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Biorational agriculture: herbicidal activity of sorghum extract in control of *Cyperus rotundus* L.

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Abstract: The present estudy aimed to identify the herbicidal effect of sorghum extract in control of *Cyperus rotundus* L. The work was carried out in greenhouse covered with transparent plastic and shade cloth in the sides with 50% light interception. The *C. rotundus* L. seedlings with 10 days after emergence were transplanted from the field to the 10 liters pots with a mix of soil, sand and manure in a 3:1:1 propotion respectively. The experiment followed the completely randomized design in 4x5 factorial array with four types of *sorghum bicolor* extract: root extraction in alcohol, leaf extraction in alcohol, root extraction in water and leaf extraction in water and five concentrations (0%, 20%, 40%, 80% e 100%). Four applications of five ml per plant were made in 10 days intervals, initiated when the plants were 30 days old. The sorghum leaf extract shows a herbicidal effect in *C. rotundus* by interfering in plant growth. The extracts diluted in water and alcohol showed efficency in *C. rotundus* growth reduction, as long as the allelochemical it's extracted from the leaf, by the fact that the extraction of root showed low herbicidal effect in *C. rotundus* plants. The sorghum leaves showed great allelochemical production with herbicidal action and represents a promising biorational alternative in weeds control, however, futher studies with variations in concentrations and large number of weed species it's necessary for a broad utilization.

Keywords: Weed, Sorgoleone, Allelochemical.

Agricultura bioracional: efeito herbicida de extrato de sorgo no controle de *Cyperus rotundus* L.

Resumo: O presente estudo teve como objetivo identificar o efeito herbicida de extrato de sorgo no controle da planta daninha *Cyperus rotundus* L. O trabalho foi conduzido em casa de vegetação coberta com plástico transparente e laterais em sombrite com interceptação de 50% da radiação solar. As mudas de *Cyperus rotundus* L. com idade de 10 dias foram transplantadas do campo para vasos de dez litros contendo uma mistura de solo, areia e esterco na proporção de 3:1:1 respectivamente. O experimento foi montado seguindo o delineamento inteiramente casualizado em esquema fatorial 4x5 com quatro tipos de extração de extrato de sorgo: Extração da raiz com álcool, extração da folha com álcool, extração da raiz com água, extração da folha com água em cinco concentrações 0%, 20%, 40%, 80% e 100%. Foram feitas quatro aplicações de 5 ml por planta em intervalos de 10 dias e iniciadas quando as plantas de *C. rotundus* estavam com 30 dias de idade. O extrato foliar de sorgo apresenta efeito herbicida em *C. rotundus* por interferir no crescimento da planta. Os extratos que utilizaram álcool ou água como diluente foram eficientes na redução do crescimento de *C. rotundus*, desde que extraído o aleloquímico da folha, pois a extração do sistema radicular mostrou-se de baixo efeito herbicida para plantas de *C. rotundus*. As folhas de sorgo apresentam produção de importantes aleloquímicos com ação herbicida e representa alternativa promissora bioracional no controle de plantas daninhas, no entanto, estudos posteriores com variações nas concentrações e maior número de espécies daninhas torna-se necessário para ampla utilização desta opção.

Palavras chave: Planta daninha, Sorgoleone, Aleloquímico..

Introduction

The *Cyperus rotundus* L. it's the most important weed in the world, mainly by the broad dissemination, persistence and aggressiveness in countless croplands, moreover, the plant produce allelochemicals with allelopathic activity. *C. rotundus* belongs to the Cyperaceae family that has a cosmopolitan distribuition, it's about 120 genres and 45 has importance in Brazil. This family has 4500 cataloged species, and 600 has important in Brazil (Loddo et al., 2019, Monquero et al., 2014 & Peerzada, 2017).

In Brazil, the purple nutsedge develops in all kinds of soil, climate and infest numerous crops (vegetables, soybean, bean and more), however, *C*. *rotundus* it's sensile to shading. The short term diffusion it happens by vegetative propagation, tuber, while the long term its by the seeds. Less than 5% of the seeds produced by *C*. *rotundus* are viables and in low temperature the tuber multiplication is slow, however, the purple nutsedge it's considered a difficult and erradication weed (Montiel et al. 2016, Loddo et al., 2019 & Peerzada, 2017).

The presence of weeds its determinant to plant production, considering that during the crop season can occur competition for production factors: light, water and nutrients (Matos et al., 2019). The level of requirement by the weed for the production factors is critical in the competition process, so that the greater is the similarity between the weed and the crop in terms of light requirement, nutrition and water, more aggressive is the competition according to Matos et al. (2019). As reported by Lamego et al. (2015), when the plants involved in competition has similar morphological characteristics, the yield loss will be bigger.

The identification of the infestant species and the utilization of selective herbicide it's a common practice in agriculture to obtain high yield (Korres et al., 2019). The constant and irrational use of only one herbicide during a long period of time has increased the incidence of weed plants (Soares et al., 2017). The use of herbicides to control weeds generates high costs and can cause risks to human health and environmental conservation (Nieder et al., 2018). The reduction of the herbicides usage it's a goal to modern birational agriculture that search safe alternatives and low cost as the use of allelopathic plants.

The allelopathy represents a positive or negative interactive form between organisms through the action of secondary metabolites denominated allelochemicals, produced by plants and microorganisms (Arroyo et al., 2018). A high number of species produce allelochemicals and a few portion of these compounds are studied. These substances can influence numerous of process in the ecosystems as inhibiting germination, establishment and growth of sensile neighbour plants, pest attack severity and disease incidence, competition, pollinators attraction, seed dispersal and plant reproduction (Trezzi et al., 2014).

In XXI century initiated a course to a biorational agriculture with greater life quality to the society. That sad, searches have been done to reduce the usage of herbicides with innovative methods that focus in the environment, and moreover show a low cost. A biorational agriculture is considered a good solution and promising source to the organic phytosanitary production.

Sorghum (*Sorghum bicolor* L. Moench) produces an allelochemical nominated sorgoleone, that has a potent allelopathic activity. The usage of sorghum as a second crop to the no-till farming has showed allelopathic activity and exhibit weed control, as *C*. *rotundus* (Borella et al., 2017). The release of allelochemicals in soil produced by sorghum decrease the germination and growth with potential of management in cropping systems (Uddin et al., 2014).

The literature it's needy in modern studies approaching the use of sorghum extract to control weed plants, and that owes to the original context of the theme that bring foward to nowadays as a promising practice to biorational agriculture. Thus, the present study has a objective to identify the herbicidal activity of sorghum extract in control of *C*. *rotundus*.

Material and methods

The study was carried out in greenhouse covered with transparent plastic and shade cloth on the sides with 50% light interception at the State University of Goiás, Ipameri *Campus* (Lat. 17°42′59.12″ S, Long. 48°08′40.49″ West, Alt. 773 m), Ipameri, GO. The region has a tropical climate with dry winter and wet summer (Aw) according to the Köppen classification and 20 °C average temperature (Alvares et al., 2013). During the experiment the average maximum, average and minimum temperatures were: 33.7 ºC, 25.9 ºC and 19.5 ºC while the average relative humidity was 49.7%.

The *C. rotundus* seedlings with 10 days after emergence (DAE) were transplanted from the field to 10 liters pot containing a mix of soil, sand and manure in a 3:1:1 proportion respectively. The plants were irrigated daily corresponding to 100% evapotranspiration rate. The experimente was carried out following the completely randomized design in 4x5 factorial array with 4 types of sorghum extract: [I)]root extraction in alcohol, [II)]leaf extraction in alcohol, [III)]root extraction in water, [IV)]leaf extraction in water and five concentrations (0%, 20%, 40%, 80% e 100%).

Four applications of 5 ml per plant were made at 10-day intervals and started when the C. rotundus plants were 30 days old. A manual sprayer with a capacity of 5 L with a fan-type nozzle was used. During the applications, the aim was to obtain maximum uniformity in the distribution of the extract throughout the plant, avoiding runoff. The extracts were obtained by the harvest of the leaves and roots of 40 DAE sorghum plants, seted in a oven for 72 h in 65 ºC to obtain the dry matter, then, grinded and layed in the water and alcohol in a 50g/L concentration in a room temperature for 72 h and filtraded later.

Ten days after the last application the analysis were performed. The plant height was measured from the root-stem transition zone, close to the ground until the top of the stem using a graded ruler. The number of leaves was obtained by counting. The stems and leaves were separated and dried in an oven at 72 ºC until constant dry mass and then weighed. The dry matter data were used to calculate the biomass adding the weights.

To determine the total chlorophylls and carotenoids concentrations, 0.6 mm diameter leaf discs were removed from completely opened leaves and placed in test tubes containing dimethyl sulfoxide (DMSO). Then extraction was carried out in a water bath at 65 °C for one hour. Aliquots were removed for spectrophotometric reading at 480, 649 and 665 nm. Then contents of chlorophyll a (Cl *a*), chlorophyll b (Cl *b*) and total carotenoids (Car) were determined according to the equation proposed by Wellburn (1994).

Chlorophyll *a* fluorescence was analyzed with six readings using a portable fluorometer JUNIOR-PAM (Walz, Germany) at 4 am with 0.3 second light saturation pulse emission of, under 0.6 KHz frequency, at 30 days after implementing the water regimes. The fluorescence data were computed using the software, WinControl-3. The variables were submitted regression analysis using the software SigmaPlot10 (Sysstat, 2006). Multivariate analysis was carried out by multiple regression using the *forward stepwise* model (Sokal & Rolf, 1995) in the Statistica software (Statsoft, 2007).

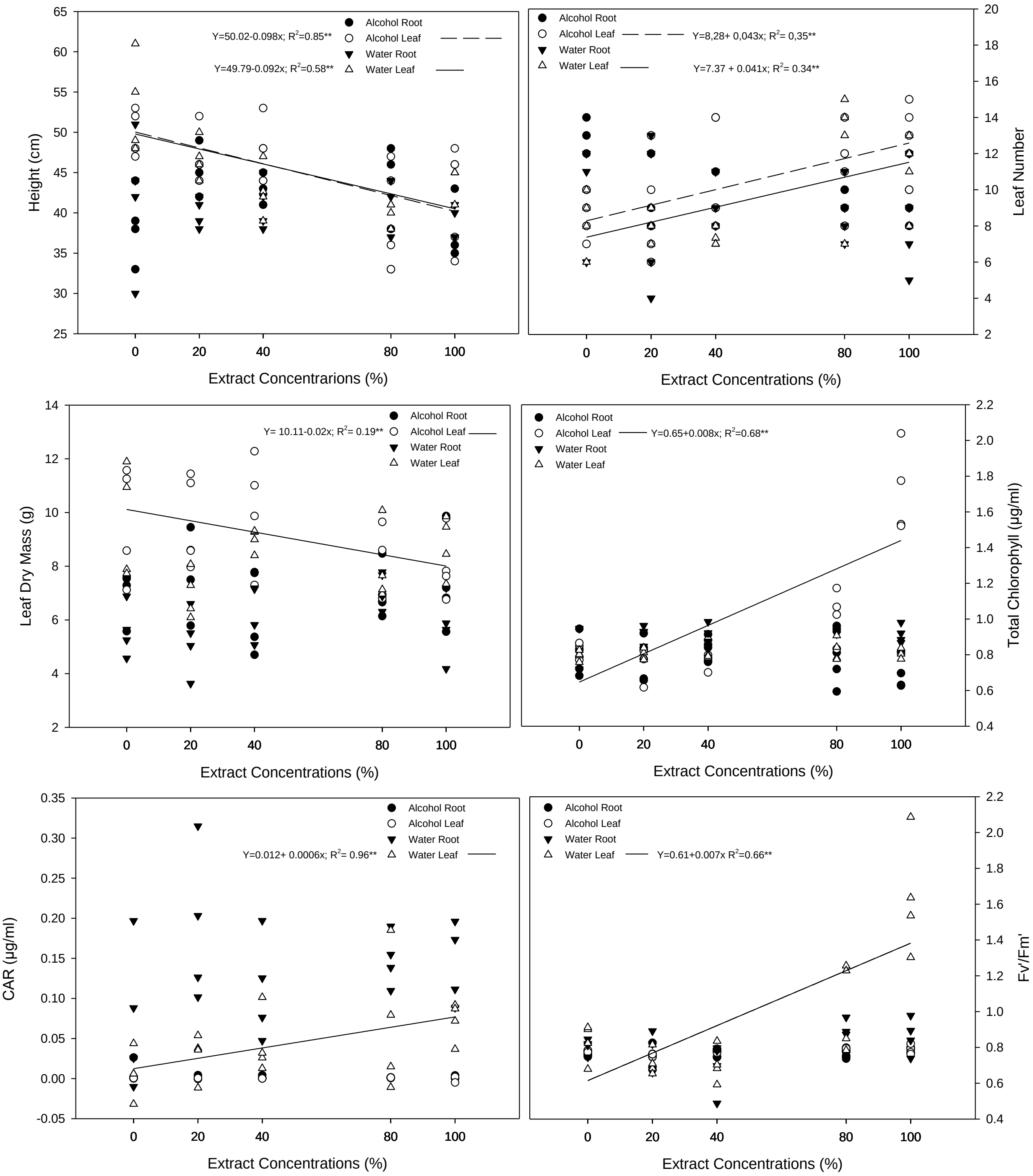
Results and discussion

Variables that didn’t show significant linear or quadratic regression adjustments weren’t presented due to the absence of response related to the imposed treatments. The plant height and leaves dry mass (Figure 1) decreased as the water sorghum extract concentration increased, indicading that the shoot growth was strongly hamper by the presence of the sorghum extract. According to Uddin et al. (2012) sorgoleone promotes delay in the growth of young weeds.

According to Hejl and Koster, (2004) and Rasmussen et al. (1992) the sorgoleone, mainly allelochemical produce by the sorghum leaves, inhibit the photosystem II (FSII), reducing the FSII quantic yield, besides that, the sorgoleone inhibit activity of plastoquinone and H+ - ATPase enzymes in the roots and intervene in water absorption, thus, ensure that the growth was affected to the point of interfer in light harvest and increase the number of leaves, chlrophyll and total carotenoid content and increase the efficiency of capture of excitation energy by open FSII reaction centers (Fv’/Fm’).

The increments in number of leaves, chlorophyll and total carotenoids content and the increased Fv’/Fm’ and the propotional increases in the sorghum extract concentrations are related to the maximization in absorption of light energy, since the limitation in height minimizes the light energy capture. Following Matos et al. (2019), the increases in photosyntetics pigments, leaf area and number of leaves are importants changes that increase the light energy absorption. In this present study the increments in carotenoids content is associated with the photoprotection function.

Figure 1 - Regression equations for height, number of leaves, dry leaf mass, leaf concentrations of total chlorophylls and carotenoids (CAR) and efficiency of capture of excitation energy by open FSII reaction centers (Fv'/Fm') in plants of *C. rotundus* submitted to sorghum extracts.



In the present study, the increase in carotenoid concentrations is associated with the photoprotection function. These results together point to the occurrence of damage to the photosynthetic apparatus of C. rotundus plants and the adjustments in the antenna system to capture light energy represent the plant's attempt to repair the damage caused by the action of sorgoleone. According to Santos et al. (2012) the effect of sorgoleone on weeds is similar to the herbicide atrazine with significant damage to FSII from photosynthesis.

The multiple regression analysis (Table 1) indicates that 34% of the leaf dry mass it's determinated by the plant height, total chlorophyll content, root dry mass and fraction of the energy absorbed by the antenna complex associated with the PSII that is not used in photochemistry or thermally dissipated (P_E). These variables certainly interferes in light harvest and are related to the excess of absorbed energy that harms the plant development, therefore, implies that the carotenoids performs photoprotection function fighting against the excess of excitation energy according to Matos et al. (2019) and Taiz et al. (2017). In addition, the root dry mass indicates the importance of water and nutrients absorption for plant growth.

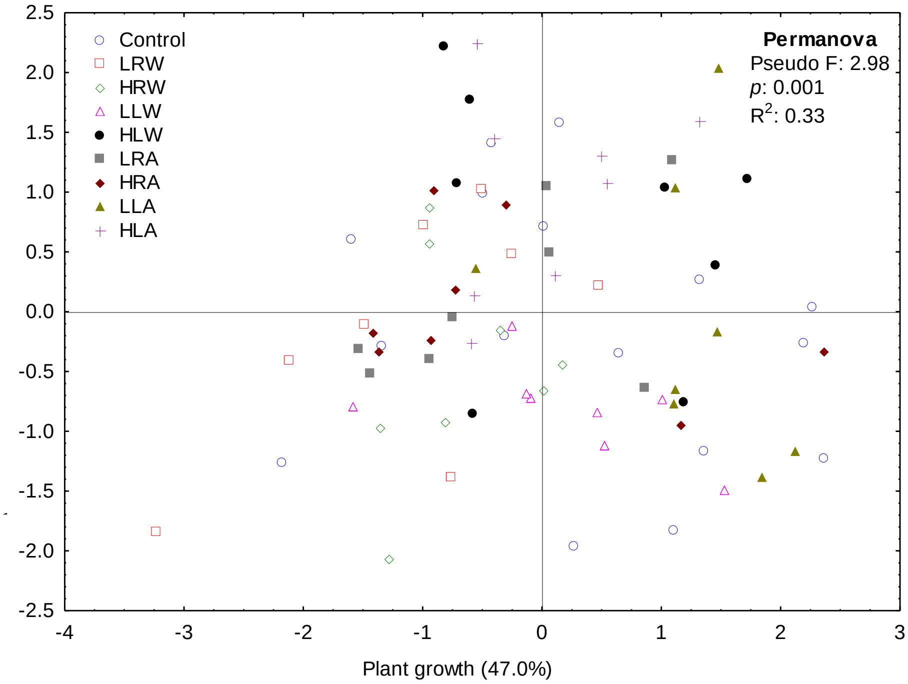
Table 1 - Multiple regression model to analyze the importance of the variables measured on the dry leaf mass in plants of *Cyperus rotundus* submitted to sorghum extracts.

	R^2= 0,34		F (07,72) =5.38		p<0,0000	
Dry leaf mass	Beta	Std.Err. of Beta	B	Std.Err. of B	t (32)	p-level
Intercept			1.23	2.123	0.579	0.564
Height	0.211	0.105	0.072	0.036	2.013	0.048*
Nº leaf	0.052	0.105	0.038	0.077	0.49	0.626
DRM	0.233	0.107	0.096	0.044	2.178	0.033*
Fv'/Fm'	0.066	0.102	0.561	0.865	0.648	0.519
Pe	-0.317	0.116	-8.687	3.168	-2.742	0.008*
Chl (*a*+*b*)	0.201	0.098	1.711	0.839	2.04	0.045*
Car	0.019	0.105	1.568	8.48	0.185	0.854

*Dry root mass (DRM), fraction of the energy absorbed by the antenna complex associated with the PSII that is not used in photochemistry or thermally dissipated (P_E) and concentration of total chlorophylls (Chl *a* + *b*).

The principal component analysis (PCA) (Figure 2) represents 81.2% of the data variation. The axis 1 represents the total plant growth whilst axis 2 correspond to the shoot growth. Despite of not verifying the occurrence of perfect clusters by concentrating treatments differently, note that the points related to the control *C. rotundus* plants are at the right of axis 1, indicating higher growth when not treated with sorghum extract, while the points referring to the plants under high concentration of the aqueous extracts extracted from leaves are to the left of the control treatment indicating limitation in the growth of the aerial part or of the whole plant in relation to the control treatment.

Figure 2 - Principal component analysis (PCA) with all variables evaluated in plants of *Cyperus rotundus* developing untreated (Control), sprayed with low-concentration sorghum extract from the root and diluted in water (LRW), at high concentration from the root and diluted in water (HRW) at low leaf concentration and diluted in water (LLW) at high leaf concentration and diluted in water (HLW) at low root concentration and diluted in alcohol (LRA) in high concentration from root and diluted in alcohol (HRA), low concentration from leaf and diluted in alcohol (LLA) and high concentration from leaf and diluted in alcohol (HLA).



The analysis of principal components shows a reduction in the growth of plants treated with aqueous *sorghum bicolor* extract in relation to the control treatment, at different levels of intensity the variation in the concentration of aqueous sorghum extract harms the development of *C. rotundus* plants. The results corroborate to the finds by Kandhro et al. (2014), that identifies negative interference of sorgoleone in *C. rotundus* growth.

The present results shows that the extracts from the roots of sorghum doesn't exert significant effects in *C. rotundus* plant growth, howerver, the extracts from the leaves of sorghum extracted in alcohol and water demonstrate herbicidal activity and shows as a promising alternative in weed plants control.

Conclusions

The sorghum leaf extract shows herbicidal activity in the *C. rotundus* weed plants by interfering in plant growth. The extracts obtained in the alcohol and water as a diluent were efficient in decrease *C. rotundus* growth, inasmuch as the allelochemical extracted from the leaf, once the root extraction showed low herbicidal activity in *C. rotundus* plants.

The sorghum leaves shows relevant allelochemical production with herbicidal activity and represents as a promising biorational alternative in weed plants control, however, further studies with variations of concentrations and more species becomes necessary to broad the use of this option.

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