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Floristic and phytosociology of weeds in pastures in Maranhão State, Northeast Brazil[1]

Florística e fitossociologia de plantas invasoras em pastagens no Estado do Maranhão

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ABSTRACT - Knowledge of weed floristic composition and phytosociology are key factors for improving weed management in pastures. Information on weed species that occur in pastures in Northeast Brazil, particularly in Maranhão State is very limited. It is, therefore, important, to search for information to help farmers to control weeds in livestock farming. This paper describes the weed flora diversity and community structure parameters, including density, frequency, abundance and importance value for each weed species found in five pastures of same age and management in Maranhão State, Northeast Brazil. The weed survey was carried out using a wooden frame (80 cm x 30 cm) placed randomly on the soil surface 30 times in each pasture (n = 150). Weeds were pulled out, separated by species and counted. The weed flora was represented by 996 individuals, from nine families, 15 genera and 19 species. Weed density within pastures was of 44.3 plants m^{-2}. The weed flora was dominated by species of the Cyperaceae and Poaceae families. The most important weed species based on Importance Value were *Eragrostis ciliaris* (IV = 32.97), *Cyperus rotundus* (IV = 31,95), *Cyperus luzulae* (IV = 27,50), *Cyperus sphacelatus* (IV = 27,42), *Pycreus lanceolatus* (IV = 27,33) *Cyperus haspan* (IV = 25,72) and *Eleusine indica* (IV = 23,49). Weed diversity, based on Shannon Diversity Index was very high (*H*' = 4.37 nats ind^{-1}). Our results could lead to improved weed management in pastures in Maranhão State, Northeast Brazil.

Key words: *Eragrostis ciliaris*. Competition. Biological invasion**.** Allelopathy. *Cyperus rotundus.*

RESUMO - O conhecimento da composição florística das plantas invasoras é crucial para melhorar o manejo das pastagens. Informações sobre essas espécies em pastagens na região Nordeste do Brasil, particularmente no Estado do Maranhão são muito limitadas. Portanto, é importante gerar conhecimentos que possam ajudar os produtores a controlar as espécies invasoras nas pastagens dessa região. Este trabalho descreve a diversidade da flora invasora e analisa parâmetros da estrutura da comunidade, incluindo densidade, frequência, abundância e valor de importância de cada espécie em cinco áreas de pastagens com o mesmo manejo e tempo de exploração, no Estado do Maranhão. O levantamento foi realizado com um quadro (0,80 cm x 0,30 cm) lançado aleatoriamente 30 vezes em cada pastagem (n = 150). As plantas foram arrancadas, separadas por espécie e contadas. A flora invasora foi representada por 996 indivíduos de nove famílias, 15 gêneros e 19 espécies. A densidade foi de 44,3 plantas m^{-2}. Espécies das famílias Cyperaceae e Poaceae predominaram na flora. As espécies mais importantes, baseado no Valor de Importância foram *Eragrostis ciliaris* (VI = 32.97), *Cyperus rotundus* (VI = 31,95), *Cyperus luzulae* (VI = 27,50), *Cyperus sphacelatus* (VI = 27,42), *Pycreus lanceolatus* (VI = 27,33) *Cyperus haspan* (VI = 25,72) e *Eleusine indica* (VI = 23,49). A diversidade das invasoras, baseado no Índice de Diversidade de Shannon foi muito alta (*H*' = 4.37 nats ind^{-1}). Estes resultados podem contribuir para melhorar o manejo de pastagens no Estado do Maranhão.

Palavras-chave: *Eragrostis ciliaris*. Competição. Invasão biológica. Alelopatia. *Cyperus rotundus*.

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INTRODUCTION

Pasture degradation due to overgrazing, lack of management and consequent weed infestation is the main agronomic problem affecting livestock industry in northeastern Brazil, particularly in Maranhão State (DIAS FILHO, 2005).

According to Dias Filho (2011), pasture degradation is a complex phenomenon that involves causes and consequences which lead to gradual decrease of carrying capacity, such as inadequate grazing practices including the use of stocking rates or grazing intervals that do not take into account pasture rhythms of growth; inadequate pasture management practices like the absence of periodic soil fertility replenishment and the excessive use of fire to eliminate not consumed pasture, to provoke grass re-sprouting or to control weeds; failures in pasture establishment due to inadequate seedbed preparation, use of low quality seeds, wrong date of planting or by the fact that the first grazing is held too early or too late; biotic factors such as pests or pathogens and abiotic factors such as the excess of or lack of rainfall and poor soil drainage capacity.

Weeds interfere in livestock production by mechanisms of competition with forage species by water, nutrients, space and light and by allelopathy, that is, the production of phytotoxins that prohibits or suppress growth of forage species (REIGOSA *et al.*, 2013).

Weed infestations impact livestock farming by lowering yield and quality of forage, increasing costs of managing, slowing animal weight gain, reducing livestock products quality like meat and milk, and eventually poisoning livestock, because many weed species that occur in pastures are toxic, such as *Palicourea marcgravii* A. St.-Hil. Rubiaceae (MATOS *et al*., 2011).

Despite this, little is known about the weed species that occur in pastures in northteastern Brazil, particularly in Maranhão State, therefore, there is a need to search for information to help farmers to find efficient ways to control weeds. Moreover, studies on weed ecology in this region are crucial to subsidize control strategies.

Weed species identification and knowledge of those species that are more important in pastures are prerequisites to start any weed management program to recover degraded pastures. This may be achieved by carrying out weed floristic surveys and studies on phytosociology which may contribute with knowledge on weed community structure. It is also important to carry out specific studies on floristic diversity to improve control methods recommendation.

There are several methods of weed control in pastures including cultural, mechanical biological and chemical (PELLEGRINI *et al*., 2007; ROOS; RÖDEL; BECK, 2011), however, no method can control weeds without basic knowledge of weed ecology, including floristic and phytosociological studies (GHERSA; MARTINEZ-GHERSA, 2000).

Research with this approach was carried out by several authors including Blackwell *et al.* (2011), Caporal and Boldrini (2007), Galvão *et al.* (2011), Guglieri-Caporal, Caporal and Pott (2010), Inoue *et al*. (2012), Magalhaes, Lopes and Mantovani (2013), Mascarenhas *et al.* (2009), Mitja and Miranda (2010), Modesto Junior and Mascarenhas, (2001), Quadros *et al.* (2003), Tuffi Santos *et al.* (2004) and Vasconcelos *et al.* (2011). However studies on floristic and phytosociology of weeds in pastures in Maranhão State have not been documented previously.

The objective of this study was to undertake weed survey and to study floristic composition, phytosociology and diversity of the weed community in pastures in Maranhão State, northeastern Brazil.

MATERIAL AND METHODS

Study site

This research was carried out in the municipality of Olinda Nova do Maranhão (2°59'52''S - 44°59'49''W), located in Maranhão State, northeastern Brazil.

Climate is of the Aw type, according to Köppen's classification, tropical hot and humid with a rainy season (January through June) and a dry season (July through December). Average temperature is 27 ^{o}C and mean rainfall is around 2,000 mm year^{-1}.

Farms are located in a region where the relief is mild and slightly undulating with elevations varying between 17 and 28 meters with the presence of round hills with modest altitudes at some points. Plinthosols are the dominant soils (EMBRAPA, 2008).

The area natural vegetation belongs to the Ombrophyllous Dense Forest which does not correspond to the original description because of anthropic activities mainly due to cutting of trees for pasture planting and subsistence farming of rice, corn, cowpea and cassava either as monocropping or intercropped.

Five replicate farms were selected for this research each possessing areas of degraded pasture. Participating farmers helped to identify degraded pastures (minimum of 1 ha) that were implemented in 1990 using *Brachiaria brizantha* cv Marandu. Grazing intensity was generally higher for the pastures

indicated as degraded. Further investigation confirmed farmer observations, noting that the degraded pastures demonstrated clear signs of productivity loss, including patches of bare soil, significantly or total loss of previously sown *Brachiaria brizantha* cv Marandu and invasion of other grasses and herbaceous weeds. All farms were located within a 40 km radius of Olinda Nova and experienced similar management histories.

Informal interviews on the management history of each pasture indicated that farmers cut down shrubs and trees from September to October 1994. The downed vegetation was allowed to dry until November, right before the rainiest part of the year, at which time it was burned. Pasture grass *Brachiaria brizantha* cv. Marandu was planted in the end of December at the onset of the rainy season in the burnt fields by means of a hand dibber. Since then, weed management consists of one weeding with a sickle in the end of February. Cattle are allowed to graze after the first seed production from June onwards. Pasture is generally burnt in September after drying out in the dry season. Thereafter fire may occur by spreading from neighboring land.

Data collection

Weed sampling was performed simultaneously in the five pastures in June, 2012 just before pasture seed production (30 per pasture, (n=150), when they were under grazing by cattle using a wooden frame (50 cm x 30 cm) maintaining a minimum distance of two meters from the pasture borders. The frame was placed randomly on the soil surface and all weeds enclosed by the internal perimeter were pulled up, separated by species and counted. For perennial species with stolons and rhizomes each ramification was considered as an individual. The same procedure was done with clumping species with several stems coming from the base.

Botanical material from each species was collected in triplicate whenever possible. The species were preserved by common techniques and incorporated into the Rosa Mochel Herbarium collection at the Center for Biological Studies of Maranhão State University. Botanical identification was done by analysis of the external morphological characteristics of the vegetative and reproductive plant parts, according to literature, by comparison with other species identified and also by consulting experts.

The species that could not be identified at sampling time were transplanted into plastic containers and cultivated until they reached the flowering stage.

The floristic list with families and species was organized according to the classification system established in the Angiosperm Phylogeny Group III guidelines (APG III, 2009). All scientific names and their authors were confirmed after verification in the International Plant Names Index (IPNI, 2013).

Phytosociological structure was assessed using parameters such as the relative values of frequency, density and abundance and the importance value for each species according to Muller-Dombois and Ellenberg (1974).

Floristic diversity was assessed by the Shannon's Diversity Index (*H'*) based on natural logarithm that gives equal weight among rare and abundant species. It is assumed that the higher the value of *H'* the greater the floristic diversity (SHANNON; WEAVER, 1949). Shannon's Index was computed using the following formula:

$$H' = -\sum_{I}^{S}{}_{=1}\ pi \ln pi \qquad (1)$$

where ln is the natural logarithm; pi = ni/N; ni is the number of sampled individuals of the species i; and N is the total number of sampled individuals.

RESULTS AND DISCUSSION

Knowledge of floristic composition in pastures is a key factor for improving weed management. The weed flora assessed in the whole study was represented by 996 individuals from nine families, 15 genera and 19 species. Total weed density within the pastures was 44.3 plants m^{-2} (Table 1).

The families with the highest species richness were Cyperaceae (n=7), Poaceae (n=2), Fabaceae (n=2) and Amaranthaceae (n=2). These families contributed with 68.4% of the total species number. In contrast, five families had only one species each, which corresponds to 55.5% of all recorded families (Table 1).

The Cyperaceae family species richness reflects the competitive advantage, that is, the ability of vegetative propagation of many of its species through a complex underground system consisting of rhizomes and tubers with many species having underground stolons (MUNHOZ; FELFILI, 2006). Additionally, formation of significant seed bank is an important regeneration component for many species of this family (LECK; SCHÜTZ, 2005; MESQUITA; ANDRADE; PEREIRA, 2013).

Conversely, Poaceae family species richness is related to the way most of their species grow with dense clumps or the presence of rhizomateous and stolonipherous individuals widely scattered in the weed community which is a major feature of the dominance of this family in many degraded pastures (MUNHOZ; FELFILI, 2006).

On the other hand, most of the species of the Fabaceae and Amaranthaceae families produce seeds with high longevity in the soil due to hard integument

Table 1 - List of weeds recorded in pastures in Maranhão State, Northeast Brazil

Species	Family	Number of individuals
Alternanthera brasiliana (L.) Kuntze	Amaranthaceae	13
Amaranthus hybridus var. patulus (Betol.) Thell.	Amaranthaceae	33
Tapirira guianensis Aubl.	Anacardiaceae	13
Chromolaena maximilianii (Schrad.) R. M. King & H. Rob.	Asteraceae	10
Cyperus haspan L.	Cyperaceae	103
Cyperus luzulae (L.) Rottb. ex Retz	Cyperaceae	108
Cyperus rotundus L.	Cyperaceae	133
Cyperus sphacelatus Roth	Cyperaceae	106
Cyperus surinamensis Rottb.	Cyperaceae	28
Kyllinga brevifolia Rottb.	Cyperaceae	15
Pycreus lanceolatus (Poir.) C. B. Clarke	Cyperaceae	110
Mimosa pudica L.	Fabaceae	11
Senna obtusifolia (L.) H. S. Irwing & Barneby	Fabaceae	27
Psidium guajava L.	Myrtaceae	2
Eleusine indica L.	Poaceae	87
Eragrostis ciliaris (L.) R. Br.	Poaceae	139
Spermacoce verticillata L.	Rubiaceae	17
Turnera subulata Sm.	Turneraceae	24
Urtica dioica L.	Urticaceae	17

which is impermeable to water entry giving them physical dormancy (BASKIN; BASKIN, 1998) and tolerance to chemical and physical agents (COSTEA; WEAVER; TARDIF, 2004).

The dominance of these families was also observed in weed survey in pastures in Pará State (MITJA; MIRANDA, 2010), Amazonas State (GALVÃO *et al*., 2011), in savannah areas of central Brazil (MUNHOZ; FELFILI, 2008) and southern Brazil (CAPORAL; BOLDRINI, 2007; FERREIRA; SETUBAL, 2009, MAGALHAES; LOPES; MANTOVANI, 2013; QUADROS *et al*., 2003). For Holm *et al*. (1977), these families have the more aggressive and competitive weeds of agroecosystems in the world.

The genus with the higher species number was *Cyperus* (n = 5). This genus alone contributed with 26.3% of the total species identified. In contrast, 14 genera (93.3%) were represented by only one species each (Table 1).

Eight species (42.1%) were found in all pastures evaluated: *Cyperus haspan*, *Cyperus luzulae*, *Cyperus rotundus*, *Cyperus sphacelatus*, *Pycreus lanceolatus*, *Senna obtusifolia*, *Eleusine indica* and *Eragrostis ciliaris* indicating great plasticity with adaptability to different sites and tolerance to the stress imposed by weed management practices used by the farmers.

The number of species found in this study was higher than those observed by Mascarenhas *et al*. (2009) in degraded pastures in savannah in Minas Gerais State and by Schuster *et al*. (2013) in Paraná State, but lower than those observed by Mitja and Miranda (2010) in Brazilian Amazonian rainforest, by Tuffi Santos *et al*. (2004) in degraded pastures in flooded lowland conditions in Minas Gerais State, by Blackwell *et al*. (2011) in pastures in South Island, New Zealand, by Galvão *et al*. (2011) in lowland conditions in Amazonas State, by Inoue *et al*. (2012) in savannah areas of Mato Grosso State, by Caporal and Boldrini (2007) in Rio Grande do Sul State, probably due to differences in edaphic and climatic factors, management, forage species, fire and grazing history.

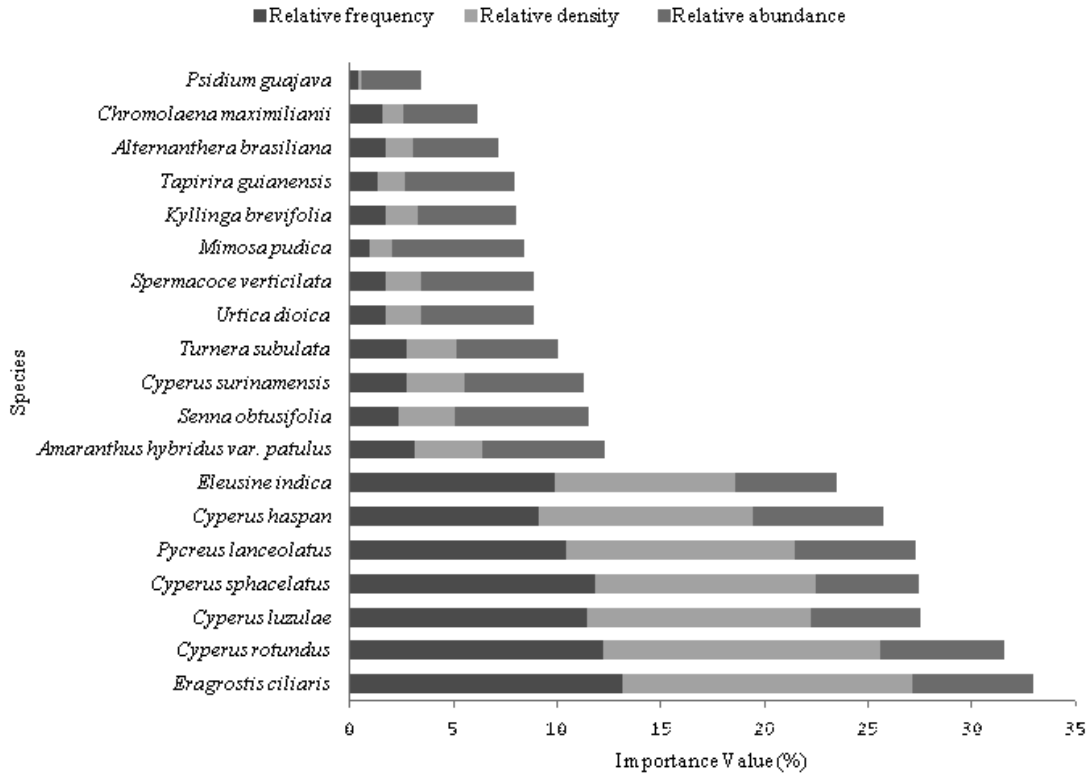
The Shannon diversity index was high (H' = 4.37 nats ind^{-1}), indicating significant weed species diversity. This value is considered higher than those reported by Dutra, Silva and Queiróz *et al*. (2004) in *Brachiaria humidicola* (Rendle) Schweick and *Brachiaria brizantha* (A.Rich.) Stapf pastures located in Pará State. This could be due to the diversity of seedlings recruited from seed

Tabela 2 - Phytosociological parameters of weed species in pastures, Maranhão State, Northeast Brazil

Species	N	RF%	RD%	RA%	IV
Eragrostis ciliaris	139	13.15	13.96	5.86	32.97
Cyperus rotundus	133	12.19	13.35	6.05	31.59
Cyperus luzulae	108	11.41	10.84	5.25	27.50
Cyperus sphacelatus	106	11.80	10.64	4.98	27.42
Pycreus lanceolatus	110	10.44	11.04	5.84	27.33
Cyperus haspan	103	9.09	10.34	6.28	25.72
Eleusine indica	87	9.86	8.73	4.89	23.49
Amaranthus hybridus var. patulus	33	3.09	3.31	5.91	12.32
Senna obtusifolia	27	2.32	2.71	6.45	11.48
Cyperus surinamensis	28	2.71	2.81	5.73	11.25
Turnera subulata	24	2.71	2.41	4.91	10.03
Urtica dioica	17	1.74	1.71	5.42	8.86
Spermacoce verticilata	17	1.74	1.71	5.42	8.86
Mimosa pudica	11	0.97	1.10	6.31	8.38
Kyllinga brevifolia	15	1.74	1.51	4.78	8.03
Tapirira guianensis	13	1.35	1.31	5.32	7.98
Alternanthera brasiliana	13	1.74	1.31	4.14	7.19
Chromolaena maximilianii	10	1.55	1.00	3.58	6.14
Psidium guajava	2	0.39	0.20	2.87	3.45

N = number of individuals; RF = Relative Frequency; RD = Relative Density; RA = Relative Abundance; IV = Importance Value

Figure 1 - Importance Value of the weed species recorded in pastures in Maranhão State, Northeast Brazil



bank or possible seed rain from neighborhood vegetation. Moreover, it is well known that weed species diversity increases with degraded pasture age (O'CONNOR, 2005).

Furthermore factors like forage productivity, soil disturbance by cattle grazing, soil fertility, and propagule supply affect weed abundance at pasture scales (TRACY *et al*., 2004).

The most important weed species (by Importance Value) in decreasing order were *Eragrostis ciliaris* (IV = 32.97), *Cyperus rotundus* (IV = 31.59), *Cyperus luzulae* (IV = 27.50), *Cyperus sphacelatus* (IV = 27.42), *Pycreus lanceolatus* (IV = 27.33), *Cyperus haspan* (IV = 25.72) and *Eleusine indica* (IV = 23.49). These species contributed with 65.34% of the IV (Table 2).

In general, the phytosociological parameters that contributed most to the high Importance Value (IV) among the species recorded in this study were Relative Frequency and Relative Density (Figure 1).

The most important weed species found in pastures in this study have in common high reproductive efficiency by means of prolific propagules production including seeds, stolons and rhizomes which together with other mechanisms such as dispersion, dormancy and longevity contribute to the formation of significant seed bank in the soil which becomes the major source of weeds in degraded pastures.

CONCLUSIONS

1. The weed flora in pastures in Olinda Nova Municipality, Maranhão State, Northeast Brazil is dominated by species of the Cyperaceae and Poaceae families;
2. The most important weed species in pastures, in decreasing order of Importance Value are *Eragrostis ciliaris*, *Cyperus rotundus*, *Cyperus luzulae*, *Cyperus sphacelatus*, *Pycreus lanceolatus* and *Eleusine indica.* These species must deserve higher attention in weed management programs;
3. Our results could lead to improved weed management strategies in pasture areas of livestock farming in Maranhão State, Northeast Brazil.

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