Pan American Agricultural School, Zamorano

Agricultural Science and Production Department

Agricultural Engineering

Special Graduation Project

Comparison of weed communities in three agroecosystems in the Yeguare Valley, Honduras

Student

Cristina Dominguez Miranda

Advisors

Rony Muñoz, M. Sc.

Oliver Komar, Ph. D.

Honduras, August 2023

Authorities

Content

Table index

Figure Index

Annex Index

Resumen

El estudio de la diversidad de especies de malezas y del índice de Shannon puede ayudar a identificar focos de malezas, evaluar la gravedad de las infestaciones y diseñar estrategias eficaces de manejo. El objetivo de este estudio fue comparar la composición de las malezas en tres agroecosistemas. El estudio se realizó en tres agroecosistemas, intensivo, extensivo y pastura, dentro de la Escuela Agrícola Panamericana. Se realizaron muestreos en los meses de enero y febrero de 2023, con un cuadrante con dimensiones de 0.5m × 0.5m. Se calculó el porcentaje de incidencia de malezas y el índice de Shannon. El programa EstimateS v 9 se usó para determinar el índice de diversidad y crear la curva de acumulación de especies. La forma de reproducción y ciclo de vida de las malezas fueron usados para entender el comportamiento de malezas en cuanto a su presencia en los diferentes agroecosistemas. Se identificaron 45 especies, distribuidas en 17 familias, de las cuales *Melapodium divaricatum*, *Bidens pilosa* y *Cyperus rotundus* presentaron mayor porcentaje de incidencia. De las especies muestreadas 40 especies son de ciclo de vida anual y 17 malezas son perennes. Según el índice de Shannon, el agroecosistema de pasturas presentó mayor riqueza (número de especies). Las curvas de acumulación de especies arrojaron la falta de muestreo para lograr registrar todas las especies en los agroecosistemas. Sin embargo, entre los tres agroecosistemas muestreados el más estable fue intensivo. Se encontró que cada agroecosistema tiende a tener una comunidad distinta de malezas asociada, que en general parece estar determinada por factores de manejo sumado a la naturaleza de las especies.

Palabras clave: Agroecosistema, biodiversidad, dominancia, índice de Shannon, perturbación

Abstract

Weed species diversity studies and the Shannon index can help identify weed problems, assess the severity of infestations, and design effective management strategies. The objective of this study was to compare the composition of weeds in three agroecosystems: intensive, extensive, and pasture, within the Pan-American Agricultural School campus. Samplings were carried out in the months of January and February 2023, using a quadrant with dimensions of 0.5m X 0.5m. Percentage of incidence and the Shannon index were calculated. The software EstimateS v 9 was used to determine the diversity index and create species accumulation curve. The form of reproduction and life cycle of weeds were used to understand the behaviour of weeds in different agroecosystems. A total of 45 species were identified, distributed in 17 families, where *Melapodium divaricatum*, *Bidens pilosa*, and *Cyperus rotundus* presented the highest percentage of incidence. From the total sampled species, 40 species were annuals and 17 were perennials. According to the Shannon index, the pasture agroecosystem presented greater richness (number of species). The species accumulation curves evidenced the incomplete sampling to register all the species in the agroecosystems. However, among the three agroecosystems sampled, the most stable was intensive. It was found that each agroecosystem tends to have a different weed community, which in general seems to be determined by management factors added to the nature of the species.

*Keywords***:** Agroecosystem, biodiversity, disturbance, dominance, Shannon index

Introduction

A weed is a plant that grows where it is not wanted or a plant that is out of place according to human judgement. We express for each situation which plants are or are not desirable in terms of how they affect our health, our crops, our pets, or aesthetics (Monaco et al. 2002). Defining a weed can be difficult; however, all attempts to define a weed point to an anthropocentric view. Weeds have not been defined by botanical, ecological, or physiological characteristics (Pitty 1997). For our purposes, weeds are plants that are not the crop. In this sense, weeds are all plants that interfere with the development of a crop; therefore, their proper management is necessary to obtain good yields in agricultural production.

Several methods have been used in weed management. These control practices are: prevention, control, and eradication. No matter what method of weed control is used, in the end the efficiency of this tactic will depend on knowledge of the ecology of the weeds present on the site (Satorre 2017). Knowing weed ecology may suggest new management strategies for agroecosystems. The persistence of annual species is due to greater seed production and rapid growth. Annuals complete their life cycle within a single growing season. As the growing season progresses, annuals reach maturity and produce flowers, which eventually develop into seeds. Following seed production the plant starts to die. The seeds will remain dormant for a next growing season. Although perennials start off as seeds, they have an additional form of reproduction. Generally, perennials have vegetative structures in the form of rhizomes, tubers, bulbs, or stolons that are ideal for asexual reproduction, adding to their ability to spread and infest areas. This then makes a more costly control compared to annual species. It is easier to deplete the soil seed bank by stimulating germination and applying herbicide than having to remove underground vegetative structures that allow for regrowth. A fundamental basis for proper weed management is to know the species present, their ecology, and their abundance.

Agricultural systems are highly disturbed ecosystems, constantly favouring changes in weed composition in crop production areas. Disturbances favour the adaptation and colonization of weeds, as they have evolved by developing mechanisms to adapt to different demands in their environment (Roschewitz et al. 2005). Soil tillage activities create disturbance levels ideal for weeds to thrive. In addition, weeds compete with crops better because of their physiology. They can often survive for longer periods of time without water, nutrients, or sunlight, allowing them to remain in a field even when conditions are not ideal. Crops generally are not as adaptable and may suffer from weed competition (Swanton et al. 2015).

Among the many species considered as weeds, only a few cause damage to the harvest. Moreover, most belong to three families: Poaceae, Cyperaceae, and Asteraceae. Weeds present in different agroecosystems appear according to agronomic soil management. Therefore, weeds in intensive and extensive agroecosystems may differ. They also differ from weeds occurring in pastures due to selection pressure by grazing animals.

Horticultural production under intensive systems is characterized by frequent mechanization of soils, irrigation, and use of fertilizers. These factors have a direct effect on the incidence of weeds in this production system. On the other hand, weed control in intensive systems is chemical, with the indiscriminate use of herbicides. In grain production, the most widely used chemical for weed control is atrazine (UNEP Chemicals 2002). Atrazine is a pre-emergent herbicide that generally restricts the growth of broadleaf weeds widely used in maize and sorghum (Rosales-Robles et al. 2011).

Although transgenic crops have been developed, e.g. glyphosate resistant maize varieties, there are always weeds in this agro-ecosystem (Livingston et al. 2015). Glyphosate resistant weeds have developed as a result of increased use of glyphosate over time and a decrease in the use of other herbicides (Schütte et al. 2017). Manual weeding, which involves physically removing weeds by hand or with tools, is an effective method of weed control. However, it is only applicable in small areas as it generates higher labour costs, which are not feasible in large areas. Manual weeding also reduces resistance to herbicides.

Monroy et al. (1993) demonstrated how weed composition changes based on herbicide application. They evaluated three herbicides and harrow land preparation as forms of weed control.

Their findings show that a change in weed composition occurred at field level. Their findings also showed a reduced weed diversity on all the herbicide applications, except for paraquat. A similar study to compare the abundance, richness, and diversity in monocultures was carried out in Bajio, Mexico. In this study, diversity evaluation considered the relative importance of native and exotic species. The most abundant native species were: *Parthenium hysterophorus* (Asteraceae), *Portulaca oleracea* (Portulacaceae), *Amaranthus hybridus* (Amaranthaceae), and *Tithonia tubaeformis* (Asteraceae). Fifth in abundance, and the most important exotic species was, *Brassica nigra* of the family Brassicaceae (Guzmán-Mendoza et al. 2022). Factors such as crop rotation and shallow soil disturbance are intimately related to weed composition, affecting not only the abundance of herbaceous plants, but also diversity and composition.

The objective of the study was to compare the herbaceous weed composition on three differently managed agroecosystems: intensive, extensive, and pasture; this include: identify the weeds present in each agroecosystem; determine the abundance of each weed species for each agroecosystem based on life cycle and form of reproduction; and compare weed diversity across agroecosystems through a diversity index.

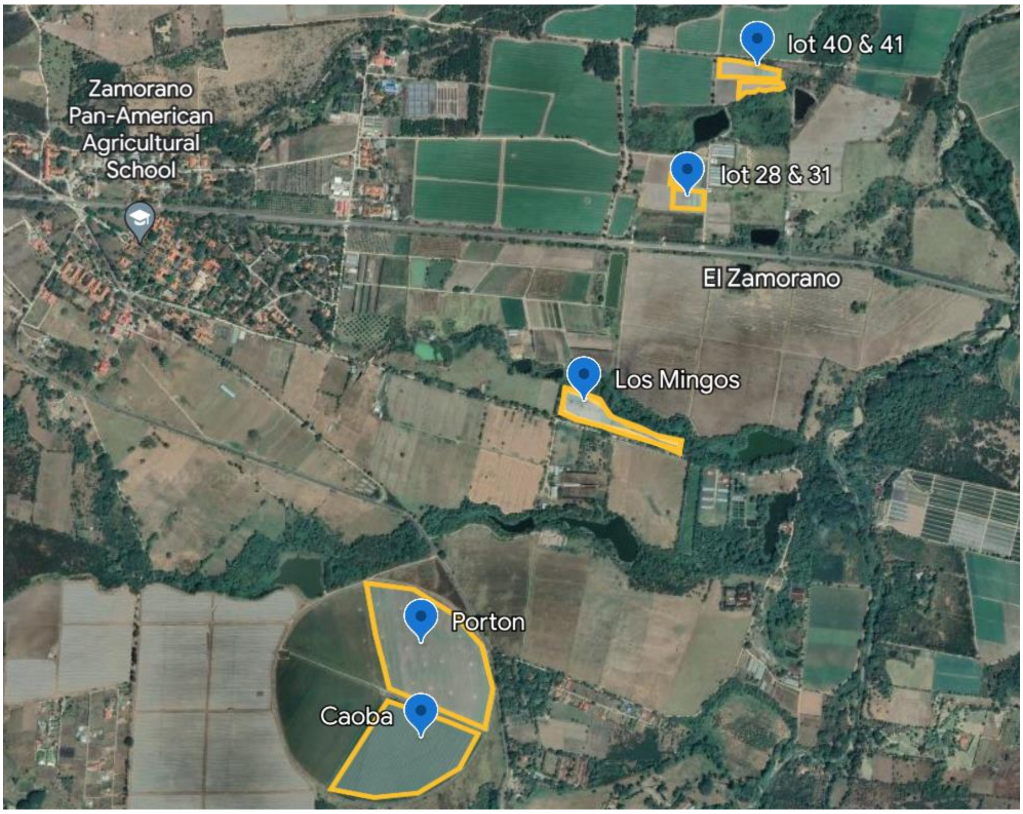
Materials and Methods

Study Area

The Pan-American Agricultural School, Zamorano, is located 32 km southeast of Tegucigalpa, Honduras. Is located at 14° 00' North latitude and 86° 59' West longitude, at an altitude of about 800 m above sea level with an average annual rainfall of 1100 mm (Figure 1). The reported mean precipitation by the meterological station at central campus for the months of January and February were 1.87 mm and 0.44 mm.

Figure 1

Map showing sampled lots for weed diversity study in Zamorano, Honduras



Description of Treatments

The study was carried out in three agroecosystems: intensive, extensive, and pasture (Table 1). These agroecosystems are managed differently for the production of different crops of economical value. The total area sampled was 12.5 m^2 for each agroecosystem.

Table 1

Description of the treatments used in weed diversity study in Zamorano, Honduras.

Treatment	Description
Extensive Agroecosystem	pH: 5 (Caoba), 4.91 (Porton); Legumes, grain, and seeds; soil compaction with low effective depth.
Intensive Agroecosystem	pH: 6.16 to 7.36; lettuce, onion, corn, and tomato; soils with reported clay presence
Pasture Agroecosystem	pH: 6.38; actual use: *Megathyrsus maximus;* soil type: Sandy loam

Intensive Agroecosystem

An intensive managed agroecosystem aims to achieve high yields and profitability based on high input of resources such as labor, fertilizers, and technology. In intensive agriculture, management is more rigorous compared to extensive agriculture. Especially weed management, through labor intensive manual weeding. Today both intensive and extensive agriculture use large areas of land due to shifts in farming methods favoring large areas. In the intensive agroecosystem sampling was carried out in lots 28, 31, 40, and 41 of Zone 3. These lots are in constant rotation with vegetable crops. During sampling lot 28 was in lettuce (*Latuca sativa*) production. On the other hand, lot 31 was planted with tomatoes which had finished the production cycle. Onion and lettuce were the established crops in lot 40 and 41. The lots are drip irrigated.

Weeding is mostly done by hand during the production stage. Plastic mulch is used mainly for weed control in lot 40. Post emergent herbicide applications are made at least twice during the production cycle. Glyphosate herbicide, a systemic post-emergence herbicide, is used to kill both annual and perennial weeds, broadleaves, and woody weeds. Since it is a non-selective herbicide, glyphosate is used in post emergence applications before transplanting. The weeds would have emerged, and control is possible in the most vulnerable stage, which is the early growth stages. The way this is done is stimulating germination with irrigation, usually around two weeks before transplanting. This way phytotoxicity to crop is avoided. In intensive agroecosystem, soil preparation is frequent for each crop established. One or even two heavy plough passes are made, followed by a light harrow pass. Sometimes roto tillering machines are used for levelling, a form of secondary tillage (Barahona 2023). All crops are planted on mechanically prepared seedbeds.

Extensive Agroecosystem

On the other hand, an extensive agroecosystem is an agricultural system that produces mainly in monoculture, wholly through technology input. For Extensive agroecosystem, sampling was distributed in Porton and Caoba sectors of the central pivot irrigation system. In the case of extensive agroecosystem sorghum, corn, and beans are produced in this area, for seed or forage production. A central pivot irrigation system allows continued production. Silage maize grown is genetically modified, being glyphosate resistant. A single application of glyphosate when corn has three true leaves (V3) is enough to suppress weeds. Furthermore, the planting densities used allow for a good cover, reducing weed incidence. For a successful crop establishment, land preparation is required for seed germination. Sorghum seeds are minute; therefore, land preparation breaks and removes soil aggregates and crop residues, making soil uniform.

The mode of weed control in this production system is mainly chemical. Preemergent herbicide application for grasses and broad leaf control is done. Land preparation as cultural control prior to seed sowing is a form of weed control. Although this method is useful, it is necessary to know weeds present and their life cycle as they can spread unintentionally. Additional weed control is also done with a tractor mounted cultivator, a task usually accompanied by nitrogen fertilization with urea. Field cultivators facilitate fertilization and pesticide applications during secondary tillage.

Lot Porton is a section of the central pivot irrigation system part of the extensive agroecosystem that was sampled. This lot has an area of 11.8 ha. At the time of weed sampling, the cover crop *Crotalaria juncea* (Fabaceae) was in adequate maturity for incorporation. Land preparation is done with one plough pass, followed by two harrow passes. Harrow passes are done perpendicular or parallel to furrows. Two corn harvests were done eight months (each cycle is 120 days) prior to incorporating *Crotalaria juncea*. This year *Crotalaria juncea* was incorporated with the purpose of adding organic matter to soil. Corn seeds used in this lot are transgenic. Glyphosate resistant corn is a genetically modified (GM) corn variety that has been engineered to withstand glyphosate herbicide. Glyphosate interferes with normal plant metabolism inhibiting the enzyme 5-enolpyruvyl-3-phosphoshikimic acid synthase (EPSPS) (Paiola Albrecht AJ. et al. 2014; Schütte et al. 2017). This enzyme is not affected by glyphosate; therefore, corn can continue its normal amino acid synthesis and grow normally, even when glyphosate is applied to the surrounding weeds. Contrary to conventional crops, glyphosate resistant corn allows glyphosate herbicide to be applied in post emergence when crop is in early phenological stages, maximum V2, second seed leaf.

The adoption of herbicide resistant crops has reduced crop rotation and favored weed management that is solely based on the use of herbicides. However, continuous herbicide resistance cropping and the intensive use of glyphosate over the last 20 years have led to the appearance of at least 34 glyphosate-resistant weeds species worldwide (Schütte et al. 2017).

Caoba forms part of the study area under extensive management. The total area for this sector is 13.8 ha. At the time of sampling there was an established sorghum plantation for seed in stage five, that is in boot stage shortly before flowering. Preemergent herbicides atrazine for dicotyledonous weeds and pendimethalin for monocotyledons weed control are used.

Pastoral Agroecosystem

Pastoral agroecosystem Los Mingos forms part of a pastoral circuit which consists of 26 grazing paddocks for bovines in the beef cattle unit. The pasture established in this agroecosystem is forage Poaceae, *Megathyrsus maximus* known locally as Tobiatá, widely used in livestock farming systems in the tropics. Tobiatá is used in direct grazing systems, cutting, and fodder conservation systems. Form of seeding is broadcast seed spreader. To make up for soil nutrient deficiencies, pastures are fertilized annually with urea, granulated KCl, and magnesium sulfate.

Data Collection and Sampling

The sampling period was carried out in January and February, during the height of the dry season in Honduras. The dry season usually runs from November to May. A quadrat of dimensions 0.50m x 0.50 m (0.25m^2) was used for sampling. A total of 50 sampling sites were arbitrarily selected within each agro-ecosystem, simulating a zigzag pattern throughout the field in order to make a representative sampling. With the help of photographic guides (Pitty and Muñoz 1994) and the iNaturalist citizen science platform, the number of species and individuals within each quadrat were identified and quantified. The iNaturalist platform uses a community-driven model to identify observations uploaded by anyone on the platform (California Academy of Sciences y National Geographic Society 2008). Additionally, experts and volunteers collaborate on identification of observations. To avoid underestimating or overestimating the number of individuals, plants were removed or cut once they were counted.

When weeds could not be identified in the field, they were collected and transported to the Paul C. Standley Herbarium at Zamorano University, for proper taxonomic identification. Some weed species were photographed and uploaded in iNaturalist for comparison to reference photos and validation from the iNaturalist user community. iNaturalist becomes a useful verification tool in this case. iNaturalist uses artificial intelligence and expert judgment to improve the efficiency and accuracy of taxonomic identification (Heberling and Isaac 2018).

Life Cycle

The length of life and season of growth can be used to classify weeds (Radosevich et al. 1997). The life cycles considered in this study include annuals, perennials, and biennials. Annuals are plants that typically start from seeds, grow, produce flowers, fruits, and then set new seeds, completing their life cycle within a year. Usually, they are considered easy to control. Annuals have fast growth rates and produce an abundance of seeds which may lay dormant in soil for many years. Many plants considered as biennials may not flower until they are three or more years of age. All biennials flower only once and then die. Perennials live for more than two years and are characterized by renewed growth year after year from the same root system. Most perennials reproduce by seed, and many can spread vegetatively, thus presenting an advantage.

Reproduction

The forms of reproduction sexual or asexual were considered as a focus in understanding their presence in the weed community. Sexual reproduction consists in the production of viable seeds. Some seeds can remain viable for a long period of time. Dormancy in seed helps weeds to emerge in a staggered manner. As for asexual reproduction, plant-specific factors such as vegetative structures and rapid growth pose challenges for control. Apical dominance in perennials is a focus of interest, as agricultural practices such as the use of disc implements, and mechanical control breaks dominance and create new growing points consequently increasing weed infestations. In conservation tillage, this effect is reduced, thus reducing potential for weed infestations.

Data Analysis

The weeds sampled were classified based on taxonomic family, species, and life cycle. For species name verification, information on life cycle, and reproduction, Tropicos v3.4.2 (Tropicos.org 2023) data base was used. Additionally, the percentage incidence was calculated. Percentage incidence refers to the number of weeds compared to the total number of weeds sampled. The abundance for each agroecosystem was determined by the number of species present. This was then used to compare species richness among the three agroecosystems. Diversity was determined using the Shannon index.

Diversity Index

To determine species diversity in a particular site, there are various diversity indices that consider the number of species and number of individuals of each species (Mostacedo and Fredericksen 2000). In this study the popular Shannon index was used. The Shannon index is one of the most widely used by researchers in ecology, as it is easy to use and to make comparisons between studies. The Shannon index ranges from 0 to 5, with the lower number indicating low diversity and the higher number indicating high diversity. The maximum diversity of this index is measured $H_{max}= \ln S$, which is given when all species have been represented (Pla 2006). The values for the Shannon index and its standard deviation were obtained with EstimateS software program. The standard deviation for the estimated index value was also used to determine whether there was significant difference (±0.05 probability is equivalent to two standard deviations in each direction when residuals are normally distributed) among the three agroecosystems.

The formula 1 used to calculate the Shannon-Wiener index is explained below:

$$H' = -\Sigma Pi * \ln Pi \qquad [1]$$

Where:

H' = Shannon-Wiener index

P_i = Proportion of each species *i*

Ln = natural Logarithm

Dominance

A dominance histogram allows for a better understanding of the weed community composition. The dominant species or groups (highest frequencies) will be the most abundant and important in any community. Important weed management decisions can be drawn with dominance histograms. This is so because, a dominating species will be the primary target for weed control. Furthermore, management efforts can be prioritized based on the relative abundance of species in agroecosystems.

Accumulation Curve

A species acumulation curve graphically represents how species richness increases with sampling effort or the increase in number of individuals sampled. When a species accumulation curve reaches its asymptote, even with increasing number of sampled units, species number does not increase, and sampling can be considered complete (Alvarez et al. 2004). Species accumulation curves can also be used to estimate species richness by extrapolating the curves until an asymptote is reached. Furthermore, the richness of communities can be compared with curves, even when the curves have not reached an asymptote and when the sampling effort differs (providing the sampling unit is similar). A curve that is different than another, and whose mean curve falls outside the 95% confidence interval of the comparison curve, can be deemed significantly different. To create accumulation curves for each agroecosystem treatment, samples were randomly ordered with the EstimateS program using the default settings (Colwell 2013). Rarefaction is a technique used in ecology and biodiversity to compare the diversity of different samples or communities, especially when sample sizes are unequal. This program generates 100 possible curves in random order and then presents an average, smoothed curve along with a 95% confidence interval for the average curve. The goal of rarefaction is to standardize the sample size.

Results and Discussion

Extensive Agroecosystem

In extensive agroecosystem, 22 species were distributed in 11 families (Table 2). The families with the most species were Asteraceae and Poaceae each with six species. In the Asteraceae all the species preferred form of reproduction is sexual, through seed. Similarly, among all the species in the Poaceae family, only *Sorghum halepense* presents asexual, vegetative reproduction. Consequently, the prevalent life cycle present in this agroecosystem is annual (18 species). Only four species present perennial life cycle. Furthermore, the most abundant species: *Melampodium divaricatum* and *Bidens pilosa*, both Asteraceae, account for 51.44% and 13.48% of incidence, respectively. Furthermore, among the Poaceae, *Digitaria sanguinalis* had the highest incidence (7.31%). However, *Cyperus rotundus* presented higher incidence (7.45%) compared to any of the Poaceae. The species with both sexual and asexual forms of reproduction are: *Commelina diffusa* (6.62%), *Cyperus rotundus* (7.45%), *Sorghum halepense* (0.41%), and *Richardia scabra* (0.27%) (Table 2).

The high incidence of *Melampodium divaricatum* could be related to its fast germination and sustained growth. Hanan-Alipi et al. (2021) showed that all seeds in this species presented 100% germination within three days. A fast growth rate was observed in the first few days in seedlings, where more than half of the five-day-old seedlings had branched roots. Another study evaluating the soil seed bank in Chiapas, Mexico, determined *Melampodium divaricatum* seeds were abundant in the first 10 cm (Aguilar Jiménez et al. 2020). Apparently, *Melampodium divaricatum* seeds at greater depths lose germinating vigor and emergence is difficult.

The form of reproduction for *Bidens pilosa* is through seeds. A single isolated plant can produce over 6,000 seeds per year (Rojas-Sandoval 2022), which can be dispersed by attaching to animals, birds, humans, or via water and wind. Given that land preparation is done in the area, it brings seeds to the soil surface. These seeds are then stimulated by sunlight. *Bidens pilosa* requires light for germination, and if buried deep in the soil far from light these will not germinate. This was evidenced in a study evaluating *Bidens pilosa* emergence at different depths, where it was observed that exceeding 8 cm there was no emergence (Bhagirath et al. 2019).

Apart from massive seed producing ability, *Bidens pilosa* has allelopathic properties which impedes growth in other species. Interestingly, this was shown in an experiment where *Bidens* exhibited a strong phytotoxicity effect on the tuber reproduction of *Cyperus rotundus* (Hsueh et al. 2020). This may explain why *Bidens pilosa* presented higher incidence vs. *Cyperus rotundus*, a perennial that reproduces through vegetative reproduction.

Table 2

Weed composition and incidence in an extensive managed agroecosystem, Central Pivot, Zamorano, Honduras.

Family	Species	Life cycle	Form of reproduction	Number of individuals	Incidence (%)
Amaranthaceae	*Amaranthus hybridus*	annual	seed	1	0.05
Asteraceae	*Bidens pilosa*	annual	seed	295	13.48
	Melampodium divaricatum	annual	seed	1126	51.44
	Sclerocarpus phyllocephalus	annual	seed	68	3.11
	Emilia fosbergii	annual	seed	1	0.05
	Ageratum conyzoides	annual	seed	7	0.32
	Eclipta alba	annual	seed	4	0.18
Commelinaceae	*Commelina diffusa*	perennial	seed, vegetative	145	6.62
Cyperaceae	*Cyperus rotundus*	perennial	seed, vegetative	163	7.45
Molluginaceae	*Mollugo verticillata*	annual	seed	2	0.09
Onagraceae	*Ludwigia octovalvis*	annual	seed	30	1.37
	Ludwigia sp.	annual	seed	4	0.18
Plantaginaceae	*Scoparia dulcis*	annual	seed	4	0.18
Poaceae	*Cynodon nlemfuensis*	perennial	seed	1	0.05
	Eleusine indica	annual	seed	112	5.12
	Digitaria sanguinalis	annual	seed	160	7.31
	Sorghum halepense	perennial	seed, vegetative	9	0.41
	Rottboellia cochinchinensis	annual	seed	9	0.41
	Urochloa fusca	annual	seed	2	0.09
Portulacaceae	*Portulaca oleracea*	annual	vegetative	21	0.96
Rubiaceae	*Richardia scabra*	annual	seed, vegetative	6	0.27
Solanaceae	*Nicandra physalodes*	annual	seed	19	0.87
Total				2189	100%

Intensive Agroecosystem

In the case of an intensively managed agroecosystem, ten families were distributed in 23 species (Table 3). The most abundant families were Asteraceae and Poaceae, with six and seven species, respectively. *Melampodium divaricatum* was the most abundant among the Asteraceae with 267 individuals. The major form of reproduction presented in this agroecosystem is sexual. The, dominant life cycle present is annual. The species with the highest incidence were *Melampodium divaricatum* (24.08%), *Cyperus rotundus* (22.63%), and *Portulaca oleracea* (12.35%) (Table 3). Presumably, the dominance of these two families reflects the large number of species they have (Chacón and Saborío-R 2006). *Melampodium divaricatum* presents an annual life cycle and seed production as the main form of reproduction. However, *Cyperus rotundus,* a perennial, presents both sexual and vegetative reproduction (Table 3).

One of the most aggressive weeds described (Holm 1977, as cited by Ferri et al., 2009), *Cyperus rotundus*, has an advantage with tillage and land preparation practices through vegetative reproduction. Land preparation prior to each new crop facilitates *Cyperus rotundus* propagation which is fragmented by agricultural implements thereby increasing the number of plants (Martínez de Carrillo and Alfonso 2003). Vegetative propagation multiplies the most successful genotypes very quickly. They produce buds or meristems that can generate shoots and roots, and they serve as storage and carbohydrate reserve tissues (Leguazimon 2000). These structures include stolon, rhizomes, tubers, and bulbs and some weeds have more than one. Such is the case of *Cyperus rotundus*, which has rhizomes, bulbs, and tubers. Tubers contribute significantly to weed propagation, increasing its competitive ability due to the mobility of energy reserves. Preexisting reserves allow for a rapid emergence and growth of new shoots presenting a greater competitive advantage compared to weeds produced through seeds.

Portulaca oleracea is a cosmopolitan species and grows well in disturbed areas. *Portulaca oleraceae* is a succulent, annual herbaceous plant. It is a highly efficient, drought resistant plant species. Kafi and Rahimi (2011) suggest that portulaca is moderately tolerant to salt and can withstand soil salinity. Therefore, salinity caused by excessive fertilization does not pose a problem to *Portulaca oleracea*. This plant can reproduce by seed and vegetatively. Its life cycle is complete in two to four months, with an exceptional ability to re root after hoeing once stems contain moisture. It stands out for its ability to switch from C4 to CAM metabolism, which has been observed under induced stress (Carrascosa et al. 2023). This in turn, makes it highly competitive in hot, dry conditions. Irrigation needs for *Portulaca oleracea* are low since it is a succulent C4–CAM plant, able to grow under severe drought stress (Carrascosa et al. 2023). Its presence in this agroecosystem can be attributed to the constant land preparation in the area. Tillage consists in mechanically manipulating the soil and plant residues to prepare an appropriate seedbed for crop planting. Although these practices offer several advantages for crop growth (Reicosky and Allamaras 2003), it promotes *Portulaca oleracea* growth through vegetative reproduction. A reduction on land preparation would allow for less vegetative fragmentation of *Portulaca oleracea* and other weeds that reproduce vegetatively, thereby reducing its growth.

Table 3

Weed composition in an intensively managed agroecosystem, Zone 3, Zamorano, Honduras.

Family	Species	Life cycle	Form of reproduction	No. of plants	Incidence (%)
Amaranthaceae	*Amaranthus spinosus*	annual	seed	53	4.78
	Amaranthus hybridus	annual	seed	15	1.35
Asteraceae	*Baltimora recta*	annual	seed	2	0.18
	Melanthera nivea	perennial	seed	1	0.09
	Parthenium hysterophorus	annual	seed	2	0.18
	Melampodium divaricatum	annual	seed	267	24.08
	Eclipta alba	annual	seed	65	5.86
Commelinaceae	*Commelina diffusa*	perennial	seed	22	1.98
Cyperaceae	*Cyperus rotundus*	perennial	seed, vegetative	251	22.63
	Cyperus odoratus	perennial	seed, vegetative	1	0.09
Fabaceae	*Aeschynomene scabra*	perennial	seed	7	0.63
Molluginaceae	*Mollugo verticilliata*	annual	seed	4	0.36
Onagraceae	*Ludwigia octovalvis*	annual	seed	7	0.63
Poaceae	*Digitaria sanguinalis*	annual	seed	91	8.21
	Echinochloa colona	annual	seed	40	3.61
	Eleusine indica	annual	seed	105	9.47
	Ixophorus unisetus	perennial	seed	11	0.99
	Leptochloa filiformis	annual	seed	10	0.90
	Rottboellia cochinchinensis	annual	seed	1	0.09
	Sorghum halepense	perennial	seed, vegetative	6	0.54
Portulacaceae	*Portulaca oleracea*	annual	seed, vegetative	137	12.35
Solanaceae	*Nicandra physalodes*	annual	seed	10	0.90
	Solanum americanum	annual	seed	1	0.09
Total				1109	100%

Pastoral Agroecosystem

A total of 14 families and 33 species were recorded in the area. Asteraceae (6), Fabaceae (7), and Poaceae (4) presented the most species (Table 4). *Sporobulus indicus* was widely spread throughout the area. In fact, it was the species with highest incidence (43.67%), followed by *Sclerocarpus phyllocephalus* (14.72%) and *Pseudelephantopus spicatus* (11.09%). The major form of reproduction was sexual. However, the life cycle was distributed in more perennial plants versus annuals (Table 4).

The species that appeared in this agroecosystem included shrubs found neither in extensive nor intensive agroecosystem. For the past seven years, no herbicides have been applied in these pastures. This agroecosystem is managed under rotational grazing. Rotational grazing is a management practice that seeks to optimize forage production and the use of natural resources. It is based on principles of respect for the soil, vegetation, and livestock, and focuses on improving rangeland health, and increasing productivity in a sustainable manner. This holistic management may have triggered *Sporobulus indicus* propagation. This is similar to the findings of Adeux et al. (2022) for grasslands with no tillage, in which pastures favored grass and perennial weed species. Similarly, Santín-Montanyá et al. (2013) reported that the weed abundance, richness, and evenness are greatly increased in the no-tillage treatment. Poaceae family high species richness is related to the way most of their species grow with dense clumps or the presence of rhizomatous and stoloniferous individuals widely scattered in the weed community (Munhoz and Felfili 2006). Pastures often present weed species that are not palatable and sometimes toxic to livestock. These species are often members of the families Asteraceae, Euphorbiaceae, and Solanaceae. All these families were found in the sampled site. Due to toxicity, these plants avoid herbivory, therefore, they can persist. According to Martin (1993), by having animals selecting the most palatable species, they allow more growing space for more of the less palatable species. As a result, the composition of the pasture will change drastically, causing weeds to predominate. Perennials allow for greater coverage and can withstand foraging as well as adverse climatic conditions.

Table 4

Weed composition in a pastoral agroecosystem managed under rotation, Los Mingos, Zamorano, Honduras

Family	Species	Life cycle	Form of reproduction	Number of individuals	Incidence (%)
Acanthaceae	*Blechum pyramidatum*	annual	seed	17	3.85
	Ruellia blechum	annual	seed	1	0.23
Amaranthaceae	*Achyranthes aspera*	annual	seed	2	0.45
Apiaceae	*Eryngium foetidum*	perennial	vegetative	5	1.13
Asteraceae	*Ageratum conyzoides*	annual	seed	1	0.23
	Cyanthillium cinereum	annual	seed	6	1.36
	Sclerocarpus phyllocephalus	annual, perennial	seed	65	14.74
	Pseudelephantopus spicatus	perennial	seed, vegetative	49	11.09
	Melanthera nivea	perennial	seed	5	1.13
	Eclipta alba	annual	seed	1	0.23
Cucurbitaceae	*Cucumis anguria*	annual	seed	1	0.23
Cyperaceae	*Cyperus odoratus*	perennial	seed, vegetative	7	1.58
Euphorbiaceae	*Euphorbia hyssopifolia*	annual	seed	1	0.23
Fabaceae	*Acacia farnesiana*	perennial	seed	1	0.23
	Aeschynomene scabra	perennial	seed	2	0.45
	Desmodium intortum	perennial	vegetative	4	0.90
	Enterolobium cyclocarpum	perennial	seed	1	0.23
	Indigofera jamaicensis	perennial	seed	3	0.68
	Macroptilium atropurpureum	perennial	seed, vegetative	3	0.68
	Mimosa pudica	perennial	seed	2	0.45
Malvaceae	*Sida acuta*	annual	seed	41	9.28
	Sida spinosa	annual	seed	1	0.23
Passifloraceae	*Passiflora foetida*	annual, perennial	seed	1	0.23
	Passiflora bicornis	perennial	seed	2	0.45
Poaceae	*Sporobolus indicus*	perennial	seed, vegetative	193	43.67
	Paspalum notatum	perennial	seed, vegetative	12	2.71
	Axonopus escoparius	perennial	seed, vegetative	2	0.45
	Cynodon dactylon	perennial	seed, vegetative	5	1.13
Solanaceae	*Nicandra physalodes*	annual	seed	1	0.23

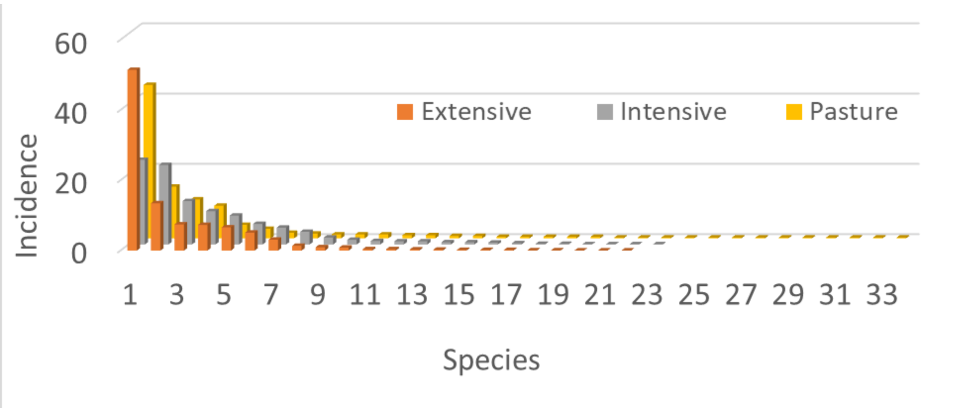
Family	Species	Life cycle	Form of reproduction	Number of individuals	Percentage incidence (%)
	Solanum viarum	perennial	seed, vegetative	1	0.23
	Solanum torvum	perennial	seed	4	0.90
Sterculiaceae	*Waltheria indica*	perennial	seed	1	0.23
Verbenaceae	*Lantana camara*	perennial	seed	1	0.23
Total				442	100%

Dominance

A community with low dominance will have a more even distribution of species. The opposite occurs in a community with high dominance. Therefore, high dominance indicates one or a few species are dominating the community or have the highest incidence. Comparing the three agroecosystems pasture and extensive agroecosystems had a single species demonstrating high dominance (Figure 2). This would have caused an unexpected higher diversity index for pasture and extensive agroecosystem. In pastoral agroecosystem the dominant species is *Sporobulus indicus* having a notable effect on a lower diversity compared to intensive agroecosystem. Extensive agroecosystem has a dominant species and intensive has a lower dominance among all the agroecosystems. The species in intensive compared to the either extensive and pasture is more even, therefore there is high diversity.

Figure 2

Histogram showing weed dominance present in three agroecosystems in Zamorano, Honduras



Comparison of Weed Diversity Across Agroecosystems

The Shannon-Wiener index is one of the most widely used by researchers in ecology, as it is easy to use and to make comparisons between studies. The index is maximized when all species are equally abundant in the sampled community. Here the mean Shannon indices, after resampling, were highest for the intensive agroecosystem (H=2.25) and lowest for the extensive agroecosystem

(H=1.72). Pastures had intermediate diversity. These indices had very low standard deviations indicating that the differences among them are highly significant (Table 5).

When the Shannon index for weeds is higher, it suggests that there are more weed species present, and their relative abundances are more evenly distributed. This can be an indicator of a healthier and more ecologically balanced weed community. According to Storkey and Neve (2018) a more diverse weed community is less competitive in any given crop. When different weed species coexist, they may occupy different ecological niches, such as variations in resource utilization, growth patterns, or rooting depths. This niche differentiation can alleviate direct competition for resources like water, nutrients, and sunlight, potentially leading to lower competition and better overall weed community balance. Aavik and Liira (2009), suggest that increase in diversity of native species would be signs of healthy ecosystem processes in the agricultural landscapes.

The pastoral agroecosystem with diversity index of 2.08, presented an intermediate diversity. Considering *Sporobulus indicus* has a percentage incidence of 43.76, being the predominant species in the area it could have caused a lower diversity compared to intensive agroecosystem. A higher incidence of a single species, in any agroecosystem may have affected the overall result for the Shannon index. The case of extensive agroecosystem presented a lower Shannon index.

Table 5

Shannon-Weiner index for the studied agroecosystems in Zamorano, Honduras.

Agroecosystem	Shannon index (Diversity)	Standard deviation
Extensive	1.72	0
Intensive	2.25	0.01
Pasture	2.08	0

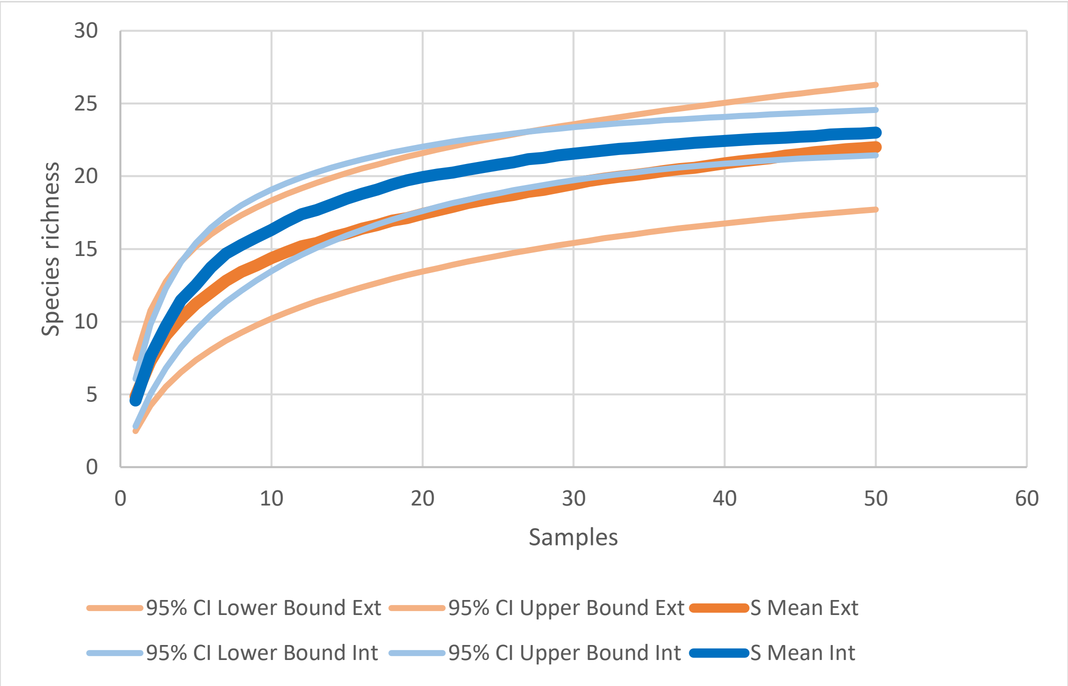
Species Accumulation Curve

The species richness curve estimates total species richness and the sampling effort needed to obtain reliable estimates of this richness. In other words, if the curve is approaching its asymptote, or stabilization point, sampling can be considered relatively complete. The species accumulation curves for extensive agroecosystem and intensive agroecosystem do not stabilize even in the final sampling.

This indicates that the sampling effort was not enough to record all species in the area (Figure 3). Intensive managed agroecosystem appears to continue rising not nearing a stabilization point. Further sampling would rarely add new species (Figure 3). Whereas, in extensive agroecosystem the curve appears to be slightly increasing. A further extrapolation of the curve would give a possible number of samples to reach a stabilization point. This then would be a complete sampling for the species in the area. These two agroecosystems are very similar in weed diversity and composition, therefore the Shannon mean for both are close.

Figure 3

Species accumulation curve comparing intensive vs. extensive managed agroecosystem in Zamorano, Honduras.

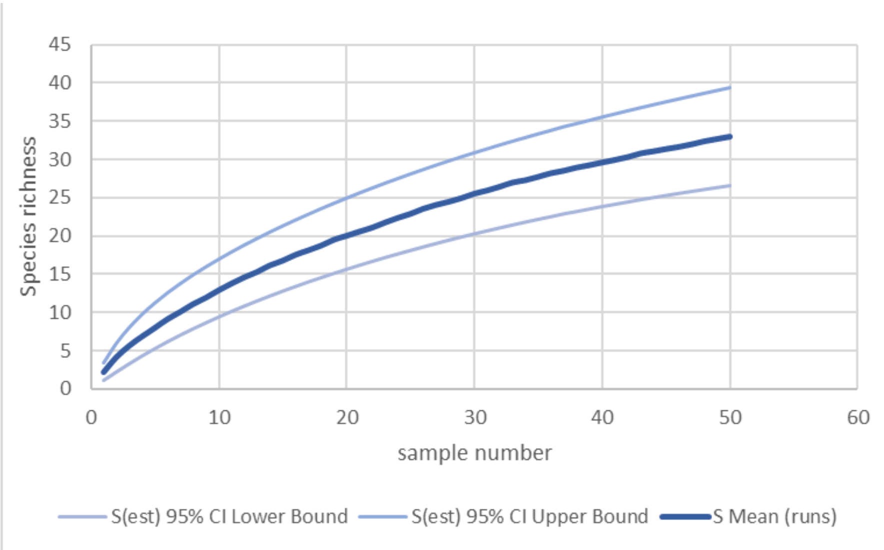


Although pastures presented the highest species richness, at sample number 50 the curve kept ascending. This indicates that more species could be found if we increased sampling effort. Futhermore, cattle trampling and foraging encourages germination of seeds accumulated in the soil seed bank after having dispersed from another location. Having more species in the area may reduce the prevalence of dominance in the species community, which explains the higher Shannon index compared to the Extensive Agroecosystem.

Although the accumulation curve indicated highest richness in pastures (Figure 4), the Shannon index did not reflect highest diversity in this agroecosystem. A higher Shannon index in intensive could be due to the more varied and intensive management practices. Intensive agroecosystems often involve more frequent and intense management practices, such as tillage, herbicide use, and monoculture cropping.

Figure 4

Species accumulation curve for pastoral agroecosystems in lot Los Mingos, Zamorano, Honduras.



Conclusions

The way agroecosystems are managed, including agricultural practices, can affect the structure and dynamics of the weed populations present.

Weeds present in agroecosystems intensive, extensive, and pasture were represented in two major families*:* Poaceae and Asteraceae.

Extensive and intensive agroecosystem presented sexual reproduction as the major form of reproduction and the predominating life cycle was annual similar to the crops grown in the area. On the other hand, pasture had more species that reproduce through vegetative structures and presented species of perennial cycle.

Intensive agroecosystem had lowest dominance and highest diversity. Pasture has significantly higher richness but also higher dominance resulting in intermediate diversity. Extensive agroecosystem has higher dominance and low species richness.

Recommendations

Evaluate the effect of different levels of tillage in perennials and annuals conforming important weed communities.

Increase the number of sampling units and sites in pasture to document all the species.

Conduct inventories at the height of the wet season, when the highest percentages of cover can be recorded, and at the beginning of the dry season when many species with short life cycles and seasonal vegetative growth are present.

Perform randomized sampling using a coordinate-based system for less bias in sampling. Replications of the study including more variables (weed phenology, soil type, moisture, and temperature, and weed distribution) that would help explain this significance.

References

Aavik T, Liira J. 2009. Agrotolerant and high nature-value species—Plant biodiversity indicator groups in agroecosystems. Ecological Indicators. 9(5):892–901. doi:10.1016/j.ecolind.2008.10.006.

Adeux G, Yvoz S, Biju-Duval L, Cadet E, Farcy P, Fried G, Guillemin J-P, Meunier D, Munier-Jolain N, Petit S, et al. 2022. Cropping system diversification does not always beget weed diversity. European Journal of Agronomy. 133:126438. doi:10.1016/j.eja.2021.126438.

Aguilar Jiménez CE, Tolón Becerra A, Martínez Aguila FB, Febles González JM, Vásquez Solís H, López Hernández JC. 2020. Caracterización del banco de semillas de cuatro agroecosistemas de la Frailesca, Chiapas, México. Siembra; [accessed 2023 Jun 28]. 7(2):93–107. https://www.redalyc.org/journal/6538/653869547008/.

Alvarez M, Cordoba S, Escobar F, Gast F, Mendoza H, Ospina M, Umaña AM, Hector V. 2004. Manual de métodos para el desarollo de inventarios de biodiversidad. Bogota: Panamericana Formas e Impresos S.A. ; [accessed 2023 Jun 24]. http://repository.humboldt.org.co/bitstream/handle/20.500.11761/31419/63.pdf?sequen.

Barahona U. 2023. Land preparation and applications of Zone 3 [Interview]. Honduras: [publisher unknown]. 2023 Mar 27; [updated 2023 Mar 27].

Bhagirath C, Hafz A, Singarayer F. 2019. Seed germination ecology of *Bidens pilosa* and its implications for weed management. Scientific research; [accessed 2023 Jun 28]. 9. doi:10.1038/s41598-019-52620-9.

California Academy of Sciences y National Geographic Society. 2008. iNaturalist. 1.29.3. California: iNaturalist; [accessed 2023 Mar 24]. https://www.inaturalist.org/.

Carrascosa A, Pascual JA, Ros M, Petropoulos SA, Alguacil Del Mar M. 2023. Agronomical Practices and Management for Commercial Cultivation of *Portulaca oleracea* as a Crop: A Review. Plants (Basel). 12(6). eng. doi:10.3390/plants12061246.

Chacón E, Saborío-R G. 2006. Análisis taxonomico de las especies de plantas introducidas en Costa Rica. LANKESTERIANA; [accessed 2023 Jun 24]. 6(3):139-147. https://www.redalyc.org/pdf/443/44339812007.pdf.

Colwell RK. 2013. EstimateS. 9.1.0. [place unknown]: Colwell; [accessed 2023 May 24]. http://purl.oclc.org/estimates.

Guzmán-Mendoza R, Hernández-Hernández V, Salas-Araiza MD, Núñez.Palenius HG. 2022. Diversidad de especies de plantas arvenses en tres monocultivos del Bajío, Mexico. Polibotanica. (53):69–85. doi:10.18387/polibotanica.53.5.

Hanan-Alipi AM, Vibrans H, Vega-Frutis R, Juárez-Rosete CR, Valdivia-Bernal R, Velázquez-Fernández J. 2021. Growth, reproduction and weediness: testing four related species on a gradient of synanthropy. Bot. Sci. 99(1):43–57. doi:10.17129/botsci.2599.

Heberling JM, Isaac BL. 2018. iNaturalist as a tool to expand the research value of museum specimens. In: Applications in Plant Sciences. Vol. 6. [place unknown]: [publisher unknown]. 4. eng.

Hsueh M-T, Fan C, Chang W-L. 2020. Allelopathic Effects of *Bidens pilosa* L. var. *radiata* Sch. Bip. on the Tuber Sprouting and Seedling Growth of *Cyperus rotundus* L. Plants (Basel). 9(6). eng. doi:10.3390/plants9060742.

Kafi M, Rahimi Z. 2011. Effect of salinity and silicon on root characteristics, growth, water status, proline content and ion accumulation of purslane (Portulaca oleracea L.). Soil Science and Plant Nutrition. 57(2):341–347. doi:10.1080/00380768.2011.567398.

Leguazimon E. 2000. Las malezas y el agroecosystema. [place unknown]: [publisher unknown]; [accessed 2023 May 24]. https://www.researchgate.net/publication/242391146_LAS_MALEZAS_Y_EL_AGROECOSISTEMA.

Livingston M, Fernandez-Cornejo J, Unger J, Osteen C, Schimmelpfennig D, Park T, Lambert D. 2015. The Economics of Glyphosate Resistance Management in Corn and Soybean Production. Economic Reseatch Service: United States Department of Agriculture. Report No.: 184; [accessed 2023 Apr 16]. https://www.ers.usda.gov/webdocs/publications/45354/err-184.pdf?v=1964.7.

Martin FW. 1993. Forages. [place unknown]: [publisher unknown]; [accessed 2023 Jul 20]. 16 p. https://www.echocommunity.org/en/resources/b89dbbd1-c5ff-4c6a-a3bd-e505c9f47feb.

Martínez de Carrillo M, Alfonso PW. 2003. Especies de malezas más importantes en siembras horticolas del Valle de Quibor, Estado Lara, Venezuela. Bioagro; [accessed 2023 Jul 1]. 15:91–96. https://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1316-33612003000200003.

Monaco TJ, Weller SC, Ashton FM. 2002. Weed Science Principles and Practices. 4th ed. New York: John Wiley and Sons Inc. ISBN: 0471370517.

Monroy JA, Pitty A, Muñoz R. 1993. El sistema de labranza cambia la flora de malezas en maiz y frijol en relevo. Ceiba; [accessed 2023 May 29]. 34(1):65–80. https://revistas.zamorano.edu/index.php/CEIBA/article/view/527/505.

Mostacedo B, Fredericksen TS. 2000. Manual de Métodos Básicos de Muestreo y Análisis en Ecología Vegetal. Santa Cruz de la Sierra, Bolivia: Proyecto de Manejo Forestal Sostenible (BOLFOR). 92 p. ; [accessed 2023 Feb 3]. http://www.bio-nica.info/biblioteca/mostacedo2000ecologiavegetal.pdf.

Munhoz CBR, Felfili JM. 2006. Fitossociologia do estrato herbáceo-subarbustivo de uma área de campo sujo no Distrito Federal, Brasil. Acta Bot. Bras. 20:671–685. pt. doi:10.1590/S0102-33062006000300017.

Paiola Albrecht AJ, Paiola Albrecht L, Martins Barroso AA, Filho RV. 2014. O milho RR2 e o glyphosate: Uma revisão. Revista Brasileira de Herbicidas. 13(1):58–67. pt. doi:10.7824/rbh.v13i1.279.

Pitty A. 1997. Introduccion a la Biologia, Ecologia y Manejo de Malezas. Honduras: Zamorano Academic Press. ISBN: 1885995385.

Pitty A, Muñoz R. 1994. Guia Fotográfica para la Identificacion de Malezas Parte I. 188599513X. [place unknown]: DPV-EAP.

Pla L. 2006. Biodiversidad: inferencia basada en el índice de shannon y la riqueza. Interciencia; [accessed 2023 Jul 19]. 31(8):583–590. https://www.redalyc.org/pdf/339/33911906.pdf.

Radosevich S, Holt J, Ghersa C. 1997. Weed ecology: Implications for management. 2nd ed. New York: [publisher unknown]. ISBN: 0471116068.

Reicosky DC, Allamaras RR. 2003. Advances in tillage research practices in North American cropping systems. Journal of Crop production; [accessed 2023 Jul 16]. 8(1):75–125. https://www.ars.usda.gov/ARSUserFiles/50600000/Products-Reprints/2003/1069.pdf.

Rojas-Sandoval J. 2022. *Bidens pilosa* (blackjack). CABI Compendium. CABI Compendium. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/wre.12310?download=true. doi:10.1079/cabicompendium.9148.

Rosales-Robles E, Sánchez-de la Cruz R, Cerda-García PA. 2011. Control químico de maleza de hoja ancha en sorgo para grano. Revista Fitotecnia Mexicana. 34(4):269–275. https://www.redalyc.org /pdf/610/61020797006.pdf.

Roschewitz I, Gabriel D, Thies C, Tscharntke T. 2005. The effects of landscape complexity on arable weed species diversity in organic and conventional farming. Journal of Applied Ecology. 42(5):873–882. doi:10.1111/j.1365-2664.2005.01072.x.

Santín-Montanyá MI, Martín-Lammerding D, Walter I, Zambrana E, Tenorio JL. 2013. Effects of tillage, crop systems and fertilization on weed abundance and diversity in 4-year dry land winter wheat. European Journal of Agronomy. 48:43–49. https://www.sciencedirect.com/science/article/pii/S1161030113000245. doi:10.1016/j.eja.2013.02.006.

Satorre EH. 2017. Ciencia y Tecnología en el problema de las malezas de los cultivos extensivos de granos. Buenos Aires: Anales de la ANAV. ISBN: 0327-8093; [accessed 2023 Feb 4]. http://sedici.unlp.edu.ar/handle/10915/87349.

Schütte G, Eckerstorfer M, Rastelli V, Reichenbecher W, Restrepo-Vassalli S, Ruohonen-Lehto M, Saucy A-GW, Mertens M. 2017. Herbicide resistance and biodiversity: agronomic and environmental aspects of genetically modified herbicide-resistant plants. Environ Sci Eur. 29(1):1–12. En;en. doi:10.1186/s12302-016-0100-y.

Storkey J, Neve P. 2018. What good is weed diversity? Weed Res; [accessed 2023 Jun 24]. 58(4):239–243. eng. doi:10.1111/wre.12310.

Swanton CJ, Nkoa R, Blackshaw RE. 2015. Experimental methods for crop-weed competition studies. Weed Science; [accessed 2023 Jul 29]. 63:2–11. https://www.jstor.org/stable/26906687.

UNEP Chemicals. 2002. Regionally Based Assessment of Persistent Toxic Substances: Central America and the Caribbean Regional Report [Regionally Based Assesment of Persistent Toxic Substances]. Switzerland; [accessed 2023 Jun 27]. http://www.oas.org/dsd/Quimicos/Central%20America%20Caribbean%20Report%20UNEP.pdf.

Annexes

Annex A

Specimen identified in the herbarium as Passiflora bicornis by Rina Fabiola Díaz.