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RESEARCH

Impact of Fallowing on the Emergence of Weed Species, Soil Nutrient Dynamics and Yield of Maize (*Zea mays* L.)

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ABSTRACT

Fallowed uplands dominated by *Chromolaena odorata, Hyptis suaveolens, Tithonia diversifolia, Imperata cylindrica* and other grasses were selected and their effects on the emergence of associated weed species, the nutrient status of the soil and subsequent maize yield were examined. A survey was conducted to estimate the floristic composition in each field in 2017 and 2018. Five fallowed fields and one arable field were used during the 2018 and 2019 seasons. The trial was laid on each field in a Randomized Complete Block Design with 3 replicates. Zero tillage was adopted for the fallow land while the arable field was ploughed, harrowed, and ridged. Weed, soil, and grain yield data were collected and subjected to analysis of variance at P=0.05. The results showed that weed composition and emergence pattern differed marginally among the five fallowed fields. *Tridax procumbens, Brachiaria lata* and *Cyperus rotundus* were the most associated weed species. Soils under *T. diversifolia* and *C. odorata* were rich in organic carbon and total porosity and low in bulk density with an average return biomass to the soil amounting to 23.18 - 27.18g/m^2. The continuously managed arable field showed maize grain yield of 2.72 t/ha compared with fallowed fields dominated by *T. diversifolia* (2.64 t/ha) and *C. odorata* (2.38 t/ha). *Tithonia diversifolia* and *C. odorata* contributed positively to reducing weed emergence and improving soil nutrients. Small-holder farmers can re-incorporate the tested weed species into the cropping system to reduce herbicide usage and improve maize grain yield in the Nigerian southern Guinea savannah.

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INTRODUCTION

Small-scale farmers in Nigeria own less than 10 hectares of land and are the poorest of the country representing around 80% of the country's farming population and producing 80% to 90% of the country's food (Mgbenka et. al., 2016). Most of these farmers have decreased to levels below what is required for sustainability because of rapid population development and increased demand on the land (Onijigin et. al., 2016). The essential inputs such as fertilizer, herbicides and insecticides are scarce and costly, especially at a time when economic reforms have compelled reductions in farm inputs subsidies (Girei et. al., 2018). Fallow, which is the traditional means of supplementing soil nutrients, minimizes weed emergence and curbs the outbreaks of diseases and other pests early in the following crop season (Akobundu et. al., 2002).

Maize is one of the most planted crops in all the geographical zones in Nigeria, and accounts for the largest share of the country's coarse grain production. In recent years, the production of maize in Nigeria has declined due to low input usage. However, in 2021, Nigeria's maize output reached its highest level of about 13.94 million Mt since the country's independence in 1960 (PWC, 2021). Poor economic conditions become a constraint to have continued access to essential inputs for maize production, would have an imminent effect on the rural households lowering their standard of life and maize output (Babatunde et. al., 2007). Therefore, there is a need to re-evaluate the fallow system although reducing the fallow time is becoming more and more attractive to farmers.

Fallows identified in this study were farmlands cultivated continuously for many years and a re-growth of vegetation for about 10 years. Fallowing cropland has reduced nitrogen losses and increases soil organic matter owing to weed growth, when compared to continuous cropping (Wortman, 2016). Planting leguminous herbs or allowing certain dominant weeds to grow would suppress other weeds and increase crop yields (Gu et. al., 2019). Fallow is reported to slow the growth of perennial weeds while increasing the population density of annual weeds (Santin-Montanya et. al., 2016). Gu et al (2019) reported that weed populations in fallowed lands outnumber those in non-fallowed lands, which is a problem exacerbated by the long-term seed dormancy of some weed species.

Fallow-effectiveness also revolves around plant traits that determine the time required to establish a dense canopy for weed inhibition and nutrient-holding capacity (Stagnari et. al., 2017; Lee & Thierfelder, 2017). Soil fertility predicts the diversity of future weed communities (Rajib et. al., 2016), while soil nutrient availability stimulates and determines weed seed germination patterns (Sweeneye et. al., 2009). This indicates that the variation in the population pattern of weed species could be an indication of soil heterogeneity (Udoh et. al., 2007; Lousada et. al., 2013). Weed species could serve as an authoritative index of optimal nutrient levels in cropping systems (Travlos et. al., 2018). The objective of this study was therefore to determine the effects of dominant weeds in a fallow land on the emergence of associated weed species, the nutrient status of the soil and subsequent maize yield.

METHODOLOGY

Site Description

This study was conducted at the University of Ilorin Teaching and Research Farm during the 2017-2019 growing season. The farm is located in Ilorin in the ecological zone of the savannah in southern Guinea (9°29'N, 4°35'E) of Nigeria at 307 m ASL. The area experienced a bimodal precipitation pattern, with peaks in July and a gradual decline from September to a dry spell in December. The total annual precipitation was 1182.41 mm in 2017, 1145.91 mm in 2018 and 1204.72 mm in 2019. Relative humidity ranged from 76.31% to 78.47% with an average maximum temperature of 30.21°C. The soil was a sandy loam Plinthustaffs. Five fallow fields dominated by different weed species were used for the study: (i) a maize-cultivated field fallowed for 7 years with >90% dominance of *Chromolaena odorata* (L. R.M. King & Robinson), (ii) a field cultivated to root and tuber crops but, fallowed for 8 years with 70% *Hyptis suaveolens* Poit and 30% *Leucas aspera* (Willd) Link; (iii) a maize-cultivated field fallowed for 5 years with the dominance of *Tithonia diversifolia* (Hensl. A. Gray); (iv) a sugarcane research field fallowed for 5 years and dominated by *Imperata cylindrica* (L) P. Beauv; and (v) a maize-cultivated field fallowed for 7-10 years dominated by several Poaceae weeds including *Eleusina indica, Digitaria horinzontalis, Brachiaria dexa, Dactylocterium aegyptium and Panicum maxima*.

Soil sampling and seedbank determination

The soil samples used for the estimation of the soil weed seed bank were collected from each fallow field in the first week of April 2017. April is the beginning of rain in the study area. The direct seedling germination method was used to determine the density of viable weed seeds in the seed bank (Swanton et. al., 2000). The fallow fields were divided into four (4) cardinal points. A square (1 m^2) was placed at each cardinal point of the field. Ten (10) drill core samples were collected from each of the cardinal points using a precision drill auger (3.7 cm diameter) to a depth of 0-15 cm. The ten core samples were combined into one composite sample for each cardinal point. The four composite samples were then sieved using a 2 mm sieve to remove impurities. For each fallow field, 100 g of the screened composite soil samples were used to fill each plastic bowl and transplanted using a randomized complete block design in 6 replicates (30 plastic bowls) on a raised bed frame for germination in the Department of Agronomy Pavilion, University of Ilorin, Nigeria. The bowls were perforated at the base to facilitate drainage of excess water in the soil samples. Soil samples were watered every other day and monitored for weed seed germination/seedling emergence. Emerging weed seedlings were enumerated as either broadleaves, grasses, and sedges; identified at the species level, counted and then extracted at 3, 6, 9, 12 and 15 weeks after establishment (WAE). Identification of weed seedlings was done using a West African weed guide (Akobundu et. al., 2016). The soil samples were stirred with a spatula after each assessment to stimulate germination by bringing to the surface other weed seeds that may have been buried deep within them. The experiment was terminated when the emergence ceased. The number (size) of weed seeds in the seed bank (Y) per land area (m^2) was estimated by multiplying the number of seeds in the soil sample (G) by the inverse ratio of the volume of soil in the borer sample to the volume of soil in an area of 1 m^2 sampled to the depth of the drill (15 cm). The ratio was calculated as in Ndarubu & Fadayomi (2006) and Takim *et al*. (2013).

Soil analyses

Two hundred grams of the composite soil samples collected from each fallow field for the seed bank estimation were used for the determination of the chemical and physical properties of the soils in 2017. The pH of the soil was determined electrometrically using a pH meter in 1:1 soil-water suspensions (Mclean, 1982). Organic carbon was determined using Walkley – Black wet oxidation method (Nelson and Sommers, 1982). The total nitrogen of the soil was determined using the micro Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus in the soil was determined using the Bray P1 method (Olsen and Sommers, 1982). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted using 1N NH4OAc (Ammonium acetate) buffered at pH 7.0 (Thomas, 1982). The K^+ and Na^+ concentrations in soil extracts were read on a Gallenkamp flame photometer while Ca^{2+} and Mg^{2+} concentrations in soil extracts were read using Perkin-Elmer Model 403 atomic absorption spectrophotometer (AAS).

Particle size analysis used the hydrometer method with 5 % sodium hexametaphosphate as the dispersing agent. Bulk density was determined in intact soil by the core method (Blake and Harge, 1986) and total porosity was calculated as the sum of macro-porosity and micro-porosity. The moisture content at saturation was determined by saturating soil in a soil core sample for 24 hours and weighed thereafter.

Determination of floristic composition

The phytosociological survey was carried out according to the quantitative survey method described by Kamal-Uddin *et al.* (2009) on each fallow field in 2017 and 2018. Thirty-two transect lines were set to cover each fallow field and quadrats of size 1 m x 1 m were arranged 10 m apart in a grid pattern across each transect line. Each transect line (which had 10 quadrats depending on the length) was surveyed and observations were recorded from the quadrats. The weeds were identified using the Handbook of West African Weeds (Akobundu et. al., 2016).

Field establishment

In the 2018 and 2019 cultivation seasons, five fallow areas and one arable field (continuously arable land) were used for the trial. Zero tillage was adopted for the fallow land, while conventional tillage was used for the arable land. Two weeks before sowing, glyphosate was applied to the fallow fields at 1.2 kg a.i.ha^{-1} before planting while the arable field was mechanically ploughed, harrowed and furrowed. On each field (five fallow lands and one arable land), the experiment was set up in a randomized complete block design with five replicates. A plot consisted of 5 rows or ridges 5 m long and 1.2 m apart. Maize seeds (*Zea mays* L.; var. LNTP-Y) were sown on July 27, 2018 and July 20, 2019 with two seeds per hole at a distance of 25 cm within a row. The seedlings were later thinned to 1 plant per stand 3 weeks after planting (WAP) to give an approximate plant population of 53,333 plants/ha.

Pre-emergence application of Primextra Gold(R)) [a proprietary mixture of metolachlor (2-chloro-N-(2-ethly-6-methlyphenyl)-N-(2-methoxy-1-methlyethyl) acetamide) (290g/L) and atrazine (6-chloro-N-ethyl-N9-(1-methylethyl)-1,3,5-triazine-2,4-diamine) (370g/L)] at 2.0 kg a.i. ha^{-1} was applied to the arable field and post-emergence application of Guardforce(R) (Nicosulfuron 40g/L) at 1.25 kg a.i. ha^{-1} was to all the fields at 3 WAP. A compound fertilizer (NPK 20:10:10) was applied in 2 splits at the rate of 200 kg ha^{-1} at 3 WAP and 100 kg ha^{-1} at 7 WAP to the continuously cultivated arable field while half-dose of the above was applied to the fallow fields.

Data collected on weed species seedling emergence was monitored in two scenarios. In one scenario, emergence was monitored in the same fixed quadrats at 3, 6, 9, 12 and 15 WAE in each transect line, hereafter referred to as continuously sampled quadrats. In the second scenario, weed species seedling emergence and the fresh weight of every weed species were monitored in different fixed quadrats at 5, 10 and 15 WAE in each transect line, hereafter referred to as discreetly sampled quadrats. Crop data collected were taken on plant stand and plant height at harvest (cm), grain yield and yield components. Grain yield was determined from the central three rows of each plot and adjusted to 150 g/kg (15%) water content.

Data analyses

The importance value index (IVI) was estimated, which numerically expresses the importance of a particular species in a community. Importance value index = relative density + relative dominance + relative frequency (Curtes & McIntosh, 1950) for emerged weed seedlings from the soil seed bank estimated in 2017 and the floristic survey of each fallow field in 2017 and 2018 (mean data was used for the IVI). Data collected on soil properties, pulled means (2018 and 2019) of weed species density and fresh weight, grain yields and yield components were subjected to analysis of variance (ANOVA) and significant means were separated using standard errors of difference of means at P=0.05.

RESULTS AND DISCUSSION

Weed species composition

Thirty-seven weed species belonging to 34 genera from 14 families were identified during the phytosociological survey and seed bank estimation on the selected fallow plots (Table 1). Most weed species were broadleaves (70.27%); Sedges accounted for 8.11% while grasses accounted for 21.62% of the total weed flora. In the fallow fields, annual weeds dominated (54.05%), perennials accounted for 35.14%, while 8.11% were either annual or perennial depending on the prevailing environment. In addition, 60% of the weed species were reported both in the field and in the seed bank, 32% and 8% were identified only in the field and in the seed bank, respectively. The result showed that the weed composition differed marginally from natural fallow species; which could be due to the similar crop history of the fields. The natural fallow fields were previously planted with either maize or cassava and there is a tendency to rebuild the soil seed bank with weed species that could get adapted to cultural practice, leading to a repositioning of weed species mimicking the crops grown. The significant occurrence of annual weeds (54.05%) within the cultivated fallow land suggests that the fields have undergone pre-cultivation operations. These operations have effectively managed the prevailing weed species and facilitated the activation of dormant annual seeds within the seed bank. Concurrently, the presence of perennials (34.14%) indicates the suppressive impact on the annual weed variety within the fallow land. Previous studies in the same ecology reported 68% annuals and 32% perennials (Takim et. al., 2013), 74% annuals and 26% perennials (Takim and Fadayomi, 2013), 72% annuals and 28% perennials (Adereti et. al., 2014). The notable percentage of similarity between the weed species observed in the field and those present in the seed bank within this study might stem from various factors. These include the potential disruption of rapidly proliferating weeds (termed as fallow weeds), along with the eradication of established niches through the application of pre-planting glyphosate or the initiation of dormancy breakage via mechanical tillage operations. Additionally, unintended occurrences such as controlled burns on natural fallow land by hunters seeking game or pastoralists deliberately burning dry fields to stimulate grass growth at the onset of the wet season could also contribute to this phenomenon.

The model of outgrowth of field weed seedlings was somewhat similar in fallow fields; *H. suaveolens* emerged continuously during the growing period with a peak at 9WAE while other weeds peaked at 3 WAE except for *Desmodium tortuosum* which peaked at 6 WAE. Six of the identified weed species ceased emergence between 6 and 9 WAE (Table 2). Similarly, thirteen species of weeds were found in *T. diversifolia-dominated* fallow field (Table 3). *Tithonia diversifolia* and *E. heterophylla* peaked at 5 and 9 WAE, respectively and then declined, while *C. rotundus* and *I. cylindrica* peaked at 6 WAE. Fifty percent (50%) of the associated weed species found in *I. cylindrica* fallow peaked at 3 WAE while *I. cylindrica* and a few others peaked at 9 WAE (Table 4). All grass species encountered on grassland fallow increased sharply and peaked at 6 WAE, while associated weeds peaked at either 3 or 6 WAE and then declined sharply (Table 5). For *C. odorata* fallow, 31% of the weed community emerged during the assessment period, while 54% peaked at 3 WAE, and 46% had peak emergence at 6 WAE (Table 6). The above confirms the results of Takim and Fadayomi (2013) that 3, 8 and 10 WAP were the likely peak emergence values for weeds in arable fields in the southern Guinea savannah of Nigeria.

In the discrete sampling process, the population and biomass of emerged weed seedlings declined below 50% at each sampling period, apart from a few relatively predominant weed species. For example, the dominant weed species in the *T. diversifolia* fallow field were *T. procumbens, B. lata* and *Perotis indica* compared to *H. suaveolens; E. heterophylla* and *C. rotundus*; in the *I. cylindrica* -fallow field, *T. procumbens* and *D. horizontalis*; and in the grass fallow field, *D. aegyptium, B. lata* and *T. procumbens*; the fallow field dominated by *C. odorata* had *B. lata* and *T. procumbens* as the most common associated weed species. The low population density and low weight of weed species in the discrete squares sampled at 10 and 15 WAE could be the result of seedlings destroyed by allelopathy, self-thinning, or germination and/or germination inhibition, reflecting shading by the fast-growing weed species (Takim and Fadayomi, 2010). Weed density

Table 1: Important value index of weed species identified across selected weed fallows

				Mean Field Emergence (2017 & 2018)					Soil seed bank Emergence, 2017				
FAMILY	**WEED SPECIES**	**M**	**LC**	**HSF**	**TDF**	**ICL**	**GSF**	**COF**	**HSF**	**TDF**	**ICL**	**GSF**	**COF**
Amaranthaceae	*Achyranthes aspera* L.	B	A	-	-	-	6.6	-	-	-	-	-	-
	Gomphrena celosioides Mart	B	A/P	15.2	-	-	-	-	-	-	-	-	-
Asteraceae	*Ageratum conyzoides* L.	B	A	-	5.1	-	-	-	14.8	13.5	15.8	9.9	-
	Chromolaena odorata (L.) R.M. King & Robinson	B	P	-	1.5	1.5	-	91.1	-	9.4	-	3.9	67.4
	Tithonia diversifolia (Hensl).A. Gray	B	P	-	52.1	-	-	-	-	74.6	-	-	-
	Tridax procumbens (L.)	B	A	16.2	-	20.8	21.7	19.2	29.0	42.5	48.6	40.6	48.6
Cleomaceae	*Cleome viscosa* L.	B	A	-	-	-	5.3	-	-		11.0	11.6	-
Cyperaceae	*Cyperus rotundus* L.	S	P	30.2	80.2	-	17.7	20.1	31.2	35.3	14.2	13.2	37.5
	Meriscus alternifolius Vahl	S	P	-	-	-	11.9	-	-	5.2	-	-	-
	Pycreus flavescens (L).P.Beauv. ex Rchb	S	P	-	-	2.9	-	-	4.9	-	-	-	-
Euphorbiaceae	*Acalypha fimbriata* Schum. &Thonn	B	A	-	5.1	-	-	-	15.9	-	-	3.9	18.4
	Euphorbia heterophylla L.	B	A	-	1.5	1.5	5.3	-	24.7	22.8	47.5	40.6	30.7
Laminaceae	*Hyptis suaveolens* Poit	B	A	57.7	-	-	-	7.9	53.4	-	-	-	11.1
Leguminosae	*Calopogonium mucunoides* Desv	B		-	27.3	2.9	-	-	-	4.2	5.5	-	-
	Desmodium tortuosum (Sw.) DC	B	P	15.9	-	-	-	-	-	-	-	-	-
	D. scorpiurus (Sw.) Desv.	B	P	41	9.9	4.3	16.0	8.8	20.8	23.9	26.2	24.2	12.8
	Indigofera hirsuta L.	B	A	-	-	0.8	12.6	-	8.8	-	11.0	26.9	11.1
	Mimosa invisa Mart	B	P	27.6	-	-	-	-					
	Stylosanthes guianensis (Aublet) Sw.	B	P	-	5.1	-	-	-					
	Tephrosia bracteolata Gull. & Perr	B	A	-	-	1.5	-	-					
	T. pedicillata Bak.	B	A	-	-	3.0	12.6	7.1					
Malvaceae	*Sida acuta* Burn. f.	B	P	13.5	-	-	-	-	-	-	-	3.9	-
Nyctoginaceae	*Boerhavia diffusa* L.	B	A	-	-	-	-	-	-	10.4	-	-	-
Passifloraceae	*Passiflora foetida* L.	B	A	11.0	-	4.4	-	-	-	-	-	-	-

Phyllanthaceae	*Phyllanthus* amarus Schum & Thonn)	B	A		-	17.1	-	-	15.9	-	11.0	7.7	5.6
	Phyllanthus pentandrus Schum & Thonn	B	A		-	0.8	-	-					
Poaceae	*Brachiaria lata* (Schumach.) C.E.	G	A	13.5	-	-	59.0	55.8	3.9	-	5.5	-	-
	Cynodon dactylon L. Pers	G	AP	5.1	-	-	-	-	-	-	-	-	-
	Dactyloctenium aegyptium (L) P. Beauv	G	AP	5.9	-	-	54.5	18.4					
	Digitaria horizontalis Willd	G	A	-	5.7	5.7	16.2	13	27.5	20.8	-	44.9	-
	Imperata cylindrica (L.) (Anderss) C.E.Hubbard	G	P	17.6	15.3	82.3	17.7		3.9	-	-	5.0	-
	Paspalum scrobiculatum L	G	P	-	-	2.2	9.8	7.1	-	-	-	-	-
	Perotis indica (L.) O. Ktze	G	A	5.9	5.3	-	-	7.9	-	-	-	-	5.6
	Setaria barbata (Lam.) Kunth	G	A	19.3	9.2	-	27	36.4	4.9	4.2	5.5	26.9	16.7
Portulacaceae	*Talinium triangulare* (Jacq.) Willd.	B	A	-	-	-	-	-	3.9	6.2	5.5	-	-
Rubiaceae	*Diodia sarmentosa* Sw.	B	P	32.0	-	-	6.0	7.1	15.9	-	-	21.5	12.8
	Oldenlandia corymbosa L.	B	A	-	-	-	-	-	20.8	22.9	33.9	15.5	21.8

M-Morphology, LC- life cycle, B- broadleaf, G-grass, S- sedge, A-annuals, AP- annual-perennials, P-perennials,
TDF-*Tithonia diversifolia* field, COF-*Chromolaena odorataa* field, HSF-*Hyptis suaveolens* field, ICF- *Imperata cylindrica* field, GSF- grass field

Table 2: Mean density and fresh weight of weed species encountered in a *Hyptis suaveolens* dominated fallow field, 2018 and 2019

		Seedlings density in continuously sampled quadrats (seedling/m²)					Seedlings density in discreetly sampled quadrats (seedlings/m²)			Fresh weight of Seedlings in discreetly sampled quadrats (g/m²)		
		Weeks After Establishment of Quadrats										
FAMILY	**WEED SPECIES**	**3**	**6**	**9**	**12**	**15**	**5**	**10**	**15**	**5**	**10**	**15**
Amaranthaceae	*Gomphrena celosioides* Mart	16	21	7	0	0	12	3	0	4.05	1.50	0.00
Asteraceae	*Tridax procumbens* (L.)	53	34	21	11	7	56	47	13	28.36	23.56	6.50
Cyperaceae	*Cyperus rotundus* L.	11	7	0	0	0	16	2	0	8.09	1.30	0.00
Laminaceae	*Hyptis suaveolens* Poit	82	114	152	73	37	101	73	51	51.43	36.85	25.59
Leguminosae	*Desmodium tortuosum (*Sw.) DC.	13	0	6	1	0	27	6	0	13.50	3.02	0.00
	D. scorpiurus (Sw.) Desv.	27	36	12	7	0	23	13	7	11.54	6.52	3.50
	Mimosa invisa Mart	23	0	0	0	0	17	6	0	8.53	3.00	0.00
Malvaceae	*Sida acuta* Burn. f.	14	13	0	0	0	21	3	4	10.56	1.50	2.00
Passifloraceae	*Passiflora foetida* L.	14	6	0	0	0	22	6	3	11.00	3.00	1.50
Poaceae	*Brachiaria lata* (Schumach.) C.E.	62	41	19	0	0	47	36	14	23.54	18.05	7.03
	Cynodon dactylon L. Pers	41	19	0	0	0	37	15	7	18.56	7.54	3.51
	Dactyloctenium aegyptium (L) P. Beauv	6	2	0	1	0	7	3	0	3.56	1.50	0.00
	Imperata cylindrica (L.) Anderss C.E. Hubbard	34	27	13	9	1	22	18	6	11.06	9.04	3.07
	Perotis indica (L.) O. Ktze	18	15	7	0	0	26	24	10	13.08	12.05	5.10
	Setaria barbata (Lam.) Kunth	12	17	10	2	0	24	13	7	12.00	6.54	3.52
Rubiaceae	*Diodia sarmentosa* Sw.	31	27	0	3	1	17	11	6	8.05	5.52	3.03
	SED@ *P≤0.05*	16.1	14.8	15.2	8.2	7.5	17.2	13.5	9.1	6.3	9.4	7.8

Table 3: Mean density and fresh weight of weed species encountered in a *Tithonia diversifolia* dominated fallow field, 2018 and 2019

		Seedlings density in continuously sampled quadrats (seedlings/m²)					Seedlings density in discreetly sampled quadrats (seedlings/m²)			Fresh weight of Seedlings in discreetly sampled quadrats (g/m²)		
		Weeks After Establishment of Quadrats										
FAMILY	**WEED SPECIES**	**3**	**6**	**9**	**12**	**15**	**5**	**10**	**15**	**5**	**10**	**15**
Asteraceae	*Ageratum conyzoides* L.	22	17	5	0	0	17	7	2	8.51	3.50	1.06
	Chromolaena odorata (L.) R.M. King & Robinson	16	24	10	0	0	27	14	10	13.00	7.04	5.04
	Tithonia diversifolia. (Hensl).A. Gray	74	65	97	51	36	64	67	51	32.07	33.07	25.54
Cyperaceae	*Cyperus rotundus* L.	53	71	105	43	12	57	21	28	28.53	7.53	4.50
Euphorbiaceae	*Acalypha fimbriata* Schum. &Thonn	10	21	16	0	0	17	9	0	8.58	2.58	0.00
	Euphorbia heterophylla L.	32	14	27	10	7	31	27	14	15.52	9.52	7.04
Leguminosae	*Calopogonium mucunoides* Desv	16	28	17	0	0	15	7	10	7.53	3.52	5.04
	Desmodium scorpiurus (Sw.) Desv.	7	19	10	0	0	3	0	0	1.50	0.00	0.00
	Stylosanthes guianensis (Aublet)SW	3	14	5	0	0	4	2	0	2.05	1.09	0.00
Poaceae	*Digitaria horizontalis* Willd	26	40	15	0	0	31	37	14	15.58	8.53	7.03
	Imperata cylindrica (L.) Anderss C.E. Hubbard	14	25	21	10	6	23	11	7	11.54	5.52	3.51
	Perotis indica (L.) O. Ktze	7	19	14	0	0	11	6	0	5.57	2.06	0.00
	Setaria barbata (Lam.) Kunth	5	12	10	0	0	14	7	0	7.09	1.52	0.00
	SED@ $P \leq 0.05$	9.3	8.2	13.7	6.2	7.4	9.2	8.9	6.2	4.8	6.8	6.0

Table 4: Mean density and fresh weight of weed species encountered in a *Imperata cylindrica* dominated fallow field, 2018 and 2019

		Seedlings density in continuously sampled quadrats (seedlings/m^2)					Seedlings density in discreetly sampled quadrats (seedlings/m^2)			Fresh weight of seedlings in discreetly sampled quadrats (g/m^2)		
		Weeks After Establishment of Quadrats										
FAMILY	**WEED SPECIES**	**3**	**6**	**9**	**12**	**15**	**5**	**10**	**15**	**5**	**10**	**15**
Asteraceae	*Chromolaena odorata* (L.) R.M. King & Robinson	6	18	12	0	0	12	0	0	6.51	0.00	0.00
	Tridax procumbens (L.)	27	16	34	6	0	13	0	0	6.53	0.00	0.00
Cyperaceae	*Pycreus flavescens* (L).P.Beauv ex Rchb	16	5	0	0	0	6	0	0	3.02	0.00	0.00
Euphorbiaceae	*Euphorbia heterophylla* L.	24	31	18	7	0	14	3	0	7.04	1.52	0.00
Leguminosae	*Calopogonium mucunoides* Desv	12	7	0	0	0	0	0	0	0.00	0.00	0.00
	Desmodium scorpiurus (Sw.) Desv.	6	4	0	0	0	0	0	0	0.00	0.00	0.00
	Indigoflora hirsuta L.	7	0	0	0	0	0	0	0	0.00	0.00	0.00
	Tephrosia bracteolate Gul & Per	21	17	0	0	0	0	0	0	0.00	0.00	0.00
	T. pedicillata Bak	16	12	0	0	0	0	0	0	0.00	0.00	0.00
Passifloraceae	*Passiflora foetida* L.	14	0	0	0	0	0	0	0	0.00	0.00	0.00
Phyllanthaceae	*Phyllanthus* amarus (Schum &Thonn)	22	18	10	2	0	14	2	0	7.02	1.00	0.00
Poaceae	*Digitaria horizontalis* Willd	4	16	20	37	14	16	14	7	8.06	7.34	3.54
	Imperata cylindrica (L.) Anderss C.E. Hubbard	34	60	92	51	21	44	31	27	22.75	15.58	13.90
	Paspalum scrobiculatum L	12	19	34	9	0	33	16	9	15.54	8.04	4.53
	SED@ $P \leq 0.05$	9.4	11.9	12.1	6.7	3.1	7.5	5.4	3.9	2.5	2.3	2.6

and biomass were higher at 5 WAE, which could be attributed to light penetration affecting rapid germination, emergence, and growth of weeds. Further, the dispersal and spatial competitiveness of the dominant weed species may prevent other weeds from producing large seeds, consequently affecting the composition of the weed seed bank (Gu et. al., 2019) and thus the population of potential weed seedlings in the following seasons. The highest average weed biomass returned to the soil was obtained from *H. suaveolens*, 27.61g/m^2, 27.18 g/m^2 from *C. odorata* fallow, *T. diversifolia*, 23.23 g/m^2, while six grass weed species that dominated the grass fallow field contributed 70% of the 21.32g/m^2 of plant biomass returned to the soil, 9.42 g/m^2 was relatively the least plant biomass obtained from fallow field dominated with *I. cylindrica*.

Soil properties

The results on chemical and physical properties of soil as influenced by weed fallow are presented in Tables 7 and 8, respectively. The soil was slightly acidic, with a pH range from 5.8 to 6.9 in water, higher than 5.1 to 5.8 in potassium chloride (Table 7), indicating that the soil had a net negative charge in the colloidal complex**.** Recent research (Hagan et. al., 2013a), however, indicates that the concentrations of several phenolic acids can be orders of magnitude higher in grass-invaded soils than in similar soils dominated by native species. This suggests that grasses would increase soil acidity. However, the reductions in soil acidity that were observed were not statistically significant (p>0.05) but could be due to higher pH buffering capacity, which had the effect of moderating pH fluctuations (Hagan et. al., 2013b). However, the pH was in the optimum range for optimal nutrient availability, minimal solubility of toxic elements and active performance of beneficial soil organisms.

Organic carbon (OC) content, which is related to N supply, ranged from 0.16 to 1.77%. It was the lowest (0.16 and 0.26 %) when relative densities of *I. cylindrica* and grass field were relatively high**,** respectively. Soil organic carbon was the highest (1.77%) when the relative density *T. diversifolia* was relatively high too. While changing the basic texture of the soil is difficult, improving the structure with more organic matter would make clayey soil more porous and sandy soil more water-retaining. Therefore, *T. diversifolia* with the highest organic carbon is said to improve soil better than all the others. The primary nutrient levels were generally low: total nitrogen (N) ranged from 0.04% to 0.21%, available phosphorus (P) levels from 3.42 to 5.78 mg kg^{-1}, while potassium (K) was at a moderate level between 0.45 and 0.72 cmol kg^{-1}. The concentration of other exchangeable bases was 1.22 – 3.38 cmol kg^{-1}for Ca, 0.02 – 0.15 cmol kg^{-1}for Mg and 0.05 – 023 cmol kg^{-1}for Na.

The soils were coarse-textured (generally sandy loam) with more than 80% sand content and relatively little clay (less than 12 %) (Table 8). The low organic carbon content combined with the associated sandy texture (Tables 7 and 8) would promote rapid leaching of cations (Enwezor et. al., 1989) and consequently, the soil had a low CEC content. The effective cation exchange capacity of the soils, calculated as a sum of the exchangeable bases, would be low. This allows the soil to be slightly acidified as the ability to hold the basic cations is low. It is important to note that the subsequent effect on potential soil fertility depends on physical soil modifications, weed control or soil-borne disease, in addition to the chemical balance (Salako et. al., 2000).

Bulk density in terms of soil structural support, water and solute movement, and soil aeration was moderate (1.28 to 1.59 kg cm^{-3}). Soils in the *T. diversifolia* and *C. odorata* fallow fields had relatively lower soil bulk density and relatively higher total porosity, which could be attributed to an increase in soil organic matter resulting in the high returned and degraded organic biomass by soil organisms. The soil under *I. cylindrica* recorded a significantly higher moisture content (p≤0.05) compared to others, but not statistically (p>0.05) different from soil dominated by grass species. Continuously cultivated arable soil had the lowest total porosity (50.27 %) and highest soil bulk density (1.59 g/cm^2) as well as the

lowest moisture content. In general, soil porosity was reduced due to an increase in bulk density. *T. diversifolia* and *C. odorata* are fast-growing weeds with the rapid conversion of biomass to organic matter (Ojeniye et. al., 2012) and in turn provide essential nutrients required for plant uptake and improved aggregate stability (Yemefack et. al., 2002).
The content of clay and silt was significantly higher ($p \leq 0.05$) in *T. diversifolia* and *C. odorata* compared to grass-dominated fallow and arable land. Conversely, the proportion of sand in soils was higher in *T. diversifolia, C. odorata* and *H. suaveolens* fallows. These changes in particle size distribution explained the high bulk density. During fallow, clay particles tend to increase and aggregate stability while bulk density decreases (Yemefack et. al., 2002).

Yield of maize

Fallow significantly affected maize yield and yield components ($p \leq 0.05$) except for the 1000 seed weight (Table 9). Fallow grasses recorded the lowest maize yield (0.72 t/ha) and yield components of maize were relatively similar to those of *I. cylindrica* (0.86 t/ha) fallow. Significantly higher yields and yield components ($p < 0.05$) were reported from *C. odorata* (2.38 t/ha) and *T. diversifolia* (2.64 t/ha) fallow, although the latter is similar ($p > 0.05$) to continuously managed arable land (2.72 t/ha) and *H. suaveleons* (1.56 t/ha) fallow fields. Overall maize performance improved in the following sequence: grass fallow, *I. cylindrica* fallow, *H. suaveolens* fallow, *C. odorata* fallow, continuously cultivated cropland, and *T. diversifolia* fallow fields.

The relatively high grain yield (2.72 t/ha) from the continuously cultivated field compared to the yield (2.64 t/ha) of *T. diversifolia* fallow field could be due to the optimal inorganic fertilizer applied and the carryover effect of fertilizers from the previous seasons. The better growth and maize yield among *T. diversifolia* and *C. odorata* compared with maize grown in other weed-dominated fallow fields could be attributed to the improved physical and chemical properties of soil because of high weed biomass returned (23.18-27.18g/m^2) and degraded in such soil, hence, the performance of maize was better compared to the grasses dominated fallow fields that contributed 9.42 - 21.32g/m^2 weed biomass to the soil. According to Daneshgar and Jose (2009), grasses have high nutrient use efficiency, which contributes to the production of low-quality tissues that decompose slowly in grass fallows. This is because the carbon cycle is intrinsically linked to other elemental cycles, alterations in biomass production affect the cycling of soil nutrients—particularly macronutrients such as N and P that are frequently limiting. This agrees with the results of Nziguheba *et al.* (1998); Yemefack *et al.* (2002); Olabode *et al*. (2007), who stated that *T. diversifolia* and *C. odorata* are high-quality organic sources with low to moderate carbon/nitrogen ratio, rich in soil nutrients (Liasu and Achakzai, 2007), while Atayese and Liasu (2001) reported *T. diversifolia* and *C. odorata* among the plants that improved the absorption of nutrients.

The biplot explained 89% of the fallow effects on nutrient enrichment and yield of maize (Fig. 1). The small circle is the average environment axis (AEA) and the arrow pointing to it is used to indicate the direction of the AEA. Fallows with shorter vectors are less informative in contrast to those with longer vectors whereas the most representative fallows are those located with smaller angles with the AEA. Therefore, *T. diversifolia* fallow is the most discriminating fallow while *C. odorata* is the most representative fallow. The implication of the above is that *T. diversifolia* and *C. odorata* are the most promising fallow sites suitable for maize production. The polygon is also divided into three sectors, suggesting the possibility of similarities among the fallow fields. The first group had *T. diversifolia* fallow field alone, *C. odorata* and arable fields made up the second group while the third fallow consisted of *H. suaveolens*, *I. cylindrica* and grass fallow fields.

Table 5: Mean density and fresh weight of weed species encountered in a grass fallow field, 2018 and 2019

		Seedlings density in continuously sampled quadrats (seedlings/m²)					Seedlings density in discreetly sampled quadrats (seedlings/m²)			Fresh weight of Seedlings in discreetly sampled quadrats (g/m²)		
		Weeks After Establishment of Quadrats										
FAMILY	**WEED SPECIES**	**3**	**6**	**9**	**12**	**15**	**5**	**10**	**15**	**5**	**10**	**15**
Amaranthaceae	*Achyranthes aspera* L.	16	6	10	2	0	11	3	0	5.52	1.54	0.00
Asteraceae	*Tridax procumbens* (L.)	24	18	10	3	2	21	16	12	10.57	8.05	6.05
Cleomaceae	*Cleome viscosa* L.	5	6	2	0	1	10	6	2	5.04	3.06	1.07
Cyperaceae	*Cyperus rotundus* L.	17	12	0	0	0	11	6	0	5.58	3.02	0.00
	Meriscus alternifolius Vahl	21	18	2	0	0	16	0	0	8.02	0.00	0.00
Euphorbiaceae	*Euphorbia heterophylla* L.	19	26	14	2	0	24	16	3	12.06	8.05	1.54
Leguminosae	*Desmodium scorpiurus* (Sw.) Desv.	17	28	0	13	0	18	6	0	9.04	3.09	0.00
	Indigoflora hirsute L.	7	12	4	0	0	3	1	0	1.54	0.54	0.00
	Tephrosia pedicillata Bak	14	6	3	0	0	12	7	1	6.04	3.54	0.54
Poaceae	*Brachiaria lata* (Schumach.) C.E.	80	101	42	16	4	64	73	51	32.65	36.05	15.59
	Dactyloctenium aegyptium (L) P. Beauv	54	75	61	20	23	37	23	24	18.56	11.34	12.06
	Digitaria horizontalis Willd	41	63	17	0	4	43	39	22	21.50	19.52	11.00
	Imperata cylindrica (L.) Anderss C.E. Hubbard	36	51	22	0	0	26	16	28	13.06	8.04	14.03
	Paspalum scrobiculatum L	18	37	14	0	0	8	12	6	4.07	6.07	3.05
	Setaria barbata (Lam.) Kunth	17	40	16	2	0	12	5	0	6.03	2.54	0.00
Rubiaceae	*Diodia sarmentosa* Sw.	3	16	7	0	0	4	1	0	2.05	0.52	0.00
	SED@ $P \leq 0.05$	7.6	11.7	3.9	2.3	6.2	9.5	8.2	5.7	4.2	3.8	3.4

Table 6: Mean density and fresh weight of weed species encountered in a *Chromolaena odorata* dominated fallow field, 2018 and 2019

		Seedlings density in continuously sampled quadrats (seedlings/m^2)					Seedlings density in discreetly sampled quadrats (seedlings/m^2)			Fresh weight of seedlings in discreetly sampled quadrats (g/m^2)		
		Weeks After Establishment of Quadrats										
FAMILY	**WEED SPECIES**	**3**	**6**	**9**	**12**	**15**	**5**	**10**	**15**	**5**	**10**	**15**
Asteraceae	*Chromolaena odorata* (L.) R.M. King & Robinson	94	124	73	41	17	86	79	73	43.07	39.06	36.59
	Tridax procumbens (L.)	57	89	34	17	6	66	24	16	33.08	6.40	2.04
Cyperaceae	*Cyperus rotundus* L.	45	27	18	2	0	38	23	6	19.05	5.52	3.02
Laminaceae	*Hyptis suaveolens* Poit	23	17	6	0	0	17	8	0	8.56	4.06	0.00
Leguminosae	*Desmodium scorpiurus* (Sw.) Desv.	13	7	0	0	0	11	6	0	5.54	3.01	0.00
	Tephrosia pedicillata Bak	41	23	17	3	0	33	19	8	16.53	9.52	1.03
Poaceae	*Brachiaria lata* (Schumach.) C.E.	67	89	51	36	23	58	67	46	14.04	5.54	3.05
	Dactyloctenium aegyptium (L) P. Beauv	48	34	12	0	0	42	36	24	21.09	`8.05	2.44
	Digitaria horizontalis Willd	28	34	25	17	7	31	29	21	15.59	7.59	1.58
	Paspalum scrobiculatum L	17	12	0	0	0	11	6	0	5.54	3.05	0.00
	Perotis indica (L.) O. Ktze	21	18	2	0	0	16	0	0	8.05	0.00	0.00
	Setaria barbata (Lam.) Kunth	19	26	14	2	0	24	16	3	12.04	4.03	1.52
Rubiaceae	*Diodia sarmentosa* Sw.	17	28	0	13	0	18	6	0	9.05	3.06	0.00
	SED@ *P≤0.05*	9.2	12.1	8.4	3.1	2.9	7.8	5.5	6.4	4.2	3.8	4.6

Table 7: Soil chemical properties (0-15 cm depth) of selected weed fallow fields, 2017

Weed Fallow	pH	pH	OC	N	AP	Ca	Mg	K	Na
	(H_2O)	(KCl)	(%)	(%)	(mgkg^{-1})	(cmolkg^{-1})			
Tithonia diversifolia,	6.9	5.8	1.77^a	0.16^b	5.78^a	3.34^a	0.05	0.72	0.23^a
Imperata cylindrica	6.2	5.1	0.16^d	0.07^{cd}	4.29^b	1.41^c	0.07	0.45	0.21^{ab}
Gramineous	6.6	5.3	0.26^d	0.04^d	3.47^c	1.22^c	0.02	0.47	0.05^d
Hyptis suaveolens	6.0	5.1	1.14^b	0.10^c	3.72^c	2.46^b	0.06	0.56	0.17^{ab}
Chromolaena odorata	5.8	5.2	1.06^b	0.21^a	3.42^c	3.38^a	0.07	0.53	0.11^c
Continuously cultivated Arable field	5.5	4.8	0.81^c	0.20^a	3.04^c	1.82^{bc}	0.05	0.57	0.16^{ab}

OC- Organic carbon, AP- Available phosphorus,

Table 8: Soil physical properties of selected weed fallow fields, 2017

Weed Fallow	BD(g/cm^3)	MaP	MiP	TP	MC	Clay	Silt	Sand	Soil texture
		%							
Tithonia diversifolia	1.27	15.35	56.02	71.37	32.01^b	9.76^c	10.00^b	84.44	Sandy loam
Imperata cylindrica	1.30	14.53	54.65	69.18	34.81^a	7.76^b	8.00^c	80.24	Sandy loam
Gramineous	1.48	26.70	41.62	68.33	33.81^{ab}	7.76^b	10.00^b	80.24	Sandy loam
Hyptis suaveolens	1.29	7.50	44.57	52.08	30.13^c	9.76^a	6.00^d	82.24	Sandy loam
Chromolaena odorata	1.25	24.30	50.25	74.55	32.01^b	9.82^b	11.94^a	82.24	Sandy loam
Continuously cultivated Arable field	1.59	11.50	38.76	50.27	26.43^d	7.76^c	8.00^b	80.24	Sandy loam

BD- Bulk density, MaP- Macro-porosity, MiP- Micro-porosity, TP- Total porosity, MC- Moisture content

Table 9: Average yield and yield components of maize as influenced by selected weed fallow, 2018 and 2019.

Weed Fallow Field	Plant Stand/plot at harvest	Plant height (cm) at harvest	No. of Cobs/plot	Cobs weight/plot (kg)	1000 seeds weight (g)	Grain yield (ton/ha)
Tithonia diversifolia	113	173.34	56	5.22	247.91	2.64
Hyptis suaveolens	107	162.35	47	3.08	233.75	1.56
Imperata cylindrica	79	147.89	34	2.24	198.81	0.86
Gramineous	74	150.07	30	2.58	209.58	0.72
Chromolaena odorata	102	168.34	62	4.43	217.34	2.38
Continuously cultivated Arable field	109	161.36	50	4.47	240.74	2.72
SED (p<0.05)	13.47	9.86	8.44	0.75	11.54	0.75

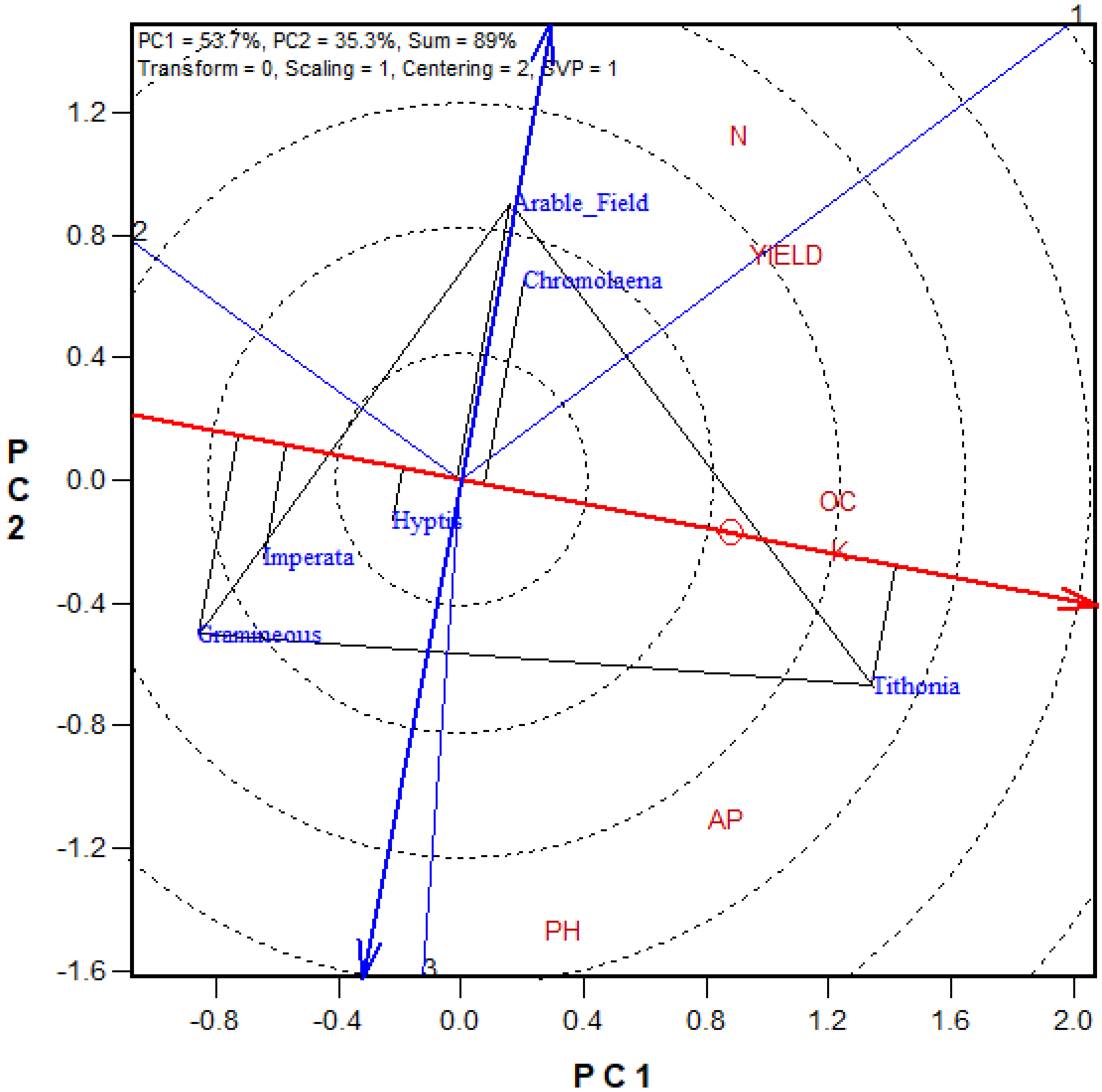

Figure 1. Mean performance and stability of fallow fields in terms of selected soil nutrients and grain yield as measured by principal componen

Table 10: Correlation matrix between weed fallows on maize grain yield

	Chromolaena odorata fallow	Continuously Arable field	Grass fallow	*Hyptis suaveolens* fallow	*Imperata cylindrica* fallow
Chromolaena odorata fallow	-				
Continuously arable field	0.543*	-			
Grass fallow	0.916	-0.803*	-		
Hyptis suaveolens fallow	-0.917*	0.799*	0.997*	-	
Imperata cylindrica fallow	-0.979*	0.641	0.970**	-0.967*	-
Tithonia diversifolia fallow	0.925	-0.196	-0.733	0.736	0.874

* =significant @0.05, ** =significant @0.01

Table 11: Correlation matrix between selected soil parameters and performance of maize

	Total Nitrogen (N)	Organic Carbon (OC)	Available Phosphorus (P)	Potassium (K)	pH	Grain Yield	1000 Seeds weight	Plant stands
Total Nitrogen (N)	-							
Organic Carbon (OC)	0.6032*	-						
Available Phosphorus (P)	-0.0619	0.5380	-					
Potassium (K)	0.5259	0.9383	0.6451	-				
pH	-0.4949*	0.1929	0.7799	0.3183	-			
Grain yield	0.8495**	0.4713*	0.2294	0.5540	-0.1930	-		
1000 seeds weight	0.5151**	0.4149	0.5389	0.5902	0.0127	0.8007*		
Plant stands	0.5869*	0.2473	0.4039	0.3849	-0.0404	0.8994**	0.9013*	-
Plant height	0.6849*	0.5531*	0.5618	0.5758	0.0894	0.8695	0.7905	0.8935

* =significant @0.05, ** = significant @0.01

The simple correlation coefficient matrix between the fallow fields on maize yield (Table 10) shows that *C. odorata* fallow field had a positive significant correlation with the continuously cultivated arable field and negatively corrected with *H. suaveolens*, and *I. cylindrica* fallow fields while the continuously cultivated arable field is negatively and positively correlated with Tithonia and grass fallow fields, respectively. Total Nitrogen had a positive significant relationship($p<0.05$) with organic carbon, yield, and yield components of maize and negative with soil pH and available P (Table 11). While organic carbon correlated positively and significantly ($p<0.05$) with grain yield and plant height, the grain yield of maize had a similar relationship with seed weight and plant stands.

CONCLUSIONS

This study has shown that weed composition and emergence pattern are slightly consistent with natural fallow species, 60% of the enumerated weed seed bank were identified in the field, *T. procumbens, B. lata* and *C. rotundus* were the most prevalent weed species on the natural fallow fields and weed occurrence peaked at 3, 6 and 9WAE. Soils under *T. diversifolia* and *C. odorata* were rich in organic carbon, low in bulk density and high in total porosity, clay, silt particles and sand fraction as compared to other fallow fields. The continuously cultivated arable land had a grain yield of 2.72 t/ha, which was similar to that of *T. diversifolia* (2.64 t/ha) and *C. odorata* (2.38 t/ha).

In overall performance, yield and yield components increased in the order of grass fallow, I. *cylindrica fallow, H. suaveolens fallow, C. odorata fallow,* continuously cultivated farmland, and *T. diversifolia* fallow fields. The study concludes that lands fallow with *T. diversifolia* and *C. odorata* were the best among tested that could contribute positively to reducing subsequent weed occurrence and improving soil nutrients in the southern Guinea savannah of Nigeria.

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