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Effect of water regimes on germination of weed seeds in a Malaysian rice field

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Abstract

The effect of different water regime treatments on the viability of weed seeds in direct-seeded rice field was evaluated. Five water regime treatments were used namely, continuous flooding condition until maturity, early flooding until 55 DAS (day after sowing) followed by saturated condition until maturity, early flooding until 30 DAS followed by saturated condition until maturity, continuous saturated condition until maturity, and continuous field capacity condition throughout the experimental period. Total weed seed population in soil sampled from March-May. The results showed that weed population dominated by broadleaved weeds (90625 seeds m^{-2}), mainly *Hedyotis corymbosa*, *Monochoria vaginalis* and *Ludwigia hyssopifolia*, followed by sedges (34257 seeds m^{-2}), mostly *F. miliacea* and *Cyperus iria*. The grasses, predominantly *Leptochloa chinensis*, recorded the lowest number in all water regime treatments (20647 seeds m^{-2}). In soils sampled from September-November, sedges (53041 seeds m^{-2}) mainly *Fimbristylis miliacea* along with broadleaved weeds (54624 seeds m^{-2}), predominantly *Monochoria vaginalis* and *Ceratopteris pteridoides*, dominated in most of the water regime treatments, while grasses, mainly *Leptochloa chinensis* and *Panicum repens*, recorded the lowest number (24935 seeds m^{-2}). Ten weed species, which were not observed in the field trials, were recorded from the same soils used in the weed seedbank study. The results showed that differences in water regime treatments did not significantly reduce the viability of weed seeds in the soil. However, a small reduction in seed viability (approximately 8%) was observed in soil samples during the September-November period.

Keyword: Weed seedbank, water regimes, seeds viability.
Abbreviations: DAS-Day After Sowing MARDI-Malaysian Agricultural Research Development Institute.

Introduction

Most agricultural soils contain a large reservoir of weed seeds, which germinate over a period of time reflecting previous history of weed populations (Zimdahl et al., 1988). The weed seedbank is the major source of weeds, especially annual weed species in most tilled agricultural sites (Cardina et al., 1991; Yenish et al., 1992). Watanabe and Azmi (1995) and Labrada (2002) emphasized that the seedbank is as important as the aboveground vegetation when assessing weed abundance. Many annual weed species produce a large number of seeds each year. However, estimates indicate that only 2 to 6% of weed seeds produced develop into seedlings in a growing season. If potential weed populations could be predicted before crops are sown, it might be possible to reduce the impact of weeds by altering crop selection or changing sowing times to avoid major weed problems (Radosevich and Holt, 1984; Ball and Miller, 1990). It has been suggested that estimates of seed bank populations in arable soils could be used to predict weed infestation, which could improve decision making for the management of specific weed problems (Ball and Miller, 1989). The control of weed populations through the manipulation of the weed seedbank is an important weed management option (Sago, 2000). Predicting potential weed emergence is also fundamental in the development of strategies for weed control and is an important tool for the estimation of weed competition, crop yield loss, need for herbicides, financial returns and weed seed production at the end of the growing season (Forcella, 1992). Furthermore, the remaining seeds in the soil are also a major concern (Cardina and Sparrow, 1996). Water management has become an important tool in rice farming. Variation in soil moisture conditions can affect weed seed emergence and viability differently (Mercado, 1979). In lowland rice, Smith and Fox (1973) observed that flooding to 5.1 cm effectively reduced the germination of *Echinochloa colona* seeded 1.3 cm deeper with a 35 % germination in Nova 66 rice seeds. The other associated weed species, *Bracharia* and

Sesbania, responded similarly. However, some aquatic weeds germinate under water and this behavior has been used as a guide in their control (Mercado, 1979). In fields known to be heavily infested with 'aquatic' weeds, germination of the seeds can be stimulated by flooding the field and, after seedlings emerged, control measures can be applied to these weed (Mercado, 1979). Ismail et al. (1996) also indicated that emergence of *E. crus-galli*, *E. colona*, *C. iria*, *L. hyssopifolia* and *Rhyncospora corymbosa* was lower in soils flooded up to 4 cm water depth compared to seeds sown at all sowing depths in saturated soil. Flooding up to a depth of 10 cm prevented germination of most weed seeds and killed a majority of weed seedlings (Williams et al., 1990). However, constant flooding to a depth of 2 cm or more could check the build-up-of *Echinochloa crus-pavonis* (Kent and Johnson, 2001). Smith and Fox (1973) had also reported that only a few or no seedlings of *E. crus-galli, Brachiara platyphylla*, *Aeschynomene virginica*, and *Sesbania exaltata* emerged when the soil was flooded, but at field capacity or saturated soil, all species grew readily. Texas weed (*Caperonia palustris*) seeds did not germinate under saturated or flooded conditions, but seeds survived flooding and germinated (23 – 25%) after flood removal (Koger, 2004). Wrinkle grass (*Ischaemum rugosum*) seeds failed to germinate when subjected to all depths of inundation (4 – 12 cm), except for those inundated with 2 cm, which registered 2% germination (Moody, 1981). In agricultural systems where irrigation and flooding are common practices (e.g. rice), the environment in which weed seeds have to germinate is characterized by the existence of low oxygen concentrations. Low oxygen concentration terminates dormancy in seeds of some weed species. This is the case with *Echinochloa turnerana* (Conover and Geiger, 1984) and *Leersia oryzoides* (Rosa and Corbineau, 1986), two well-known weeds of rice crops. However, detailed information on the presence, composition and viability of weed seeds is limited due to changes in water availability in Malaysian rice fields. In recent years, there has been an increasing need for more information on the occurrence and distribution of weed seeds in the soil so the appropriate control measures can be adopted. The present study was designed to determine the relative influence of different water regime treatments on the composition of the weed seedbank and its viability in Malaysian rice fields. Knowledge on the nature, composition and viability of weed seeds in the soil is essential for more effective weed control, mainly due to variability in water conditions.

Results and Discussion

Effect of water regime treatments on weed seedbank composition

Seeds of twenty one weed species representing all three major weed groups (broadleaved weeds, grasses and sedges) were identified in soils taken from the 20 rice plots treated with five different water regime treatments during September-November and March-May, 2004. The broadleaved weeds included a fern, namely *Ceratopteris pteridoides* (Hook) Hieron. In general, the weed seed composition were not significantly influenced by water regime treatments, where broadleaved weeds showed higher dominance than grasses and sedges in all water regime-treated soil samples (Tables 1–4). In soil samples taken from the plots during September-November 2004, the weed seed composition in rice plots treated with continuous flooding (T1), flooded until 55 DAS followed by saturated conditions (T2) and continuously saturated (T4) conditions were largely dominated by *Hedyotis corymbosa* (L.) Lam. (Table 1), which can be attributed to the large number of total weed seeds in these soils (Table 2). *Leptochloa chinensis* (L.) Nees. and *Monochoria vaginalis* (Burm. f.) Presl. were also highly dominant in T1 and T2 soil samples. In soil samples flooded until 30 DAS followed by saturation (T3) and under continuous field capacity conditions (T5), seeds from two broadleaved species [*Ludwigia hyssopifolia* (G. Don) Exell, *M. vaginalis*] and two sedges [*Cyperus iria* L. and *Fimbristylis miliacea* (L.) Vahl.] were most abundant. A similar pattern was observed in soil samples taken during the September-November (2004), where seeds from broadleaved weeds again largely dominated in all water regime-treated soil samples compared to the other weed groups (Tables 3 and 4). However, sedges, namely *F. miliacea* were found to be the most prevalent species in all water regime-treated soils (Table 3). Interestingly, seeds of grasses, which were more dominant than sedges in the previous season, were however significantly restricted in the current season. Aquatic broadleaved weed *M. vaginalis* was found to be dominant in soils under treatments T1, T2, T4, and T5, while *C. pteridoides* which was less dominated in the previous season showed high dominance in T1, T2, T4 and T5. However, seeds of broadleaved weeds such as *H. corymbosa* and grasses, mainly *L. chinensis*, which were highly dominant in the majority of water regime-treated soils in the previous season, were found to be less dominant in the current season. The dominance of *L. hyssopifolia*, which was relatively high in March-May 2004, also decreased in September-November 2004. Meanwhile, two weed species; *Panicum repens* L. and *Microcarpaea minima* (Koen) Merr., which were not recorded in the soil samples in the previous season were found in the soil samples in the current season, while two sedges, namely *C. difformis* and *C. haspan* and the broadleaved weed *Sphenoclea zeylanica* Gaertn., which were present in March-May 2004 water regime-treated soils were not recorded in the latter season. The variability in the dominance of a weed species, as well as the presence and absence of seeds of some weed species between the two planting seasons is attributed to the uneven distribution of the weed species in the plots. Most weed species were scattered around the plots, and many were distributed in small patches (data not shown), and hence may have escaped during samplings, thus affected the weed seedbank spectrum and size in this study. It is also plausible that these seeds may have been brought into the soils by contaminated irrigation water. In addition, other factors such as water level, temperature, salinity and nutrient levels in the soil can also influence species composition in the seedbank, longevity of seeds, germination success, and seedling recruitment from the seedbank (Johnson, 2004). Variation in germination of weed seeds in the soil under different water conditions has been reported earlier. Johnson (2004) observed that flooding conditions reduced the number of viable seeds in the soils especially grasses and sedges, while inundation suppressed germination of certain weed species in the seedbank (Smith et al., 2002; Williges and Harris, 1995). Watanabe et al. (1996) observed that emergence of weed seeds was related to environmental factors such as water condition. Ismail et al. (2002) in their survey of rice fields in Muda area also revealed that the seeds of broadleaved weeds, namely *Utricularia aurea* and *Sphenochloa zeylanica* were most dominant in dry and wet seeded rice fields compared to

Table 1. Effect of water regime treatments on composition of total weed seeds (% I. V. value; soils sampled in March-May 2004).

Weed group	Weed species	Water regime treatments				
		T1	T2	T3	T4	T5
Broadleaved weeds	*Bacopa rotundifolia* (Michx.) Wettst.	1.31	1.69	1.06	1.00	1.81
	Ceratopteris pteridoides (Hook) Hieron	5.48	1.29	3.71	3.16	8.32
	Hedyotis corymbosa (L.) Lam.	32.43	29.81	13.26	29.22	1.01
	Limnophila erecta Benth.	1.25	1.04	1.43	1.16	1.17
	Limnocharis flava (L.) Buchenau	6.02	4.80	5.35	10.16	8.26
	Ludwigia hyssopifolia (G. Don) Exell	8.51	8.93	16.73	13.42	17.96
	Lindernia pusilla (Willd.) Bold.	1.00	0.50	1.00	0.52	0.74
	Monochoria vaginalis (Burm. f.) Presl.	10.10	14.45	14.63	6.23	19.04
	Najas graminea Del.	0.29	0.27	0.82	0.72	1.35
	Sagittaria guyanensis H. B. K.	1.04	1.48	1.79	0.85	2.55
	Sphenoclea zeylanica Gaertn.	0.99	2.04	2.28	4.42	1.35
Grasses	*Echinochloa colona* (L.) Link.	1.15	1.46	1.02	2.02	7.55
	Echinochloa crus-galli (L.) P. Beauv.	0.46	1.11	0.88	0.85	1.58
	Leptochloa chinensis (L.) Nees.	15.40	15.84	9.34	5.90	1.29
	Oryza sativa L.	0.37	0.71	1.02	0.39	0.46
Sedges	*Cyperus difformis* Roxb.	0.33	0.22	0.61	1.53	0.58
	Cyperus haspan L.	0.15	0.50	0.36	0.28	0.28
	Cyperus iria L.	5.99	5.99	9.92	6.53	11.52
	Fimbristylis miliacea (L.) Vahl.	7.72	7.87	14.76	11.63	13.17

T1 = continuous flooded condition: T2 = early flooding for the first month followed by saturated: T3 = early flooding up to panicle initiation stage followed by saturated: T4 = continuous saturated condition: T5 = continuous field capacity condition.

Table 2. Effect of water regime treatments on weed seed populations (number m^{-2}; soils sampled in March-May 2004).

Weed group	Weed species	Water regime treatments				
		T1	T2	T3	T4	T5
Broadleaved weeds	*Bacopa rotundifolia* (Michx.) Wettst.	2528e	2537e	1296f	1435f	2185d
	Ceratopteris pteridoides (Hook) Hieron	10556d	1926e	4518e	4519ef	10037c
	Hedyotis corymbosa (L.) Lam.	62408a	44622a	16148b	41852a	1222d
	Limnophila erecta Benth.	2407e	1556ef	1741ef	1667f	1407d
	Limnocharis flava (L.) Buchenau	11593d	7186d	6519d	14556c	9963c
	Lindernia pusilla (Willd.) Bold.	1926e	741f	1222f	741g	889d
	Ludwigia hyssopifolia (G. Don) Exell	16371cd	13371c	20370a	19222b	21667a
	Monochoria vaginalis (Burm. f.) Presl.	19445c	21630b	17815ab	8926de	22963a
	Najas graminea Del.	556e	407f	1000f	1037fg	1630d
	Sagittaria guyanensis H. B. K.	2000e	2222e	2185ef	1222f	3074d
	Sphenoclea zeylanica Gaertn.	1908e	3056e	2778ef	6333e	1630d
Grasses	*Echinochloa colona* (L.) Link.	2222e	2185e	1240f	2889f	9111c
	Echinochloa crus-galli (L.) P. Beauv.	889e	1667ef	1074f	1222f	1908d
	Leptochloa chinensis (L.) Nees.	29630b	23704b	11370c	8444de	1555d
	Oryza sativa L.	720e	1060ef	1240f	560g	560d
Sedges	*Cyperus difformis* Roxb.	630e	333f	741f	2185f	704d
	Cyperus haspan L.	296e	741f	444f	398g	333d
	Cyperus iria L.	11519d	8963d	12074c	9352de	13889b

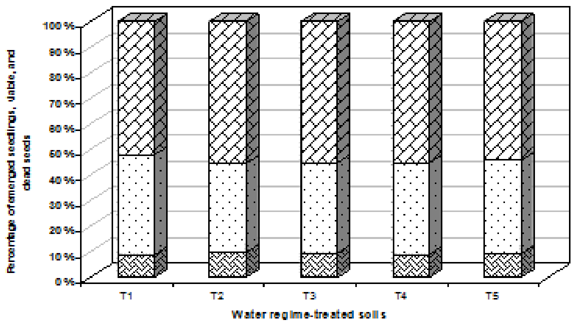

Fig 1. Effect of water regime treatments on viability of weed seeds (%; soils sampled in March-May 2004). T1 = continuous flooded condition: T2 = early flooding up to panicle initiation stage (55 DAS) followed by saturated: T3 = early flooding for the first month (30 DAS) followed by saturated: T4 = continuous saturated condition: T5 = continuous field capacity condition.

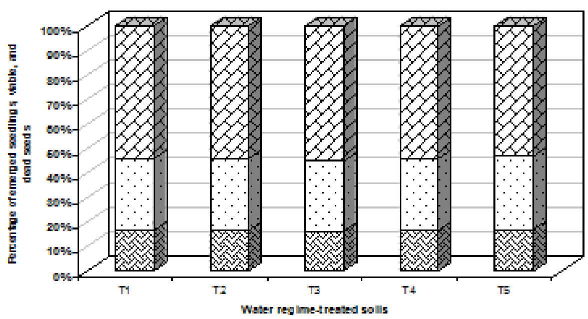

Fig 2. Effect of water regime treatments on viability of weed seeds (%; soils sampled in September-November 2004). T1 = continuous flooded condition: T2 = early flooding up to panicle initiation stage (55 DAS) followed by saturated: T3 = early flooding for the first month (30 DAS) followed by saturated: T4 = continuous saturated condition: T5 = continuous field capacity condition.

sedges and grasses. Kamoshita et al. (2010) also found that extreme water deficiency in the previous season had a negative influence on the size of the weed seedbank in the following year. Our results however, were clearly contradictory to previous reports. These results indicate that difference in the weed seedbank composition between the five different water regime-treated soils was relatively small and not significant. In contrast, the apparent weed populations and compositions in the same plots, from where the soil samples taken were significantly varied under different water regime treatments in our previous aboveground weed survey (Juraimi et al., 2011). Clearly, in depth investigations are needed to quantify more precisely the effects of water regime treatments on the weed seedbank in rice field soils.

Total weed seedbank and viability under different water regimes

The range of 121,115-200,201 m^{-2} in the March-May 2004 and 95,716-148,113 m^{-2} in September-November 2004 samples were observed in all water regime-treated soils, in terms of total seedlings (and seeds). In March-May 2004 season, soil samples receiving treatment T1 recorded the highest number of weed seed reserves (200,201 m^{-2}), while the lowest number was obtained in soils receiving treatment T5 (121,115 m^{-2}). In the September-November 2004 samples, a slight reduction in the number of weed seed reserves was observed. This was probably due to no new seed input into the soils since all weeds that emerged in the plots were eradicated completely.

The highest number of total weed seed reserves was obtained from soils receiving treatment T1 (148,113 m^{-2}), while soils receiving treatment T3 produced the lowest number of total weed seed reserves (95,716 m^{-2}). Meanwhile, differences in water regime treatments applied onto soils did not have any significant effect on the viability of weed seeds. The results showed that the number of emerged seedlings in all water regime-treated soils was significantly higher than potentially viable and dead seeds; comprising of more than half the total number of weed seed reserves for soils sampled in both planting seasons (Figs 1 and 2).

However, in the September-November 2004 samples, the percentage of potentially viable seeds decreased to approximately 8%, and this was accompanied by an increase in the number of dead seeds to 8% in all soil samples (Fig 2). There is no clear logical explanation for these observations since the reduction was observed in all five water regime-treated soil samples. The results obtained in the present study were in direct contrast to previous studies. Johnson (2004), observed that flooding reduced the total number of weed seed germination and total seed numbers in the soils. Similarly, Smith et al. (2002) also reported the effectiveness of flooding in suppressing germination from the seedbank. Thus, it appears that detailed studies over a longer period is required to verify the effect of water regime treatments on the composition and viability of weed seeds in the soil.

Materials and methods

Experimental location

The experiment was carried out under controlled environment in a glasshouse at the Weed Biological Control Laboratory, Faculty of Agriculture, Universiti Putra Malaysia (UPM), Selangor, Malaysia.

Soil sampling for weed seedbank determination

Soil samples were taken from the twenty rice weeded plots (weed control methods applied) in an experimental field at MARDI Bertam Rice Research Station in Seberang Perai, Penang (5° 32’ 47.64” N, 100° 27’ 58.91” E), which were exposed to five different water regime treatments for 2 planting seasons continuously (March-May 2004 and September-November 2004).

Table 3. Effect of water regime treatments on composition of total weed seeds (% I. V. value; soils sampled in September-November 2004)

Weed group	Weed species identified	Water regime treatments				
		T1	T2	T3	T4	T5
Broadleaved weeds	*Bacopa rotundifolia* (Michx.) Wettst.	1.33	1.82	4.65	2.37	1.90
	Ceratopteris pteridoides (Hook) Hieron	15.53	17.29	8.42	11.35	14.09
	Hedyotis corymbosa (L.) Lam.	7.50	5.80	9.02	9.52	13.31
	Limnophila erecta Benth.	2.13	1.24	2.34	6.15	1.61
	Limnocharis flava (L.) Buchenau	3.78	5.51	4.49	3.23	2.63
	Ludwigia hyssopifolia (G. Don) Exell	2.59	0.68	2.37	0.69	0.88
	Lindernia pusilla (Willd.) Bold.	3.20	2.38	4.89	8.57	6.48
	Microcarpaea minima (Koen) Merr.	0.15	0.00	0.24	0.20	0.50
	Monochoria vaginalis (Burm. f.) Presl.	16.00	12.93	12.32	7.56	11.83
	Najas graminea Del.	0.40	1.99	0.32	0.98	0.37
	Sagittaria guyanensis H. B. K.	4.13	6.19	2.70	2.72	1.98
Grasses	*Echinochloa colona* (L.) Link.	3.20	4.14	3.18	4.86	4.95
	Echinochloa crus-galli (L.) P. Beauv.	4.20	5.61	5.09	6.40	7.32
	Leptochloa chinensis (L.) Nees.	8.10	9.20	12.04	5.64	9.30
	Oryza sativa L.	0.19	0.35	0.04	0.20	0.00
	Panicum repens L.	0.00	0.00	0.00	0.50	0.26
Sedges	*Cyperus iria* L.	9.75	8.23	13.07	11.74	8.19
	Fimbristylis miliacea (L.) Vahl.	17.83	16.63	14.82	17.31	14.41

T1 = continuous flooded condition: T2 = early flooding for the first month followed by saturated: T3 = early flooding up to panicle initiation stage followed by saturated: T4 = continuous saturated condition: T5 = continuous field capacity condition.

Table 4. Effect of water regime treatments on weed seed populations (number m^{-2}; soils sampled in September-November 2004)

Weed group	Weed species identified	Water regime treatments				
		T1	T2	T3	T4	T5
Broadleaved weeds	*Bacopa rotundifolia* (Michx.) Wettst.	1963e	2445f	4333c	3482f	2667f
	Ceratopteris pteridoides (Hook) Hieron	23000a	23185a	7852bc	16685b	19815a
	Hedyotis corymbosa (L.) Lam.	11111b	7778d	8407bc	14000bc	18722ab
	Limnophila erecta Benth.	3148d	1667fg	2185d	9037d	2259f
	Limnocharis flava (L.) Buchenau	5593cd	7389d	4185c	4741f	3704f
	Lindernia pusilla (Willd.) Bold.	4741cd	3185f	4556c	12593c	9111d
	Ludwigia hyssopifolia (G. Don) Exell	3833d	908g	2213d	1019g	1232fg
	Microcarpaea minima (Koen) Merr.	222e	-	222e	296g	704g
	Monochoria vaginalis (Burm. f.) Presl.	23704a	17333b	11481ab	11111c	16630b
	Najas graminea Del.	593e	2667f	296e	1435g	519g
	Sagittaria guyanensis H. B. K.	6111c	8297d	2518d	4000f	2778f
Grasses	*Echinochloa colona* (L.) Link.	4741cd	5556e	2963d	7148e	6963e
	Echinochloa crus-galli (L.) P. Beauv.	6222c	7519d	4741c	9408d	10296d
	Leptochloa chinensis (L.) Nees.	12000b	12333c	11222b	8296de	13074c
	Oryza sativa L.	280e	470g	40e	294g	-
	Panicum repens L.	-	-	-	741g	370g
Sedges	*Cyperus iria* L.	14445b	11037cd	12185a	17259b	11518cd
	Fimbristylis miliacea (L.) Vahl.	26408a	22296a	13815a	25444a	20260a

In a column, means followed by the same letter are not significantly different at 5% level by Least significance differences. T1 = continuous flooded condition: T2 = early flooding up to panicle initiation stage (55 DAS) followed by saturated: T3 = early flooding for the first month (30 DAS) followed by saturated: T4 = continuous saturated condition: T5 = continuous field capacity condition.

Details of five applied water regime treatments and the rice plots were described in Juraimi et al. (2011). Soil sampling for weed seedbank analysis was conducted twice from the same plots (but different sampling times): in late March-May 2004 and in late September-November 2004 after the rice harvest but before land preparation (dry tillage) for the next planting season. Soil samples from each individual plot were taken to a depth of 15 cm using a standard 7 cm diameter soil core sampler (Elamotte™). A total of 60 points of soil samples were collected from each plot as suggested by Dessaint et al. (1996) and Ambrosio et al. (1997).

Weed seedling counts

Bulked soil samples were partially air-dried and any clods were broken into smaller pieces by hand. All soil samples from each plot were then thoroughly mixed by passing through a 6-mm mesh sieve. Each soil sample was placed in a plastic bucket with a diameter of 35 cm and 50 cm height and the buckets were placed in a glasshouse. The weed seedbank evaluation was carried out using the seedling germination method described by Ball and Miller (1989) and subsequently employed by several researchers (Swanton et al. 2000; Vanasse and Leroux, 2000; Moonen and Barberi, 2004; Carter and Ivany, 2006; and Kamoshita et al., 2010). The emerged weed seedlings were identified, counted and then removed. Seedling identification was based on several seedling keys (Soerjani et al., 1987; Noda et al., 1994; Harada et al., 1996; and Marita et al., 1999). Unidentified seedlings were transplanted into pots and grown until their identity could be verified. Emerged weed seedlings were recorded as apparently viable following water regime treatments in the plots. Seedling counts were converted to numbers m^{-2} at 10 cm soil depth as described by Pane (1997) and Mahfuza (2006). Observations were made for ten 4-week growth periods (Pane, 1997).

Viability test of non-germinated seeds

In addition to the seedlings germination method, a viability test of the non-germinated weed seeds extracted from the soils was also carried out in this study in order to provide a better estimation and indication of the actual seedbank in the soil (Ball and Miller, 1989). After the ten 4-week periods of weed seedling counts were completed, all remaining seeds in the soils were separated and identified by the method described by Wilson et al. (1985). All weed seeds separated from organic matter by a filter paper (Krishnasamy and Seshu, 1989). Seed viability was determined by 'destructive crushing' using gentle pressure to each seed with a pair of forceps. Seeds containing undecayed endosperm (resisting pressure) were recorded as potentially viable (dormant seeds) and those that did not resist pressure were assumed as dead seeds. This method was similar to that described by Roberts and Ricketts (1979) and subsequently employed by Forcella (1992) and Rahman et al. (2001). Potentially viable seeds were converted to numbers m^{-2}. The dominance of each weed seeds species was calculated by importance value (I.V.) based on the following standard equation (Pane, 1997; Mahfuza, 2006):

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

Data collection and statistical analysis

All treatments were arranged in randomized complete block design with four replications. Statistical analysis was performed using the analysis of variance procedure in the Statistical Analysis System Software (SAS, 9.1 version 2004) and means were tested using the least significance difference test at the 5% level of probability.

Conclusion

Unlike the aboveground weed seedling composition, weed seedbank composition in rice field soils was not greatly affected by water regime treatments. In total, seeds of 21 weed species were recorded, with seeds of broadleaved weed species being the most abundant in all water-regime treated soils. However, seeds of several sedges and grass weed species were also dominant in some water regime-treated soils. Differences in water regime treatments also did not show significant variation in the viability of weed seeds in the soils, since there were a large number of seedlings compared to dead seeds in soils in both planting seasons. Thus, detailed studies over longer periods is needed to advise a beneficial weed management options in rice fields with respect to weed seedbank composition and influence of water conditions on their longevity in the soil.

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