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Article

Growth and Accumulation of Nutrients by Weeds, in Maize and Legumes Intercrops

Crescimento e Acúmulo de Nutrientes em Plantas Daninhas no Consórcio Milho e Leguminosas

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ABSTRACT - The presence of weeds on fields is a concern for farmers, due to competition with the commercial crops, reducing yields. The intercropping of maize with legumes provides weed control; after senescence, the nutrients accumulated by plants are released, recycling nutrients. The study of plant species and their diversity is called phytosociology. This study aimed at evaluating the accumulation of dry phytomass by maize intercropped with legumes and weeds species, and at evaluating nutrient cycling and the phytosociology of weeds. The experiment consisted of maize intercropped with legumes cover crops: jack-beans, Brazilian jack-beans, velvet bean, lablab-beans, and pigeon pea, and the control treatment (maize without intercrop), all without chemical or mechanical weed control. Maize was sown in the plots, and legumes were sown 64 days after maize. Maize was harvested 120 days after sowing (DAS), and legumes at 144 DAS. Weeds were sampled at 84 and 144 DAS. It was possible to evaluate the accumulation of dry phytomass, the nutrient content of the intercrop components, and the phytosociology of weeds. The phytomass accumulation by maize was not affected by the intercrop with legumes. The intercrop with velvet bean accumulated higher dry phytomass and suppressed weeds. Jack beans accumulated dry mass, but did not suppress weeds. The intercropping system changed the diversity of weeds. Panicum maximum, Commelina nudiflora, Commelina benghalensis, Leonotis nepetaefolia and Melampodium divaricatum stood out by presenting higher values of phytosociological index and nutrient recycling.

Keywors: green manure, phytosociology, jack beans, modified importance value index, velvet bean.

RESUMO - A presença de plantas daninhas nos campos é uma preocupação dos agricultores, devido à competição com culturas comerciais, causando perdas em produtividade. A consorciação do milho com leguminosas de adubação verde propicia controle das plantas daninhas; após a senescência, os nutrientes acumulados pelas plantas são liberados, reciclando nutrientes. O estudo das espécies vegetais e sua diversidade é chamado de fitossociologia. Este trabalho objetivou avaliar o acúmulo de fitomassa do consórcio milho com leguminosas e plantas daninhas, bem como a ciclagem de nutrientes e a fitossociologia das infestantes. O experimento consistiu na consorciação de milho com as leguminosas de adubação verde: feijão-de-porco, feijão-bravo-do-ceará, mucuna-preta, lablab e guandu, além da testemunha (milho solteiro), todas sem controles químicos ou mecânicos de plantas daninhas. Semeou-se milho nas parcelas, e as leguminosas foram semeadas 64 dias após. O milho foi colhido aos 120 dias, e as leguminosas, aos 144 dias. As plantas daninhas foram amostradas aos 84 e 144 dias.

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Determinou-se acúmulo de fitomassa seca, o conteúdo de nutrientes dos componentes do consórcio e a fitossociologia das plantas daninhas. O acúmulo de fitomassa pelo milho não foi afetado pelo consórcio com adubos verdes. O consórcio com mucuna-preta acumulou maior fitomassa seca e suprimiu as plantas daninhas. O feijão-de-porco acumulou matéria seca, mas suprimiu pouco as plantas daninhas. A consorciação alterou a diversidade das plantas daninhas. Panicum maximum, Commelina nudiflora, Commelina benghalensis, Leonotis nepetaefolia, Melampodium divaricatum se destacaram por apresentar altos valores dos índices fitossociológicos e pelo potencial na reciclagem de nutrientes.

Palavras-chave: adubo verde, fitossociologia, feijão de porco, índice do valor de importância modificado, mucuna-preta.

INTRODUCTION

The presence of weeds has always been a concern for farmers, because it causes losses in productivity, caused mainly by competition effects with the commercial crop (Kozlowski et al., 2009). Thus, legumes used as green manure have been intercropped, because of their power to cover soil and their ability to modify the environment, competing for light, water and nutrients and suppressing the weed population (Oliveira et al. 2014). Its suppressing effect depends on the cover plant (Queiroz et al., 2010; Castro et al., 2011), with an emphasis on velvet beans (*Mucuna aterrima*) (Favero et al., 2000) and jack-beans (*Canavalia ensiformis*) (Alvarenga et al., 1995; Favero, 1998), and on the amount of phytomass produced by the plants (Monquero et al., 2009), which may be increased when green manures are intercropped (Rodrigues et al., 2012).

Their suppressing effect was demonstrated using a maize intercrop with jack-beans, which reduced the relative importance of Chinese mugwort (*Artemisia verlotiorum*), blackjack (*Bidens pilosa*) and crabgrass (*Digitaria* sp.) (Correa et al., 2014).

After the senescence of plants in the field, including the invasive ones, the accumulated nutrients are released again, through the decomposition of their residues (Teixeira et al., 2010), at a rate that varies according to the climatic conditions and the C/N ratio of each species, contributing to the cycling of these nutrients in the soil (Viola et al., 2013). Thus, weeds and legumes may have a potential for soil protection and nutrient cycling, including nitrogen, calcium, potassium, phosphorus and magnesium (Pacheco et al., 2011).

Alongside the release of nutrients by the decomposition of plant residues, the release of allelopathic chemicals may occur, which may interact with other plant species, inhibiting or stimulating their growth (Fontanétti et al., 2007). Among the plants, it was possible to observe an allelopathic effect of the velvet bean on nut grass (Zanuncio et al., 2013), of the jack-bean on signal grass (*Brachiaria decumbens*) and of the sida (*Sida* sp.) (Soares et al., 2015) and of ryegrass on crabgrass (Moraes et al., 2011), which demonstrates the importance of floristic diversity in the suppression of weeds.

To study the diversity of species that constitute the plant community, techniques are adopted in order to measure the importance of a particular species in that place; for this, it is necessary to know the local floristic composition and its structure (number of specimens, dry phytomass accumulation and frequency of occurrence). One of the most used techniques to evaluate the diversity of species is phytosociology, which uses different population indices as for dominance, frequency and density, in an absolute or relative way (Gluguieri-Caporal et al., 2010).

Absolute density indicates the number of individuals of a given species and is calculated by observing the total number of individuals in the area. With this value, it is possible to determine the relative density of each plant of the floristic composition; on the other hand, frequency measures the horizontal distribution regularity of each species (Mueller-Dombois and Ellenberg, 1974). High frequency values indicate a homogeneous floristic composition, and low values show a marked floristic heterogeneity (Lamprecht, 1990).

The dominance of the species is defined as the sum of the basal areas of plants on the soil (Lamprecht, 1990). Based on data about density, dominance and frequency, Curtis and Mcintosh (1957) introduced the importance value index (IVI), defined as the sum of the relative values of density, dominance and frequency indices. Based on the IVI, it becomes possible to compare the "ecological weights" of the species of the experiment, in which similar values indicate a situation of stand equality in terms of composition, structure, site and dynamics (Lamprecht, 1990).

In light of the aforementioned, the objective of this study was to evaluate the phytomass accumulation and nutrient immobilization of maize intercropped with green manure and weed legumes, as well as to evaluate the phytosociology and changes occurred in the weed community, when using maize intercropped with several legumes used as green manure.

MATERIAL AND METHODS

The experiment was conducted in the municipality of Sete Lagoas - Minas Gerais state, on a typical dystrophic Red Latosol, where green manure legumes are cultivated – velvet bean (*Mucuna aterrima*), pigeon pea (*Cajanus cajan*), lablab-bean (*Lablab purpureus*), jack-bean (*Canavalia ensiformis*) and Brazilian jack-bean (*Canavalia brasiliensis*) – intercropped with maize (*Zea mays*), for two years in a row, and one control treatment (maize followed by fallow), where weeds were developed. The plots measured 25 m^2 (5 x 5 m).

The soil was sampled at the installation of the experiment in the 0-10 cm layer, and the results of the chemical and physical characterization (Embrapa, 2011) are described in Table 1. At the beginning of the study, weed and green manure legumes were incorporated with a plowing and two harrowing, subsequently sowing maize (creole Caiano de Sobrália variety), spaced 1.00 m between the rows, and with the useful plot of the experiment being composed of the two central rows by two meters of length, totaling an area of 4.00 m^2. Legumes were sown 64 days later, in furrows, between the maize rows. The final legume stands were: five plants per meter of jack-bean, Brazilian jack-bean and velvet bean; seven lablab-bean plants; and two pigeon pea plants.

Table 1 - Chemical and granulometric analysis (0-10 cm) of a Red Latosol according to the cover vegetables during the experiment installation phase

Attribute	Lablab-bean	Velvet bean	Brazilian jack-bean	Jack-bean	Pigeon pea	Control treatment[(1)]
Ca^{2+} ($cmol_c\ dm^{-3}$)	5.47	5.25	5.74	4.97	5.18	5.21
Mg^{2+} ($cmol_c\ dm^{-3}$)	0.68	0.64	0.80	0.63	0.61	0.68
P ($mg\ dm^{-3}$)	12.42	9.28	9.14	8.87	6.67	8.15
K^+ ($cmol_c\ dm^{-3}$)	0.09	0.10	0.12	0.08	0.08	0.10
S ($cmol_c\ dm^{-3}$)	6.24	5.99	6.66	5.68	5.87	5.99
Al^{3+} ($cmol_c\ dm^{-3}$)	0.02	0.02	0.01	0.02	0.02	0.02
$H^+ + Al^{3+}$ ($cmol_c\ dm^{-3}$)	4.38	4.72	4.24	4.76	4.78	4.69
Base saturation (%)	59	56	61	54	55	56
pH (H_2O)	6.16	6.06	6.12	6.07	6.08	6.10
pH (KCl)	5.05	4.96	5.16	5.00	4.95	5.00
Clay (%)	19.23	19.55	17.90	19.57	19.18	18.50
Organic matter ($g\ kg^{-1}$)	23.77	23.30	24.18	23.43	22.87	23.45

(1) Control treatment; Extractors: Al^{3+}, Ca^{2+} and Mg^{2+} = KCl 1 mol l^{-1}; P and K = Mehlich1.

Maize was harvested after 120 days, maintaining the vegetative part of plants, below the cob, in the respective plots. Subsequently, moisture was determined by drying grains in an oven at 105 °C for 24 hours, and the weight of grains per plot was determined by trailing the cobs of the three central lines, in order to estimate the grain yield per hectare. Samples were collected from each plant at full flowering (144 days after maize sowing) for further analysis, using a 0.5 x 0.5 m cast frame, which was randomly cast four times in each plot. The legumes were cut at the height of the neck. Weeds were sampled at 84 and 144 days, with the same methodology used while harvesting legumes. The chemical analysis of weeds was performed only on those sampled on day 144.

The determination of the dry matter of the sampled plant materials was done after drying them in a forced air circulation oven at 65 °C for 72 hours, with the results expressed as kg ha^{-1}. After determining the dry matter of the species, in each plot, samples were ground in a Wiley-type mill, with subsequent mixing and homogenization of the whole material, obtaining a composite sample for each material. The sampled plant material was placed in paper bags for further determination of dry matter and nutrient content. Plant samples (0.2 g) were mineralized via nitric-perchloric digestion (3 mL of nitric acid: 1 mL of perchloric acid). In the extracts, the calcium, magnesium, phosphorus, potassium and total nitrogen contents were determined, following the methodology described by Silva (1999).

The study of the phytosociology of weeds sampled in both periods (84 and 144 days after maize sowing) was based on the phytosociological indices used in forest communities. Therefore, these indices have undergone adaptations, because many characteristics regarding the weed communities are unknown. Indices were used to evaluate the importance of weed species within a system.

Density, defined as the number of individuals of each species in the floristic composition of the population (Mueller-Dombois and Ellenberg, 1974), was estimated in terms of absolute density (DA_i) and relative density (DR_i) for the i-th species. The absolute density was calculated by the ratio between the number of sampled plants from the species (n_i) and the sample area (m^2). The relative density was obtained by the ratio between the absolute density of each species and the sum of all densities. The formulas used to estimate these indices were, respectively:

$$DA_i = n_i \div A$$

$$DR_i = DA_i \div \left(\sum_{i=1}^{p} DA_i\right) \text{ x } 100$$

where: DA_i = absolute density for the i^{th} species; n_i = number of sampled specimens of the i^{th} species; DR_i = relative density of the i^{th} species, as %; A = samples area, as m^2; and P = number of sampled species.

Another estimated phytosociological index was dominance, defined as the estimate of the basal area of the species in the population (Mueller-Dombois and Ellenberg, 1974). Due to difficulties in determining the basal area of weeds, the way of determining the index was modified. Thus, the modified absolute dominance ($DoA_i m$) was calculated by the ratio between the dry matter of the individuals of a species and the sampled (m^2) area (A). The modified relative dominance ($DoR_i m$) was calculated by the ratio between the absolute dominance of the species and the sum of the dominances of all species, expressed as percentage.

$$DoA_i m = m_i \div A$$

$$DoR_i m = DoA_i m \div \left(\sum_{i=1}^{p} DoA_i\, m\right) \text{ x } 100$$

where: $DoA_i m$ = modified absolute dominance for the i^{th} species, as kg m^{-2}; m_i = dry matter of the i^{th} species, as kg ha^{-1}; $DoR_i m$ = modified relative dominance of the i^{th} species, as %; A = sampled area; and P = number of sampled species.

The absolute frequency (FA_i) was calculated by the percentage of the number of sample units (μ_i) of the i^{th} species, in relation to the total samples (μ_t). The relative frequency was calculated by the ratio between the absolute frequency of the i^{th} species and the sum of the absolute frequencies of all sampled species (Mueller-Dombois and Ellenberg, 1974).

$$FR_i = FA_i \div \left(\sum_{i=1}^{p} FA_i\right) \text{ x } 100,$$

where: FA_i = absolute frequency of the i^{th} species, as %; μ_i = number of sample units in which the i^{th} species is present; μ_t = total number of sample units; FR_i = relative frequency of the i^{th} species, as %; and P = number of sampled species.

The importance value index (IVI) brings together, in a single expression, the number of individuals, the basal area and the distribution of individuals in the sampled area (Curtis and Mcintosh, 1957). The modification made while determining the dominance of plant species replaces the determination of the basal area by the determination of the dry matter of plants. The modified importance value index was calculated by the sum of the number of individuals, their dry matter and the distribution of individuals in the sampled area.

$$IVIm = \Sigma (DR_i + DoR_i m + FR_i)$$

where: $IVIm$ = modified importance value index; DR_i = relative density of the i^{th} species, as %; $DoR_i m$ = modified relative dominance of the i^{th} species, as %; and FR_i = relative frequency of the i^{th} species, as %.

All the results were submitted to analysis of variance by SISVAR program, and the means were compared by Tukey's test ($p<0.05$ error).

RESULTS AND DISCUSSION

The production of dry phytomass by maize plants did not differ among intercrops, although there was a variation by more than 20% among them (Table 2).

When the maize + green manure + weed system is considered, the maize + velvet bean + spontaneous plant system stands out from the others because it presents a greater accumulation of dry phytomass; this difference is due to the high dry matter production of the velvet bean (5,979 kg ha^{-1}). The jack-bean had a lower accumulation (1,904 kg ha^{-1}) of phytomass than the velvet bean, but it was more efficient than the other legumes, which presented low phytomass production (295 - 880 kg ha^{-1}).

Even with a higher phytomass production by velvet beans, maize produced 4,927 kg ha^{-1}, a similar amount to that of the other intercrop, which is due to the fact that during the critical competition period of maize, lasting 42 days (Ramos and Pitelli, 1994), the crop grew only with the competition from weed species (Table 2). This can be explained by the determination of the relative contribution of the intercrop components (Table 3), defined as the relation between the dry phytomass of a given intercrop component and the total dry phytomass of the considered system.

The observed dry phytomass productions of maize (3,950 to 5,068 kg ha^{-1}) are lower than those of commercial crops, which may exceed 14,000 kg ha^{-1} (Santos et al., 2017), indicating that the supply of nutrients to the system, only with nutrients recycled by plants, was deficient. It is also possible to observe that the amounts of total nitrogen immobilized by the components of the systems are enough for productions of more than 3,000 kg ha^{-1} of maize grains, immobilized in their plants, and another 4,000 kg ha^{-1} of maize grains immobilized in other components of the intercrop (Fancelli, 2008). However, the nitrogen release rate of the other components should be considered (Table 4).

The percentage of N immobilized by maize plants was 43.5% of the total (94 kg ha^{-1}), a great part of which is not mineralized and available during the period of demand for N by maize plants. The amount of phosphorus immobilized in the phytomass was low (18.27 kg ha^{-1} by the system) and may be considered the main nutritional limitation for plants. Potassium, calcium and magnesium were not limiting (Table 4); their indices were enough for productions above 5,000 kg ha^{-1} (Fancelli, 2008). Another aspect to be considered is the competition of weeds, since there is no control of them during the maize cycle, and it is known that competition during the first 50 days of growth is critical to crops, causing significant losses in productivity.

Although maize had the lowest relative contribution (41.17%) in the intercrop with the velvet bean (Table 3), it presented a dry phytomass accumulation of 4,927 kg ha^{-1}, demonstrating that a relatively lower contribution does not necessarily mean that production is also low. In addition, the velvet bean, despite having the highest accumulation of dry phytomass (5,979 kg ha^{-1}) and the highest relative contribution (49.97%) among legumes (Tables 2 and 3), and had a suppression effect only on weeds. This fact confirms the suppression effect provided by velvet beans, which reduced by more than 60% the contribution of phytomass and by more than 46% the accumulation

Table 2 - Shoot dry phytomass production of maize, cover crops and weeds in maize + legume intercrop

Component	Variation coefficient (%)	Dry phytomass (kg ha^{-1})					
		Lablab-bean	Velvet bean	Brazilian jack-bean	Jack-bean	Pigeon pea	Control treatment(1)
Maize	78.16	4.810 a	4.927 a	4.564 a	3.950 a	3.993 a	5.068 a
Legume	40.50	880 c	5.979 a	718 c	1.904 b	295 c	-
Weeds	23.06	1.758 bc	1.060 c	1.612 bc	2.150 ab	2.208 ab	2.682 a
System total	50.12	7.448 b	11.966 a	6.894 c	8.004 b	6.496 c	7.750 b
Ageratum conyzoides		38	39	37	96	-	55
Bidens pilosa		-	97	178	47	89	233
Blainvillea fhomboidea		-	-	-	14	57	-
Borreria latifolia		9	32	10	10	-	23
Brachiaria plantaginea		19	11		115	-	83
Cenchrus echinatus		169	46	200	463	669	322
Commelina benghalensis		138	39	110	-	141	207
Commelina nudiflora		272	104	154	128	12	39
Crotalaria incana		15	-	-	144	-	106
Cuphea mesostemon		-	-	44	-	-	-
Cynodon dactylon		194	76	149	122	58	70
Cyperus esculentus		2	5	-	-	6	-
Digitaria horizontalis		45	51	35	189	208	60
Eleusine indica		-	-	5	-	-	16
Emilia sanchifolia		6	1	-	9	4	40
Euphorbia heterophylla		-	5	-	19	-	5
Galinsoga parviflora		176	156	92	130	107	112
Leonotis nepetaefolia		77	148	179	382	314	699
Melampodium divaricatum		24	16	45	-	-	18
Panicum maximum		365	187	290	79	380	120
Panicum rivulare		-	-	3	20	5	14
Raphanus raphanistrum		58	-	-	-	-	-
Richardia brasiliensis		26	31	70	165	157	209
Setaria sp.		37	-	-	-	-	-
Sida glaziovii		-	-	-	-	-	2
Sida rhombifolia		-	14	5	9	1	-
Solanum americanum		-	-	5	8	-	28
Sorghum halepense		-	-	-	-	-	214
Outros		87	-	44	114	-	6

(1) Control treatment. Means followed by equal letters, on the same line, do not differ by Tukey's test ($p<0.05$) of error.

Table 3 - Relative contribution (%) in the total dry phytomass of maize, weeds and green manure legumes in an intercrop

Treatment	Relative contribution (%)		
	Maize	Legumes	Weeds
Lablab-bean	64.58	11.82	23.60
Velvet bean	41.17	49.97	8.86
Brazilian jack-bean	66.21	10.41	23.29
Jack-bean	49.35	23.79	26.87
Pigeon pea	61.47	4.54	33.99
Control treatment	65.40	-	34.60

of nutrients by weeds (Tables 4 and 5), in order to control the density of weed, which presented a relative contribution of 8.86%, confirming the low (1,060 kg ha^{-1}) accumulation of dry phytomass (Tables 2 and 5). According to Zanuncio (2013), the velvet bean is able to effectively control weeds, since its allelopathic extract is persistent in the soil.

Table 4 - Average nutrient composition in the shoot of plants in an intercrops between maize and legume cover crops

Component	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
Maize	40.89 a	1.97 b	41.53 a	8.69 b	7.19 a
Legume	22.53 b	13.75 a	7.75 b	26.08 a	0.65 b
Weeds	30.59 b	2.54 b	33.53 a	22.36 a	5.08 a
System total	94.00	18.27	82.82	57.13	12.91
Variation coefficient (%)	34.23	46.12	43.99	40.21	37.78
Ageratum conyzoides	0.86	0.14	0.83	1.13	-
Bidens pilosa	-	0.32	3.77	0.42	0.23
Blainvillea fhomboidea	-	-	-	0.07	0.11
Borreria latifolia	0.12	0.06	0.15	0.13	-
Brachiaria plantaginea	0.18	0.02	0.00	0.71	-
Cenchrus echinatus	2.91	0.08	3.50	2.55	1.00
Commelina benghalensis	2.43	0.07	3.55	-	0.41
Commelina nudiflora	4.46	0.17	3.80	0.95	0.03
Crotalaria incana	0.34	-	-	0.79	-
Cuphea mesostemon	-	-	0.97	-	-
Cynodon dactylon	2.93	0.11	1.64	0.57	0.06
Cyperus esculentus	0.02	0.00	-	-	0.01
Digitaria horizontalis	0.53	0.09	0.48	0.83	0.42
Eleusine indica	-	-	0.05	-	-
Emilia sanchifolia	0.12	0.00	-	0.09	0.01
Euphorbia heterophylla	-	0.00	-	0.11	-
Galinsoga parviflora	3.22	0.48	2.26	1.22	0.27
Leonotis nepetaefolia	1.46	0.40	2.86	3.63	1.13
Melampodium divaricatum	0.33	0.04	1.34	-	-
Panicum maximum	5.95	0.41	6.35	0.26	0.68
Panicum rivulare	-	-	0.07	0.09	0.01
Raphanus raphanistrum	1.28	-	-	-	-
Richardia brasiliensis	0.42	0.05	0.96	3.15	0.33
Setaria sp.	0.36	-	-	-	-
Sida glaziovii	-	-	-	-	-
Sida rhombifolia	-	0.05	0.06	0.08	0.00
Solanum americanum	-	-	0.14	0.08	-
Sorghum halepense	-	-	-	-	-
Others	1.67	-	0.77	1.44	-

Means followed by equal letters, in the same column, did not differ by Tukey's test ($p<0.05$ error).

Table 5 - Reduction in dry phytomass by the presence of weeds associated with legumes

Treatment	ES[1]	N	P	K	Ca	Mg
	(%)					
Lablab-bean	34.5	22.9	25.0	10.7	-0.5	32.2
Velvet bean	60.5	63.9	62.5	54.1	46.7	62.7
Brazilian jack-bean	39.9	27.9	25.0	13.9	17.6	40.7
Jack-bean	19.8	10.2	12.5	2.9	4.4	16.9
Pigeon pea	17.7	10.0	8.90	-2.4	14.8	25.4
Control treatment	0.0	0.0	0.00	0.0	0.0	0.0

[1] Effect of legume suppression on weeds = 100 - (weed accumulated content in the given legume treatment/cumulative content of the plants in the control treatment) x100. Cumulative content = accumulation of plant dry phytomass x nutrient concentration.

Maize intercropped with jack-bean showed a dry phytomass accumulation 22% lower than that of the control treatment maize (Table 2) and a low relative contribution (49.35%) (Table 3), providing a dry phytomass accumulation of 19.82%, which is lower than that of maize intercropped with velvet-beans (Table 2). In the intercrop, the jack-bean showed a small (19.8%) suppression effect on weeds (Table 5), as these showed a dry phytomass accumulation twice as much as that of the intercrop with the velvet bean (Table 2), confirming the relative contribution of weeds by 26.87% in relation to the dry matter of the intercrop (Table 3). Probably, due to the fact that its development rate is higher than the others (Cardoso et al., 2013), this exerted less suppression on weeds than the other legumes.

In the intercrops with lablab-bean and Brazilian jack-bean, the components showed very similar dry phytomass accumulations (Table 2). Although the relative contribution of lablab-bean (11.8%) and Brazilian jack-bean (10.4%) was lower than that of the jack-bean (23.79%), there was suppression in the dry phytomass of weeds in the intercrops: 34.5% with lablab-bean, 39.9% with Brazilian jack-bean and only 19.8% with jack-bean (Tables 4 and 5).

The pigeon pea, with a relative contribution of 4.54% to the system, confirmed its low production of dry phytomass (295 kg ha^{-1}) and its reduced weed suppression (17.7%) (Tables 2 and 3), probably due to deficiency in its stand, which reduced its weed suppression potential. Thus, the relative contribution of weeds (33.99%) was similar to that of the control treatment (34.6%), confirming the weed dry phytomass accumulation of 2,208 kg ha^{-1} in the intercrop with pigeon peas and of 2,681.8 kg ha^{-1} in the control treatment (Tables 2 and 5). The relative contribution of maize in the two evaluated treatments was similar: 61.4% (pigeon pea) and 65.4% (control treatment). Probably, due to the presence of the maize component in the system and the planting of the green manure 64 days after planting maize, there was a greater competition for water, light and nutrients, reducing the dry phytomass accumulation of Brazilian jack-beans.

Weeds are known as plants capable of causing damages to soil and crops. A differentiated approach can be given to them in terms of phytomass production and soil cover and the absorption of nutrients and recycling that they enable. In this test, they showed that their presence contributed to increase the dry phytomass and nutrients of the maize and green manure intercrops (Tables 2 and 3); this agrees with the observations of Costa (1994), who mentioned the importance of weeds in the accumulation of dry phytomass and nutrient cycling. Therefore, all components are indispensable because they gave their contribution to the system, thus promoting soil cover and protection, which avoids the harmful effects of raindrops on the soil, as well as the reduction of water loss by evaporation (Pires et al., 2008).

The average content of nutrients immobilized in the phytomass (Table 4) showed that, in addition to maize and green manures, weeds contributed to the system, being intermediaries between maize and green manures; this shows their importance for the cycling of nutrients. Maize or green manure are distinct species within each system, which exhibit different nutrient uptake. Weeds varied in the nutrient cycling capacity, helping to balance the amount of nutrients recycled in the soil. This is especially important at the end of the commercial crop cycle, when there is a reduction in nutrient uptake, which can be leached or adsorbed (Viola et al., 2013). In the studied systems, some weed species showed greater efficiency in nutrient absorption (Table 4). Among them, *Ageratrum conyzoides* (P and Ca), *Bidens pilosa* (P and K), *Cenchrus echinatus* (N, K, Ca and Mg), *Commelina benghalensis* (K and Mg), *Commelina nudiflora* (N, P and K), *Cynodon dactylon* (N and P), *Digitaria horizontalis* (Mg), *Galinsoga parviflora* (N, P, K and Ca), *Leonotis nepetaefolia* (K, Ca and Mg), *Panicum maximum* (N, P and K) and *Richardia brasiliensis* (Ca) stand out. The potential of recycling of phosphorus, potassium and magnesium by weeds has already been mentioned by some researchers (Pacheco et al., 2011; Fialho et al., 2012).

Quantitatively analyzing weed data, it was possible to obtain estimates of the phytosociological indices, considering the dry phytomass, the number of species and the number of specimens of each species (Table 6).

The diversity and phytosociology of weeds was altered by the suppression effect exerted by legumes (Table 6), so that it can be represented by the modified importance value index (IVIm). In the intercrop with velvet beans (Table 6), the highest (5,979 kg ha^{-1}) dry phytomass production (Table 2) and the indeterminate growth habit provided greater suppression, decreasing IVIm

Table 6 - Weed species with higher Modified Importance Value Index values in the evaluated intercrops, 88 and 144 days after maize sowing

Weed	Lablab-bean		Velvet bean		Brazilian jack-bean		Jack-bean		Pigeon pea		Control treatment	
	84	144	84	144	84	144	84	144	84	144	84	144
Ageratum conyzoides	-	-	-	-	-	25.04	-	19.83	-	-	-	21.43
Bidens pilosa	-	-	-	-	-	-	-	-	-	-	-	16.12
Blainvillea fhomboidea	-	-	-	-	-	-	-	-	-	-	18.36	-
Borreria latifolia	-	-	-	-	14.43	-	-	-	-	-	-	-
Cenchrus echinatus	26.40	30.12	26.59	-	42.24	32.07	44.19	46.60	55.70	67.00	28.71	33.87
Commelina benghalensis	-	24.08	-	-	-	22.94	-	-	-	22.03	-	21.34
Commelina nudiflora	18.74	41.08	-	41.08	-	35.33	-	20.82	-	-	-	13.87
Cynodon dactylon	20.50	24.49	27.55	20.67	25.53	26.02	22.72	17.47	-	-	-	-
Cyperus esculentus	39.44	-	43.63	-	32.70	-	34.64	-	32.54	-	35.76	-
Digitaria horizontalis	-	-	-	22.35	-	-	19.22	24.01	15.58	23.43	19.19	-
Galinsoga parviflora	-	21.81	12.90	33.63	-	-	14.45	-	14.55	19.95	-	-
Leonotis nepetaefolia	-	-	-	26.31	-	-	-	34.45	-	25.55	-	38.84
Melampodium divaricatum	-	-	24.80	-	-	-	-	-	-	-	-	-
Panicum maximum	14.43	33.02	25.26	23.11	16.61	25.26	-	-	18.97	31.22	20.52	-
Portulaca olearecea	34.76	-	-	-	-	-	-	-	-	-	-	-
Raphanus raphanistrum	-	-	-	-	-	-	13.34	-	14.04	-	15.27	-
Richardia brasiliensis	-	22.16	35.15	21.49	41.42	33.67	51.13	44.55	48.01	47.04	21.39	39.08
Setaria sp.	29.23	-	-	-	-	-	-	-	-	-	-	-
Sida glaziovii	-	-	-	-	16.18	-	-	-	-	-	-	-

values and species diversity at 144 days (Table 6). In the intercrop with lablab-beans, weeds showed an increase in IVIm at 144 days, leading to a decrease in species diversity (Table 6). In the intercrop with jack-beans, species diversity remained similar between the two harvest periods (Table 6); this may be associated with lower legume efficiency in suppressing weeds due to their lower growth and accumulation of biomass (Table 2). High IVIm values were presented by weeds mainly at 84 days (Table 6), but several species showed low IVIm values at 144 days (Table 6), probably due to the competition among weeds.

Weeds from the intercrop with pigeon pea presented the highest IVIm values (Table 6), due to the lower suppression effects exerted by the legume (Table 5). Thus, the diversity of weeds intercropped with pigeon pea was lower, with weeds being more rustic and competitive for growth factors, especially nutrients. In the absence of the green manure legumes (Table 6), weed diversity increased in both periods (Table 6) and, consequently, there was increased competition, which reduced the IVIm values.

Among the weeds found in the experiment, there were *Cenchrus echinatus*, *Richardia brasiliensis*, *Cynodon dactylon* and *Panicum maximum*, as they were present during both periods, in most intercrops, with the highest IVIm values (Table 6), as well as being tolerant to the competition by legumes and maize. This demonstrates their greater potential to support competitive environments and that they are able to recycle larger amounts of nutrients. *Melampodium divaricatum*, *Leonotis nepetaefolia*, *Galinsoga parviflora* and *Digitaria horizontalis* also stood out in both periods (Table 6). However, the contributions of dry phytomass and density were lower because of the competition, presenting lower IVIm values. Therefore, they were not included among the species with the highest indices.

Eighty-four days after maize sowing, it was observed that *Cyperus esculentus*, *Cenchrus echinatus* and *Richardia brasiliensis* stood out because they presented the highest IVIm values in all intercrops (Table 6). *Panicum maximum* presented high indices, except for the treatments with jack-beans, where it was not possible to observe a high value of the modified importance value index (IVIm); the same happened for *Cynodon dactylon* in treatments with pigeon pea.

One-hundred forty-four days after sowing, the occurrence of some weeds decreased and others increased; this altered the floristic diversity of treatments. This may be associated with the suppression of legumes and the completion of the weed development cycle, in cases of occurrence reduction. On the other hand, when there was an increase in the occurrence of weeds, it may be associated to the adaptation to new environmental conditions by these plants. *Cyperus esculentus*, *Raphanus raphanistrum* and *Portulaca oleracea* had high values of the modified importance value index 84 days after maize sowing (Table 6); 144 days after the sowing of maize, these species were no longer identified in the intercrops. This may be due to the allelopathic effects of the plant community and cultural remains (Fontanétti et al., 2007) and to the suppression exerted by the maize + legume system. *Ageratum conyzoides*, *Commelina benghalensise* and *Commelina nudiflora*, species that were not found at 84 days, were the most important 144 days after maize sowing, because they were competitive and they could bear the effects exerted by legumes and weeds, confirming the modification of the floristic composition of the species during the legume cycle (Table 6).

Weeds with high values of their phytosociological indices in both periods and that appeared in the second sampling (144 days) demonstrated their competitive capacity for environmental resources, in order to support the suppression exerted by maize and by the legumes found in the intercrop (Table 6). Among these species, there were *Panicum maximum*, *Commelina nudiflora*, *Galinsoga parviflora*, *Leonotis nepetaefolia*, *Cenchrus echinatus* and *Richardia brasiliensis*, as they were able to accumulate more nutrients (Tables 4 and 6).

In light of the aforementioned, it is possible to conclude that the accumulation of dry phytomass by maize was not altered by the intercrop with green manures. Velvet beans intercropped with maize showed a higher accumulation of dry phytomass and higher weed suppression pressure, followed by jack-beans, which presented greater phytomass accumulation than the other green manures, but did not suppress weeds. Maize intercropping with green manures promoted a change in weed diversity. The weeds with higher IVIm and that stood out for the potential of nutrient recycling were *Galinsoga parviflora*, *Cenchrus echinatus*, *Richardia brasiliensis*, *Panicum maximum, Commelina nudiflora* and *Leonotis nepetaefolia*.

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