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RELATIONSHIP BETWEEN THE SOIL SEEDBANK AND WEED POPULATION AS INFLUENCED BY LAND USE INTENSITY IN SOUTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT

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This 2 year study investigated the relationship between the number of weed seeds in the soil seedbank and the emerged population of weed seedlings in 4 land use intensities in a southern Guinea savanna of Nigeria. Soil samples were collected soon after harrowing to a depth of 15cm and the weed seeds therein were enumerated. The emerged weed seedlings in the field sampling areas were counted over the following 12 or 15 weeks. The overall average proportion of the active weed seedbank emerging as seedlings at these fields range from 15.8 to 33.6 % of the total weed seedbank enumerated and found to be slightly differed across the cropping systems, weed control practices and land use intensities. The results showed a significant ($P \leq 0.05$) linear relationship between the weed seed numbers in the soil and the weed seedling numbers on the arable fields. The result will be valuable in aiding the prediction of likely weed infestations in arable crops and provide a valuable input in timing of weed control.

***Keywords**: Soil, seedbank, land use, weed species, weed emergence, cowpea, maize*

INTRODUCTION

Weeds are unique group of plant species because of their ability to infest and thrive in intensively disturbed habitats, despite extensive efforts to eliminate them. Weeds are successful because they are generally plastic plants that adapt to and survive changes in the environment. At maturity, weeds shed their seeds on agricultural land and thus add to the population of weed seeds in or on the soil. Yenish *et al.,* (1992) described weed seedbank as the reservoir of viable weed seeds in the soil. For Clements *et al.*(1996) this reservoir corresponds to the seeds not germinated but, potentially capable of replacing the annual adult plants, which had disappeared by natural death, and perennial plants that are susceptible to plant diseases, disturbance and animal consumption, including man. All the viable seeds present in the soil or mixed with soil debris constitute the soil seedbank and it reflects the cumulative effects of many years of crop and soil management (Ndarubu and Fadayomi, 2006).
Weed seedbank gives an insight of the history of weed management successes or failures of a cropping system. Seedbank studies help to increase the efficiency and efficacy of management decisions (Clements *et al.*,1996). As weed seedbank is an indicative of a field's cropping systems history, it would be useful to know if weed seedbank and the aboveground community are closely related. If this relationship were predictive, seedbank data could be used in the design of predictive weed management. Although a number of studies have evaluated the relationship between the weed seedbank and the floristic compositions, results have not been consistent. While some studies have reported strong relationships between the weed seedbank and aboveground communities (Dessaint *et al*., 1997; Rahman *et al*. 2001 and 2006; Tuesca *et al*. 2004; Ndarubu and Fadayomi, 2006), others have found that correlations were generally low and very variable (Wilson *et al.* 1985; Forcella, 1993; Cardina and Sparrow, 1996; Webster *et al.* 2003). Despite the importance of weed seedbank as a propagule source for agricultural weeds (Cavers and Benoit, 1989), only few studies on the relationship between weed seedbank and aboveground weed community composition have been conducted in southern Guinea savanna (SGS) of Nigeria. This study was designed to compare the volume of weed seedbank with floristic composition under the different landuse intensities in SGS of Nigeria.

MATERIALS AND METHODS

This investigation was conducted at 4 study sites with known cropping history between 2009 and 2010 in Ilorin, southern Guinea savanna zone of Nigeria. Site I, had been under cultivation with different crop(s) per season continuously for 8 years. Site II was continuously cultivated with sole maize field between 2002 and 2008, site III which was adjacent to site II, had been under continuously sole cowpea cultivation for 5 years and site IV had been under natural weed fallow between 1997 and 2008. The field trial was designed as a randomized complete block with a split-plot arrangement and three replicates. At site I, the main plots consisted of four cropping systems, made up of maize and cowpea intercrop (MZCP), sole crop of maize (SMZ), sole crop of cowpea

(SCP) and no- cropping (NCRP) treatment. Site II had sole maize and no cropping while site III had sole cowpea and no cropping as the main plots. The sub plots in each site consisted of three weed control methods, which included: 1. Chemical weed control (CWC); 2. Hoe weeding (HWC) at 3 and 6 weeks after planting and 3. No weed control (NWC). Site IV was divided into equal halves. Each portion was either cultivated to sole maize (FSMZ) or sole cowpea (FSCP), had the same treatments and established on the same date using the same experimental procedures as in site II and site III, respectively. The experiments were conducted on the same experimental sites and plots in 2009 and 2010 cropping seasons.

Data collection

At site I, weed seedling emergence was monitored in the same fixed quadrats at 3, 6, 8, 10,12 and 15 WAP while on the others sites weed seedling emergence was monitored at 3, 6, 9 and 12 WAP using similar number and size of quadrant. In all the sites seedling emergence was assessed in two fixed 0.5 m^2 quadrats per sub plot.

Soil sampling

After harrowing, but before ridging, the experimental field, on each site, was divided into nine (9) cardinal points. Two quadrants (1.0 m^2) were randomly located at each of the cardinal points. Nine core soil samples were collected from each quadrant using a precision auger (7.4 cm in diameter) to a depth of 15 cm. Eight core samples from each of the two quadrants at each cardinal point were combined to form a composite sample for that cardinal point (Composite A). The remaining core sample from each of the two quadrants at each of the cardinal points were similarly be combined to form another cardinal point composite sample (composite B). These latter composite samples for each of the cardinal points were further combined to form an overall composite sample for the entire field. Thus, a total of ten composite samples (1 for each of the 9 cardinal points and one for the overall field) were analysed for weed seedbank. The composite samples were air-dried and passed through a 2 mm sieve. The sieved samples were used for the estimation of the soil weed seedbank using the direct germination method.

Nine core soil samples were also taken from each sub-plot after the crops had been harvested in 2009 and 2010 cropping seasons. Samples from similar treatment combinations from each replicate were combined to form a composite sample.

Soil seedbank determination

Nine hundred grams of the sieved composite soil samples were used to fill three plastic bowls (13 cm in diameter and 6 cm in depth) which were arranged in the screen house. Each of the bowls had four perforations at the base to facilitate drainage of excess water in the soil samples. The soil samples were watered to field capacity at the commencement of the experiment and on alternate days thereafter; then monitored for weed seed germination/seedling emergence at three weekly intervals. Germinating weed seedlings were enumerated either as broadleaves, grasses and sedges; identified to species level, counted and then pulled out. Identification of weed seedlings was carried out with the aid of the weed identification manual of Akobundu and Agyakwa (1998). Soil samples were stirred after each assessment to stimulate germination by bringing to the surface other weeds seeds that might have been deeply buried in them. The experiment was terminated at three months after its commencement.

Weed seedbank estimation

The number (size) of weed seeds in the seedbank (Y) per land area (m^2) was estimated by multiplying the number of seeds in soil sample (G) by the inverse ratio of the volume of soil in the auger sample to the volume of soil in 1 m^2 area sampled to the depth of the auger (15 cm).

The ratio was computed as in Ndarubu and Fadayomi (2006):

Volume of soil from the auger sample (V_1)

$V_1 = \pi r^2 h$, where $\pi = 22/7$, r = radius of the auger and h= depth of sampling

$V_1 = 22/7 \times (3.7\ cm)^2 \times 15\ cm = 645.2097\ cm^3$; or $6.45 \times 10^{-4}\ m^3$

Volume of soil from 1 m^2 area sampled (V_2)

$V_2 = L \times B \times H$, where L = length, B = breadth and H = depth of sampling.

$V_2 = 100\ cm \times 100\ cm \times 15\ cm = 1.5 \times 10^{-1}\ m^3$

$Y = V_2/V_1 \times G$, where Y = estimated density of weeds per m^2 to the depth of 15 cm.

G = number of emerged weed seedling per soil sample.

The calculated inverse ratio of the volume of soil from an auger sample to the volume of soil per m^2 was 232.56. The data of weed density per soil samples were then extrapolated to weed density per m^2 by multiplying with 232.56.

Data analysis

Data so obtained were subjected to analysis of variance (ANOVA) using Gen Stat statistical package (Discovery Edition 3) and the following comparisons were made: pre cultivation seedbank data among the different field sites; post-harvest seedbank data within individual fields and between the different field types; pre-cultivation seedbank data within a field type with floristic data in the same field for years I & II, respectively; post- harvest seedbank data in year I with floristic data in year II. The seedbank data were regressed against the floristic data with individual fields and between the different field types.

RESULT

Effect of previous land use on pre-cultivation weed seedbank

The density of weed seeds obtained from the pre-cultivation seedbank estimation was significantly (P≤ 0.05) affected by the previous land use intensity in each experimental site (Table 1). Broadleaved weed seeds were significantly higher in the continuously cultivated maize fields followed by field with alternate cropping system and continuously cultivated cowpea fields while significantly lower density of broadleaved weed seeds were obtained from the natural fallow fields. Grass seedlings were significantly lower in natural fallow fields and those fields had similar density of grass weed seeds with continuously cultivated cowpea fields. Site I and continuously cultivated maize fields had similar grass seeds that were significantly higher than those obtained from other fields. Sedge weed seeds were significantly highest in continuously cultivated maize fields followed by alternate cropping systems field while natural fallow fields had statistically lowest sedge seedlings. The continuously cultivated cowpea fields had similar sedge weed seedlings as in Site I and natural fallow fields. The total emerged weed seedling from the pre-cultivation seedbank was significantly lower under the natural fallow fields while the continuously cultivated maize fields had significantly higher weed seeds. Site I had similar volume of weed seeds with continuously cultivated maize fields while continuously cultivated cowpea fields had similar volume of weed seeds as in site I and natural fallow fields.

Effect of land use intensity on density of post harvest weed seedbank

The total weed seedbank estimated was significantly affected by land use intensity in 2009 but not in 2010 (Table 2). In 2009, the post-harvest weed seedbank followed a fairly similar trend with the pre-cultivation weed seedbank except that continuously cultivated cowpea field had significantly higher density of weed seeds. The post-harvest weed seedbank in 2010 was not significantly affected by land use intensity. The progressive increase in the density of weed seedbank in each land use was significantly affected by year of cultivation and/ or estimation except in continuously cultivated cowpea fields. Site I had a significant increase in density of weed seedbank. The 2009 weed seedbank was 32% higher than the pre-cultivation density while 2010 post-harvest weed seedbank was 36% significantly higher than 2009 post-harvest weed seedbank. In the natural fallow fields, the density of post-harvest weed seedbank in 2009 was 5313 seeds/m^2 in FSMZ and 3088 seeds/m^2 in FSCP both were similar to the pre-cultivation weed seedbank density of 1679 seeds/m^2 while the density of weed seedbank in the 2010 post-harvest weed seedbank in FSMZ field was significantly higher than the density obtained in the pre-cultivation weed seedbank in the same field.

Effect of cropping system and weed management practice on post harvest weed seedbank

At site I, total post- harvest weed seedbank estimated was not significantly affected by cropping system in both years of the study, while weed control practice significantly influenced total weed seedbank in 2009, but not in 2010 (Table 3). In 2009, total weed seeds were significantly higher in the unweeded control plots than in the other two plots. The herbicide treated plots had similar density of weed seeds as in the hand weeded plots. In the 2010 growing season, weed control treatment did not significant affect the density of weed seedbank.

In table 4, total density of post-harvest weed seedbank was not significantly affected by current cropping system established on different land use intensities whereas weed control treatment significantly affected the total density of post- harvest weed seedbank. The density of weed seedbank under herbicide treated plots in all land use intensities were significantly lower in both years except under continuously cultivated cowpea fields in 2010. The density of weed seeds obtained in hand weeded plots were similar to the herbicide treated plots, except in the cowpea plots in both fields in 2010. Unweeded control plots had significantly higher density of weed seeds except under continuously cultivated cowpea fields in 2010 where herbicide treated plots had relatively higher density of weed seeds. No significant differences between cropping system and weed control were observed in both years of the study.

Relationship between the soil seedbank and field weed population

The percentage emerged weed seedlings across the cropping systems was inconsistent while the unweeded control plots had the lowest percentage of emerged weed seedlings and weed types compared to other weed control treatments (Table 5) In a similar manner, unweeded plots had the highest percentage of weed emerged from soil seedbank at all the land use fields while the hand weeded plots had the lowest percentage of emerged weed seeds (Table 6). The regression analysis between floristic emergence and volume of weed seeds obtained from post-harvest seedbank estimations indicate significant (P≤0.05) positive linear relationship at the different land use fields except under the continuously cultivated sole maize and sole cowpea fields. The mean percentage emergence and regression equations relating seedbank and aboveground weed community is presented in Table 7.

DISCUSSION

Emerged weed seedlings usually provide the primary indication of the success of the weed management efforts, monitoring the seedbank offer additional information about the long term weed management and cropping history. Land use significantly influences both weed seedbank and floristic composition. Previously natural fallow fields, had a relatively narrow average range of emergence (15.8- 33.6 % in both cases) other land use intensities had a much large average range of emergence, for example, 21 - 39 % for continuously cultivated maize fields and 23 - 37 % for continuously cultivated cowpea fields. Similarly, for weed types, over the fields evaluated, the average emergence of broadleaf weeds ranged from 22.3 % while grasses and sedges varied from 20.1 - 24.7 %, respectively. Though emerging seedling from this study gave a reasonably good estimate of the possible field emergence, they represented only a small and variable fraction of the weed seedbank in the soil. This low percentage is in line with the findings of Rahman et al (2006) who found an average of 2.1 - 8.2 % and 6.2 – 11.9 % of the seeds of broadleaf and grass weed species, respectively. Ball & Miller (1989) reported 20 - 30 % of the seeds in the soil emerged as seedlings over six months but in contrast to the result of Rahman et al (1998) who obtained 65 - 100 % germination for three quarters of the species over 6 months. Jensen (1969) also found seedling emergence accounted for about 25 % of the seeds in the soil and that most of those that emerged did so in the first month.

The regression analyses of the data assumed a linear relationship between the seed number and seedling emergence. However, in complex biological systems such as the soil, this assumption is not always valid (Forcella, 1993). Rahman *et al*., (2006) reported that the asymptotic behavior of weed seedlings might be expected when soil seedbank become very large. This study showed that, there was a strong positive linear relationship between the seed numbers in the soil and the seedling number in the field, the overall average proportion of the active weed seedbank emerging as seedlings at these fields range from 15.8 to 33.6 % of the total weed seedbank enumerated and found to be slightly differed across the cropping systems, weed control and land use intensities. The highest percentage emergence of seedlings occurred in the treatment with the a higher soil disturbance (hand hoeing), whereas the unweeded control treatment (with highest volume of weed seeds in the seedbank) had the lowest percentage translating into weed seedlings.

CONCLUSION

It can be established that, there is a positive linear relationship between the weed seedbank in the soil and field weed emergence and farming practices had relatively immediate impacts on changes to the emerged weed population. The results of this study will be valuable in aiding the prediction of likely weed infestations in arable crops. This ability to predict weed emergence would also provide a valuable input in timing of weed control.

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Table 1: Effect of previous landuse on pre-cultivation weed seedbank (No m^{-2})

Fields	Broadleaves	Grasses	Sedges	Total
Site I	1288	2088	1223	4600
Site II	2563	2039	1936	6538
Site III	1269	1004	994	3268
Site IV	448	577	654	1679
LSD(0.05)	1038.26	1138.52	650.51	2752.37

Site I = continuously cultivated field with alternate cropping system, Site II = Continuously cultivated maize field, Site III = Continuously cultivated cowpea field, Site IV= Natural fallow field

Table 2: Effect of landuse intensity on pre-cultivation and post-harvest weed seedbank (No m^{-2})

	Pre-cultivation	Post-harvest		
Fields	2009	2009	2010	LSD(0.05)
Site I	4600	6082	8374	1378.48
Site II	6538	3876	11162	2423.75
Site III	3268	8308	14850	NS
Site IV (SMZ)	1679	5313	13184	5093.04
Site IV (SCP)	1679	3088	2297	2678.69
LSD(0.05)	2752.37	2686.98	NS	

Site I = continuously cultivated field with alternate cropping system, Site II = Continuously cultivated maize field, Site III = Continuously cultivated cowpea field, Site IV= Natural fallow field, SMZ = Sole maize plot SCP= Sole cowpea plot.

Table 3: Effect of cropping system and weed management practice on density (No m^{-2}) of weed types in post-harvest weed seedbank at Site I.

Treatment	2009				2010			
Cropping system (CS)	BL	GR	SD	Total	BL	GR	SD	Total
MZCP	1394	2815	1316	5525	2271	4394	2239	8884
SCP	1997	2206	1327	5530	3213	4110	2863	10186
SMZ	2869	2377	1266	6512	2394	2868	1963	7225
NCRP	2564	2667	2531	6762	1985	3354	2011	7350
Sed	773.14	358.19	472.08	1552.94^{ns}	695.63	1253.28	927.74	2728.73^{ns}
Weed control (WC)								
CWC	1250	1790	740	3780	2410	3870	2150	8430
HWC	1880	2133	1104	5117	2577	3330	2147	8054
NWC	3487	3623	2247	9357	2325	3700	2307	8490
Sed	763.84	2631.56	318.59	877.51^{*}	109.91	372.18	822.67	2389.47^{ns}
Interaction								
CS x WC	NS	NS	NS	NS	NS	NS	NS	NS

MZCP = Maize/Cowpea intercrop, SCP = Sole Cowpea, SMZ = Sole maize, NCRP= No cropping, CWC= Chemical weed control, HWC = Hoe weeding, NWC = No weed control, BL = broadleaves, GR = grasses, SD = sedges * = significant at $P \leq 0.05$

Table 4: Effect of cropping system and weed management practice on post-harvest weed seedbank in different landuse

Treatment	CSMZ		CSCP		FSMZ		FSCP	
Cropping System (CS)	2009	2010	2009	2010	2009	2010	2009	2010
CRP	4006	9409	7391	14648	4742	12200	2753	9868
NCRP	3747	12914	9225	14804	5885	14167	3436	14724
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed Control (WC)								
CWC	2519	9092	5970	18225	3168	8326	1667	8863
HWC	3450	7900	6744	11095	3992	11051	2714	12285
NWC	5659	16493	12210	15480	8778	20176	4884	15743
LSD(0.05)	1820.54	4201.48	2982.84	3076.48	2560.54	5013.51	1462.09	2678.15
Interaction								
CS x WC	NS	NS	NS	NS	NS	NS	NS	NS

CSMZ = Continuously cultivated maize field, CSCP = Continuously cultivated cowpea field, FSMZ = sole maize in the previously natural fallow field, FSCP = sole cowpea in the previously natural fallow field, CRP = Cropped plots, NCRP = uncropped plots, CWC= Chemical weed control, HWC = Hoe weeding, NWC = No weed control

Table 5: Comparison of weed densities based on estimations from the post-harvest seedbank in 2009 and field emergence in 2010 at site I.

	Broadleaves			Grasses			Sedges			Total weed density		
Treatment	SB	FE	%E	SB	FE	%E	SB	FE	%E	SB	FE	%E
MZCP	1394	302	22%	2815	685	24%	1316	172	13%	5525	1159	21%
SMZ	1997	487	24%	2206	652	30%	1327	267	20%	5530	1376	25%
SCP	2869	428	15%	2377	617	26%	1266	302	24%	6512	1347	21%
NCRP	2564	648	25%	2667	525	20%	2531	283	18%	6762	1456	22%
CWC	1250	393	31%	1790	431	24%	740	173	23%	3780	997	26%
HWC	1880	433	23%	2133	598	28%	1104	284	26%	5117	1315	26%
NWC	3487	550	16%	3623	758	21%	2247	382	17%	9357	1690	18%

SB = seedbank weed estimation, FE = field weed emergence, E = emergence, , MZCP = maize-cowpea intercrop, SMZ= sole maize, SCP= sole cowpea, NCRP= no cropping, CWC= chemical weed control, HWC= hoe weeding, NWC= no weed control,

Table 6: Comparison of post-harvest seedbank estimates in 2009 and field emergence in 2010 in various landuse intensity and cropping system.

	CSMZ			CSCP			FSMZ			FSCP		
Treatment	SB	FE	%E	SB	FE	%E	SB	FE	%E	SB	FE	%E
CRP	4006	1019	25%	7391	2518	34%	4742	752	16%	2738	898	33%
NCRP	3747	1099	29%	9225	2350	25%	5885	836	14%	3436	1019	30%
CWC	2519	631	25%	5970	2044	34%	3168	483	15%	1667	772	46%
HWC	3450	1355	39%	6744	2475	37%	3992	873	22%	2714	1022	37%
NWC	5659	1191	21%	12210	2794	23%	8778	1027	12%	4884	1083	22%

SB = seedbank weed estimation, FE = field weed emergence, E = emergence, CRP = cropped , NCRP= no cropping, CWC= chemical weed control, HWC= hoe weeding, NWC= no weed control, CSMZ = maize plots continuous maize field, CSCP = cowpea plots in continuous cowpea field, FSMZ = maize plots in natural fallow field, FSCP = cowpea plots in natural fallow field.

Table 7: Regression statistics for the seedling numbers (y) of weeds relative to the soil seedbank (x) and the mean percentage of seeds that emerged

Landuse	% of seeds that emerged	Regression equation	r^2	r	Probability
Site I	22.7%	Y = 625 +0.117x	0.859	0.926	0.0027
Site II	27.8%	Y = 1406 +2.33x	0.303	0.5503	0.337ns
Site III	30.6%	Y = 8877 +7.05x	0.597	0.7728	0.126ns
Site IV (SCP)	15.8%	Y = 1692 + 8.82x	0.658	0.8112	0.0096
Site IV (SMZ)	33.6 %	Y = 5031 + 8.31x	0.702	0.8377	0.0076

Site I = continuously cultivated field with alternate cropping systems, Site II = Continuously cultivated maize field, Site III = Continuously cultivated cowpea field, Site IV= Natural fallow field, SMZ = Sole maize plot, SCP = Sole cowpea plot, r = correlation coefficient of seedbank with field emergence, r^2 = coefficient of determination, ns = not significant at $p \leq 0.05$