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Diversity And Abundance Of Weeds Associated With Cocoa (Theobroma Cacao L.) Cultivation In Three Zones Of The Ecuadorian Tropics

César Ramiro Bermeo Toledo[1], Daniel Federico Vera Aviles [1]* Mary Paz Muñoz Ronquillo [1], Favio Eduardo Herrera Eguez[1] and Freddy Agustin Sabando Avila [1]
[1]Faculty of Agricultural and Forestry Sciences, Quevedo State Technical University, Quevedo 120550, Ecuador.

*Corresponding Author: dvera@uteq.edu.ec

Abstract
Ecuador ranks as the fourth-largest global producer of cocoa and leads in the production of fine-flavor varieties. In this context, weeds—non-crop plants with no agronomic value—pose a significant threat to cocoa productivity and development. This study aimed to characterize the weed communities associated with cocoa (Theobroma cacao L.) cultivation by assessing their diversity and abundance across three tropical Ecuadorian regions: Quevedo, Buena Fe, and Valencia. Biodiversity analyses revealed that the families Caryophyllaceae, Fabaceae, and Cucurbitaceae exhibited high diversity indices. At the local scale, Buena Fe recorded the highest individual abundance, while Valencia showed elevated values in Simpson_1-D, Shannon_H, and Equitability_J indices. Floristic similarities and differences among sites were quantified using Jaccard and Bray-Curtis coefficients. The Importance Value Index (IVI) identified Geophila macropoda (Ruiz & Pav.) DC. as the most dominant species overall. Locally, Drymaria cordata (L.) Willd. ex Schult. was most prominent in Buena Fe, while Psychotria nervosa Sw. dominated Valencia. Functional analysis of reproductive traits and interference potential revealed a wide range of morphotypes and reproductive strategies, including annual and perennial life cycles and both sexual and vegetative propagation. The families Poaceae, Asteraceae, and Urticaceae were consistently prevalent. These findings underscore the ecological complexity of weed communities in cocoa systems and highlight the need for site-specific, sustainable weed management strategies.
Keywords: *community, species, abundance, dominance, importance value index*

1. INTRODUCTION

Cocoa (Theobroma cacao L.), a member of the Malvaceae family, is one of the most economically and nutritionally significant fruit crops worldwide. Beyond its central role in the chocolate industry, cocoa is valued for its nutritional profile, containing approximately 11.5% protein and only 1.0% sugars. The increasing global demand for cocoa has driven expansion in cultivation, particularly for chocolate production and cocoa butter extraction [1].

Weeds have coexisted with crops since the advent of agriculture. Despite ongoing efforts to develop effective control strategies, weed species exhibit remarkable adaptability to evolving agroecosystems. Their persistence and expansion, including the emergence of herbicide-resistant biotypes, continue to pose major challenges to crop productivity [2].

Weeds—also referred to as adventitious, noxious, or ruderal plants—are defined as “plants growing in undesired locations, typically lacking economic value and interfering with normal crop development” [3].

Understanding the composition and structure of weed communities in specific agroecological zones is essential for assessing their impact and informing management decisions [4]. Phytosociological studies provide insights into the distribution, dynamics, and ecological roles of weed species in cultivated fields. Identifying dominant and ecologically significant species enables the development of targeted cultural practices to mitigate weed pressure [5].

In Ecuador, particularly in coastal regions, weed surveys have proven effective in characterizing plant habitats and identifying species that serve as alternative hosts for pests and diseases. Their interference with agronomic operations often results in increased production costs [6]. This study aims to identify and characterize the weed communities associated with cocoa cultivation in three tropical regions of Ecuador, providing a comprehensive analysis of species diversity, structural composition, and ecological interactions.

2. MATERIALS AND METHODS

Location of the Experiment

The study was conducted between September 2023 and February 2024 in three cocoa-producing cantons of Los Ríos Province, Ecuador: Quevedo, Buena Fe, and Valencia. These regions are located within the tropical zone and exhibit distinct agroclimatic conditions (Table 1), including variations in temperature, precipitation, relative humidity, and soil characteristics.

Table 1. Agroclimatic Characteristics of the study areas

Parameters	Quevedo	Buena Fe	Valencia
Temperature (°C)	24.8 °C	24 Co	24.4 Co
Relative humidity (%)	84 %	84 %	89 %
Precipitation (mm)	2252.5 mm	2178 mm	3166 mm
Heliophany (light-hours-year)	894	1347	653
Altitude (m)	80	24	60
Topography	Irregular	Irregular	Irregular
pH	6.0	5.5	6.0
Soil texture	Loam - Clay	Loam - Clay	Franco

Source: [7] (INAMHI, 2023)

Sampling and data analysis

The study was conducted across five farms within each selected locality, with each farm constituting a one-hectare sampling unit. Within each hectare, sampling quadrats were systematically distributed following a zigzag transect pattern to ensure spatial heterogeneity. Three primary monitoring points were established per farm, and at each point, five sub-monitoring quadrats (50 × 50 cm) were delineated, resulting in a total of 45 quadrats per locality. The sampling protocol adhered to the methodology outlined by [8].

During field assessments, weed species were identified and their relative abundance recorded in accordance with the procedures described by [9]. Taxonomic classification and categorization of weed species were performed based on floristic diversity criteria as proposed by [10].

To evaluate the structural composition of the weed community within cocoa agroecosystems, quantitative ecological parameters were calculated, including absolute and relative values for density (D, DR), frequency (F, FR), dominance (Do, DoR), and the Importance Value Index (IVI). These metrics were derived using the formulas established by [8], enabling a comprehensive assessment of species' contribution to community structure.

Species diversity was quantified using standard ecological indices: species richness (S), Shannon–Wiener diversity index (H′), and Simpson's dominance index (D), following the methodologies proposed by [11, 12]. Inter-site similarity was evaluated using the Jaccard and Bray–Curtis indices to determine compositional overlap among sampling zones. All statistical analyses were performed using the software package described in [13].

D = total number of individuals of the species / total area (m^2) sampled;
DR = density / density of all species x 100;
F = number of quadrats where the species was found / total number of quadrats;
FR = frequency of the species / frequency of all species x 100;
Do = number of individuals of a species x 100 / total number of individuals of all species;
DoR = dominance of the species / dominance of all species x 100;
IVI = FR + DR + DoR.

3. RESULTS

Diversity, wealth and equity index

Analysis of weed community composition at the family level revealed a total of 27 botanical families encompassing 2,891 individual specimens. Among these, the Fabaceae family exhibited the highest diversity values, with a Simpson's index (1–D) of 0.65 and a Shannon–Wiener index (H′) of 1.08, indicating both richness and dominance within the sampled population. In contrast, the Cucurbitaceae family demonstrated greater distributional uniformity, reflected by elevated values in the Evenness index (e^H/S = 1.03) and Pielou's Equitability index (J = 1.05). Conversely, the Caryophyllaceae and Amaranthaceae families recorded the lowest diversity metrics, suggesting minimal representation and limited ecological contribution within the study area. These findings underscore the heterogeneity in species distribution and equitability across weed families, as detailed in Table 2.

Table 2. Biological diversity indices at weed family level.

N°	Family	Individuals	Simpson_1-D	Shannon_H	Evenness_e^H/S	Equitability_J
1	Rubiaceae	548	0.41	0.69	0.66	0.62
2	Poaceae	280	0.52	0.89	0.82	0.81
3	Asteraceae	124	0.48	0.79	0.73	0.72
4	Urticaceae	46	0.26	0.44	0.77	0.63
5	Fabaceae	31	0.65	1.08	0.98	0.98
6	Araceae	11	0	0	1	0
7	Lamiaceae	34	0	0	1	0
8	Aspleniaceae	71	0.34	0.65	0.64	0.59
9	Vitaceae	19	0.28	0.46	0.79	0.67
10	Commelinaceae	58	0.45	0.64	0.95	0.92
11	Acanthaceae	723	0.47	0.82	0.76	0.74
12	Araliaceae	2	0	0	1	0
13	Ericaceae	8	0	0	1	0
14	Primulaceae	2	0	0	1	0
15	Apocynaceae	8	0	0	1	0
16	Cleomaceae	5	0	0	1	0
17	Celastraceae	43	0	0	1	0
18	Oxalidaceae	10	0	0	1	0
19	Caryophyllaceae	769	0.40	0.71	0.68	0.64
20	Amaranthaceae	8	0	0	1	0
21	Cucurbitaceae	15	0.53	0.72	1.03	1.05
22	Euphorbiaceae	8	0.25	0.44	0.78	0.63
23	Apocynaceae	54	0	0	1	0
24	Talinaceae	9	0	0	1	0
25	Solanaceae	3	0	0	1	0
26	Geraniaceae	1	0	0	1	0
27	Piperaceae	1	0	0	1	0

Determining diversity, richness and equity at the locality level

As presented in Table 3, a total of 2,891 individual weed specimens were recorded across the three sampling localities. Buena Fe exhibited the highest number of individuals (n = 1,356), followed by Quevedo (n = 985) and Valencia (n = 550). Despite its lower abundance, Valencia demonstrated the highest biological diversity, as indicated by a Simpson's diversity index (1–D) of 0.84, compared to Quevedo (0.77) and Buena Fe (0.67), the latter reflecting the lowest diversity among the sites. Shannon–Wiener diversity values (H′) further supported this trend, with Valencia registering the highest index (H′ = 2.11), followed by Quevedo (H′ = 1.92) and Buena Fe (H′ = 1.44). These results suggest a more heterogeneous weed community structure in Valencia, characterized by a broader distribution of species. Evenness, as measured by the e^H/S index, was also greatest in Valencia (0.48), indicating a more balanced distribution of individuals among species. Quevedo and Buena Fe followed with values of 0.43 and 0.33, respectively. Equitability, assessed via Pielou's J index, showed a similar pattern: Valencia (J = 0.74), Quevedo (J = 0.69), and Buena Fe (J = 0.56). These findings highlight significant ecological variation in weed community composition across the sampled localities, suggesting the presence of distinct agroecological conditions that influence species distribution and dominance.

Table 3. Indices of biological diversity at weed locality level.

Zones	Individuals	Simpson_1-D	Shannon_H	Evenness_e^H/S	Equitability_J
Quevedo	985	0.77	1.92	0.43	0.69
Buena Fe	1 356	0.67	1.44	0.33	0.56
Valencia	550	0.84	2.11	0.48	0.74
Total	2 891				

Jaccard coefficient

Table 4 presents the Jaccard similarity coefficients calculated to assess floristic overlap among the weed communities in Quevedo, Buena Fe, and Valencia. The overall similarity among the three localities was moderate, with a coefficient of 0.32, indicating a shared but limited presence of common species across the broader region. Notably, the pairwise comparison between Buena Fe and Valencia yielded a higher similarity coefficient of 0.58, suggesting a more substantial overlap in floristic composition between these two sites. This elevated similarity may be attributed to analogous environmental conditions, agricultural practices, or ecological factors influencing weed community structure in both localities. These results underscore the spatial variability in weed species distribution and highlight the potential influence of site-specific conditions on floristic composition.

Table 4. Jaccard similarity coefficient.

Locations	Quevedo	Buena Fe	Valencia
Quevedo	—	0.32	0.32
Buena Fe	0.32	—	0.58
Valencia	0.32	0.58	—

Bray - Curtis coefficient

Table 5 presents the Bray–Curtis similarity coefficients, which quantify the degree of floristic resemblance among the sampled localities. The comparison between Quevedo and Buena Fe yielded a coefficient of 0.26, indicating low similarity in species composition and suggesting distinct weed communities in these areas. In contrast, the coefficient between Quevedo and Valencia was 0.45, reflecting a moderate level of floristic overlap and implying shared ecological characteristics or management practices. The similarity between Buena Fe and Valencia was intermediate, with a coefficient of 0.35, denoting a modest degree of species commonality. These results highlight the spatial variation in weed community structure and underscore the influence of local environmental conditions on floristic composition.

Table 5. Bray - Curtis similarity coefficient.

Locations	Quevedo	Buena Fe	Valencia
Quevedo	—	0.26	0.45
Buena Fe	0.26	—	0.35
Valencia	0.45	0.35	—

Importance Value Index (IVI) of the sampled species

Table 6 presents the Importance Value Index (IVI) percentages for weed species associated with cocoa cultivation. The species *Geophila macropoda* (Ruiz & Pav.) DC exhibited the highest ecological prominence, with an IVI of 23.65%, indicating its dominant structural role within the weed community. This was followed by *Asystasia gangetica* (L.) T. Anderson (IVI = 9.79%), *Brachypodium sylvaticum* (Huds.) P. Beauv. (IVI = 6.33%), and Drymaria cordata (L.) Willd. ex Schult (IVI = 6.05%), all of which demonstrated moderate ecological significance. In contrast, the lowest IVI values were recorded for Lysimachia nummularia L. and Aralia nudicaulis, both with IVI values of 0.91%, as well as *Cyanthillium cinereum* (L.) H. Rob and *Cleome rutidosperma* DC, each with an IVI of 0.80%. These species exhibited minimal structural influence within the sampled cocoa agroecosystems, suggesting limited distribution and ecological impact.

Table 6. Weed species associated with cocoa cultivation with Importance Value Index (IVI) "Quevedo".

Scientific name	**DR**	**FR**	**DoR**	**IVI**	**IVI** (%)
Geophila macropoda (Ruiz & Pav.) DC.	21.99	8.33	40.61	70.94	23.65
Asystasia gangetica (L.) T. Anderson	4.47	12.50	12.39	29.36	9.79
Echinochloa colona (L) Link	0.66	2.08	0.30	3.05	1.02
Digitaria ciliaris (Retz.) Koeler	0.88	2.08	0.41	3.37	1.12
Panicum trichoides Sw.	3.08	2.08	1.42	6.58	2.19
Brachypodium sylvaticum (Huds.) P. Beauv.	1.72	12.50	4.77	18.99	6.33
Asplenium adiantum-nigrum L.	6.27	4.17	5.79	16.22	5.41
Commelina erecta L.	1.10	2.08	0.51	3.69	1.23
Aralia nudicaulis L.	0.44	2.08	0.20	2.73	0.91
Dichanthelium clandestinum (L.) Gould	6.16	2.08	2.84	11.08	3.69
Gaultheria shallon Pursh	1.76	2.08	0.81	4.66	1.55
Digitaria sanguinalis (L.) Scop.	6.60	4.17	6.09	16.86	5.62
Stachys arvensis (L.)	5.50	2.08	2.54	10.12	3.37
Eleusine indica (L.) Gaertn.	1.32	4.17	1.22	6.70	2.23
Elephantopus mollis Kunth	1.54	2.08	0.71	4.33	1.44
Rotheca myricoides (Hochst.) Steane & Mabb.	1.98	2.08	0.91	4.98	1.66
Lysimachia nummularia L.	0.44	2.08	0.20	2.73	0.91
Asclepias syriaca L.	1.76	2.08	0.81	4.66	1.55
Commelina benghalensis L.	3.08	2.08	1.42	6.58	2.19
Desmodium incanum (Sw.) DC.	0.77	4.17	0.71	5.65	1.88
Cleome viscosa L.	0.88	2.08	0.41	3.37	1.12
Mitracarpus hirtus (L.) DC.	0.66	2.08	0.30	3.05	1.02
Euonymus latifolius (L.) Mill.	4.73	4.17	4.37	13.26	4.42
Verbesina virginica L.	3.96	2.08	1.83	7.87	2.62
Paspalum paniculatum L.	2.42	2.08	1.12	5.62	1.87
Oxalis barrelieri L.	2.20	2.08	1.02	5.30	1.77
Cyanthillium cinereum (L.) H. Rob.	0.22	2.08	0.10	2.40	0.80
Cleome rutidosperma DC.	0.22	2.08	0.10	2.40	0.80
Drymaria cordata (L.) Willd. ex Schult.	11.00	2.08	5.08	18.16	6.05
Tridax procumbens L.	2.20	2.08	1.02	5.30	1.77

RD: relative density; **FR:** relative frequency; **DoR**: relative dominance; **IVI**: importance value index.

Table 7 presents the Importance Value Index (IVI%) for weed species associated with cocoa cultivation in the locality of Buena Fe. *Drymaria cordata* (L.) Willd. ex Schult. exhibited the highest ecological dominance, with an IVI of 33.96%, indicating its significant structural role within the weed community. This was followed by *Asystasia gangetica* (L.) T. Anderson (IVI = 15.51%) and *Gonolobus edulis* Himsl (IVI = 7.31%), both contributing moderately to the overall community composition. Conversely, species with minimal ecological influence included *Cissus verticillata* (L.) Nicolson & C.E. Jarvis (IVI = 1.42%), *Asplenium adiantum* L. (IVI = 1.77%), and *Laportea aestuans* (L.) Chew (IVI = 1.88%). These low IVI values suggest limited distribution and structural relevance within the cocoa agroecosystem of Buena Fe. The IVI analysis provides insight into the relative dominance and ecological roles of individual weed species, informing potential management strategies tailored to local floristic dynamics.

Table 7. Weed species associated with cocoa cultivation with Importance Value Index (IVI) "Buena Fe".

Scientific name	DR	FR	DoR	IVI	IVI (%)
Asystasia gangetica (L.) T. Anderson	10.49	16.10	19.90	46.50	15.51
Achyranthes aspera L.	2.01	3.22	0.76	5.99	2.00
Drymaria cordata (L.) Willd. ex Schult.	35.32	12.88	53.62	101.82	33.96
Stellaria media (L.) Vill	0.50	6.44	0.38	7.32	2.44
Rottboellia cochinchinensis (Lour.) Clayton	2.63	6.44	2.00	11.08	3.69
Geophila macropoda (Ruiz & Pav.) DC.	2.51	6.44	1.90	10.86	3.62
Momordica charantia L.	2.01	3.22	0.76	5.99	2.00
Setaria palmifolia (J.Koenig) Stapf	3.26	6.44	2.48	12.18	4.06
Canavalia rosea (Sw.) DC.	3.76	3.22	1.43	8.41	2.81
Euphorbia hirta L.	0.88	6.44	0.67	7.99	2.66
Erigeron canadensis L.	13.30	3.22	5.05	21.57	7.19
Cissus verticillata (L.) Nicolson & C.E. Jarvis	0.75	3.22	0.29	4.26	1.42
Brachypodium sylvaticum (Huds.) P. Beauv.	2.13	6.44	1.62	10.19	3.40
Gonolobus edulis Hemsl.	13.55	3.22	5.14	21.91	7.31
Chromolaena odorata (L.) R.M. King & H. Rob.	3.64	6.44	2.76	12.84	4.28
Laportea aestuans (L.) Chew	1.76	3.22	0.67	5.64	1.88
Asplenium adiantum-nigrum L.	1.51	3.22	0.57	5.30	1.77

RD: relative density; **FR:** relative frequency; **DoR**: relative dominance; **IVI**: importance value index.

Table 8 summarizes the Importance Value Index (IVI%) of weed species associated with cocoa cultivation in the locality of Valencia. *Psychotria nervosa* Sw. exhibited the highest ecological prominence, with an IVI of 18.89%, indicating its dominant role in the local weed community. This was followed by *Drymaria cordata* (L.) Willd. ex-Schult. (IVI = 15.17%) and *Asystasia gangetica* (L.) T. Anderson (IVI = 13.37%), both of which demonstrated substantial structural relevance. Species with moderate representation included *Commelina erecta* L. and *Browallia americana* L., with IVI values of 7.18%, while *Colocasia esculenta* (L.) Schott registered a lower IVI of 1.17%. Several species exhibited minimal ecological influence, such as *Cecropia obtusifolia* Bertol., *Geranium robertianum* L., *Piper hispidum* Sw., and *Canavalia rosea* (Sw.) DC, each with an IVI of 0.83%. These results reflect the relative dominance and ecological contribution of individual weed species within the cocoa agroecosystem of Valencia, offering insights into species composition and potential management priorities.

Table 8. Weed species associated with cocoa cultivation with Importance Value Index (IVI) "Valencia".

Scientific name	DR	FR	DoR	IVI	IVI (%)
Asystasia gangetica (L.) T. Anderson	3.22	19.61	17.27	40.10	13.37
Momordica charantia L.	1.19	3.92	1.27	6.38	2.13
Pueraria montana (Lour.) Merr.	2.71	1.96	1.45	6.13	2.04
Canavalia rosea (Sw.) DC.	0.34	1.96	0.18	2.48	0.83
Talinum paniculatum (Jacq.) Gaertn.	3.05	1.96	1.64	6.65	2.22
Cecropia obtusifolia Bertol.	0.34	1.96	0.18	2.48	0.83
Browallia americana L.	1.02	1.96	0.55	3.52	1.17
Caladium bicolor (Aiton) Vent.	1.36	3.92	1.45	6.73	2.24
Euphorbia hirta L.	0.34	1.96	0.18	2.48	0.83
Geophila macropoda (Ruiz & Pav.) DC.	3.39	3.92	3.64	10.95	3.65
Drymaria cordata (L.) Willd. ex Schult.	9.70	9.80	26.00	45.50	15.17
Psychotria nervosa Sw.	35.62	1.96	19.09	56.67	18.89

Vitis rotundifolia Michx.	3.73	1.96	2.00	7.69	2.56
Synedrella nodiflora (L.) Gaertn.	2.04	1.96	1.09	5.09	1.70
Commelina erecta L.	6.61	7.84	7.09	21.55	7.18
Laportea aestuans (L.) Chew	1.09	9.80	2.91	13.80	4.60
Cissus verticillata (L.) Nicolson & C.E. Jarvis	1.70	1.96	0.91	4.57	1.52
Boehmeria cylindrica (L.) Sw.	0.34	3.92	0.36	4.62	1.54
Geranium robertianum L.	0.34	1.96	0.18	2.48	0.83
Asplenium adiantum-nigrum L.	0.68	1.96	0.36	3.00	1.00
Colocasia esculenta L. Shott	1.02	1.96	0.55	3.52	1.17
Brachypodium sylvaticum (Huds.) P. Beauv.	1.53	3.92	1.64	7.08	2.36
Parietaria officinalis L.	6.78	1.96	3.64	12.38	4.13
Piper hispidum Sw.	0.34	1.96	0.18	2.48	0.83
Gymnocarpium dryopteris (L.) Newman	2.04	1.96	1.09	5.09	1.70
Panicum trichoides Sw.	9.50	1.96	5.09	16.55	5.52

RD: relative density; **FR:** relative frequency; **DoR**: relative dominance; **IVI**: importance value index.

Weed species composition

Table 9 presents the functional analysis of reproductive strategies and taxonomic composition within the weed community associated with cocoa cultivation. A total of 30 morphologically distinct species were identified, comprising 20 dicotyledonous and 10 monocotyledonous taxa. Life cycle classification revealed that 13 species were annual, 12 perennials, and 5 exhibited both annual and perennial growth habits, indicating ecological plasticity within the community. Regarding reproductive mechanisms, seed-based propagation was predominant, with 23 species relying exclusively on sexual reproduction. Two species reproduced vegetatively, while five demonstrated dual reproductive capacity, utilizing both seed and vegetative propagation pathways. Taxonomic analysis showed that the Poaceae family was the most represented, with eight species identified, followed by Asteraceae with four species. The families Commelinaceae, Rubiaceae, Lamiaceae, and Cleomaceae each contributed to two species. The remaining ten species were distributed across ten families—Acanthaceae, Aspleniaceae, Araliaceae, Ericaceae, Primulaceae, Apocynaceae, Fabaceae, Celastraceae, Oxalidaceae, and Caryophyllaceae—each represented by a single species.

Table 9. Reproductive characteristics and interference of weed species in the "Quevedo" locality.

Scientific name	**Cycle**	**Morphotype**	**Propagation**	**Family**	**Harmful degree**
Geophila macropoda (Ruiz & Pav.) DC.	P	Dico	S/S	Rubiaceae	HH
Asystasia gangetica (L.) T. Anderson	P	Dico	V	Acanthaceae	HH
Echinochloa colona (L) Link	A	Mono	S	Poaceae	SH
Digitaria ciliaris (Retz.) Koeler	A	Mono	S	Poaceae	SH
Panicum trichoides Sw.	A	Mono	S	Poaceae	SH
Brachypodium sylvaticum (Huds.) P. Beauv.	P	Mono	S	Poaceae	HH
Asplenium adiantum-nigrum L.	P	Mono	V	Aspleniaceae	MH
Commelina erecta L.	P	Mono	S/S	Commelinaceae	SH
Aralia nudicaulis L.	P	Dico	S	Araliaceae	SH
Dichanthelium clandestinum (L.) Gould	A	Dico	S	Poaceae	MH
Gaultheria shallon Pursh	P	Dico	S/S	Ericaceae	SH
Digitaria sanguinalis (L.) Scop.	A	Mono	S/S	Poaceae	MH
Stachys arvensis (L.)	A	Dico	S	Lamiaceae	SH
Eleusine indica (L.) Gaertn.	A	Mono	S	Poaceae	MH
Elephantopus mollis Kunth	P	Dico	S	Asteraceae	SH

Rotheca myricoides (Hochst.) Steane & Mabb.	A/P	Dico	S	Lamiaceae	SH
Lysimachia nummularia L.	P	Dico	S	Primulaceae	SH
Asclepias syriaca L.	P	Dico	S	Apocynaceae	SH
Commelina benghalensis L.	A	Mono	S	Commelinaceae	SH
Desmodium incanum (Sw.) DC.	P	Dico	S	Fabaceae	MH
Cleome viscosa L.	A	Dico	S	Cleomaceae	SH
Mitracarpus hirtus (L.) DC.	A	Dico	S	Rubiaceae	SH
Euonymus latifolius (L.) Mill.	A/P	Dico	S/S	Celastraceae	MH
Verbesina virginica L.	A/P	Dico	S	Asteraceae	SH
Paspalum paniculatum L.	A/P	Mono	S	Poaceae	SH
Oxalis barrelieri L.	P	Dico	S	Oxalidaceae	SH
Cyanthillium cinereum (L.) H. Rob.	A	Dico	S	Asteraceae	SH
Cleome rutidosperma DC.	A	Dico	s	Cleomaceae	SH
Drymaria cordata (L.) Willd. ex Schult.	A	Dico	S	Caryophyllaceae	SH
Tridax procumbens L.	A/P	Dico	S	Asteraceae	SH

A= Annual, **P=** Perennial, **Mono=** Monocotyledonous, **Dico=** Dicotyledonous, **S=** Seed, V= Vegetative, **HH=** Highly Harmful, **MH=** Moderately Harmful, **SH=** Slightly Harmful.

Table 10 presents the functional characterization of weed species associated with cocoa cultivation, focusing on reproductive strategies and taxonomic distribution. A total of 17 morphotypes were identified, comprising 13 dicotyledonous and 4 monocotyledonous species. Based on life cycle classification, 7 species were annual and 10 were perennials, indicating a predominance of long-lived taxa within the sampled agroecosystem. Regarding reproductive mechanisms, seed-based propagation was the most common strategy, observed in 9 species. One species reproduced exclusively through vegetative means, while 7 species exhibited dual reproductive capacity, utilizing both sexual and vegetative propagation pathways. Taxonomic analysis revealed that the Poaceae family was the most represented, with three species recorded. The Caryophyllaceae and Asteraceae families followed, each contributing two species. The remaining ten species were distributed across ten distinct families—Acanthaceae, Amaranthaceae, Rubiaceae, Cucurbitaceae, Fabaceae, Euphorbiaceae, Vitaceae, Apocynaceae, Urticaceae, and Aspleniaceae—each represented by a single species. These findings underscore the ecological diversity and reproductive adaptability of the weed flora in the cocoa-growing region, offering insights into species persistence, competitive dynamics, and potential management considerations.

Table 10. Reproductive characteristics and interference of weed species in the locality of "Buena Fe".

Scientific name	**Cycle**	**Morfo type**	**Propagation**	**Family**	**Harmful degree**
Asystasia gangetica (L.) T. Anderson	P	Dico	S/S	Acanthaceae	HH
Achyranthes aspera L.	P	Dico	V	Amaranthaceae	SH
Drymaria cordata (L.) Willd. ex Schult.	A	Dico	S	Caryophyllaceae	MH
Stellaria media (L.) Vill	A	Dico	S/S	Caryophyllaceae	MH
Rottboellia cochinchinensis (Lour.) Clayton	A	Mono	S	Poaceae	MH
Geophila macropoda (Ruiz & Pav.) DC.	P	Dico	S/S	Rubiaceae	MH
Momordica charantia L.	A	Dico	S/S	Cucurbitaceae	SH
Setaria palmifolia (J.Koenig) Stapf	P	Mono	S/S	Poaceae	MH
Canavalia rosea (Sw.) DC.	P	Dico	S	Fabaceae	SH
Euphorbia hirta L.	A	Dico	S	Euphorbiaceae	MH
Erigeron canadensis L.	A	Dico	S	Asteraceae	SH
Cissus verticillata (L.) Nicolson & C.E. Jarvis	P	Dico	S/S	Vitaceae	SH
Brachypodium sylvaticum (Huds.) P. Beauv.	P	Mono	S	Poaceae	MH
Gonolobus edulis Hemsl.	P	Dico	S	Apocynaceae	SH
Chromolaena odorata (L.) R.M. King & H. Rob.	P	Dico	S/S	Asteraceae	MH
Laportea aestuans (L.) Chew	A	Dico	S	Urticaceae	SH
Asplenium adiantum-nigrum L.	P	Mono	S	Aspleniaceae	SH

A= Annual, **P**= Perennial, **Mono**= Monocotyledonous, **Dico**= Dicotyledonous, **S**= Seed, V= Vegetative, **HH**= Highly Harmful, **MH**= Moderately Harmful, **SH**= Slightly Harmful.

Table 11 presents a functional assessment of the reproductive strategies and taxonomic composition of weed species associated with cocoa cultivation. A total of 26 morphotypes were identified, comprising 19 dicotyledonous and 7 monocotyledonous species. Based on life cycle classification, 10 species were annual and 16 were perennials, indicating a predominance of long-lived taxa within the sampled agroecosystem. Reproductive mode analysis revealed that 12 species propagated exclusively by seed, while 5 species reproduced vegetatively. An additional 9 species demonstrated dual reproductive capacity, utilizing both sexual and vegetative mechanisms, suggesting ecological adaptability and resilience. Taxonomic distribution showed that the Urticaceae family was the most represented, with four species recorded. Fabaceae, Araceae, Rubiaceae, Vitaceae, Aspleniaceae, and Poaceae each contributed to two species. The remaining ten species were distributed across ten distinct families—Acanthaceae, Cucurbitaceae, Talinaceae, Solanaceae, Euphorbiaceae, Caryophyllaceae, Asteraceae, Commelinaceae, Geraniaceae, and Piperaceae—each represented by a single species. These findings underscore the reproductive diversity and taxonomic heterogeneity of the weed flora in the Valencia cocoa growing region, offering insights into species persistence, competitive dynamics, and potential implications for agroecological management.

Table 11. Reproductive characteristics and interference of weed species in the locality of Valencia

A= Annual, **P**= Perennial, **Mono**= Monocotyledonous, **Dico**= Dicotyledonous, **S**= Seed, V= Vegetative, **HH**= Highly Harmful, **MH**= Moderately Harmful, **SH**= Slightly Harmful.

4. DISCUSSION

Scientific name	**Cycle**	**Morfo type**	**Propagation**	**Family**	**Harmful degree**
Asystasia gangetica (L.) T. Anderson	P	Dico	S/S	Acanthaceae	HH
Achyranthes aspera L.	P	Dico	V	Amaranthaceae	SH
Drymaria cordata (L.) Willd. ex Schult.	A	Dico	S	Caryophyllaceae	MH
Stellaria media (L.) Vill	A	Dico	S/S	Caryophyllaceae	MH
Rottboellia cochinchinensis (Lour.) Clayton	A	Mono	S	Poaceae	MH
Geophila macropoda (Ruiz & Pav.) DC.	P	Dico	S/S	Rubiaceae	MH
Momordica charantia L.	A	Dico	S/S	Cucurbitaceae	SH
Setaria palmifolia (J.Koenig) Stapf	P	Mono	S/S	Poaceae	MH
Canavalia rosea (Sw.) DC.	P	Dico	S	Fabaceae	SH
Euphorbia hirta L.	A	Dico	S	Euphorbiaceae	MH
Erigeron canadensis L.	A	Dico	S	Asteraceae	SH
Cissus verticillata (L.) Nicolson & C.E. Jarvis	P	Dico	S/S	Vitaceae	SH
Brachypodium sylvaticum (Huds.) P. Beauv.	P	Mono	S	Poaceae	MH
Gonolobus edulis Hemsl.	P	Dico	S	Apocynaceae	SH
Chromolaena odorata (L.) R.M. King & H. Rob.	P	Dico	S/S	Asteraceae	MH
Laportea aestuans (L.) Chew	A	Dico	S	Urticaceae	SH
Asplenium adiantum-nigrum L.	P	Mono	S	Aspleniaceae	SH

The analysis of biological diversity and reproductive traits of weed communities across different localities provides valuable insights into the ecological dynamics and interference potential of these species. At the family level, Caryophyllaceae, Acanthaceae, and Rubiaceae exhibited the highest diversity index values, indicating a notable presence in the study areas [14]. A total of 12 weed species distributed across 9 families were identified, with Poaceae being the most represented, followed by Amaranthaceae, Polygonaceae, Solanaceae, Cyperaceae, Commelinaceae, Lamiaceae, Urticaceae, and Asteraceae. This taxonomic distribution reflects the complexity and richness of weed communities in each evaluated locality, where individual species contribute to local biodiversity.

At the locality level, weed diversity assessments revealed that Buena Fe exhibited the highest number of individuals, suggesting greater species richness compared to Quevedo and Valencia. This underscores the influence of geographic location on weed community composition. Diversity indices—including Simpson's 1–D, Shannon–Wiener (H′), Evenness (e^H/S), and Equitability (J)—provided a comprehensive characterization of biological diversity. Valencia recorded the highest Simpson's index, indicating dominance by a few species, while also showing the highest Shannon index, suggesting a relatively even distribution of species in terms of abundance. These findings have implications for weed management, emphasizing the need to consider both species richness and relative abundance.

In a related study by [15], the effects of weed management in maize (*Zea mays*) on phenology, yield, biodiversity, and weed/insect abundance were evaluated. The study identified 15 families, 22 genera, and 24 weed species, with Poaceae being the most represented. Diversity indices for the Nutrader and NB-6 plots were 2.46 and 2.43, respectively.

Similarity analyses using Jaccard and Bray–Curtis coefficients provided further insights into weed community composition across localities. The comparison between Quevedo and Buena Fe yielded a Jaccard index of 0.32, indicating moderate similarity. Valencia showed greater differentiation from Quevedo, with Jaccard and Bray–Curtis values of 0.32 and 0.45, respectively. In contrast, the similarity between Buena Fe and Valencia was higher (Jaccard = 0.58; Bray–Curtis = 0.35). These results suggest notable compositional differences among localities, likely driven by site-specific environmental and agronomic conditions, reinforcing the need for localized weed management strategies.

Importance Value Index (IVI) analysis across the three localities highlighted variation in species dominance within cocoa systems. *Geophila macropoda* (Ruiz & Pav.) DC., *Asystasia gangetica* (L.) T. Anderson, and *Drymaria cordata* (L.) Willd. ex Schult. were among the most ecologically significant species. A study by [16] examining weed community structure and diversity identified 122 species across 93 genera and 39 families, with Poaceae and Cyperaceae showing high species richness, and Commelinaceae exhibiting elevated IVI values. Accurate species identification is essential for developing targeted management strategies. These findings contribute to optimizing weed control in cocoa agroecosystems by emphasizing the importance of understanding species-specific ecological roles.

Functional analysis of reproductive traits revealed the presence of both annual and perennial species across all localities, underscoring the need to address continuous weed propagation. The occurrence of species capable of both seed and vegetative reproduction further highlights the necessity of integrated control strategies. In a comparable study, [17] qualitatively and quantitatively assessed weed community composition, identifying 19 species across 11 families. Poaceae was again the most represented, followed by Asteraceae, Brassicaceae, Amaranthaceae, Portulacaceae, Chenopodiaceae, Cyperaceae, Lamiaceae, Oxalidaceae, Caryophyllaceae, and Verbenaceae. Dicotyledons predominated over monocotyledons, with 12 annual and 7 perennial species identified. Eleusine indica was notable for its high abundance and frequency.

Collectively, these findings underscore the importance of incorporating weed community diversity and reproductive biology into agricultural decision-making. An adaptive management approach that accounts for local variability and species-specific traits is essential to mitigate weed interference and promote sustainable cocoa production.

5. CONCLUSIONS

Diversity metrics underscore the ecological significance of the Caryophyllaceae, Fabaceae, and Cucurbitaceae families, which exhibited elevated values across multiple indices. Among the sampled localities, Buena Fe demonstrated the highest overall species richness, whereas Valencia recorded the highest values for Simpson's diversity index (1 - D), Shannon–Wiener index (H′), and Pielou's equitability index (J), indicating both species dominance and evenness in distribution. The Jaccard and Bray - Curtis similarity coefficients revealed distinct patterns of floristic overlap and differentiation among localities, reflecting spatial variation in weed community composition.

Species-level analysis based on the Importance Value Index (IVI) identified *Geophila macropoda* (Ruiz & Pav.) DC., *Drymaria cordata* (L.) Willd. ex Schult., and *Psychotria nervosa* Sw. as the most dominant taxa, with IVI percentages ranging from 33.96% to 18.89%. These species were consistently prominent across the sampled agroecosystems, suggesting strong ecological influence and competitive capacity.

Functional analysis of reproductive traits and interference potential revealed a diverse assemblage of morphotypes exhibiting both annual and perennial life cycles, as well as varied reproductive strategies, including seed-based, vegetative, and dual propagation modes. The families Poaceae, Asteraceae, and Urticaceae were recurrently represented, indicating their structural and functional prominence within the weed communities.

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