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Weed seed distribution at different depths of soil in a crop field

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ABSTRACT

The seed banks are the sole source of future weed populations and enhance the survival of a species by buffering against harsh environmental conditions or drastic weed control measures. Seed bank allows weed species to germinate over a period of many years. This experiment was undertaken with a view to evaluating the weed seed distribution pattern at different soil depths in order to estimate the potential weed population in the crop field. The experiment was conducted at the net house of the Department of Agronomy, Bangladesh Agricultural University during April to September 2014. Soil samples were collected from 12 plots at three depths *viz.* 0-5, 5-10 and 10-15 cm of Durba Chara village of Mymensingh district. A total of 33 weed species belonging to 17 families were found of which 23 species were broadleaved, 6 grasses and 5 sedges. Thirty weed species from 19 annuals and 11 perennials belonging to the 15 families, 23 weed species from 15 annuals and 8 perennials belonging to 10 families andonly 19 weed species from 13 annuals and 6 perennials belonging to 11 families were identified at 0-5, 5-10 and 10-15 cm soil depth, respectively. The seven dominant weed species i.e. *Fimbristylis miliacea* L., *Lindernia antipoda* L., *Lindernia hyssopifolia* L., *Cyperus difformis* L., *Eleusine indica* L., *Hedyotis corimbosa* L. and *Eclipta alba* L. were found at different soil depths. The result revealed that weed density decreased with increase of the soil depth. The higher number of weed species and density were observed at 0-5 cm depth of soil followed by 5-10 cm and 10-15 cm depth of soil, respectively. All weed types *viz.* grasses, sedges and broadleaves were found in abundance at 0-5 cm depth than 5-10 cm and 10-15 cm depth. Annual and perennial weeds were also higher at 0-5 cm depth and annual weeds were dominant over perennial weeds at each of the three soil depths. Out of the total number of weed seedlings emerged from three soil depths, about 65% of seedlings emerged within first two months (April-May) of commencement of germination trial and rest 35% seedlings emerged within last 4 months (June-September). Based on Sorenson's Index of Similarity, the diversity of occurring weed species between 5-10 cm and 10-15 cm depths was lower as Sorenson's Index of Similarity was the highest (81%) as well as between 0-5 cm and 10-15 cm depths was higher as Sorenson's Index of Similarity was the lowest (69%).

Keywords: Floristic diversity, seed bank, crop field, Sorenson's Index of Similarity

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1 Introduction

Weeds are an ever-lasting problem in crop production as they compete with their associate crops for nutrients, space and light resulting significant reduction in yield as well as quality. Globally, actual yield losses due to pests have been estimated approximately 40%, of which weeds caused the highest loss of 32% (Rao et al., 2007). Extensive research has been done to address this problem and various management packages have been formulated. But weeds have continued to proliferate and to perfect their survival mechanisms. Therefore, the success of weeds is enhanced by the soil seed reservoir that is the major source of weed infestation in most tilled agricultural soils (Altieri and Liebman, 1988).

The soil weed seed bank is the reservoir of weed seeds in the soil or on the soil surface and it largely determines the species composition and potential densities of weeds that subsequently interfere with crops during the growing season. The seed bank consists of new seeds recently shed by weeds and old seeds that have persisted in the soil for several years. It is an important part of crop weed ecology as it is the most important source of annual weeds in cropping systems and therefore represents a significant point in the weed life cycle for control. Soltani et al. (2013) reported that in agro ecosystems the weed population is related to their seed bank, so that knowledge of the seed bank size and of its species composition can be used to predict future infestation. Predictions of emerged seedling densities allow estimation of weed competition, crop yield loss, need for herbicides, financial returns and weed seed production at the end of growing season (Forcella, 1992).

The distribution of weeds within fields is often spatially aggregated or patchy and this, in conjunction with various cultural factors, results in seed banks that are spatially heterogeneous (Rew and Cussans, 1997). The importance of spatial distribution in sampling weed populations, modeling population dynamics and long term weed management, has drawn attention to need for methods to describe and analyze the spatial distribution of weeds (Doyle, 1991). The vertical seed movement is of greater consequence as different types of cultivation move seeds to different depths in the soil (Dessaint et al., 1996) than horizontal movement. Roberts and Potter (1980) observed that most weeds show some periodicity of emergence. So practical knowledge of periodicity of emergency is of significant importance, since it is a major factor in determining the association of weeds with cropping systems and to enable a degree of forecasting as to which weed species may occur in a seedbed. In addition to weed population dynamics, the spatial distribution of seeds in the soil influences the degree of inter- and intra-specific competition.

Study of weed seed distribution at different soil depths provides basic information about the potential weed population in the crop field. In Bangladesh no more studies have been done in details on weed seed distribution pattern. Large number of seeds with numerous weed species are deposited and stored in the soil each year. But most of the farmers of Bangladesh are very reluctant to prevent the buildup of weed seed bank in the soil and its further dissemination. Therefore, the present study was undertaken to evaluate the weed seed distribution pattern at different soil depths in order to estimate the potential weed population in the crop field.

2 Materials and Methods

2.1 Experimental site

The experiment was conducted at the net house of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh (24°43′8.3″N, 90°25′41.2″E) from April to September 2014. Samples were collected from a farmer's field of DurbaChara Village at Vangamari union under Mymensingh district belonging to the Old Brahmaputra Floodplain (AEZ-9) (UNDP/FAO, 1988) and Sonatala series of dark grey floodplain soil type (Brammer, 1966) having pH 6. The cropping pattern of this study area was '*Boro* rice–Fallow–Transplant *aman* rice'. Mustard was included in the existing cropping pattern after T. *aman* rice to find out the change in floristic composition of that area due to its inclusion in the pattern. Soil samples were collected after harvest of T. *aman* rice.

2.2 Soil sampling procedure

Soil samples was collected from twelve plots at three different depths *viz*. 0-5, 5-10 and 10-15 cm using a stainless steel pipe of five cm diameter from five spots of each plot following 'W' shaped pattern. Data on weed seedlings emerged from several depths of soil in net house were collected following the net house tray method. Samples from each plot were mixed according to the depths and placed in 36 plastic bowls (28 cm × 10 cm). Each bowl was filled with 1 kg of soil.

2.3 Weed seed emergence study

The samples were daily sprinkled with water as needed in order to keep them moist. Weed seedlings that emerged were identified using the seedling keys of (Chancellor, 1966), counted, and removed within 30 d intervals throughout the six month emergence period. Seedlings of questionable identity were transferred to pots and grown until maturity for identification. After the removal of each batch of seedlings, soils were air dried, thoroughly mixed in order to expose the weed seeds to the upper level of the soil, and re-wetted to permit further emergence. This process was repeated six times. Seedling emergence counts were converted to numbers per m^2.

The dominant weed species was determined by the calculation of importance value (IV) as follows:

$$IV_x\ (\%) = \frac{N_x}{\sum N} \times 100 \qquad (1)$$

where, IV_x = importance value of weed x, N_x = number of weed x in a community, $\sum N$ = total number of weed in the community, and x is an individual weed.

2.4 Sorenson's Index of Similarity

Comparison of species affiliation among weed communities of different depths *viz*. 0-5, 5-10 and 10-15 cm were made using the 'Sorenson's Index of Similarity' (S) (Goldsmith et al., 1986). Computation of the S values was as follows:

$$S = \frac{2J}{A + B} \times 100 \qquad (2)$$

where, S = index of association between two depths A and B, J = Number of species common to both A and B, A = Number of species present at depth a, and B = Number of species present at depth b.

Higher S value indicates close similarity in species composition between two depths. Conversely, lower S values reflect divergence in species composition in the two depths.

3 Results and Discussion

3.1 Composition of weed species

Thirty weed species from 19 annuals and 11 perennials belonging to the 15 families were identified at 0-5 cm depth. Among these species, Poaceae, Cyperaceae, Amaranthaceae contributed six, five and three weed species, respectively. Each of the family Asteraceae, Pontederiaceae, Rubiaceae, Scrophulariaceae contributed two weed species and each of therest 8 families contributed only one weed species. Based on the importance value of weed, the five most dominant weed species in descending order are *F. miliacea* (L.) Vahl. (34%) >*L. antipoda* L. (13%) >*L. hyssopifolia* L. (12%) >*C. difformis* L. (7%) >*E. indica* L. (5%) and rest of the weed species represent 29% (Fig. 1). Among thirty weed species, six species from grasses, five species from sedges and nineteen species were identified from broadleaf. Within the six months experiment period the highest weed seed density was found at 0-5 cm depth of soil which was 5455 m^{-2} (Table 1). This result is substantiated by Begum et al. (2006) who had recognized 20 taxa as emerged seedling in the soil seed bank of 0-5 cm depth in rice granary area of Malaysia of which the five most dominant species with decreasing trend were *Fimbristylis miliacea*, *Leptochloa chinensis*, *Ludwigia hyssopifolia*, *Cyperus difformis* and *Cyperus iria*.

A total of 23 weed species with 15 annuals and 8 perennials belonging to 10 families were emerged from 5-10 cm soil depth. Six weed species were found from Poaceae family, four weed species from Cyperaceae family, two from family Asteraceae, Compositae, Pontederiaceae, Rubiaceae and Scrophulariaceae, one from each of the family Amaranthaceae, Onagraceae and Solanaceae. The rank and order five most dominant weed species based on importance value were *Fimbristylis miliacea* L. Vahl. (35%) >*Lindernia hyssopifolia* L. (14%) >*Lindernia antipoda* L. (12%) >*Cyperus difformis* L. (8%) >*Hedyotis corimbosa* L. (6%)and rest of the 18 weed species represent 25% (Fig. 1). Among the twenty three weed species, six species from grasses, four species from sedges and thirteen species were identified from broadleaf. At 5-10 cm soil depth the weed seed density was found 4046 m^{-2} within the six months experimental period (Table 1). A reduction in the number of emerged weed species was observed in 5-10 cm depth. Similar result was found by dos Santos et al. (2015) who identified 14 families at 0-5 cm depth while at 5-10 cm soil depth 15 weed species belonging to 10 families were identified being poaceae the most abundant.

At the depth of 10-15 cm the number of weed species decreased significantly. Only 19 weed species with 13 annuals and 6 perennials belonging to 11 families were emerged from 10-15 cm soil depth. Four weed species were found from Poaceae and Cyperaceae family, two of the family Pontederiaceae, Rubiaceae and Scrophulariaceae, one each of the family Asteraceae, Compositae, Leguminosae, Onagraceae and Solanaceae. The five most dominant weed species based on importance value in descending order were *Fimbristylis miliacae* (L.) Vahl. (31%) >*Lindernia hyssopifolia* L. (11%) >*Lindernia antipoda* L. (7%) >*Cyperus difformis* L. (6%) >*Eclipta alba* L. (5%) and rest of the 13 weed species represent only 40% (Fig. 1). The identified 19 weed species were comprises of 4 grass species, 4 sedges species and 11 broadleaf species (Table 1). At 10-15 cm soil depth the weed seed density was found 2796 m^{-2} within the six months experimental period (Table 1).

Weed fruits and seeds are a viable reservoir in the upper part (0-5 cm depth) of the soil profile, which determines the composition of weed flora in the concrete region (Caetano et al., 2001). Relative abundance of weed seeds is double in the surface layer (0-5 cm) of control plots, but it was reduced by half in the lower layer (10-15 cm). Overall species and seed numbers were lower in the lower layers (10-15 cm) 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 what has been found in other studies (Olano et al., 2002).

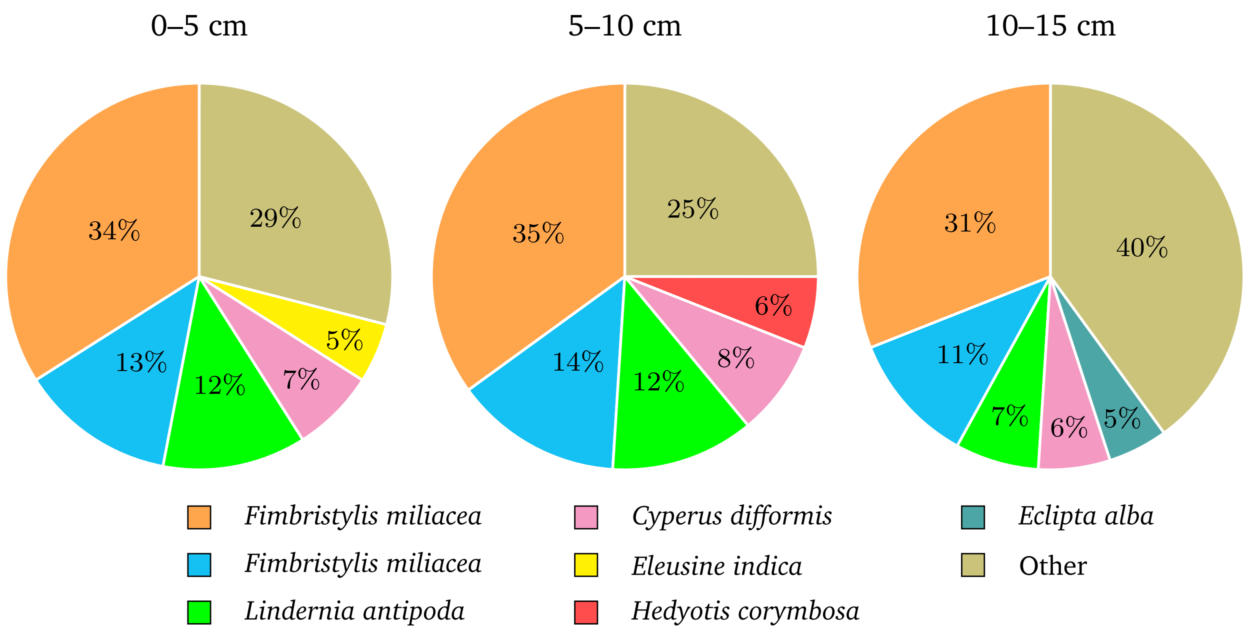

Figure 1. Five most dominant weed species at different soil depth

3.2 Emergence of weed seeds

Irrespective of soil depth the experimental plots had weed seeds from 33 weed species belonging to 17 families. Number of weed species found at 0-5 cm soil depth was higher than that of 5-10 cm and 10-15 cm soil depths. Out of 33 weed species 30, 23 and 19 weed species were present at 0-5 cm, 5-10 cm and 10-15 soil depth, respectively. Among them 21 weed species were found common for 0-5 cm and 5-10 cm depths of soil (Table 1). Two weed species *Gnaphalium luteo-album* and *Nicotina plumbaginifolia* L. were absent at 0-5 cm soil depth but present at 5-10 cm soil depth. On the other hand, nine weed species *viz.* *Alternanthera sessilis* L., *Altrnaria philoxeroides* L., *Cyanotis axillaris* Roem., *Brassica kaber* L., *Marsilea crenata* Presl., *Pistia stratiotes* L., *Rotala ramosior* L., *Solanum nigrum* and *Eleocharis atropurpurea* (Retz.) were absent at 5-10 cm soil depth but present at 0-5 cm soil depth. Among them 17 weed species were found common between 0-5 cm and 10-15 cm depths of soil (Table 1).

Thirteen weed species *viz.* *Spilanthesi abadicensis* A.H. Moore, *Alternanthera philoxeroides* L, *Alternanthera sessilis* L., *Amaranthus viridis* L. Solms., *Brassica kaber* L., *Cyanotis axillaris* Roem., *Pistia stratoites* L., *Gnathalium luteo-album*, *Marsilea crenata* Presl., *Solanum nigrum* L., *Panicum distichum* L., *Cynnodon dactylon* L., *Rotala ramosior* (L.) and *Eleocharis atropurpurea* (Retz.) were absent at 10-15 cm soil depth but present at 0-5 cm soil depth. On the other hand, *Desmodium triflorum* L. and *Nicotina plumbaginifolia* L. Kochne were absent at 0-5 cm depth while these two weed species were present at 10-15 cm soil depth (Table 1). Eighteen weed species were found common at 5-10 cm and 10-15 cm depths of soil. *Spilanthes iabadicensis* A.H. Moore, *Cynodon dactylon* L., *Gnaphalium luteo-album*, *Panicum distichum* L., and *Amaranthus viridis* L. were absent at 10-15 cm depth but present at 0-5 cm depth. On the other hand, *Desmodium triflorum* L. was absent at 5-10 cm soil depth but present at 10-15 cm soil depth (Table 1). This might be caused due to different tillage systems which interact with the micro-environment of weed seeds and can influence the pattern of recruitment from the weed seed bank. Chauhan et al. (2006) reported that tillage systems can have a major influence on the vertical distribution of weed seeds in the soil seed bank. Usually weed seedling recruitment increases if tillage equipment brings buried seed to, or close to, the soil surface, and seedling recruitment decreases if surface seed is buried deeper in the soil. However, tillage responses have a tendency to be species specific and can also be influenced by the intensity of tillage. From the experimental result it was observed that, weed seedlings density varies from depth to depth. The density of weed seedlings found higher at 0-5 cm depth (5455 weeds m^{-2}) than that of 5-10 cm and 10-15 cm soil depth (4046 and 2796 weeds m^{-2}, respectively) (Table 1). Weed pressure became excessive in 0-5 cm depth compared to 5-10 cm and 10-15 cm soil depth. In the study area about 85% weeds were emerged within 0-5 cm depth. All weed type *viz.* (grass, sedge, broadleaf) was found in abundance in 0-5 cm depth than 5-10 cm and 10-15 cm soil depth. At 0-5 cm depth the density of sedge, broadleaf weeds and grasses were found 2530 m^{-2}, 2208 m^{-2} and 717 m^{-2}, respectively which were higher than that of 5-10 cm depth where the density of sedge, broadleaf weeds and grasses were found 1934 m^{-2}, 1582 m^{-2}

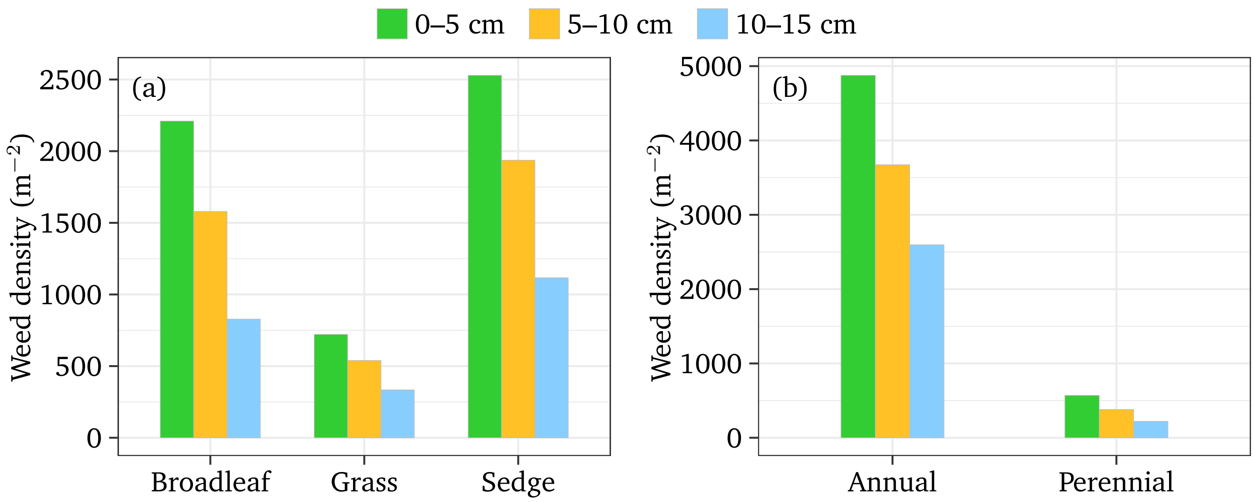

Figure 2. Density of weeds at different depths of soil based on (a) morphology, and (b) life cycle

and 530 m^{-2}, respectively. On the contrary, quite lower density of sedge, broadleaf weeds and grasses were found in 10-15 cm soil depth *viz.* 1110 m^{-2}, 823 m^{-2} and 332 m^{-2}, respectively (Table 1 and Fig. 2a).

The result of the experiment also indicates that annual and perennial weeds were most prevalent in upper layer (0-5 cm) than lower layer (5-10 cm) of soil. The annual weed density at 0-5 cm, 5-10 cm and 10-15 cm soil depths were 4888 m^{-2}, 3664 m^{-2} and 2589 m^{-2}, respectively (Table 2 and Fig. 2b) . Similarly, the perennial weed density at 0-5 cm and 5-10 cm and 10-15 cm soil depths were 567 m^{-2} and 382 m^{-2} and 207 m^{-2}, respectively (Table 2 and Fig. 2b). Number of weed seeds in the seed bank differed within the soil depths receiving the conventional tillage system. The concentration of weed seeds decrease with the burial depth (Cardina et al., 1991). Clements et al. (1996) reported that the top 5 cm of the soil contained most of the weed seeds. Based on the number of seedlings that emerged from the soil cores, the top 5 cm soil contained the largest proportion (60-70%) of the weed seeds. Only 18% weed seeds were buried within 10-15 cm on a silt soil.

Species composition and density are influenced by farming practices and vary from field to field and among areas within fields (Buhler et al., 1997). Buhler et al. (2001) reported that, seed densities of common water hemp, foxtail species, other species and all species were affected by soil depth and the year by soil depth interaction. Weed seeds were concentrated near the soil surface. The highest density of common water hemp seeds were found in upper 5 cm, with seed density decreasing as soil depth increased. Common water hemp density was found 3 fold greater at 0-5 cm than 5-10 and 10-15 cm. Foxtail species density was greatest at 0-5 cm depth followed by 5-10 cm depth. Adhikary and Ghosh (2014) reported that annual weed species were dominated over perennial weed species. More than 90% of the weeds in the seed bank of his experiment were small seeded annual weeds, especially *Echinochloa colona*, *Dactyloctaneum aegyptym*, *Digitaria sanguinalis*, *Eleusine indica*, *Amaranthus viridis*, *Chenopodium album*, *Cyperus difformis*, *Fimbristylis miliacea* etc. Tanaka (1976) found that sedges and grasses accounted for more than 70% of soil seed bank.

3.3 Emergence of soil weed seed bank

In general, weed emergence is influenced by soil disturbance, temperature, rainfall, soil moisture and radiant energy. From the present study it was observed that the highest number of weed seedlings (37%) emerged at 0-5 cm, 5-10 cm and 10-15 cm at the month of April which were found 1980, 1510 and 1109 m^{-2}, respectively. During the period from April to September, a total of 12297 weed seedlings m^{-2} emerged from three of the above mentioned soil depths and the highest percentage of weed emergence (37%) was found in the month of April. Gradually the emergence percentage decreased as the number of weed seed in the soil was decreasing and the lowest one was found in the month of September (7%) (Table 3). About 65% of seedlings had emerged within first two months of commencement of germination trial and 35% seedlings emerged within last 4 months. In this experiment it was observed that, weed seedlings were continued to emerge up to September but at the month of June the percentage of seedlings emergence (only 5%) decrease significantly i.e only 300, 200 and 105 weeds m^{-2} were found to be emerged at 0-5 cm, 5-10 cm and 10-15 cm soil depths, respectively in the month of June. It might be due to the effect of low light intensity because of cloudy weather. After that from July weed seeds were found to continue their germination but at low rate. Weed seedlings contin-

Table 1. Emergence and density of different weed species at 0-5 cm, 5-10 cm and 10-15 cm soil depths (six months experimental period)

Morphology	Scientific name	Weed density (m^{-2}) †		
		0-5 cm	5-10 cm	10-15 cm
Broadleaf	*Lindernia hyssopifolia* (L.) Haines	674	550	300
	Lindernia antipoda L.	720	491	207
	Hedyotis corymbosa (L.) Lamk	242	227	114
	Eclipta alba L.	161	146	138
	Ludwigia octovalvis (Jacq.) P. H. Raven	97	40	11
	Spilanthesia badicensis A.H. Moore	79	43	0
	Ageratum conyzoides L.	47	12	6
	Dentella repens L.	42	37	27
	Cyanotis axillaris Roem.	31	0	0
	Amaranthus viridis L.	24	9	0
	Alternanthera philoxeroides L.	19	0	0
	Monochoria hastata L.	15	6	3
	Alternanthera sessilis L.	12	0	0
	Pistia stratiotes L	12	0	0
	Marsilea crenata Presl.	9	0	0
	Gnaphalium luteo-album	0	7	0
	Brassica kaber L.	6	0	0
	Nicotinaplum baginifolia L.	0	10	5
	Solanum nigrum L.	6	0	0
	Eichhornia crassipes (Mart.) Solms.	6	4	7
	Desmodium triflorum L.	0	0	5
	Rotala ramosior (L.) Kochne	6	0	0
	Total	2208 (19)	1582 (13)	823 (11)
Grass	*Eleusine indica* L.	280	181	137
	Digitaria sanguinalis L.	166	125	116
	Leersia hexandra L.	99	102	63
	Panicum distichum L.	73	59	0
	Cynnodon dactylon L.	51	41	0
	Echinochloa crusgalli L.	48	22	16
	Total	717 (6)	530 (6)	332 (4)
Sedge	*Fimbristylis miliacea* L.	1825	1431	863
	Cyperus difformis L.	400	333	142
	Cyperus rotundus L.	197	120	81
	Cyperus iria L.	89	50	24
	Eleocharisatro purpurea (Retz.)	19	0	0
	Total	2530 (5)	1934 (4)	1110 (4)

† Values in parentheses are number of weed species recorded.

Table 2. Density of annual and perennial weed species at different soil depths (6 months period)

Life cycle	Weed density (m^{-2})		
	0-5 cm	5-10 cm	10-15 cm
Annual	4888	3664	2589
Perennial	567	382	207

Table 3. Monthly dynamics of weed seedlings emergence at different depths of soil

Months	Number of weed emerged (m^{-2})			Total	Average
	0-5 cm	5-10 cm	10-15 cm		
April	1980	1510	1109	4599	37%
May	1535	1130	812	3477	28%
June	300	210	105	615	5%
July	790	571	390	1751	14%
August	520	385	250	1155	9%
September	330	240	130	700	7%
Total	5455	4046	2796	12297	

Table 4. Sorenson's Index of Similarity of weed vegetation among the sampling depths

Depths	0-5 cm	5-10 cm	10-15 cm
0-5 cm	–	75%	69%
5-10 cm	75%	–	81%
10-15 cm	69%	81%	–

ued to emerge up to September (Table 3). Mulugeta and Boerboom (1999) observed common weeds like giant foxtail and common lambsquarters, the majority of seedlings will emerge within six weeks after planting. In soybeans, they found that over 80% of giant foxtail and common lambsquarters emerged by six weeks in both years.

3.4 Sorenson's Index of Similarity

Based on Sorenson's Index of Similarity, the highest similarity index (81%) was recorded between 5-10 cm and 10-15 cm depths and the lowest (69%) was between 0-5 cm and 10-15 cm depths (Table 4). This indicated that the difference of number of occurring weed species between those depths was lower and higher, respectively. The similarity between the two depths of weed vegetation might be due to similar climate, land type and cultural management which reflects on weed seed bank status. Begum et al. (2005) observed that high values of Sorenson's Index (82.76∼95.08) indicated close similarity in weed species in four districts of Muda rice granary area in Malaysia.

4 Conclusions

Seven dominant weed species, *Fimbristylis miliacea* L., *Lindernia antipoda* L., *Lindernia hyssopifolia* L., *Cyperus difformis* L., *Eleusine indica* L., *Hedyotis corimbosa* L. and *Eclipta alba* L. could be found at different soil depths of the study site. Based on Sorenson's Index of Similarity, the difference of number of occurring weed species between 5-10 cm and 10-15 cm depths (81%) and 0-5 cm and 10-15 cm depths (69%) was lower and higher, respectively. All weed type *viz.* grass, sedge and broadleaves were found in abundance at 0-5 cm depth than 5-10 cm and 10-15 cm depth. The annual and perennial weeds were also higher at 0-5 cm depth and annual weeds were dominant over perennial weeds.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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