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Spatial Abundance of Soil Seed Bank in Parthenium Infested Maize Fields in Western Gojjam Zone, Ethiopia

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Abstract: Background: The reserve of viable weed seeds present on the soil surface and scattered throughout the soil profile.

Objective: A glasshouse study was conducted to determine the special abundance of soil seed bank flora in parthenium invaded maize fields in West Gojjam Zone.

Methods: The soil samples were collected from 90 fields at 0-5 cm, 5-10 cm and 10-15 cm soil depth with 10 cm width.

Results: A total of 121 weed species belonging to 27 families were found in the soil seed banks. The most frequent families were Poaceae (31 species), Asteraceae (21 species) and Leguminosae (9 species). The highest importance value was recorded by *Parthenium hysterophorus*, *Ageratum conyzoides* and *Echinochloa colona* with 19.05, 19.02 and 14.37%, respectively at 0-5 cm soil depth. The highest importance values of 20.39, 20.16 and 16.54% were registered by *P. hysterophorus*, *A. conyzoides* and *Galiansago parviflora*, respectively at 5-10 cm soil depth. Likewise, at 10-15 cm soil depth highest importance value was recorded by *A. conyzoides*, *P. hysterophorus* and *E. colona* with 19.12, 17.30 and 116.13%, respectively. The Shannon diversity index at 0-5, 5-10 and 10-15 cm soil depth were 4.46, 4.41 and 4.17, respectively. High similarity (68.10%) was observed between 0-5 and 5-10 and followed by 5-10 and 10-15 cm (60.19%) and 0-5 and 10-15 cm (55.39%).

Conclusions: These results could help to predict infestation potential and could lead to improved weed management strategies in maize growing areas in the study area.

Keywords: Diversity; importance value; parthenium; soil seed bank and soil depth

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1. Introduction

The weed seed bank is the reserve of potential weed seeds present inside a soil profile, on the soil floor and scattered throughout the soil (Singh et al., 2012). Seed banks comprise both dormant and non-dormant seeds, which enhances the probability of persistence of a species at a particular area when germination conditions are unfavorable or in absence of additional seed rain (Li, 2011). Thousands of weed seeds and more vegetative weed propagules per square foot can be included in agricultural soils (Menalled, 2013). The initial population of weeds is directly related to seed density in the seed bank (Brainard et al., 2008). In farming systems where there is no soil disturbance and no tillage, as is the case for subsistence farming, weed seeds prefer to stay on the soil surface where they are easier to manage (Grundy et al., 2003). It has also been noted that the vertical movement is very limited and is conditioned by soil texture, accumulated rainfall and seed size, weight and shape (Benvenuti, 2007).

The weed seed bank can not only reflect the management history of farmland but also predict the future weed dynamics and compared with the aboveground community, it is more suitable to express the diversity of weeds. According to Karim et al. (2017), ruining weed seeds in seed banks is one of the crucial strategies in weed management. Data from weed seed bank reports will estimate the past and potential plant species within a habitat (Golafshan, Yasari, 2012). Awareness of soil weed seed banks is critical for the population dynamics studied, for the establishment of appropriate weed management programs and weed infestation forecasts (Ambrosio et al., 2004; Golafshan, Yasari, 2012).

To understand the soil weed seed bank germination dynamics and its relationship with the weed flora on maize fields, glasshouse studies are needed. This study will contribute to infestation prediction and may lead to enhanced management practices to minimize the negative effects of weed intrusion on the growth and yield of maize crops. Hence, the purpose of this research was to determine the spatial abundance of soil seed bank flora in parthenium invaded maize fields in West Gojjam Zone.

2. Materials and method

2.1 Soil Seed Bank Sampling

Soil seed bank sampling was conducted in September 2019/2020 main cropping season in Jabitenah and Burie, West Gojjam Zone, Ethiopia. Three farmers associations from each district and three private large-scale farm (Upper Bir, Lower Bir and Amhara Seed Enterprise) were selected. Soil seed bank sampling was conducted in ten maize fields in each farmer's associations (a total of 60 fields) and in three private farms (a total of 30 fields). Soil cores (10 cm width and 15 cm depth) were taken at the center of each quadrat in a diagonal way in the field. Soil cores were separated into three 5 cm sections up to a 15 cm depth (0-5 cm, 5-10 cm and 10-15 cm) (Ranjit, 2007; Shabbir, 2015). The sample soil were taken by using a flat nife from each depth. The three soil samples from the same layers within a field was placed into one plastic bag to form a composite sample. The samples were stored until the soil was air-dried in the study area and transported to the Haramaya University for germination tests in the glasshouse.

2.2 Soil Seed Bank Germination

The plastic pot (20 cm height and 25 cm diameter) were prepared and filled with sterilized coarse sandy soil. The soil samples were spread thinly over sterilized soil in 270 plastic pot from 90 fields with 3 depth. The trays were placed randomly on a bench. The soil samples were stirred at an interval of one month and cycled five times to stimulate seed germination (Forcella, 1992). During the study, the glasshouse temperature is 16-25 ^{0}C, day neutral photoperiod and a relative humidity of 80%.

2.3 Identification and Collection of Weed Flora

One month after sowing readily identifiable emerged seedlings were recorded by scientific name, counted and pulled out. Ambiguous sample were collected, labeled, dried and taken to Haramaya university (Harar, Ethiopia) herbarium for proper identification. Nomenclature of the weed plant species was done with reference to Stroud and Parker (1989) and Hedberg et al. (2003).

2.4 Data Analysis

The data were recorded on the following parameters as adopted from (Hussain et al., 2004; Wittenberg et al., 2004).

$$\textbf{Relative frequency (RF)} = \frac{\text{The frequency value (}\mathbf{F}\text{) for species }\mathbf{I}}{\text{Total sum of all frequency values for all species surveyed}} \times 100$$

$$\textbf{Relative Density (RD)} = \frac{\text{Density of an individual weed species (}\mathbf{I}\text{) (all fields)}}{\text{Sum of the densities for all weed species present in all fields}} \times 100$$

$$\textbf{Relative Abundance (RA)} = \frac{\text{Abundance of a particular weed species}}{\text{Total abundance of all weed species}} \times 100$$

Similarity Index (SI): The similarity of weed community between any two-soil depths in terms of weed composition.

$$SI = (Epg / (Epg+EPa+Epb)) \times 100$$

Where, SI = similarity index; Epg = number of species found in both depth; EPa = number of species found only in depth-1; Epb = number of species found in depth

Shannon Diversity Index (H'):

$$H' = -\sum_{i=1}^{S} pilnpi$$

Where, pi = relative abundance of each species; S = number of species

Species evenness (E):

$$E = \frac{H'}{InS}$$

3. Results and discussion

3.1 Composition of Germinable Soil Seed Bank Weeds

Irrespective of soil depth the experimental pots had 121 weed species belongs to 27 families were found in soil seed bank weed community in maize fields. The most frequent families based on the number of species were Poaceae (31), Asteraceae (21) and Leguminosae (9) with a proportion of 25.62, 17.36 and 7.44%, respectively. Poaceae, Asteraceae and Leguminosae families contributed 50.42% of the total species of the floristic composition of the weed community in the soil seed bank. The soil seed bank at 0-5 cm soil depth had 100 species belong 26 families and followed by 5-10 cm with 96 species (25 families) and 10-15 cm with 71 species (21 families) (Table 1).

The majority of species in Table 2 identified in the soil seed bank study were broad leaved 86 (71.07%) and followed by grass 31 (25.62%) and sedges 4 (3.31%). Out of 100 species at 0-5 cm, 73 (73.00%) were broad leaved, 23 (23.00%) were grass and 4 (4.00%) were sedges (Table 2). The highest number of weed species was recorded by broad leaved followed by grass and sedges at 5-10 cm with 71 (77.74%), 22 (23.16%) and 2 (2.11%), respectively from 95 species. Similarly, from 71 species at 10-15 cm majority of the species were recorded by broad leaved, grass and sedge with 56 (78.81%), 13 (18.31%) and 2 (2.82%),

Table 1 – Family, number of weed species in each family and its % at three soil depths and total soil seed bank with in the family

Name of Family	Soil Depth (cm)						Total No. of Species	%
	0-5		5-10		10-15			
	No. of Species	%	No. of Species	%	No. of Species	%		
Acanthaceae	2	2	1	1.05	1	1.41	2	1.65
Aizoaceae	1	1	1	1.05	1	1.41	1	0.83
Amaranthaceae	8	8	4	4.21	3	4.23	8	6.61
Asteraceae	18	18	17	17.89	15	21.13	21	17.36
Boraginaceae	1	1	1	1.05	1	1.41	1	0.83
Brassicaceae	2	2	2	2.11	2	2.82	2	1.65
Chenopodiaceae	1	1	1	1.05	1	1.41	2	1.65
Commelinaceae	5	5	5	5.26	4	5.63	6	4.96
Convolvulaceae	2	2	2	2.11	1	1.41	3	2.48
Cyperaceae	4	4	2	2.11	2	2.82	4	3.31
Euphorbiaceae	3	3	3	3.16	3	4.23	4	3.31
Lamiaceae	1	1	1	1.05	-	-	2	1.65
Leguminosae	8	8	8	8.42	6	8.45	9	7.44
Malvaceae	2	2	4	4.21	4	5.63	4	3.31
Oxalidaceae	3	3	3	3.16	3	4.23	3	2.48
Papaveraceae	1	1	1	1.05	1	1.41	1	0.83
Papilionoideae	2	2	3	3.16	2	2.82	2	1.65
Phyllanthaceae	1	1	2	2.11	-	-	2	1.65
Plantaginaceae	1	1	-	-	-	-	1	0.83
Poaceae	23	23	22	23.16	13	18.31	31	25.62
Polygonaceae	4	4	4	4.21	3	4.23	4	3.31
Portulacaceae	1	1	1	1.05	1	1.41	1	0.83
Primulaceae	1	1	1	1.05	-	-	1	0.83
Ranunculaceae	-	-	1	1.05	-	-	1	0.83
Resedaceae	2	2	2	2.11	2	2.82	2	1.65
Rubiaceae	1	1	-	-	-	-	1	0.83
Solanaceae	2	2	3	3.16	2	2.82	2	1.65
Total	**100**		**95**		**71**		**121**	

Table 2 - Species number under weed morphology and life form classification

Soil Depth (cm)	Morphology			Life Form			Total Species Number
	Broad leaf	Grass	Sedge	Annual	Perennial	Biennial	
0-5	73 (73.00%)	23 (23.00%)	4 (4.00%)	71 (71.00%)	30 (30.00%)	2 (2.00%)	100
5-10	71 (77.74%)	22 (23.16%)	2 (2.11%)	73 (76.84%)	21 (22.11%)	2 (2.11%)	95
10-15	56 (78.87%)	13 (18.31%)	2 (2.82%)	54 (76.06%)	15 (21.13%)	2 (2.82%)	71
Total Soil Seed Bank	86 (71.07%)	31 (25.62%)	4 (3.31%)	86 (71.07%)	33 (27.27%)	2 (1.65%)	121

*** The number in the parenthesis is the percentage of species number per categories

respectively. In general, a high number of broad leave and sedge species were recorded at a soil depth of 0-5 cm than at 0-5 and 5-10 cm.

Annual weeds generally show a greater density and higher seed output per individual in each soil depth than the other seeds. This is due to the prolific seed production, early

maturity and more reproduction per year these characters help for the survival strategy of weeds under unfavorable conditions. Adhikary and Ghosh (2014) reported that annual weed species were dominated over perennial weed species. Annual weeds possess prodigious seed capacity and thus develop small superabundant seeds (Marwat et al., 2010).

3.2 Soil Seed Bank Seedling Relative Frequency

The soil depth at 0-5 cm was dominated by *A. conyzoides, P. hysterophorus and E. colona* and accounted for 6.77, 6.34 and 5.83%, respectively while the least was by 19 species with 0.09% the relative frequency. Among the recorded weed species *P. hysterophorus, A. conyzoides* and *G. parviflora* were record the highest relative frequency of 8.21, 7.57 and 5.73% and least by 29 species with 0.11% at 5-10 cm soil depth. The maximum relative frequency at 10-15 cm was registered by *A. conyzoides* (9.32%), *P. hysterophorus* (7.83)% *and E. colona* (5.97%) and least was by 15 species with 0.12%. In general, *A. conyzoides, E. colona, G. parviflora* and *P. hysterophorus* showed the highest frequency and relative frequency from all soil depths (Table 3).

Table 3 - Percentage value of relative frequency (RF), relative density (RD), relative abundance (RA) and importance value (IV) of each weeds at different soil depth

No.	Name of Weed Species	0-5 cm				5-10 cm				10-15 cm			
		RF	RD	RA	IV	RF	RD	RA	IV	RF	RD	RA	IV
1	*Abutilon figarianum*	2.00	0.84	0.56	3.40	2.16	0.94	0.68	3.78	2.73	1.60	1.06	5.39
2	*Achyranthes aspera*	0.17	0.07	0.54	0.78	-	-	-	-	-	-	-	-
3	*Aeschyomene schimperia*	0.17	0.06	0.43	0.66	0.22	0.09	0.63	0.93	-	-	-	-
4	*Aeschynomene virginica*	0.35	0.06	0.21	0.62	0.32	0.31	1.51	2.15	0.62	0.31	0.89	1.82
5	*Ageratum conyzoides*	6.87	10.16	1.98	19.02	7.57	10.43	2.17	20.16	9.32	8.21	1.59	19.12
6	*Agrostis alba*		-	-	-	0.76	0.26	0.54	1.56	-	-	-	-
7	*Alternanthera repens*	0.09	0.08	1.29	1.46	0.11	0.10	1.51	-	-	-	-	
8	*Alysicarpus rugosus*	0.09	0.03	0.43	0.54	0.11	0.05	0.76	-	-	-	-	
9	*Alysicarpus Spp.*	0.70	0.28	0.54	1.51	0.97	0.31	0.50	1.79	0.99	0.39	0.71	2.09
10	*Amaranthus cruentus*	0.96	0.53	0.74	2.23	1.30	0.78	0.95	3.02				
11	*Amaranthus graecizans*	2.35	1.41	0.80	4.56	2.38	1.30	0.86	4.54	2.11	2.96	2.53	7.59
12	*Amaranthus hybridus*	2.52	1.68	0.90	5.10	0.97	0.28	0.45	1.70	4.47	3.16	1.28	8.91
13	*Amaranthus spinosus*	0.17	0.13	0.97	1.27	-	-	-	-	-	-	-	-
14	*Anagallis arvensis*	0.09	0.06	0.86	1.00	0.11	0.05	0.76	0.92	-	-	-	-
15	*Andropogon abyssinicus*	0.09	0.03	0.43	0.54	0.11	0.03	0.50	0.65	-	-	-	-
16	*Argemone mexicana*	0.09	0.04	0.64	0.77	0.11	0.07	1.01	1.19	0.25	0.10	0.75	1.10
17	*Aspilia kotschyi*	0.09	0.11	1.72	1.92	0.11	0.09	1.26	1.46	-	-	-	-
18	*Bidens biternata*		-	-	-	-	-	-	-	0.12	0.23	3.28	3.63
19	*Bidens pilosa*	4.35	7.09	2.19	13.62	4.54	7.10	2.46	14.09	4.47	7.06	2.85	14.39
20	*Brachiaria eruciformis*	0.26	0.15	0.79	1.20	0.11	0.16	2.27	2.53				
21	*Brassica carinata*	0.26	0.63	3.22	4.11	0.43	0.17	0.63	1.24	0.50	0.37	1.34	2.21
22	*Caylusea abyssinica*	3.74	5.54	1.99	11.27	3.78	5.19	2.16	11.13	3.36	5.58	3.00	11.94
23	*Celosia argentea*	0.17	0.40	3.11	3.69	-	-	-	-	-	-	-	-
24	*Celosia trigyna*	1.39	1.75	1.69	4.84	-	-	-	-	1.37	2.46	3.25	7.08
25	*Chenopodium album*	-	-	-	-	0.11	0.07	1.01	1.19	0.12	0.10	1.49	1.72
26	*Chenopodium ambrosioides*	0.17	0.11	0.86	1.14	-	-	-	-	-	-	-	-
27	*Chloris inflata*	-	-	-	-	0.54	0.19	0.55	1.29	-	-	-	-
28	*Chloris radiata*	-	-	-	-	0.11	0.02	0.25	0.38	-	-	-	-
29	*Commelina albescens*	0.26	0.18	0.93	1.37	0.11	0.03	0.50	0.65	0.25	0.12	0.89	1.27
30	*Commelina benghalensis*	2.00	1.18	0.79	3.98	1.95	1.49	1.21	4.64	2.11	1.66	1.42	5.20
31	*Commelina diffusa*	0.70	0.29	0.56	1.55	0.86	0.33	0.60	1.79	0.50	0.37	1.34	2.21

Continue

Continuation

No.	Name of Weed Species	0-5 cm				5-10 cm				10-15 cm			
		RF	RD	RA	IV	RF	RD	RA	IV	RF	RD	RA	IV
32	*Commelina forskalaei*	1.83	1.32	0.97	4.12	2.16	1.48	1.07	4.71	3.73	2.11	1.02	6.87
33	*Commelina latifolia*	0.52	0.26	0.68	1.47	-	-	-	-	-	-	-	-
34	*Commelina subulata .*			-	-	0.54	0.38	1.11	2.03	-	-	-	-
35	*Convolvulus arvensis*	0.70	0.32	0.62	1.63	-	-	-	-	-	-		
36	*Conyza bonariensis*				-	-	-	-	-	-	-	-	0.76
37	*Corchorus olitorius*	4.35	6.61	2.04	13.00	5.19	6.91	2.09	14.19	5.10	6.16	2.18	13.44
38	*Corchorus trilocularis*			-	-	0.11	0.09	1.26	1.46	0.12	0.10	1.49	1.72
39	*Crassocephalum rubens*	0.09	0.08	1.29	1.46	0.11	0.10	1.51	1.73	-	-	-	-
40	*Crotalaria filipes*	0.52	0.14	0.36	1.02	0.11	0.07	1.01	1.19	0.62	0.47	1.37	2.46
41	*Crotalaria spinosa*	0.78	0.29	0.50	1.58	-	-	-	-	-	-	-	-
42	*Cynodon dactylon*	0.09	0.11	1.72	1.92	-	-	-	-	0.25	0.14	1.04	1.44
43	*Cyperus alopeouraides*	0.09	0.07	1.07	1.23	-	-	-	-	-	-	-	-
44	*Cyperus eragrostis*	0.09	0.06	0.86	1.00	0.11	0.07	1.01	1.19	0.25	0.21	1.49	1.94
45	*Cyperus esculentus*	0.17	0.32	2.47	2.96	-	-	-	-	-	-	-	-
46	*Cyperus rotundus*	3.31	2.73	1.11	7.14	1.95	1.91	1.54	5.40	1.86	1.85	1.79	5.50
47	*Dactyloctenium aegyptium*	0.35	0.39	1.50	2.24	0.32	0.28	1.35	1.95	-	-	-	-
48	*Datura stramonium*	0.26	0.22	1.15	1.63	0.32	0.17	0.84	1.34	-	-	-	-
49	*Desmodium uncinatum*	0.09	0.01	0.21	0.32	-	-	-	-	0.37	0.21	0.99	1.57
50	*Digitaria abyssinica*	0.09	0.14	2.15	2.37	0.11	0.09	1.26	1.46	-	-	-	-
51	*Digitaria horizontalis*			-	-	0.65	0.17	0.42	1.24	-	-	-	-
52	*Digitaria Sanguinalis*	0.35	0.13	0.48	0.96	0.86	0.31	0.57	1.74	0.12	0.06	0.89	1.08
53	*Digitaria ternata*	0.35	0.32	1.23	1.90	0.11	0.17	2.52	2.80	0.25	0.27	1.94	2.45
54	*Digitaria velutina.*	-	-	0.09	0.63	0.93	0.25	0.08	0.60	0.93	-	-	-
55	*Dinebra retroflexa*	4.35	4.18	1.29	9.81	4.43	6.94	2.46	13.83	3.73	6.14	2.97	12.84
56	*Echinochloa colona*	5.92	6.89	1.56	14.37	5.73	7.31	2.00	15.04	5.97	7.80	2.36	16.13
57	*Eleusine indica*	2.18	3.03	1.87	7.08	3.46	4.95	2.25	10.65	3.85	5.42	2.54	11.81
58	*Eleusine Jaegeria*	0.26	0.08	0.43	0.77	-	-	-	-	-	-	-	-
59	*Eragrostis ciliaris*	0.26	0.19	1.00	1.46	0.22	0.23	1.64	2.08	-	-	-	-
60	*Eragrostis paniciformis*	0.52	0.43	1.11	2.06	0.32	0.36	1.77	2.45	-	-	-	-
61	*Eragrostis schweinfurthii*				-	0.11	0.02	0.25	0.38				-
62	*Eriochloa fatmensis*						-	-	-	0.12	0.06	0.89	1.08
63	*Erocastrum arabicum*	0.35	0.24	0.91	1.50	0.22	0.14	1.01	1.36	0.12	0.10	1.49	1.72
64	*Euphorbia heterophylla*	0.70	0.39	0.75	1.84	0.11	0.05	0.76	0.92	0.12	0.06	0.89	1.08
65	*Euphorbia hirta*	0.44	0.40	1.25	2.08	0.32	0.14	0.67	1.14	0.37	0.23	1.09	1.69
66	*Euphorbia hypericifolia*			-	-	-	-	-	-	0.12	0.06	0.89	1.08
67	*Euphorbia indica*	0.26	0.17	0.86	1.29	0.97	0.30	0.48	1.74	-	-	-	-
68	*Fallopian convolvulus*	0.26	0.07	0.36	0.69	0.32	0.10	0.50	0.93	0.37	0.16	0.79	1.33
69	*Flaveria trinervia*	0.17	0.13	0.97	1.27	0.11	0.10	1.51	1.73	-	-	-	-
70	*Galinsoga ciliata*	4.70	7.52	2.15	14.36	-	-	-	-	-	-	-	-
71	*Galinsoga parviflora*			-	-	5.73	8.49	2.33	16.54	4.97	6.75	2.45	14.18
72	*Galium spurium*	0.17	0.17	1.29	1.63	-	-	-	-	-	-	-	-
73	*Guizotia scabra*	0.35	0.18	0.70	1.23	0.11	0.07	1.01	1.19	0.25	0.31	2.24	2.79
74	*Gutenbergia rueppellii*	0.70	0.28	0.54	1.51	0.65	0.31	0.76	1.72	0.75	0.21	0.50	1.45

Continue

Continuation

No.	Name of Weed Species	0-5 cm				5-10 cm				10-15 cm			
		RF	RD	RA	IV	RF	RD	RA	IV	RF	RD	RA	IV
75	*Heliotropium cinerascens*	0.61	0.32	0.71	1.63	0.54	0.26	0.76	1.56	0.62	0.25	0.72	1.58
76	*Hygrophila auriculata*	0.17	0.07	0.54	0.78	-	-	-	-	-	-	-	-
77	*Hypochaeris radicat*	0.09	0.03	0.43	0.54	0.11	0.07	1.01	1.19	-	-	-	-
78	*Ipomoea cairica*			-	-	0.11	0.02	0.25	0.38	-	-	-	-
79	*Ipomoea purpurea*	0.35	0.19	0.75	1.29	0.22	0.21	1.51	1.94	0.25	0.33	2.38	2.96
80	*Justicia flava*	0.44	0.40	1.25	2.08	0.43	0.33	1.20	1.96	0.12	0.06	0.89	1.08
81	*Lactuca saligna*	0.61	0.25	0.55	1.41	0.76	0.35	0.72	1.82	0.87	0.35	0.72	1.94
82	*lactuca serriola*	0.61	0.50	1.10	2.21	0.86	0.33	0.60	1.79	0.37	0.25	1.19	1.81
83	*Launaea cornuta*	0.61	0.29	0.64	1.55	0.86	0.30	0.54	1.70	0.75	0.35	0.84	1.94
84	*Leucas martinicensis*				-	0.11	0.05	0.76	0.92	-	-	-	-
85	*Malva parviflora*		-	-	-	0.11	0.03	0.50	0.65	0.12	0.12	1.79	2.04
86	*Medicago denticulata*			-	-	0.11	0.05	0.76	0.92	-	-	-	-
87	*Medicago polymorpha*	0.61	0.38	0.83	1.81	0.54	0.50	1.46	2.51	0.62	0.37	1.07	2.06
88	*Melinis repens*	0.52	0.32	0.82	1.67	0.76	0.35	0.72	1.82	0.87	0.37	0.77	2.01
89	*Nicandra physalodes*	3.05	2.55	1.12	6.72	3.89	5.00	2.02	10.91	4.60	4.85	1.90	11.35
90	*Nigella sativa*		-	-	-	0.22	0.09	0.63	0.93	-	-	-	-
91	*Ocimum Lamiifolium*	0.35	0.22	0.86	1.43	-	-	-	-	-	-	-	
92	*Oxalis corniculata*	0.26	0.25	1.29	1.80	0.22	0.28	2.02	2.51	0.12	0.16	2.38	2.67
93	*Oxalis latifolia*	0.52	0.28	0.72	1.52	0.76	0.35	0.72	1.82	0.62	0.43	1.25	2.30
94	*Oxalis stricta*	1.31	1.18	1.22	3.71	0.65	0.75	1.81	3.20	0.87	0.57	1.19	2.64
95	*Oxygonum sinuatum*	0.35	0.18	0.70	1.23	0.22	0.12	0.88	1.22	0.25	0.16	1.19	1.61
96	*Parthenium hysterophorus*	6.44	10.44	2.18	19.05	8.21	10.22	1.95	20.39	7.83	7.70	1.77	17.30
97	*Paspalidium desertorum*	0.17	0.06	0.43	0.66	0.22	0.10	0.76	1.08	0.25	0.08	0.60	0.93
98	*Pennisetum polystachion*	-	-	-	-	-	-	-	-	0.12	0.04	0.60	0.76
99	*Pennisetum sphacelatum*	0.09	0.07	1.07	1.23	-	-	-	-	-	-	-	-
100	*Phalaris paradoxa*	0.17	0.07	0.54	0.78	-	-	-	-	-	-	-	-
101	*Phyllanthus fraternus*				-	0.11	0.05	0.76	0.92	-	-	-	-
102	*Phyllanthus maderaspatensis*	0.09	0.01	0.21	0.32	0.11	-	-	-	-	-	-	-
103	*Plantago lanceolata*	0.61	0.22	0.49	1.32	-	-	-	-	-	-	-	-
104	*Polygonum nepalense*	0.70	0.29	0.56	1.55	0.54	0.24	0.71	1.49	0.50	0.18	0.67	1.35
105	*Portulaca oleracea*	2.52	2.85	1.52	6.89	2.70	2.62	1.52	6.85	1.74	2.09	2.17	6.01
106	*Reseda luteola*	0.70	0.28	0.54	1.51	0.97	0.31	0.50	1.79	0.62	0.33	0.95	1.90
107	*Rumex bequaertii*	0.26	0.24	1.22	1.71	0.22	0.10	0.76	1.08	-	-	-	-
108	*Setaria pumila*	0.09	0.07	1.07	1.23	-	-	-	-	-	-	-	-
109	*Solanum nigrum*	2.09	1.17	0.75	4.01	1.51	1.16	1.21	3.88	2.36	1.83	1.40	5.58
110	*Sonchus asper*	1.65	0.97	0.79	3.42	1.62	0.83	0.81	3.26	2.11	1.35	1.16	4.63
111	*Sonchus oleraceus*	0.09	0.04	0.64	0.77	0.11	0.05	0.76	0.92	-	-	-	-
112	*Tagetes minuta*	1.65	0.96	0.78	3.39	1.30	0.71	0.86	2.87	1.24	0.90	1.31	3.46
113	*Tragus berteronianus*	0.09	0.04	0.64	0.77	0.11	0.05	0.76	0.92	0.12	0.04	0.60	0.76
114	*Trianthema pentandra*	0.78	0.28	0.48	1.54	0.86	0.31	0.57	1.74	0.99	0.37	0.67	2.03
115	*Tridax procumbens*	0.78	0.25	0.43	1.46	0.65	0.17	0.42	1.24	0.12	0.02	0.30	0.44
116	*Trifolium semipilosum*	1.57	1.17	1.00	3.74	0.54	0.21	0.61	1.35	0.25	0.16	1.19	1.61
117	*Trifolium steudneri*	0.78	0.74	1.26	2.79	0.54	0.52	1.51	2.57	0.50	0.74	2.68	3.92

Continue

Continuation

No.	Name of Weed Species	0-5 cm				5-10 cm				10-15 cm			
		RF	RD	RA	IV	RF	RD	RA	IV	RF	RD	RA	IV
118	*Urochloa panicoides.*	0.61	0.49	1.07	2.17	0.65	0.33	0.80	1.78	1.37	0.47	0.62	2.46
119	*Vicia hirsuta*	0.09	0.04	0.64	0.77	0.32	0.16	0.76	1.24	-	-	-	-
120	*Vicia monantha*	0.78	0.36	0.62	1.77	1.08	0.49	0.71	2.27	0.87	0.31	0.64	1.82
121	*Xanthium strumarium*	1.04	0.71	0.91	2.67	0.65	0.24	0.59	1.48	0.87	1.05	2.17	4.09

The current study showed that when the soil depth increase the frequency and relative frequency of the species were decrease and vice versa. Next to *A. conyzoides,* higher frequency and relative frequency were recorded by *P. hysterophorus* this suggesting its high competitiveness to the herbaceous plant community in the study area. Similarly, parthenium (54%) is recorded that the second most common weed after Digitaria abyssinica (63%) in eastern Ethiopia (Tamado, 2001).

3.3 Soil Seed Bank Relative Density

The relative density at 0-5 cm soil depth dominantly occupied by *P. hysterophorus, A. conyzoides* and *G. parviflora* with 10.44, 10.16 and 7.52%, respectively while *Desmodium uncinatum and Phyllanthus maderaspatensis* species with 0.01% were the least (Table 3). Among the weed species at 5-10 cm soil depth *A. conyzoides* (10.43%), *P. hysterophorus* (10.22%) and *G. parviflora* (8.49%) had the highest relative density and the least was recorded by *Chloris radiate, Eragrostis schweinfurthii and Ipomoea cairica* species with 0.02% at 5-10 cm soil depth. The relative density showed that *A. conyzoides, E.* colona and *P. hysterophorus* had the highest value of 8.21, 7.80 and 7.70%, respectively whereas, the least was by *T. procumbens* with 0.02% at 10-15cm soil depth. From all soil depths, *A. conyzoides, E.* colona, *G. parviflora* and *P. hysterophorus* had maximum seedling density and relative density (Table 4).

Parthenium contributed the highest seedling relative density of 10.44, 10.22 and 7.70% at 0-5, 5-10 and 10-15 cm soil depth, respectively (Table 3). The farmers practice crop rotation, tillage, hand hoeing, quality seed and fertilization but still they don't control parthenium due to its prolific seed production, control resistance, deep rooted character, high canopy formation and other they are ineffectiveness to control. This can be providing evidence for a high contribution of parthenium in the top layer of the seed bank, which may be attributed to repeated germination and persistence of viable seeds on and/or below the soil surface. The invasiveness of parthenium resulted due to several aspects like its very large viable seed production, its large and persistent soil seed banks (Navie et al., 2004). Similarly, the longevity of its seeds when buried, its fast germination and quick flowering time, its ability to flower over a long period of time, its allelopathic interactions with neighboring plants and its ability to adapt to many different environments result in more densely (Adkins, Shabbir, 2014).

Table 4 - Similarity index of soil seed bank weeds among soil depths

Similarity Between	Number of Weed Species			Similarity Index (%)
	On Both Depth	On First Depth	On Second Depth	
0-5 and 5-10 cm	79	21	16	68.10
0-5 and 10-15 cm	61	39	9	55.96
5-10 and 10-15 cm	62	33	8	60.19

The domination of parthenium in the soil seed banks indicated that the weed had a substantial negative impact on the ecology of plant communities (Shabbir, 2015). In the underground species present in the form of soil seed banks, parthenium can substantially reduce plant diversity. The diversity of a pasture plant community in Queensland was significantly reduced by the presence of parthenium even when the weed was present in relatively low density (2 plants/m^2) and this trend was seen in both the aboveground plant community and the soil seed bank (Nguyen et al., 2017).

3.4 Soil Seed Bank Relative Abundance

The relative abundance varied significantly among the different soil depths and species. The soil depth (0-5 cm) showed the highest relative abundance (3.22, 3.11 and 2.47%) by *B. carinata, C. argentea* and *C. esculentus,* respectively and the least was by *A. virginica*, *D. uncinatum and P. maderaspatensis* each with 0.21%. At 5-10 cm soil depth, *D. ternata* (2.52%), *D. retroflexa* (2.46%) and *B. pilosa* (2.46%) had the highest relative abundance and the least was by *Chloris radiate*, *E. schweinfurthii* and *Ipomoea cairica* with 0.25%. Finally, *B. biternata, C. trigyna* and *C. abyssinica* were showed the highest relative abundance of 3.28, 3.25 and 3.00%, respectively whereas, the least was by *T. procumbens* with 0.30% at 10-15 cm soil depth. This result also showed that *P. hysterophorus* was abundant species with 337.84, 258.33 and 198.41 plants while its relative abundance was 2.18, 1.95 and 1.77% at 0-5, 5-10 and 10-15 cm soil depth, respectively (Table 3).

The weed species including parthenium that had high frequency, relative frequency, density, and relative density

were relatively recorded less abundance and relative abundance. This is due to these species found in most of the experimental pot whereas, high abundance value species were in few pots this implies a lower denominator for abundance calculation. In the lower layers (10-15 cm), the total species and seed numbers were lower than in the upper layer (0-5 cm). This might be caused due to different tillage systems as well as other soil intervention methods, and this is consistent with (Nur et al., 2019).

3.5 Importance Value of Weeds

As demonstrated by Table 3 the importance value varied from 0.32 to 19.05, 0.38 to 20.39 and 0.44 to 19.12% at 0-5, 5-10 and 10-15 cm soil depth, respectively. Data from the soil seed bank shows that the highest importance value was recorded by *P. hysterophorus, A. conyzoides and E. colona* with 19.05, 19.02 and 14.37%, respectively whereas, the least was by *D. uncinatum* and *P. maderaspatensis* each with 0.32% at 0-5 cm soil depth. The highest importance value of 20.39, 20.16 and 16.54% were registered by *P. hysterophorus, A. conyzoides* and *G. parviflora,* respectively and least by *Chloris radiate, E. schweinfurthii* and *I. cairica* with 0.38% at 5-10 cm soil depth. Likewise, at 10-15 cm soil depth *A. conyzoides, P. hysterophorus and E. colona* with 19.12, 17.30 and 116.13%, respectively were showed the highest importance value whereas, *D. uncinatum* and *T. procumbens* each with 0.44% were the least. Overall, the result showed that *A. conyzoides, E. colona, G. parviflora* and *P. hysterophorus* were the uppermost weed species with an important value from all soil depths. The most dominant species were *A. conyzoides, E. colona, G. parviflora* and *P. hysterophorus* in the soil seed bank study, with the highest contributions from the relative frequency and relative density. Among the species reported, parthenium was one of the dominant species, with a higher value relative to all other plant species. Due to its high invasive ability, allelopathic characteristics and short life cycle parthenium were the dominant (Dalip et al., 2013). Similarly, showed that parthenium were the most successful species in Ethiopia (Belachew, Tessema, 2015).

3.6 Weed Species Diversity in Soil Seed Bank

The weed species richness for the entire soil seed bank study period was highest (100 species) at 0-5 cm, while 95 species at 5-10 cm and the least was at 10-15 cm with 71 species. The Shannon diversity index at 0-5 cm, 5-10 cm and 10-15 cm soil depth were 4.46, 4.41 and 4.17, respectively. Whereas, the evenness of weeds at 0-5, 5-10 and 10-15 cm soil depth were 0.98, 0.97 and 0.96, respectively (Figure 1; Table 1 and 2).

Concerning species richness, Shannon diversity index and evenness, the vertical distribution of total weed seedlings in the soil seed bank showed a decreasing trend with increasing depth in parthenium infested maize fields. The higher Shannon diversity index and evenness

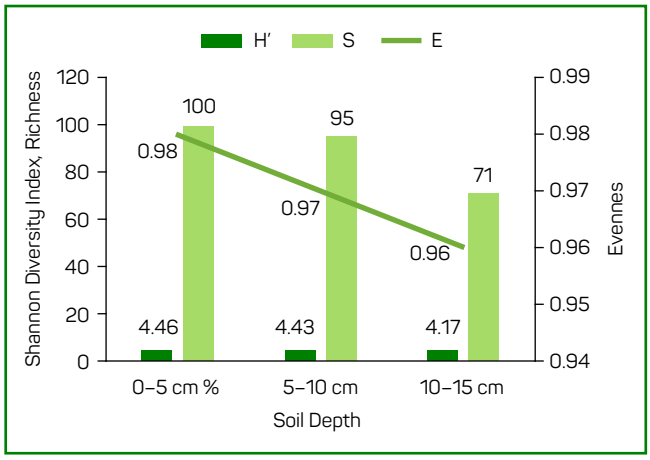

Figure 1 - Weed species richness, Shannon diversity index and evenness in parthenium infested soil seed bank of maize fields

value for the species indicated that the more dominance, diversification, and even distribution over other species throughout the depth. The higher value of the index of diversity indicates the variability in the type of species and heterogeneity in the community whereas the lesser values point to the homogeneity of the community (Belachew, Tessema, 2015).

3.7 Similarity among soil seed sank depth

There were 121 weed species germinated from the soil seed bank samples, out of which 58 species were found at all soil depths. The highest similarity was observed between 0-5 and 5-10 cm (68.10%) and followed by between 5-10 and 10-15 cm (60.19%) and 0-5 and 10-15 cm (55.96%) (Table 4).

The result submits that the plant species composition among the different soil depth was similar by 55.96 to 68.10%. If the index of similarity is greater than 60%, it is said that the two depths have similar weed communities (Taye, Yohanes, 1998). Subsequently the similarity index of 0-5 with 10-15 and 5-10 with 10-15 cm soil depth were greater than 60% and it can be concluded that both soil depths in two comparisons exhibited similar weed community and thus, require similar weed management options.

4. Conclusions

The study showed that 121 weed species were identified from all soil seed bank. When the soil depth increase the relative frequency, relative density, relative abundance and importance value of the weed species were decreased and vice versa. Similarly, species richness, Shannon diversity index and evenness of total weed seedlings in the soil seed bank showed a decreasing trend with increasing depth. The similarity index between 0-5 with 10-15 cm soil depth and 5-10 with 10-15 cm soil depth were greater than 60% and it exhibited similar weed community and thus, require similar weed management options. Overall, the result showed that *A. conyzoides, E. colona,*

G. parviflora and *P. hysterophorus* were the uppermost dominant weed species in all soil depths. Specifically, *P. hysterophorus* had shown high importance value in all soil depths. Weed soil seed bank is a sign of future weed infestation potential of the species and is crucial for creating a strategic planning for an appropriate weed management. The study suggests for the government to take immediate action to control weed soil seed banks in parthenium maize infested fields of the study site.

Authors' contributions

All authors have read and agreed to the published version of the manuscript. DM: apprehended the ideas of the document, performed the research, the data collection, analyzed the data and wrote the original manuscript. LN and ZB: were advising all the research activity and data analysis as well as review and editing manuscript.

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