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Weed Flora Dynamics in Maize (*Zea mays* L.) Field as Influenced by Cover Crop Types and Planting Densities at Jalingo, Northeast, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Competition from weeds is an obstacle to profitable maize production. Knowledge of weed species limiting productivity is essential for sustainable management. A two years field experiment was conducted to evaluate the effect of a leguminous cover crop, akidi (*Vigna unquiculata sub-sp sequipedalis)* and two non-leguminous cover crops (melon and sweet potato) planted at three densities on weed flora composition and shift in maize at Jalingo, North-eastern Nigeria.
Study Design: There were 11 treatments replicated three times in a randomized complete block design.
Methodology: Low, moderate and high densities (20,000, 30,000 and 40,000 stands/ha respectively) of Akidi, Melon and Sweet potato (A_1, A_2, A_3, M_1, M_2, M_3, S_1, S_2, S_3) with weeded (C_1) and unweeded (C_2) checks constituted the treatments laid out in a randomized complete block design replicated three times. Weed flora abundance, percentage density, percentage frequency, frequency index and percentage contributions were determined from a 50cm x 50cm quadrat thrown twice per plot at various phases of maize growth.
Results: Thirteen weed families made up of 11 broad leaves, one grass and one sedge were

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identified. The abundance was in the order Broad leaf > Grass > Sedges. The most abundant weed species were: *Imperata cylindrica* L (3.8), *Mucuna utilis* (3.0), *Oldenlandia herbacea* L. (2.6) *Sida acuta* Burm F, *Tridax procumbens* L. (2.5 each), *Leucas martinicensis*, *Pennisetum pedicellatum* (2.3 each). *Commelina benghalensis, Cyperus difformis* (3.5), *Digitaria horizontalis*, *Fimbristylis littoralis* (2.8 each). The influence of selected cover crops on individual weed percentage the contribution shows: *Commelina benghalensis* (C_2<C_1 < M <S< A), *Euphorbia hyssopifolia* (C_2<M/S < A<C_1), *Euphorbia heterophylla* (M<S<A), *Leucasmartinicensis* (C_1<C_2<M<A<S), *Mucunautilis* (S<M<C_1<C_2<A) and *Sida acuta* (M<S<A<C_2<C_1) while grassy weeds, *Imperata cylindrical* (A<C_2<S<M), *Pennisetum pedicellatum* (A<C_2), *Digitaria horizontalis* (C_1/ C_2< A < M <S), *Kyllinga squamulata* (M/S <C_2<A <C_1). *Commelina* spp. increased in status from an accessory (21.2%) to abundance (66.7%) while others increased from rare to accessory (from 0.0 to 20-40%).

Conclusion: Akidi was more effective on broad-leaved weeds while melon and sweet potato were more effective on grasses and *Commelina benghalensis* need to be monitored.

Keywords: Weed flora; flora shift; cover crops; akidi; melon; sweet potato; maize.

1. INTRODUCTION

Weeds have been identified as the number one problem in crop production, especially in the tropics, causing global yield loss of over 43% [1] and reducing the quality of harvested produce [2-4]. Nigeria is ranked as the tenth-largest maize producer in the world and the largest in Africa producing 10.4 million metric tonnes in 2016 [5-6]. Maize is an important component of the diet of many Africans and an important source of carbohydrate, protein, vitamin B, and minerals and constitutes 25% of the food intake in Nigeria with per capital of 40 kg/year [7].

Improper and inadequate management of weeds in maize could reduce yield by 40-100% [8-12] and in some extreme cases result in the abandonment of farmers' fields [13]. Despite the great potential of maize, both for human consumption and livestock feed, as well as industrial processing [14-15], the average yield obtained on Farmers' fields is very low, about 1 t ha^{-1} (in Africa), 1.13 t ha^{-1} (in Nigeria) compared with the world average of 4.04 t ha^{-1} [16]. In Taraba State, about 61.2% of the farmers harvest less than 1 t ha^{-1} [17], which is far below the actual yield of 1 – 2 t ha^{-1} (open pollinated) and 3.5t ha^{-1} (hybrid) expected in the Savanna [18]. The low yield obtained by farmers may be due to factors including low soil fertility, pest's infestation, weed and diseases infection beyond the threshold level, change, and loss of biodiversity [19-20]. William and Lagoke, [21] affirmed that weeds are the most underestimated pests in tropical agriculture and inefficient control of weeds such as *Imperata cylindrica, Rottboellia cohinchinensis, Eleusine indica, Panicum* spp, *Bidens pilosa, Pennisetum* spp, parasitic weeds like *Striga hermonthica, S. asiatica, S. aspera* in a maize field could lead to total yield loss. They observed that the sequence of incidence and weed flora composition was in the order, broadleaf > sedge > grass at Ogun state. Jafun and Abdul, [22] in their evaluation of weed flora in cereals farms at Bauchi State reported 66 weed species within 18 families. Broad-leaves, grass weeds, and sedges constituted 62.12, 25.76 and 12.12% respectively. About two broad leaf weeds (Commelina and Leucas), five grasses (Digitaria, Echinochloa, Imperata, Chloris and Cynodon) and two sedges (Cyperus and Kyllinga) were prevalent in their study [22].

Variation in yield loss across agro-ecological zones have been attributed to the composition of weeds [23-25]. Udensi *et al* [26] reported a yield loss of 82% due to speargrass (*Imperata cylindrica* L.), which has been ranked as the most serious weed affecting crops in the Savanna/Forest Transition zone causing over50% loss in maize [27].

A major interest in the use of cover crops by farmers in any cropping system is their potential to suppress weeds to the advantage of the associated crops [28-29]. The degree of weed suppression provided by cover crops depends on the cover crop species, residue biomass, weed species, and environmental factors [30]. Exploring the influence of species of cover crops on individual weed species is the essence of this study, with the resultant enhanced decision by farmers. Living cover crops suppress the growth and development of weeds through niche pre-emption by filling the spaces and growth resources in the cropping systems that would otherwise be occupied and utilized by the weeds [30] and through allelopathic mechanisms [2]

[31]. Living cover crops also affect the persistence of weeds [32] and weed flora composition [33] as they influence access to light, nutrients, and water [34]. Akobundu *et al*. [35] found that the development of early ground cover was more important than the quantity of dry matter produced for suppression of cogon grass by velvet bean accessions.

Cover cropping could prevent or reduce the production of propagules, germination, emergence, and growth, thereby minimizing successful establishment of individual weeds [36]. Teasedale *et al.* [37] observed that live cover crops can be effective in suppressing perennial weeds ranging from cogon grass in Africa to quack-grass and Canada thistle in Scandinavia. The decision to use non-chemical weed management options including cover crops, either as sole or mixed by farmers is a business decision [38]. Knowing the specific or major weeds contributing to yield loss in the crop will make for enhanced precision in weed control, cost reduction and enhanced profit. Perennial weeds are often better competitors, and are more difficult to control with cover crops than annual weeds because of larger nutritional reserves and faster rates of the establishment. Blackshaw *et al*. [39] found that yellow sweet clover-controlled dandelion (*Taraxacum officinale* Weber ex Wiggers) and perennial sowthistle (*Sonchus arvensis* L.) as well as several annual weeds in Canada. Håkansson [40] reported that perennial weeds (quackgrass (Elytrigia repens (L.) Nevski), sowthistle and Canada thistle (Cirsium arvense (L.) Scop.) were suppressed in cereal-based rotations when cultivation is combined with cover crops.

About 90% reduction of aggressive perennial weeds (*Imperata cylindrica* (L.) Beauv., *Cynodon dactylon* (L.) Pers. and *Cyperus* spp.) that thrive in many parts of Africa have been achieved through the use of various cover crop species [41].

The use of various types and densities of cover crops has varying degrees of merits and limitations. Addressing weed problems without knowing the characteristics, life cycle, and biology of the weeds will truncate sustainable weed management.

Most researches in weed control focus majorly on the efficiency of techniques on weeds in general without reference to weed composition and impact on individual weeds. The potentials of edible cover crops like vegetable cowpea (*Vigna unguiculata subsp. sesquipedalis* L), melon (*Citrullus lanatus*), and sweet potato (*Ipomea batatas*) to suppress weed, enhance soil nutrients in maize have been reported [42-45]. Past investigations seem to emphasize the ground coverage impact of weeds in general with little mention of such impact on individual weeds in the matrix. Thus, the current study is aimed at investigating the influence of selected cover crops, Akidi, melon, and sweet potato, planted at three densities in suppressing major weeds in maize production.

2. MATERIALS AND METHODS

2.1 The Experimental Site

Field trials were conducted at the Teaching farm of Taraba State College of Agriculture (08^0 50' N, 11^0 50' E), Jalingo, in the Northern Guinea Savannah ecological zone. Jalingo has a wet and dry tropical climate with rainy season of about 150 days and an average annual rainfall of about 700 mm – 1000 mm. Mean annual temperature of Jalingo is about 28^{o}C.

2.2 Experimental Design and Layout

There were 11 treatments replicated three times in a randomized complete block design. The treatments included 20,000, 30,000 and 40,000 stands/ha of Akidi (A_1, A_2, A_3), Melon (M_1, M_2, M_3) and Sweet potato (S_1, S_2, S_3), respectively, in addition to hand weeding (at 3 & 6 weeks after planting). The unweeded plot served as the control. Each plot measured 4 m x 4 m with 1 m space between plots and 2 m border separating blocks. The total land area was 864 m^2.

2.3 Planting and Agronomic Practices

Maize seeds, an open-pollinated and early maturing variety 95-TZEE-W1 obtained from International Institute for Tropical Agriculture (IITA), Ibadan. This was the test crop in all the plots and planted at 25 cm × 100 cm spacing, to give a population of 40,000 plants/ha. Cover crops were planted within 24hrs of planting maize (Akidi and melon seeds from open market) were sown 4/hole, while 2-3 sweet potato vines/hole), spaced 50 cm × 100 cm and later thinned to give the required population densities of 20,000; 30,000 or 40,000 plants/ha. All cover crop treated plots were weeded once at 3 WAP to allow them to establish and suppress weeds. Manual weeding was carried out twice at 3 and 6 WAP on hoe-weeded control plots. Fertilizer was applied to maize at the recommended rate of 120 kgN/ha. Maize cobs were harvested dry at 14 -16 WAP.

2.4 Data Collection

Three hundred and ninety-six (396) quadrats were studied in the course of this investigation. A 50 cm × 50 cm quadrat was randomly placed in two locations in each plot at each sampling time.

Weed parameters were collected at 4, 10 WAP and at harvest of maize included

1. The density of weeds per treatment was determined by harvesting all weeds within a 50 cm x 50 cm quadrat, grouped them into broadleaf, grasses, and sedges, and counting each group.
2. The weed flora count (number of each species present) was determined after identification using standard weed album by Agyakwa and Akobundu [46] counts the number of each species present in 0.5m x 0.5m quadrat.
3 The abundance, frequency and density of individual species were determined using the method suggested by Misra [47]:

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Number of quadrats of occurrence}}$$

$$\text{Percentage density} = \frac{\text{Total number of individual species}}{\text{Total number of occurrences of all species}} \times \frac{100}{1}$$

$$\text{Percentage frequency} = \frac{\text{Total number of quadrats of occurrence}}{\text{Total number of quadrats studied}} \times \frac{100}{1}$$

The frequency index was designated after Caratini [48] as follows

V(c) = constant (80-100 % frequency);
IV (ab) = abundant (60-80% frequency);
III (f) = frequent (40-60% frequency);
II (ac) = accessory (20-40% frequency) and
I (r) = rare (0-20% frequency).

3. RESULTS AND DISCUSSION

3.1 Weed Flora Abundance, Percentage Density, Percentage Frequency, and Frequency Index

Weed flora abundance, percentage density, percentage frequency, and frequency index in maize as influenced by sole cover crop weed management are presented in Table 1. There were changes in the occurrence and distribution of some weed species over time. The abundance was in the order Broadleaf > Grass > Sedges. The predominance of broadleaves could be attributed to effective tillage, which destroys the seedlings of emerging grasses as well as the suppression, by the cover crops. This is in agreement with the report of Jafun and Abdul [22] in their survey of weed composition at Bauchi and Michael and Tijani-Eniola [17], in Taraba State Northeastern Nigeria. The weed suppression potential is confirmed by the report of Chikoye *et al.* [49] and Akobundu *et al.* [35] on the effectiveness of velvet bean in smothering spear grass in maize and cassava. Sedges only came up in 2009. Generally, there was an appreciable increase in the abundance of broadleaf and sedges but grassy weeds increased marginally. In 2008, the most abundant weed species were: *Imperata cylindrica* (3.8), *Mucuna utilis* (3.0), *Oldenlandia herbacea* L. (2.6) *Sida acuta* Burm F, *Tridax procumbens* L. (2.5 each), *Leucas martinicensis*, *Pennisetum pedicellatum* (2.3 each). Chikoye *et al*. [27] ranked speargrass (*Imperata cylindrica* L.) as the most serious weed affecting crops in the Savanna/Forest Transition zone. This is confirmed in this study. In 2009, all the above weed species decreased in abundance between 1.3 in *Tridax procumbens* to 2.0 in *Oldenlandia herbaceae*. This implied that the cover crops were effective in managing these weeds. The selected cover crops must have affected persistence of weeds [32] and flora composition [33] by reducing access to light, nutrients, and water (Linares *et al*., 2008) through effective ground coverage. Akobundu *et al*. [35] reported that development of the early ground cover was more important than the quantity of dry matter produced for suppression of cogon grass by velvet bean accessions.

Conversely, *Commelina benghalensis*, increased in abundance from 1.9 to 3.2. Commelina has been reported to be very difficult to control [50] due to the high regenerative ability. Other weeds with high abundance values in 2009 included

Cyperus difformis (3.5), *Digitaria horizontalis*, *Fimbristylis littoralis* (2.8 each), *Hyptis lanceolata,*

Euphorbia hyssopifolia (2.2 each), *Fimbristylis ferruginea* (2.4). Others like *Euphorbia hirta, Sida garckeana, Andropogon gayanus, and Panicum maximum* all have 2.0 each.

The above confirmed a similar study at Bauchi State, where dominant weeds were Cyperus, Commelina, Kyllinga, Digitaria, Echinochloa, Imperata, Cynodon, Leucas and Chloris [22].

The density of individual weeds followed about a similar pattern to weed abundance. *Mucuna utilis*, which recorded the highest density, decreased from 24.4% in 2008 to 5.7%, *Leucas martinicensis* from 15.4 to 0.5%, *Sida acuta* from 12.5 to 0.5%. On the other hand, *Commelina benghalensis* increased from 5.0% in 2008 to 24.0% in 2009, *Digitaria horizontalis* from 0.0 to 16.8%.

Most of the broadleaved weeds found in 2008 decreased in frequency in the 2009 cropping season. For example, *Mucuna utilis* (an annual broadleaved weed) decreased from a frequency of 63.6% in 2008 to 34.9% in 2009, thereby declining to accessory status. *Leucas martinicensis* (53.0 to 3.0%) and *Sida acuta* (39.4 to 3.0%) declined respectively from frequent and accessory status to rare.

However; *Commelina* spp. increased in status from an accessory (21.2%) to abundance (66.7%) while others like *Hyptis lanceolata, Aspilia bussei, Mitracarpus villosus, Euphorbia hyssopifolia, and Flimbristylis ferruginea* increased from rare to accessory. (from 0.0 to 20-40%). The increase in *Commelina* spp. status shows its invasiveness, rapid regeneration when cut and strong adaptive features, and competitiveness for growth resources [51]. William and Lagoke [21], also confirmed a number of these weeds in association with maize in Ogun State.

Tables 2 and 3 show the percentage contribution of different weed species to the weed population in maize under various sole cover crops weed management treatments in 2008 and 2009 cropping seasons. *Mucuna utilis* (an annual broadleaf), constituted the highest percentage population in all the treatments except A_3, M_2, S_2, S_3 and C_1 in 2008. This indicates that *Mucuna utilis, which is fast spreading,* can only be suppressed at high planting densities of the selected cover crops. The planting densities of 30,000 – 40,000 stands per hectare must have been high enough to reduce the space available for *Mucuna utilis* when compared with the low density [44]. *Leucas martinicensis*, *Mucuna utilis*, *Sida acuta* were among the weeds that thrived across almost all the sole cover crop treated plots. The influence of sole cover crop on individual weed percentage contribution shows: *Commelina benghalensis* ($C_1 < S < A < M$), *Euphorbia heterophylla* ($M < S < A$), *Leucas martinicensis*($C_1 < C_2 < M < A < S$), *Mucuna utilis*($S < M < C_1 < C_2 < A$) and *Sida acuta* ($M < S < A < C_2 < C_1$) while grassy weeds, *Imperata cylindrica* ($A < C_2 < S < M$), *Pennisetum pedicellatum* ($A < C_2$). Sweet potato and melon seem to suppress grassy weeds better than Akidi, while reversed is the case for broadleaved weeds, where leguminous Akidi performed better. Grasses being generally a C4 plant were less shade-tolerant than broadleaved weeds which are C3 plants [8]. Hence, the dense canopy formed by sweet potato over a longer duration must have effectively suppressed grassy weeds. However, in 2009, *Commelina benghalensis* constituted the highest percentage population in all the treatments except. M_1, M_2, S_1 and C_2. *Hyptis lanceolata*, *Aspilia bussei*, *Mucuna utilis, Commelina benghalensis*, *Digitaria horizontalis*, were among the weeds that thrived across almost all the sole cover crop treated plots. The influence of individual cover crop on specific major weeds was in the order: *Commelina benghalensis* ($C_2 < C_1 < M < S < A$), *Euphorbia hyssopifolia* ($C_2 < M/S < A < C_1$), *Mitracarpus villosus*($M < A < S < C_1 < C_2$), *Digitaria horizontalis*($C_1 / C_2 < A < M < S$), *Kyllinga squamulata* ($M/S < C_2 < A < C_1$). The effect of cover crops followed the 2008 trend, with Akidi more effective on broadleaves when compared with the non-leguminous cover crops. There was a general increase in percentage contribution by grasses and sedges, which might be attributed to possible reduction in soil fertility since grassy weeds can survive at a much less fertility level compared to broadleaf weeds [50]. Out of the six weeds (*Commelina benghalensis*, *Leucas martinicensis*, *Mucuna utilis*, *Sida acuta, Oldenlandia herbacea*, *Tridax procumbens*) that contributed across the years, all decreased except *Commelina benghalensis*. This is an indication of the reduction in weed seed bank by the cover crops [52] and a call for special attention, study, and management of *Commelina benghalensis* in maize in the study area. In 1998, Georgia extension agents ranked *Commelina* spp. among the top 39 most troublesome weeds across all crops [53].

Table 1. Effects of sole cover crops weed management on weed flora change (abundance, density, and frequency) in maize in 2008 and 2009

Weed types	Abundance		Density (%)		Frequency (%) †		Index of frequency ‡	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Broadleaf weeds								
Hypoestes cancellata Nees.	1.5	0.0	0.58	0.0	3.03	0.0	I (r)	I (r)
Monechma ciliatum (Jacq.) Milne-Redhead	2.08	0.0	4.81	0.0	18.18	0.0	I (r)	I (r)
Aspilia bussei O.Hoffm. & Muschl.	0.0	1.37	0.0	4.49	0.0	28.79	I (r)	II (ac)
Tridax procumbens L.	2.5	1.33	7.69	0.69	24.24	4.55	II (ac)	I (r)
Cleome viscosa L.	0.0	1.67	0.0	0.86	0.0	4.55	I (r)	I (r)
Evolvulus alsinoides L.	0.0	1.5	0.0	0.52	0.0	3.03	I (r)	I (r)
Acalypha ciliata Forsk.	0.0	1.8	0.0	1.55	0.0	7.58	I (r)	I (r)
Euphorbia hirta L.	0.0	2	0.0	0.35	0.0	1.52	I (r)	I (r)
Euphorbia hyssopifolia L.	0.0	2.2	0.0	5.7	0.0	22.73	I (r)	II (ac)
Euphorbia heterophylla L.	2.16	0.0	7.88	0.0	28.79	0.0	II (ac)	I (r)
Indigofera hirsuta Linn var.hirsuta	0.0	1	0.0	0.17	0.0	1.52	I (r)	I (r)
Mucuna utilis Baker ex Bruck	3.02	1.43	24.42	5.7	63.64	34.85	IV (ab)	II (ac)
Hyptis lanceolata Poir.	0.0	2.21		5.35	0.0	21.21	I (r)	II (ac)
Leucas martinicensis Jacq.	2.29	1.5	15.38	0.52	53.03	3.03	III (f)	I (r)
Plastostoma africanum P.Beauv.	2	0.0	2.31	0.0	9.09	0.0	I (r)	I (r)
Mitracarpus villous (Sw.) DC.	0.0	1.86	0.0	6.74	0.0	31.82	I (r)	II (ac)
Oldenlandia herbacea L	2.6	2	5	0.35	15.15	1.52	I (r)	I (r)
Aspilia africana (Pers),C.O.Adams	0.0	1	0.0	0.17	0.0	1.52	I (r)	I (r)
Sida acuta Burm F	2.5	1.5	12.5	0.52	39.39	3.03	II (ac)	I (r)
Sida garckeana Polak	0.0	2	0.0	3.11	0.0	13.64	I (r)	I (r)
Triumfetta rhomboidea Jacq.	0.0	1	0.0	0.52	0.0	4.55	I (r)	I (r)
Commelina benghalensis L.	1.86	3.16	5	24	21.21	66.67	II (ac)	IV(ab)

Table 1. Continued

	Abundance		Density (%)		Frequency (%) †		Index of frequence ‡	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Grasses								
Rottboellia cochinchinensis (Lour.) Clayton	1.63	1.7	2.5	2.94	12.12	15.15	I (r)	I (r)
Cynodon plectostachyum	1.5	0.0	0.58	0.0	3.03	0.0	I (r)	I (r)

	Abundance		**Density (%)**		**Frequency (%) †**		**Index of frequence ‡**	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Pennisetum pedicellatum Trin.	2.25	0.0	1.73	0.0	6.06	0.0	I (r)	I (r)
Digitaria horizontalis Willd	0.0	3.46	0.0	16.8	0.0	42.42	I (r)	III (f)
Chloris pilosa Schumach	0.0	1	0.0	0.17	0.0	1.52	I (r)	I (r)
Andropogon gayanus Kunth *var. Gayanus*	0.0	2	0.0	3.11	0.0	13.64	I (r)	I (r)
Anthephora ampullacea Staff & C.E.Hubbard	0.0	1	0.0	0.17	0.0	1.52	I (r)	I (r)
Panicum maximum Jacq.	0.0	2	0.0	1.73	0.0	7.58	I (r)	I (r)
Paspalum orbiculare Forst.	0.0	1.33	0.0	0.69	0.0	4.55	I (r)	I (r)
Eragrostis atrovirens (Desf.) Trin. Ex Steud.	2	0.0	0.77	0.0	3.03	0.0	I (r)	I (r)
Imperata cylindrica (Anderss) C.E. Hubbard	3.83	0.0	8.85	0.0	18.18	0.0	I (r)	I (r)
Sedges								
Cyperus difformis L.	0.0	2.75	0.0	1.9	0.0	6.06	I (r)	I (r)
Fimbristylis littoralis Gaudet	0.0	2.75	0.0	1.9	0.0	6.06	I (r)	I (r)
Kyllinga squamulata Thonn.ex Vahl	0.0	1.64	0.0	3.11	0.0	16.67	I (r)	I (r)
Cyperus esculentus L.	0.0	1.33	0.0	0.69	0.0	4.55	I (r)	I (r)
Fimbristylis ferruginea (L.) Vahl	0.0	2.36	0.0	5.7	0.0	21.21	I (r)	II (ac)

$$\text{Abundance} = \frac{\text{Number of individuals of the species}}{\text{Total number of quadrats of occurrence}} \qquad \text{Density (\%)} = \frac{\text{Total number of individuals of the} \times 100}{\text{Total number of individuals of all species}}$$

$$Frequency\ (\%) = \frac{Number\ of\ quadrats\ of\ occurrence \times 100}{Number\ of\ quadrats\ studied}$$

‡IV (ab) =adundant (between 60 and 80% frequency), II (ac) = accessory (between 20 and 40% frequency),
III (f) = frequent (between 40 and 60 % frequency), I (r) = rare or accidental (between 0 and 20% frequency)

Table 2. Effects of sole cover crops on percentage contribution of different weed species to the weed population in maize in 2008

Weed types	Family	Sole cover crop weed management treatment										
		A_1	A_2	A_3	M_1	M_2	M_3	S_1	S_2	S_3	C_1	C_2
Broadleaf weeds												
Hypoestes cancellata Nees.	Acanthaceae	0	0	0	0	0	0	0	0	0	6.5	0
Monechma ciliatum (Jacq.) Milne-Redhead	Acanthaceae	0	0	0	8.7	7.4	7.9	7.4	12.5	0	0	10
Tridax procumbens L	Asteraceae	0	7.9	0	8.7	24.1	0	0	0	27.3	0	7.5
Euphorbia heterophylla L	Euphorbiaceae	14.0	10.5	0	20.3	0	0	0	6.3	16.4	13.0	0
Mucuna utilis	Fabaceae	41.9	42.1	19.6	26.1	11.1	31.6	37.0	0	7.3	26.1	27.5
Leucas martinicensis Jacq.	Lamiaceae	16.3	21.1	11.8	0	27.8	10.5	22.2	31.3	14.6	8.7	15
Plastostoma africanum P.Beauv.	Lamiaceae	7.0	0	5.9	0	0	0	0	0	10.9	0	0
Oldenlandia herbacea L	Rubiaceae	0	10.5	0	21.7	0	0	0	0	0	8.7	7.5
Commelina benghalensis L	Commelinaceae	0	0	15.7	0	22.2	7.9	5.6	0	0	0	0
Sida acuta Burm F	Malvaceae	7.0	0	27.5	0	7.4	15.8	22.2	9.4	0	37.0	15
Grasses												
Rottboellia cochinchinensis (Lour) Clayton	Poaceae	0	7.9	0	0	0	0	5.6	12.5	5.5	0	0
Cynodon plectostachyum	Poaceae	0	0	0	0	0	0	0	9.4	0	0	0
Pennisetum pedicellatum Trin.	Poaceae	0	0	11.8	0	0	0	0	0	0	0	7.5
Eragrostis atrovirens (Desf.) Trin. Ex Steud.	Poaceae	0	0	7.8	0	0	0	0	0	0	0	0
Imperata cylindrical (Linn)	Poaceae	14.0	0	0	14.5	0	26.3	0	18.8	18.2	0	10

A=Akidi, M=Melon, S=Sweet potato, C_1=weeded control, C_2=unweeded control 1=20,000 stands/ha , 2=30,000 stands/ha, 3=40,000 stands/ha

Table 3. Effects of sole cover crops on percentage contribution of different weed species to the weed population in maize in 2009

Weed types	Family	Sole cover crop weed management treatments										
Broadleaf weeds		**A_1**	**A_2**	**A_3**	**M_1**	**M_2**	**M_3**	**S_1**	**S_2**	**S_3**	**C_1**	**C_2**
Aspilia bussei O.Hoffman & Muschl	Asteraceae	2.13	2.3	4.4	4.8	1.7	6.6	5.7	1.9	7.3	6.5	6.8
Tridax procumbens L	Asteraceae	0	0	4.4	0	0	0	0	0	0	0	1.7
Cleome viscosa L.	Cleomaceae	0	0	0	0	0	0	7.6	0	2.4	0	0
Evolvulus alsinoides L.	Convolvulaceae	0	0	0	0	0	0	0	0	0	9.7	0
Acalypha ciliate Forsk	Euphorbiaceae	0	2.3	1.5	0	0	0	0	0	14.6	3.2	0
. *Euphorbia hirta* L.	Euphorbiaceae	0	0	0	0	3.4	0	0	0	0	0	0
Euphorbia hyssopifolia L.	Euphorbiaceae	21.3	0	4.4	1.6	10.2	0	3.8	7.4	0	19.4	1.7
Mucuna utilis	Fabaceae	2.1	4.7	4.4	8.1	10.2	6.6	7.6	0	2.4	9.7	6.8
Hyptis lanceolata Poir.	Lamiaceae	8.5	2.3	1.5	1.6	17.0	6.6	5.7	0	2.4	0	10.2
Leucas martinicensis Jacq.	Lamiaceae	0	4.7	0	0	0	0	1.9	0	0	0	0
Indigofera hirsuta Linn var.hirsuta	Papilionoideae	0	0	0	0	0	0	0	0	0	0	0
Mitracarpus villosus	Rubiaceae	4.3	0	8.7	6.5	0	3.3	0	9.3	12.2	9.7	20.3
Oldenlandia herbacea L	Rubiaceae	0	0	0	3.2	0	0	0	0	0	0	0
Aspilia africana (Pers),C.O.Adams	Asteraceae	0	0	0	0	0	0	0	0	2.4	0	0
Commelina benghalensis L	Commelinaceae	29.8	37.2	31.9	11.3	13.6	39.3	20.8	37.0	24.4	9.7	6.8
Sida acuta Burm F	Malvaceae	0	0	0	0	0	0	0	5.6	0	0	0
Sida garckeana Polak	Malvaceae	0	4.7	0	3.2	17.0	0	0	1.9	4.9	3.2	0

A=Akidi, M=Melon, S=Sweet potato, C_1=weeded control, C_2=unweeded control 1=20,000 stands/ha, 2=30,000 stands/ha, 3=40,000 stands/ha

Table 3. continued

Weed types	Family	Sole cover crop weed management treatments										
***Triumfetta rhomboidea* Jacq.**	**Tiliaceae**	**0**	**0**	**1.5**	**0**	**0**	**1.6**	**0**	**0**	**0**	**0**	**1.7**
Grasses												
Chloris pilosa Schumach	Poaceae	0	0	0	0	0	0	0	0	0	3.2	0
Digitaria horizontalis Willd	Poaceae	21.3	14	11.6	24.2	8.5	21.3	34.0	22.2	9.8	6.5	6.8
Rottboellia cochinchinensis (Lour.) Clayton	Poaceae	0	14	4.4	0	8.5	1.6	0	3.7	0	0	0

Weed types	**Family**	**Sole cover crop weed management treatments**										
***Triumfetta rhomboidea* Jacq.**	**Tiliaceae**	**0**	**0**	**1.5**	**0**	**0**	**1.6**	**0**	**0**	**0**	**0**	**1.7**
Andropogon gayanus Kunth *var. Gayanus*	Poaceae	10.6	0	0	0	0	0	7.6	9.3	4.9	0	3.4
Anthephora ampullacea Staff & C.E.Hubbard	Poaceae		0	0	1.6	0	0	0	0	0	0	0
Panicum maximum Jacq.	Poaceae	0	0	0	3.2	0	0	0	0	7.3	0	8.5
Paspalum orbiculare Forst.	Poaceae	0	0	0	0	1.7	0	0	0	0	0	5.1
Sedges												
Fimbristylis littoralis Gaudet	Cyperaceae	0	0	0	1.6	0	0	0	1.9	0	0	15.3
Cyperus difformis L.	Cyperaceae	0	0	11.6	0	0	0	1.9	0	0	6.5	0
Kyllinga squamulata Thonn.ex Vahl	Cyperaceae	0	7.0	10.1	1.6	0	0	0	0	2.4	9.7	5.1
Cyperus esculentus L.	Cyperaceae	0	7.0	0	0	0	0	0	0	0	3.2	0
Fimbristylis ferruginea (Linn.) Vahl.	Cyperaceae	0	0	0	27.4	8.5	13.1	3.8	0	2.4	0	0

A=Akidi, M=Melon, S=Sweet potato, C_1=weeded control, C_2=unweeded control 1=20,000 stands/ha, 2=30,000 stands/ha, 3=40,000 stands/ha

Table 4. Effects of sole cover crops on percentage contribution shift of different weed families in maize in 2008 and 2009

	A		M		S		C_1		C_2		MEAN	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Acanthaceae	0.00	0.00	8.00	0.00	6.63	0.00	6.50	0.00	10	0.00	6.2	0.0
Asteraceae	2.63	4.41	10.93	4.37	9.10	5.77	0.00	6.5	7.5	8.5	6.0	5.9
Cleomaceae	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0	0.00	0	0.0	0.7
Commelinaceae	5.23	32.97	10.03	21.40	1.87	27.40	0.00	9.7	0.00	6.8	3.4	19.7
Convolvulaceae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.7	0.00	0	0.0	1.9
Euphorbiaceae	8.17	8.57	6.77	5.07	7.57	3.73	13.00	19.4	0.00	1.7	7.1	7.7
Fabaceae	34.53	3.73	22.93	8.30	14.77	3.33	26.10	9.7	27.5	6.8	25.2	6.4
Lamiaceae	20.7	5.67	12.77	8.40	26.33	3.33	8.70	0	15	10.2	16.7	5.5
Malvaceae	11.5	1.57	7.73	6.73	10.53	4.13	37.00	3.2	15	0	16.4	3.1
Rubiaceae	3.5	4.33	7.23	4.33	0.00	7.17	8.70	9.7	7.5	20.3	5.4	9.2
Tiliaceae	0.00	0.50	0.00	0.53	0.00	0.00	0.00	0	0.00	1.7	0.0	0.5
Poaceae	13.83	25.30	13.60	23.53	23.33	32.93	0.00	9.7	17.5	23.8	13.7	23.1
Cyperaceae	0.00	11.90	0.00	17.40	0.00	4.13	0.00	19.4	0.00	20.4	0.0	14.6

A=Akidi, M=Melon, S=Sweet potato, C_1=weeded control, C_2=unweeded control

Table 5. Effect of sole cover crop weed management treatments on yield of maize and cover crops

Treatment	2008				2009			
	MGY (kg/ha)	M100s (g)	CC EY (kg/ha)	CCAGB (t/ha)	MGY (kg/ha)	M100s (g)	CC EY (kg/ha)	CCAGB (t/ha)
A_1	3269.8a	25.5ab	187.12b	7.04a	2025.7b	26.0a	187.12b	3.500.0a
A_2	4051.9a	26.8ab	409.73a	8.335a	2755.6ab	25.3a	424.67a	3.500.0a
A_3	3826.7a	25.8ab	411.60a	7.056a	2822.8ab	27.5a	312.0b	4.000.0a
M_1	3581.0a	27.5a			2550.0ab	25.4a		
M_2	3723.0a	24.3abc			3733.3a	26.0a		
M_3	3000.0a	24.7ab			3228.5ab	26.7a		
S_1	2800.0ab	22.6bc	8167b	7.133c	1847.6bc	24.6a	3000b	5.333b
S_2	3042.9a	23.1abc	18450a	13.850b	2600.0ab	25.3a	10000a	12.500a
S_3	3303.7a	23.2abc	21467a	17.333a	2847.6ab	24.8a	12000a	16.667a
C_1	4026.7a	27.7a			3866.7a	29.3a		
C_2	1200.0b	19.8c			557.5c	18.2b		

Means followed by the same letter (s) in the same column are not significantly different by DMRT at 5% Probability level. A=Akidi, M=Melon, S=Sweet potato, C_1=weeded control, C_2=unweeded control 1=20,000 stands/ha, 2=30,000 stands/ha, 3=40,000 stands/ha. MGY=Maize grain yield M100s=Maize 100 seed weight CCEY= Cover crop Economic Yield, Akidi grain or Tuber yield of sweet potato, CCAGB= Cover crop Above Ground Biomass

Commelina benghalensis has been reported to be problematic in Georgia and Florida following the 2004 growing season [54-55] being confirmed in many counties [56]. Under high nutrient availability, *Commelina benghalensis* had a higher relative growth rate than a related non-invasive weeds Hassk [57] and also tolerant to many commonly used weed control techniques [58-59]. *Commelina benghalensis* will often establish itself in moist soil and then move into drier parts of any field [60]. The effectiveness of Akidi on *Commelina* could be attributed to the rapid emergence and early establishment and ground coverage which smother invasive *Commelina benghalensis* when compared with sweet potato, with a slower rate of the establishment being propagated from the vine and less dense canopy of the melon which dies off before the maturity of maize [44]. Generally, vigorous cover crop species such as velvet bean (*Mucuna* spp.) cowpea (*Vigna unguiculata (*L.) Walp.) and others which are well adapted to growth in hot climates, are effective smother crops in the warm season environments [39].

Thirteen weed families made up of 11 broad leaves, 1 grass and 1 sedge (Poaceace and Cyperacea) were identified in solely planted cover crops in maize (Table 4). Four families which contributed over 70% in 2008 were Fabaceae> Lamiaceae>Malvaceae>Poaceae and Five families in 2009, Poaceae> Commelinaceae>Cyperaceae>Rubiaceae>Euphorbiaceae. This was reflected in reduced yield in 2009, because grassy weeds and sedges with Commelinaceae are known to have higher competition [50] (Webster *et al,* 2006). Some of these families were among the ones identified by Jafun and Abdul [22] in Bauchi which is in the same zone as the study area.

3.2 Effects of Sole Cover Crops Weed Management Treatments on Yield of Maize and Cover Crops

The yield of maize and associated cover crops is presented in Table 5.

3.2.1 Maize Grain yield and 100 Seed Weight (100SW)

Cover crop density did not significantly affect MGY within a given cover crop. Though, in 2008 and 2009, the increasing plant density of 'S' resulted in increasing maize grain yield MGY). Similarly, in 2009, increasing density of planting of 'A' resulted in increasing MGY. In 2008, MGY in all the weed control treatments were similar, but each had MGY significantly higher than in C_2

In 2008, 100SW in M_1 was significantly different from that in S_1. In 2009, C_2 significantly reduced 100SW when compared with all other treatments. Cover crop has been reported to conserve water, enhance the nutrient status and increase the yield of the associated crop when compared with untreated plots [61]. In 2009, MGY under M_2 and C_1 were significantly higher than in A_1, S_1 and C_2.

Melon cover crop being ephemeral has higher decomposition rate which makes the nutrient to be more readily available within the growing cycle of maize when compared to the long season Akidi or sweet potato which continues to grow even till the end of maize cycle. Hence, a higher maize grain yield was observed [62].

3.2.2 Cover crop yields

The grain yield, above-ground biomass of akidi, as well as fresh tuber yield and above-ground biomass of sweet potato. Melon did not reach harvestable age under these experiments. Population densities in 2008, the higher population densities (A_2 and A_3) produced significantly higher grain yield than the lowest density population (A_1). However, in 2009, only the medium plant population density (A_2) produced significantly higher grain yield than the low population density (A_1). However, above-ground biomass was not significantly different at various planting populations in 2008 and 2009.

Generally, increasing as the plant population of sweet potato resulted in increasing fresh tuber yield. In 2008 and 2009, the higher population densities (S_2 and S_3) produced significantly higher fresh tuber yield than the lowest density population (S_1). Similarly, in 2009, above-ground biomass for S_2 and S_3 were significantly more than what was obtained in S_1. However, in 2008, there was a significant increase in AGB as the plant population increases in the order $S_3 > S_2 > S_1$.

4. CONCLUSION

Four families which contributed over 70% in 2008 included: Fabaceae> Lamiaceae> Malvaceae> Poaceae in that order, while five families in the order, Poaceae> Commelinaceae>Cyperaceae> Ubiaceae> Euphorbiaceae contributed in 2009.

Six major weeds, *Commelina benghalensis*, *Leucas martinicensis*, *Mucuna utilis*, *Sida acuta, Oldenlandia herbacea*, *Tridax procumbens* thrived across the experimental years. All decreased in abundance and contribution in the subsequent years except for *Commelina benghalensis* which increased.

It was concluded that above-identified weed species, families, and growth form with widespread occurrence especially *Commelina benghalensis,* should be monitored before they become a menace to maize growers in the study area. Education to increase farmers' knowledge of the dominant weeds and improved choice of appropriate cover crops is critical to sustainable weed management in maize.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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