Relation between Soil Weed Seedbank and Weed Management Practises and Diversity in Farms in Kisii Central Sub County, Nyanza

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Abstract. This study sought to determine the relation between soil weed seed bank and weed management practices and diversity in farms in Kisii Central Sub County, Western Kenya. Eight administrative sub-locations were randomly selected. Ten farms were selected at equal distance along transect laid across each sub-location. Weed soil seed bank was assessed from soil samples collected from each of the farms; a sub-sample was taken from a composite sample of ten soil cores of 5cm diameter and 15cm deep and placed in germination trays in a greenhouse. Weed diversity in soil weed seedbank was calculated using the Shannon index (H'). Twelve weed species from 12 genera of nine families were recorded. Diversity of the weed species in soil weed seed bank was ($H'=1.48$). Weed management practises significantly affected weed species soil weed seedbank reserves. Use of inefficient and ineffective hand-weeding techniques resulted in high weed species diversity and abundance.

1. Introduction

Agricultural weeds are plants that compete with crops for moisture, light, space and nutrients [20, 25]. The conflict between crop productivity and weeds has so far mainly been managed through cultural practices and use of herbicides, but relying solely on chemicals can be unsustainable when weed populations develop resistance to herbicides [19], and because of the environmental impacts of herbicides and their residues. One alternative is the application of current knowledge on the effects of agricultural practices on weed populations to design novel cropping systems of integrated weed management (IWM) that would require few herbicides to manage weeds. IWM combines the use of crop rotation design and adapting cultural practices such as mulching, type of soil tillage and mechanical weeding [2]. IWM relies on weed management principles that have proved to have satisfying efficiency for long-term weed management in organic farming for decades [21].

The weed seed bank is the reserve of viable weed seeds present on the soil surface and scattered in the soil profile and formation of the soil weed seed bank represents an important regeneration components of many weed species [17]. It consists of both new weed seeds recently shed and older seeds that have persisted in the soil for several years. Agricultural soils can contain thousands of weed seeds per square foot and understanding the factors impacting the dynamics of weed seed banks can help in the development of integrated weed management programs [11].

The production of a large number of small seeds is an important survival strategy developed by weeds to survive control methods. According to [12], one plant of *Ludwigia octovalvis* (Onagraceae) is capable of producing 250,000 seeds. After their dispersal, the seeds might remain on the soil surface or be buried by various biotic and abiotic agents, thus forming a soil seed bank that becomes the primary source of weeds in agro-ecosystems. Weed seed location in the soil seed bank influences germination, emergence and vertical seed distribution in the soil [24].

Weed seed bank studies *in situ*, that is, the identification and enumeration of weed seedling emergence in the field, might provide a general indication of the composition of the weed flora in the seed bank. However, this method is not precise because seeds from many species can remain viable for long periods but do not germinate because they possess some degree of physical or

physiological dormancy, while others germinate but do not emerge due to unfavourable environmental conditions. Possible causes in reduction in soil weed seedbank may be explained by various factors like seed and seedling losses in the field due to activities of microorganisms, insects, birds, rodents, lizards and other animals. [10] carried out a study in organic cereal fields in Netherlands and observed that weed seed losses due to predators range between 5-15%. Similarly, the weed seed losses may be due to occasional periods of soil water stress and germination failure [13]. The dominance of a weed species in the soil weed seed bank is related not only to cultural factors and crop history but also to reproductive capacity of the weed species [18].

However, weed seed bank study; the identification and enumeration of weed seedling emergence from soil samples placed in trays in the greenhouse and irrigated daily for longer periods is more efficient for assessing germination dynamics. It is also possible to assess the potential size of the weed seed bank because many species are capable of extended fluxes of emergence over several weeks under favorable environmental conditions. Under controlled conditions like those in the green house, weed seed germination varies due to dormancy breaking because of greater exposure to sunlight as observed by [4].

There is a need to understand soil weed seed bank germination dynamics and its relationship with observed weed flora on smallholder fields. In ecosystems, weed population is related to the seed bank. The knowledge of seed bank size and of its species composition will contribute to the prediction of infestations and thus leading to improved management strategies for minimizing the effects of the interference of invasive plants with crop growth and yields [29]. The weed seed bank not only serves as a physical history of the past successes and failures of cropping systems, it can also help producers predict the degree to which crop-weed competition will affect crop yield and quality [6].

2. Materials and Methods

2.1 Description of the study area

Kisii Central Sub County is one of the nine Sub Counties of Kisii County in Southwest Kenya. Temperatures can range from 10°C to 30°C. According to the [15], Kisii Central Sub County (formerly Kisii Central district) had a population of 588,000, but with a population growth rate of 3.6% the population is now over 700,000 (19% of whom live in urban areas. It is one of the most densely populated Sub Counties in Kenya and covers an area of 317.4Km². Due to the high population density, almost all land is put to maximum agricultural use. Land is subdivided within families, meaning that farm size is reducing and an average farm is only 15,000 m² in area [22], with an average of a quarter of an acre allocated for arable farming throughout the Sub County and almost all farmers engage largely in subsistence and minimal commercial production. The acreage under cash crops in Kisii Central Sub County is approximately 3,800ha while the area under food crops is about 12,500ha [23]. Livestock production is dominated by dairy and local poultry. Agriculture employs an estimated 80% of the population either directly or indirectly and the estimated rural poverty is 30% with some areas having as high as 61% according to Kisii county profile [23].

Figure 2.2: Kisii Sub-County Regions in Kisii County where the research was done

Source: Kisii county profile plan (20/4/2017)

Eight administrative sub-locations were randomly selected in the sub-county. Ten farms were then selected at an equal 50m distance along a 150m transect laid across each sub-location in the study area. Soil samples were collected from each of the farms; a sub-sample was taken from a composite sample of ten soil cores of 5cm diameter and 15cm deep and put in germination trays in a greenhouse for weed seed bank assessment. Weed emergency was monitored after a week and later on weekly basis for three months. The number of seeds was estimated by counting the seedlings after germination. Diversity in the seed bank was calculated. Botanical identification of weed species was done by analysis of vegetative and reproductive parts in reference to guide books and comparing the weeds with voucher specimen deposited at National Museums of Kenya. Plant taxonomists were consulted to help identify weed species that could not be identified in the field.

Assessment of phytosociological structure was done using absolute and relative values of density, frequency, abundance and importance value for each weed species [8]. The following parameters were computed;

Relative frequency = species absolute frequency/sum of all absolute frequencies x100.

Where, H' = diversity

$$p_i = n_i / N_{\text{total}},$$

ln = natural logarithm,

n_i = number of individuals of species i

N_{total} = Total number of individuals on all species

Data on weed management practices and number of weeds in the farms was subjected to analysis of variance using Genstat, Release 15.1. Mean separation was accomplished using Fisher's protected Least Significant Difference. The relation between weed management practices and soil weed seed bank was determined based on the effect of weed management practices on mean number of weeds in soil weed seed bank reserves. General analysis of variance (ANOVA) was used to compare the effect on mean number of weed species.

4 Results

4.1 Weed management practises and soil weed seedbank

The weed management practices recorded in the respective farms were tallied with the number of weed species obtained from the soil weed seedbank. Cover cropping, mulching and organic farming had 3 weed species, hoeing and mechanical tillage recorded 4 weed species, livestock grazing/browse and slashing had 3 weed species while crop rotation and use of herbicides recorded 2 weed species as shown in Table 4.1.

Table 4.1: Categories of weed management practises and number of weed species recorded in soil weed seedbank

Serial No.	Weed management practises	Number of weed species on weed soil seed bank
1	Cover cropping, mulching and organic farming.	3
2	Crop rotation and use of herbicides.	2
3	Hoeing and Mechanical tillage.	4
4	Livestock graze/Browse, Slashing and Hand pulling.	3
Totals		12

Hoeing and mechanical tillage recorded the highest number of weed species on soil weed seedbank of 4 weed species and was closely followed by cover cropping, mulching and organic farming and livestock grazing/browse and slashing which had 3 weed species respectively while crop rotation and use of herbicides recorded 2 weed species as shown in Figure 4.1.

Figure 4.1: Combination of weed management methods and number of weed species recorded in soil weed seed bank

Key; CC- Cover cropping, M- Mulching, OF- Organic farming, CR- Crop rotation, HB- Herbicides, H- Hoeing, MT- Mechanical tillage, HP- Hand pulling, LG/B- Livestock graze/ Browse, S- Slashing

A comparison between number of weed species and weed management practises both on farms and soil weed seed bank was done. Hoeing recorded the highest weed species both on farms and in soil weed seedbank of 9 and 4 respectively as illustrated in Figure 4.2

Figure 4.2: Comparison between numbers of weed species obtained from farms and in soil weed seed bank with the different categories of weed management methods

Key; CC- Cover cropping, M- Mulching, OF- Organic farming, CR, Crop rotation, H- Hoeing, MT- Mechanical tillage, HP- Hand pulling, LG/B- Livestock graze/ Browse, S- Slashing

4.2 Diversity index of weed species in soil weed seedbank

4.2.1 Weed species diversity index in soil weed seedbank in each sampled farm

In each of the sampled farms, computation of soil weed seedbank diversity index based on Shannon formula was done. Farm 33, 14 and 20 had the highest diversity index of 1.94, 1.76 and 1.74 respectively while farm 44 and 79, each had the lowest diversity index of 0.14 as shown in Table 4.2. Variation of weed diversity index across the sampled farms was noted and this might be attributed to the differences in management practises and adaptive features among individual weed species.

Table 4.2: Weed species diversity index in soil weed seedbank in each of the surveyed farms

Farm	Weed species Diversity Index	Farm	Weed species Diversity Index	Farm	Weed species Diversity Index	Farm	Weed species Diversity Index
	0.9322	21	1.2995	41	1.2210	61	1.1646
2	1.4533	22	1.0139	42	1.0877	62	0.7563
3	1.2481	23	0.9296	43	1.1823	63	0.0914
4	1.3939	24	0.3018	44	0.1357	64	0.8647
5	1.0920	25	1.4767	45	0.3379	65	0.7651
6	1.4707	26	0.9232	46	1.2912	66	0.8903
7	0.5364	27	1.2511	47	0.3284	67	0.8883
8	1.1008	28	1.4978	48	0.3676	68	0.7665
9	1.1753	29	0.9505	49	0.3117	69	0.9468
10	0.9743	30	1.2059	50	1.2633	70	1.1268
11	1.2758	31	0.1869	51	1.2136	71	0.3962
12	0.4374	32	1.0705	52	1.1545	72	1.4847
13	1.6085	33	1.9449	53	1.1052	73	1.3631
14	1.7663	34	0.8897	54	1.1745	74	0.1906
15	0.6851	35	0.8897	55	1.3729	75	1.0941
16	1.5496	36	0.9407	56	0.4427	76	0.1530
17	1.4098	37	0.8599	57	0.1743	77	1.2677
18	1.5683	38	0.9259	58	1.2610	78	1.3926
19	1.2033	39	0.7998	59	1.0237	79	0.1448
20	1.7426	40	0.7381	60	1.2582	80	1.0367

4.2.2 Weed species diversity index in soil weed seedbank on farms in each sampled sub-location

Weed species diversity index on farms of the sampled administrative sub-locations was calculated and the findings are as shown in Table 4.3. Nyanchwa recorded the highest diversity index followed by Kirwa, Nyamware and Nyaguta with 1.525, 1.218 1.152 and 1.140 weed species diversity index respectively while Taracha recorded the least weed species diversity index of 0.926. Weed species diversity was higher in relatively low and medium altitude zones and weed diversity increased in farms with hoeing and hand pulling weed management practises. The widespread of weed species found in most altitudes can also be attributed to their best adaptability in different edaphic, prevailing environmental conditions and resistance to management practises.

Table 4.3: Weed species diversity index in soil weed seedbank on farms in each sampled sublocation

Location	Sub-location	Weed species diversity index (H')
Kisii Central	Nyaguta	1.14027
Kiogoro	Nyanchwa	1.52467
Bobaracho	Kegati	1.18500
Ibeno	Nyamagwa	1.02461
Keumbu	Nyamware	1.15268
Ibeno	Kirwa	1.21806
Birongo	Taracha	0.92608
	Birongo	1.25235

Nyanchwa recorded the highest diversity index (1.52) followed by Kirwa (1.218), Nyamware (1.152) and Nyaguta with 1.140 weed species diversity index while Taracha ranked last with weed species diversity index of 0.926 as indicated in Figure 4.3.

Figure 4.3: Weed species diversity index in soil weed seed bank on farms in each sampled administrative sub-location

Key: Nyaguta- NG, Nyanchwa- NC, Kegati- KG, Nyamagwa- NM, Nyamware- NR, Kirwa- KR, Taracha-TR, Birongo- BR

4.2.3 Overall weed species diversity index in the surveyed farms in soil weed seedbank

The total number of all individual weed species collected from the soil weed seed bank was determined. The overall diversity index of the weed species in the soil weed seed bank from the surveyed farms was calculated using Shannon index and tabulated as shown in Table 4.4. Weed species diversity was relatively lower than that recorded on farms and this can be linked to weed management practises that contributed to decrease in weed soil seed bank because they limit new seed deposition to the bank and also hinder seed germination from taking place through mechanisms such as seed rains.

Table 4.4: Overall diversity index of weed species in soil weed seedbank

Weed species	No. of sample	$p_i = \text{sample}/\text{sum}$	$\ln(p_i)$	$p_i * \ln(p_i)$
<i>Galinsoga parviflora</i>	1239	0.50	-0.69	-0.345
<i>Amaranthus hybridus</i>	123	0.05	-2.99	-0.150
<i>Bidens pilosa</i>	5	0.002	-6.21	-0.012
<i>Digitaria scaralum</i>	710	0.29	-1.23	-0.357
<i>Cyperus esculentus</i>	211	0.09	-2.53	-0.228
<i>Oxalis latifolia</i>	51	0.02	-3.91	-0.078
<i>Nicandra physalodes</i>	47	0.02	-3.91	-0.078
<i>Commelina benghalensis</i>	42	0.02	-3.91	-0.078
<i>Tagetes minuta</i>	2	0.0008	-7.13	-0.006
<i>Portulaca oleracea</i>	65	0.03	-3.51	-0.105
<i>Chenopodium opulifolium</i>	20	0.008	-4.83	-0.039
<i>Gynandropsis gynandra</i>	1	0.0004	-7.82	-0.003
Sum= 2,516				Sum=-1.479

Therefore, $H' = 1.48$

4.3 Relation between weed species in soil weed seed bank and management practises

4.3.1 Weed species in soil weed seedbank

A total of 2,516 individual weeds belonging to nine families of 12 genera and 12 weed species were recorded. The family Asteraceae had the highest number of species richness (3) followed by Amaranthaceae family with 2 species while the remaining families had one species each (Table 4.5)

Table 4.5: Families, genera and species names of weed species in soil weed seed bank

Family	Genus name	Species name	Absolute Frequency	Relative frequency (%)
1 Poaceae	<i>Digitaria</i>	<i>D. scalarum</i>	710	28.6
2 Asteraceae	<i>Bidens</i>	<i>B. pilosa</i>	5	0.20
	<i>Tagetes</i>	<i>T. minuta</i>	21	0.85
	<i>Galinsoga</i>	<i>G. parviflora</i>	1239	51.9
	<i>Commelina</i>	<i>C. benghalensis</i>	42	1.7
	<i>Nicandra</i>	<i>N. physalodes</i>	47	1.9
	<i>Amaranthus</i>	<i>A. hybridus</i>	123	4.8
3 Commelinaceae	<i>Chenopodium</i>	<i>C. opulifolium</i>	21	0.9
4 Solanaceae	<i>Gynandropsis</i>	<i>G. gynandra</i>	1	0.4
5 Amaranthaceae	<i>Oxalis</i>	<i>O. latifolia</i>	51	2.1
6 Capparaceae	<i>Cyperus</i>	<i>C. esculentus</i>	211	8.5
7 Oxalidaceae	<i>Portulaca</i>	<i>P. oleracea</i>	64	2.6
8 Cyperaceae				
9 Portulacaceae				

4.3.2 Comparison between weed species in farms and in soil weed seed bank

Twenty four weed species were recorded on farms while the soil weed seedbank had twelve weed species. Relative frequency of weed species on farms and in soil weed seedbank was computed and comparison made. Weed species *G. parviflora* had the highest relative frequency both on farms and in soil weed seedbank. Weed species *P. clandestinum*, *C. dactylon*, and *C. banariensis* occurred only in the farms and not in soil weed seedbank while others like *C. opulifolium* and *P. oleracea* occurred only in soil weed seedbank (Table 4.6).

Table 4.6: Comparison between relative frequencies of weed species on farms and in soil weed seedbank

Weed species	Farm Relative frequency (%)	Soil weed seedbank Relative frequency (%)
<i>Pennisetum clandestinum</i>	8.52	-
<i>Bidens pilosa</i>	7.96	0.20
<i>Digitaria scalarum</i>	7.85	28.6
<i>Commelina benghalensis</i>	4.37	1.7
<i>Tagetes minuta</i>	6.73	0.85
<i>Galinsoga parviflora</i>	9.30	51.9
<i>Nicandra physalodes</i>	2.69	1.9
<i>Amaranthus hybridus</i>	5.72	4.8
<i>Cynodon dactylon</i>	8.18	-
<i>Solanum nigrum</i>	1.35	-
<i>Gynandropsis gynandra</i>	0.67	0.4
<i>Oxalis latifolia</i>	4.26	2.1
<i>Conyza banariensis</i>	5.72	-
<i>Datura stramonium</i>	2.80	-
<i>Solanum incanum</i>	3.81	-
<i>Cyperus esculentus</i>	7.17	8.5
<i>Emilia brachycephala</i>	3.92	-
<i>Pteridium aquilinum</i>	0.67	-
<i>Crassocephalum vitellinum</i>	1.79	-
<i>Leonotis mollissima</i>	0.56	-
<i>Leonotis martinicensis</i>	0.56	-
<i>Physalis ixocarpa</i>	0.56	-
<i>Chenopodium opulifolium</i>	-	0.9
<i>Portulaca oleracea</i>	-	2.6

4.3.3 Relation between weed management practises and soil weed seedbank

The relation between weed management practises and weed species in soil weed seed bank was determined based on the effect of weed management practises on weed species diversity in soil weed seed bank reserves. Weed management practises hoeing, cover cropping, mulching, and crop rotation had equal effect on soil weed seed bank index compared with other weed management practises. Means accompanied by different letter(s) are significantly different (Fisher's protected least significant difference test, $P \leq 0.05$). [Appendix I(i)]. Weed management practises significantly affected soil weed seedbank diversity index ($P \leq 0.05$) and therefore, the index values were statistically different among samples from farms with different weed management practises. [Appendix I(ii)]. Therefore, the null hypothesis that there is no relationship between abundance and diversity of growing weeds and weed soil seed bank on farms in Kisii Central Sub County, Western Kenya is rejected.

5 Discussions

5.1 Weed management practises and soil weed seed bank

In this study, the weed species abundance declines across the studied farms. Study results indicate that weed management practises contributed to decrease in weed soil seed bank because they limit new seed deposition to the bank and also hinder germination from taking place through mechanisms such as seed rains which concurs with observations made by [9]. In temperate regions, weed seed bank declines by 32% annually, [27] while in tropical regions, the soil weed seed bank is smaller and the decline tends to be rapid because, according to [9], though there is high seedling recruitment rate linked to conducive ecological conditions for seed germination which persist for longer periods than in temperate regions, there is high seed mortality due to high relative humidity and temperatures, predators, pathogens, seedling mortality due to seed germination in short, hot dry seasons that occur during the rainy season, a shorter duration or absence of seed dormancy of most weed species and other seeds having a low seed viability.

Additionally, this study shows that the soil weed seed bank tend to decrease due to management practises that hinder weed seed germination hence limiting new weed seed deposition into the soil weed seed bank. Therefore, if arable farms are not cultivated regularly for planting and situations where deposition of new weed seeds is low then the rate of reduction of weed seed bank will vary depending on ecological conditions [9].

5.1.2 Weed species diversity in soil weed seedbank

5.1.3 Weed species diversity in soil weed seedbank in each surveyed farm

Across the studied farms, there was variations in weed species diversity. The diversity of a weed species in the soil weed seed bank is related not only to weed management factors and crop history but also to reproductive capacity of the weed species [18]. These findings are in agreement with those of [13] who noted that possible causes in the decline of the amount weed species in soil weed seed bank may be due to various factors such as seed and seedling losses in the field due to activities of microorganisms, insects, birds, rodents, lizards and other animals which in turn leads to variations in soil weed seed bank.

5.1.4 Weed species diversity in soil weed seedbank in each sampled sub-location

Weed diversity varied across the sampled sub-locations and this might be due to the differences in growth, production of high number of seeds, dormant seeds, excellent seed dispersal mechanisms, high competitive ability among individual weed species. Weed species diversity was higher in relatively low and medium altitude zones and weed diversity increased in farms with adoption of inefficient and ineffective weed control practises. The widespread of weed species found in most altitudes can also be attributed to their best adaptability in different edaphic, prevailing environmental conditions and resistance to management pressures. Similar study conducted by [31] in wheat fields of district Rahim Yar Khan, Pakistan reflected same results.

5.1.5 Overall weed species diversity in soil weed seedbank

The Shannon index increases as abundance of a community increases. The higher values of H' indicate greater floristic diversity [28].

Weed species diversity was calculated and recorded a diversity index of $H' = 1.48$ for weed species in the soil weed seed bank which was lower than 2.66 obtained by [1] who carried out a similar study in Southern Brazil. The higher values of H' obtained usually will indicate greater floristic diversity [28] and therefore, weed species found in the farms had diversity index (H') = 2.77 and indicates a high floristic diversity than in soil weed seed bank. Species of the family Asteraceae largely dominated in the weed soil seed bank as evaluated. However, studies carried out in other tropical regions by [14] observed that 86% of species found in the soil weed seed bank of 22 rice fields in Cambodia were of Cyperaceae family. In another related study conducted in Nepal, [5] reported that 37% of the grasses and sedges contributed to the soil weed seed bank. Generally, the dominance of a weed species in the soil weed seed bank can be related to cultural weed management practises, weed species history and also the reproductive capacity.

These results depicts that weed seed bank reserve at this study area might drastically decreased since management practices prevent new seed deposition into soil weed seed bank through mechanisms such as seed rains. These findings are in agreement with those obtained by [30] that the traditional weed management practises farmers employ in their farms like hand weeding, hoeing contribute to high weed diversity, persistence and ever re-occurring in the farms since they are ineffective and untimely carried out.

5.2 Relation between weed species in soil weed seed bank and management practises

5.2.1 Weed species in soil weed seedbank

The five most dominant and widespread weed species within the soil weed seedbank in the study area were *G. parviflora*, *D. scalarum*, *C. esculentus*, *A. hybridus*, and *P. oleraceae* while the rest of the other weed species were infrequent. Species of the family Asteraceae largely dominated in the soil weed seed bank as evaluated. However, studies carried out in other tropical regions by [14] observed that 86% of species found in the weed seed banks of 22 rice fields in Cambodia were of Cyperaceae family.

5.2.2 Comparison between weed species on farms and in soil weed seed bank

On the studied farms, twenty four weed species from twenty two genera belonging to ten families were observed with Asteraceae being the most abundant family while in soil weed seedbank, nine families of 12 genera and 12 weed species were recorded. The family Asteraceae was still dominant in the soil weed seedbank. In farms, *P. clandestinum* and *C. dactylon* dominated with a relatively higher frequency though they did not occur in soil seed bank. *G. parviflora* highly dominated both in soil weed seed bank and in farms. Though farms recorded higher number of weed species than in soil weed seed bank, weed seeds are usually prone to possible predation and also subjected to periods of water shortages. Possible differences observed between the amount weed species in farms and in soil weed seedbank may be explained by various factors like seed and seedling losses in the field due to activities of microorganisms, insects, birds, rodents, lizards and other animals. [10], carried out a similar study in organic cereal fields in Netherlands and observed that weed seed losses due to predators range between 5-15%. Similarly, the weed seed losses may be due to occasional periods of soil water stress and germination failure [13]. The dominance of a weed species in the soil weed seed bank is related not only to cultural factors and crop history but also to reproductive capacity of the weed species [18]. [32], carried out a similar study on soil weed seed banks in natural fields and observed that soil moisture content was one of the most vital abiotic factor that affects vegetation patterns in a given area. The weed species with higher relative frequency values occurred in relatively all farms. Weeds such as *G. parviflora* and *D. scalarum* have well adaptive features like excellent modes of seed dispersal and tolerance to human and environmental pressure thus persist and dominate in arable farms. In related studies done by [33] on different weed control methods in coffee in Kenya, observed that *G. parviflora*, *C. dactylon* and *B. pilosa* were the most frequent weed species compared to the rest of other weed species. [34]) conducted a similar study and reported that weed species with high percentage of frequency might exert competitive and allelopathic stress to reduce growth and yield of associated crop. These weed flora composition has a negative impact of lowering crop yield quantity and quality. In this study therefore, the results indicate that the weed seed bank is lower than weed species on farms due to limited weed seed deposition into this bank.

5.2.3 Weed management practises and soil weed seedbank

This study results depicts that soil weed seed bank reserve in this study area might have drastically decreased since the diversity index value H' of 1.48 is lower than 2.77 obtained on farms which implies that management practises prevent new seed deposition into the soil weed seed bank through mechanisms such as seed rains. Further still, these results shows that the weed management practises employed by most farmers hinder weed seed germination hence limiting new weed seed deposition into the soil weed seed bank. Similarly, if arable farms are not cultivated regularly for planting and situations where deposition of new weed seeds is low then the rate of reduction of weed seed bank will vary depending on ecological conditions [9]. In agreement with these findings,

[30] observes that weed management practises adopted by most farmers in their farms like hoeing, mulching and cover cropping contribute to high weed diversity, persistence and ever re-occurring in the farms since they are ineffective and untimely carried out.

5.2.4 Relation between weed management practises and soil weed seedbank

Results of this study shows that the soil weed seed bank tend to vary due to weed management practises that hinder weed seed germination hence limiting new weed seed deposition into the soil weed seed bank. From the results obtained, weed management practises especially mechanical tillage, livestock grazing/browse and organic farming had significantly ($p \leq 0.05$) higher effect in increasing soil weed seedbank. Livestock grazing or browsing on weeds or weed-infested crops can destroy the viability of weed seeds. However, some seeds pass through livestock digestive system unharmed and can germinate if spread back onto the farms. Hoeing, crop rotation and hand pulling significantly ($p \leq 0.05$) reduced weed seed reserves; were observed to have a negative effect on number of weed species in soil weed seedbank. In related studies, [3] observed that mechanical weed management practises such as hand-pulling, hoeing, slashing, and tillage destroy weeds or make the environment less favorable for seed germination and weed survival thus reducing weed seed reserves.

In similar a study conducted by [26] observed that cutting of mature weed plants before the spread their seeds proves to be an effective preventive measure in weed control thus reduction in weed seed reserves. Cultural weed management practises such as mulching, crop rotation and cover cropping leads to suppression of weeds in arable farms. Cover crops are known to prevent the development of weed population through smothering and suppression of weed growth and development and therefore should be incorporated in a cropping system [16].

Adoption of tillage operations and application of non-selective herbicides produces weed-free fields for planting and reduces weed seed deposition into soil weed seedbank [7]. Therefore, it is observed that if arable farms are not cultivated regularly for planting and situations where deposition of new weed seeds is low then the rate of reduction of weed seed bank will vary depending on the prevailing ecological conditions [9].

6 Conclusion

The soil weed seed bank tend to vary depending on weed management practises employed by farmers that affect weed seed germination hence limiting new weed seed deposition into the soil weed seed bank. The number of weed species recorded in soil weed seed bank on farms with hoeing, crop rotation and hand-pulling was significantly different from those obtained from farms with mechanical tillage, livestock grazing/browse and organic farming weed management practises.

Recommendations

- Farmers to be exposed to agricultural experts who will train them on weed management practises. Effective land preparation, mulching, cover-cropping and crop rotation should be adopted by farmers to reduce rates of weed invasion to maximise crop yields. However, farmers should adopt the integrated weed management (IWM) technique which is a holistic approach to weed management that integrates different methods of weed control to provide the crop with an advantage over weeds.
- Farmers to be encouraged to continue studying weeds, their damage and control and have weed cultural knowledge which should be passed to the next generations.

Conflict of Interest

“The author(s) declare(s) that there is no conflict of interest.”

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Appendix I: Data Analysis Output

(i): Weed management practises on soil weed seedbank diversity

Variate: Diversity index

Source of variation	d.f.	s.s.	m.s.	F	Sig.
Weedmgt	31	7.8454	0.2531	1.75	0.039
Residual	48	6.9324	0.1444		
Total	79	14.7778			

(ii): Fisher's protected least significant difference test

Weed management	Mean
Cover cropping and organic farming	0.153a
Livestock grazing and slashing	0.191ab
Mulching and organic farming	0.396abc
Hoeing and mulching	0.547abcd
Mulching and slashing	0.629abcde
Hoeing and slashing	0.656abcde
Cover cropping and slashing	0.766abcdef
Hoeing and hand pulling	0.805abcdef
Mechanical tillage and livestock grazing	0.890abcdef
Crop rotation and livestock grazing	0.890abcdef
Crop rotation and mechanical tillage	0.906abcdef
Hand pulling and cover cropping	0.951abcdef
Herbicides and mechanical tillage	1.068abcdef
Hoeing and livestock grazing	1.101abcdef
Mulching and mechanical tillage	1.105abcdef
Hoeing and crop rotation	1.134cef
Cover cropping and livestock grazing	1.155abcdef
Crop rotation and cover cropping	1.155cef
Hoeing and livestock grazing	1.157cef
Hoeing and herbicides	1.206abcdef
Hand pulling and herbicides	1.248bcdef
Hoeing and mechanical tillage	1.251bcdef
Crop rotation and use of herbicides	1.263bcdef
Crop rotation and slashing	1.300cdef
Hoeing and cover cropping	1.317f
Slashing and use of herbicides	1.363cef
Mulching and hand pulling	1.386ef
Mechanical tillage and organic farming	1.394cef
Hoeing and organic farming	1.405f
Mechanical tillage and slashing	1.485ef
Crop rotation and organic farming	1.550ef
Cover cropping and mechanical tillage	1.685f

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