PLANTA DANINHA

SBCPD
SOCIEDADE BRASILEIRA DA
CIÊNCIA DAS PLANTAS DANINHAS
<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Panicum maximum cv. Aries Establishment under Weed Interference with Levels of Light Interception and Nitrogen Fertilization

*Estabelecimento de **Panicum maximum** cv. Áries sob Interferência de Plantas Daninhas em Níveis de Interceptação Luminosa e de Adubação Nitrogenada*

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ABSTRACT - The aim of this study was to evaluate the establishment of the pasture of *Panicum maximum* cv. Aries in an environmentally protected area under levels of interspecific interaction with the weed community. The experiment started after sowing *P. maximum*, and it was carried out in a randomized block design with four replications and the following factors: 3 light interception levels, 2 nitrogen rates, and 7 weekly sampling dates along pasture establishment (3x2x7). The light interception treatments, determined by photosynthetically active radiation, were given by mowing weeds over the canopy of *P. maximum* at 40% and 70% light interception, and no mowing (uncontrolled growth of weeds and *P. maximum*). Topdressing application of nitrogen in the form of urea was performed or not (0 or 200 kg N ha^{-1}). The plant community was evaluated by number of species, dry matter accumulation, and density, and phytosociological indices were determined. The relative importance and dry matter accumulation of *P. maximum* were greater after nitrogen fertilization, which favored the species against weed competition. In contrast, there was lower weed density without nitrogen fertilization. Mowing weeds at 40% of light interception enabled *P. maximum* to accumulate more dry matter, while there was no difference between mowing weeds at 70% light interception and growing the forage crop freely with weeds. Reducing weed light interception as well as nitrogen fertilization, and consequently reducing the competitive ability of the weed, favored the establishment of *P. maximum* in diversified agro-ecosystems.

Keywords: interespecific competition, Aries grass, forage, phytosociological indexes.

*RESUMO - O objetivo deste trabalho foi avaliar o estabelecimento da pastagem de **Panicum maximum** cv. Áries em área de proteção ambiental sob influência de níveis variados de interação interespecífica exercidos pela comunidade de plantas daninhas. O experimento foi executado após semeadura da forrageira, delineado em blocos casualizados, no esquema fatorial 3x2x7, com quatro repetições, incluindo três níveis de interceptação luminosa, duas doses de nitrogênio e sete avaliações semanais durante o estabelecimento da pastagem. Os tratamentos de interceptação luminosa, determinada pela radiação fotossinteticamente ativa, foram instituídos pela roçada das plantas daninhas acima do dossel da forrageira, quando estas exerciam interceptação luminosa de 40% e 70% sobre o capim Áries, como também pelo crescimento livre das plantas daninhas e forrageira. Foi realizada aplicação de 0 ou 200 kg ha^{-1} de nitrogênio na forma de ureia em cobertura. A comunidade de plantas foi avaliada por número de espécies, matéria seca e densidade e foram determinados índices fitossociológicos. O índice de importância relativa e a matéria seca da forrageira foram maiores com adubação*

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Received: December 1, 2017
Approved: December 4, 2017

Planta Daninha 2019; v37:e019188589

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Doi: 10.1590/S0100-83582019370100011

nitrogenada, o que a favoreceu na competição com as plantas daninhas. Nos tratamentos sem aplicação de nitrogênio, houve maior densidade de plantas daninhas. O corte das plantas daninhas a 40% de interceptação luminosa propiciou maior acúmulo de matéria seca da forrageira, ao passo que não houve diferença no acúmulo de matéria seca entre os tratamentos de 70% de interceptação luminosa e sem cortes. A redução da interceptação luminosa e o uso do nitrogênio e consequente redução na competitividade interespecífica das plantas daninhas favorecem o estabelecimento de pastagens de ***P. maximum*** *em agroecossistemas diversificados.*

Palavras-chave: competição interespecífica, capim Áries, forrageira, índices fitossociológicos.

INTRODUCTION

Sustainability is a recurrent and increasingly common theme in the debate on agricultural development in Brazil, and there has been criticism of the excessive use of soil tillage, low biodiversity (monoculture) and degradation of pastures and natural resources (Macedo, 2009). Agricultural processes have been constantly evolving to prevent the increase of cultivated areas and also to provide greater environmental care, through sustainable intensification of production (Foley et al., 2011; Godfray and Garnet, 2014; Lemaire et al., 2014).

Duru et al. (2015) proposed two forms of ecological modernization of agriculture with a view to agricultural sustainability: efficiency-replacement agriculture and biodiversity-based agriculture. Biodiversity-based agriculture seeks to develop different cropping systems to provide ecosystem services and, in turn, drastically reduce the use of anthropogenic inputs (Duru et al., 2015; Gaba et al., 2015, Rollin et al., 2016). Gaba et al. (2015) reported that the main challenge faced by sustainable agriculture is to determine the diversity of plants and associated management practices that could provide a range of services for certain environmental and socioeconomic conditions.

In the plant community, especially when weeds are present in a crop, spatial distribution and stage of development of each specimen and species are very uneven (Colbach et al., 2006; Bourgeois et al., 2012). Because of this temporal and spatial heterogeneity among the species, there is great variability of canopies, which makes competition complex (Munier-Jolain et al., 2013). Competition for light from weeds can interfere with growth and development of forage crops. However, increased availability of nitrogen in the soil can help crops respond to shading (Deiss et al., 2014; Szymczak et al., 2016). Factors provided by nitrogen that can aid such response include better light capture for photosynthesis, increased leaf area index, increased root dry matter production, greater plant height, increased tillering, higher leaf production and regrowth speed (Mahajan et al., 2012). Moreover, Freitas et al. (2005), in a study that evaluated dry matter of *P. maximum* under different nitrogen rates, found a greater quantity of dry matter and a greater amount of nitrogen in the plant when the highest nitrogen rates were applied (which ranged from 70 to 280 kg ha^{-1} yr^{-1}). This is indicative of a great contribution of this nutrient to plants.

When there is high plant density in the same area, there is high competition for solar radiation, arising from higher radiation capture by the canopy of the community, which provides several patterns of extracts of quantity and quality of light in organs and plants through the canopy (Aphalo et al., 1999; Munier-Jolain et al., 2013). Multiple systems that consist of two or more cultivars or species with spatial and temporal interaction combine crop production with pest and disease regulating services, erosion control, climate regulation and maintenance of soil fertility (Gaba et al., 2015, Rollin et al., 2016). However, in a plant community, not all species interfere in the crop with the same intensity when competing for abiotic resources (Cook and Ratcliff, 1984; Kuva et al., 2007). Therefore, agroecosystem management should favor crops of interest without causing biodiversity depletion in a production system and/or degrading it. This way, production can be combined with provision of ecosystem services.

Phytosociological indices are important for an analysis of the impact of soil management systems and agricultural practices on the dynamics of growth and occupation of weed communities in agroecosystems (Pitelli, 2000; Kuva et al., 2007; Deiss et al., 2017). They are also useful tools to shed light on the dynamics of weed species and their interactions in arable fields (Concenço et al., 2013). According to Pitelli (2000), populations respond differently to varying levels of pressure from the environment, and compositions of weed communities may indicate some trends that will allow relatively safe predictions of the consequences of certain agricultural practices on weeds.

Thus, one needs to understand the dynamics of plant communities in agroecosystems as well as create farming strategies that can be aligned with new global demands on production of food, fiber and energy. The hypothesis of this work is that there can occur establishment and production of *P. maximum* in coexistence with weeds as long as abiotic growth factors, such as availability of light and nitrogen in the soil, are not limiting factors for the forage crop. Therefore, the objective of this work was to study how the establishment of pasture with *Panicum maximum* cv. Aries is influenced by levels of interspecific interaction with the weed community in the Southern region of Brazil, in an environmentally protection area.

MATERIAL AND METHODS

The experiment used a randomized block design in a 3x2x7 factorial arrangement, with four replications. Factors include three intensities of light interception by the weeds on the pasture, topdressing application of two rates of nitrogen (N) and seven evaluations during the period of establishment of *Panicum maximum* cv. Aries, allocated in plots of 5 x 2.5 m. The levels of interspecific interactions were determined by mowing all weeds found above the canopy of the grass. They were established on the basis of intensity of light interception quantified by photosynthetically active radiation, and topdressing application of N rates was performed to control the presence or absence of limitation of this nutrient for the plants. The light interception treatments consisted of three interspecific competition intensities and were determined by: i) cutting the weeds above the canopy of the forage crop at 40% light interception by weeds; ii) cutting the weeds above the canopy of the forage crop at 70% light interception by weeds; iii) and no cutting, i.e., uncontrolled growth of the weeds and the forage crop. The second evaluated factor was broadcast application of 0 kg ha^{-1} or 200 kg ha^{-1} of N in the form of urea at 36 days after sowing, when the plants had four leaves. The third factor consisted of weekly collections of weeds and the forage crop for temporal characterization of the plants, over a period of 42 days as of the 43th day after planting, from February 25, when the forage crop was at the four-leaf stage, to April 8, 2013, which corresponded to 85 days after planting.

The experiment was carried out in the Environmentally Protection Area of the Iraí River, in the municipality of Pinhais, Paraná, which is a territorial unit created by State Decree no. 1.753/96 (Paraná, 1996), according to Law 6.938/81 (Brasil, 1981). Such decree prohibits the use of pesticides for crop production, but there are no restrictions on the use of exotic species, nor on soil turnover. The climate in the region is Cfb, without a defined dry season, with cool summers and moderate winter, according to the Köppen classification. The altitude is approximately 934.6 m and average annual rainfall ranges between 1,400 and 1,600 mm. The area is located at 25°26’4" south latitude and 49°11’33" east longitude. Figure 1 shows variations in temperature and precipitation in the experimental period.

Furrow sowing of *P. maximum* was performed on January 13, 2013 with minimum tillage, spacing of 0.17 m, at a density of 9 kg ha^{-1} seeds, which resulted in a variation of 28 to 60 plants m^{-2} through all experimental units during the experiment; 40 kg ha^{-1} of P_2O_5 was applied in the furrow along with sowing and topdressing application of 180 kg ha^{-1} K_2O (at 36 days after sowing), according to the Brazilian Society of Soil Science (SBCS, 2004). Nitrogen application (200 kg ha^{-1}) in the form of urea was based on the work of Lemaire et al. (2008a,b) and Lemaire et al. (2007) for C4 grasses on the non-limiting perspective of N availability in the soil in the plant community. Soil analysis in the study area at a depth of 0 to 20 cm showed 6.74% of organic matter ($C_{organic}$ x [1.74]/10), pH = 5.10 ($CaCl_2$), exchangeable Al = (0.10 cmol$_c$ dm^{-3}), K = 0.10 (cmol$_c$ dm^{-3}), Ca = (5.40 cmol$_c$ dm^{-3}), 3.55 (cmol$_c$ dm^{-3}), V(%) = 55.50, P = 2.30 (mg dm^{-3}).

For evaluation of the plant community, including weeds and Aries grass, samples were collected in cast iron squares of 0.25 m^2. Evaluations were made of plant dry matter per species, total number of species and density of each species. Collection of all plants present in the sample square was performed by cutting them flush to the ground. Then, the samples were dried in continuous flow ovens at 60 °C to constant weight.

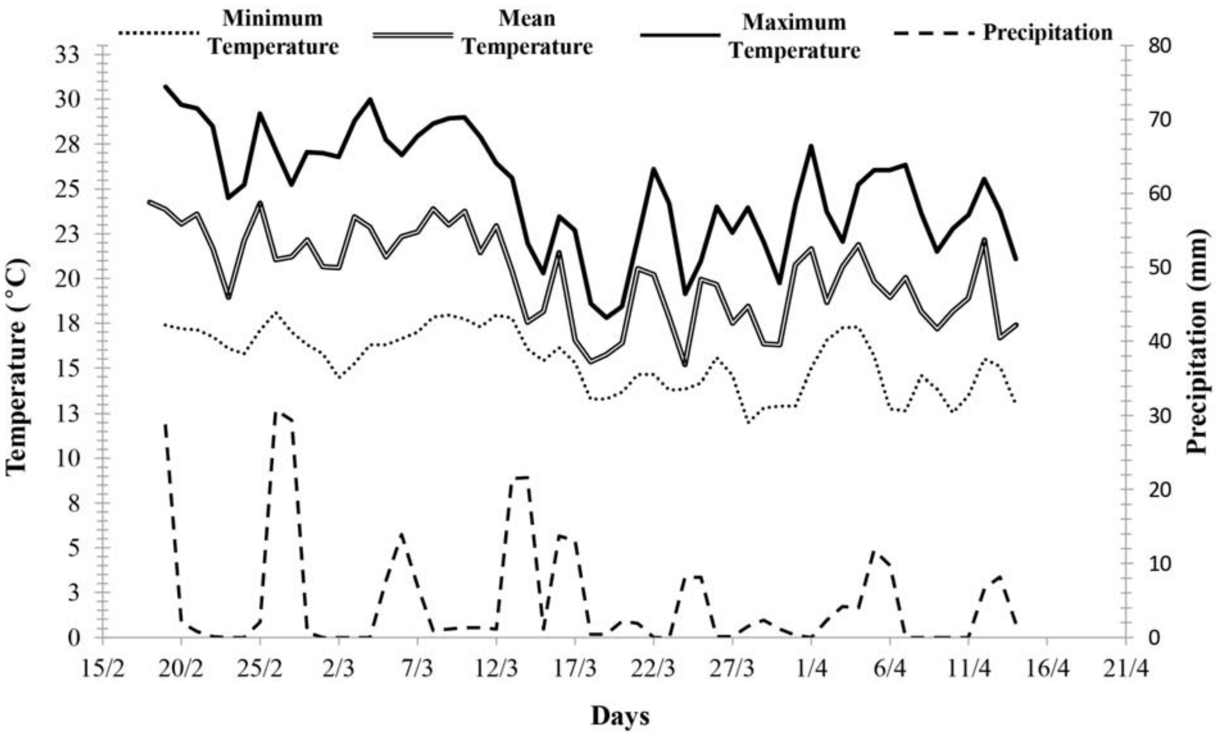


Figure 1 - Maximum, mean and minimum temperature (ºC) and average rainfall (mm) during the period of the experiment (experimental station of SIMEPAR, Pinhais, Paraná).

Light interception by weeds was measured using an AccuPAR LP-80 ceptometer at the intersection of the canopies of *P. maximum* and weeds. Mean radiation under full sun throughout the experiment was 27.10 µmol m^{-2} s^{-1}. In the plots intended for the control of interception, the weeds were cut when they reached 40% and 70% light interception. The weeds were carefully mowed with a backpack mower, and cutting heights were adjusted above the average maximum height of the grass in the treatment. The plots intended for control of 40% light interception were mowed when they reached this rate, which occurred at 43 days and 64 days after sowing; for the plots intended for control of 70% light interception, mowing occurred at 54 days after sowing, when this rate was achieved (Figure 2). In the plots with coexistence between weeds and forage crop (no mowing), light interception was 60% on average, when the entire evaluation period was taken into account.

This study used the phytosociological indices described in Mueller-Dombois & Ellenberg (1974), Pitelli (2000) and Consenço (2013), e.g., relative constancy, relative frequency and relative dominance. These indices determined the relative importance index (RII), which represents the importance value of a species resulting from the sum of the importance values of all the populations of the study community. The data on *P. maximum* were used to determine phytosociological indices, in order to consider this species as a component of the plant community. The data on density and dry matter were treated with analysis of variance (ANOVA). Tukey's test was used at 5% probability level for comparison of means.

RESULTS AND DISCUSSION

Phytosociology

This study included only the five weed species found in the experimental area which had the highest relative importance index (RII). They were present in all treatments during the seven weeks of evaluation of the experiment: *Raphanus raphanistrum*, *Bidens pilosa*, *Ipomea* spp., *Brachiaria plataginea* and *Cyperus esculentus* (Table 1). Other species, e.g., *Euphorbia heterophylla*, *Galinsoga quadriradiata*, *Cynodon dactylon*, *Digitaria sanguinalis*, *Richardia brasiliensis*,

Table 1 **-** Major weed species, on the basis of the Relative Importance Index (RII) of the plant community, found in the establishment of the pasture of *Panicum maximum* cv. Aries

Scientific name	Common name	RRI	Code
Raphanus raphanistrum	Wild radish	29.77	RAPRA*
Bidens pilosa	Hairy beggarticks	14.26	BIDPI*
Ipomea spp.	Purple morning glory	6.25	IPOSP**
Brachiaria plantaginea	Alexandergrass	8.21	BRAPL*
Cyperus esculentus	Yellow nutsedge	9.48	CYPES*
Panicum maximum cv. Aries	Aries grass	12.90	Aries**
Other species	-	19.13	Other**

* International code, according to the International Weed Science Society.** Code used in the present study.

Eleusine indica, *Sida rhombifolia*, *Avena strigosa*, *Oxalis latifolia*, *Rumex obtusifolius*, *Vicia sativa*, *Setaria geniculata*, *Plantago tomentosa*, *Gnaphalium spicatum*, *Aipium leptophyllum* and *Oxalis corniculata*, were also found in the area. However, they had lower RII and were not present in all the treatments during the assessment periods.

The RII of *P. maximum* was higher in treatments that received fertilization of 200 kg N ha^{-1} than in the treatments with 0 kg ha^{-1} (Figure 2). The mean RII values of the forage crop along the entire experiment were 11.32 with 0 kg N ha^{-1} and 14.48 after application of 200 kg ha^{-1} N. This possibly occurred because the weed community had a greater negative effect on Aries grass in plots with 0 kg ha^{-1} of N, while the application of 200 kg ha^{-1} of N favored the competitive ability of *P. maximum* against weeds. According to Booth et al. (2003), under the condition of high nutrient availability, in the short term, some species may stand out in interspecific competition because of high efficiency of nutrient absorption and response during growth.

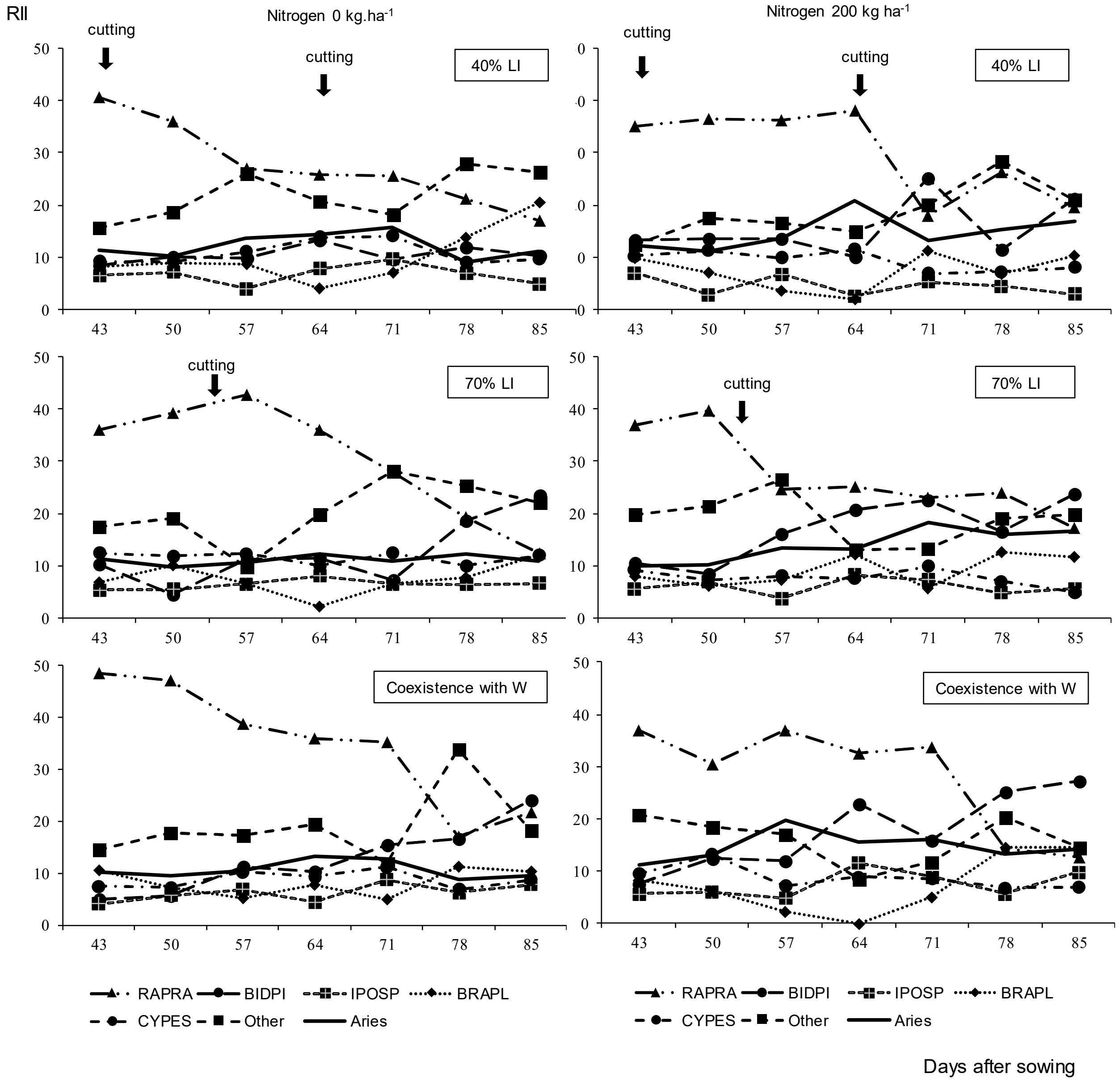
As expected, the descriptive responses of RII were not uniform between the weed species. According to Booth et al. (2003), weed populations are dynamic and interact through time and space. Considering the two most important species, it was found that the RII of *R. raphanistrum* decreased over time, while for *B. pilosa*, RII increased over time, thus showing a dynamic response of the weed population in the period of establishment of *P. maximum* (Figure 2).

Dry matter production

The production of forage dry matter and total number of weeds was higher in plots with nitrogen application and also in some collection periods (Figure 3A, B). Nitrogen may not only promote the growth of pasture (Dias-Filho, 2006; Agostinetto et al., 2017) but also encourage the development of the weed community, depending on the species, as found for *B. pilosa* (Figure 3C). However, when there is high nutrient availability, there tends to be less interspecific competition for soil resources. Nevertheless, with there is greater canopy development in response to nutrient availability, there may be increased competition for light, which limits the growth of plants with lower competitive ability (Booth et al., 2003; Szymczak et al., 2016). When nitrogen fertilization is used, the advantage of forage crops can be seen in their response, e.g., increase in leaf area index, production of root dry matter weight, plant height, tillering/branching, leaf production, regrowth and higher quality of forage (Mahajan et al., 2012), which could benefit forage crops against negative responses of light interception by weeds (Szymczak et al., 2016).

In the treatment with 40% light interception, Aries grass accumulated a higher amount of dry matter, compared to the treatment of coexistence with weeds. However, in the treatment with 70% light interception control showed the same amount of dry matter accumulation as the treatment of coexistence with weeds (Table 2). The greater availability of light for *P. maximum*, which resulted from cutting the weeds, especially in the control with 40% light interception, may have favored the forage crop by increasing its ability to suppress the other species when competing for abiotic resources.

The weed community responded dynamically to the study treatments for dry matter accumulation during the establishment of *P. maximum*. Although *R. raphanistrum* was the species

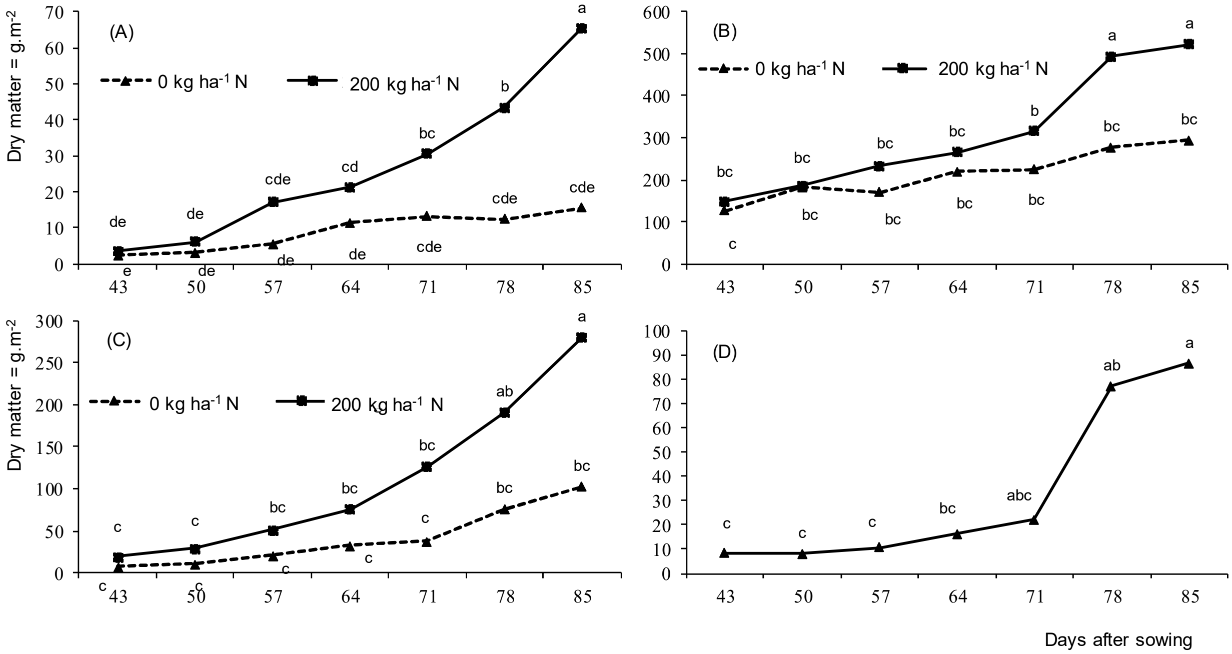


W: weeds; RAPRA: Raphanus raphanistrum; BIDPI: Bidens pilosa; IPOSP: Ipomea spp.; BRAPL: Brachiaria plantaginea; CYPES: Cyperus esculentus; Other: other species; Aries: Panicum maximum cv. Aries.

Figure 2 - Relative Importance Index (RII) in the establishment of the pasture of the main species of weeds and *Panicum maximum* cv. Aries in the treatments: 40% light interception control by weeds, performed on the 43th and 64th days after sowing the pasture (40% LI, upper panels); control of light interception to 70% light interception control by weeds, performed on the 54th day after sowing the pasture (70% LI, mid-panels); coexistence with weeds (coexistence with W, lower panels); application of 200 kg ha-1 nitrogen (right panels); and 0 kg ha-1 nitrogen (left panels).

with the highest RII (which decreased throughout the experiment - Figure 2), there were no apparent differences for dry matter between the treatments of nitrogen fertilization and light interception control. This possibly occurred because it is a fast-growing species which has great ability to remove soil nutrients (Kissmann & Groth, 1999). As a result, its establishment was less influenced by fertilization, and its rapid growth meant that it was at the end of its life cycle before mowing was completed.

B. pilosa was not influenced by mowing levels; however, nitrogen fertilization favored dry matter accumulation throughout the study period (Figure 3C). The cuts may not have reached their apical meristem, which could have inhibited the growth in these meristems and resulted in lower dry matter production.



Evaluation periods with the same letter did not differ significantly by Tukey's test at 5% probability.

Figure 3 - Dry matter production of *Panicum maximum* cv. Aries (A), of the total number of weeds (B) and of *B. pilosa* (C) after application of 200 kg ha^{-1} and 0 kg ha^{-1} of nitrogen and during the establishment of the pasture, and of *B. plantaginea* (D) during the establishment of the pasture (there was no significant difference in the nitrogen fertilization treatments for *B. plantaginea).*

Table 2 - Total dry matter production of weeds and of *Panicum maximum* cv. Aries in the establishment of the pasture (average of seven weekly assessments between 43 and 85 days after sowing the grass) for the treatment of light interception above the canopy of the forage crop, determined by interspecific interaction with weeds

Light interception control	Dry matter (g m^{-2})	
	Weeds	*P. maximum*
40% light interception	238.9 b	20.3 a
70% light interception	240.0 b	19.5 ab
Coexistence between weeds and *P. maximum*	305.3 b	13.9 b

Means followed by the same lowercase letter in the column do not differ significantly from each other by Tukey's test at 5% probability.

Dry matter production of plants of the genus *Ipomea* was affected by mowing treatments only in the last assessment period, in which the largest accumulation occurred in the coexistence between the weeds and the forage crop (no cutting) (Table 3). The strategy of the plants of the family Convolvulaceae is to produce highly branched and twining stems, with climbing habits, which twine around and grow on top of other plants (Kissmann & Groth, 1999). In this way, mowing tends to control this species more effectively when it reaches the plants around which *Ipomea* is twined, as a strategy to search for light. This was partially found the results because there was a reduction in dry matter production only in the control treatment with 70% light interception, in comparison to the treatment with uncontrolled weed growth.

B. plantaginea had increasing dry matter accumulation as the experiment progressed (Figure 3D). However, *B. plantaginea* presented lower RII in comparison to the other most important species, because there was lower contribution of density and relative frequency to RII in the community. There was no influence of mowing above the canopy of Aries grass on *B. plantaginea*, possibly because the growth of this grass is similar to that of *P. maximum*. The main growth meristem of grasses is located at the base of plants and their growth may be stimulated by cutting (Nelson, 2000).

Table 3 **-** Dry matter (DM) production of *Ipomea* spp. in the establishment of the pasture of *Panicum maximum* cv. Aries (at 85 days after sowing) for treatments of light interception above the canopy of the forage crop, determined by interspecific interaction with weeds

Light interception control	*Ipomea* spp. (g m^{-2})
40% light interception	10.78 ab
70% light interception	9.18 b
Coexistence between weeds and *P. maximum*	16.30 a

Means followed by the same lowercase letter do not differ significantly from each other by Tukey's test at 5% probability.

Density

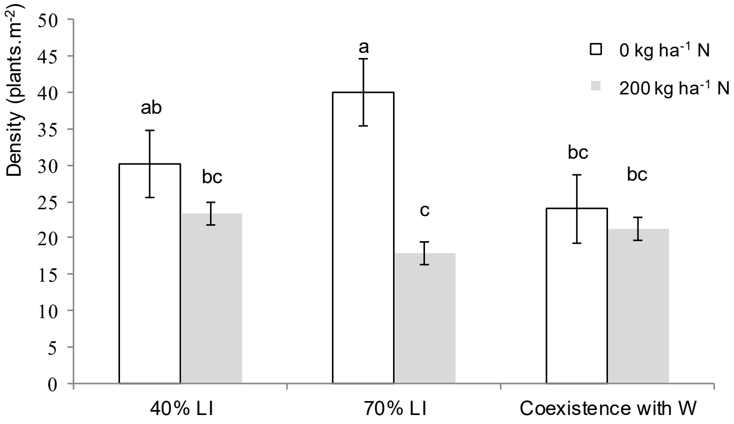
In plots with 0 kg N ha^{-1}, total weed density was higher (Table 4). This is possibly due to the fact that the forage crop had slow growth in these plots, compared to the highest rate of N. Corroborating this statement, Silva et al. (2014), in an experiment on the establishment of sweet sorghum in Brazil's Midwest region, found higher weed densities also at the early stages of the crop, which decreased as the crop was established. However, in the present work, we argue that higher plant density in plots with 0 kg N ha^{-1} may have been due to a greater number of individuals of the weed community that are tolerant to lower fertility. Another possible reason may be a greater intensity of factors that stimulate weed emergence, e.g., light and temperature. In plots with application of 200 kg N ha^{-1}, weed density was reduced, probably because grass pastures tend to be favored in interspecific competition by application of N (Dias-Filho, 2006).

Table 4 **-** Total weed density in the establishment of pasture of *Panicum maximum* cv. Aries (average of seven weekly assessments between 43 and 85 days after sowing grass) for the nitrogen topdressing fertilization treatments

Nitrogen fertilization	Weed density (plants m^{-2})
0 kg ha^{-1}	179.1 a
200 kg ha^{-1}	140.3 b

Means followed by the same lowercase letter do not differ significantly from each other by Tukey's test at 5% probability.

Density responded differently in the weed species after application of N, as is the case of *R. raphanistrum*. Although it was the species with the highest RII, it showed no differences between the rates of N. Conversely, *C. esculentus* presented higher plant density in plots without application of nitrogen, possibly because there was higher light incidence (Figure 4). Nitrogen fertilization fosters greater potential of the forage crops to capture light, particularly those with C4 photosynthetic mechanism, thus hindering the development of species with lower competitive ability. According to Kissmann & Groth (1997), *C. esculentus* has more vigorous development in sunny areas. Mhlanga et al. (2016), in an experiment with maize-cover crop rotations in Zimbabwe, showed that *C. esculentus* presented higher plant density in areas more exposed to sunlight.



Treatments with nitrogen fertilization and mowing with the same lowercase letter do not differ significantly from each other by Tukey's test at 5% probability. W = weed; N = nitrogen; LI = light interception.

Figure 4 **-** Density of *Cyperus esculentus* in the treatments of light interception above the canopy of the forage crop, determined by interspecific interaction with weeds (40% light interception of weeds = 40% LI; 70% light interception of weeds = 70% LI; and coexistence with weeds = coexistence with W) and with nitrogen topdressing fertilization.

B. pilosa had higher density only in the last evaluation, in which N was not applied. This species, according to Kissmann & Groth (1999), presents varied cycles, and, thus, the greater density in the last week of the experiment can be attributed to the high degree of local infestation. In plots with the highest incidence of light (without nitrogen fertilization), there was a greater chance of emergence of new seedlings, thereby increasing density, which can be reflected in higher dry matter values, as previously described. In a study with crop rotation, Mhlanga et al. (2016) found higher densities of *B. pilosa* in crops that enabled greater light incidence. Germination of *B. pilosa* depends on the quality of light (Valio, 1972). Therefore, the greater light interception by the canopy must have been a determinant factor for the occurrence of lower density of *B. pilosa*.

The main findings of this study are: a) the establishment of *P. maximum* is favored by the reduction of interspecific competition by mowing and nitrogen application in agroecosystems with diverse plant communities; (b) the absence of nitrogen fertilization favored the weeds, which had higher total density in these conditions, hence the establishment of pastures of *P. maximum* is hampered without the addition of nitrogen; c) the RII of *P. maximum* was increased after nitrogen fertilization, which favored competition against weeds; d) weed mowing with 40% light interception control was more efficient for an increase in DM values of the forage crop, while there was no difference in dry matter accumulation among the treatments at 70% light interception and without cuts; and e) the density values of *C. esculentus* and *B. pilosa* were higher when nitrogen fertilization was not performed. However, the lower density of *B. pilosa* in plots that received nitrogen application did not reduce dry matter accumulation. The findings of this study show that establishment and production of *P. maximum* can occur when the crop coexists with weeds as long as abiotic growth factors, e.g., light availability and nitrogen in the soil, are not limiting factors for the forage crop.

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