PLANTA DANINHA

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS

<http://www.sbcpd.org>

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

Article

Weeds Associated with Banana Crops in Magdalena Department, Colombia

Plantas Daninhas Associadas a Culturas de Banana no Departamento de Magdalena – Colômbia

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ABSTRACT - This study was conducted to determine the richness and composition of weed communities associated with banana plantations in Magdalena department, Colombia. Between September 2016 and May 2017, a total of 164 hectares were assessed over four agroecological zones (Alta, Media, Baja and Norte); in each zone, three representative farms were selected where, through zigzag paths, botanical collections were made in cultivated lots. Information on life cycle, growth habit and origin of each species was included. The floristic composition was represented by 204 species distributed among 143 genera and 54 families. Poaceae, with 31 species, was the family with the highest species richness, followed by Fabaceae (12) and Asteraceae (11). From the total species recorded, 113 are perennial (55%) and 91 are annual (45%); 141 species are herbaceous (68%), 38 are climbers (20%), and 25 are arboreal or shrubby (12%). Native species predominate over introduced species. The species richness does not differ significantly between the sampling zones, but the weed community composition does. The presence of common species reported as important weeds worldwide was recorded in the four zones. However, some species were recorded in only one of the zones, generating a differential composition pattern. Comparison with local inventories showed changes in the composition of the weed complex over time. The presence of various species not previously considered weeds in the banana crops of this region is highlighted.

Keywords: banana plantations, floristic composition, species richness, weed community.

RESUMO - Esta pesquisa foi realizada com o objetivo de determinar a riqueza e a composição das comunidades de plantas daninhas associadas às plantações de banana no departamento de Magdalena (Colômbia). Entre setembro de 2016 e maio de 2017, uma área total de 174 hectares foi avaliada em quatro zonas agroecológicas (Alta, Média, Baixa e Norte). Em cada área, foram selecionadas três fazendas representativas, realizando coletas botânicas em lotes cultivados. Foram incluídas informações sobre ciclos de vida, hábito de crescimento e origem de cada espécie registrada. A composição florística foi representada por 204 espécies, incluídas em 143 gêneros e 54 famílias. Poaceae, com 31 espécies, foi a família com maior riqueza específica, seguida por Fabaceae (12) e Asteraceae (11). Do total de espécies registradas, 113 são perenes (55%) e 91 anuais (45%); 141, ervas (70%); 38, videiras (18%); e 25, árvores ou arbustos (12%). As espécies nativas predominam sobre as introduzidas. Foi determinado que a riqueza de espécies não difere significativamente entre as quatro áreas produtoras, ao passo que a composição varia. A presença de espécies comuns relatadas como plantas daninhas de importância global foi registrada em todas as áreas, entretanto

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Received: December 7, 2018
Approved: April 25, 2019

Planta Daninha 2020; v38:e020217466

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Doi: 10.1590/S0100-83582020380100015

algumas delas foram registradas em apenas uma das zonas, gerando um padrão diferenciador de composição. Comparações com inventários locais mostraram mudanças na composição do complexo de plantas daninhas ao longo do tempo. É destacada a presença de várias espécies que não foram listadas como plantas daninhas na região.

Palavras-chave: bananeiras, composição florística, riqueza de espécies, comunidade de plantas daninhas.

INTRODUCTION

Weed interference is considered a limiting factor in banana production due ability to compete for essential resources with crops and they can become host to plague and pathogen (Moura Filho et al., 2015; López et al., 2014; Rivera et al., 2010; Obregón et al., 2008). Consequently, it is essential to define appropriate weed management strategies that guarantee adequate productivity.

In order to provide adequate forms of weed management, it is necessary to study their communities and a first stage is to identify the species present in the area, as well as those that are of significant importance. In this sense, floristic inventories are the first step to know the composition and estimate the richness of species in a community, basic measures that are used to represent diversity (Booth et al., 2003).

Floristic inventories also allow comparing the magnitude of diversity between two or more communities of different habitats, or the same habitat over time, or natural and anthropic environmental gradients (Campo and Duval, 2014). Based on the hypothesis that a more diverse weed community will be less competitive, the taxonomic diversity of weeds has been proposed as an indicator of the overall sustainability of a crop (Storkey and Neve, 2018). Likewise, determining the set of species, considering the influence of the spatial scale and environmental heterogeneity in the proportion of central species, have application to construct descriptive models of the successional trajectories in weed communities before changes in agricultural systems (Poggio, 2012).

It has been shown that the flora of agroecosystems undergoes changes in diversity, composition and abundance as a response to climatic variations, the crop cycle, edaphic factors and primarily to agricultural management practices (Zimdahl, 2013; Nichols et al., 2015). These changes may be expressed through the appearance of new species within the community, the disappearance of some preexisting species or the evolution of biotypes with a greater competitive capacity in response to the selection pressures exerted by the given agricultural practices (Pollnac et al., 2008; Ghersa and Ferraro, 2012).

Banana cultivation in Magdalena department was implemented since the late XIX century, has had in the last three decades important changes in their management practices, such as provision of irrigation systems and greater use of external inputs, among these, new varieties, fertilizers and pesticides (Viloria, 2008). These changes, added to the seasonal variations in rain season and temperature, including prolonged droughts or floods (MINAMBIENTE - Colombia, 2015), and the degradation of soils in these agricultural areas (IGAC, 2009), constitute factors that can determine changes in the weed communities associated with the crop.

Under these considerations, the objective of this study was to determine the richness and composition of the weed communities associated with banana crops in Magdalena department. Floristic inventories were carried out in four agroecological producing banana zones that have different soil-climatic characteristics, to answer the following questions: What is the weeds complex associated with banana crops in the department under current conditions? Does the richness of the weed community vary among the agroecological banana producing areas of the department? Is there a difference in the composition of the weed complex between the agro-ecological production zones? Local inventories (Carbonó and Cruz, 2005) were considered to compare and obtain information about changes in the weed complex over time.

This work provides updated and verifiable information to the extent of advances in plant systematics and attempts to contemplate possible variations of phytocenosis in the banana agroecosystem, information that may be useful when defining weed management operations.

MATERIALS AND METHODS

Study area

The study was conducted in banana plantations in Magdalena department, Colombia, encompassing a total cultivated area of 13,218 hectares, of which 92% is located in the municipalities of Ciénaga, Zona Bananera, Retén, Aracataca and Fundación. This area forms the well-known Magdalena banana zone on the foothills of Santa Marta's Sierra Nevada. Another important cropping area (8%) is located in the northern part of Santa Marta District, which are more recent and the majority (70%) are under organic production. This area is located between the mouths of the Guachaca and Don Diego rivers (AUGURA, 2018).

For field sampling, the area of the department cultivated in banana was divided into four zones namely, Baja, Media, Alta and Norte (Figure 1). The division or classification of these zones is given by differences in the climatic and edaphic characteristics they have, described by IGAC (2009), Aguirre et al. (2012), Vásquez and Macías (2017), and that are summarized in Table 1. A sampling size of 1.2% (164 ha) was estimated according to Spiegel (1988) described by Ramírez and Plaza (2015):

$$n = \frac{N * Z_{\alpha}^{2} * p * q}{d^{2} * (N-1) + Z_{\alpha}^{2} * p * q}$$

where n is the sample size, N represents 13,218 ha cultivated in the deparment, Z_{α}^{2} equals 2.58^2 with a confidence of 99%, p is the expected proportion (0.5), q equals 1 - p (in this case 1 - 0.5 = 0.5) and d^2 is the desired precision of 10%. The area to be sampled in each zone (nh) was estimated by a proportional allocation according to the area planted in each one (Nh) (Table 1). The following formula was used: $nh = (n * Nh)/N$

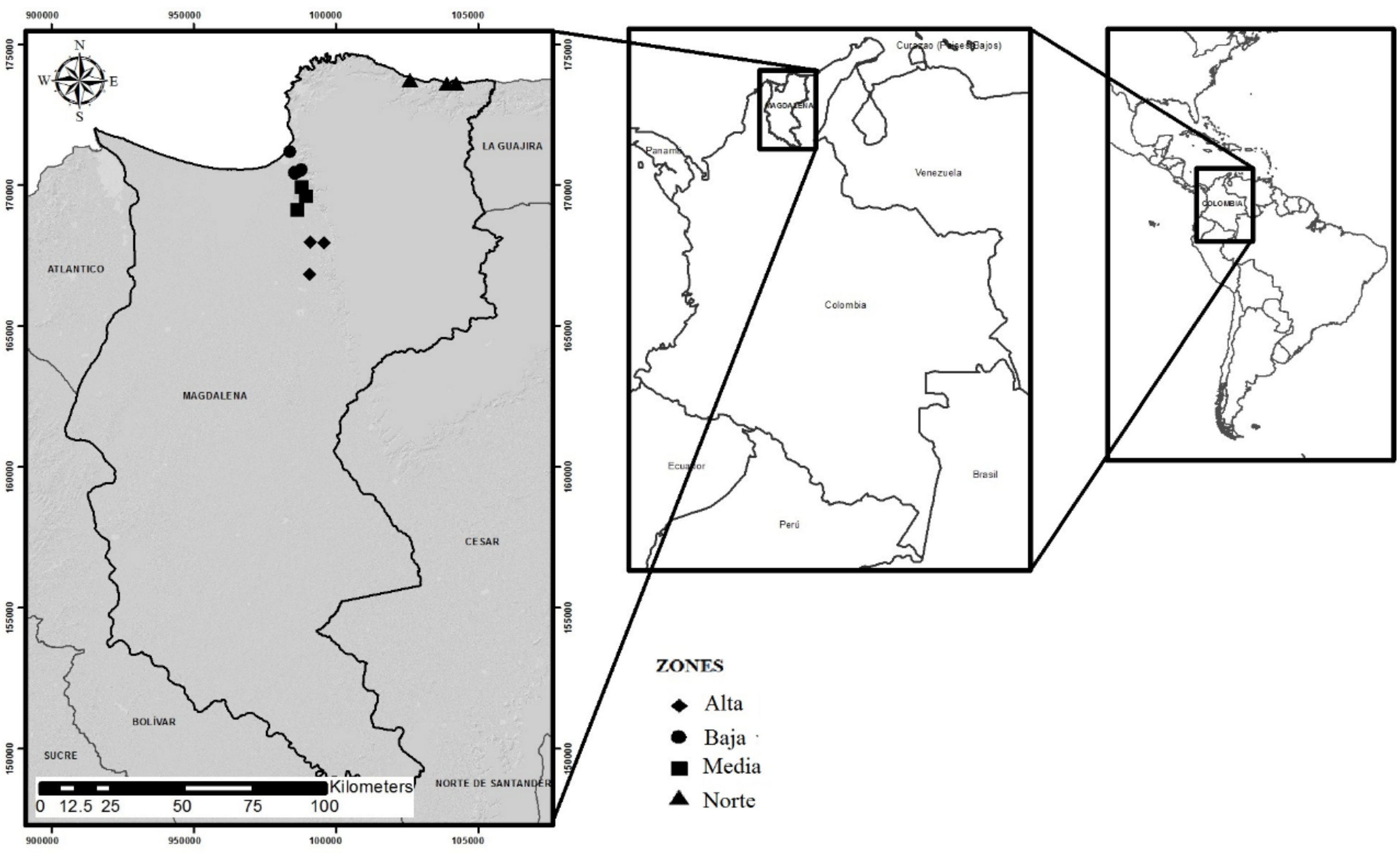

Figure 1 - Location of the study area.

Table 1 - Edaphoclimatic description of the zones and total area of study

Zone	Characteristics		Municipality/Sector	Farms	Cultivated area by zone (ha)	Estimated area (ha)
	Climate	Soil				
Norte	Warm dry, Altitude 20 m, R 1500 mm, PET 1739 mm, T 27 °C	pH 6.5, medium and coarse textures; high to moderate natural fertility	Santa Marta: Guachaca, Don Diego	Don Diego Linas 1 y 4 Caballos	1,100	14
Baja	Warm very dry, Altitude 24 m, R 500 mm, PET 1910 mm, T 30 °C	pH 8.6, medium to coarse texture; low to moderate fertility	Ciénaga: La Aguja, Costa Verde	Burdeos Margarita Rosa La Lola	1,200	15
Media	Warm dry, Altitude 30 m, R 800 mm, PET 1890 mm, T 27.5 °C	pH 7.1, fine to medium texture; limited by salts and sodium	Zona Bananera: Río Frío, Orihueca	Florida Chavela Josefina San Rafael	5,500	68
Alta	Warm dry, Altitude 53 m, R 1400 mm, PET 1500 mm, T 28.4 °C	pH 6.3, fine to medium texture; limited by salts and sodium	Zona Bananera: Guacamayal, Sevilla, Tucurinca	Crisol Carmen Envidia Esmeralda Fortuna	5,418	67
Total area estimated and sampled (ha)						164

R = mean annual rainfall; PET = Potential evapotranspiration; T = temperature.

Data collection and analysis techniques

In the four zones, representative commercial farms were selected and in each of them lots in production were located. The general inventory of weeds was carried out since September 2016 to May 2017 from twenty-four samplings (six per zone). Zigzag routes were carried out in lots of each farm, covering the estimated sampling area for each zone (Table 1). The richness and composition of the weed communities, as represented by the number of species, genera and families.

Collected samples were processed according with the established standards for preparing exsiccates, and they were deposited in the UTMC Herbarium of University of Magdalena. A taxonomic identification was performed using comparisons with the herbarium's collection, consultation of the nomenclatural types available online, specialized bibliography and taxonomic keys and specialists who were consulted for some groups. The APG IV classification system was followed (Angiosperm Phylogeny Group 2016). The species names were verified by consulting The Plant List (http://www.theplantlist.org/). Information about the life cycle, growth habit and origin of each species was obtained through bibliographic consultation.

Differences in the weed species richness among the sampled farms and zones was determined by one-way analysis of variance (ANOVA), by first testing the assumptions of randomness (Durbin-Watson test) and the normality of the ANOVA residuals (Shapiro-Wilks test) as well as the homogeneity of variances (Bartlett's test). All the assumptions were met. To evaluate the similarity of the floristic composition among the zones according to the presence and absence of weed species, a cluster analysis was performed using the Jaccard coefficient with the unweighted pair group method with arithmetic mean (UPGMA) because it presented the best adjustment as defined by its cophenetic distance. The evaluation of statistical differences among zones was carried out by means of a one-way Multivariate Variance Analysis - npMANOVA, based on permutations, on the Jaccard distance of the non-redundant species (61 species) and on 1000 permutations, where each variable corresponded to the presence-absence data of the species and the factor to the zones. The pattern of differences between the zones and their farms was visualized with a Non-Metric Multidimensional Scaling (nMDS), also based on the Jaccard distance and the level of adjustment established by the "stress" statistic. All statistical analyses were performed in R version 3.4.3.

RESULTS AND DISCUSSION

Richness and composition of the weed community

A total of 204 weed species belonging to 143 genera and 54 families were identified. No significant differences ($p>0.05$) in species richness were found among the four study zones. In the Norte zone there were 89 species grouped in 38 families and 75 genera; in the Baja Zone

121 species of 46 families and 98 genera; in the Media Zone 104 species of 38 families and 83 genera, and in the Alta zone 117 species of 37 families and 98 genera (Table 2).

Table 2 - Weed species associated with banana crops in Magdalena department, Colombia

Family	Species	LC	Ha	Ori	BZ	MZ	AZ	NZ
ACANTHACEAE	*Blechum pyramidatum* (Lam.) Urb.	P	H	N		x	x	x
	Justicia carthaginensis Jacq.	P	H	N			x	
	Justicia comata (L.) Lam.	P	H	N	x	x	x	
	Ruellia ciliatiflora Hook	P	H	N				x
	Ruellia tuberosa L.	P	H	N		x	x	x
	Thunbergia fragrans Roxb.	P	C	I	x			
	Trichanthera gigantea (Bonpl.) Nees	P	Ar	N	x			
ALISMATACEAE	*Limnocharis flava* (L.) Buchenau	P	H	I			x	
AMARANTHACEAE	*Achyranthes aspera* L.	A	H	I		x	x	
	Alternanthera albotomentosa Suess.	A	H	N	x		x	x
	Alternanthera flavescens Kunth	P	H	N			x	
	Amaranthus dubius Mart. ex Thell.	A	H	N	x	x	x	
	Amaranthus spinosus L.	A	H	N		x		
	Amaranthus viridis L	A	H	I	x	x	x	x
	Chamissoa altissima (Jacq.) Kunth	A	H	N	x		x	
	Cyathula prostrata (L.) Blume	P	H	I			x	
	Gomphrena serrata L.	A	H	N			x	
AMARYLLIDACEAE	*Hymenocallis littoralis* (Jacq.) Salisb.	P	H	N	x			
ANACARDIACEAE	*Spondias mombin* L.	P	Ar	N	x			
APOCYNACEAE	*Cynanchum racemosum* (Jacq.) Jacq.	A	H	N				x
	Marsdenia macrophylla (Humb. & Bonpl. ex Schult.) E. Fourn.	P	L	N	x			x
	Mesechites trifidus (Jacq.) Müll. Arg.	P	C	N	x		x	x
	Rauvolfia littoralis Rusby	P	Ar	N	x			
	Rauvolfia tetraphylla L.	P	Ar	N	x	x		
	Rauvolfia viridis Willd. ex Roem. & Schult.	P	Ar	N	x			
	Sarcostemma clausum (Jacq.) Schult.	P	C	I	x			
	Sarcostemma glaucum Kunth	A	C	I	x	x		
ARACEAE	*Caladium bicolor* (Aiton) Vent.	P	H	I		x	x	
	Monstera obliqua Miq.	P	C	N	x	x		x
	Philodendron hederaceum (Jacq.) Schott	P	C	N		x	x	
	Syngonium podophyllum Schott	P	C	I	x	x	x	x
	Xanthosoma sagittifolium (L.) Schott	P	C	N		x		x
ARISTOLOCHIACEAE	*Aristolochia anguicida* Jacq.	P	C	N		x		x
ASPLENIACEAE	*Asplenium cristatum* Brack.	P	F	N				x
ASTERACEAE	*Cyanthillium cinereum* (L.) H. Rob.	P	H	I	x	x	x	x
	Eclipta prostrata (L.) L.	A	H	I		x	x	
	Eleutheranthera ruderalis (Sw.) Sch. Bip.	A	H	N	x	x		x
	Emilia coccinea (Sims) G. Don	A	H	I				x
	Emilia sonchifolia (L.) DC.	A	H	I				x
	Erechtites hieracifolia Raf.	A	H	N	x			
	Erigeron bonariensis L.	A	H	N			x	
	Melampodium divaricatum (Rich.) DC.	A	H	N	x		x	x
	Mikania micrantha Kunth	P	C	N				x
	Spilanthes urens Jacq.	A	H	N	x	x	x	
	Tridax procumbens L.	A	H	N	x		x	
BIGNONIACEAE	*Adenocalymma inundatum* Mart. ex DC.	P	L	N			x	
	Dolichandra unguis-cati (L.) L.G. Lohmann	P	L	N	x	x		
BLECHNACEAE	*Salpichlaena* sp.	P	F	N	x			
BORAGINACEAE	*Cordia alba* (Jacq.) Roem. & Schult.	P	Ar	N	x		x	
	Heliotropium angiospermum Murray	P	H	N	x	x	x	
CAMPANULACEAE	*Hippobroma longiflora* (L.) G. Don	P	H	N	x			
CARYOPHYLLACEAE	*Drymaria cordata* (L.) Willd. Ex Schult.	A	H	N				x

To be continued...

Table 2, cont.

Family	Species	LC	Ha	Ori	BZ	MZ	AZ	NZ
CLEOMACEAE	*Cleome aculeata* L.	A	H	U		x		
COMMELINACEAE	*Callisia cordifolia* (Sw.) Andiers. & Woodson	A	H	N	x	x	x	x
	Callisia monandra (Sw.) Schult. & Schult. f.	P	H	N				x
	Callisia repens (Jacq.) L.	P	H	N	x	x		
	Commelina erecta L.	P	H	N	x	x	x	x
	Murdannia nudiflora (L.) Brenan	A	H	I	x	x	x	x
	Tripogandra multiflora (Sw.) Raf.	P	H	N	x	x	x	x
CONVOLVULACEAE	*Evolvulus nummularius* (L.) L.	P	H	N	x	x	x	
	Ipomoea incarnata (Vahl) Choisy	A	L	N		x		
	Ipomoea meyeri (Spreng.) G. Don	A	C	N			x	
	Merremia umbellata (L.) Hallier f.	P	C	N		x	x	x
COSTACEAE	*Cheilocostus speciosus* (J. Koenig) C.D. Specht	P	C	N	x			
CUCURBITACEAE	*Cayaponia glandulosa* (Poepp. & Endl.) Cogn.	P	C	N	x	x	x	x
	Cayaponia racemosa (Mill.) Cogn.	P	C	N		x		
	Lagenaria siceraria (Molina) Standl.	A	C	I	x			
	Melothria pendula L	A	C	N	x	x	x	x
	Momordica charantia L.	A	C	I	x	x	x	x
	Rytidostylis carthagenensis (Jacq.) Kuntze	A	C	N	x	x	x	
CYPERACEAE	*Cyperus compressus* L.	A	H	N			x	x
	Cyperus hermaphroditus (Jacq.) Standl.	P	H	N	x	x	x	x
	Cyperus iria L.	A	H	I		x		
	Cyperus laxus Lam.	A	H	N				x
	Cyperus luzulae (L.) Rottb. ex Retz.	P	H	N				x
	Cyperus odoratus L.	A	H	N	x	x	x	x
	Cyperus rotundus L.	P	H	I	x	x	x	
	Cyperus surinamensis Rottb.	A	H	N	x			
	Fimbristylis dichotoma (L.) Vahl	A	H	N			x	
	Fimbristylis littoralis Gaudich.	A	H	N		x	x	
	Kyllinga pumila Michx.	A	H	N	x	x	x	x
EUPHORBIACEAE	*Acalypha alopecuroidea* Jacq.	A	H	N	x	x	x	x
	Acalypha schiedeana Schltdl.	P	Ar	N	x			
	Astraea lobata (L.) Klotzsch	A	H	N	x	x	x	x
	Croton hirtus L'Hér	P	H	U	x			
	Euphorbia densiflora (Klotzsch & Garcke) Klotzsch	A	H	N		x		
	Euphorbia dioeca Kunth	A	H	N			x	
	Euphorbia hirta L.	A	H	N	x	x	x	x
	Euphorbia hypericifolia L.	A	H	I	x	x	x	x
FABACEAE	*Alysicarpus vaginalis* (L.) DC.	P	H	I	x		x	
	Cassia grandis L. f.	P	Ar	N			x	
	Centrosema plumieri (Turpin ex Pers.) Benth.	P	C	N			x	x
	Chamaecrista nictitans (L.) Moench	P	H	N			x	
	Crotalaria incana L.	P	H	U			x	
	Desmodium incanum (Sw.) DC.	P	H	N	x	x	x	
	Desmodium scorpiurus (Sw.) Poir.	P	H	N	x	x		
	Dioclea virgata (Rich.) Amshoff	P	L	N				x
	Senegalia polyphylla (DC.) Britton	P	Ar	I	x			
	Senna obtusifolia (L.) H.S. Irwin & Barneby	A	H	N			x	
	Senna occidentalis (L.) Link	A	H	I		x		
	Teramnus volubilis Sw.	P	C	N	x	x	x	x
LINDERNIACEAE	*Lindernia crustacea* (L.) F. Muell.	A	H	N	x	x	x	x
LOGANIACEAE	*Spigelia anthelmia* L.	A	H	N	x	x	x	x
LYGODIACEAE	*Lygodium venustum* Sw.	P	C	N	x			
MALPIGHIACEAE	*Stigmaphyllon dichotomum* (L.) Griseb.	P	C	N	x		x	
MALVACEAE	*Corchorus aestuans* L.	A	H	U		x		
	Corchorus orinocensis Kunth	A	H	N	x	x	x	x
	Melochia parvifolia Kunth	P	Ar	N		x	x	
	Melochia pyramidata L.	A	H	N				x
	Sida acuta Burm. f.	P	H	N		x	x	x
	Sida hyssopifolia C. Presl	P	Ar	N		x		
	Sida rhombifolia L.	P	H	N	x			

To be continued...

Table 2, cont.

Family	Species	LC	Ha	Ori	BZ	MZ	AZ	NZ
MELASTOMATACEAE	*Clidemia quinquenervia* (Mill.) Almeda	P	Ar	N				x
MENISPERMACEAE	*Cissampelos pareira* L.	P	C	N	x			
	Odontocarya tamoides (DC.) Miers	P	C	N	x	x	x	x
MORACEAE	Moraceae sp.	P	Ar	U	x			
	Maclura tinctoria (L.) D. Don ex Steud.	P	Ar	N		x		x
MYRTACEAE	*Syzygium jambos* (L.) Alston	P	Ar	I	x			
NYCTAGINACEAE	*Boerhavia erecta* L.	A	H	N		x	x	x
	Mirabilis jalapa L.	A	H	N			x	
ONAGRACEAE	*Ludwigia erecta* (L.) H. Hara	A	H	N	x	x	x	x
	Ludwigia hyssopifolia (G. Don) Exell	A	H	N	x			
PHYLLANTHACEAE	*Phyllanthus niruri* L.	A	H	I	x	x	x	x
PHYTOLACCACEAE	*Microtea debilis* Sw.	A	H	I	x	x	x	x
	Rivina humilis L.	P	H	N	x	x		x
PIPERACEAE	*Peperomia pellucida* (L.) Kunth	A	H	N	x	x		x
	Piper dilatatum L. C. Rich	P	Ar	N			x	x
	Piper marginatum Jacq.	P	Ar	N		x	x	
	Piper peltatum L.	P	Ar	N	x	x	x	x
	Piper reticulatum L.	P	Ar	N			x	
	Piper tuberculatum Jacq.	P	Ar	N	x	x	x	x
	Piper umbellatum L.	P	Ar	N			x	
PLANTAGINACEAE	*Mecardonia procumbens* (Mill.) Small	A	H	N	x	x	x	
	Micranthemum umbrosum (J.F. Gmel.) S.F. Blake	A	H	I				x
	Scoparia dulcis L.	P	H	N	x		x	
	Stemodia verticillata (Mill.) Hassl.	P	H	N		x	x	
POACEAE	*Axonopus compressus* (Sw.) P. Beauv.	P	H	N		x	x	x
	Bothriochloa pertusa (L.) A. Camus	A	H	I			x	
	Brachiaria distachya (L.) Stapf.	P	H	I	x			x
	Brachiaria fasciculata (Sw.) Parodi	A	H	N	x	x	x	
	Cynodon dactylon (L.) Pers.	P	H	I			x	
	Cynodon nlemfuensis Vanderyst	P	H	I	x			
	Dactyloctenium aegyptium (L.) Willd.	A	H	I			x	
	Digitaria bicornis (Lam.) Roem. & Schult.	A	H	I	x		x	x
	Digitaria ciliaris (Retz.) Koeler	A	H	N		x	x	x
	Digitaria insularis (L.) Fedde	P	H	N	x			
	Digitaria sanguinalis (L.) Scop.	A	H	I	x			
	Echinochloa colona (L.) Link	A	H	I	x	x	x	x
	Echinochloa crus-pavonis (Kunth) Schult.	A	H	N		x		
	Echinochloa polystachya (Kunth) Hitchc.	P	H	N			x	x
	Eleusine indica (L.) Gaertn.	A	H	I	x	x	x	x
	Eragrostis amabilis (L.) Wight & Arn.	A	H	I		x		
	Eragrostis ciliaris (L.) R. Br.	A	H	I		x		
	Ixophorus unisetus (J. Presl) Schltdl.	P	H	N			x	
	Leptochloa mucronata (Michx.) Kunth	A	H	N	x	x	x	x
	Leptochloa virgata (L.) P. Beauv.	P	H	N	x			
	Oplismenus burmannii (Retz.) P. Beauv.	A	H	N			x	x
	Panicum antidotale Retz.	P	H	I	x			
	Panicum maximum Jacq.	P	H	I	x			
	Panicum trichoides Sw.	A	H	N	x	x	x	x
	Paspalum conjugatum P.J. Bergius	P	H	N	x	x	x	x
	Paspalum microstachyum J. Presl	A	H	N		x		
	Paspalum paniculatum L.	P	H	N	x		x	
	Rottboellia cochinchinensis (Lour.) Clayton	A	H	I	x		x	
	Setaria parviflora (Poir.) M. Kerguelen	P	H	N	x			
	Sporobolus indicus (L.) R. Br.	P	H	N	x			
	Steinchisma laxum (Sw.) Zuloaga	P	H	N	x		x	x
PONTEDERIACEAE	*Heteranthera reniformis* Ruiz & Pav.	A	H	N				x

To be continued...

Table 2, cont.

Family	Species	LC	Ha	Ori	BZ	MZ	AZ	NZ
PORTULACACEAE	*Portulaca oleracea* L.	A	H	N	x	x	x	x
PTERIDACEAE	*Adiantum petiolatum Desv.*	P	H	N				x
	Adiantum tetraphyllum Humb. & Bonpl. ex Willd.	P	F	N		x	x	
	Pityrogramma calomelanos (L.) Link	P	F	N	x	x	x	x
RUBIACEAE	*Oldenlandia corymbosa* L.	A	H	I	x	x	x	x
	Oldenlandia lancifolia (Schumach.) DC.	A	H	I		x		
	Oldenlandia umbellata L.	P	H	I				x
	Spermacoce confusa Rendle	A	H	N	x			
	Spermacoce exilis (L.O. Williams) C.D. Adams	A	H	N		x	x	x
	Spermacoce remota Lam.	P	H	N	x	x	x	x
	Spermacoce tenuior L.	A	H	N	x			
	Mitracarpus hirtus (L.) DC.	A	H	N	x			
SAPINDACEAE	*Serjania mexicana* (L.) Willd.	P	L	N	x	x	x	
	Paullinia macrophylla Kunth	A	L	N	x	x		
	Paullinia nitida Kunth	P	L	N	x			
SCROPHULARIACEAE	*Capraria biflora* L.	P	Ar	N	x			
SELAGINELLACEAE	*Selaginella horizontalis* (C. Presl) *Spring*	P	F	N	x	x	x	x
SMILACACEAE	*Smilax spinosa* Mill.	P	C	N	x			
SOLANACEAE	*Capsicum annuum* L.	P	H	N			x	
	Cestrum scandens Vahl	P	L	N	x	x	x	
	Lycianthes lenta (Cav.) Bitter	P	L	N		x		
	Physalis angulata L.	A	H	N	x			
	Solanum bicolor Willd.	P	H	N			x	
	Solanum jamaicense Mill.	P	H	N				x
	Solanum scabrum Mill.	P	C	I		x	x	
TALINACEAE	*Talinum paniculatum* (Jacq.) Gaertn.	A	H	N	x		x	
THELYPTERIDACEAE	*Christella dentata* (Forssk.) Brownsey & Jermy	P	F	I	x	x	x	x
URTICACEAE	*Cecropia peltata* L.	P	Ar	N	x	x	x	
	Laportea aestuans (L.) Chew	A	H	U	x	x	x	x
	Phenax sonneratii (Poir.) Wedd.	A	Ar	N	x	x	x	x
	Pilea fendleri Killip	A	H	N		x		
	Pilea microphylla (L.) Liebm.	A	H	N	x	x	x	x
VERBENACEAE	*Priva lappulacea* (L.) Pers.	A	H	N	x	x		x
	Lantana camara L.	P	Ar	N	x			
VIOLACEAE	*Hybanthus attenuatus* (Humb. & Bonpl. ex Schult.) Schulze-Menz	A	H	N	x	x	x	x
VITACEAE	*Cissus verticillata* (L.) Nicolson & C.E. Jarvis	P	C	N	x	x	x	
Total number of species per zone					121	104	116	89

LC: life cycle; Hab: growth habit: Ori: origin; A: annual; P: perennial; Ar: arboreal; C: creeping; H: herbaceous; F: fern; L: liana; N: native; I: introduced; U: unknown; BZ: Baja Zone; MZ: Media Zone; UZ: Alta Zone; NZ: Norte Zone. x indicates the presence of the species per zone.

The families with the highest species richness were Poaceae (31), Fabaceae (12), Asteraceae (11), Cyperaceae (11) and Amaranthaceae (9), followed by Apocynaceae, Euphorbiaceae and Rubiaceae, with 8 species each. In all, 15 families encompass 143 species, which represent 70% of the total recorded species; the remaining species were grouped into 39 different families. The genera with the highest species richness were *Cyperus* (Cyperaceae), with 8 species; *Piper* (Piperaceae), with 6; and *Euphorbia* (Euphorbiaceae), *Digitaria* (Poaceae) and *Spermacoce* (Rubiaceae), with four species each. Nine genera had three species each, and the remaining genera are represented by one or two species, with 72% of the total recorded species concentrated in these genera.

The number of weed species recorded in this study coincide with those reported by Carbonó and Cruz (2005), who list 204 species belonging to 50 families. Likewise, there is agreement in both works when highlight the families Poaceae, Fabaceae, Asteraceae and Cyperaceae, as those of greater specific richness. Other studies of weed communities on banana crops in Brazil

(Lanza et al., 2017, Moura Filho et al., 2015), also report the Poaceae family as having the highest specific richness.

The multivariate analysis (UPGMA) showed that the study areas are associated in three groups according to the similarity in the floristic composition. A first group consists of the Alta and Media zones, which share the greatest number of species. The Norte zone forms the second group, and the Baja zone is the third group. The third group shared a smaller number of species with the others, observing a greater dissimilarity with the first group (Figure 2).

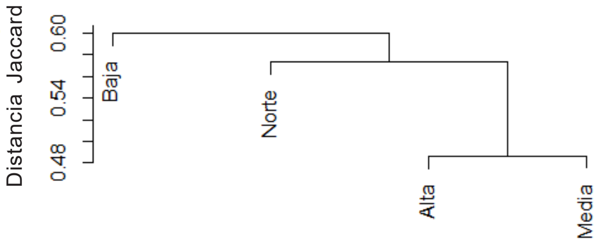

Figure 2 - Grouping of the study zones based on the similarities of the weed communities. UPGMA clustering method, Jaccard similarity coefficient and cophenetic distance: 0.85.

The similarity or dissimilarity in the composition of weed community between the zones are related to the edaphoclimatic characteristics prevailing in each one of these. In the Alta and Media zones, which were the most similar, predominantly fine to medium-textured soils, strongly acidic to neutral and limited by salts and sodium. The rainfall, averages from 800 to 1,400 mm, also presents similar periods of rain and drought. The Norte zone (second group), although it has certain soil conditions (acidic to neutral pH, medium textures) similar to those given in the Alta and Media zones, differs by presenting significant rainfall most of the year, with an annual average 1,500 mm and a short dry season. The Baja zone (coastal zone), the one with the least similarity, is characterized by very different soils with alkaline pH and thicker textures, and because it is an area with less rainfall (around of 500 mm).

According to it described above, we can infer that the characteristics of the soils and climate factors (especially variations in the rainfall regime), present in the agroecological zones of the banana region in Magdalena, affect the composition of the community of weeds associated with this crop. Similar results were found by Pizano et al. (2014), who commented that the floristic composition varies over environmental gradients in tropical dry forest environments in the Colombian Caribbean. It also agrees with Poggio (2012), who argues that climate factors, especially variations in rainfall and temperatures, affect the composition and abundance of plant communities. Regarding the edaphic factors, a preference of some weeds for different soil textures and pH values has been observed (Tanaka et al., 2010).

The npMANOVA analysis indicated that there were significant differences (PseudoF = 1.48, g.l. = 3, 8, p value = 0.004) between the zones in terms of floristic composition. The nMDS analysis, allows visualizing a gradient in the distribution of the weed species for the different zones along the first axis (Dim 1). To the right of the (Figure 3A) there is a clear separation or difference of the Baja zone with respect to the others. In the center, the total overlap of the Media and Alta zone is displayed, which indicates greater similarity in the composition between these two zones. On the other hand, the Norte and Alta zones with partial overlap, have a similarity in the composition, although less. Differences in the composition between the farms of each zone were also evident. The farms of the Norte zone presented the biggest dissimilarity (greater distance between centroids), followed by those located in the Alta and Baja zone; whereas, the farms of the Media zone (less distance between centroids) presented a greater similarity (Figure 3B). In this sense, there is a variability in the composition of the weed community in the farms, that generates a differentiating pattern similar to that registered when comparing only the zones. This indicates that there are species or groups of species that characterize the zones and farms.

The species that generate a differentiating pattern in the Norte zone are *Ruellia ciliatiflora*, *Oplismenus burmannii* and *Maclura tinctoria*. The most characteristic species of Baja zone are *Stigmaphyllon dichotomum*, *Paullinia macrophylla*, *Alysicarpus vaginalis* and *Trichanthera gigantea*. Those characterize to the Alta zone *Astraea lobata*, *Serjania mexicana*, *Paspalum conjugatum* and *Heliotropium angiospermum*. On the other hand, weeds from the Media zone were the most common in the whole study.

According to the presence in the four zones, 43 species were recognized as common weeds. These represent 21% of the total registered, among these highlight, *Callisia cordifolia*,

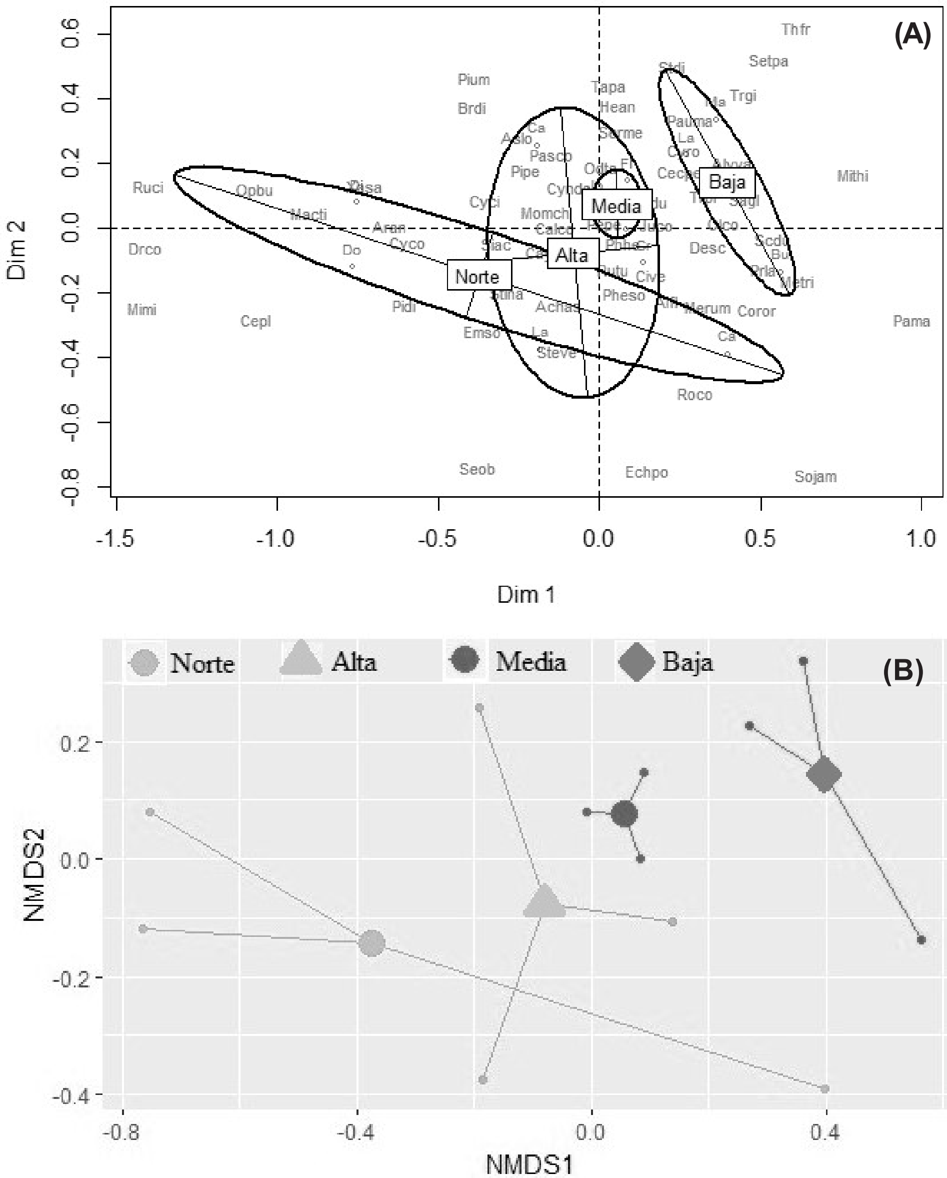

Figure 3 - NDMS Ordination of filtered weed species (61 species that best characterize the zones) (A) and their farms (B). In adjustment defined by the "stress" was 0.15 (15%).

Commelina erecta, *Cyperus odoratus*, *Echinochloa colona*, *Euphorbia hirta*, *Laportea aestuans*, *Lindernia crustacea*, *Melothria pendula*, *Murdannia nudiflora*, *Panicum trichoides*, *Phyllanthus niruri*, *Piper tuberculatum* and *Teramnus volubilis*, for their presence in more than 70% of the lots sampled (Table 2).

The set of species of a community is the result of the filtering of species of the regional flora, which it is determined by the restrictions imposed by the abiotic environment, the limitations in the dispersion of the species and the biotic interactions, whose effect varies with the spatial and temporal scales (Poggio, 2012). Agricultural dynamics and the changes associated with the structure of small-scale habitat are pointed out as the main abiotic factors that affect the composition and distribution of weed species in the landscape (Nagy et al., 2017).

In this sense, the agricultural dynamic in the Magdalena banana production systems is another factor that would be related to the composition of weed communities and distribution in the landscape. When comparing the current inventory with the one made by Carbonó and Cruz (2005), about 50% similarity was observed in the composition of the flora; 102 species registered at present did not appear in the previous inventory, and 93 of the previous one, were not found in the present. This finding allows us to infer that there has been a change in the composition of weed species associated with the banana crop over the last decade.

A change to highlight in the study area is the presence of *Syngonium podophyllum*, *Erigeron bonariensis* and several species of the genus *Piper* that did not appear as weeds associated with the crop in the region. These weeds are characterized by higher aggregated populations or patches in several farms and because they are recognized by field workers as difficult to control, given that they do not respond to the control methods used to combat them, such as mechanical and chemical control.

This behavior exhibited by some populations of weeds, is directly related to evolutionary mechanisms in response to intense selection pressures derived from agricultural practices and control methods used to combat them (Neve et al., 2009), thus, these are factors that determine the characteristics and composition of plant communities associated with small-scale crops (Cardenal Rubio et al., 2016).

Description by life cycle, growth habit and origin

Of the total weed community, 113 species are perennial (55%) and 91 are annual (45%). According to the growth habit, 141 species are herbaceous (69%), 38 are climbers (19%), and 25 are arboreal or shrubby (12%). When considering their origin, 154 native species (75%), 44 introduced species (22%) and six species of unknown origin (3%) were identified. These proportions are similar in the communities of each of the zones.

The higher proportion of perennial species may be related to the microclimatic conditions inside banana plantations, with little soil disturbance after the crop is established, and the type of weed control, such as chemical and mechanical cutting (with scythes). These factors cause some populations life cycles to change from annual to perennial and their reproductive strategies and growth habits to change or alternate (Aragón, 2014; Plaza, 2012). The ability of perennial species to produce seeds and vegetative propagules such as rhizomes, stolons, tubers and bulbs makes this type of weed very competitive in farming systems. In addition, by eliminating aerial vegetation, the underground growth points are stimulated, contributing to greater and constant weed propagation (Talaka and Rajab, 2013). These functional traits are present in Commelinaceae (Nisensohn et al., 2011) and Cyperaceae (Heinzen et al., 2010) families, increasing their competitive ability, explaining why species such as *Commelina erecta* and *Cyperus odoratus* are the most frequently found and disseminated weeds in banana plantations (Table 2).

Species of the Commelinaceae family are considered some of the most common and problematic weeds in banana and other crops (Isaac and Brathwaite, 2007). These are referenced as hosts of viral diseases and nematodes in banana and plantain fields (Rivera et al., 2010; Guzmán, 2011). They are also recognized as hosts of *Ralstonia solanacearum* in plantain and banana fields in Colombia (Obregón et al., 2008), so we must prioritize in the management of weeds of this family in Magdalena plantations.

Although the level of damage from creeping weeds in the study area is unknown, they deserve special attention, since there are records of the harmfulness of some of these weeds in banana crops. *Syngonium podophyllum*, *Cayaponia glandulosa*, *Melothria pendula*, *Momordica charantia* and *Odontocarya tamoides* highlight for their presence in the four sampling zones and because they are recognized as weeds that are difficult for field workers to control. In particular, *S. podophyllum*, which is characterized by an adequate adaptation to conditions of semi-penumbra and rapid growth (Agüero et al., 2008) and *M. pendula*, host of the cucumber mosaic virus (CMV) or banana mosaic virus (BMV) that affects the crop (López et al., 2014).

The composition of the weed communities associated with the banana plantations of the Magdalena is heterogeneous, with differences in floristic composition, represented by 204 species belonging to 143 genera and 54 families. The richest families were Poaceae, Fabaceae and Asteraceae. The observed richness is similar among zones with different edaphoclimatic conditions, and compared to a previous inventory, this richness has been maintained over the last decade, whereas the composition varies, because a change or succession in the weed species associated with banana crops was observed. In general, it was characterized a large number of herbs and a greater proportion of perennial weeds than the annual life cycle. Native or naturalized species, characteristics of tropical regions, predominate over those introduced. *Syngonium podophyllum* (Araceae), *Erigeron bonariensis* (Asteraceae), *Commelina erecta*, *Murdannia nudiflora*

(Commelinaceae), *Cyperus odoratus* (Cyperaceae), *Echinochloa colona* and *Eleusine indica* (Poaceae) highlight for their broad distribution in the plantations and for their difficult control.

ACKNOWLEDGMENTS

We thank AUGURA, particularly engineer Helena Bornecelly, the research students in Weed Science and the Vice-Chancellor of Research at the University of Magdalena and the anonymous reviewers for their valuable contributions.

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