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Floristic diversity of the soil weed seedbank in *boro* rice fields: *in situ* and *ex situ* evaluation

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Abstract

This study was conducted at the research fields of Agronomy Field Laboratory and in the net house of Department of Agronomy, Bangladesh Agricultural University, Mymensingh. The objective of this study was to compare the *in situ* and *ex situ* floristic diversity of soil weed seedbank in *boro* rice. The soil weed seedbank status was observed through weed survey at research fields and seed germination method in the net house. Five fields were selected randomly with four replications. Soil samples were collected to a depth up to 15 cm and placed in plastic pots in the net house. Weed seedlings that emerged were identified, counted and removed at 30 day intervals throughout the four months emergence period. At the same time, weed survey was done using a 0.25 m^{-2} quadrate. Diversity was computed by the Shannon index (*H'*). Under *in situ* condition, 31 weed species belonging to 15 families germinated and 33 weed species belonging to 17 families germinated under *ex situ* condition. The family Cyperaceae had the highest species richness under both *in situ* and *ex situ* conditions. The five most dominant weed species under *in situ* condition based on importance value were *Eleocharis atroperpurea* > *Cyperus difformis* > *Echinochloa crusgalli* > *Monochoria vaginalis* > *Lindernia antipoda* whereas, under *ex situ* condition, two new weed species, *Fimbristylis miliacea* and *Echinochloa colonum* were observed in the dominant list instead of *Monochoria vaginalis* and *Lindernia antipoda* having slightly different rank and order. The *ex situ* density was 2721 plants m^{-2}, approximately four times higher than the 700 plants m^{-2} observed under *in situ* situation and similarly *ex situ* condition had higher Shannon Index (*H'*) value (*H'*=2.412) indicating greater diversity than *in situ* (*H'*=2.211) condition. The information obtained from the study would help determine the infestation potential of identified species, which could lead to improved management strategies.

Introduction

Rice is the world's single most important crop and a primary food source for half of the world's population. The people in Bangladesh depend on rice as staple food and the crop has tremendous influence on agrarian economy of Bangladesh. Food production in Bangladesh is dominated by a single crop (rice) and a single season (*boro*, which accounts for over 60% of total rice production) (MoFDM, 2012). *Boro* rice covers about 11,793,512 acres area and contributes to 18,937,581 M tons of rice production in the country (BBS, 2016). The average yield of *boro* rice is low compared to other rice growing countries. BRRI (2008) reported that 70-80% yield reduction in *aus* rice, 30-40% in transplanted *aman* rice and 22-36% in *boro* rice were caused by weed infestation. Chauhan and Johnson (2011) reported as high as 95% yield reduction in rice due to weed competition throughout the rice growing season. This loss is, therefore, a serious threat for the food deficit countries like Bangladesh. One of the most important, yet often neglected, weed management strategies is to reduce the number of weed seeds present in the field, and thereby limit potential weed populations during crop production. This could be accomplished by managing the weed seedbank.

Weeds are unique group of plant species having the ability to infest and thrive in intensively disturbed habitats, despite extensive efforts to eliminate them. Weeds are successful because of their nature of plasticity that adapt to and survive changes in the environment. At maturity, weeds shed their seeds on agricultural land and thus add to the population of weed seeds in or on the soil which constitutes the weed seedbank. Weed seedbank is the reservoir of viable weed seeds, present on the soil surface and scattered throughout the soil profile (Singh *et al.*, 2012). It consists of both new weed seeds recently shed, and older seeds that have persisted in the soil from previous years. The weed seedbank largely determines the potential density and species composition of weeds that subsequently interfere with crops during the growing season (Forcella, 1993). In this respect, an estimation of the weed seedbank population in the soil, combined with knowledge of the germination and behavior of specific weed species, presents practical opportunities to develop integrated and environmentally sound weed management programs. If prediction of potential weed populations could be done before crops were sown, the infestation of weeds might be reduced by altering crop selection in relation to various patterns of resource competition, soil distribution, plant architectures or changing sowing times to avoid major weed problems.

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In situ study of weed seedbank is the identification and enumeration of weed seedling emergence in the field which might provide a general indication of the composition of the weed flora in the seedbank. On the other hand, weed seedbank study *ex situ*, that is, the identification and enumeration of weed seedling emergence from soil samples placed in trays in the net house and irrigated daily for longer periods, is more efficient for assessing germination dynamics. Moreover, it is also possible to assess the potential size of the weed seedbank because many species are capable of extended fluxes of emergence over several weeks under favorable environmental conditions. Species those present both *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 seedbank is an indicative of a field's cropping systems history, it would be useful to know if weed seedbank and the aboveground community are closely related. If this relationship were predictive, seedbank data could be used in the design of predictive weed management.

Although a number of studies have evaluated the relationship between the weed seedbank and the floristic compositions, results have not been consistent. While some studies have reported strong relationships between the weed seedbank and aboveground communities (Tuesca *et al*. 2004; Ndarubu and Fadayomi, 2006), others have found that correlations were generally low and very variable (Cardina and Sparrow, 1996; Webster *et al.* 2003). In Bangladesh, since almost no study has been done in this context, very little is known about the soil weed seedbank and their pattern of occurrence in crop fields. Therefore, the present study was carried out to assess the total number of weed seeds reserve, species composition and dominant weed species present as well as to compare the floristic diversity, *in situ* and *ex situ* of the soil weed seedbank in *boro* rice field.

Materials and Methods

This study was carried out at two locations of Bangladesh Agricultural University in Mymensingh district during the period from January to May 2016. *In situ* study was conducted at the Agronomy Field Laboratory whereas *ex situ* study was performed in the net house of the same Department. The area was situated under the latitude of 24.75^0 N and the longitude of 90.50^0 E 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 from Agronomy Field Laboratory. Each field was divided into four plots. Each plot was considered as a replication. The size of each plot was 1 m^2.

In situ evaluation of seedbank was done by conducting weed survey in half of the area ($0.5m^2$) of each plot of Agronomy Field Laboratory. A 0.25 m^2 quadrate was used to collect data on 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. A soil auger was used to take soil samples to a depth up to 15 cm following a W shape pattern from in the rest of 0.5 m^2 area of the same plots. Each soil sample was weighed approximately 1.5 kg. Samples were bagged and excess air was removed from the bagged sample to reduce the risk of seed germination during storage. Samples of each plot were placed in an individual plastic pot (28 cm diameter × 10 cm depth) in the Net house. The soils were daily sprinkled with water as needed in order to keep them moist. Weed seedlings that emerged were identified, counted, and removed at 30 days intervals throughout the four months emergence period. The seedling key of Chancellor (1966) was used to identify weed seedlings. Seedlings that could not be identified down to the species level 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. This process was repeated four times. 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.

Results

Composition of weed species under *in situ* condition

Agronomy Field Laboratory, where *in situ* evaluation has been done, were occupied with 31 weed species belonging to 15 families and 24 genera representing diversity in their composition (Table 1). Eight weed species were found from Poaceae family, five weed species from Cyperaceae family, three from Amaranthaceae family, two weed species from each of the family Commelinaceae, Pontederiaceae and Polygonaceae and one weed species from each of the family from Araceae, Azollaceae, Compositae, Hydrophyllaceae, Marsileaceae, Nymphaeceae, Onagraceae, Rubiaceae and Scrophulariaceae. In case of density, species of the family Cyperaceae largely dominated the soil weed seedbank followed by Poaceae (15.3%) (Fig. 1). It was observed that, 55.2% of species present in the seedbank belonged to Cyperaceae family. Among 31 weed species, 18 from broadleaf, eight from grasses and five from sedges were identified (Table 1) which indicated that broadleaves were dominated over grasses and sedges. The five most dominant weed species based on importance value in descending order were *Eleocharis atroperpurea* (27.3%) > *Cyperus difformis* (25.4%) > *Echinochloa crusgalli* (12.6%) > *Monochoria vaginalis* (10.4%) > *Lindernia antipoda* (3.9%) and rest of the species represented 20.4% (Fig. 2).

Composition of weed species under *ex situ* condition

Under *ex situ* condition which was conducted in the net house, a total of 33 weed species were emerged which belonged to 17 families and 27 genera from the weed seedbank (Table 1). Seven weed species from Poaceae family, five weed species from Cyperaceae, three weed species from the family Amaranthaceae, two weed species from each of the family Compositae, Commelinaceae, Scrophulariaceae and Polygonaceae, one weed species from each of the family Azollaceae, Araceae, Chenopodiaceae, Labiatae, Marsileaceae, Onagraceae, Portulaceae, Pontederiaceae, Rubiaceae and Solanaceae. The family with the highest species richness was Cyperaceae which accounted for 53.0% of the species followed by Poaceae (23.2%) identified under *ex situ* condition (Fig. 3). Among the 33 weed species, 21 from broadleaves, seven from grasses and five from sedges were identified (Table 1). So from the experimental result it was found that broadleaves were outnumbered grasses and sedges. According to the importance value of the identified weed species, the descending order of the five most dominant weed species under *ex situ* condition were *Cyperus difformis* (23.6%) > *Eleocharis atroperpurea* (16.3%) > *Echinochloa crusgalli* (15.5%) > *Fimbristylis miliacea* (10.2%) > *Echinochloa colonum* (6.2%) and rest of the weed species represented 28.2% (Fig. 4).

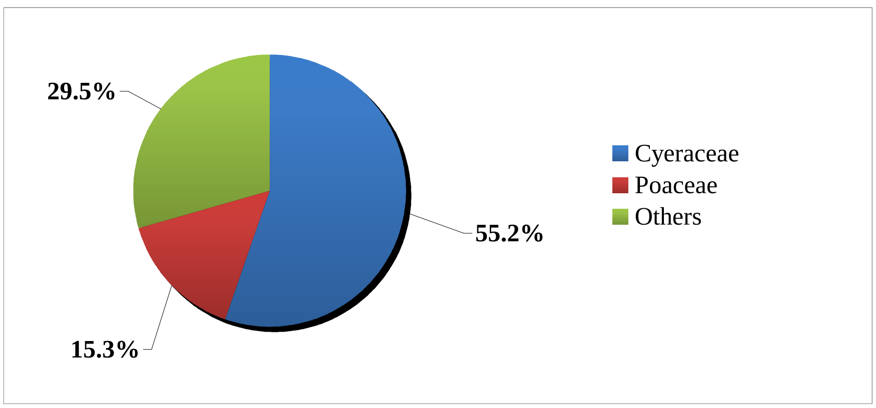

Fig. 1. Two most dominant families in the soil weed seedbank under *in situ* condition

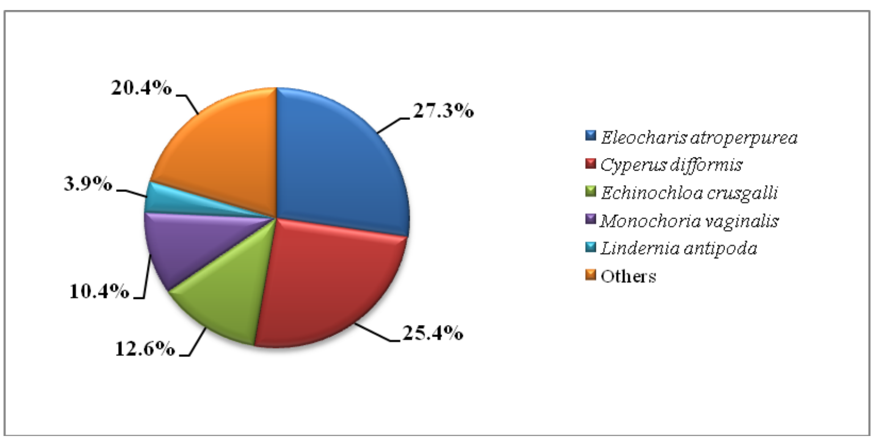

Fig. 2. Five most dominant weed species in the soil weed seedbank under *in situ* condition based on importance value

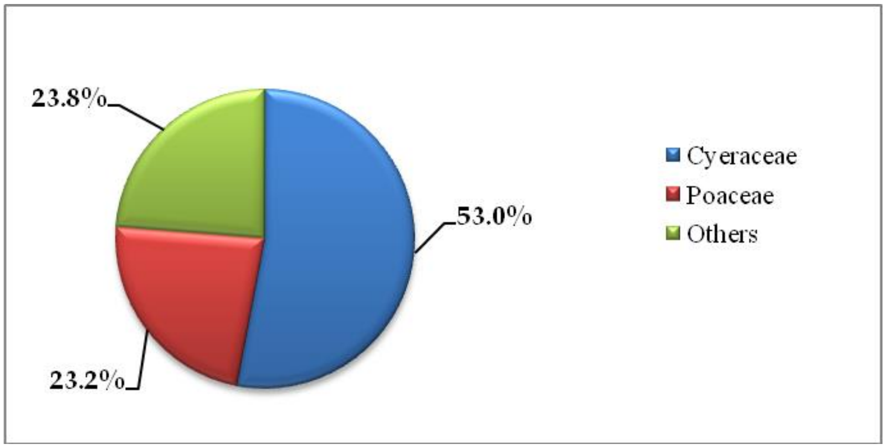

Fig. 3. Two most dominant families in the soil weed seedbank under *ex situ* condition

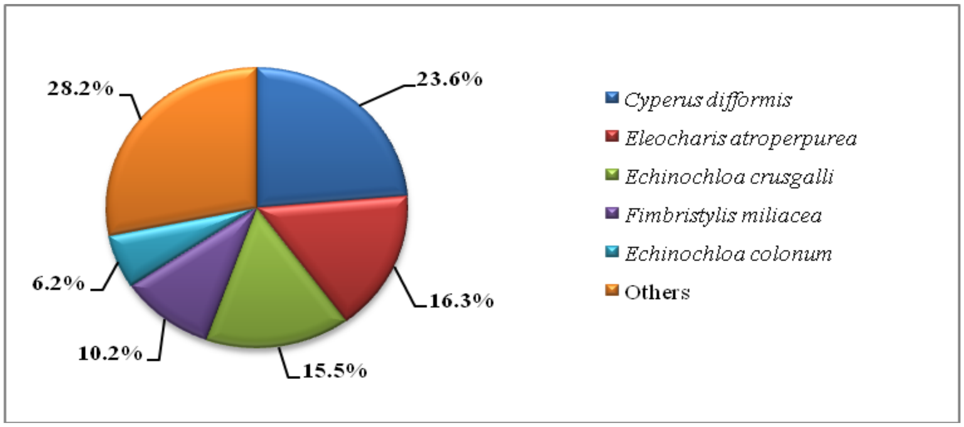

Fig. 4. Five most dominant weed species in the soil weed seedbank under *ex situ* condition based on importance value

Comparison of soil weed seedbank between *in situ* and *ex situ* condition

The higher floristic diversity, with the highest number of families, genera and species, was observed under *ex situ* condition than *in situ* condition. A total of 68,408 weed individuals per twenty square meters belonging to 19 families, 32 genera and 39 species were recorded under both *in situ* and *ex situ* condition per (Table 1). Of those, 13,996 individuals within 31 species were recorded under *in situ* and 54,412 individuals within 33 species were recorded under *ex situ* condition. Among the 19 families, weed species of *in situ* condition belonged to 15 families and 24 genera and weed species of *ex situ* condition belonged to 17 families and 27 genera (Fig. 5). Thirteen families were common in both *in situ* and *ex situ* condition. Two families such as Hydrophyllaceae and Nymphaceae were only observed under *in situ* condition and four families such as Chenopodiaceae, Labiatae, Portulaceae and Solanaceae were only present under *ex situ* condition. The family with the highest species richness based on importance value was Cyperaceae in both conditions. Nine weed species were present under *ex situ* condition but absent under *in situ* condition such as *Eleusine indica, Cynodon dactylon, Mazus rugosus, Gnaphalium affine, Commelina benghalensis, Portulaca oleracea, Chenopodium album, Solanum rostratum* and *Leucas aspera*. Six weed species were absent under *ex situ* condition but present under *in situ* condition such as *Digitaria ischaemum, Panicum distichum, Parapholis incurve, Eichhornia crassipes, Nymphaea nouchali* and *Hydrolea zeylanica*. In case of weed density, similar results were obtained that is, the *ex situ* density was 2721 plants m^{-2}, four times higher than the 700 plants m^{-2} observed under *in situ* situation (Fig. 6).

The Shannon diversity index (*H'*) is an index that is commonly used to characterize species diversity in a community. In the present study, the highest floristic diversity with the highest number of families, genera and species, was observed under *ex situ* condition than *in situ* condition in Agronomy fields. Shannon Index (*H'*) was higher under *ex situ* condition (*H'*=2.412) than *in situ (H'*=2.211*)* condition. 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 (Fig. 7). Weed seedlings continued to emerge up to May but in reduced numbers compared to first flush in the two locations under *in situ* and *ex situ* condition. 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 1. Total number of weed seedlings per twenty square meters recorded under *in situ* and *ex situ* conditions in the soil weed seedbank of *boro* rice

Morphological type	Local name	Scientific name	Family	*In situ*	*Ex situ*
Grasses	Shama	*Echinochloa crusgalli* L.	Poaceae	1768	8454
	Chapra	*Eleusine indica* L.	Poaceae	-	570
	Khude shama	*Echinochloa colonum* L.	Poaceae	32	3358
	Arail	*Leersia hexandra* L.	Poaceae	118	112
	Khudey anguli ghash	*Digitaria ischaemum* L.	Poaceae	6	-
	Anguli ghash	*Digitaria sanguinalis* L.	Poaceae	98	84
	Angta	*Panicum distichum* L.	Poaceae	98	-
	Gaicha	*Paspalum commersonii* Lamk.	Poaceae	8	14
	Chela ghash	*Parapholis incurve* L.	Poaceae	14	-
	Durba	*Cynodon dactylon* L.	Poaceae	-	42
Sedges	Sabuj nakful	*Cyperus difformis* L.	Cyperaceae	3556	12862
	Panichase	*Eleocharis atroperpurea* (Retz.) Kunth	Cyperaceae	3822	8860
	Joina	*Fimbristylis miliacea* L.	Cyperaceae	296	5540
	Bara chucha	*Cyperus iria* L.	Cyperaceae	48	1572
	Khudey patai	*Cyperus flavidus* L.	Cyperaceae	4	14
Broadleaf weeds	Malancha	*Alternanthera philoxeroides* L.	Amaranthaceae	108	312
	Chanchi	*Alternanthera sessilis* L.	Amaranthaceae	48	128
	Shaknotey	*Amaranthus viridis* L.	Amaranthaceae	106	1458
	Topa pana	*Pistia stratiotes* L.	Araceae	170	28
	Azolla	*Azolla pinnata* L.	Azollaceae	346	680
	Bathua	*Chenopodium album* L.	Chenopodiaceae	-	14
	Monayna	*Commelina diffusa* L.	Commelinaceae	6	28
	Kanaibashi	*Commelina benghalensis* L.	Commelinaceae	-	14
	Keshuti	*Eclipta alba* L.	Compositae	220	1758
	Shetlomi	*Gnaphalium affine* L.	Compositae	-	56
	Nodulgia	*Hydrolea zeylanica* L.	Hydrophyllaceae	26	-
	Shetodrone	*Leucas aspera* L.	Labiatae	-	14
	Sushni shak	*Marsilea crenata* Presl.	Marsileaceae	462	112
	Panishapla	*Nymphaea nouchali* Burm. f.`	Nymphaeaceae	6	-
	Panilong	*Ludwigia hyssopifolia* (Jacq.) P. H. Raven	Onagraceae	110	772
	Biskatali	*Polygonum hydropiper* L.	Polygonaceae	156	1670
	Pani morich	*Polygonum orientale* L.	Polygonaceae	228	1042
	Panikachu	*Monochoria vaginalis* (Burm. F.) C. Presl.	Pontederiaceae	1450	2914
	Kachuripana	*Eichhornia crassipes* (Mart.) Solms.	Pontederiaceae	20	-
	Nunia shak	*Portulaca oleracea* L.	Portulaceae	-	28
	Khetpapri	*Hedyotis corymbosa* (L.) Lamk.	Rubiaceae	122	542
	Bon palong	*Mazus rugosus* Lour	Scrophulariaceae	-	172
	Bakopa	*Lindernia antipoda* L.	Scrophulariaceae	544	1102
	Chuchalo begun	*Solanum rostratum* Dunal.	Solanaceae	-	86
		Total		**13996**	**54412**

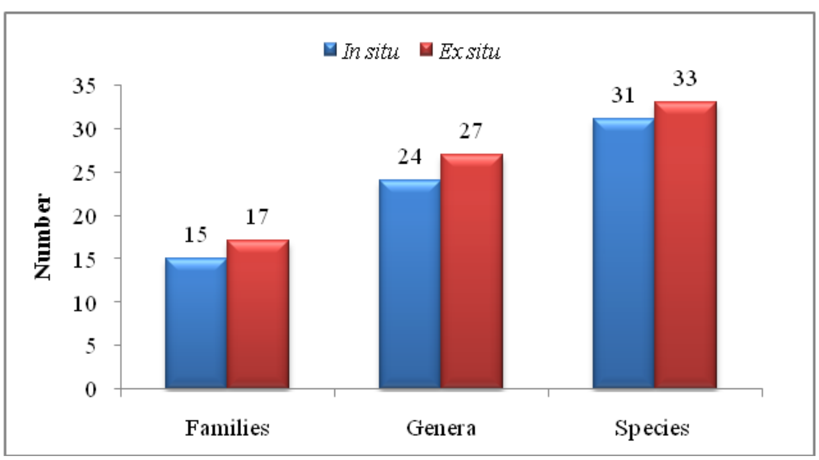

Fig. 5. Number of families, genera and species in the soil weed seedbank under both *in situ* and *ex situ* condition

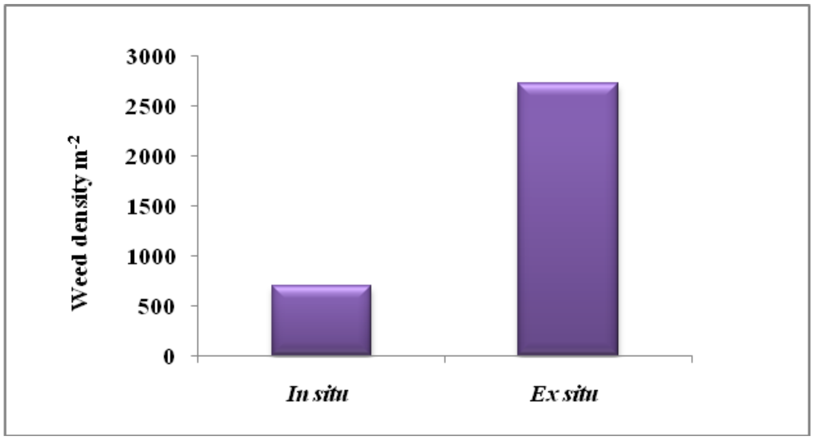

Fig. 6. Comparison of weed density m^{-2} between *in situ* and *ex situ* condition

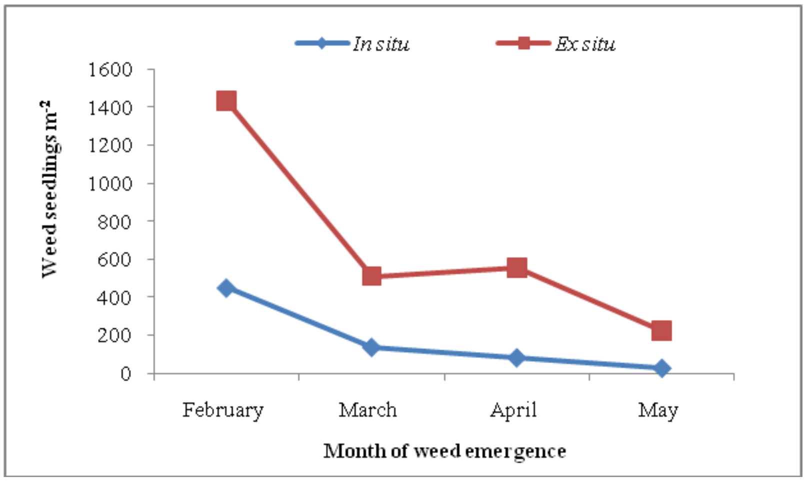

Fig. 7. Emergence pattern of weed seedlings (m^{-2}) at different months

Discussion

The higher floristic diversity was recorded under *ex situ* condition than under *in situ* condition. This indicates that the higher 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 they observed a total of 13,892 individuals, belonging to 20 families, 40 genera and 60 species in a rice-growing area of Brazil. Among those, 11,530 individuals from 50 species were recorded under *ex situ* and 2,362 individuals from 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 greater under *ex situ* (*H'*=2.66) than *in situ* (*H'*=2.53).

Species of the family Cyperaceae largely dominated in the soil weed seedbank evaluated both under *in situ* and *ex situ* condition. This result agrees with those of similar studies carried out in other tropical regions, such as Kamoshita *et al*. (2010) observed that 86% of species present in the seedbanks of 22 rice fields belonged to the Cyperaceae family in Cambodia. In another study in 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.

Differences observed between the amount of seeds germinated *in situ* and *ex situ* might be explained by various factors including seed and seedling losses in the field due to the activities of microorganisms, insects, rodents, lizards, birds and other animals. According to Ghersa *et al.* (2000), weed seed losses due to predators range from 5% to 15%. Another possible explanation for the differences observed in the present study is that occasional periods of soil water stress and losses (due to intra and inter-specific 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, seeds were protected from predators and systematically irrigated, which did not happen in the field. In our *ex situ* study, the seeds were further protected by the removal of weed seedlings from the trays after the assessments, which eliminated competition, and by the fact that we controlled abiotic factors such as air relative humidity, light and temperature.

In our present study, the highest percentage of seedling emergence was observed in the first month under both *in situ* and *ex situ* condition. The higher germination rates in the first 30 days of our study is probably due to dormancy breaking because of greater exposure to sunlight and temperature variation, as observed by Baskin and Baskin (1998) and Benech-Arnold *et al*. (2000). Mesquita *et al.* (2013) stated that, in the greenhouse, 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. Jensen (1969) also found seedling emergence accounted for only about 25% of the seeds in the soil and most of those that did so in the first month. He found the strong correlation between immediate seedling emergence in the net house and field emergence suggests only the first flush of seedling emergence need to be considered. 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

The soil weed seedbank largely determines the species composition and potential densities of weeds that subsequently interfere with crops during the growing season. From the findings, it may be concluded that the floristic diversity of the soil weed seedbank was higher under *ex situ* than *in situ* in research fields. Cyperaceae family had the highest species richness under both *in situ* and *ex situ* conditions. The density of the soil weed seedbank was approximately five times higher under *ex situ* than *in situ.* Our findings could help predict future weed infestation and could lead to improved weed management strategies.

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