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In situ and *ex situ* floristic diversity of weed seedbank in rice at farmers' fields

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Abstract

A study was conducted in the net house of Department of Agronomy, Bangladesh Agricultural University as well as in farmers' fields at Digarkanda village of Mymensingh district to evaluatethe *in situ* and *ex situ* floristic diversity of the weed seedbank in rice. Five fields were surveyed for *in situ* evaluation with four replications and soil samples (1.5 kg soil) were collected and placed in plastic pots in the net house for *ex situ* study. Diversity was computed by the Shannon index (*H'*). A-total of 33 weed species belonging to 17 families were found under *in situ* whereas, 37 species belonging to 22 families germinated under *ex situ* condition. The family Cyperaceae had the highest species richness and density under both conditions. Based on importance value, the five most dominant species under *in situ* condition were *Eleocharis atroperpurea*, *Cyperus difformis*, *Alternanthera philoxeroides*, *Azolla pinnata* and *Echinochloa crusgalli*. Whereas, under *ex situ* condition, two new weed species i.e. *Fimbristylis miliaceae* and *Lindernia antipoda* were found dominant instead of *Alternanthera philoxeroides* and *Azolla pinnata* and rest of the three species remained the same with slightly different rank and order. Weed density and diversity were also higher under *ex situ* condition than *in situ* condition. *Ex situ* condition had higher *H'* index (*H'*=2.396) than *in situ* condition (*H'*=2.230). The highest percentage of weed emergence was observed within the first month of commencement of germination trial under both *in situ* and *ex situ* conditions.The information obtained from the study would help to determine the infestation potential of identified weed species and predict the upcoming threat which could lead to construct and improve successful weed management strategies.

Keywords: Diversity, *ex situ*, floristic, *in situ*, seedbank

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1. Introduction

Weeds are plants that occur in the wrong place. It is an everlasting problem in crop production that causes reduction in yields due to their many ways of interfering with crop growth and development. Weeds compete with crops for mineral nutrients, water, solar energy and space and thus they hinder crop cultivation operations and managements which often results in a partial or complete failure of crops. Rice is one of the most extensively cultivated cereals of the world and in Bangladesh, people depend on rice as staple food which has tremendous influence on agrarian economy of Bangladesh. The area and production of total rice in Bangladesh is about 11.41 million hectares and 33.83 mMT (BBS, 2013), respectively where *boro* rice contributes to the production of 18.06 mMT (BRRI, 2008). However, the average yield of rice is low (2.92 t ha^{-1}) in Bangladesh compared to other rice growing countries (BBS, 2013). Poor weed control is one of the major factors reported by Amarjit et al. (1994) for rice yield reduction depending on the type of floristic composition and weeds intensity. Weed causes reduction of grain yield by 70-80% in *aus* rice, 30-40% transplanted *aman* rice and 22-36% in *boro* rice (BRRI, 2008). This loss poses a serious threat for the food deficit countries like Bangladesh. According to Isley (1960), the losses due to infestation of weeds are greater than the combined losses caused by insect, pest and diseases in rice. So, proper weed management is essential for rice production.The weed seed bank acts as a reservoir of weed seeds in the soil that largely determines the potential density and species composition of weeds that subsequently interfere with crops during the growing season (Forcella, 1993). The density and composition of weed plants determined by the soil weed seed bank and the proportion of seeds expected to give rise to emerged seedlings at that time of year (Roberts and Ricketts, 1979). Weed species vary in the fraction of their seed banks emerging as seedlings because of species-specific dormancy and germination characteristics (Egley, 1986). *In situ* study of weed seed bank refers to the identification and enumeration of weed seedling emergence in the field that provide a general indication of the composition of the weed flora in the seed bank. On the other hand, *ex situ* study is the identification and enumeration of weed seedling emergence from soil samples placed in trays in the net house. Species that present *in situ* and *ex situ*, demonstrated great plasticity (the capacity to adapt to different sites), as well as tolerance to human activities and stress conditions imposed by environmental factors. As weed seed bank is an indicative of a field’s cropping systems history, it would be useful to know if weed seed bank and the aboveground community are closely related. If this relationship were predictive, seed bank data could be used in the design of predictive weed management. Estimating the size of the seed bank and predicting the emergence of different weed species is very difficult (Forcella et al. 1992) and almost no study has been done in this context in our country. So, the present field study was designed to establish the relationship between the soil seed bank and field populations of various weed species to predict the seedling emergence. Therefore, the study was conducted with the objective of determining the total number of weed seeds reserve, species composition and dominant weed species present as well as comparing the floristic diversity, *in situ* and *ex situ*, of the soil weed seed bank in rice.

2. Materials and Methods

A study of weed seed bank was conducted at farmers' *boro* rice fields of Digarkanda village as well as Bangladesh Agricultural University, Mymensingh during the period from January to May 2016 to assess the *in situ* and *ex situ* diversity of weed seed bank. Farmers' fields where *boro* rice (winter rice) was grown, were surveyed for *in situ* evaluation whereas, *ex situ* evaluation was done in the net house of the Department of Agronomy, Bangladesh Agricultural University. Surveyed area was situated on 24.75 ^{0}N latitude and 90.50^0 Elongitude with an elevation of 18 m above sea level which belongs to the Agro-ecological region of the Old Brahmaputra Floodplain (AEZ-9). The experimental area is under the sub-tropical climate which is characterized by high temperature, high humidity and heavy precipitation during the months from April to September (*Kharif* season) and scanty precipitation associated with moderately low temperature during the period from October to March (*Rabi* season). The soil belonged to the Sonatala series of dark grey floodplain soil type having pH 6.5. Five *boro* rice fields were selected and from each field, four plots were surveyed considering each plot as a replication. The size of each plot was 1 m^2. *In situ* evaluation was performed by surveying half of the area (0.5m^2) of each plot with a 0.25 m^{2}size quadrat for collecting data on weed species composition within 30 days intervals up to harvesting of *boro* rice. All collected data were converted to per meter square. For *ex situ* evaluation, soil samples were collected before transplanting of *boro* rice. Soil samples were taken using a soil auger to a depth up to 15 cm following a W shape pattern from the rest of 0.5m^2 area of the same plots. Each soil sample was weighed approximately 1.5 kg which were bagged and excess air was removed to reduce the risk of seed germination during storage. Samples of each plot were placed in an individual plastic pot in the Net house. The diameter and depth of each pot was 28 cm and 10 cm, respectively. The samples were daily sprinkled with water as needed in order to keep them moist and ensure proper germination. Emerged weed seedlings were identified, counted, recorded throughout the four months emergence period. The seedling keys of Chancellor (1966) were used to identify weed seedlings. Seedlings that could not be identified were transplanted to plastic pots and cultivated until reaching the flowering stage. After the removal of each batch of seedlings, soils were thoroughly mixed in order to expose the weed seeds to the upper level of the soil, and re-wetted to permit further emergence. Seedling emergence counts were converted to number per m^2.

The dominant weed species was determined by the calculation of Importance Value (I.V.) which was expressed as:

$$\text{I.V. } (\%) = \frac{\text{Number of each species in a community}}{\text{Total number of all species in a community}} \times 100$$

Floristic diversity was assessed by the Shannon index (*H'*) based on natural logarithm which considers equal weight among rare and abundant species. Higher values of *H'* indicate greater floristic diversity (Shannon and Weaver, 1949).

The Shannon index was computed by the following formula:

$H' = \sum - pi \ln pi$

Where, ln is the natural logarithm, *pi*= *ni*/*N*, *ni* is the number of sampled individuals of species *I*, *N* is the total number of sampled individuals.

3. Results and Discussion

Under *in situ* condition, the soils of experimental plots were occupied by 33 different weed species belonging to 17 families comprising 20 broadleaf weeds, seven grasses and six sedges (Table 1). Among the families, Poaceae contributed the highest number of weed species i.e. seven followed by the family Cyperaceae (6). Three weed species were from the family Scrophulariaceae and two weed species from each of the family Compositae, Amaranthaceae and Pontederiaceae and rest of the 11 families i.e. Marsileaceae, Polygonaceae, Commelinaceae, Chenopodiaceae, Rubiaceae, Solanaceae, Araceae, Umbelliferae, Azollaceae, Nymphaeaceae and Boraginaceaerepresented by only one species each.Despite of contributing lower number of weed species than Poaceae, Cyperaceae family had the highest weed density which accounted for 52.97% of the total weed species than by Poaceae (11.16%)based on importance value (Table 1). From the species composition, it was observed that, though broadleaf weedscontributed twenty weed species which was higher than grasses (7) and sedges (6), yet according to the importance value, sedges were dominant over broadleaf weeds and grasses. The most dominant weed species among the grasses were *Echinochloa crusgalli* and *Leersia hexandra*, among the sedges, *Eleocharis atroperpurea* and *Cyperus difformis* and among the broadleaf weeds, *Alternanthera philoxeroides* and *Azolla pinnata* (Table 1). The rank and order of five most dominant weed species under *in situ* condition based on importance value were *Eleocharis atroperpurea* (27.23%) > *Cyperus difformis* (23.66%) > *Alternanthera philoxeroides* (12.67%) > *Azolla pinnata* (10.72%) > *Echinochloa crusgalli* (7.67%) and rest of the species constituted 18.05% (Figure 1).

3.1. Weed composition under *ex situ* condition

A total of 37 weed species belonging to 22 families were emerged from the experimental pots containing the soil of farmers' fields under *ex situ* condition in the net house (Table 2). Seven weed species from Poaceae family, five species from Cyperaceae family, three species from the family Amaranthaceae, two from each of the family Pontederiaceae, Scrophulariaceae and Compositae, one weed species from each of the family Marsileaceae, Polygonaceae, Solanaceae, Rubiaceae, Araceae, Azollaceae, Nymphaeceae, Sphenocleaceae, Portulaceae, Onagraceae, Boraginaceae, Chenopodiaceae, Leguminosae, Asteraceae, Cruciferae and Lythraceae were identified. Cyperaceae family had the highest species richness under *ex situ* condition.

Table 1- Morphological distribution of weed species with common name, scientific name, family and importance value under *in situ* condition

Morphological type	Common name	Scientific name	Family	Importance value (%)
Grass	Barnyard grass	*Echinochloa crusgalli* L.	Poaceae	7.67
	Swamp rice grass	*Leersia hexandra* L.	Poaceae	1.76
	Bermuda grass	*Cynodon dactylon* L.	Poaceae	0.25
	Paspalum grass	*Paspalum commersonii* Lam	Poaceae	0.27
	Crab finger grass	*Digitaria sanguinalis* L.	Poaceae	0.17
	Water finger grass	*Panicum distichum* L.	Poaceae	0.94
	Coast barbgrass	*Parapholis incurva* L.	Poaceae	0.10
Sedge	Smallflower umbrella	*Cyperus difformis* L.	Cyperaceae	23.66
	Purple nut sedge	*Eleocharis atroperpurea* (Retz.)	Cyperaceae	27.23
	Rice flat sedge	*Cyperus iria* L.	Cyperaceae	1.09
	Grass like fimbry	*Fimbristylis miliaceae* L.	Cyperaceae	0.77
	Purple nut sedge	*Cyperus rotundus* L.	Cyperaceae	0.10
	White Water Sedge	*Cyperus nemoralis* Cherm.	Cyperaceae	0.12
Broadleaf	Alligator weed	*Alternanthera philoxeroides* L.	Amaranthaceae	12.67
	Sessile joyweed	*Alternanthera sessilis* L.	Amaranthaceae	0.67
	Water cabbage	*Pistia stratiotes* L.	Araceae	1.24
	Water velvet	*Azolla pinnata* R. Br.	Azollaceae	10.72
	Wild clary	*Heliotropium indicum* L.	Boraginaceae	0.12
	Goose foot	*Chenopodium album* L.	Chenopodiaceae	0.03
	Spreading day flower	*Commelina diffusa* L.	Commelinaceae	0.15
	White eclipta	*Eclipta alba* L.	Compositae	1.63
	Creeping water primerose	*Jussiea repens* L.	Compositae	0.32
	Water clover	*Marsilea crenata* Presl.	Marsileaceae	0.97
	Water lily	*Nymphaea nouchali* Burm. f.`	Nymphaeaceae	0.07
	Water hyacinth	*Eichhornia crassipes* (Mart.) Solms.	Pontederiaceae	1.34
	Heartshape false pickerel weed	*Monochoria vaginalis* (Burm. F.)C. Presl	Pontederiaceae	1.71
	Smart weed	*Polygonum hydropiper* L.	Polygonaceae	1.66
	Old world diamond flower	*Hedyotis corymbosa* (L.) Lamk	Rubiaceae	0.17
	Asian Mazus	*Mazus rugosus* Lour.	Scrophulariaceae	1.09
	Sparrow false pimpernel	*Lindernia antipoda* L.	Scrophulariaceae	0.35
	Yellow seed false pimpernel	*Lindernia hyssopifolia* (L.)	Scrophulariaceae	0.74
	Buffalobur nightshade	*Solanum rostratum* Dunal.	Solanaceae	0.07
	Asiatic penny wort	*Hydrocotyle asiatica* L.	Umbelliferae	0.15

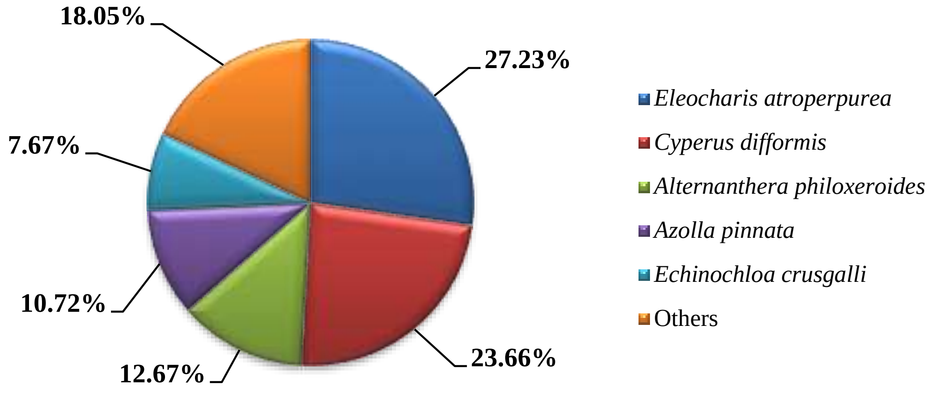

Figure 1- Five most dominant weed species in the soil weed seedbank based on importance value under *in situ* condition.

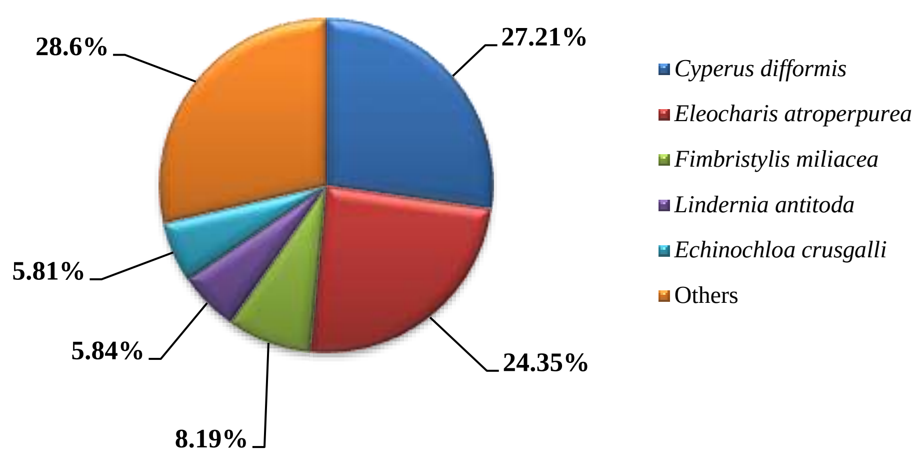

Figure 2- Five most dominant weed species in the soil weed seedbank based on importance value under *ex situ* condition.

Table 2- Morphological distribution of weed species with common name, scientific name, family and importance value under *ex situ* condition

Morphological type	Common name	Scientific name	Family	Importance value (%)
Grasses	Barnyard grass	*Echinochloa crusgalli* L.	Poaceae	5.81
	Bermuda grass	*Cynodon dactylon* L.	Poaceae	0.11
	Jungle grass	*Echinochloa colonum L.*	Poaceae	0.31
	Smooth crab grass	*Digitania ischaemum L.*	Poaceae	0.13
	Water finger grass	*Panicum distichum* L.	Poaceae	0.12
	Crab finger grass	*Digitaria sanguinalis* L.	Poaceae	0.13
	Goose grass	*Eleusina indica* L.	Poaceae	0.16
Sedges	Smallflower umbrella	*Cyperus difformis* L.	Cyperaceae	27.21
	Purple nut sedge	*Eleocharis atroperpurea* (Retz.)	Cyperaceae	24.35
	Grass like fimbry	*Fimbristylis miliaceae* L.	Cyperaceae	8.19
	Rice flat sedge	*Cyperus iria* L.	Cyperaceae	1.37
	White Water Sedge	*Cyperus nemoralis* Cherm.	Cyperaceae	0.67
Broadleaf	Sessile joyweed	*Alternanthera sessilis* L.	Amaranthaceae	0.62
	Alligator weed	*Alternanthera philoxeroides* L.	Amaranthaceae	2.38
	Pig weed	*Amaranthus viridis* L.	Amaranthaceae	1.73
	Water cabbage	*Pistia stratiotes* L.	Araceae	0.05
	Whiteweed	*Ageratum conyzoides* L.	Asteraceae	0.15
	Water velvet	*Azolla pinnata* R. Br.	Azollaceae	0.19
	Wild clary	*Heliotropium indicum* L.	Boraginaceae	0.09
	Goose foot	*Chenopodium album* L.	Chenopodiaceae	0.58
	Cocklebur	*Xanthium italicum* L.	Compositae	1.15
	White eclipta	*Eclipta alba* L.	Compositae	4.06
	Wild mustard	*Brassica kaber* L.	Cruciferae	0.11
	Threeflower beggarweed	*Desmodium triflorum* L.	Leguminosae	0.11
	Lowland rotala	*Rotala ramosior* (L.) Kochne	Lythraceae	1.72
	Water clover	*Marsilea crenata* Presl.	Marsileaceae	0.34
	Water lily	*Nymphaea nouchali* Burm. f.`	Nymphaeaceae	0.12
	Winged water primerose	*Ludwigla hyssopifolia* (Jacq.) P. H. Raven	Onagraceae	0.22
	Smart weed	*Polygonum hydropiper* L.	Polygonaceae	3.07
	Water hyacinth	*Eichhornia crassipes* (Mart.) Solms.	Pontederiaceae	0.05
	Heartshape false pickerel weed	*Monochoria vaginalis* (Burm. F.) C. Presl	Pontederiaceae	1.87
	Common purslaane	*Portulaca oleracea* L.	Portulaceae	0.12
	Old world diamond flower	*Hedyotis corymbosa* (L.) Lamk	Rubiaceae	3.36
	Yellow seed false pimpernel	*Lindernia hyssopifolia* L.	Scrophulariaceae	2.54
	Sparrow false pimpernel	*Lindernia antipoda* L.	Scrophulariaceae	5.84
	Wedgewort	*Sphenoclea zeylanica* Gaertn.	Sphenocleaceae	0.43
	Wild tobacco	*Nicotiana plumbaginifolia* L.	Solanaceae	0.54

It was observed that 61.79% of the species present in farmers' field belonged to the Cyperaceae family (Table 2). Here, among the thirty seven weed species, twenty five weed species were from broadleaf weeds, seven from grasses and five from sedges and hence, sedges had higher importance value (61.79%) than broadleaf weeds (31.44%) and grasses (6.77%) (Table 1). So it can be said that, sedges were dominant over broadleaf weeds and grasses. *Echinochloa crusgalli* and *Echinochloa colonum* among grasses, *Cyperus difformis* and *Eleocharis atroperpurea* among sedges and *Lindernia antipoda* and *Eclipta alba* among broadleaf weeds were the two most dominant weed species under *ex situ* condition. *Cyperus difformis* (27.21%) > *Eleocharis atroperpurea* (24.35%) > *Fimbristylis miliacea* (8.19%) > *Lindernia antipoda* (5.84%) > *Echinochloa crusgalli* (5.81%) was the five most dominant weed species in descending order and rest of the species represented 28.6% according to the importance value under *ex situ* condition in the net house (Figure 2).

3.2. Comparison of weed emergence between *in situ* and *ex situ* condition

In the soil weed seedbank of farmers' fields, *ex situ* condition showed highest floristic richness with highest number of families, genera and species than *in situ* condition. A total of 59864 weed individuals belonging to 24 families, 39 genera and 46 species were recorded under both *in situ* and *ex situ* condition where, 51784 weed individuals within 37 species were emerged under *ex situ* and 8080 individuals within 33 species were emerged under *in situ* condition (Table 3). Among the 24 families, weed species of *in situ* condition belonged to 17 families and 28 genera and weed species of *ex situ* condition belonged to 22 families and 32 genera (Figure 3).

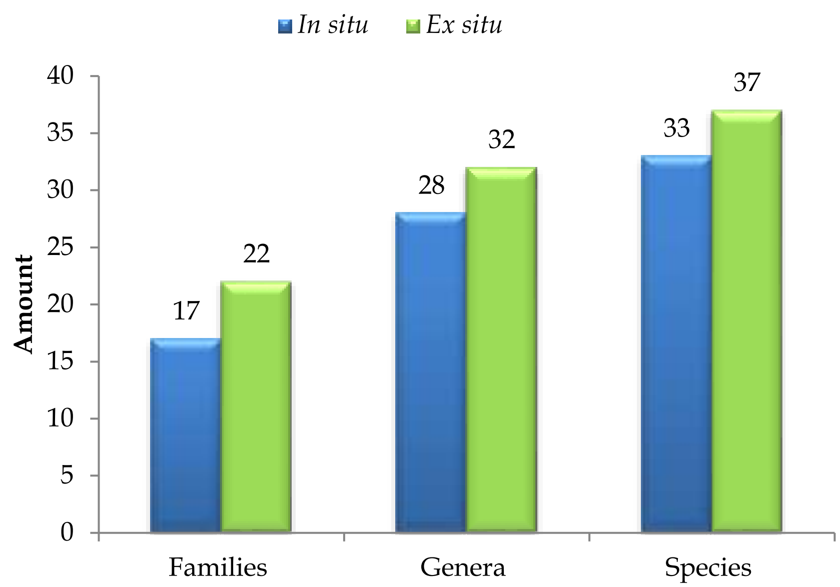

Figure 3- Number of families, genera and species in the soil weed seedbank under both *in situ* and *ex situ* condition.

Fourteen families were common in both *in situ* and *ex situ* condition such as Poaceae, Cyperaceae, Scrophulariaceae, Amaranthaceae, Pontederiaceae, Marsileaceae, Compositae, Chenopodiaceae, Solanaceae, Rubiaceae, Nymphaceae, Boraginaceae, Azollaceae and Araceae. Eight families such as Portulaceae, Asteraceae, Polygonaceae, Lythraceae, Cruciferae, Onagraceae, Sphenocleaceae and Leguminosae were only present under *ex situ* condition. Two families such as Commelinaceae and Umbelliferae were present under *in situ* condition but absent under *ex situ* condition. Cyperaceae family had the highest species richness in both condition (Table 3). Twenty four weed species were common under both *in situ* and *ex situ* condition. Thirteen weed species were present under *ex situ* condition but absent under *in situ* condition such as *Digitaria ischaemum, Eleusina indica, Echinochloa colonum, Sphenoclea zeylanica, Xanthium italicum, Amaranthus viridis, Ageratum conyzoides*, *Rotala ramosior*, *Nicotiana plumbaginifolia*, *Brassica kaber, Ludwigla hyssopifolia, Portulaca oleracea* and *Desmodium triflorum*. Nine weed species were absent under *ex situ* condition but present under *in situ* condition such *Leersia hexandra*, *Paspalum commersonii, Parapholis incurve, Cyperus rotundus*, *Mazus rugosus, Jussiea repens, Solanum rostratum, Hydrocotyle asiatica* and *Commelina diffusa*. From the five most dominant weed species lists, *Eleocharis atroperpurea*, *Cyperus difformis* and *Echinochloa crusgalli* were found under both *in situ* and *ex situ* condition with different rank and order. *Alternanthera philoxeroides* and *Azolla pinnata* were in the dominant list of *in situ* condition where as two new weed species i.e. *Fimbristylis miliaceae* and *Lindernia antipoda* were recorded dominant under *ex situ* condition. From the experiment, it was also found that, the *ex situ* density was higher than *in situ.* The *ex situ* density was 2589 plants m^{-2}, almost six times higher than the 404 plants m^{-2} observed under *in situ* condition (Figure 4). The Shannon diversity index (*H'*) is an index that is commonly used to characterize species diversity in a community. Higher value of *H'* indicates greater floristic diversity and conversely, lower value indicates less diversity in species composition of a location. Shannon indexwas found higher under *ex situ* condition (*H'*=2.396) than *in situ* condition (*H'*=2.230) in our experimental plot and it proves that in the present study, the highest number of individuals and species found under *ex situ* condition contributed to the great floristic diversity. The highest percentage of the emerged seedlings was recorded in February under both *in situ* and *ex situ* condition (Figure 5). Weed seedlings continued to emerge upto May but in reduced numbers compared to first flush under *in situ* and *ex situ* condition.Under *in situ* condition, the percentage of weed emergence was 69.49% within the first month and 30.51% weeds emerged within the next three months. Under *ex situ* condition, 68.89% weeds germinated within the first month and rest 31.11% weeds germinated within the next three months (Figure 5). Over the four months emergence period, percent emergence of weed seedlings showed a clear peak and continued to emerge irrespective of the time of all study period, but in reduced numbers under both condition.

Table 3- Number of individuals recorded, *in situ* and *ex situ*, in the soil weed seed bank of *boro* rice.

Species	Family	*In situ*	*Ex situ*
Grasses			
Echinochloa crusgalli	Poaceae	620	3010
Leersia hexandra	Poaceae	142	-
Cynodon dactylon	Poaceae	20	54
Digitaria ischaemum	Poaceae	-	68
Paspalum commersonii	Poaceae	22	-
Digitaria sanguinalis	Poaceae	14	68
Panicum distichum	Poaceae	76	64
Eleusina indica	Poaceae	-	82
Parapholis incurve	Poaceae	8	-
Echinochloa colonum	Poaceae	-	162
Sedges			
Cyperus difformis	Cyperaceae	1912	14090
Eleocharis atroperpurea	Cyperaceae	2200	12610
Cyperus iria	Cyperaceae	88	712
Fimbristylis miliaceae	Cyperaceae	62	4240
Cyperus rotundus	Cyperaceae	8	-
Cyperus nemoralis	Cyperaceae	10	346
Broadleaf weeds			
Alternanthera sessilis	Amaranthaceae	54	322
Alternanthera philoxeroides	Amaranthaceae	1024	1234
Amaranthus viridis	Amaranthaceae	-	894
Pistia stratiotes	Araceae	100	28
Ageratum conyzoides	Asteraceae	-	76
Azolla pinnata	Azollaceae	866	98
Heliotropium indicum	Boraginaceae	10	48
Chenopodium album	Chenopodiaceae	2	300
Commelina diffusa	Commelinaceae	12	-
Eclipta alba	Compositae	132	2102
Jussiea repens	Compositae	26	-
Xanthium italicum	Compositae	-	596
Brassica kaber.	Cruciferae	-	58
Desmodium triflorum	Leguminosae	-	58
Rotala ramosior	Lythraceae	-	892

Marsilea crenata	Marsileaceae	78	174
Nymphaea nouchali	Nymphaeaceae	6	62
Ludwigla hyssopifolia	Onagraceae	-	104
Polygonum hydropiper	Polygonaceae	134	1588
Eichhornia crassipes	Pontederiaceae	108	28
Monochoria vaginalis	Pontederiaceae	138	970
Portulaca oleracea	Portulaceae	-	64
Hedyotis corymbosa	Rubiaceae	14	1728
Lindernia antipoda	Scrophulariaceae	28	3022
Lindernia hyssopifolia	Scrophulariaceae	60	1330
Mazus rugosus	Scrophulariaceae	88	-
Nicotiana plumbaginifolia	Solanaceae	-	282
Sphenoclea zeylanica	Sphenocleaceae	-	220
Solanum rostratum	Solanaceae	6	-
Hydrocotyle asiatica	Umbelliferae	12	-
Total		**8080**	**51784**

The highest floristic diversity, with the highest number of families, genera and species, was recorded under *ex situ* condition than under *in situ* condition in farmers' fields. This indicates that the high number of individuals and species found *ex situ* contributed to the great floristic diversity in the experimental area. Mesquita et al. (2013) conducted a similar *in situ* and *ex situ* study where he observed a total of 13,892 individuals, belonging to 20 families, 40 genera and 60 species in a rice-growing area of Brazil. Of those, 11,530 individuals within 50 species were recorded under *ex situ* and 2,362 individuals within 34 species were recorded under *in situ*. The *ex situ* density was 3,206 plants m^{-2}, which was five times higher than the 653 plants m^{-2} observed *in situ*. Floristic diversity was also greater under *ex situ* (*H'*=2.66) than *in situ* (*H'*=2.53). Cyperaceae family largely dominated the soil weed seedbank under both *in situ* and *ex situ* condition. It may be because of having large amount of seeds of sedges stored in the seedbank from previous years. A seed bank formation represents an important regeneration component for many species of this family (Uddin et al. 2018; Leck and Schütz, 2005). Kamoshita et al. (2010) reported that 86% of species present in the seed banks of 22 rice fields belonged to the Cyperaceae family in Cambodia. In another study on Muda rice granary in North West Peninsular Malaysia, Begum et al. (2008) found *Fimbristylis miliaceae* contributing 66.07% of the total seed reserves to the soil weed seed bank of rice fields.The differences observed between *in situ* (in the field) and *ex situ* (in the net house) might be due to the activities of microorganisms, insects, rodents, lizards, birds and other animals that causes seed and seedling losses in the field. Ghersa et al. (2000) observed that around 5% to 15% weed seed loss occurs by predators. Another possible reason might be the occasional periods of soil water stress and losses (due to intraspecific and interspecific competition) resulted in germination failure, as observed by Herault and Hiernaux (2004) in a weed seed and population dynamics study carried out in Africa. In the net house, we protect seeds from predators and systematically irrigate, which do not happen in the field.

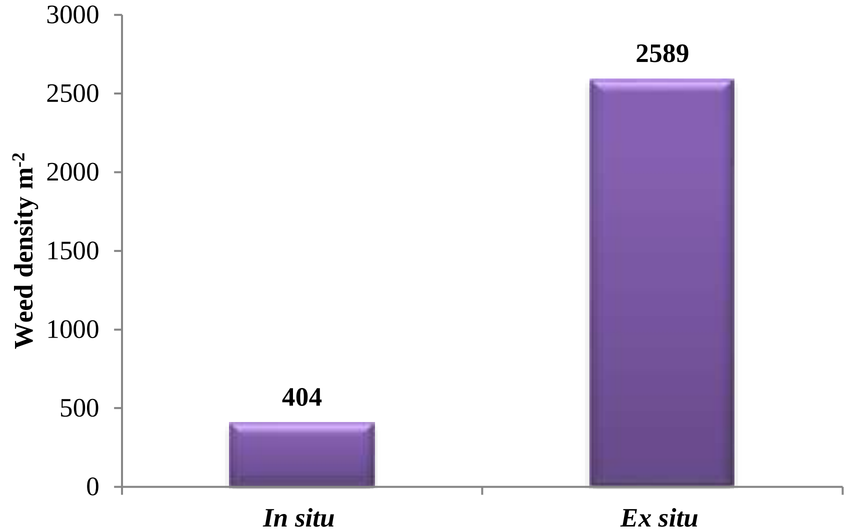

Figure 4- Weed density m^{-2} under *in situ* and *ex situ* conditions.

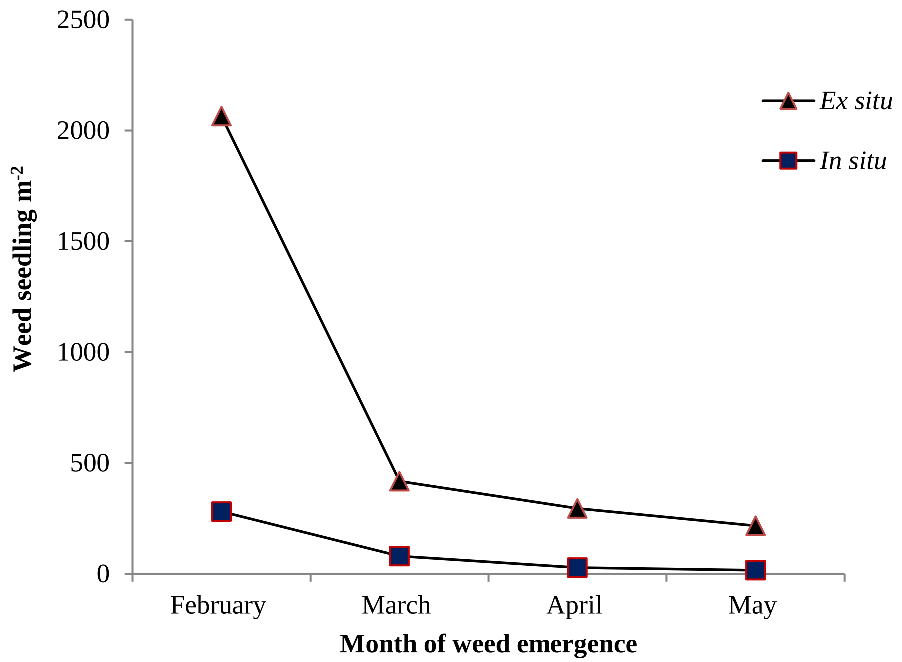

Figure 5- Emergence pattern of weed seedlings (m-2) at different months.

The removal of weed seedlings from the pots after the assessments reduced competition, and controlled abiotic factors such as air, relative humidity, light and temperature, provided a favorable condition for germination.In our present study, the highest percentage of emerged seedlings was observed in the first month under both *in situ* and *ex situ* condition. Baskin and Baskin (1998) and Benech-Arnold et al. (2000) observed the higher germination rates in the first 30 days and the possible explanation might be the dormancy breaking because of greater exposure to sunlight and temperature variation. Mesquita et al. (2013) stated that, in the net house, approximately 80% of seeds germinated by day 60. In addition, Begum *et al.* (2006) observed a germination peak at 30 days in a soil weed seedbank in a rice field in Malaysia. Variable weed emergence patterns have many consequences for site-specific weed management. Understanding the causes of differential weed emergence permits more informed decisions, more timely operations, and better management. Without the ability to predict weed emergence, management decisions are less efficient, less reliable, and often more prone to agronomic and financial risk.

Conclusion

In situ and *ex situ* studies were carried out in order to understand the weed seedbank emergence patterns to improve weed management program. From the experiment it was found that, the floristic diversity of the soil weed seedbank was higher under *ex situ* than *in situ* in farmers' fields. Cyperaceae family had the highest species richness under both condition. From the five most dominant weed species lists, *Eleocharis atroperpurea, Cyperus difformis* and *Echinochloa crusgalli* were found dominant under both *in situ* and *ex situ* condition. The density of the soil weed seedbank was approximately five times higher under *ex situ* than *in situ.* The information available from our findings may be used to predict future weed infestation and could lead to construct successful and improved weed management strategies.

Conflict of interest

Authors declare no conflicts of interest for this study.

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