Diversity of the arvense flora present in plots of small farmers, planned for polyculture in five municipalities of Boyacá

Diversidad de la flora arvense presente en parcelas de pequeños agricultores, previstas para policultivos en cinco municipios de Boyacá

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Abstract

Introduction— The most critical impact of weeds is the negative effect on cultivated plants exerted through competition for limited resources and allelopathies. Studies have demonstrated the dominance of weeds in crops and have established ecological methods for good integrated management.

Objective— To characterize the diversity of weed species in 60 smallholder farms in five municipalities of Boyacá, planned for polycultures.

Methodology— The research was carried out in 60 farms in five municipalities of the Department: Aquitania, Belén, Garagoa, Panqueba and Soatá, in each one two plots of 0.5 ha were sampled where the weeds present were determined in two frames of 1m^2.

Results— The presence of 109 species of weeds located in 93 genera and 38 botanical families was observed, being the most representative Poaceae with 18 species, Asteraceae with 15 species and Fabaceae with 9. The families Amarantaceae Apiaceae, Lamiaceae, Oxalidaceae, Poligonaceae and Solanaceae were represented by 4 species. The farms were grouped into 3 or 4 groups in each municipality according to the biodiversity indicators of the weeds, while the municipalities formed three groups.

Conclusions— From the point of view of their agricultural importance, the species most frequently present in the municipalities were: P. clandestinum, Sonchus oleraceus L, Trifolium repens and Rumex crispus. In general, species richness at the farm level was low, equity medium and dominance high, while at the municipal level were observed high species richness, medium indicators of diversity and equity and low dominance

Keywords— Competition; yield; productivity; agroecosystem; soil conservation; species richness

Resumen

Introducción— El impacto más crítico de las arvenses es el efecto negativo sobre las plantas cultivadas ejercido a través de la competencia por recursos limitados y las alelopatías.

Objetivo-. Caracterizar la diversidad de especies de arvenses en 60 fincas de pequeños agricultores de cinco municipios de Boyacá previstos para policultivos.

Metodología— La investigación se desarrolló en 60 fincas de cinco municipios del Departamento: Aquitania, Belén, Garagoa, Panqueba y Soatá, en cada una se muestrearon dos parcelas de 0,5 ha donde se determinó en dos marcos de 1m^2 las arvenses presentes.

Resultados— Se observó la presencia de 109 especies de arvenses ubicadas en 93 géneros y en 38 familias botánicas, siendo las más representativas Poaceae con 18 especies, Asteraceae con 15 especies y Fabaceae con 9. Las familias Amarantaceae Apiaceae, Lamiaceae, Oxalidaceae, Poligonaceae y Solanaceae estuvieron representadas por 4 especies. Las fincas se agruparon en 3 o 4 grupos en cada municipio de acuerdo a los indicadores de biodiversidad de las arvenses, mientras que los municipios formaron tres grupos.

Conclusiones— Desde el punto de vista de su importancia agrícola las especies que con más frecuencia estuvieron presentes en los municipios fueron: P. clandestinum, Sonchus oleraceus, Trifolium repens y Rumex crispus. En general la riqueza de especies a nivel de finca fue baja, la equidad media y la dominancia alta, mientras que a nivel municipal se apreció una alta riqueza de especies, indicadores medios de diversidad y equidad, y baja dominancia.

Palabras clave— Competencia; rendimiento; productividad; agroecosistema; conservación de suelo; riqueza de especies

I. Introduction

In agroecosystems, weeds contribute positively and negatively to ecological and conservation processes, whether soil, environmental or crop. In turn, they have great interaction in the competition for resources such as nutrients, water, space and light. Weeds are defined as those plants that cause more damage than benefits; those plant species that have the ability to compete for limiting resources such as soil, water and light with cultivated plants [1].

Weeds are a special form of vegetation that is highly successful in agricultural environments, since they are plant populations that grow in environments disturbed by humans without having been planted. From an ecological point of view, vines can be placed among the pioneers of secondary succession. In the agroecosystem, the most critical impact of weeds is the negative effect on cultivated plants exerted through competition for limited resources and allelopathies [2].

Over time, these plants have retained a bad reputation due to the characteristics and interspecific relationships generated with the organisms that inhabit the crops. Competition for resources has led these plants to adapt and resist adverse conditions. Considering the interspecific competition relations, weeds represent the greatest constraint to world agriculture, since their invasive work facilitates competition with economic crops and at the same time they are hosts of pests and diseases [3].

Weeds are considered “weeds” when they affect the interests and objectives of man, being qualified in agriculture as the main pests due to the negative economic impact they can cause in this activity. Unlike other pests, undesirable plants almost always arise in an association of species which remain in equilibrium until the ecosystem is affected by practices such as tillage, fertilization and pesticide application. For this reason, the systematic evaluation of the weed population becomes indispensable in crop areas as a guide for the control measures to be developed [4].

On the other hand, it is considered of great importance to carry out studies on the evaluation of the dominance of weeds present in crops. When identified, ecological methods can be established for a good integrated management of unwanted plants, which in turn regulate and maintain environmental potentials in balance. Weeds have adaptations that allow them to survive in crop environments, and because of this they are considered dynamic colonizing plants that have a high reproductive capacity and effective interactions with other organisms in the agroecosystem [5].

Research and studies on interactions between weeds as host plants, as ecological indicators, as a source of biomass and allelopathic agents in tropical cropping systems have multiplied. However, the need for weed management continues to be investigated in order to find the most effective way to eradicate species or populations of these plants in tropical agricultural ecosystems [6].

In order to be in tune with existing environmental and socioeconomic conditions, there are currently a large number of practices and technologies to improve the functioning of agroecosystems, the end result of which is to achieve greater ecological sustainability. By adopting ecological management practices, the farmer has the potential to increase the stability and resilience of the agroecosystem [7].

Nowadays, weeds have gained space in crop systems through conventional agriculture, since it is considered that the presence of different species within crops generates a great impact on the crop entomofauna, to such an extent that there is a greater effectiveness of predators and parasitoids. At the same time, beneficial insects have greater possibilities of finding alternative prey, shelter, breeding sites and refuges for dormancy [8].

Taking into account the above mentioned, the objective of the research was to characterize the arvense flora at taxonomic level and predominant richness in number of species in plots of smallholder farms in 5 municipalities of the department of Boyacá Characterize the diversity of arvense species in 60 smallholder farms in five municipalities of Boyacá planned for polycultures, within the framework of the project “Implementation of associative agricultural models with traditional crops for economic and environmental management in the department of Boyacá” ,in order to take it into account for future weed management plans.

II. Materials and Methods

Observational research was carried out in plots of 60 smallholder farms, 12 in each of the 5 selected municipalities in the Department of Boyacá, as shown in Fig. 1: Panqueba, Aquitania, Belén, Soatá and Garagoa; farmers who participated in a project that considered polycultures as a sustainable alternative.

Fig. 1. Map showing the location of the municipalities where the research was carried out.
Source: Authors.

In the areas under study, the history of land use was considered for the characterization of the arvense flora (Table 1).

Table 1.
History of the properties in the municipalities studied.

Farm	Land use of the lot	Time in use
Soata		
Ronquilla	Native savanna	4 years
El Ralo	Native savanna	3 years
Gallinacera	Corn cultivation	2 years
La Palma	Fallow	3 years
El Almorzadero	Fallow	5 years
Los Laureles	Native savanna	4 years
El Cito	Native savanna	5 years
Florencia	Native savanna	3 years
La Primavera	Fallow	2 years
Gallinero	Native savanna	3 years
Copa de Oro	Corn cultivation	5 years
El Gaque	Corn cultivation y Native savanna	5 years

Farm	Land use of the lot	Time in use
Panqueba		
Los fiquetones	Native savanna	5 years
Laguna de Ruchical	Native savanna	3 years
Cuatro Esquinas	Onion cultivation	3 years
Oreganillal	Corn cultivation	4 years
Picachito	Fallow	5 years
El Uvo	Onion cultivation	4 years
La Rinconada	Bean cultivation	6 years
El Carmen	Native savanna	4 years
El Recuerdo	Fallow	5 years
El Reposo	Corn cultivation	6 years
Santo Domingo	Native savanna	3 years
El Tuno	Onion cultivation	6 years
Belén		
Peña Colorada	Native savanna	5 years
Ojo de Agua	Native savanna	3 years
El Aguirre	Potato cultivation	3 years
El Chital	Potato cultivation	4 years
Hoya	Fallow	5 years
El Cardón	Native savanna	4 years
El Pino	Potato cultivation	3 years
Buenos Aires	Native savanna	4 years
Puerto Nuevo	Fallow	5 years
El Morito	Native savanna	5 years
La Meseta	Potato cultivation	4 years
La Primavera	Potato cultivation	5 years
Garagoa		
El Pincel	Fallow	5 years
La Realidad	Fallow	3 years
El bosque	Sugar cane	5 years
Portin	Fallow	3 years
Los pinos	Native savanna	4 years
Betania	Pastures (*Brachiaria*)	3 years
El arrayan	Sugar cane	4 years
San Luis	Pastures (*Brachiaria*)	5 years
La Rivera	Fallow	5 years
La quinta	Native savanna	4 years
San José	Lulo cultivation	5 years
Granja Guaney	Sugar cane	3 years
Aquitania		
Tomita 2	Potato cultivation	3 years
El Romero	Onion cultivation	5 years
Cañada Honda	Potato cultivation	4 years
Buenavista	Onion cultivation	4 years
El Espinal	Fallow	3 years
La Laja	Native savanna	5 years
El Colorado	Fallow	3 years
La Laja 1	Native savanna	4 years
Las pilas	Fallow	3 years
Las cañas	Native savanna	5 years
Encenecillo y Ladera	Native savanna	4 years
San Fernando	Fallow	3 years

Source: Authors.

The farms incorporated into the project had to have between 1 and 3 ha, of which two plots of 0.5 ha were used in the research, which would be used to compare polyculture and monoculture production models, as shown in Table 2.

Table 2.
Agroecological models to be established and their crops by municipality.

Municipality	Monocrop	Polycrop
Panqueba	Onion (*Allium cepa* L.)	Onion, Beans
	Peach (*Prunus persica* L.)	Peach, Beans y Corn
	Corn (*Zea mays* L.)	Corn, Beans y Pea
Soatá	Peach (*Prunus persica* L.)	Peach, Beans and Corn
	Pea (*Pisum sativum* L.)	Pea, Corn
	Corn (*Zea mays* L.)	Corn, Beans and Peas
Belén	Potato (*Solanum tuberosum* L.)	Potato, Peas
	Creole potato (*Solanum phureja* Juz. & Bukasov)	Creole potato, Pea
	Corn (*Zea mays* L.)	Corn, Beans
Aquitania	Onion stalk (*Allium fistulosum* L.)	Onion stalk, Pea, Potato
	Onion stalk (*Allium fistulosum* L.)	Onion stalk, Peas
	Onion stalk (*Allium fistulosum* L.)	Onion stalk, Potato
Garagoa	Coffee (*Coffea Arábica*), Banana (*Musa paradisiaca*).	Coffee, Banana, Beans
	Coffee (*Coffea Arábica*), Banana (*Musa paradisiaca*).	Coffee, Banana y Peas
	Coffee (*Coffea Arábica*), Banana (*Musa paradisiaca*).	Coffee, Banana, Corn

Source: Authors.

To determine the species of weeds, present on each farm and their abundance, samples were taken in the 12 farms previously selected from the information provided by the Governor's Office of Boyacá on the farms of small farmers that were representative of their similar farms in the municipality, for which the formula proposed by FUSM [9] was used, where a margin of error of 10% and a confidence level of 95% were considered, resulting in a sample size of 60 farms.

Before sampling, a tour of each of the farms was carried out to determine the two 0.5 ha plots that were selected to participate in the research and to determine which was the plot where the agroecological polyculture was located and which was the monoculture or control crop.

Subsequently, the selection of the area with the highest possible representativeness of the adventitious and/or herbaceous vines of each plot was carried out. The groups included in the characterization were the class Liliopsida (monocotyledons), Magnoliopsida (dicotyledons) and Pteridophytas (ferns). For the determination of the arboreal species, a square PVC frame measuring $1 \times 1 = 1$ m^2 was randomly thrown twice in each plot of 0.5 ha in order to obtain the greatest number of representative arboreal species per plot.

The identification of the weeds was carried out in situ, taxonomically classifying all the adult species present based on the characteristics of the roots, leaves, flowers, inflorescence and fruits, and also photographic records were taken for later identification by comparative botany, considering the taxonomy of each weed, for which specimens of the species were collected.

Each species collected was identified by common name and photographic record in a preliminary species inventory. Information on habit, life cycle, habitat and some vegetative characters from field observations and secondary information was also included. For the collection of the material, the collection protocols of the HFAB of the UNAL (Bogotá, Colombia) were followed. This information was complemented and verified with that of the virtual herbarium of the UNAL [10].

The species richness index [11] was determined and these data were tabulated in Microsoft Excel. A descriptive analysis was made of all the information related to abundance, species richness and cover by plot, farm and municipality. The number of individuals of each species in each quadrat was also determined, which allowed us to have the abundance or number of individuals per quadrat.

With this information, other variables were determined [11], such as:

- The Margalef species diversity index (1), thus:

$$D\,Mg = \frac{(S - 1)}{\ln N} \qquad (1)$$

Where:

S = total number of species present.

N = total number of individuals.

In addition, Shannon and Simpson index [12] as:

- Shannon index (2), thus:

$$H' = -\Sigma\,(pi)\,Ln\,(pi) \qquad (2)$$

Where:

H' = Shannon.

pi = Proportional abundance of the species.

Ln = Natural logarithm.

- Simpson's dominance index (3):

$$D = \frac{1}{\Sigma pi2} \qquad (3)$$

Where:

D = Simpson.

pi = Proportional abundance of the species.

Since this was a descriptive study and the variables were quantitative (biodiversity indices), univariate (summary tables and figures) and multivariate (Principal Component Analysis (PCA) and Cluster Analysis (CA) statistical techniques were used to classify the farms in each municipality according to the biodiversity indices: specific richness, Margalef diversity, equity and dominance. The significance level was 5% and the R package version 4.1 was used.

III. Results and Analysis

Characterization in taxonomic groups of the weeds. In the study carried out in the 60 farms in the five municipalities, 109 species of weeds were present in 93 genera and 38 botanical families. The most representative families were Poaceae with 18 species, Asteraceae with 15 species and Fabaceae with 9. The families Amarantaceae Apiaceae, Lamiaceae, Oxalidaceae, Poligonaceae and Solanaceae were represented by 4 species (Table 3).

Table 3.
List of weeds present in the municipalities of Aquitania, Soatá, Belén, Panqueba and Garagoa.

Family	Scientific Name	Common Name
Adoxaceae	*Viburnum lantana* L.	Amargoso
Amarantaceae	*Chenopodium ambrosioides* L.	Paico
Amaranthaceae	*Amaranthus hybridus* Kunth	Bledo
Amaranthaceae	*Chenopodium album* L.	Cenizo
Amaryllidaceae	*Allium fistulosum* L.	Cebolla junca
Amaryllidaceae	*Allium cepa* L.	Cebolla cabezona
Apiaceae	*Foeniculum vulgare* Mill	Hinojo
Apiaceae	*Daucus carota* L.	Zanahoria
Apiaceae	*Hydrocotyle andina* Cuatrec.	Oreja de raton
Apiaceae	*Arracacia xanthorriza* Bancr	Arracacha
Araceae	*Philodendron scandens* K. Koch & Sello	Hiedra
Araceae	*Colocasia esculenta* (L.) Schott	Chicolo
Asteraceae	*Taraxacum officinale* (L.) Weber ex F.H.Wigg.	Diente de león
Asteraceae	*Matricaria recutita* L.	Manzanilla
Asteraceae	*Sonchus oleraceus* (L.) L.	Cerraja
Asteraceae	*Lactuca sativa* L.	Lechuga
Asteraceae	*Acmella ciliata* (Kunth) Cass.	Risaca
Asteraceae	*Acanthospermum hispidum* DC.	Silicio
Asteraceae	*Bidens pilosa* L.	Amor seco
Asteraceae	*Galinsoga parviflora* Cav.	Upa
Asteraceae	*Pentacalia abietina* (Willd. ex Wedd.) Cuatrec.	Panque
Asteraceae	*Stevia lucida* Lag.	Jarilla blanca
Asteraceae	*Conyza trihecatactis* (S.F. Blake) Cuatrec.	Venadillo
Asteraceae	*Ambrosia peruviana* Willd.	Altamisa
Asteraceae	*Sphagneticola tribulata* (L.) Pruski	Boton de oro
Asteraceae	*Tanacetum parthenium* (L.) Sch.Bip.	Manzanilla silvestre
Asteraceae	*Alloispermun caracasanum* Lag.	Jarilla
Balsaminaceae	*Impatiens balsamina* L.	Caracucho morado
Boraginaceae	*Symphytum officinale* L.	Suelda con suelda
Brasicaceae	*Brassica oleracea* L.	Repollo
Brasicaceae	*Raphanus raphanistrum* L.	Nabo
Brasicaceae	*Brassica rapa* L.	Alpiste
Cariofilaceae	*Agrostemma githago* L.	Neguilla
Cariofilaceae	*Drymaria cordata* (L.) Willd. ex Schult.	Golondrina
Compositae	*Calendula officcinalis* L.	Calendula
Compositae	*Bellis perennis* L.	Pascua
Crasulaceae	*Kalanchoe pinnata* (Lam.) Pers.	Hoja santa
Cucurbitaceae	*Cucurbita pepo* L.	Calabaza
Cyperaceae	*Cyperus luzulae* (L.) Retz.	Pasto estrella
Cyperaceae	*Rhynchospora nervosa* Vahl	Tote
Cyperaceae	*Cyperus seslerioides* Kunth	Toche
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn	Helecho
Euforbiaceae	*Manihot esculenta* Crantz	Yuca
Fabaceae	*Trifolium pratense* L.	Trebol rojo
Fabaceae	*Trifolium repens* L.	Trebol blanco
Fabaceae	*Vicia faba* L.	Habas
Fabaceae	*Pisum sativum* L.	Arverja
Fabaceae	*Mimosa pudica* L.	Dormidera
Fabaceae	*Senna obtusifolia* (L.) H.S. Irwin & Barneby	La brusca
Fabaceae	*Medicago sativa* L.	Alfalfa
Fabaceae	*Desmodium incanum* DC.	Pega Pega
Fabaceae	*Senna obtusifolia* (L.) H. S. Irwin & Barneby	Bicho
Hypericaceae	*Hypericum juniperinum* Kunth	Pino Guarda Rocio
Iridaceae	*Gladiolus hybridus* C. Morren	Gladiolo

Family	Scientific Name	Common Name
Juncaceae	*Juncus effusus* L.	Junco
Lamiaceae	*Salvia palifolia* Kunth	Salvia
Lamiaceae	*Salvia aratocensis* (J.R.I. Wood & Harley) Fern.Alonso	Velero
Lamiaceae	*Ocimum basilicum* L.	Albahaca
Lamiaceae	*Mentha piperita* L.	Hierbabuena
Malvaceae	*Malva parviflora* L.	Malva
Malvaceae	*Sida rhombifolia* L.	Escobilla
Malvaceae	*Malvastrum coromandelianum* (L.) Garcke	Escobilla 1
Melastomataceae	*Brachyotum strigosum* (L. f.) Triana	Zarcillejo
Musaceae	*Musa x paradisiaca* L.	Platano
Oxalidaceae	*Oxalis filiformis* Kunth	Cederita
Oxalidaceae	*Oxalis pes-caprae* L.	Vinagrillo
Oxalidaceae	*Oxalis tuberosa* Molina	Ibia
Oxalidaceae	*Oxalis acetosella* L.	Platanillo
Papaveraceae	*Fumaria officinalis* L.	Fumaria
Plantaginaceae	*Plantago major* L.	Yanten
Plantaginaceae	*Scoparia dulcis* L.	Mastuerzo
Poaceae	*Zea mays* L.	Maiz
Poaceae	*Brachiaria mutica* (Forssk.) Stapf	Pasto paja
Poaceae	*Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone	Pasto kikuyo
Poaceae	*Dactylis glomerata* L.	Pasto azul
Poaceae	*Holcus lanatus* L.	Falsa poa
Poaceae	*Eleusine indica* (L.) Gaertn.	Pasto burro
Poaceae	*Lolium perenne* L.	Pasto Raigrás
Poaceae	*Urochloa mutica* (Forssk.) T.Q. Nguyen	Pasto para
Poaceae	*Urochloa decumbens* (Stapf) R.D. Webster	Pasto brecharia
Poaceae	*Cenchrus purpureum* Schumach.	Pasto taiwan
Poaceae	*Hyparrhenia rufa* (Nees) Stapf	Pasto jaragua
Poaceae	*Holcus lanatus* L.	Pasto poa
Poaceae	*Megathyrsus maximus* (Jacq.) B.K. Simon & Jacobs	Pasto guineo
Poaceae	*Cynodon dactylon* (L.) Pers.	Pasto Comun
Poaceae	*Triticum aestivum* L.	Trigo
Poaceae	*Phalaris arundinaceae* L.	Pasto brasilero
Poaceae	*Cortaderia nítida* (Kunth) Pilg	Cortadera
Poaceae	*Dactylis glomerata* L.	Pasto grama
Poligonaceae	*Polygonum segetum* Kunth	Barbasco
Poligonaceae	*Rumex crispus* L	Romaza o lengua de vaca
Poligonaceae	*Polygonum hydropiperoides* Michx.	Gualola
Polygonaceae	*Rumex acetosella* L.	Envidia
Portulaceae	*Portulaca oleracea* L.	Verdolaga
Rosaceae	*Rubus eriocarpus* Liebm.	Mora silvestre
Rosaceae	*Acaena elongata* L.	Cadillo
Rutaceae	*Ruta graveolens* L.	Ruda
Saccolomataceae	*Saccoloma inaequale* (Kunze) Mett	Helecho macho
Sapindaceae	*Cardiospermum halicacabum* L.	Globitos
Solanaceae	*Physalis peruviana* L.	Uchuva
Solanaceae	*Solanum tuberosum* L.	Papa
Solanaceae	*Solanum nigrum* L.	Moro
Solanaceae	*Solanum americanum* Mill.	Hierbamora
Tropeolaceae	*Tropaeolum tuberosum* Ruiz & Pav.	Cubios
Urticaceae	*Boehmeria nivea* (L.) Gaudich.	Ramio
Urticaceae	*Urtica dioica* L.	Ortiga
Valerianaceae	*Valeriana officinalis* L.	Valeriana
Verbenaceae	*Verbena litoralis* Kunth	Verbena
Zygophyllaceae	*Tribulus terrestris* L.	Abrojo

Source: Authors.

In the municipality of Belén, 37 species of weeds belonging to 18 families and 35 genera were identified. The three most represented families were Poaceae (8 species), followed by Asteraceae with 5 species and Fabaceae with 4 species. For the municipality of Soatá, 33 species of weeds belonging to 15 families and 31 genera were identified. The three most representative families were Poaceae with 7 species, followed by Asteraceae with 6 species and Fabaceae with 3 species. In the municipality of Panqueba, 35 species of weeds belonging to 15 families and 31 genera were identified. The most represented families were Poaceae with 7 species, followed by Asteraceae with 6 species and Fabaceae with 5. In the municipality of Aquitania, 44 species of weeds belonging to 21 families and 41 genera were identified. The most representative families were Poaceae with 7 species, followed by Asteraceae with 5 species and Fabaceae with 5 species. In the municipality of Garagoa, 37 species of weeds belonging to 23 families and 36 genera were identified. The most represented families were Asteraceae with 7 species, Poaceae with 5 species and Poligonaceae with 3. Thus, as can be seen, the greatest relative number of species and genera was observed in Panqueba and the greatest diversity of families in Garagoa (Fig. 2).

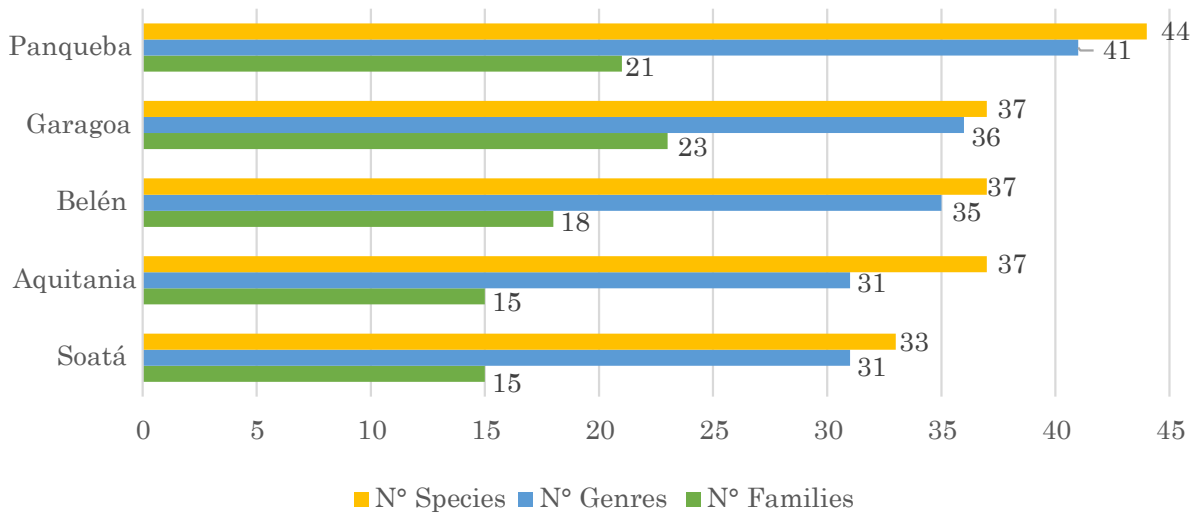

Fig. 2. Number of families, genera and species identified in each municipality.
Source: Authors.

A. *Biodiversity indexes*

Table 4 shows the biodiversity indexes by farm in the municipality of Belén. The abundance of weed species was quite variable among the farms in the municipality. The farm with the highest relative abundance with 12.5% was Meseta and the lowest was El Chital with only 5.63%.

TABLE 4.
BIODIVERSITY INDICATORS FOR FARMS IN THE MUNICIPALITY OF BELÉN

N°	Farm	Abundance (N)	Relative abundance (%)	Specific richness (S)	Margalef diversity (DMg)	Fairness (Shannon-Wiener) H	Dominance (Simpson)
1	Peña Colorada	20	6.25	9	2.67	1.94	0.19
2	Ojo de Agua	33	10.31	12	3.15	2.25	0.13
3	El Aguirre	34	10.63	11	2.84	2.01	0.19
4	El Chital	18	5.63	4	1.04	1.09	0.43
5	Hoya	19	5.94	8	2.38	1.91	0.17
6	El Cardón	26	8.13	5	1.23	1.41	0.27
7	El Pino	25	7.81	12	3.42	2.29	0.12
8	Buenos Aires	35	10.94	12	3.09	2.30	0.12
9	Puerto Nuevo	23	7.19	5	1.28	1.29	0.35
10	El Morito	21	6.56	7	1.97	1.62	0.26
11	La Meseta	40	12.50	8	1.90	1.79	0.21
12	La Primavera	26	8.13	13	3.68	2.32	0.13
Average		26.67	8.33	8.83	2.39	1.85	0.21
Standard deviation		7.19	2.25	3.16	0.90	0.42	0.10

Source: Authors.

There was also great variability in the number of weed species. Four farms had the highest specific richness; La Primavera (13), Ojo de Agua, El Pino and Buenos Aires with 12 species. The Margalef diversity index showed a maximum of 3.68 (La Primavera) and a minimum of 1.04 in El Chital. The minimum value in the equity index was 1.09 (El Chital) and the maximum was 2.32 at the Primavera farm. The species dominance index had a maximum value of 0.43 (El Chital) and a minimum of 0.12 for El Pino and Buenos Aires (Table 4).

The Table 4 also show the variability in the indices: relative abundance (2.25%) and specific richness (3.16) in particular. Five (5) farms present equity indexes between 2 and 3.5 considered medium and 4 farms present dominance indexes lower than 0.17 considered as low [13].

The Cluster Analysis (CA) carried out for the four biodiversity indicators resulted in three groups of farms (Fig. 3). In the first one, there were five (5) farms located within the red oval: El morito, La maceta, Peña Colorada, Hoya and El Aguirre, characterized by a specific richness range between 7 and 11, Margalef diversity between 1.90-2.84, equity between 1.62-2.01 and a dominance index of less than 0.3. In the second grouping, three (3) farms were located within the green oval: El chital, El cardón and Puerto nuevo, characterized because the specific richness is lower in the range 4-5; the diversity between 1.04 -1.41; the equity index between 1.09-1.41 and the dominance index between 0.27-0.43. In the third blue oval four farms were grouped: La primavera, El pino, Ojo de agua and Buenos Aires, they are characterized because the specific richness is in a range of 12-13; the diversity between 3.09-3.68; the equity between 2.25-2.32 and the dominance index is the lowest relative value with a range of 0.12-0.13.

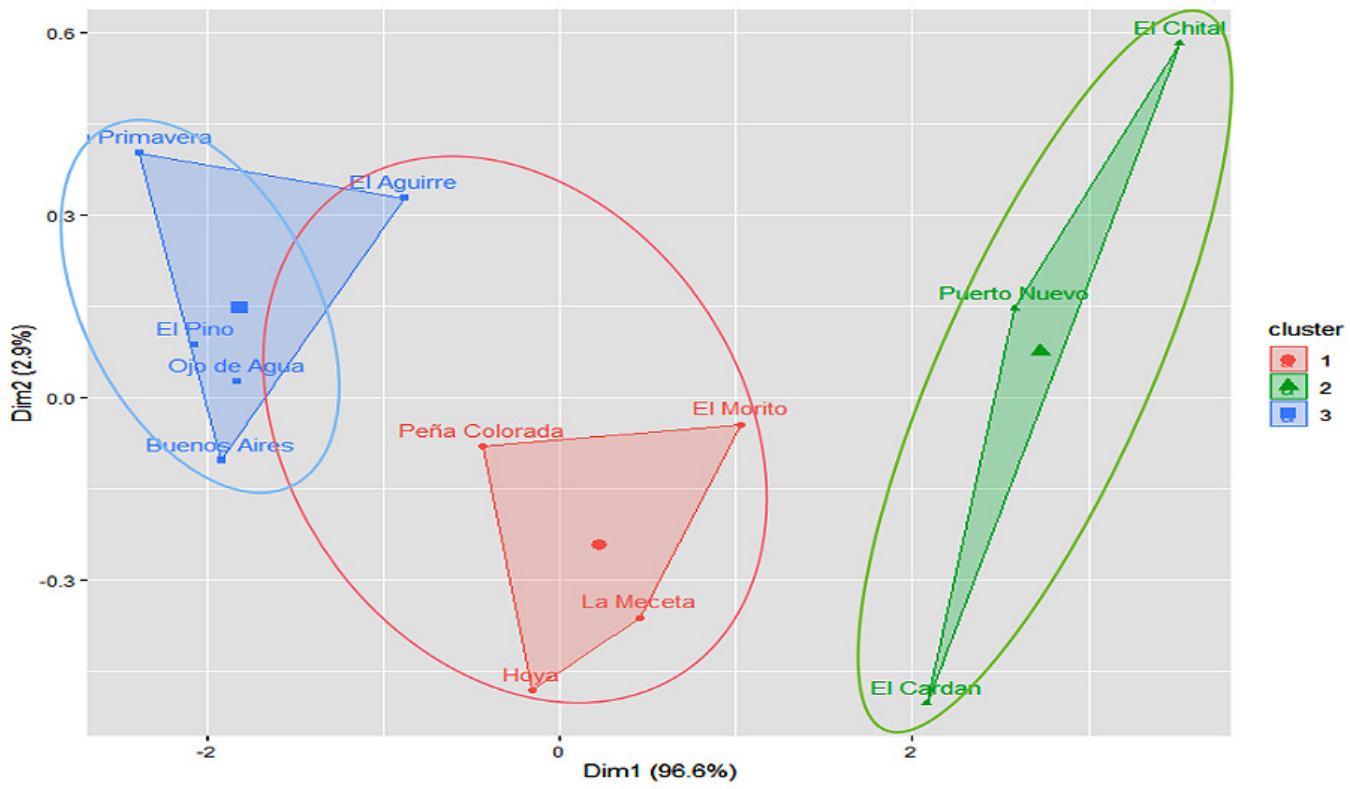

Fig. 3. Grouping of farms according to biodiversity indicators in the municipality of Belén.
Source: Authors.

In the municipality of Soatá, the farm with the highest relative abundance was El Gaque with 16.11% and the lowest was Copa de Oro with 2.78%. Four farms represented the highest number of species: La Palma (9), Ronquilla (6), Los Laureles and El Gaque (5). The Margalef diversity index obtained a maximum of 2.52 (La Palma) and a minimum of 0.62 in Copa de Oro. Regarding equity, the minimum was 0.67 (Copa de Oro) and the maximum was 2.08 (La Palma), and regarding the species dominance index, the maximum value was 0.52 (Copa de Oro) and the minimum was 0.14 (La Palma) (Table 5). In this municipality, only one farm had an equity above 2, considered medium, and this one had a dominance lower than 0.17, considered low (La Palma) [13].

Table 5.
Biodiversity indicators for the municipality of Soatá.

N°	Farm	Abundance (N)	Relative abundance (%)	Specific richness (S)	Margalef diversity (DMg)	Fairness (Shannon-Wiener) H	Dominance (Simpson)
1	Ronquilla	27	15.00	6	1.52	1.63	0.22
2	El Ralo	19	10.56	3	0.68	1.02	0.39
3	Gallinacera	18	10.00	4	1.04	1.36	0.27
4	La Palma	24	13.33	9	2.52	2.08	0.14
5	El Almorzadero	8	4.44	4	1.4	1.32	0.28
6	Los Laureles	11	6.11	5	1.67	1.52	0.24
7	El Cito	6	3.33	3	1.12	1.01	0.39
8	Florencia	6	3.33	3	1.12	1.01	0.39
9	La Primavera	18	10.00	4	1.04	1.33	0.28
10	Gallinero	9	5.00	3	0.91	1.06	0.36
11	Copa de Oro	5	2.78	2	0.62	0.67	0.52
12	El Gaque	29	16.11	5	1.19	1.34	0.31
Average		15.00	8.33	4.25	1.24	1.28	0.32
Standard deviation		8.26	4.59	1.79	0.49	0.35	0.10

Source: Authors.

The multivariate analysis in the municipality of Soatá allowed grouping the farms into three groups based on their similarity. In the first group there was one (1) farm corresponding to the red grouping called La Palma, characterized because the richness, diversity and equity indexes are higher than 2.0 and its dominance is the lowest relative value, being 0.14. In grouping 2, six (6) farms (green color) were located: La Ronquilla, Los Laureles, Gallinacera, La Primavera, El Almorzadero and El Gaque, characterized because the specific richness is in a range of 4-6; the diversity between 1.04 -1.67; the equity index between 1.32-1.1.63 and the dominance index in a range of 0.22-0.31. Finally, in the third grouping there were farms (5) farms (blue color) where the following farms are found: Copa de Oro, El cito, Florencia, El ralo and Gallinero; they are characterized because the specific richness is in a range of 2-3; the diversity between 0.62-1.12; the equity index between 0.67-1.02 and the dominance index between 0.36-0.52 (Fig. 4).

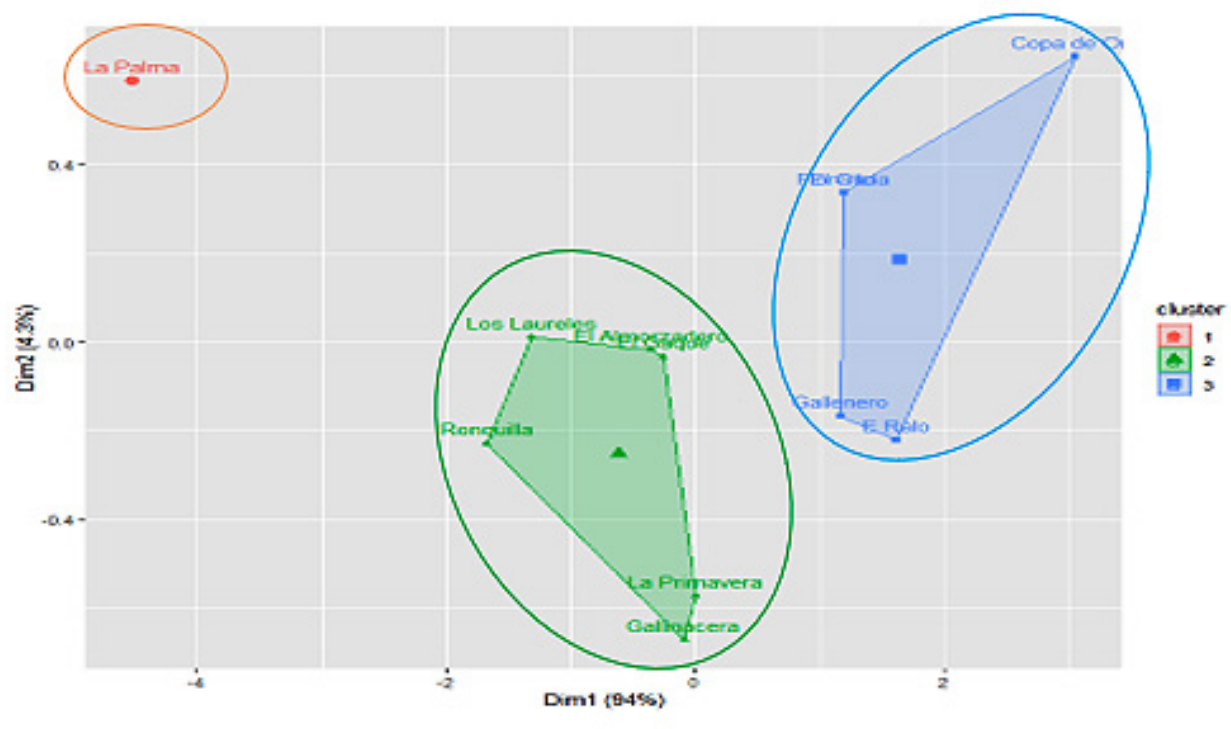

Fig. 4. Grouping of farms according to biodiversity indicators in the municipality of Soatá.
Source: Authors.

The farm with the highest relative abundance of weeds in the municipality of Panqueba was El Recuerdo with 12.38% and the lowest was Cuatro Esquinas with 4.17%. Three farms had the highest number of species (8): La Rinconada, El Recuerdo and El Reposo. The Margalef diversity index showed a maximum of 1.61 (El Reposo) and a minimum of 0.53 in Santo Domingo. With respect to equity, the minimum was 1.05 (Santo Domingo) and the maximum was 2.05 (El Reposo) and with respect to the species dominance index, the maximum value was 0.37 (Santo Domingo) and the minimum was 0.13 (El Reposo) (Table 6). Only two farms had an equity above 2, considered medium, while 4 farms (including the three previous ones) had dominances below 0.17, considered low [13].

Table 6.
Biodiversity indicators in the municipality of Panqueba.

N°	Farm	Abundance (N)	Relative abundance (%)	Specific richness (S)	Margalef diversity (DMg)	Fairness (Shannon-Wiener) H	Dominance (Simpson)
1	Los fiquetones	88	10.48	7.00	1.34	1.85	0.17
2	Laguna de Ruchical	60	7.14	6.00	1.22	1.73	0.19
3	Cuatro Esquinas	35	4.17	6.00	1.41	1.70	0.20
4	Oreganillal	70	8.33	5.00	0.94	1.57	0.22
5	Picachito	55	6.55	5.00	1.00	1.53	0.23
6	El Uvo	79	9.40	6.00	1.14	1.72	0.19
7	La Rinconada	89	10.60	8.00	1.56	2.03	0.14
8	El Carmen	55	6.55	4.00	0.75	1.28	0.31
9	El Recuerdo	104	12.38	8.00	1.51	2.00	0.15
10	El Reposo	78	9.29	8.00	1.61	2.05	0.13
11	Santo Domingo	45	5.36	3.00	0.53	1.05	0.37
12	El Tuno	82	9.76	7.00	1.36	1.93	0.15
Average		70.00	8.33	6.08	1.20	1.70	0.20
Standard deviation		20.29	2.42	1.62	0.34	0.31	0.07

Source: Authors.

The multivariate analysis in the municipality of Panqueba allowed grouping the farms into four groups based on their similarity. In the first group there were two (2) farms corresponding to the red grouping. In this grouping are the farms: El Carmen and Santo Domingo, characterized by a relatively lower range of specific richness, between 3-4; the Margalef diversity is between 0.53-0.75; equity is between 1.05-1.28 and the dominance index is greater than 0.3 (Fig. 5).

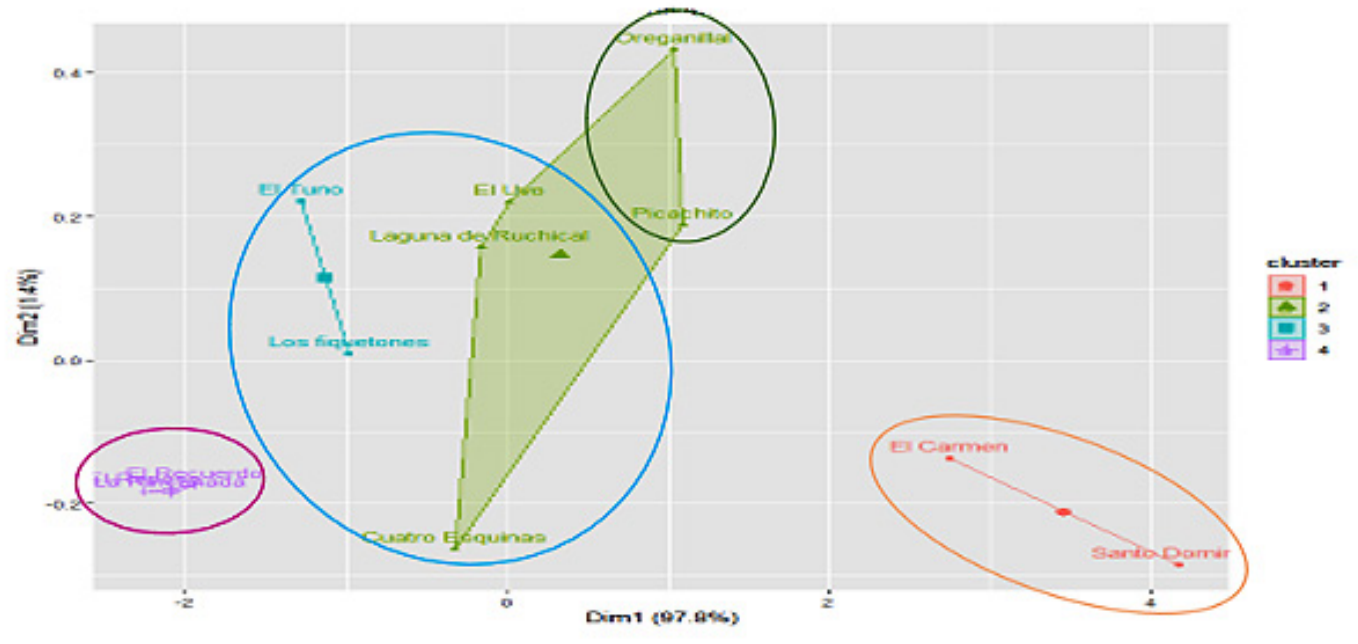

Fig. 5. Grouping of farms according to biodiversity indicators in the municipality of Panqueba.
Source: Authors.

In group 2 there were two (2) farms (green color): Organillal and Picachito, which are characterized because the specific richness is only 5; the diversity is between 0.94 -1; the equity index is between 1.53-1.57 and the dominance index is between 0.22-0.23. In the third grouping there were five (5) farms (light blue color). The farms Los Fiquetones, El Tuno, Cuatro Esquinas, Laguna Ruchical and El Uvo are characterized by a range of specific richness between 6-7; the Margalef diversity is between 1.14-1.41; the equity is between 1.70-1.93 and the dominance index in a range of 0.15-0.20. Finally, in the fourth grouping there were three (3) farms El Recuerdo, La Rinconada and El Reposo, these are identified by a richness of 8, relatively higher; the Margalef diversity is between 1.51-1.61; the equity is between 2-2.05 and the dominance index between 0.13-0.15 (Fig. 5).

The farm with the highest relative abundance of weeds in the municipality of Aquitania was Encenecillo with 12% and the lowest was La Laja 1 with 4%. Two farms had the highest number of species (14) Tomita 2 and Encenecillo and Ladera. The Margalef diversity index showed a maximum of 3.29 (Tomita 2) and a minimum of 1.55 in Las Pilas. With respect to equity, the minimum was 1.78 (Las Pilas) and the maximum was 2.30 (Tomita 2) and with respect to the species dominance index, the maximum value was 0.19 (Las Pilas) and the minimum was 0.10 (Encenecillo and Ladera) (Table 7). In general, eight farms had an index of medium equity and none high, while only two farms could be considered high dominance [13], so the farms in this municipality could be considered to have a more favorable relative situation than the previous ones.

Table 7.
Biodiversity indicators in the municipality of Aquitania.

N°	Farm	Abundance (N)	Relative abundance (%)	Specific richness (S)	Margalef diversity (DMg)	Fairness (Shannon-Wiener) H	Dominance (Simpson)
1	Tomita 2	52	9	14	3.290	2.308	0.135
2	El Romero	49	8	8	1.799	1.993	0.148
3	Cañada Honda	48	8	12	2.842	2.249	0.121
4	Buenavista	46	8	7	1.567	1.834	0.174
5	El Espinal	41	7	8	1.885	2.014	0.141
6	La Laja	52	9	8	1.772	1.877	0.180
7	El Colorado	58	10	11	2.463	2.181	0.137
8	La Laja 1	26	4	10	2.762	2.228	0.115
9	Las pilas	47	8	7	1.558	1.787	0.195
10	Las cañas	46	8	11	2.612	2.260	0.114
11	Encenecillo y Ladera	72	12	14	3.040	2.459	0.103
12	San Fernando	51	9	12	2.798	2.357	0.106
Average		49.00	8	10.17	2.37	2.13	0.14
Standard deviation		10.65	2	2.55	0.61	0.22	0.03

Source: Authors.

In the municipality of Aquitania, the farms were classified into four groups. In the first group there were three (3) farms corresponding to the red group. In this grouping are the following farms: El Colorado, La Laja 1 and Las Cañas, characterized by a relatively high range of specific richness, between 10-11; the Margalef diversity is between 2.46-2.76; equity is between 2.18-2.26 and dominance is between 0.11-0.13. In the second green group, there were two farms, Tomita 2 and Encenecillo y Ladera, because their specific richness is the highest in the municipality (14); Margalef diversity is between 3.04-3.29; equity is between 2.30-2.45 and dominance is the lowest (0.103). The third group corresponds to the light blue sector where the farms Las Pilas, La laja, Buenavista, El Romero and El Espinal share similarity due to their specific richness is between 7 and 8; Margalef diversity is between 1.55-1.88; equity is between 1.78 and 2.01 and dominance is between 0.14-0.19. Finally, the purple grouping 4 corresponds to the Cañada Honda and San Fernando farms, where the specific richness is 12; the Margalef diversity is between 2.79-2.84; the equity is between 2.24-2.35 and the dominance is between 0.10-0.11 (Fig. 6).

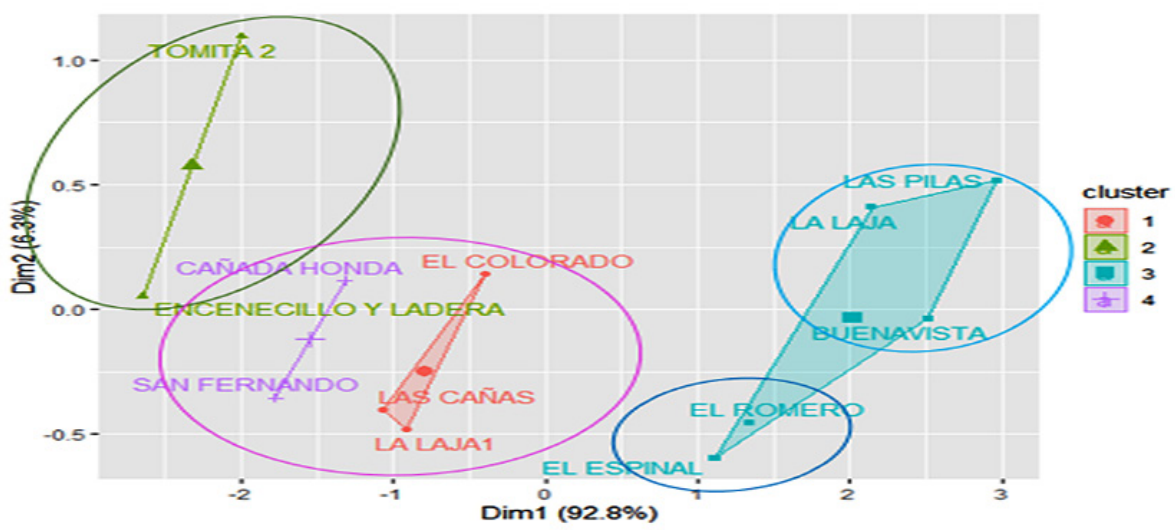

Fig. 6. Grouping of farms according to biodiversity indicators in the municipality of Aquitania.
Source: Authors.

The farm with the highest relative abundance of weeds in the municipality of Garagoa with 11% was San José and the lowest was Granja Guaney with 5%. Three (3) farms had the highest number of species, San José (11) and Betania and La Rivera with 9. The Margalef diversity index showed a maximum of 2.54 (San José) and a minimum of 0.91 in El Arrayan. Regarding equity, the minimum was 1.16 (El Arrayan) and the maximum was 2.07 (La Rivera) and regarding the species dominance index, the maximum value was 0.35 (El Arrayan) and the minimum was 0.14 (Betania) (Table 8). In the municipality of Garagoa, only three farms presented an equity above 2, considered medium, and three (coinciding with the previous ones) with dominances below 0.17, considered low [13], which denotes an unfavorable situation in terms of biodiversity indicators of arboreal species.

Table 8.
Biodiversity indicators in the municipality of Garagoa.

N°	Farm	Abundance (N)	Relative abundance (%)	Specific richness (S)	Margalef diversity (DMg)	Fairness (Shannon-Wiener) H	Dominance (Simpson)
1	El Pincel	35	8	5	1.125	1.238	0.344
2	La Realidad	40	9	7	1.627	1.575	0.258
3	El bosque	34	7	8	1.985	1.788	0.197
4	Portin	36	8	6	1.395	1.445	0.285
5	Los pinos	39	8	6	1.365	1.569	0.240
6	Betania	44	10	9	2.114	2.056	0.142
7	El arrayan	27	6	4	0.910	1.165	0.353
8	San Luis	36	8	8	1.953	1.824	0.199
9	La Rivera	47	10	9	2.078	2.072	0.143
10	La quinta	47	10	6	1.299	1.602	0.226
11	San José	51	11	11	2.543	2.036	0.168
12	Granja Guaney	23	5	6	1.595	1.640	0.214
Average		38.25	8	7.08	1.67	1.67	0.23
Standard deviation		8.26	2	1.98	0.48	0.30	0.07

Source: Authors.

The multivariate analysis in the municipality of Garagoa allowed grouping the farms into three groups. In the first group there were five (5) farms corresponding to the red grouping. The farms San José, El Bosque, San Luis, Betania and La Rivera are characterized by a range of specific richness between 8 and 11; the Margalef diversity is between 1.95 and 2.54; equity is between 1.78 and 2.07, and dominance is between 0.14-0.19. In grouping 2 of green color are the farms: El Pincel and El Arrayan are characterized because the range of their specific richness is the lowest, between 4 and 5; the Margalef diversity is between 0.91-1.12; the equity is between 1.16 and 1.23 and the dominance index is higher than 0.3.

The last grouping is group 3, which corresponds to the light blue color. Here we find the farms La Realidad, Portin, Los Pinos, Granja Guaney and La Quinta. They are related because the range of their specific richness is between 6 and 7; their Margalef diversity is between 1.29-1.62; equity is between 1.44-1.64 and dominance is between 0.21-0.28 (Fig. 7).

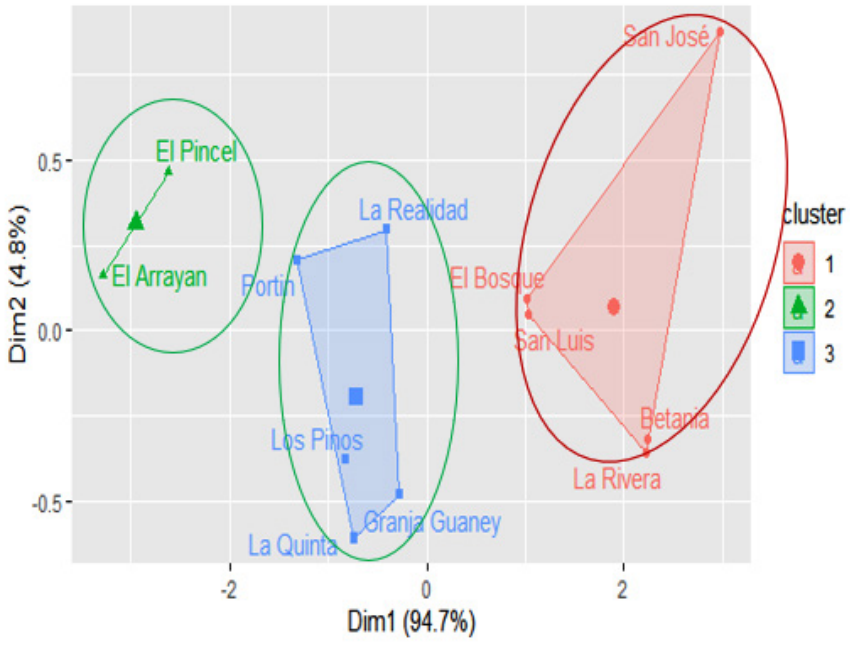

Fig. 7. Grouping of farms according to biodiversity indicators in the municipality of Garagoa.
Source: Authors.

B. *Biodiversity indicators by municipality*

When analyzing the biodiversity indicators for each municipality, it became evident that the highest relative number of species was found in the municipality of Aquitania with a total of 44, and the lowest in Soatá. The Margalef Diversity index obtained a maximum in the municipality of Aquitania (6.59) and a minimum in Panqueba with a result of 5.20, although both extremes can be valued as good. With respect to equity the highest municipality was Panqueba with 3.31 and the lowest Garagoa with 2.57 both considered high [13]. The species dominance index was higher in Belén and Garagoa with a value of 0.14, and for the rest 0.04 considered low [13] (Table 9).

Table 9.
General biodiversity indicators for the municipalities of Belén, Soatá, Panqueba, Aquitania and Garagoa.

Municipalities	Specific Wealth	Diversity	Fairness	Dominance
Belén	37	6.24	2.65	0.14
Soatá	33	6.16	2.95	0.04
Panqueba	35	5.20	3.31	0.04
Aquitania	44	6.59	3.01	0.05
Garagoa	37	5.71	2.57	0.14

Source: Authors.

In the first grouping, 2 municipalities were located within the orange oval: Panqueba and Soatá, which are characterized because their specific richness was 35 and 33 respectively; the diversity between 5.20 and 6.16; the index of equity between 2.95 and 3.31 and the index of dominance between 0.05 and 0.04. In the second grouping was the municipality of Aquitania, located within the green oval, characterized by a specific richness index of 44; Margalef's diversity index of 6.59; equity index of 3.31 and dominance index of 0.5. Two municipalities were grouped in the third blue oval: Garagoa and Belén, in them their specific richness it was 37; diversity between 5.71 and 6.24; equity between 2.65-3.01 and a relatively high dominance within the group with 0.14 (Fig. 8).

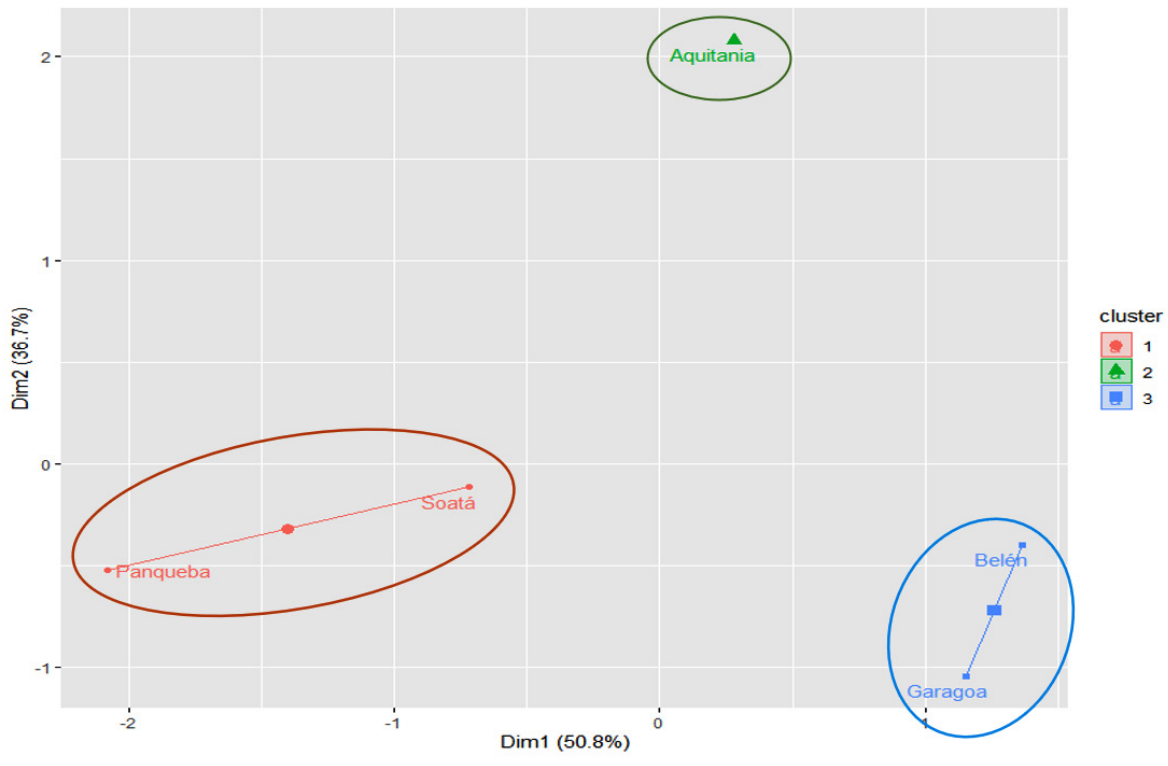

Fig. 8. Grouping by municipality according to biodiversity indicators.
Source: Authors.

In general, 109 species were recorded in the plots of the 60 farms; however, the arithmetic sum of the total number of species in the five municipalities was 186, with a maximum of 44, a minimum of 33 and an average of 37.2, indicating a low level of coincidence or repetition of species in the different municipalities, which may be due to the low ecological plasticity of many of them.

The families with the highest representation of species were Poaceae, Asteraceae and Fabaceae, but it is known that Poaceae and Asteraceae are among the families with the highest number of species in the world [14]. The dominance of these two families in this study may be due to the large number of species they have in various ecosystems as has been mentioned by some authors [15].

The level of species richness of Poaceae in the farms is related to other research where it is mentioned that this botanical family is considered one of the most extensive worldwide, with about 700 genera and about 11 000 species [16]. The predominance of Poaceae species in the farms sampled in the municipalities under study may be related to the adaptability to conditions characteristic of cold climate thermal floors, which makes some of these plant species to adapt more easily. On the other hand, the morphology of root systems and leaves is involved, which contribute to optimize water and nutrient uptake and generate resistance to water stress [17]. It is also necessary to consider the use of soils of the farms where most of them were dedicated to native savanna, fallow, sugarcane, and pastures with abundant weeds of the Poaceae family.

Among the Poaceae, *P. clandestinum* was observed in the five municipalities, which is a perennial species with a rhizomatic root system, which allows this plant to compete for space and cover. Because it has been used as a crop for animal consumption, fertilization plans have been used, making the plant more competitive with others [18].

In the group of Asteraceae, *Sonchus oleraceus* L stood out in all the municipalities, which could be due to its easy adaptability, since in spite of its fragile aspect, it grows easily in diverse environmental conditions, supporting sudden changes of temperature; being limiting in transitory crops [19]. This species of arvense has been reported for years as one of the most important for the cultivation of sugarcane in Cuba, especially since it can abound both in dry and lowlands and in wetlands on the banks of irrigation canals [20].

Regarding the Fabaceae, *Trifolium repens* L. stood out in the five municipalities. This leguminous species is responsible for fixing nitrogen, favoring infiltration and soil biodiversity. In addition, it is a plant with a two- or three-year cycle, so it can accumulate seeds and be aggressive for the establishment of transitory crops, although it can be useful as a cover for fruit trees. On the other hand, it is favorable for attracting pollinators [21].

Another species observed in the five municipalities was *Rumex crispus* L. whose colonization or distribution is due in many cases to chemical processes or allelopathies, which are widely present in agroecosystems according to some authors [22].

In three of the municipalities studied, the presence of species such as *Bidens pilosa* L. and *Taraxacum officinale* L., characterized by their broad leaves, was highlighted; these are considered aggressive weeds due to their high capacity to colonize and compete with transitory crops that will be planted on the farms, such as corn, beans, onions and peas. This type of species is characterized by being adaptable to different weeds, since within their morphology they have deep root systems, causing greater affectation when there is more coverage, interfering with the established plantations for nutrients, water and light [23].

The presence of species of the genus Oxalys is to be considered since it was evidenced in three municipalities and studies record that specimens of this genus cause great interference in the peach crop [24] which will be planted in several models of Soatá and Panqueba.

To evaluate the specific species richness, the Margalef index was used, which mentions that an index with values lower than 2.00 denotes a low species richness and, on the contrary, values close to 5.00 or higher reflect a high species richness [13]. Considering the above mentioned and knowing the results obtained in each municipality, it can be noted that all values are higher than 5.0, which indicates a high biodiversity, being Aquitania the one with the highest relative biodiversity of weeds with 6.59. When estimating the biological diversity of the areas under study, the Shannon index was calculated, considering that its normal value is between 2 and 3. The five municipalities are within the normal range and even with high diversity indexes, Panqueba being the highest with a value of 3.31 and Garagoa the lowest with 2.57. According to what was established by these authors, it can be mentioned that the municipalities under study presented high species richness, moderate or medium diversity and low dominance since all values were < 0.17, which did not occur at the farm level as could be observed previously when the farms within each municipality were analyzed.

IV. Conclusions

The study determined the presence of 109 species of weeds in 93 genera and 38 botanical families, the most representative families being Poaceae, Asteraceae and Fabaceae and the genera Pennisetum, Solanum, Dactylis, Trifolium and Oxalis.

From the point of view of their agricultural importance, the species most frequently present in the municipalities were: *P. clandestinum*, *Sonchus oleraceus* L, *Trifolium repens*, *Rumex crispus*.

Within each municipality, the levels of abundance, relative abundance and biodiversity indicators varied, resulting in general in a low to medium index of species equity in the farms and a predominantly high dominance index.

The variability of the farms within each municipality resulted in the discrimination of three groupings in Belén Garagoa and Soata, and four in Aquitania and Panqueba according to their similarity in the biodiversity indicators of the weeds.

Considering the biodiversity indices estimated in general, the five municipalities presented a high richness of weed species, medium diversity and equity indicators, and low dominance.

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