DECOMPOSITION OF COVER CROP MULCH AND WEED CONTROL UNDER A NO-TILL SYSTEM FOR ORGANIC MAIZE

DECOMPOSIÇÃO DA PALHADA E CONTROLE DE PLANTAS DANINHAS EM PLANTIO DIRETO ORGÂNICO DE MILHO

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ABSTRACT: The decomposition dynamics of cover crop mulch influence the nutrient supply of successor crops and weed suppression. This is even more relevant in organic production systems, due to their limited use of chemical fertilizers and herbicides. As such, the aim of this study was to quantify biomass production, model the decomposition and N, P and K release of the mulch of different cover crops, and assess the weed suppression of cover crops in the form of mulch and in consortium with organic maize. A randomized block design was used, with a 7x2 factorial scheme (7 cover crop management strategies and 2 cropping systems - maize in monoculture and intercropped with jack bean) and 4 replicates. The management practices that produced the most biomass were white lupine intercropped with black oat and the white lupine, black oat and sunflower monocultures. The use of cover crops did not differ from manual weeding in terms of weed biomass, but did affect the relative importance (RI) of nutgrass. Additionally, maize intercropped with jack bean reduced weed biomass in subsequent crop growth stages.

KEYWORDS: *Lupinus albus*. *Avena strigosa*. *Helianthus annuus*. *Zea mays*. Plant nutrition. Weed suppression.

INTRODUCTION

Organic farming combines traditional and conservation-oriented farming methods with modern agricultural technologies. It emphasizes crop rotation, biological pest control, plant and animal diversification, and enhanced soil quality through the use of compost and green manure (REGANOLD; WACHTER, 2016). In this context, cover crops are grown for non-commercial purposes and serve as green manure when incorporated into the soil (FAGERIA et al., 2005).

Cover crops have a number of important characteristics, including their rapid growth under sub-optimal conditions, ability to produce sufficient biomass to cover the soil, nitrogen-fixing capacity, deep root system, low mulch C:N ratio, and the fact that no harmful substances are produced for the successor crop. Over time, they have evolved from being a tool in nitrogen management to increasing yield and sustainability in agroecosystems (FAGERIA et al., 2005) in addition to contributing to weed control in organic and agroecological production systems.

Organic farmers rely more heavily on cover crops as multifunctional management tools and value them as an ecosystem service. They are also willing to spend more on cover crop seeds (WAYMAN et al., 2016).

The production of mulch cover crops became popular with the adoption of the no-till, system, which is generally closely linked to herbicide use to desiccate cover crops and control weeds. However, agricultural extension agencies are working to disseminate the use of cover crops and no-till systems adapted to small farms, including strategies to reduce herbicide application, such as selecting cover crop species and using roller crimpers (ALTIERI et al., 2011).

In the Brazilian Cerrado region, low rainfall during the off-season results in low biomass production and hampers the adoption of no-till systems (MENEZES; LEANDRO, 2004). This significantly limits the growing season and means that irrigation is often required to establish cover crops in the off-season.

As such, the aim of this study was to quantify biomass production, model the decomposition and N, P and K release of the mulch

Received: 18/04/18
Accepted: 05/12/18

of different cover crops, and assess the weed suppression of cover crops in the form of mulch intercropped with organic maize.

MATERIAL AND METHODS

The study was carried out at an experimental station in Minas Gerais state, located at 20°45'S, 45°51′W and an altitude of 650 m. The soil in the area is classified as red yellow argisol (EMBRAPA, 2013) and the climate is mesothermal, with average annual temperature and rainfall of 19.4 °C and 1,165 mm, respectively (RAMOS et al., 2009) (Figure 1).

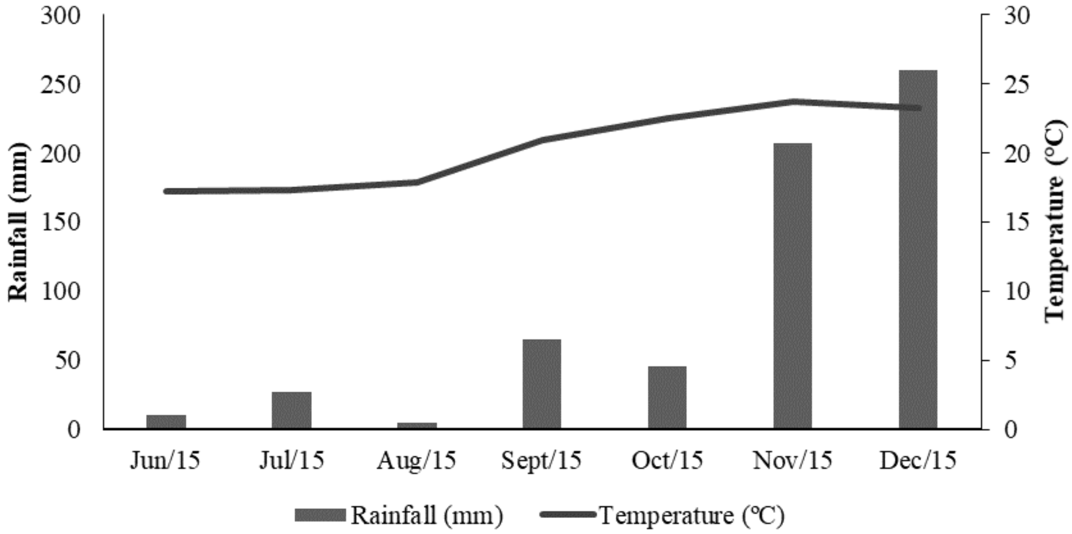

Figure 1. Meteorological data from the automated weather station located 20 km from the experimental area. June to December, 2015.

Prior to the experiment, soil samples were collected at a depth of 0-10cm, with the following results: pH in water = 5.70, P = 9.4 mg dm^{-3}, K = 350 mg dm^{-3}, Ca = 25 $mmol_c$ dm^{-3}, Mg = 13 $mmol_c$ dm^{-3}, Al^{3+} = 0 $mmol_c$ dm^{-3}, H+Al = 46.2 $mmol_c$ dm^{-3}, sum of bases = 47 $mmol_c$ dm^{-3}, effective CEC = 47 $mmol_c$ dm^{-3}, potential CEC = 93.2 $mmol_c$ dm^{-3}, base saturation = 50%, organic matter = 39.9 g kg^{-1} and remaining P = 23.2 mg L^{-1}, measured in accordance with Silva (2009).

The experiment was carried out in the 2015/2016 growing season, under an organic maize no-till system, using a randomized block design in a 7 x 2 factorial scheme (7 cover crop management strategies and 2 cropping systems – maize in monoculture and intercropped with jack bean (*Canavalia ensiformis*), with four replicates. Cover crop management in the 2 cropping systems consisted of mulch from spontaneous plants, black oat, sunflower, white lupine and black oat (intercropped in rows), white lupine and black oat (intercropped by broadcasting), white lupine in monoculture and a control with no cover crop.

The cover crops were planted on June 28, 2015 and mowed on October 5, after flowering. The *Embrapa 29* black oat (*Avena strigosa*) cultivar was sown by broadcasting at a density of 80 kg ha^{-1} of seeds. The *Catissol 01* sunflower (*Helianthus annuus*) variety was planted in rows spaced 0.90 m apart, reaching a population of 55,000 plant ha^{-1} after thinning. The spontaneous plants that emerged from the soil seed bank were kept as plant cover in the corresponding treatment. White lupine (*Lupinus albus*) in monoculture was sown by broadcasting at a density of 85 kg ha^{-1}. Black oat intercropped with white lupine was planted in rows spaced 0.33 m apart at densities of 30 kg ha^{-1} and 40 kg ha^{-1}, respectively. Thirty percent more seeds were used in the black oat/white lupine treatment with broadcast seeding. No base or topdressing fertilizers were applied to cover crops and additional irrigation was performed for plant establishment.

The experimental unit (19.2 m^2) consisted of six 4-meter-long rows of maize spaced 0.80 m apart. The maize variety used was *AL Bandeirante,* characterized by tall plants with a normal growth cycle. Maize seeds were sown 10 days after the cover crops were mowed, at a planting density of 50,000 plants ha^{-1}. Jack bean was manually planted in the maize row at the same time as maize, at a density of five plants per meter. Additional irrigation was performed in the early stages of maize cultivation.

At phenological stage V4, i.e., four fully expanded maize leaves, 40 m^3 ha^{-1} (~12 Mg ha^{-1}) of organic compost was applied next to the row without incorporation. The results of chemical analysis of the compost (dry matter), conducted according to the methodology described by Silva (2009), were as follows: organic carbon = 106.1 g kg^{-1}; total N = 11 g kg^{-1}; P = 3.8 g kg^{-1}; K = 12 g kg^{-1}; Ca = 9.4 g kg^{-1}; Mg = 4.2 g kg^{-1}; S = 5.3 g kg^{-1}; Zn = 158 mg kg^{-1}; Fe = 37686 mg kg^{-1}; Mn 239 mg kg^{-1}; Cu = 68 mg kg^{-1}; B = 13.1 mg kg^{-1}, Na = 1.8 g kg^{-1} and pH 8.83.

In order to determine cover crop biomass production, a 0.25 x 0.25 m grid was randomly placed in the plot four times, except for the sunflower crop, in which all the whole plants within one linear meter were collected. The plants were cut at ground level and dried in an oven at 70 °C for 72 h.

Nutrient cycling was assessed in experimental units consisting of 2 mm mesh 0.25 x 0.25 m litterbags (REZENDE et al., 1999, AMADO et al., 2002), filled with 60 g of fresh matter fragments of the respective mulch material. Next, the bags were placed in the field in the respective experimental units from which the material originated. Assessments were conducted immediately after cover crop plants were cut, and 15, 30, 45, and 60 days after plant residue decomposition.

The litterbags were collected and dried in an oven to determine the remaining dry matter and nutrient contents. The mulch was ground in a Wiley mill and submitted to chemical analysis in the laboratory to determine N, P and K content. Nitrogen content was analyzed using Kjeldahl's method, and P and K were determined by nitric-perchloric digestion with blue molybdenum spectrophotometry and flame photometry, respectively, as described in Silva (2009). The residual nutrient content was calculated by multiplying the remaining biomass and nutrient concentration in the biomass.

A 0.25 x 0.25 m grid was used to assess the weed population at 15, 30 and 90 days after emergence (stages V2, V5 and R4), with three subsamples collected from the experimental unit at each assessment. The weeds were cut at ground level, separated by species, counted and dried in an oven at 70 °C for 72 h. The relative importance (RI) of each species was determined based on plant weight and number, in accordance with Pitelli (2000). When the maize plants reached stages V3 and V6, weeding was performed with a backpack brushcutter. Maize grown without a cover crop was manually weeded before planting and at the same phenological stages.

Data were submitted to analysis of variance ($p < 0.05$) and means compared using Tukey's test (when appropriate) and ASSISTAT software (SILVA & AZEVEDO, 2016). Regression adjustment was performed for remaining biomass and nutrient concentration in the mulch, using GENES software (CRUZ, 2016) and a simple negative exponential model (THOMAS AND ASAWAKA, 1993; ROSSI et al., 2013), as follows:

(Eq. 1) $$X_t = X_o e^{-kt}$$

where "X_t" is the biomass or nutrient concentration at "t" days; "X_o" the initial biomass or nutrient concentration; and "k" the decomposition/release constant.

The half-life time (T1/2), i.e., time required to decompose 50% of the biomass or release 50% of the nutrient, was calculated using the "k" values of the mathematical model.

(Eq. 2) $$T_{1/2} = \frac{\ln 0.5}{k}$$

RESULTS AND DISCUSSION

As expected, maize grown in monoculture or intercropped with jack bean did not influence mulch decomposition or its nutrient release rate. The cover crop management systems that produced the most biomass were white lupine in monoculture and intercropped with black oat (in rows and by broadcasting) and sunflower (Table 1). This can be explained by the size of white lupine and sunflower plants and their adaptation to winters with higher temperatures (WUTKE et al., 2014). Black oat, a smaller species with superior tillering at low temperatures, produced an intermediate amount of biomass (MASCARENHAS; WUTKE, 2014).

The spontaneous plant cover crop system produced the smallest amount of biomass. Although spontaneous plants have several functions, including soil protection, allowing them to dominate an area can increase the soil seed bank, hampering the management of cash crops such as maize. Moreover, cover crops introduced to the area do not become weeds.

A major advantage of using legumes as cover crops is N addition through biological fixation. In this case, although white lupine monoculture and intercropping did not differ in terms of biomass production, higher N levels (230 kg ha^{-1}) were recorded for the monoculture, whereas intercropping recycled 175 kg ha^{-1} of N.

Table 1. Estimated biomass production, nutrient recycling and C:N ratio of six cover crop management strategies in Minas Gerais, 2015.

	Biomass		N		P		K		C:N[1]	
	---------------------- kg ha^{-1} ----------------------								--	
Spontaneous plants	4940	b[2]	46	b	50	ab	201	ab	47	ab
Black oat	7020	ab	46	b	33	b	97	b	68	a
Sunflower	9012	a	126	ab	75	a	251	a	34	bc
BO + WL (rows)	9360	a	174	a	61	ab	169	ab	25	c
BO + WL (broadcasting)	9320	a	176	a	43	ab	128	b	32	bc
White lupine	9800	a	230	a	35	b	96	b	19	c
Mean	8242		133		49		157		37	
CV (%)	28		56		45		48		38	

[1]Calculations assumed 42% C in the biomass; [2]Means followed by the same letter do not differ statistically according to Tukey's test at 5%; BO = Black oat; WL = white lupine.

Legume intercropping with grasses produces mulch with a higher C:N ratio than legumes alone. However, the C:N ratio of the intercropping systems in this experiment remained at around 30, with decomposition rates similar to those recorded in the legume monoculture (Figure 2).

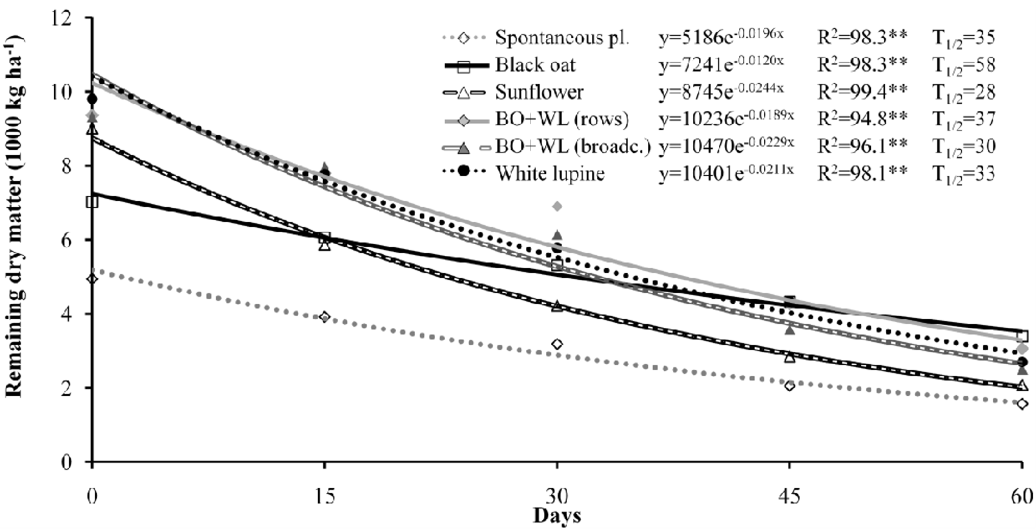

Figure 2. Remaining biomass of cover crops: spontaneous plants, black oat, sunflower, black oat + white lupine (BO+WL) intercropped in rows and by broadcasting, and white lupine in monoculture. Minas Gerais - Brazil, 2015.

Sunflower exhibited one of the highest decomposition rates. The plant parts of this species vary significantly in terms of their decomposition rate, with leaves decomposing quickly while the more lignified stem takes longer. According to Zobiole et al. (2010), the leaves and stem contain 39.9 g kg^{-1} and 7.7 g kg^{-1} of N, respectively, at R6 (final flowering).

Although sunflower does not contribute to biological N fixation, as a non-leguminous plant it exhibits high N scavenging capacity, as reported by Fageria et al. (2005). Their high biomass production and N absorption mean sunflowers enhance nutrient cycling and reduce N losses.

Black oat provides little N for the successor crop, largely because, as a grass, it contains less nitrogen. Additionally, the high C:N ratio of the mulch can immobilize N from the soil. Even the spontaneous plants showed a higher N concentration when compared to black oat, but their lower biomass production resulted in less recycling of this nutrient. Moreover, the cover crops with the highest C:N ratio took longer to release 50% of their N (Figure 2).

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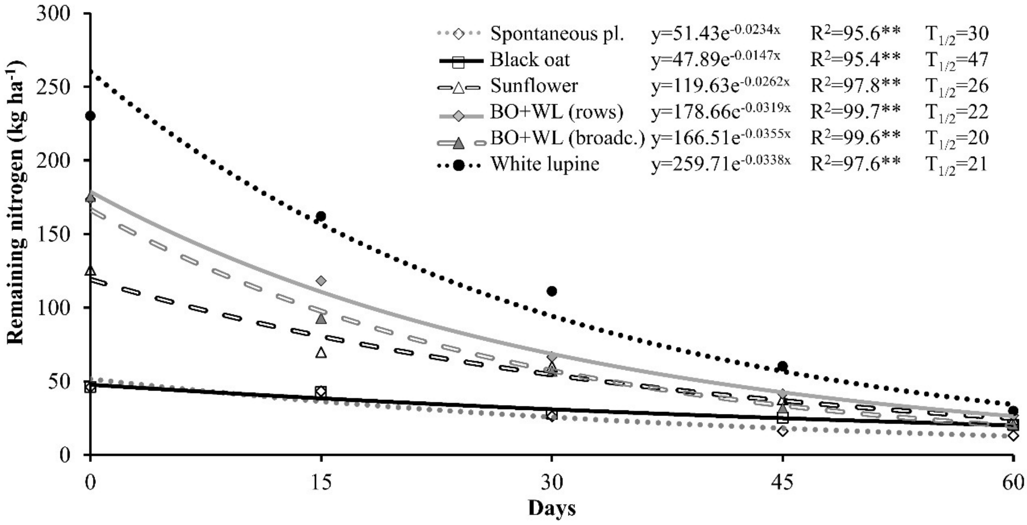

Figure 3. Remaining N in cover crop mulch: spontaneous plants, black oat, sunflower, black oat + white lupine (BO+WL) intercropped in rows and by broadcasting, and white lupine in monoculture. Minas Gerais - Brazil, 2015.

Sunflower also stood out as the crop that recycled the most P and K (75 and 250 kg ha^{-1}, respectively), while black oat contributed with smaller amounts (33 and 97 kg ha^{-1}, respectively).

With respect to P release in the cash crop, this nutrient is typically less limiting to decomposition (GIACOMINI et al., 2003), resulting in lower P immobilization by microorganisms when compared to N and therefore higher P release rates (Figure 4). Unlike N, cover crop species had almost no influence on P and K release rates, with half-lives ranging from 13 to 15 days and 8 to 11 days, respectively (Figure 5).

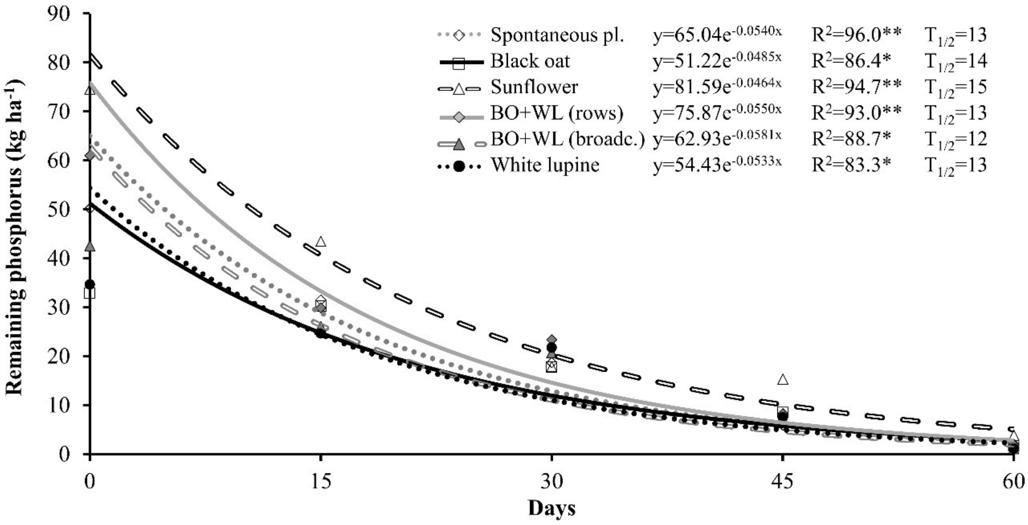

Figure 4. Remaining P in cover crop mulch: spontaneous plants, black oat, sunflower, black oat + white lupine (BO+WL) intercropped in rows and by broadcasting, and white lupine in monoculture. Minas Gerais - Brazil, 2015.

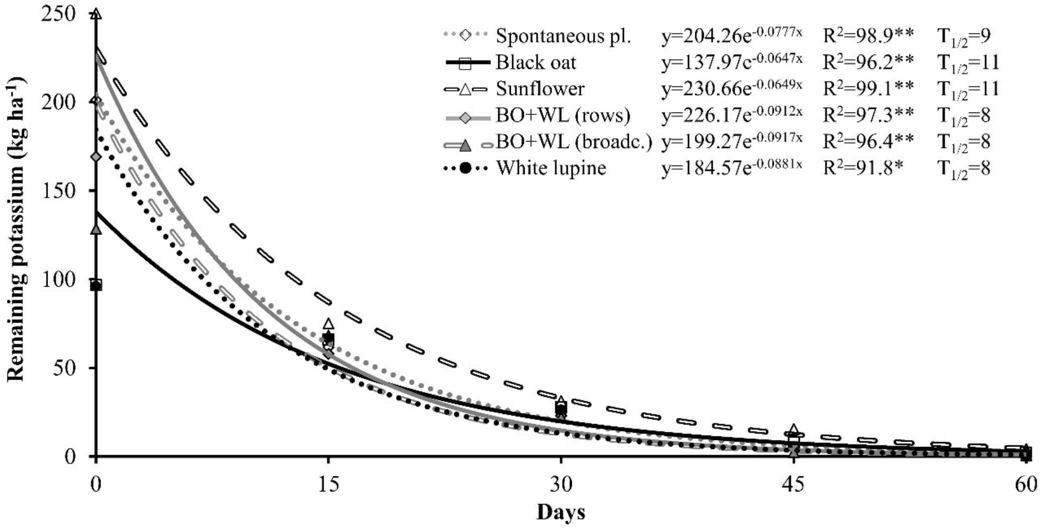

Figure 5. Remaining K in cover crop mulch: spontaneous plants, black oat, sunflower, black oat + white lupine (BO+WL) intercropped in rows and by broadcasting, and white lupine in monoculture. Minas Gerais - Brazil, 2015.

Although black oat produced an intermediate amount of biomass, it had a longer half-life and lower decomposition rate, making it similar to white lupine during the critical period of weed competition with maize. Aita and Giacomini (2003) reported 81% biomass remaining on the soil for black oat and only 57% for common vetch (Fabaceae) at the end of the first month.

In regarding to weed biomass (Table 2), there was no difference between the cover crop management strategies in any of the maize phenological stages. Thus, mulch combined with mowing provided the same level of weed control as manual weeding, although the weed species composition differed. While on one hand manual weeding eradicates almost all the plants, the resulting uncovered soil favors the germination of new seeds and rapid regrowth of weeds such as nutgrass (*Cyperus rotundus*). Additionally, although mulch provides soil cover, it does not last long because 50% of the mulch biomass decomposed between 28 and 58 days, depending on the species.

Table 2. Estimated weed biomass as a function of maize growth stage, cover crop management and cropping system. Minas Gerais - Brazil, 2015.

Cover crop management	Weed biomass (g m^{-2})		
	V2	V5	R4
Spontaneous plants	34.3^{ns}	27.0^{ns}	3.1^{ns}
No cover crop	16.1	14.5	3.5
Black oat	29.5	18.6	4.7
Sunflower	31.2	11.9	6.1
BO + WL (rows)	41.6	22.0	4.3
BO + WL (broadcasting)	30.9	13.5	5.1
White lupine	28.1	17.2	4.7
Cropping system			
Maize monoculture	34.1^{ns}	19.2^{ns}	6.9 a[1]
Intercropped with jack bean	26.4	16.4	2.2 b
Mean	30.3	17.8	4.5
CV (%)	65.2	67.9	129.2

[1]Means followed by the same letter do not differ statistically according to the F-test at 5% probability; ^{ns} not significant according to the F-test at 5% probability; BO = Black oat; WL = white lupine.

Nutgrass obtained the highest RI% at all the assessment times (Figure 6). In stage V2 of maize, nutgrass accounted for more than half of the relative importance, declining as the maize crop developed. This is due to the C4 metabolism of nutgrass, which loses its ability to compete when shaded by maize.

Among the cover crops studied, nutgrass showed the greatest relative importance in the management system with no cover crop, that is, more than 80% in stage V2. The absence of mulch favors nutgrass tuber budding (JAKELAITIS et al., 2003). Moreover, while manual weeding kills other plants, nutgrass quickly regrows. As such, in addition to being onerous, manual weeding benefits nutgrass growth and propagation.

Cover crop management did not influence biomass production in intercropping with Jack bean, which produced 2,730 kg ha^{-1}. This lowered weed biomass production in later maize growth stages. Thus, the combination of cover crop mulch and intercropping maize with jack is beneficial controlling weed populations control in maize crops.

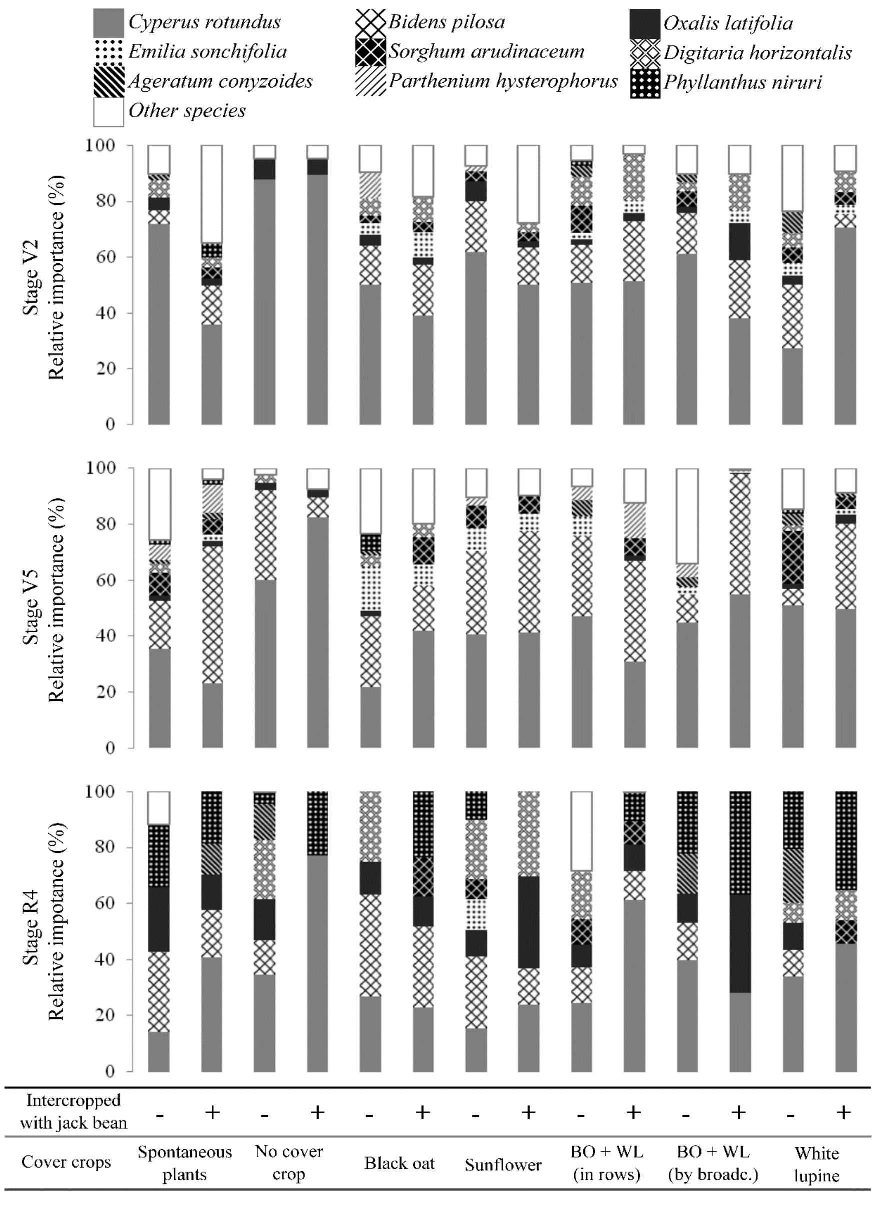

Figure 6. Relative importance of weeds in three maize phenological stages as a function of cover crop mulch management (spontaneous plants, black oat, sunflower, black oat + white lupine (BO+WL) intercropped in rows and by broadcasting, and white lupine in monoculture) and cropping system (with and without intercropping with jack bean). Minas Gerais - Brazil, 2015.

CONCLUSIONS

White lupine and sunflower cover crops obtained the highest N recycling and decomposition rates, which resulted in the rapid decline of mulch soil covering.

While cover crop mulch suppresses weeds in the early maize growth stages, intercropping with jack bean contributes to weed control in the final stages. The combination of these two management practices improves weed control in no-till organic maize systems.

ACKNOWLEDGMENTS

The authors are grateful to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for supporting this study. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) Finance Code 001.

RESUMO: A dinâmica de decomposição da palhada de plantas de cobertura influencia o suprimento de nutrientes para a cultura sucessora e a supressão de plantas daninhas. Desse modo, o objetivo deste estudo foi quantificar a produção de biomassa e de modelar a decomposição e liberação de N, P e K da palhada de diferentes plantas de cobertura, assim como, avaliar a supressão de plantas daninhas por plantas de cobertura na forma de palhada e em consórcio com milho orgânico. O experimento foi realizado em esquema fatorial 7 x 2 (7 tipos de manejos de planta de cobertura e 2 sistemas de cultivo – milho em monocultivo e consorciado com feijão-de-porco) em blocos ao acaso com 4 repetições. Os manejos que produziram a maior biomassa foram os consórcios de tremoço branco e aveia preta, além dos monocultivos de tremoço branco, aveia preta e girassol. Os manejos de planta de cobertura não se diferenciaram do manejo com capina manual para biomassa de plantas daninhas, porém afetaram a importância relativa da tiririca. Já o consórcio de milho com feijão-de-porco diminuiu a biomassa de plantas daninhas em estádios avançados da cultura.

PALAVRAS CHAVE: *Lupinus albus*. *Avena strigosa*. *Helianthus annuus*. Nutrição vegetal. Supressão de plantas daninhas

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