World Applied Sciences Journal 20 (8): 1086-1091, 2012
ISSN 1818-4952
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DOI: 10.5829/idosi.wasj.2012.20.08.621

Seasonal Variation in Weed Seedbank in the Rice Field Soils of Muda Area, Peninsular Malaysia

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Abstract: An investigation was carried out at the Muda rice fields, Peninsular Malaysia during four consecutive seasons of 2004 and 2005 to study the seasonal variation in the weed seedbank. Species composition with their dominance ranking and similarity between the species were recorded. A total of 577 seeds/sample (3337 seeds/m^2) in 1/2004, 970 seeds/sample (5659 seeds/m^2) in 2/2004, 928 seeds/sample (5384 seeds/m^2) in 1/2005 and 471 seeds/sample (2722 seeds/m^2) were recorded in the season 2/2005. Time taken to emerge the whole seedbank varied from 44 to 72 weeks. Eight weed species namely, *Fimbristylis miliacea,. Ludwigia. hyssopifolia, Oryza sativa* complex (weedy rice), *Scirpus grossus, Echinochloa crusgalli, Sagittaria guyanensis, Scirpus juncoides* and *Ischaemum rugosum* were found to emerge from the seedbank. The species *F. miliacea, L. Hyssopifolia* and *O. sativa* contributed more than 80% of the total weed population. Among the weed species, *F. miliacea* and *L. hyssopifolia* are grouped, *E. crusgalli, S. guyanensis* and *S. grossus* are grouped and *S. juncoides* and *I. rugosum* are grouped together due to their similar frequencies of occurrence within the respective groups. Among the seasons of study, 1/2005 and 2/2005 were most similar with high value of similarity index (0.981).

Key words: Weed seedbank · Cluster analysis · Pricipal Component Analysis · Similarity index

INTRODUCTION

Weed seedbank is the storage of weed seeds in the soil, which emerge in different flushes to compete with the crops. The seedbank is regarded to as the "dispersal in time" because it provides the same essential benefits to the species as dispersal through space. The weed seedbank is known as the memory of the land, since its species abundance and diversity reflect the previous cropping history [1]. It is the potential key to future weed problem because many weed species can retain their viability and survive in soil for long periods. The recruitment of new individuals from seedbank at different times may play a major role in the composition, structure and dynamics of the plant community. That is why, to study the soil seedbank and the process that occur between them for understanding weed persistence in agricultural land are considered important [2, 3]. In rice fields in Malaysia, particularly in Muda area, the seed conservation in soil and seed germination have been documented [4, 5]. But studies have not been conducted to distinguish the portion of the seedbank that is transient and contains seeds that germinate during the growing season. Monitoring soil seedbank is a useful approach in determining the population trends and annual rates of change for the various treatments and thereby indicates the best time to manipulate the seedbank under natural conditions in the field. The aim of the study was to study the abundance of weed seeds and species composition of weed seedbank in the soils of rice fields for four consecutive seasons in Muda rice ecosystems of Malaysia.

MATERIALS AND METHODS

The investigation was carried out in the rice fields of Muda area of Peninsular Malaysia from February 2004 to September 2006 to study the size and weed species of soil seedbank. Soil samples were collected before sowing of rice in two main and two off seasons within the study period. Samples were collected randomly from ten holes in each quadrat of 1 m x 1 m size by using a soil borer of 8 cm

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diameter which was driven into the ground to a depth of 15-20 cm from each sampling site in a W shaped pattern. Each site had 10 quadrats and soils were collected from 100 holes. All soil samples from each site were mixed and allowed to air-dry *in-situ*. The dried soil was then passed through 6 mm sieve to remove large debris and to break up soil peds. They were placed in plastic trays of 23 cm x 18 cm x 10 cm size filling the same with 2.0 kg of soil sample from each sampling site. In order to keep the soil moist at 80% water-holding capacities, the samples were sprinkled with 1600 ml of water every morning. Plastic trays were then placed in a case and kept in the laboratory for germination under light for 12 hours. Number of weed seeds in the soil was determined by the number of emerging seedlings. Each species was counted and removed periodically at two weeks interval and was continued for 20 days while no more germination was noticed. After removal of seedlings, soils were thoroughly mixed in order to expose the weed seeds to upper layer and continued the germination test in the same way. Weed populations were classified into five groups: i) very high infestation (100 or above seedlings/m^2), ii) high infestation (60-99 seedlings/m^2), iii) medium infestation (30-59 seedlings/m^2), iv) low infestation (10-29 seedlings/m^2) and very low infestation (10 or less seedlings/m^2). Dominance of the weed species was studied by determining the relative density as follows –

$$\text{Relative density (\%)} = \frac{\text{Number of each species in a community}}{\text{Total number of species in the community}} \times 100$$

Cluster analysis and Principal Component Analysis (PCA) were done. Cluster analysis was used to see the similarity between different species and between different seasons; and PCA was used to partition the resemblance matrix into a data set of orthogonal axes [6] and to create new variables which explain much of the information in the data sets. PCA and dendograms were constructed from these values using Multivariate Statistical Package (MVSP) software Release 3.1.

RESULTS

Eight species of weeds were found to emerge from the soil and the size of the seedbank varied seasonally. A total of 577 seeds germinated, which were equivalent to 33.37 million seeds/ha in the main season of 2004 (1/2004), 970 seeds (56.59 millions/ha) in 2/2004, 928 seeds (53.64 million seed/ha) in 1/2005 and 471 seeds (27.22 million seeds/ha) germinated in 2/2005 seasons.

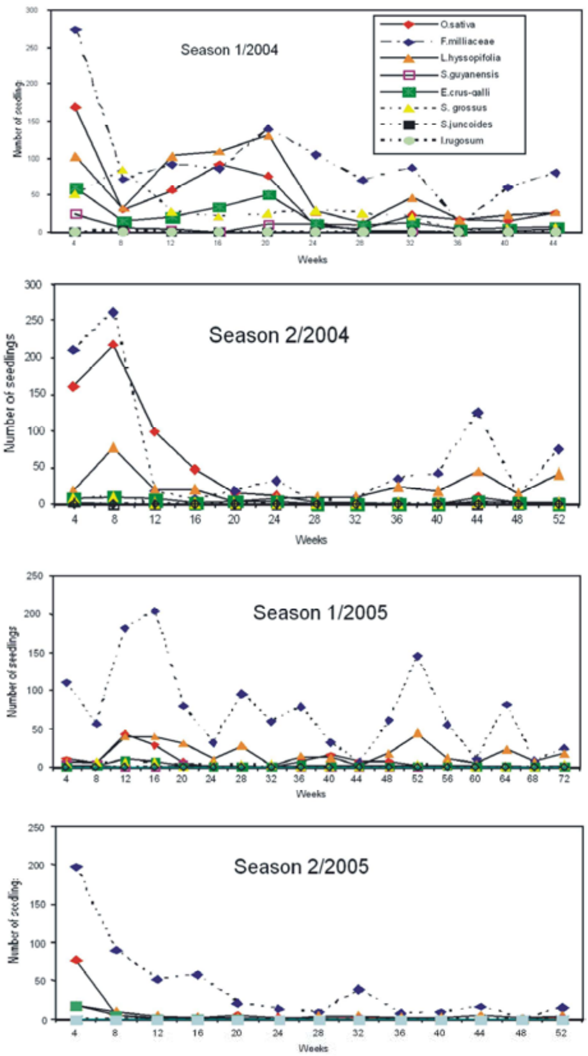

Fig. 1: Number of weed seedlings recorded in different weeks (W4 to W72) in four

The highest number of weed seeds germinated within two months of commencement of germination trial (Fig. 1). The whole seedbank germinated in different times in different seasons. For example, seed germination stopped at 44th week in the 1st season, 52 weeks in the 2nd season, 72 weeks in the 3nd season and 52 weeks in the 4th seasons respectively.

The species of weed emerged from the soil seedbank were *Fimbristylis miliacea, Ludwigia hyssopifolia, Oryza sativa* complex (weedy rice), *Scirpus grossus, Echinochloa crusgalli, Sagittaria guyanensis, Scirpus juncoides* and *Ischaemum rugosum.* In general *F. miliacea, L. hyssopifolia* and *O. sativa* complex were greater in number than other species (Fig. 2). During the main season of 2004, very high population of seeds

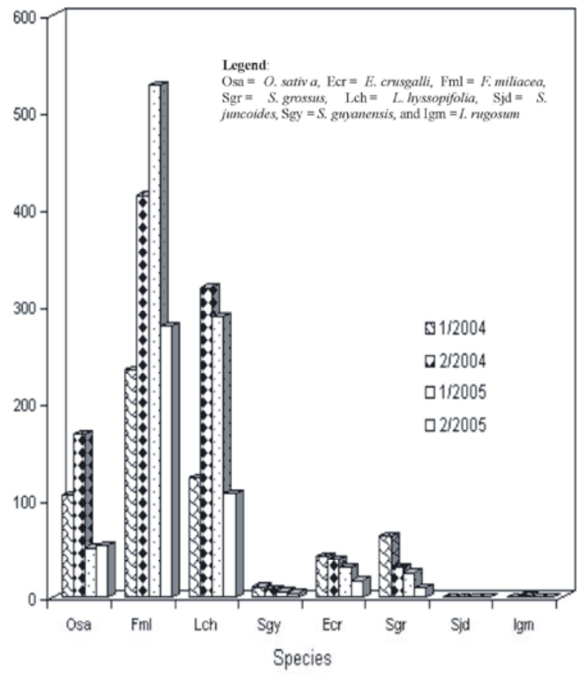

Fig. 2: Distribution of eight recorded weed species germinated from soil seed bank of the experimental site during four consecutive seasons

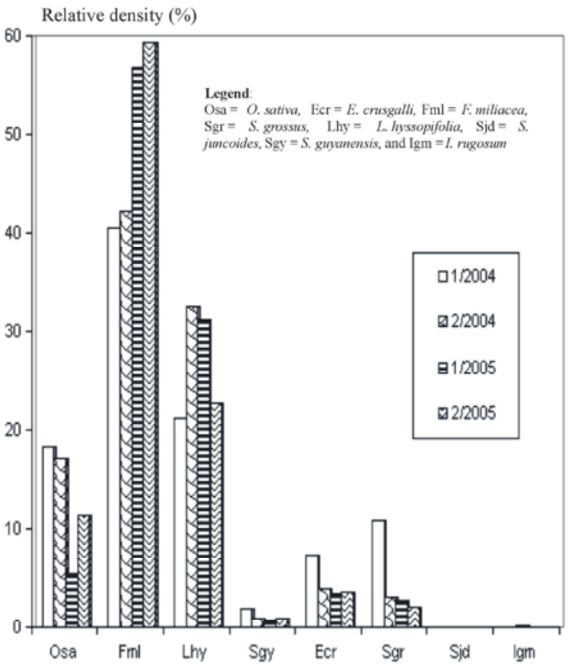

Fig. 3: Predominant weed species germinated from the soil seed bank with their relative densities during four consecutive seasons

germinated from *F. miliacea, L. hyssopifolia* and *O. sativa* complex. The weeds with high population was from *S. grossus,* medium population was from *E. crusgalli*, low population was from *S. guyanensis* and very low populations were from *S. juncoides* and *I. rugosum*. In the off season of 2004 (2/2004) again very high populations were from *F. miliacea, L. hyssopifolia* and *O. sativa* complex, *E. crusgalli* and *S. grossus* were in the medium population and *S. guyanensis, S. juncoides* and *I. rugosum* were in the very low category of population. During the seasons of 2005, slight variation in the weed seed emergence was noticed. In the main season, (1/2005) although *F. miliacea* and *L. hyssopifolia* were in very high population group but *O. sativa* complex and *E. crusgalli* were in the medium population category, *S. grossus* in the low population and other three, *S. guyanensis, S. juncoides* and *I. rugosum* were in very low population. During the off season of 2005, similar trend of weed emergence was observed (Fig. 1).

When the dominance of weed species was compared it was noticed that the most dominat species in 1/2004 was *F. miliacea* (40.5%) followed by *L. hyssopifolia* (21.2%), *O. sativa* (18,2%), *S. grossus* (10.9%), *E. crusgalli* (7.28%) and *S. guyanensis* (1.85%) with other two species sharing only 0.07% of the total emerged seedlings.

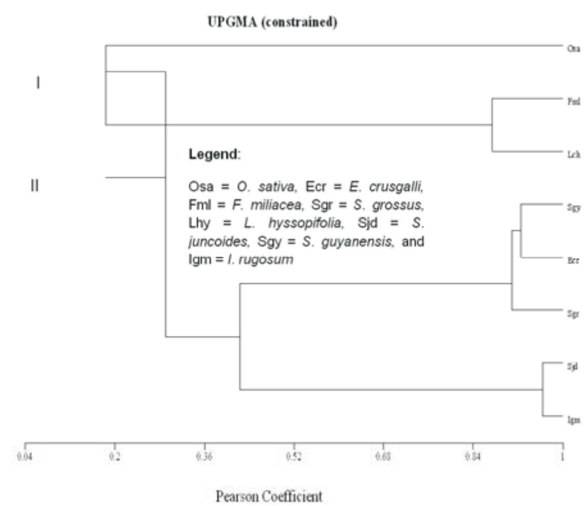

Fig. 4: A dendogram resulting from cluster analysis of eight weed species emerged from soil seedbank using Pearson'e similarity coefficient

In the season 2/2004, the trend was more or less similar, *F. miliacea* (42.3%), *L. hyssopifolia* (32.5%), *O. sativa* (17.1%), *E. crusgalli* (3.97%), *S. grossus* (3.08%) and *S. guyanensis* (0.82%) with other two having 0.24% only. In the season 1/2005, the dominance of weed species was *F. miliacea* (56.8%), *L. hyssopifolia* (31.1%), *O. sativa* (5.5%), *E. crusgalli* (3.3%), *S. grossus* (2.67%) and

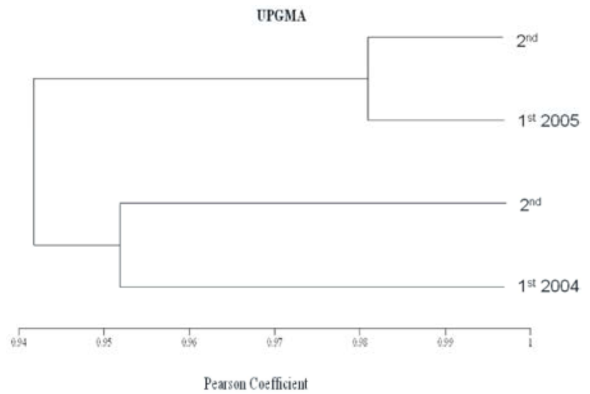

Fig. 5: A dendogram resulting from cluster analysis for four seasons of soil seedbank study using Pearson'e similarity coefficient

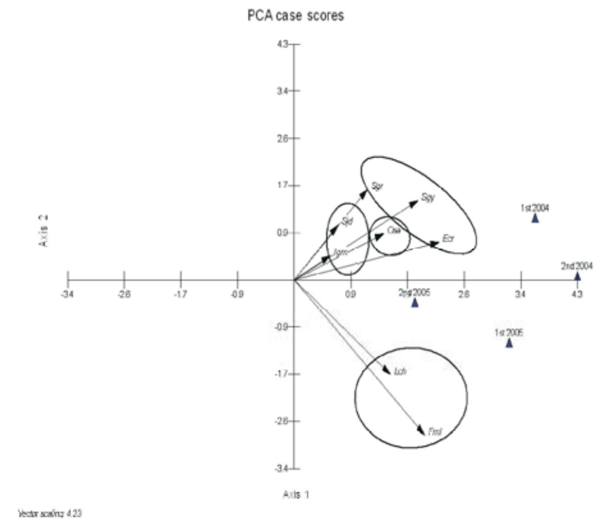

Fig. 6: PCA biplot of distribution of weed species emerged from soil seedbank during four consecutive seasons, based on scores Eigenvalues
Legend: Osa = O. sativa, Ecr = E. crusgalli, Fml = F. miliacea, Sgr = S. grossus, Lhy = L. hyssopifolia, Sjd = S. juncoides, Sgy = S. guyanensis, and Igm = I. rugosum

Table 1: Cluster nodes for weed species with their similarity coefficient values

Node	Group 1	Group 2	Similarity value	Object in group
1	Sjd	Igm	0.964	2
2	Sgy	Ecr	0.925	2
3	Node 2	Sgr	0.909	3
4	Fml	Lhy	0.874	2
5	Node 3	Node 1	0.423	5
6	Osa	Node 4	0.181	3
7	Node 6	Node 5	0.292	8

Table 2: Cluster nodes for four seasons with their similarity coefficient values

Node	Group 1	Group 2	Similarity value	Object in group
1	1st 2005	2nd 2005	0.981	2
2	1st 2004	2nd 2004	0.952	2
3	Node 2	Node 1	0.942	4

S. guyanensis (0.60%). During the off season of 2005, the dominance was *F. miliacea* (59.4%), *L. hyssopifolia* (22.7%), *O. sativa* (11.4%), *E. crusgalli* (3.6%), *S. grossus* (2.02%) and *S. guyanensi*s (0.87%) respectively (Fig. 3).

The dendogram from Unweighted Pair Group Mean Cluster Analysis using simple matching coefficient of eight species of weeds, which summarized the relationships among the weed species emerged from the seedbank, showed that they formed clusters separately into distinct sub-clusters based on their species similarity (Fig. 4, Table 1) and similarity between the seasons (Fig. 5, Table 2). The dendogram can be divided into two major sub-clusters I and II at approximately 28% and 94% similarity. From Table 2 and Fig. 5 it is obvious that the most similar seasons were 1/2005 and 2/2005 with a similarity value of 0.981 at node 1. Principal Component Analysis was also done by plotting the species in the ordinal space between axes 1 and 2 which showed that *E. crusgalli, S. guyanensis* and *S. grossus* are grouped together. These species stand out from the others due to their frequency of occurrence with the value ranged from 36% to 64%. Similarly, *F. miliacea* and *L. hyssopifolia* are grouped together and *S. juncoides* and *I. rugosum* are grouped together (Fig. 6).

DISCUSSION

Information on seed germination behavior is important for planning sustainable weed management. It is clear from this study that the size of weed seedbank varied in different seasons, which might be due to differences in climatic conditions, especially rainfall. The off season (February to May) was characterized by about 220 mm monthly rainfall; whereas the main season (June to September) was characterized by more than double (about 500 mm monthly rainfall). Ismail *et al*. [7, 5] reported that the density of weed seeds in the rice fields of Muda areas ranged from 71228 to 93091 seeds/m^2. These findings were comparatively higher than the present study. In this study, the number of weed seed germination was based on only the natural emergence of weed seedlings from the soil between 44 and 72 weeks. Torresen and Skuterus [8] stated that weather conditions, which vary from year to year, are crucial in contributing to weed seed germination. Dessaint *et al*. [9] pointed out that the type of spatial pattern was dependent on the abundance of the species, the species with low density had either randon pattern or aggregate pattern and species with high densities always had aggregate pattern. Thus in this study *S. juncoides* and *I. rugosum* had random pattern because of their low density, whereas *E. crusgalli, S. guyanensis* and *S. grossus,* who were with medium density had aggregate pattern. The species with high densities such as *F. miliacea, L. hyssopifolia* and *O. sativa* had aggregate pattern. The composition of seedbank is usually spatially heterogenous. Variations among four consecutive seasons in the proportion of weed seeds, were more or less similar but the differences were based on ranking. Pane [4] reported that the predominant weed species in the soil seedbank of Muda area were *Leptochloa chinensis ((*26.9%), *F. miliacea* (22.9%), *Cyperus difformis* (20.2%), *Spenoclea zeylanica* (8.3%) and *Ludwigia octovulvis* (6.3%). However, in the wet-seeded rice field of Muda area, Watanabe *et al*. [10] found that emergence of *Monochoria vaginalis* was related to environmental conditions especially water condition rather than soil seedbank in individual fields. Thus recruitment of species from the seedbank is governed by environmental conditions such as temperature, light and other conditions [11]. In this study the germination period was found different in different seasons (44 weeks to 72 weeks). The reason for this increase in germination time in the soil seedbank might be due to dormancy of seeds. Cousens and Mortimer [12] stated that in general, seeds with only short term dormancy can germinate, however, if buried too deeply could make unable the seeds to germinate. Those with long term dormancy mechanism may be preserved by burial and can only germinate when they are brought closer to the surface.

Through cluster and PCA analyses of the weed species composition, two groups of weed species namely, group I: *F. miliacea, L. hyssopifolia* and Group II: *O. sativa*, *E. crusgalli, S. grossus, S. guyanensis, S. juncoides, I. rugosum* have the highest Pearson's Coefficient index of 0.98, which indicates that distribution of these species are similar throughout the year. This is probably explained the fact that the farmers of the experimental sites did similar kind of activities in their plots and thus the species were well adapted for growing for the next season. Ghashemi *et al*. [13] stated that weed composition and dry weight per unit area are influenced by the kind of tillage and other operations.

The dendogram that resulted from the cluster analysis showed that the study seasons can be grouped into two as shown in Fig. 5. Group one has 1^{st} 2005, 1^{st} 2004 and Node2 (1^{st} 2004/2^{nd} 2005), whereas the other group included 2nd 2005, 2nd 2004 and Node 1 (1^{st} 2005/2nd 2005). The first group meets the group at 0.983 of similarity distance, which means 98% of the species within these two groups was similar. The second cluster however, can be sub-divided into two other groups. The first sub-group consists of only 2^{nd} 2005/2004 season and second sub-group is node 1 i.e. 1^{st} 2005/2^{nd} 2005. Both groups were similar toward each other at 0.942, which means that 94% of the species present were similar. Nevertheless, the two seasons (1^{st} 2004 and 1^{st} 2005) had the highest similarity index (0.966), which suggests the high similarity of weed composition between these seasons. This similarity is related to the fact that the weed control and other management practices adopted by the farmers were similar throughout the years and same species could adapt well and grow back as soon as the land was cleared for the cultivation for next season.

ACKNOWLEDGEMENT

The authors thankfully acknowledged the supports of Universiti Sains Malaysia, Penang, Malaysia and Universiti Malaysia Kelantan, Jeli, Kelantan Malaysia in relation to publication of the article.

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