and *R. brasiliensis* were present in all treatments. *G. coarctata* presented high RD, RA and IVI for the treatments 30/90 (11.1, 7.1 and 23.9 respectively), 60/60 (4.3, 3.7 and 12.3 respectively), 90/30 (14.7, 12.6 and 31.6 respectively), 150/0 (12.8, 8.1 and 26.5 respectively) and F0/Rec (14.5, 12.4 and 31.2 respectively). The highest RF among the species present in the same treatment was obtained for *R. brasiliensis* in 0/120 (4.3%), 30/90 (5.8%), 60/60 (5.8%), 90/30 (5.7%), 120/0 (5.7%) and 150/0 (5.8%). The FR obtained for *R. brasiliensis* was equal to the FR of *G. coarctata* in the treatments F0/Rec (4.3%). The species named as "others" presented higher RA and IVI only in the treatment 120/0 (5.8 and 9.5% respectively).

The variation of indices and species of occurrence obtained in this work may be related to the cultivation systems used at the time of evaluation. According to Batista

et al. (2017) and Sarmento et al. (2015) the weed population is influenced by the type of soil, seed bank, region, previous crops and factors such as microclimate, management employed and allelopathy. Thus, such variations in the indices and in the composition of the species found in the present work show the relevance of carrying out populational studies, especially in areas under crop rotation and early fertilization. These studies allow a better understanding of the distribution and composition of the weed populations, as well as the occurrence or disappearance

of some species, allowing the adoption of targeted management strategies and avoidance of crop productivity loss (Silva et al., 2018).

The period of evaluation affected the amount of dry mass between treatments (Table 4). In the 1st period the fallow treatment had four times more dry weed mass than treatments with *U. ruziziensis* (Figure 3). The 1st period had more dry mass than the 3rd period, but dry mass in the 1st and 2nd periods did not differ.

Table 4. ANOVA summary for the dry mass, weed species and weed density in the 1st, 2nd and 3rd period of evaluations in the treatments.

Source	Dry mass (g m^{-2})	Weed species (Species m^{-2})	Weed density (Plants m^{-2})
	Level of significance		
Period	0.001**	0.005**	0.0005**
1st vs 2nd	0.02**	0.004**	0.0003**
2nd vs 3rd	0.003**	0.002**	0.0004**
Treatment	0.0001**	0.22ns	0.004**
Fallow vs others	0.0001**	0.05ns	0.0003**
Period vs Treatment	0.0001**	0.07ns	0.32ns
Fal. vs Others, 1st vs 2nd periods	0.0002**	0.30ns	0.05ns
Fal. vs Others, 2nd vs 3rd periods	0.45ns	0.24ns	0.01**
Fal. vs Others, 1st vs 3rd periods	0.0001*	0.03**	0.54ns

**=Significant at P≤0.05. ns=Not significant, P>0.05. "Others" is the mean of the cover crop treatments. 1st period: before cutting the *Urochloa ruziziensis* (November 2021); 2nd period: at the maize V$_4$ growth stage before herbicides were applied (January 2021); 3rd period: before maize silage harvest (April 2021).
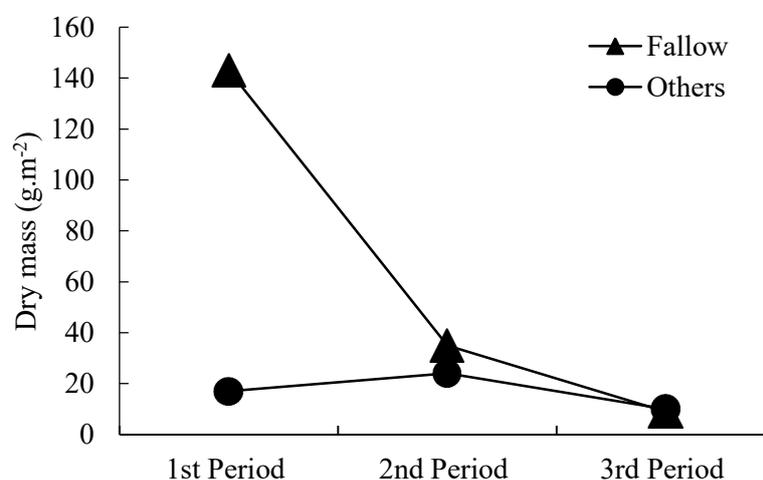

Figure 3. Dry mass of weeds in the fallow and cover crops treatments in the 1st, 2nd and 3rd period of evaluation. The "others treatment" was the mean of all treatments with *Urochloa ruziziensis* cover crop planted in the season before maize planting. 1st period: before cutting the *Urochloa ruziziensis* (November 2020); 2nd period: at the maize V$_4$ growth stage before herbicides were applied (January 2021); 3rd period: before maize silage harvest (April 2021).

Weed species m^{-2} differed by period of evaluation but was unaffected by cover crop and fertilizer treatments and there was no interaction between the period of evaluation and treatments. The 2nd period had more weed species (17.3 species m^{-2}) than the 1st (10.1 species m^{-2}) or 3rd period (9 species m^{-2}) (Table 4; Figure 4).

Weed density (plants m^{-2}) differed by period of

evaluation and treatment, but there was no interaction between these two variables. The 2nd period has 5 times more weeds (186 plants m^{-2}) than the 1st period (36 plants m^{-2}) and 3 times more than the 3rd period (52 plants m^{-2}) (Table 4; Figure 5). The fallow treatment had higher weed density (152 plants m^{-2}) than the treatments with *U. ruziziensis* (81 plants m^{-2}) (Table 4; Figure 5).
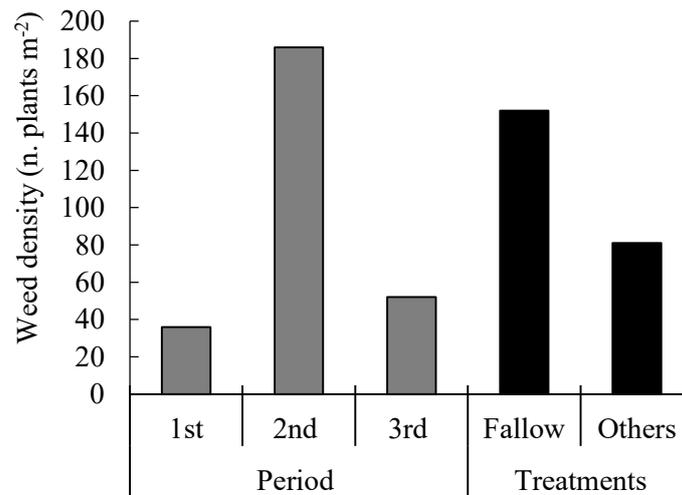
Figure 4. Weed species (species m⁻²) in the 1st, 2nd and 3rd period of evaluation. 1st period: before cutting the *Urochloa ruziziensis* (November 2021); 2nd period: at the maize V₄ growth stage before herbicides were applied (January 2021); 3rd period before maize silage harvest (April 2021).
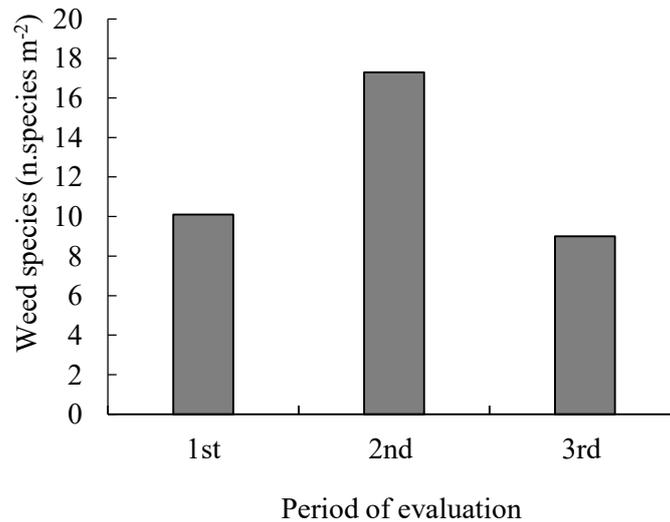

Figure 5. Weed density (plants m⁻²) in the 1st, 2nd and 3rd period of evaluation and in the treatments, fallow and treatments with *Urochloa ruziziensis*. 1st period: before cutting the *Urochloa ruziziensis* (November 2020); 2nd period: at the maize V₄ growth stage before herbicides were applied (January 2021); 3rd period: before maize silage harvest (April 2021).

The higher amount of dry mass in the 1st period of evaluation (Figure 3) and consequently higher weed density in the fallow (Figure 5) when compared with others treatments can be related to the lack of plant cover on the soil. Also, the time between the establishment of the experiment and the 1st evaluation (five months) was longer than the other periods of evaluations (two months) and contributed to the increased weed dry mass accumulation. The presence of straw in the soil surface can promote suppression of the plants due the physical and chemical effects as well as through allelochemicals, and contribute to the reduction of weed seedling emergence (Oliveira Jr et al., 2014).

The higher number of weed species (17.3 species m⁻²) and total plant density (186 plants m⁻²) found in the 2nd period compared to the 1st period may be related to greater water availability, and the maize growth stage at the time of

the evaluations, added to the greater availability of nutrients in view of the planting fertilizations carried out for the maize added to the possible residual effect of the fertilizations carried out in the previous harvest. Another factor that must be taken into account was the type of plant used to cover the ground in the harvest prior to maize. *U. ruziziensis* is a species known for its high biomass production that promotes a good soil cover in the off-season and also weed suppression (Lima et al., 2014; Oliveira Jr et al., 2014). Although, in this experiment, due the season of cultivation and particularities of the region like low water availability in this season, this species had its development delayed. Consequently, the limited growth of *U. ruziziensis* contributed to uncovered soil until the beginning of the rainy season, which likely favored weed establishment and growth. Greater incidence of light on the soil surface due to the lack of cover increases the emergence and development of weeds (Lima et al., 2014).

For Concenço et al. (2015), the fall-winter crop directly influences the weed infestation in the summer crop. Plants grown during fall/winter that promote less ground cover favor greater infestation in the crop grown in sequence. The authors also reported that in a crop succession system, the reduction of the most problematic weeds to the system is observed after the third year, and for better results, it is also necessary to use long-term crop rotation.

The number of species and plant density was lowest in the 1st period, likely due to the efficiency of the roundup and atrazine herbicides in controlling the weeds present. For Silva et al. (2020) the association of glyphosate with other herbicides such as atrazine, applied pre- or post-emergence, increased control effectiveness, contributed to the management of resistant and/or tolerant species, and thus increased maize productivity. Shading of the weeds by the maize plants may have also contributed to low weeds in the 1st period. According to Carvalho et al. (2011) maize is a crop that has rapid initial growth and soil shading capacity, which impairs solar interception by weeds, thus affecting their development.

4. Conclusion

For the same cultivation area, the weed community as well as its phytosociological indices were altered as a result of the growing season and the crop.

The Asteraceae family was the main family and *Acanthospermum hispidum* DC, *Commelina bengalensis* L., *Cenchrus echinatus* L. and *Richardia brasiliensis* Gomes was the main species found in tree period of evaluations in the study area.

Potassium fertilization in the absence of cover crop seems to create a favorable condition for some weed proliferation, such as *Acanthospermum hispidum* DC. However long term studies should focus on exploring the residual effects of potassium fertilization on weed dynamics and its potential in crop rotation systems.

The weed dry mass was higher before cutting the *U. ruziziensis.* The number species and the weed density were higher at the maize V_4 growth stage before applying herbicides.

The fallow presented higher number of species than the cover crops treatments. However, better results can be obtained in long term systems.

Acknowledgements

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