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Weed communities in the organic cultivation of fresh maize intercropped with legumes and coffee husk

Comunidad de malezas en el cultivo orgánico de maíz verde en asociación con leguminosas y cascarilla de café

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ABSTRACT

Keywords:
Agroecology
Organic production systems
Phytosociology
Weed suppression

The objective of this study was to evaluate the phytosociology of the weed communities in maize intercropped with legumes and coffee husk in an organic production system, emphasizing on the relative importance of the weeds and their biomass. The experiment was implemented with the following treatments: T1 - Maize intercropped with *Phaseolus vulgaris* and weed mowing, T2 - Maize intercropped with *Crotalaria juncea* and weed mowing, T3 - Maize intercropped with *Canavalia ensiformis* and weed mowing, T4 - Maize intercropped with *Cajanus cajan* and weed mowing, T5 - Maize grown on soil covered with coffee husk (100 m^3 ha^{-1}) and manual weeding and T6 - Maize grown under conventional tillage system and manual weeding (control). The treatments were performed under a random block design with five replications each. A phytosociological analysis of the weeds was performed at stages V4, V8, and R1 to determine the relative importance (RI%) and biomass. The lowest biomass (11.6 g m^{-2}) of weeds occurred when maize was grown on soil covered with coffee husk. In total, 13 species of weeds were identified, being *Cyperus rotundus* L. the most prevailing species (%). From this study, it was determined that growing maize on soil covered with coffee husk is an alternative to suppress weeds in the organic fresh maize system when coffee husk is available.

RESUMEN

Palabras clave:
Agroecología
Sistema de producción orgánico
Fitosociología
Supresión de malezas

El objetivo de este trabajo fue evaluar la fitosociología de las comunidades de malezas en un cultivo intercalado de maíz con leguminosas y cascarilla de café en un sistema de producción orgánica, haciendo enfasis en la importancia relativa de las malezas y su biomasa. El experimento constó de los siguientes tratamientos: T1 - de maíz intercalado con *Phaseolus vulgaris* y siega de malezas, T2 - maíz intercalado con *Crotalaria juncea* y siega de malezas, T3 - maíz intercalado con *Canavalia ensiformis* y siega de malezas, T4 - maíz intercalado con *Cajanus cajan* y siega de malezas, T5 - maíz cultivado en suelo cubierto con cáscara de café (100 m^3 ha^{-1}) y deshierbado manual y T6 - Maíz cultivado bajo un sistema de labranza convencional y deshierbado manual (control), dispuestos en un diseño de bloques al azar con cinco repeticiones. El análisis fitosociológico de las malezas se realizó en los estadios V4, V8 y R1 para determinar la importancia relativa (RI%) y la biomasa. La menor biomasa (11,6 g m^{-2}) de malezas ocurrió cuando el maíz creció en suelo cubierto con cascarilla de café. Se identificaron un total de 13 especies de malezas, siendo *Cyperus rotundus* L. la especie más predominante (%). A partir de este estudio, se determinó que cultivar maíz en suelo cubierto con cascarilla de café es una alternativa para suprimir las malas hierbas en un sistema orgánico de maíz fresco, cuando las cáscaras de café están disponibles.

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The management of weeds without the use of agrochemicals is one of the challenges of the organic production systems, which depends on the intensity of the interference, the floristic formation, period, and intensity of the infestation (Fialho *et al*., 2010). Usually, in this type of systems, the chemical method is replaced by mechanical and/or cultural methods, as well as other methods such as brushing, weeding, fertilization and irrigation, and duration of coexistence time (Fialho *et al*., 2011).

The modern agriculture systems rely on the economic system and require the use of external inputs based on mineral fertilizers and agrochemicals, being characterized by the simplification of agroecosystems (Gonçalves, 2014; Abreu *et al*., 2012). Opposite to this modern farming, the organic production system is based on the crop consortium. This practice is mainly used by family farmers because its adaptation to the characteristics of family-run properties, the heterogeneity of products grown in the same area, less dependence on external resources, less need of capital, greater hand absorption of family work, and an ecological adjustment (Sediyama *et al*., 2014).

In comparison to the monoculture practice, the consortium presents some advantages, such as the optimization of inputs and manpower. The consortium can provide better use of production resources and reduce pest and disease problems and can control weeds (Guedes *et al*., 2010; Araújo *et al*., 2012).

Coffee production in the state of Minas Gerais was estimated at 30,724,085 sacks in 2016, which placed Brazil as the largest producer and exporter in the world (Conab, 2016). In this region, coffee is one of the major crops. The large coffee production of Minas Gerais is being held in the region of Zona da Mata Mineira. One of the residues of this high production is the coffee husk which, due to is availability, is used as fertilizer in the crop production (Caldeira *et al*., 2013) and the weed suppression.

As the coffee husk availability is high, it can be used as fertilizer for other types of crops. Since there are no studies that evaluate the use of coffee husk applied to the soil surface on fresh maize production, the objective of this study was to evaluate the phytosociology of the communities of weeds in maize intercropped with legumes and coffee husk in an organic production system, placing emphasis on the relative importance of the weeds and their biomass.

MATERIALS AND METHODS

Experimentation area and treatments performed

The experiment was carried out at the Experimental Station of Coimbra-MG (20°45’00.0”S 45°51’00.0”W) of the Universidade Federal de Viçosa at an altitude of 650 m in the Zona da Mata (Mesoregion of Minas Gerais). The soil of the experimental area is classified as dystrophic Yellow Red Argissol, terrace phase, clay texture (EMBRAPA, 2011).

The soil chemical analysis (layer 0-10) showed the following results: pH in water 4.8, 35.8 mg dm^{-3} P, 161 mg dm^{-3} K, 2.8 $cmol_c$ dm^{-3} Ca, 1.1 $cmol_c$ dm^{-3} Mg, 0.00 $cmol_c$ $dm^{-3}$of Al^{3+}, 5.45 $cmol_c$ dm^{-3} H + Al, 4.31 $cmol_c$ dm^{-3} base sum (SB), 4.31 $cmol_c$ dm^{-3} of Effective CTC, 9.76 $cmol_c$ dm^{-3} of CTC Potential, 50% base saturation (V), 0% aluminum saturation index (m), 3.99 dag kg^{-1} of organic matter and 23.2 mg L of P-remainder. The determinations were made according to EMBRAPA (2011); pH (1:2.5 for soil: water), Ca, Mg and Al (extractor KCl 1N), P and K (extractor Mehlich 1) and extractable acidity (H + Al) extractant Calcium Acetate 0.5 mol L^{-1}.

The experiment was implemented with the following treatments:

T1: Maize intercropped with *Phaseolus vulgaris* (Common bean) and weed mowing.
T2: Maize intercropped with *Crotalaria juncea* (Sunn hemp) and weed mowing.
T3: Maize intercropped with *Canavalia ensiformis* (Jack bean) and weed mowing.
T4: Maize intercropped with *Cajanus cajan* (Dwarf pigeon pea) and weed mowing.
T5: Maize grown on soil covered with coffee husk and manual weeding.
T6: Maize grown under conventional tillage system and manual weeding (control).

The plot was constituted by six rows, totaling 24 square meters (5×4.8 m) with 12.8 m^2 of useful area (squareplot), being evaluated the four maize central lines, discarding the border of 1 m.

Before sowing maize, it was performed a harrowing operation to minimize the population of weeds in the site of the experiment. Maize sowing was performed on February 24th, 2016 with a mechanized sowing machine. The open-pollinated maize variety Al Bandeirantes 1310 was sown at five seeds per meter with 0.80 m of spacing, aiming at the final population of 62,500 plant ha^{-1}. The sowing of the jack bean (*Canavalia ensiformis* (L.) DC) was carried out in the density of five plants per meter, simultaneously to maize planting, in the same line of planting, using manual seed sowing tool. For the sowing of common bean (*Phaseolus vulgaris* L.), five plants per meter were used in the same planting line, using the manual seed sowing tool. Sunn hemp (*Crotalaria juncea* L.) and dwarf pigeon pea (*Cajanus cajan* L.) were planted in the planting row of maize, requiring a thinning to 10 plants per meter, a quantity recommended by farmers.

In the T5 treatment, the coffee husk was distributed in the equivalent of 100 m^3 ha^{-1} on the soil surface of each plot, without incorporation before planting the maize.

An organic fertilization of maize was carried out when the crop was in the vegetative stage V4 (four fully expanded maize leaves), by applying 40 m^3 ha^{-1} of organic compost (made from bovine manure and maize husk, 44.84% moisture) next to the sowing row and it was not incorporated into the soil (Galvão *et al*., 1999). The results of the chemical analysis of the compost based on the dry matter weight determined according to the methodology described by Kiehl (2010) were: 10.61 g kg^{-1} organic carbon, 1.10 g kg^{-1} total N, 9.6 C/N ratio, 0.38 g kg^{-1} P, 1.20 g kg^{-1} K, 0.94 g kg^{-1} Ca, 0.42 g kg^{-1} Mg, 0.53 g kg^{-1} S, 158 mg kg^{-1} Zn, 37686 mg kg^{-1} Fe, 239 mg kg^{-1} Mn, 68 mg kg^{-1} Cu, 13.1 mg kg^{-1} B, 018 g kg^{-1} Na, and pH 8.83 g kg^{-1}.

Weeds were cut twice using a brushcutter when maize had three and six leaves completely developed (V4 and V8) after phytosociological evaluations in the treatments intercropped with maize. Maize in monoculture with coffee husk applied in the surface of soil and maize in monoculture it was realized manual weed control at stages V2 (two fully developed maize leaves), V5 (five fully developed maize leaves) and V8 (eight completely developed maize leaves).

The average of the monthly temperature and rainfall was 20 °C and 48 mm, respectively, during the conduction of the experiment. Although there was rainfall during the experimental time, the cultures were supplemented via irrigation water.

Dry mass production of intercropped plants and weeds

After the maize harvest, the dry mass of jack bean (*Canavalia ensiformis* (L.) DC), common bean (*Phaseolus vulgaris* L.), dwarf pigeon pea (*Cajanus cajan* L.) and sunn hemp (*Crotalaria juncea* L.) were determined by sampling an area of 1 m^2. Samples of the plants were cut close to the soil; then they were placed in a drying oven with forced air ventilation at 70 °C for 72 h. After reaching constant weight, the samples were weighed, and the amount of dry mass was used to estimate the production per hectare of each treatment in the intercropped system. The same procedure was performed for weeds.

Phytosociological study of weeds plant communities

After planting the maize, samples of weeds were collected at three different stages: V4 (four fully developed maize leaves), V8 (eight fully developed maize leaves), and during the reproductive stage R1 (flowering). These evaluations were done before the mowing operation between the maize rows. Plants were collected using a 0.25 m side (0.0625 m^2), randomly placed between the lines of maize; then it was collected three samples per plot.

Samples of weeds were cut close to the soil, later identified according to species and family and then placed in a drying oven with forced air ventilation at 70 °C for 72 h to obtain the dry matter of the plant species evaluated. After registering the number and the dry matter value of the weeds, were determined the phytosociological parameters represented by the relative importance (RI%), following the methodology described by Pitelli (2000).

Data analysis

The descriptive analysis of the phytosociological parameters was represented by the relative importance (RI%). For the characteristics, dry mass from intercropped plants and weeds, the data were interpreted through the analysis of variance and the means compared by the Duncan test, at a significant level of 5%. The analyses were performed with the statistical program Assistat, version 7.7 (Silva and Azevedo, 2016).

RESULTS AND DISCUSSION

Dry mass production of intercropped plants and weeds

Among the intercropped plants, the jack bean resulted in the highest amount of dry matter, differing statistically from the other evaluated plants (Table 1).

The values found in the present study may be related to edaphoclimatic factors. Like the research done by Cesar *et al*. (2011) on the performance of green manure cultivated in two seasons of the year in the Cerrado of Mato Grosso do Sul, where values of dry mass yields varied according to the sowing time of the legume. Their study concluded that jack bean had higher dry mass values in the autumn-winter crop. However, in the present study, the sowing of the jack bean was carried out in a non-seasonal period.

The dry matter values of *C. juncea* L. in this study did not show relevance. According to Timossi *et al*. (2014), the best time for the cultivation of *Crotalaria juncea* L., targeting production of biomass, it is at the beginning of the rainy season.

Table 1. Dry mass production of intercropped plants. Coimbra - MG, Brazil, 2016.

Intercropped plants	Dry mass (Mg ha^{-1})
Common bean	0.402 b
Sunn hemp	0.996 b
Jack bean	2.188 a
Dwarf pigeon pea	0.352 b
Mean	0.985
CV (%)	49.35

The averages followed by the same letter do not differ statistically from each other. It was applied by the Duncan Test at the 5% significant level. CV: Coefficient of Variation.

The common bean presented low dry matter, which may be related to insects; especially, Cucurbit Bee (*Diabrotica speciosa*), whose attack caused significant loss of leaf area and probably contributed negatively to its development.

Table 2 shows data from the dry mass and the number of weeds in the phenological stages V4, V8, and R1. It was verified that for the evaluated characteristics there were significant effects for the dry mass of weeds in V8 and R1, and the number of weeds in V8 and R1.

Table 2. Dry mass of weeds and number of weeds in the V4 (vegetative stage of 4 leaves), V8 (8 leaves) and R1 (female flowering), as a function of cover crops, monoculture maize (control) and coffee husks. Coimbra-MG, 2016.

Treatments	Dry mass (g m^{-2})			Number of plants (plants m^{-2})		
	V4	V8	R1	V4	V8	R1
T1: Common bean	14.2^{ns}	54.8 ab	33.8 a	9.0^{ns}	16.2 a	10.7^{ns}
T2: Sunn hemp	15.1	66.8 a	36.5 a	9.4	13.5 ab	8.8
T3: Jack bean	13.4	45.3 bc	37.6 a	7.2	10.9 b	6.4
T4: Dwarf pigeon pea	14.7	35.9 cd	26.0 ab	8.5	9.5 bc	8.7
T5: Coffee husk	16.1	20.5 d	11.6 b	10.6	5.7 c	4.2
T6: Control	8.8	20.0 d	17.4 b	7.9	11.6 ab	4.9
Mean	13.7	40.5	27.2	8.8	11.2	7.2
CV (%)	57.9	31.2	40.6	47.4	32.2	54.6

The averages followed by the same letter do not differ statistically from each other. It was applied by the Duncan Test at the 5% of significant level. CV: Coefficient of Variation. ns: not significant

At the phenological stage V4, there was no statistical difference among the treatments for both dry mass and the number of weeds. At phenological stage V8, the dry mass of weeds in all treatments increased concerning the previous evaluation (V4), as well as the number of plants, which may be associated with regrowth of the weeds after weeding and mowing. The planting of intercropped maize with *Crotalaria juncea* L. differed from the treatments T5: Maize grown on soil covered with coffee husk, T6: maize grown under conventional tillage system, and T4: maize intercropped with *Cajanus cajan* L., resulting on a higher dry mass of weeds. The sowing time of the crop may have influenced these results, since the dry matter of *Crotalaria juncea* L. in this study was not efficient to suppress the weeds.

At the end of the evaluations, at the R1 stage, the T5 treatment differed from the other treatments, showing lower dry matter (11.6 g m^{-2}) of weeds. These results are related to the soil cover provided by the husk, which decreases the necessary incidence of light for the survival of the weeds. According to Gusmão *et al*. (2014), coffee husk has several applications, being mainly used as fertilizers and biocomposite. At V8 stage, maize grown on soil covered with coffee husk differed significantly from the other treatments, except for the maize intercropped with *Cajanus cajan* L. with weed mowing. This result can be interpreted as the effect of the cover on the weeds, which may have influenced in the inhibition of their germination.

The mowing performed in the intercropping treatments after the sampling of the weeds in the evaluated phenological stages, it was not efficient in the suppression of weeds. However, the efficiency of this brushing depends, for the most part, on weed species, on the repetition of cutting, and the stage of the plant's development (Queiroz *et al*., 2010). Planting maize in monoculture with coffee husk applied on the soil surface was highlighted by the potential to suppress weeds during the maize cycle in the organic system. So, it is presented as an effective management strategy for the suppression of weeds.

Phytosociological study of weed communities

It was identified 13 species of weeds in the three stages of maize (V4, V8, and R1), as follows: *Cyperus rotundus* L., *Bidens pilosa* L., *Emilia sonchifolia* (L.) DC., *Sonchus oleraceus* L., *Galinsoga parviflora* Cav., *Artemisia vulgaris* L., *Eleusine indica* (L.) Gaertner., *Digitaria horizontalis* Willd., *Euphorbia heterophylla* L., *Conium maculatum* L., *Ipomoea* sp., *Phyllanthus niruri* L., and *Oxalis latifolia* Kunth.

In the treatments, the RI% of nut grass (*Cyperus rotundus* L.) was higher in all stages (V4, V8, and R1). In the evaluated stages, all the treatments provided differences in the dynamics of the weeds and the phytosociological relationship.

Cyperus rotundus L. is a perennial species, with wide adaptability to many agricultural environments and with sexual and asexual reproduction capacity (Panozzo *et al.,* 2009). It is one of the most important weed species in the world due to its rapid reproduction and dissemination, yielding difficulties for its control (Araújo Jr *et al*., 2015).

After sampling weeds in the evaluated phenological stages (V4, V8, and R1), it was performed mowing in the intercropped treatments. The treatments of maize in monoculture with coffee husk applied on the soil surface and the treatment of maize in monoculture were performed under manual weeding. The stage of competition between weeds and culture can be modified according to the period in which the community is demanding a given resource (Agostinetto *et al*., 2008).

The application of phytosociological indexes is significant to infer the impact of management systems and agricultural practices on the growth and occupation activity of weed communities in agroecosystems. These indexes provided the knowledge of the most important weeds within the weed community, for which management alternatives or even modifications must be established in the system to enable its control (Marques *et al*., 2011). In the first evaluation, performed at V4 stage, the species with highest values of RI% were the *Cyperus rotundus L*., *Bidens pilosa* L., *Oxalis latifolia* Kunth, and *Artemisia vulgaris* L., showing variation of the RI% values according to the treatment applied.

The RI% of the *Bidens pilosa* L. and *Artemisia vulgaris* L. together (58.63%) presented a value similar to the one represented by *Cyperus rotundus* L. in the treatment of maize in monoculture with coffee husk. T5 treatment, Maize in monoculture with coffee husk applied on soil surface, stood out, among the other treatments, in the capacity to suppress *Cyperus rotundus* L. in the first phytosociological evaluation (Figure 1). The suppression of the other weeds that appeared during the V4 stage was more efficient in the treatment of maize intercropped with common bean (T1).

Besides, to become more popular for representing low cost (Oliveira *et al*., 2012), the coffee husk has been studied for its allelopathic effect on weeds (Minassa *et al*., 2017). Although the *Canavalia ensiformis* (L.) DC had covered the soil, due to its higher dry matter value in comparison to the other treatments, possibly due to the low allelopathic effect on *Cyperus rotundus* L. and the other plants found in the experiment area, it did not allow a significant reduction of phytomass of this weed plant. In the evaluation carried out, in the V8 phenological stage, there was a similar proportion of plant numbers in the treatments compared to the first vegetative stage (V4), but with less representative RI.

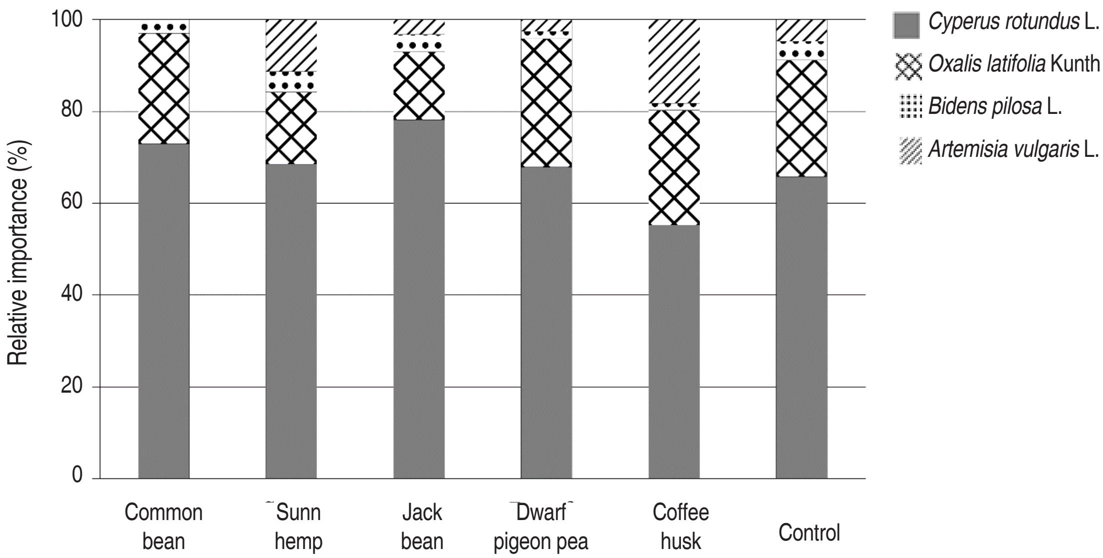

Figure 1. Graphical representation of the values of the relative importance of the plants in the growth V4 (vegetative stage of 4 leaves) maize. Coimbra - MG, 2016.

In the second phytosociological evaluation, the weeds that appeared with the highest frequency were: *Cyperus rotundus* L., *Bidens pilosa* L., *Oxalis latifolia* Kunth, and *Artemisia vulgaris* L. At this stage (V8), *Cyperus rotundus* L. remained the most important species among the treatments; however, there was a reduction in its RI%. The maize and common bean consortium (T1) was the least significant treatment of *Cyperus rotundus* L. (Figure 2). The data do not relate to the value of dry matter provided by the crop, probably due to the attack of *Diabrotica speciosa*.

At V8 phenological stage, it was observed the regrowth of the *Bidens pilosa* L. However, in the coffee husk treatment, there was a reduction of the *Bidens pilosa* L. with 6.75%. This reduction may have occurred due to the large area of soil covered with the coffee husk, which may have influenced the inhibition of germination of *Bidens pilosa* L., by smothering.

Maize grown on soil covered with coffee husk caused a greater suppressive effect on the other weeds in V8 phenological stage, but it was not efficient in the suppression of *Cyperus rotundus* L., compared to the first evaluation (V4). This result may be related to the decomposition of the coffee straw. The other spontaneous plants were affected by the maize shading. The most prevalent species in the reproductive stage were: *Cyperus rotundus* L., *Bidens pilosa* L., and *Oxalis latifolia* Kunth.

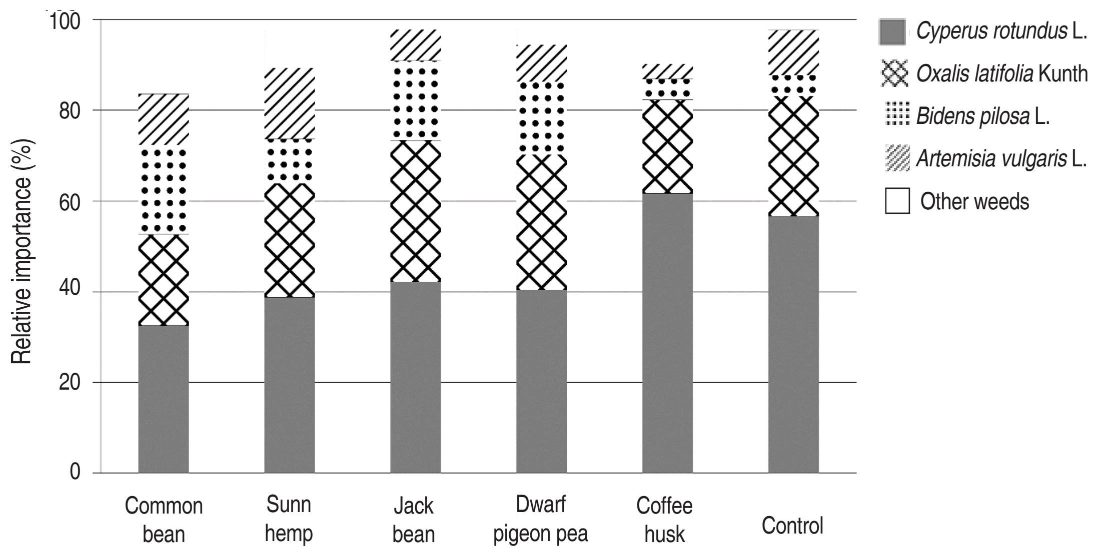

Figure 2. Graphical representation of the relative importance of weeds plants in the phenological stage V8 (vegetative stage of 8 leaves) of maize. Coimbra - MG, 2016.

At the end of the evaluations (V4, V8, and R1), *Cyperus rotundus* L. presented the highest RI%, being smaller in the consortium with dwarf pigeon pea. Regarding monoculture maize with coffee husk applied on the soil surface, it presented higher RI%; however, the treatment was efficient in the suppression of the other weeds (Figure 3).

In the third evaluation, at the R1 stage (flowering), the *Canavalia ensiformis* (L.) DC was not efficient in the suppression of weeds. These circumstances caused the decline of the suppression, which increased the emergence and growth of the weeds. The same fact may have occurred in the present study.

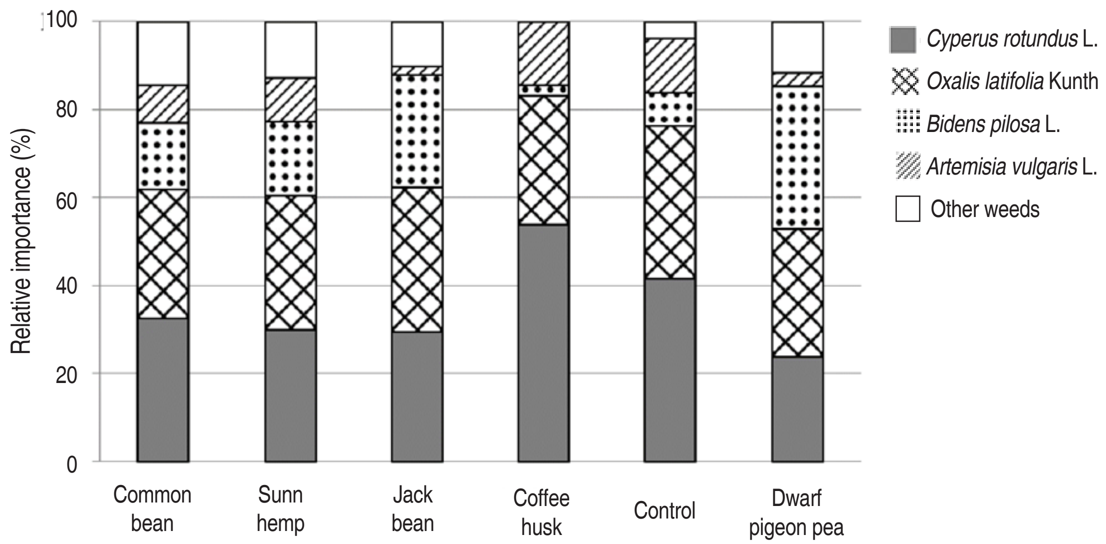

Figure 3. Graphic representation of the values of the relative importance of weeds plants populations in maize growth R1(female flowering). Coimbra - MG, 2016.

Cyperus rotundus L., *Bidens pilosa* L., *Oxalis latifolia* Kunth and *Artemisia vulgaris* L. were the species present in the three phenological stages (V4, V8, and R1). The monitoring of the population of weeds in intercropped systems can evaluate the allelopathic capacity between both plants, which makes possible to improve the production system, both adequately and economically, by reducing herbicide applications.

CONCLUSIONS

Growing maize in monoculture with coffee husk applied on the soil surface is an alternative to suppress weeds on organic fresh maize system. The knowledge about alternative methodologies concerning the chemical use, which efficiently manage the weeds, can help the decision of better planning to execute agricultural operations that benefit soil conservation. Among the evaluated weeds, *Cyperus rotundus* L. was the weed of highest relative importance (RI%) in organic maize culture.

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