Comparative Biodiversity Assessment of Weed Species in Monocropping Plantations of University of Ilorin, Nigeria

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Abstract

The present study investigates the weed species diversity in four plantations of university of Ilorin, Ilorin, Nigeria using quadrat method. The survey revealed two major life cycles (annual and perennial) and recorded a total of 88 weed species belonging to 32 families. Four species (*Azadirachta indica*, *Daniellia oliveri*, *Desmodium tortuosum*, and *Tridax procumbens*) were common in all the surveyed plantations while the family Fabaceae was the most dominant. The abundant weed species analysis showed a high importance value index and were more adapted to the plantations. Diversity analysis revealed high species richness in the sugarcane plantation. The non-canopy nature of the plantation, soil structure as well as ability to coexist with many other species may underscore the reasons for this pattern of diversity. The evenness and similarity indices between and across the plantations were generally low, thus, indicating varying diversity. As a result of the recorded variation in weed composition between and across the plantations, the study has provided an insight on the pattern of weed diversity in the studied plantations. The study recommended that the most abundant weed species populations be checked for the plantations to thrive. Finally, there is an urgent need to conserve weed species that are not only rare in abundance but also showed great social and economic values.

Introduction

Plantations are cultivated ecosystems established either by seedlings or cuttings primarily to generate profit. Other reasons for their establishment may include conservation of soil and water or wind protection, ornamental purposes, biomass production, and provision of raw materials for industrial uses (Carnus et al. 2006). The role plantations play is not limited to industrial and ecological but also for indigenous consumption such as food, forest grazing, game harvesting among others (Savill et al. 1997).

Sugarcane (*Saccharum officinarum* L) is a tall perennial grass from the family Poaceae. It is a significant source of sugar, which is useful in medicine, pharmaceutical, confectionery and beverages, electricity, as well as motor fuels (Wada et al. 2017). Jatropha (*Jatropha curcas* L) is a large drought-resistant multipurpose shrub with several potentials. It belongs to the family Euphorbiaceae. In recent times, the clear oil extracted from its seeds is used for the production of biofuel (Aransiola et al. 2012). Teak (*Tectona grandis* L.), a member of the family Lamiaceae, is one of the essential hardwoods (a timber tree) of the world and used for furniture, plywood, panelling, and all types of construction poles, piles, and ship-building (Dotaniya et al. 2013). Date palm (*Phoenix dactylifera* L), popularly known as the tree of life, belongs to the family Arecaceae. It is a slow-growing tree that produces highly nutritious fruits (Johnson et al. 2013). It also provides material for roofing, boxes, basket, animal feed, raw materials for the processing of beverages. It serves as a windbreaker and helps in the control of desertification.

Plantations have tremendous potentials that can only be fully exploited if their growths are not hindered by factors such as poor cultural practices, use of unimproved seeds/stem, high cost of inputs, erratic rainfall, low soil fertility, diseases, and weed infestation. Weeds are all non-cropped plant species encountered in plantations, which constitute a significant component of the pest complex, limiting the agricultural production system (Takim and Amodu 2013). The majority could be harmful to plantation growth as they compete with them for light, moisture, and nutrients, especially during the early stage of their development (Sharma 1990). They also enhance the expansion of bushfires, which is one of the factors of plantation destruction (Kanate et al. 2013).

The roles of weeds in an agricultural ecosystem have been the subject of an ongoing debate in recent years. Many trophic and peritrophic relationships rely on arable weeds as primary producers (Petit et al. 2011). In other climes, 27 weed species that are of great economic and medicinal values across 10 cocoa plantations, where most of these plants were rare and endangered, have been reported (Akinyemi 2010). It had been found that some weeds are good sources of drug used in orthodox medicine, while others have been used locally for decades for treatments of ailments such as dysentery, gastrointestinal disorder, urinary tract infections, infertility (Meyer et al. 1996, Soladoye et al. 2006). Other roles of weeds include the provision of vegetative cover that protects soil surface against erosion action of rain and wind; nutrients recycling, hosts for beneficial insects, nectar for bees, and addition of organic matter to soil (Soladoye et al. 2005, Soladoye et al. 2010).

There is the need to recognise the important variations among weed species so that reasonable eradication procedures can be effectively implemented and control may depend on the particular characteristics of each species (Silva et al. 2009). An effective weed control measure, the Integrated Weed Management System, which depends on the ability to predict and manage the response of weed communities to changes in agronomic practices, requires that weeds be first of all correctly identified and named before effecting the weed management (Sharma 1990, Jordan 1992, Stevenson et al. 1997, Mortimer 1998, Ueda 2006). Similarly, documenting the weed spectrum in any agricultural field in terms of their composition, diversity, and similarity measures will help not only to determine the species that are abundant and rare but also to conserve and domesticate those species that have ethnobotanical relevance.

University of Ilorin has an average climate for the region, which is a transition between the rain forest in the south and the Sahel Savanna in the north. It has two distinct seasons; the hot dry season starts from late October to late March, and the wet season from late April to October (Akoshile et al. 2015). The rainfall pattern is monomodal with annual total rainfall, which ranges from 12.7mm to 180.3mm, most of which falls between May and September. The average daily temperature ranges between 17.8 ºC and 35ºC. Radiation is in the range of 11.6 hours to 12.6 hours (WeatherSpark 2020).

In Nigeria, much work had been done on weed management on crops in the fields. The cashew, cocoa, and coffee plantations in the Western Region of Nigeria had earlier been surveyed, and the need to do regular enumeration of weed species in plantations was reported (Obadoni et al. 2009). The weeds that are prevalent in sugarcane crops had been documented in Ilorin, Southern guinea savanna of Nigeria (Takim and Amodu 2013). To our knowledge, there is a dearth of information on comparative analyses of composition, prevalence or rarity, diversity, and similarity measures of weed species in the University of Ilorin plantations. It is this gap in knowledge that the present study aims to address.

Materials and Methods

Study area

The study was carried out in University of Ilorin (Unilorin), Kwara state, Nigeria. University of Ilorin is located on latitude 80, 29'N and longitude 40, 35'E, and 320 m above sea level (UNILORIN 2020). We surveyed four plantations (Date Palm, Jatropha, Sugarcane and Teak) in University of Ilorin. The geographical positioning system (GPS) was used to obtain the coordinates of these (Fig. 1).

Data collection

The method employed for data collection for this study was based on weed survey plot sampling and quadrant techniques (Priestley 1913).

Plot Sampling and quadrant design.

Two main plots, each of 100m by 100m dimensions, were mapped out in each plantation. A total of forty quadrants (dimension 1m by 1m) were placed along an inverted M-pattern (Fig. 2) that was initially constructed in each of the main plots making a gross total of 80 quadrants per plantation (Thomas 1985).

The distance of 9 m was left between quadrants to reduce the repetition of plant species, and 20m was left on each of the four sides of the main plot to minimise edge effect. The two

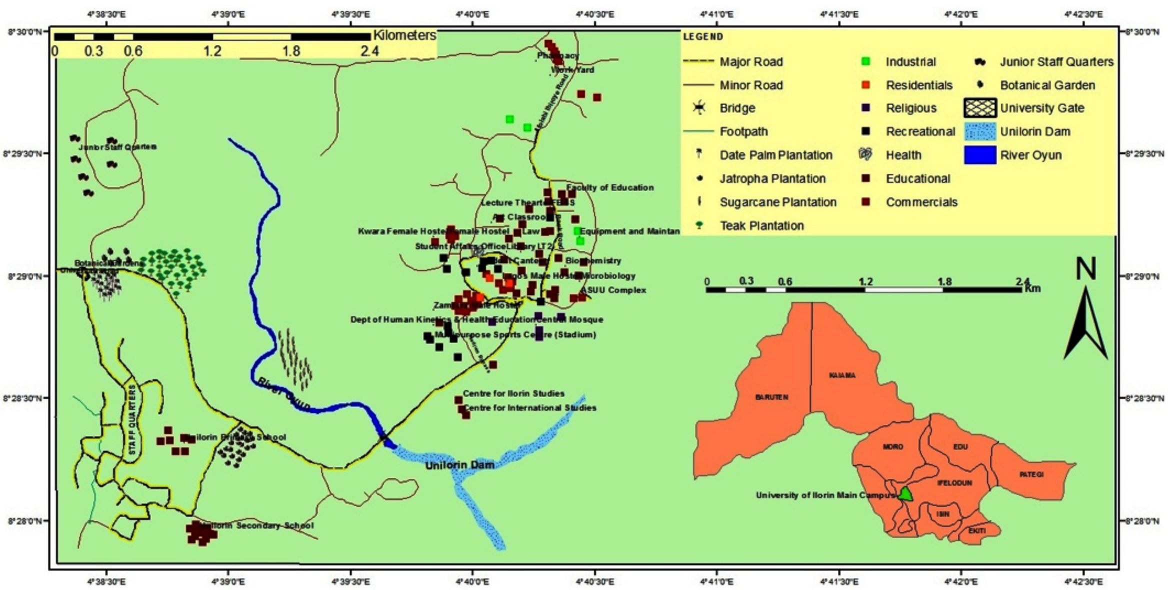
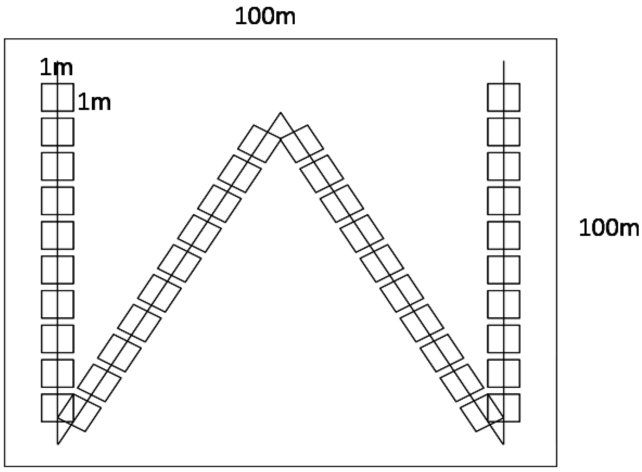


Fig. 1 Map of University of Ilorin showing the plantations



Source: Thomas (1985)

Fig. 2 Plot and quadrant design

main plots were 100 m apart. Enumeration and identification of encountered weed species were made in each quadrant. The number of individuals of each species and the total number of weed species was recorded in each plantation.

Species Identification

Identification of the sampled weed species was made using some of the earlier reported guidelines (Hutchinson and Dalziel 1954, 1958, Hutchinson et al. 1963, Harris and Harris 1994, Okezie Akobundu and Agyakwa 1998), alongside local monographs and flora. Additional species identification was carried out by a trained taxonomist who is one of the authors as well as the curator assigned to the Herbarium unit of Department of Plant Biology, University of Ilorin. Ilorin. All the plants were identified to species level except two individuals whose specific epithet could not be ascertained, and their genus was referred to, respectively. Also, types of life cycles and habits encountered were documented.

Data analysis

The taxonomic composition of the weed species encountered was documented. The occurrence data were used to compute frequency distribution (F, %) relative frequency (RF, %), density (D, m2), relative density (RD, %), and abundance (Curtis 1959, Kedir et al. 1999, Alix and Scribailo 2006, Bowles and Jones 2006, Kumar and Chelak 2015). A Venn diagram approach was used to analyse weed species overlap across the plantations using an interactive web-based tool (Heberle et al. 2015). The importance value index (IVI) of each species encountered in all the plantations were determined using the method of Barbour et al. (1988). Importance Value Index (IVI) as a measure of the ecological importance of a species concerning other species, was calculated by summing up the values of relative density (R.Dn.), relative dominance (R.Do.), and relative frequency (RF) as shown below:

$$IVI = (RF + R.Dn. + RDo. / 3)$$

Diversity indices (Margalef, Shannon-Wieners, Simpson, Equitability, Menhinick, Brillouin, Fisher_Alpha, and Berger- Parker and Evenness index) were estimated in PAlaeontological STatistics software (PAST v 2.17c) (Hammer et al. 2001). The method of (Oyebanji et al. 2020) was employed in ascertaining the similarities among the plantations by plotting two similarity indices using PAST software (PAST v 2.17c).

Also, Sorenson's coefficient (CCs) and Jaccard Coefficient similarity (JCs) indices, as implemented in PAST software, were used to compute the similarity between the plantations based on the presence/absence of species and number of species common to the plantations. We assessed the conservation status of the encountered species using the International Union for Conservation of Nature (IUCN) Red List Criteria (IUCN 2016).

Results

Species composition

Our study recorded 88 plant species belonging to 32 families (Table 1). We recorded two (2) types of life cycles in the encountered weed species, annuals (n=22) and perennials (n=66). Broadleaved (n=80), sedges (n=1), and grasses (n=7) were documented as the habits exhibited by the interferent plant species in the studied plantations (Table 1).

According to IUCN Red List Criteria, the encountered species were grouped as follows; Not Evaluated (NE= 63), Least Concerned (LC=22 species), and Vulnerable (VU= 3 species) (Table 1).

Out of the 32 families encountered on the plantations, Fabaceae family (n=17 species), Euphorbiaceae family (n=8 species), Asteraceae family (n=7 species), and Poaceae family (n=7 species) were the most dominant weed species (Fig. 3) which accounted for 44% of the species.

Relative frequency, Relative density, and Relative dominance

In the sugarcane plantation, *Tridax procumbens*, and *Panicum maximu*m recorded the highest relative frequency (7.06%) followed by *Desmodium tortuosum* and *Euphorbia hyssopifolia* with respective frequencies of 6.4% and 5.7%. The least relative frequency value of 0.18% was recorded for *Corchorus olitorius*, and it was followed by *Biophytum petersianum* (0.27%) *Desmodium scorpiurus*

TABLE 1

Weed Species recorded at the four Plantations studied

Family	Scientific Name	Life Cycle	Plantations				IUCN Status
			Sugar Cane	Date Palm	Jatropha	Teak	
Acalthaceae	*Monechma ciliatum* (Jacq.) Milne Redhead	ABL		√	√	√	NE
Amaranthaceae	*Celosia trigyna* Linn.	PBL	√				NE
	Gomphrena celosoides Mart.	PBL		√	√		NE
Asclepiadaceae	*Leptadenia hastata* (Pers) Deene	PBL				√	NE
	Parquetina nigrescens (Afzel.) Bullock	PBL	√	√			NE
Asteraceae	*Ageratum conyzoides* Linn.	ABL	√				NE
	Aspilia africana (Pers) C.D. Adams	PBL		√		√	NE
	Blumea aurita (Linn.) DC.	PBL	√		√		LC
	Chromolaena odorata (L) R.M. King & H. Rob	PBL	√	√		√	NE
	Erigeron floribundus (Kunth) Sch.Bip.		√				NE
	Spilanthes filicaulis (Schum. & Thonn.) C.D. Adams	ABL	√				NE
	Tridax procumbens Linn.	ABL	√	√	√	√	NE
	Vernonia amygdalina Delile	PBL			√		NE
Basellaceae	*Basella rubra* Linn.	PBL	√				NE
Capperaceae	*Cleome ciliata* Schumach & Thonn.	ABL	√				NE

TABLE 1 cont.
Weed Species recorded at the four Plantations studied

Family	Scientific Name	Life Cycle	Plantations				IUCN Status
			Sugar Cane	Date Palm	Jatropha	Teak	
Chrysobalanaceae	*Parinari curatellifolia* Planch. Ex Benth	PBL			√	√	LC
	Maranthes polyandra (Benth.) Prance.	PBL			√		LC
Combretaceae	*Combretum glutinosum* Perr. ex DC	PBL			√	√	LC
	Combretum grandiflorum Perr.	PBL			√		NE
	Combretum racemosum P. Beauv.	PBL				√	NE
	Combretum spp.	PBL			√		NE
	Terminalia avicennioides Guill. & Perr.	PBL		√			LC
	Terminalia ivorensi A. Chev.	PBL				√	VU
Commelinaceae	*Commelina diffusa* Burm F.	PBL	√				LC
Convulvulaceae	*Evolvulus alsinoides* Linn.	AH		√			NE
	Ipomoea triloba Linn.	AH			√		LC
	Merremia aegyptia (L.) Urban	ABL		√			NE
Cucurbitaceae	*Momordica charantia* Linn.	PBL	√				NE
Cyperaceae	*Mariscus alternifolius* Vahl.	PBL	√				NE
Euphorbiaceae	*Bridelia ferruginea* Benth	PBL				√	NE
	Croton lobatus Linn.	ABL	√				NE
	Euphorbia heterophylla Linn.	ABL	√				NE
	Euphorbia hirta Linn.	ABL	√				NE
	Euphorbia hyssopifolia Linn.	ABL	√				NE
	Phyllanthus amarus Schum. & Thonn.	ABL	√				NE
	Phyllanthus muellerianus Kuntze	PBL			√		NE
	Securinega virosa (Roxb. Ex Willd) Baill	PBL				√	NE
Fabaceae	*Faidherbia albida* (Delile) A. Chev.	PBL		√			LC
	Acacia ataxancantha DC	PBL				√	NE
	Albizia ferruginea Guill	PBL				√	VU
	Albizia lebbeck (L.) Benth.	PBL	√		√		NE
	Bauhinia monandra Kurz	PBL		√	√	√	NE
	Centrosema pubescens Benth	PBL		√	√		NE
	Crotalaria macrocalyx Benth	PBL		√			NE
	Crotalaria retusa Linn.	ABL		√		√	NE
	Daniellia oliveri (Rolfe) Hutch & Dalz.	PBL	√	√	√	√	LC
	Desmodium Scorpiurus (SW.) DeSV	PBL	√			√	NE
	Desmodium spp.	ABL	√				NE
	Desmodium tortuosum (SW.) DC	ABL	√	√	√	√	NE
	Desmodium triflorum (L.) DC	ABL	√				LC
	Entada africana Guill & Perr.	PBL		√			LC
	Indigofera hirsuta Linn.	AH			√		NE
	Parkia biglobosa (Jacq.) G.Don.	PBL			√	√	LC
	Zornia latifolia Sm.	PH		√	√	√	NE
Lamiaceae	*Hyptis suaveolens* Poit.	AH			√		NE
Malvaceae	*Corchorus olitorius* Linn.	ABL	√				NE
	Hibiscus surattensis Linn.	ABL		√			NE
	Sida acuta Burm F.	PH	√		√		NE
	Sida linifolia Juss ex Cab.	PH		√			NE
	Sida rhombifolia Linn.	PS		√	√		NE
Meliaceae	*Azadirachta indica* A. Juss	PBL	√	√	√	√	LC

TABLE 1 cont.
Weed Species recorded at the four Plantations studied

Family	Scientific Name	Life Cycle	Plantations				IUCN Status
			Sugar Cane	Date Palm	Jatropha	Teak	
Menispermaceae	*Cissampelos mucronata* Linn.	PBL				√	NE
Moraceae	*Ficus thonningii* Blume	PBL	√			√	LC
Nyctaginaceae	*Boerhavia diffusa* Linn.	PBL	√				NE
Oxalidaceae	*Biophytum petersianum* Klotzsch	PBL	√				NE
Passifloraceae	*Passiflora foetida* Linn.	PBL	√				NE
Plantaginaceae	*Scoparia dulcis* Linn.	ABL	√	√			NE
Poaceae	*Andropogon gayanus* Kunth	PG			√		NE
	Eleusine indica Gaertn.	Glaborous Herb		√			LC
	Imperata cylindrica Linn.	PBL		√	√	√	LC
	Loudetia arundinacea (Hochst) ex. A. Rich Steud	AG		√	√		NE
	Panicum maximum Jacq.	Tufted Perennial	√		√		NE
	Pennisetum pedicellatum Trin.	AG			√	√	LC
	Cenchrus violaceus (Lam.) Morrone	AG			√		LC
Polygalaceae	*Securidara longepedunculata* Fresen.	PBL				√	NE
Portularaceae	*Talinum triangulare* (Jacq.) Willd.	PH	√				NE
Rubiaceae	*Diodia scandens* SW.	PH			√		NE
	Nauclea latifolia Linn.	PBL			√	√	LC
	*Oldenlandia corymbos*a Linn.	AH	√				NE
	Oldenlandia herbacea Linn.	AH	√		√		LC
	Spermacoce verticillata Linn.	AH	√				NE
Sapotaceae	*Vitellaria paradoxa* C.F. Gaertn.	PBL	√			√	VU
Scrophulariaceae	*Striga hermonthica* (Del.) Benth.	AH		√			NE
Solanaceae	*Physalis angulata* Linn.	ABL	√				LC
	Schwenkia americana Linn.	ABL			√		NE
	Solanum erianthum Linn.	PBL				√	NE
Sterculiaceae	*Waltheria indica* Linn.	PH			√		NE
Verbanaceae	*Vitex doniana* Sweet	PBL		√	√		LC

Note Key: ABL = Annual Broadleaved; AH = Annual Herb; AG = Annual Grass; PBL = Perennial Broadleaved; PH = Perennial Herb; PS = Perennial Shrub; NE = Not Evaluated; LC = Least Concerned; VU = Vulnerable.

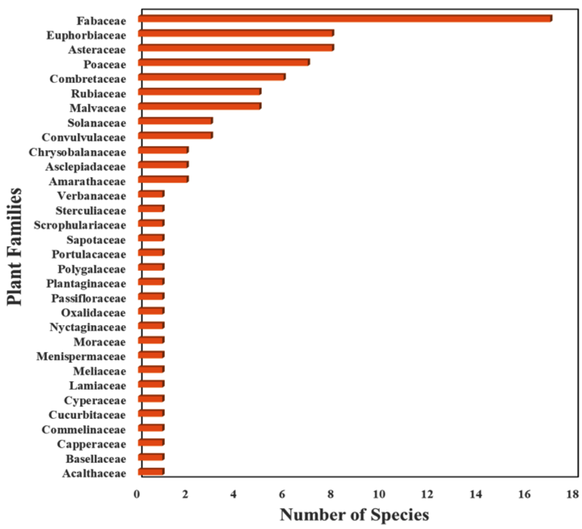


Fig. 3 The pattern of family distribution observed during the survey

(0.36%) (Table 2).

The results of relative density and relative dominance followed a similar trend as recorded for relative frequency except that *Euphorbia hirta* occurred with the lowest relative density and relative abundance values of 0.04% and 0.46%, respectively. In the date palm plantation, the highest relative frequency, relative density, and relative dominance were recorded for *Desmodium tortuosum* with respective values of 11.38%, 30.99%, and 27.8%, followed in decreasing order of magnitude by *Tridax procumbens*, *Eleusine indica*, and *Imperata cylindrica* (Table 3). *Aspilia africana* had the lowest values of the parameters mentioned above, and it was followed by *Terminalia avicennioidesa* and *Scoparia dulcis* (Table 3).

The highest relative frequency value of 7.57% was recorded by *Tridax procumbens* in the Jatropha plantation, followed by *Desmodium tortuosum* (7.08%), *Zornia latifolia* (5.92%),

TABLE 2
Relative distribution and life cycle of the weed species in the sugarcane plantation

Family	Weed species	Life cycle	Rf	R.dn.	R.do.
			%		
Amaranthaceae	*Celosia trigyna*	PBL	0.54	0.37	1.06
Asclepiadaceae	*Parquetina nigrescens*	PBL	0.9	0.29	0.89
Asteraceae	*Ageratum conyzoides*	ABL	1.81	0.59	1.17
	Blumea aurita	PBL	1.99	0.22	0.87
	Chromolaena odorata	PBL	1.27	0.70	1.24
	Erigeron floribundus	PBL	1.36	0.27	0.88
	Spilanthes filicaulis	ABL	3.62	1.41	2.04
	Tridax procumbens	ABL	7.06	43.39	32.23
Basellaceae	*Basella rubra*	PBL	1.81	0.40	1.06
Capperaceae	*Cleome ciliate*	ABL	0.90	0.05	0.59
Commelinaceae	*Commelina diffusa*	PBL	2.71	0.33	1.01
Cucurbitaceae	*Momordica charantia*	PBL	4.52	0.36	1.02
Cyperaceae	*Mariscus alternifolius*	PBL	3.35	0.10	0.68
Euphorbiaceae	*Croton lobatus*	ABL	1.36	0.11	0.74
	Euphorbia heterophylla	ABL	5.43	0.23	0.87
	Euphorbia hirta	ABL	2.17	0.04	0.46
	Euphorbia hyssopifolia	ABL	5.70	3.18	2.92
	Phyllanthus amarus	ABL	2.99	0.09	0.63
Fabaceae	*Albizia lebbeck*	PBL	1.72	0.23	0.87
	Daniellia oliveri	PBL	6.06	3.18	2.75
	Desmodium Scorpiurus	PBL	0.36	0.15	0.74
	Desmodium spp.	ABL	0.45	1.12	1.78
	Desmodium tortuosum	ABL	6.43	10.27	8.38
	Desmodium triflorum	ABL	4.07	0.90	1.62
Malvaceae	*Corchorus olitorius*	ABL	0.18	0.88	1.27
	Sida acuta Burm	PH	2.99	0.43	1.08
Meliaceae	*Azadirachta indica*	PBL	0.63	0.10	0.73
Moraceae	*Ficus thonningii*	PBL	0.45	0.19	0.85
Nyctaginaceae	*Boerhavia diffusa*	PBL	4.07	0.15	0.76
Oxalidaceae	*Biophytum petersianum*	PBL	0.27	0.31	0.99
Passifloraceae	*Passiflora foetida*	PBL	1.09	0.16	0.78
Plantaginaceae	*Scoparia dulcis*	ABL	1.36	0.62	1.19

TABLE 2 cont.
Relative distribution and life cycle of the weed species in the sugarcane plantation

Family	Weed species	Life cycle	Rf	R.dn.	R.do.
			%		
Poaceae	*Panicum maximum*	PG	7.06	26.78	19.9
Portularaceae	*Talinum triangulare*	PH	3.08	1.26	1.91
Rubiaceae	*Oldenlandia corymbose*	AH	1.81	0.19	0.79
	Oldenlandia herbacea	AH	0.45	0.52	1.1
	Spermacoce verticillate	AH	1.9	0.05	0.61
Sapotaceae	*Vitellaria paradoxa*	PBL	1.99	0.07	0.62
Solanaceae	*Physalis angulate*	PBL	4.07	0.3	0.91

Note Key: ABL = Annual Broadleaved; AH = Annual Herb; AG = Annual Grass; PBL = Perennial Broadleaved; PH = Perennial Herb; PS = Perennial Shrub; Rf = Relative frequency; R.dn = Relative density; R.do = Relative dominance

TABLE 3
Relative distribution and life cycle of the weed species in the Datepalm plantation

Family	Weed species	Life cycle	Rf	R.dn.	R.do.
			%		
Acalthaceae	*Monechma ciliatum*	PBL	2.88	0.09	0.31
Amaranthaceae	*Gomphrena celosoides*	PBL	1.44	0.01	0.1
Asclepiadaceae	*Parquetina nigrescens*	PBL	0.72	0.01	0.08
Asteraceae	*Tridax procumbens*	ABL	10.52	23.35	22.09
	Chromolaena odorata	PLB	4.03	0.2	0.49
	Aspilia africana	PBL	0.29	0	0.09
Combretaceae	*Terminalia avicennioides*	PBL	0.29	0	0.14
Convulvulaceae	*Evolvulus alsinoides*	AH	2.59	0.09	0.34
	Merremia aegyptia	ABL	2.59	0.07	0.27
Fabaceae	*Daniellia oliveri*	PLB	4.61	0.82	1.77
	Desmodium tortuosum	ABL	11.38	30.99	27.08
	Zornia latifolia	PH	8.65	9.2	10.59
	Centrosema pubescens	PBL	2.45	0.05	0.22
	Crotalaria macrocalyx	PBL	1.73	0.03	0.17
	Entada africana	PBL	0.72	0.01	0.14
	Bauhinia monandra	PBL	2.02	0.03	0.14
	Crotalaria retusa	ABL	1.01	0.01	0.09
	Faidherbia albida	PBL	0.86	0.01	0.07
Malvaceae	*Sida linifolia*	PH	2.74	0.03	0.11
	Sida rhombifolia	PS	1.73	0.02	0.1
	Hibiscus surattensis	ABL	0.58	0	0.08
Meliaceae	*Azadirachta indica*	PLB	7.93	0.94	1.18
Plantaginaceae	*Scoparia dulcis*	ABL	0.43	0	0.11
Poaceae	*Eleusine indica*	Glab. Herb	10.37	26.82	25.72
	Imperata cylindrica	PBL	9.37	6.63	7.04
	Loudetia arundinacea	AG	4.32	0.54	1.25
Scrophulariaceae	*Striga hermonthica*	AH	2.02	0.02	0.1
Verbanaceae	*Vitex doniana*	PBL	1.73	0.03	0.15

Note Key: ABL = Annual Broadleaved; AH = Annual Herb; AG = Annual Grass; PBL = Perennial Broadleaved; PH = Perennial Herb; PS = Perennial Shrub; Rf = Relative frequency; R.dn = Relative density; R.do = Relative dominance

and *Panicum maximum* (4.75%), whereas the least relative frequency value of 0.01% was recorded for *Nauclea latifolia* and *Hyptis suaveolens* (Table 4). The relative density ranged from 0.003% to 36.85%. The highest relative density was recorded for *Tridax procumbens* (36.85%) followed by *Desmodium tortuosum* (37.93%), *Zornia latifolia* (6.46), and *Imperata cylindrica* (1.31). The lowest relative density was recorded for *Nauclea latifolia* and *Hyptis suaveolens* (0.003) and followed by *Schwenkia americana* (0.01%).

TABLE 4
Relative distribution and life cycle of the weed species in the Jatropha plantation

Family	Weed species	Life cycle	Rf	R.dn.	R.do.
			%		
Acalthaceae	*Monechma ciliatum*	PBL	3.30	0.58	1.03
Amaranthaceae	*Gomphrena celosoides*	PBL	0.97	0.02	0.11
Asteraceae	*Blumea aurita*	PBL	1.84	0.16	0.51
	Tridax procumbens	ABL	7.57	36.85	28.41
Chrysobalanaceae	*Maranthes polyandra*	PBL	0.87	0.02	0.12
	Parinari curatellifolia	PBL	3.01	0.51	0.99
Combretaceae	*Combretum glutinosum*	PBL	3.01	1.53	2.97
	Combretum grandiflorum	PBL	1.07	0.03	0.15
	Combretum spp.	PBL	2.91	0.71	1.42
Convulvulaceae	*Ipomoea triloba*	AH	0.10	0.01	0.31
Euphorbiaceae	*Phyllanthus muellerianus*	PBL	2.91	0.62	1.24
Fabacea	*Bauhinia monandra*	PBL	3.20	0.34	0.62
	Centrosema pubescens	PBL	3.10	0.62	1.17
	Albizia lebbeck	ABL	1.94	0.15	0.44
	Daniellia oliveri	PBL	3.20	1.49	2.71
	Desmodium tortuosum	ABL	7.08	37.93	31.24
	Indigofera hirsute	AH	2.91	0.44	0.89
	Parkia biglobosa	PBL	3.10	0.40	0.76
	Zornia latifolia Sm.	PH	5.92	6.46	6.36
Lamiaceae	*Hyptis suaveolens*	AH	0.10	0.00	0.21
Malvaceae	*Sida acuta*	PH	2.81	0.38	0.79
	Sida rhombifolia	PH	3.88	0.36	0.55
Meliaceae	*Azadirachta indica*	PBL	4.27	0.60	0.82
Poaceae	*Andropogon gayanus*	PG	4.75	2.66	3.26
	Cenchrus violaceus	AG	3.98	1.73	2.54
	Imperata cylindrica	PBL	3.49	1.31	2.19
	Loudetia arundinacea	AG	2.81	1.22	2.53
	Panicum maximum	Tufted Perennial	4.27	0.82	1.12
	Pennisetum pedicellatum	AG	3.30	1.59	2.82
	Vernonia amygdalina	PBL	0.10	0.00	0.21
Rubiaceae	*Diodia scandens*	PH	2.72	0.24	0.51
	Nauclea latifolia	PBL	0.10	0.00	0.21
	Oldenlandia herbacea	AH	2.13	0.14	0.39
Solanaceae	*Schwenkia americana*	ABL	0.39	0.01	0.13
Sterculiaceae	*Waltheria indica*	PH	1.36	0.03	0.13
Verbanaceae	*Vitex doniana*	PBL	1.55	0.04	0.16

Note Key: ABL = Annual Broadleaved; AH = Annual Herb; AG = Annual Grass; PBL = Perennial Broadleaved; PH = Perennial Herb; PS = Perennial Shrub; Rf = Relative frequency; R.dn = Relative density; R.do = Relative dominance

Maranthes polyandra (0.02%). The results of relative dominance were consistent with those recorded for relative density (Table 4).

In teak plantation, the highest relative frequency was recorded for *Imperata cylindrica* (10.45%), followed by *Albizia ferruginea* (6.34), *Tridax procumbens* (6.16%), and *Daniellia oliveri* (5.22%). In contrast, the least value was recorded for *Leptadenia hastata* (0.75%) followed in ascending order by *Combretum glutinosum* (0.93%), and *Parinari curatellifolia* (1.12%) (Table 5). The relative density ranged from 0.05% to 43.76%. The highest relative density was recorded for *I. cylindrica* (43.76%) and followed by *Tridax procumbens* (26.17%), and *Daniellia oliveri* (10.87%) whereas, the lowest value was recorded by *L. hastata* (0.05%) followed by *Combretum glutinosum* and *Aspilia africana* (0.09%) (Table 5). *Tridax procumbens*

TABLE 5

Relative distribution and life cycle of the weed species in Teak plantation

Family	Weed species	Life cycle	Rf	R.dn.	R.do.
			%		
Acalthaceae	*Monechma ciliatum*	PBL	3.54	0.33	0.59
Asclepiadaceae	*Leptadenia hastata*	PBL	0.75	0.05	0.46
Asteraceae	*Aspilia Africana*	PBL	1.49	0.09	0.38
	Chromolaena odorata	PBL	2.99	0.33	0.71
	Tridax procumbens	ABL	6.16	26.17	27.32
Chrysobalanaceae	*Parinari curatellifolia*	PBL	1.12	0.16	0.94
Combretaceae	*Combretum glutinosum*	PBL	0.93	0.09	0.65
	Combretum racemosum	PBL	1.87	0.17	0.58
	Terminalia ivorensi	PBL	1.68	0.08	0.32
Euphorbiaceae	*Bridelia ferruginea*	PBL	3.17	0.21	0.43
	Securinega virosa	PBL	4.29	0.88	1.31
Fabacea	*Zornia latifolia*	PH	3.17	0.59	1.19
	Acacia ataxancantha	PBL	3.92	1.24	2.04
	Albizia ferruginea	PBL	6.34	1.79	1.81
	Bauhinia monandra	PBL	3.36	0.65	1.24
	Crotalaria retusa	ABL	4.66	1.51	2.08
	Daniellia oliveri	PBL	5.22	10.87	13.37
	Desmodium Scorpiurus	PBL	2.43	0.36	0.94
	Desmodium tortuosum	ABL	5.04	4.28	5.45
	Parkia biglobosa	PBL	2.24	0.3	0.87
Meliaceae	*Azadirachta indica*	PBL	5.04	1.18	1.5
Menispermaceae	*Cissampelos mucronate*	PBL	3.92	0.32	0.53
Moraceae	*Ficus thonningii*	PBL	3.36	0.24	0.47
Poaceae	*Imperata cylindrica*	PBL	10.45	43.76	26.92
	Pennisetum pedicellatum	AG	4.48	3.31	4.75
Polygalaceae	*Securidaca longepedunculata*	PBL	2.99	0.22	0.48
Rubiaceae	*Nauclea latifolia*	PBL	1.49	0.12	0.53
Sapotaceae	*Vitellaria paradoxa*	PBL	2.24	0.51	1.45
Solanaceae	*Solanum erianthum*	PBL	1.68	0.18	0.69

Note Key: ABL = Annual Broadleaved; AH = Annual Herb; AG = Annual Grass; PBL = Perennial Broadleaved; PH = Perennial Herb; PS = Perennial Shrub; Rf = Relative frequency; R.dn = Relative density; R.do = Relative dominance

showed the highest relative dominance value of 27.32%, followed by *Imperata cylindrica* (26.92%) and *D. oliveri* (13.37%). The lowest relative dominance value of 0.46% was recorded for *L. hastata*, and closely followed by *Ficus thonningii* (0.47%) and *Securidaca longepedunculata* (0.48%) (Table 5).

Rank abundance curve

The relative abundance of the most common weed species in sugar cane, date palm, *Jatropha*, and teak plantations were 43.4%, 30.9%, 37.9%, and 43.8%, respectively (Fig. 4). The gradient of the graph was steep as displayed by the long tail of rare weed compared to few abundant weeds.

Diversity indices (alpha)

The species richness recorded in sugar cane, date palm, Jatropha, and teak plantations were 39, 28, 36, and 29, respectively; sugarcane plantation being the richest and date palm, the poorest plantation (Table 6). The Simpson index (1-D) value ranged from 0.714 to 0.765. Date palm plantation had the highest Simpson diversity index of 0.765, sugarcane and teak plantation had 0.727 and 0.724, respectively. The least Simpson diversity index of 0.714 was recorded in Jatropha plantation. A closer look at the Simpson Index values recorded across the plantations showed that there was little to no difference in their diversity status. It, therefore, follows that the most important weeds in the plantations are the most dominant and, as such, represented by a few species. Shannon-Weiner index (H) value ranged from 1.62 to 1.86. In contrast to the Simpson index, H was highest at the sugarcane (1.86) and lowest at the date palm (1.62).

The evenness index E was calculated for each plantation. The value of equitability ranges from 0 to 1. It is equal to 1 when all the species have the same abundance and tend towards 0 when near-total flora is concentrated on only one species. In this study, the value of this index varies from 0.49 to 0.53 in the date palm and teak plantations, respectively. This could be interpreted to mean that the plantations were less diverse and that a few individuals represented the most abundant weed species. For instance, in sugarcane weed species such as *Tridax procumbens* and *Panicum maximum* both accounted for 70.1% of the total weed abundance.

Weed species such as *Desmodium turtuosum*, *Eleusine indica*, and *Tridax procumbens*

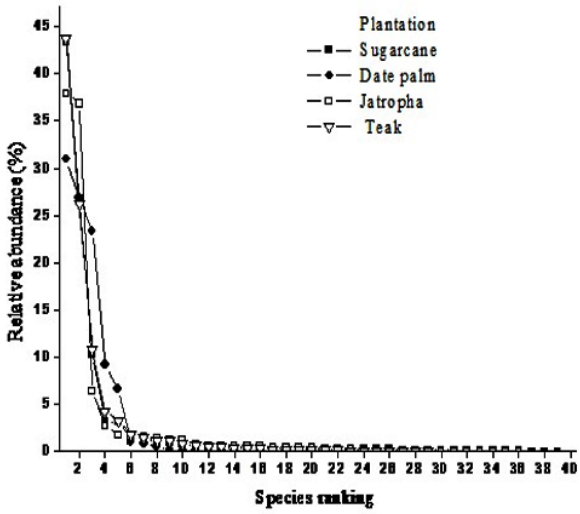


Fig. 4 Rank abundance plots of the four plantations

TABLE 6
Diversity indices of the four plantations

Diversity indices	Plantations			
	Sugarcane	**Date palm**	**Jatropha**	**Teak**
Species richness (S)	39	28	36	29
No of family	20	14	15	16
Individuals (n)	13,636	149,356	57,778	29,844
Dominance (D)	0.27	0.24	0.29	0.28
Simpson (1-D)	0.73	0.76	0.71	0.72
Simpson (1/D)	3.656	4.246	3.494	3.625
Dmax	0.97	0.96	0.97	0.97
Shannon (H)	1.86	1.62	1.77	1.77
H max	3.66	3.33	3.58	3.37
Equitability (J/E)	0.51	0.49	0.49	0.53
Brillouin	1.85	1.62	1.77	1.77
Menhinick	0.33	0.07	0.15	0.17
Margalef	3.99	2.27	3.19	2.72
Fisher_alpha	4.92	2.55	3.73	3.17
Berger-Parker	0.43	0.31	0.38	0.44

accounted for 80.1% of the total weed abundance in date palm. The most abundant weed species in *Jatropha* plantation were *Desmodium turtuosum* and *Tridax procumbens* and both accounted for 74% of the total weed abundance. In the teak plantation, *Imperata cylindrica* and *Tridax procumbens* were the most common, and they accounted for 69.8% of the total weed abundance. Generally, date palm had the lowest evenness, and such that the weed species were less diverse when compared to other plantations in this study. Brillouin, Menhinic, Margalef, and Fisher_alpha had the same results; they represented that sugar plantation had the highest diversity than date palm, teak, and *Jatropha*. This could be ascribed to the fact that the species richness and evenness of sugarcane were higher than other plantations. The Berger-Parker had values that range from 0.31 to 0.44 in date palm and teak plantations, respectively (Table 6).

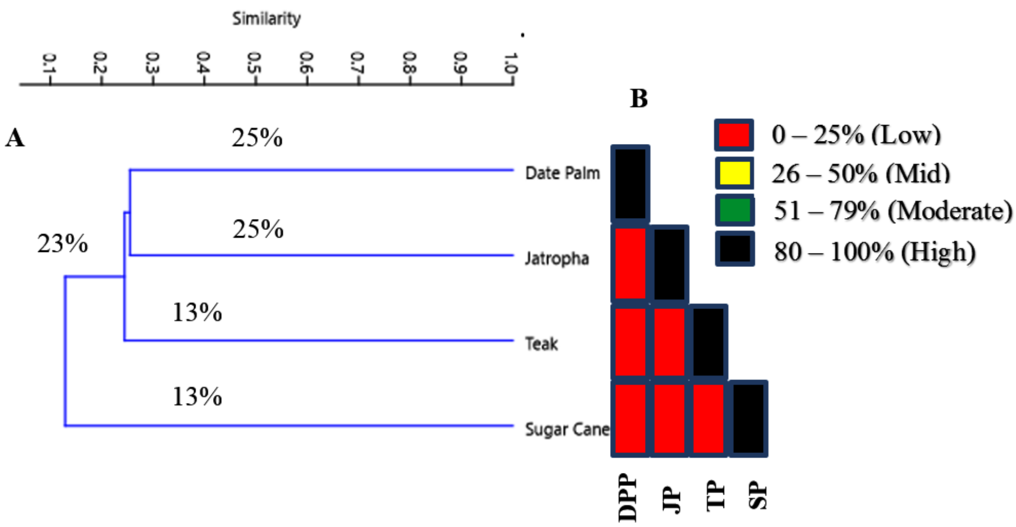


Fig. 5 Similarity indices; Jaccard Similarity index (A) showing the similarity in species composition of the respective plantations. Sorenson's coefficient (B) showing the similarity coefficients among the plantations

Similarity: Sorensen and Jaccard indices (beta)

Weed species similarities between the following pairs of plantation types were studied, i.e., sugar and date palm, Jatropha and sugar cane, teak and sugar cane, date palm and Jatropha, as well as teak and Jatropha. Concerning the Jaccard index, the lowest value was recorded between sugarcane and date palm (11.7%), whereas the highest value of 25% was recorded between teak and Jatropha (Fig. 5A). The similarity values for both indices, which range from 5.9% to 25%, were low (Fig. 5A). It was observed that the lowest Sorensen index value was recorded in sugarcane and date palm (5.9%). The highest value was noted between teak and date palm (17.2%) (Fig. 5B).

Weed species overlap in the plantations

Weed species overlap in the studied plantations is generally low. For instance, four weed species intercepted in all the plantations (Fig. 6) These were *Desmodium tortuosum*, *Tridax procumbens*, *D. oliveri*, and *A. indica.*

Important value index of weed species

The important value index ranged from 0.03% to 22.54%. Among the broadleaved weed *T. procumbens* (22.54%) was top in ranking and followed in decreasing order of magnitude by *D. tortuosum* (15.46%), *D. oliveri* (4.67%), *Zornia latifolia* (4.30%), and *A. indica* (2.08%). Concerning grasses, *I. cylindrica* (9.26%) was topmost and followed by *Eleusine indica* (5.24%) and *Panicum maximum* (4.98%).

Discussion

The species composition in terms of habit encountered in this study is similar to earlier reported field surveys where perennial weeds, especially broadleaved, were higher than annual grasses and that low sedge is a common feature of weed communities in the Southern Guinea savanna zone of Nigeria (Takim and Fadayomi 2010, Olayinka and Etejere 2016). The perennial species was more significant in number than annual species, and similarly, perennials broadleaved were more prevalent than perennial grasses. The abundance of perennial weeds could be because the plantations under investigation were perennials in their life cycle. Similar findings of a high prevalence of annual weeds in rice and groundnut fields had earlier been reported (Hakim et al. 2010, Olayinka and

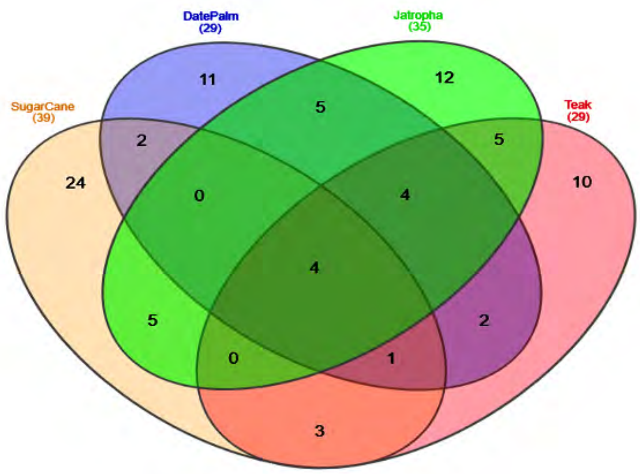


Fig. 6 Venn diagram showing weed species overlap among the plantations

Etejere 2016).

The maximum number of species in the encountered families, most importantly, family Fabaceae might be due to better dispersal mechanism and high adaptability under the prevailing conditions which favoured their prolific populations. Distribution of weeds had been found to depend on factors such as dissemination mechanism, structure, time of germination, the viability of their seeds or fruits, and soil seeds bank (Bokhari et al. 1986, Nasir and Sultan 2004). Similarly, the occurrence of weed vegetation's in a particular area is governed by factors such as edaphic factors (pH, nutrients, moisture), weed control measure, and the history of the field(s) in which the weeds occurred (Kim et al. 1983).

In terms of conservation status, our study showed that out of the 88 weed species encountered, 22 are least concerned, 66 species have not been evaluated for conservation. However, our study recorded 3 vulnerable species (*Albizia ferruginea* Guill, *Terminalia ivorensi* A. Chev., and *Vitellaria paradoxa* C.F. Gaertn.). The vulnerability of these 3 species requires urgent and prompt conservation attention.

The vulnerable weed species were consistently less abundant, and effort should be put in place to domesticate them. These species, however, may be experiencing population reduction with limited distribution, and they are as well prone to human exploitation.

The presence of weed species is a significant environmental and economic problem in the studied plantations. According to previously reported studies, the economic importance of weed species is directly related to their high frequency and dominance (Takim and Amodu 2013, Gidesa et al. 2016). It should be noted that weed species with high relative frequency and high relative density showed that they are highly adapted and tolerant to the environmental conditions in which they are found. A high density of weed species had been correlated with large seed banks provided that the seeds are viable and conditions are favourable (Nasir and Sultan 2004).

The large seed bank ensures their dense population as species with high seed output have a high capacity to colonise, perpetuate, and establish themselves (Buhler et al. 2001). Such a scenario is observed in this study. All other weed species with low relative frequency, relative density, and relative dominance values showed that they were either less competitive or were effectively controlled by weed control methods that were employed in the studied plantations.

The striking disparities in the abundance of weed species showed that the plantations have low evenness. A steep gradient indicates low evenness as the high-ranking species have much abundance than the low ranking species, whereas a shallow gradient indicates high evenness as the abundances of different species are similar (Magurran 2004). Similar observations had also been reported (Yeon and Kim 2011) in their evaluation of species diversity indices of the natural deciduous forest of Mt. Jeombong.

The increase in weed diversity at the sugarcane plantation could be attributed to the emergence of new weed species not present in date palm or species richness (Concenço et al. 2011). The growth characteristics of Sugarcane which include canopy type and soil structure among others may be responsible for such weed diversity encountered in the sugarcane plantation.

The similarity test carried out revealed that there was a considerable difference in weed species composition between any two sets of plantations. The result is supported by (Tesema and Lema 1998), who affirmed that two locations have different weed communities if the index of similarity is below 60%. The low similarity indices showed that there were differential environmental conditions in the studied plantations. More or less uniform environmental conditions are revealed by a higher value of similarity index; in contrast, a lower value indicates distinct heterogeneity (Singh 2012). It should also be noted that the variation in weed communities observed across the plantations requires that similar weed management options may not be applied. The weed overlap results had shown that weed species composition varied from one plantation to another on account of low weed species overlap. The results further give credence to the low value obtained from similarity indices. Topography and edaphic factors could be used to explain the issue of weed heterogeneity of the studied plantations. The results confirmed the earlier observation of significant differences in weed flora composition between regions and soil type (Hallgren et al. 1999).

The high values of IVI of the encountered weed species on the plantations studied showed that they are ecologically important in terms of being best adapted to the prevailing environmental conditions in the plantations where they occurred (Nasir and Sultan 2004). All other weed species showed shallow IVI values that ranged from 0.03% (*Hyptis suaveolens*) to 1.68% (*Pennisetum pedicellatum*).

It should be noted that all the encountered weeds, aside from being viewed as detrimental to the plantations, are also beneficial. For instance, they provide vegetative cover to protect the soil surface against water and wind erosion (Soladoye et al. 2010). In addition to their agricultural uses, the majority of the weed species had been reported to have medicinal/economic uses (Adesina et al. 1995, Soladoye et al. 2010).

Conclusion

Weed species significantly varied from one plantation to another, as indicated by the low values of Sorenson and Jaccard similarity indices. Diversity indices indicated that weed species richness was highest in the sugarcane plantation and lowest in date palm. The evenness was generally low in all the plantations, as evident from the Shannon-Weiner index, equitability, Brillouin, Menhinic, Margalef and Fisher_alpha, and Berger-Parker values. All the encountered weed species have social and economic advantages, and concerted effort should be put in place to conserve them, most especially *A. ferruginea*, *T. ivorensi* and *V. paradoxa* that are not only vulnerable but economically important. We, however, recommend adequate attention be focused on the dominant weed species in each of the plantations studied to check their population to increase productivity in the plantations. A similar method of weed control should not be adopted for all the plantations studied.

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Data Availability Statement

All data pooled in the current study have been analysed and presented as tables and figures.

Conflict of interest

The authors declare no conflict of interest. The authors unanimously approve the final copy of this manuscript.

References

Adesina S., Gbile Z., Odukoya O., Akinwusi D., Illoh H., and Jayeola A. (1995). Survey of indigenous useful plants of West Africa with special emphasis on medicinal plants and issues associated with management. *The United Nations Programme on Natural Resources in Africa* **2**:84-85.

Akinyemi O. (2010). *Partial variation in biodiversity of weeds in ten cocoa plantation*. Thesis. University of Ibadan, Nigeria.

Akoshile C. O., Ajibola T. B., Rabiu B. A., Ige V. T., Iborida A. O., Sanda A. S., Aladodo S. S., and Sani M. T. (2015). Annual behaviour of average wind speed, temperature and solar radiation at Ilorin, Kwara State, Nigeria. *Nigerian Journal of Solar Energy* **26**:7-14.

Alix M. S., and Scribailo R. W. (2006). The history and aquatic flora of Silver Lake, Porter County, Indiana, with comments on the adequacy of floristic quality assessment for lakes. Pages 13-31 *in* Proceedings of the Indiana Academy of Science.

Aransiola E. F., Daramola M. O., Ojumu T., Aremu M. O., Layokun S. K., and Solomon B. O. (2012). Nigerian Jatropha curcas oil seeds: prospect for biodiesel production in Nigeria. *International Journal of Renewable Energy Research* **2:3**17-325.

Barbour M. G., Burk J. H., and Pitts W. D. (1988). *Terrestrial plant ecology*. 3rd edition. Addison Wesley Longman, Boston, MA, USA.

Bokhari M., Dasti A., and Ahmed S. (1986). Preliminary studies on weeds of wheat in Multan. *Biologia* **32**:289-303.

Bowles M., and Jones M. (2006). Testing the efficacy of species richness and floristic quality assessment of quality, temporal change, and fire effects in tallgrass prairie natural areas. *Natural Areas Journal* **26**:17-30.

Buhler D. D., Kohler K. A., and Thompson R. L. (2001). Weed seed bank dynamics during a five-year crop rotation. *Weed Technology* **15**:170-176.

Carnus J.-M., Parrotta J., Brockerhoff E., Arbez M., Jactel H., Kremer A., Lamb D., O'Hara K., and Walters B. (2006). Planted forests and biodiversity. *Journal of Forestry* **104**:65-77.

Concenço G., Salton J., Secretti M., Mendes P., Brevilieri R., and Galon L. (2011). Effect of long-term agricultural management systems on occurrence and composition of weed species. *Planta Daninha* **29**:515-522.

Curtis J. T. (1959). *The vegetation of Wisconsin: an ordination of plant communities*. University of Wisconsin Press, USA.

Dotaniya M., Meena V., Lata M., and Meena H. (2013). Teak plantation-a potential source of income generation. *Popular Kheti* **1**:61-63.

Gidesa A., Tadesse T., and Dabi A. (2016). Quantitative Determination of Weed Occurrence on Upland Rice of Bambasi, Ethiopia. *Ecology and Evolutionary Biology* **1**:53-56.

Hakim M., Juraimi A., Ismail M., Hanafi M., and Selamat A. (2010). Distribution of weed population in the costal rice growing area of kedah in peninsular Malaysia. *Journal of Agronomy* **9**:9-16.

Hallgren E., Palmer M. W., and Milberg P. (1999). Data diving with cross-validation: an investigation of broad-scale gradients in Swedish weed communities. *Journal of Ecology* **87**:1037-1051.

Hammer Ø., Harper D. A., and Ryan P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia electronica* **4**:1-9.

Harris J. G., and Harris M. W. (1994). *Plant identification terminology: an illustrated glossary*. Spring Lake Publishing Utah.

Heberle H., Meirelles G. V., da Silva F. R., Telles G. P., and Minghim R. (2015). InteractiVenn: a web-based tool for the analysis of sets through Venn diagrams. *BMC bioinformatics* 16:169.

Hutchinson J., Dalziel J., and Hepper F. (1963). *Flora of West Tropical Africa*. Crown Agents, London. Uk.

Hutchinson J., and Dalziel J. M. (1954). *Flora of west tropical Africa*. Crown Agent, London, UK.

Hutchinson J., and Dalziel J. M. (1958). *Flora of West Tropical Africa*. Crown Agent, London, UK.

IUCN. (2016). *Red List of threatened species Version* 2019-3. IUCN.

Johnson D., Al-Khayri J., and Jain S. (2013). Seedling date palms (Phoenix dactylifera L.) as genetic resources. *Emirates Journal of Food and Agriculture* **25**:809-830.

Jordan N. (1992). Weed demography and population dynamics: implications for threshold management. *Weed Technology* **6**:184-190.

Kanate Z., Messoum F. G., Sekou A., Yao-Kauame A., Camara M., and Kelizagbahi J. (2013). Effets des cultures de soja (Glycine max) et de niébé (Vigna unguiculata) sur la densité apparente et la teneur en eau des sols et sur la productivité du riz pluvial de plateau sur ferralsol hyperdystrique. International *Journal of Biological and Chemical Sciences* **7**:47-59.

Kedir N., Feyissa T., and Tilahun G. (1999). Results of weed survey in the major field pea and faba bean growing-areas of the Bale highlands. *Arem* **5**:109-121.

Kim S., Park R., and Moody K. (1983). Changes in the weed flora in transplanted rice as affected by introduction of improve rice cultivars and the relationship between weed communities and soil chemical properties. *Research Reports of the Office of Rural Development (Korea R)* **25**:90-97.

Kumar S., and Chelak E. P. (2015). Survey of Macrophytic diversity in different ponds of Ongargarh city of Chattisgarh. *IOSR journal of Environmental Science, Toxicology and Food Technology* **1**:57-59.

Magurran A. E. (2004). *Measuring biological diversity. Blackwell Publishing Company*, Main Street, Malden, MA, USA.

Meyer J., Afolayan A., Taylor M., and Engelbrecht L. (1996). Inhibition of herpes simplex virus type 1 by aqueous extracts from shoots of Helichrysum aureonitens (Asteraceae). *Journal of Ethnopharmacology* **52**:41-43.

Mortimer M. (1998). The need for studies on weed ecology to improve weed management. *in* Expert Consultation on Weed Ecology and Management, Rome (Italy), 22-24 Sep 1997. FAO.

Nasir Z. A., and Sultan S. (2004). Survey of weeds in mustard fields of district Chakwal, Pakistan. *Pak. J. Biol. Sci* **7**:279-286.

Obadoni B., Edema N., Erheni H., Ogie-Odia E., and Amukali O. (2009). A checklist of the flora of edaphic grasslands in the rainforest belts of Edo and Delta states of Nigeria. *World Rural Observations* **1**:43-49.

Okezie Akobundu I., and Agyakwa C. (1998). *A handbook of West African weeds*. International Institute of Tropical Agriculture, Ibadan.

Olayinka B. U., and Etejere E. O. (2016). Weed control methods affect growth, yield and economic returns in groundnut. Annales of West University of Timisoara. *Series of Biology* **19**:17-24.

Oyebanji O. O., Bolarinwa K. A., and Olowokudejo J. D. (2020). Diversity and distribution patterns of aquatic macrophytes in selected ecosystems of south western Nigeria. *African Journal of Ecology*.

Petit S., Boursault A., Le Guilloux M., Munier-Jolain N., and Reboud X. (2011). Weeds in agricultural landscapes. A review. *Agronomy for sustainable development* **31**:309-317.

Priestley J. H. (1913). The Quadrat as a Method for the Field Excursion. *Journal of Ecology* **1**:89-94.

Savill P., Evans J., Auclair D., and Falck J. (1997). *Plantation silviculture in Europe*. Oxford University Press, UK.

Sharma B. (1990). Preliminary observations on weed of the Afcott Cotton Farm in Eastern Nigeria. *Pakistan Journal of Weed Science Research (Pakistan)* **3**:140-144.

Silva P., Damasceno A., Silva K., Oliveira O., and Queiroga R. (2009). Growth and yield of corn grain and green ear in competition with weeds. *Planta Daninha* **27**:947-955.

Singh E. (2012). Comparative analysis of diversity and similarity indices with special relevance to vegetations around sewage drains. *World Academy of Science, Engineering and Technology* **6**:606-608.

Soladoye M., Osipitan A., Sonibare M., and Chukwuma E. (2010). From 'Vagabonds' to ethnobotanical relevance: weeds of the campus sites of Olabisi Onabanjo University, Ago-Iwoye, Nigeria. *Ethnobotanical Leaflets* 2010:546-558.

Soladoye M., Yakubu F., Kola-Oladiji K., Alabi D., and Agbomeji Y. (2006). The Collection, Conservation and Cultivation of Local Medicinal Plants for Natural Medicine Production. Pages 19-23 in Seminar/Workshop and Exhibition of Natural Medicine Products. Organized by Nigeria Traditional Medical Association, Ijebu-North in Collaboration with Faculty of Science, Olabisi Onabanjo University Ago-Iwoye, Olabisi Onabanjo University Ago-Iwoye.

Soladoye M. O., Sonibare M. A., Nadi A. O., and Alabi D. A. (2005). Indigenous angiosperm biodiversity of Olabisi Onabanjo University permanent site. *African Journal of Biotechnology* **4**:554-562.

Stevenson F. C., Légère A., Simard R. R., Angers D. A., Pageau D., and Lafond J. (1997). Weed species diversity in spring barley varies with crop rotation and tillage, but not with nutrient source. *Weed Science* **45**:798-806.

Takim F., and Amodu A. (2013). Quantitative estimate of weeds of sugarcane (*Saccharum officinarum* L.) crop in Ilorin, Southern Guinea Savanna of Nigeria. *Ethiopian Journal of Environmental Studies and Management* **6**:611-619.

Takim F., and Fadayomi O. (2010). Influence of Tillage and Cropping Systems on Field Emergence, Growth of Weeds and Yield of Maize ('*Zea mays*' L.) and Cowpea ('*Vigna unguiculata*'L.). *Australian Journal of Agricultural Engineering* **1**:141-148.

Tesema T., and Lema Y. (1998). Qualitative and quantitative determination of weeds in tef in West Shewa Zone. *Arem* (Ethiopia) **4**:46-60.

Thomas A. G. (1985). Weed survey system used in Saskatchewan for cereal and oilseed crops. *Weed Science* **33**:34-43.

Ueda K. (2006). How to adopt botanical names and the importance of voucher specimens. *Weed Research* **36**:227-235.

UNILORIN. (2020). About Us, University of Ilorin.

Wada A., Abo-Elwafa A., Salaudeen M., Bello L., and Kwon-Ndung E. (2017). Sugarcane production problems in Nigeria and some Northern Africa Coutries. Direct Research *Journal of Agriculture and Food Science* **5**:141-160.

WeatherSpark. (2020). Average weather in Nigeria.

Yeon S.-M., and Kim Y.-C. (2011). Complete sequence and organization of the Sphingobium chungbukense DJ77 pSY2 plasmid. *The Journal of Microbiology* **49**:684-688.