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Enhancing Rice Establishment in Anaerobic Direct Seeding Through Control of Weedy Rice

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ABSTRACT
A glasshouse and field trial was conducted to investigate the effects of pre-treated rice seeds on cultivated rice and weedy rice establishment in direct seeding planting system. Treatments applied were wet seeding (T1) and water (anaerobic) seeding at 10 cm flooding depth (T2). In the glasshouse trial, water seeding significantly reduced weedy rice seedling emergence almost three-fold compared to control; the usage of pre-treated seeds in both seeding methods significantly increased the viability of cultivated rice compared to weedy rice. The weedy rice population was significantly decreased (32%) in the water seeding plot compared to wet seeding at 90 DAS in season 2/04 in the field. The water seeding technique also profoundly reduced weedy rice population by about 50% at both 60 and 90 days after sowing (DAS) the following season (season 1/05) compared to wet seeding. The use of pre-treated seeds for the anaerobic direct seeding technique had an advantage on seedling vigour that out- competed the growth of weeds, and increased rice seeds viability.

Keywords: Oryza sativa L., weeds, yield loss, pre-treated seeds, water seeding

INTRODUCTION
Weedy rice poses a serious threat to the rice industry in Malaysia. The weeds are the outcome of natural crossings between selected rice varieties with wild rice species, and have been reported to cause severe rice yield losses (Wahab and Suhaimi 1991). Weedy rice is also known as red rice in USA and Latin America (Olofsdotter *et al*. 2000). Lately, due to its grain shattering characteristics, it was named scientifically as Oryza sativa var. spontanea (Bui 2000; Gupta and Upadhyaya 2000) or padi angin in Malaysia. Weedy rice was observed as early as 1988 in Projek Barat Laut Selangor (PBLS). In the second season of 1993, several fields in PBLS (Northeast Selangor Project), a rice-granary area covering a total of 700 ha were reported to be infested with this weed. According to Watanabe *et al*.

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(2000), the dropped seeds supplemented with sown seeds during the drought season developed into the next crop. Under field conditions, weedy rice dispersed about 970 kg ha^{-1} seeds in one season indicating a great harvest loss and an increase in seed bank (Rezaul *et al*. 2004). One of the weedy rice variants was found to shatter as high as 51% of its grains at 95% ripening compared to rice varieties MR84 and MR214, which had less than 0.05% shattered seeds (Rezaul *et al*. 2004).

Anaerobic seeding involves broadcasting pre-germinated seeds onto standing water in rice fields (Yamauchi 1995). Rice seeds treated with peroxide materials and sown in flooded soils have shown some promising results in enhancing rice establishment. The rapid seedling emergence of this treated seeds showed increased shoot and root growth for three-day-old rice seedlings in a laboratory experiment (Syed Omar *et al*. 2004). Nevertheless, the effectiveness of using pre-treated rice seeds in controlling germination and emergence of weedy rice in anaerobic direct seeding (water seeding) is yet to be studied. Thus, this experiment was carried out to investigate the effect of peroxide pre-treated rice seeds on cultivated rice and weedy rice establishment in direct seeding in glasshouse and field trials.

MATERIALS AND METHODS

Glasshouse Trial

The experiment was carried out in a glasshouse in Universiti Putra Malaysia (UPM). Weedy rice seeds collected from a rice field before crop harvest in Sawah Sempadan, Selangor was used for the glasshouse experiment. MR 219 rice seed variety which is commonly used by rice farmers was selected and treated with 1% ZAPPA-PLUS® (peroxide material) solution for the experiment. The soil used for this study was collected from the rice field at Sg. Leman, Sekinchan, Selangor (3° 31'N, 101° 112' E). It belongs to the fine, mixed and isohyperthermic family of Tropic Fluvaquent. The soil was dried and sieved using a 1-cm sieve for homogeneity. Ten soil samples weighing 100 g each were collected randomly and tested for off-type rice seeds and weedy rice seeds by sieving using a 2-mm sieve opening. The soil samples were later transferred into petri dishes and kept saturated to facilitate seed germination for seven days to ensure that the soil used was free from weedy rice and off-type rice seeds. Observations showed no germination of rice seeds during this period. The sieved (1.0 cm) soil was transferred into 25.5 cm diameter x 40 cm height experimental containers up to 15 cm depth. Both weedy rice seeds and pre-germinated MR 219 rice seeds were sown on the soil surface. Treatments given were (i) wet seeding method (T1) and (ii) water seeding method, (10 cm flooding depth) [T2]. Pests and diseases control was done as required. Fertiliser was applied according to standard practice (MARDI 2004) but adjusted to suit glasshouse conditions to minimise root injury. Both treatments were replicated ten times and arranged in a complete randomised design (CRD). The effects of using pre-treated seeds in water seeding on the seedling emergence and tillering ability of weedy rice were subjected to unpaired t-test and compared at $p \geq 0.05$. Statistical Analysis System (SAS) software version 8.12 was used for all the statistical analysis.

Field Trials

Pre-experimentation Information

The field experiment was carried out at Sungai Leman, Sekinchan, Selangor (3° 31'N, 101° 112' E) due to its high weedy rice infestation for season 2/04 and season 1/05. The gross yield and average weedy rice population were recorded before the experiment. Fifty sampling points were taken using one meter square quadrates to estimate the average number of weedy rice panicles m^{-2}. The average number of weedy rice panicles m^{-2} was 82 and cultivated rice yield recorded was 4.3 t ha^{-1}.

Treatments

The rice field measuring 200 m x 60 m (1.2 ha) was divided equally into two plots measuring 100 m x 60 m. A ridge was built in the centre to divide both plots and to ease irrigation management. The details of the treatments are shown in Table 1.

Weedy Rice Seed Bank Determination

The weedy rice seed bank was evaluated by using the tray method (Cardina and Sparrow 1996) and the extraction method (Ball and Miller 1989) before seed broadcasting for seasons 2/04 and 1/05. The number of emerged seedlings (tray method) and the number of germinated weedy rice seeds (extraction method) are commonly used to estimate the actual seed bank in the soil.

Rice Seed Treatment and Seed Broadcasting

MR 220 rice seeds which was a sister line of MR 219 was selected for the field trials. The rice seeds were treated with ZAPPA-PLUS® (peroxide material) solution to supply oxygen. Seeds were soaked in ZAPPA-PLUS for 24 h, and incubated until coleoptile/emergence. The rate recommended (1.5L ZAPPA-PLUS in 100 L water for 100 kg seeds) by the manufacturer was used. The pre-germinated seeds were sown at a rate of 150 kg ha^{-1} (MARDI 2002). Standard land preparation (MARDI 2002) was carried out for both plots before broadcasting the seeds. Crop maintenance was done accordingly as recommended by MARDI (2002).

TABLE 1
Treatment plots for seasons 1 and 2

Treatments	Water management
T1: Wet seeding (control) (rear)	- The field was kept saturated at seed broadcasting and water was introduced seven days after seeding to 10 cm flooding depth.
T2: Water seeding (front)	- Continuous standing water was practised from seeding day until 20 days before harvest at 5 to 10 cm flooding depth

Determination of Weedy Rice Population

Twenty-five sampling points were taken systematically using 1 m^{-2} quadrates at 60 and 90 DAS to estimate the average number of weedy rice panicles m^{-2} for each treatment plot. Weedy rice tillers/panicles were distinguished by its light green shade of leaf (MARDI 2004) and its grain shattering characteristics (Azmi *et al*. 2004; Ferrero *et al*. 1999; Noldin 2000). Log transformation was done for count data before statistical analysis was carried out. Means of treatments for weedy rice population for seeding methods in each season were subjected to unpaired t-test and compared at $p \leq 0.05$ using SAS version 8.12.

Determination of Gross Rice Yield

To estimate the gross rice yield, eighteen samples of 1 m^{-2} quadrates were placed randomly on each plot. The weedy rice panicles were removed and the remaining panicles (cultivated rice) were harvested, dried, threshed, weighted and recorded as gross yield. The actual gross rice yield which was harvested using a harvester was recorded for the season. Analysis of variance was used to analyse the significance of the treatment effects. Means of treatments for gross rice yield for seeding methods in each season were subjected to unpaired t-test and compared at $p \leq 0.05$. SAS version 8.12 was used.

RESULTS AND DISCUSSION

Glasshouse Trial

Water seeding significantly reduced weedy rice seedling emergence by almost three-fold compared to control (wet seeding) at 14 DAS (*Fig. 1*). It has been reported that early emergence of weedy rice gave a competitive advantage leading to poor establishment of rice cultivar (Watanabe *et al*. 2000). However, our results indicate that weedy rice emergence was impeded in water seeding.

The number of cultivated rice tillers was significantly higher compared to weedy rice in wet seeding (*Fig. 2*). This was due to the enhanced emergence of cultivated rice after treatment. The decline in weedy rice tillers in water seeding (*Fig. 3*) confirms findings by Azmi *et al*. (2004) that pre-germinated seeds under water at 5 to 10 cm depth had significant impact on weedy rice population. Findings by De Avila and Marchezan (2000) further confirmed that the occurrence of anaerobic conditions reduced the germination rate of weedy rice seeds (*Fig. 3*). Thus, water seeding plays an important role in delaying the emergence of weedy rice compared to control (wet seeding). The delayed emergence of weedy rice tillers in water could be attributed to minimised light penetration created by the leaf canopy of rice cultivars (Mortensen *et al*. 2000).

Field Trial

Observation showed no emergence of weedy rice seedlings after ten months (Pane 1996) for the tray method. The weedy rice seed bank was reduced to 43% in season 1/05 compared to season 2/04 for the extraction method. The tray method showed similar trends where seed bank was reduced by almost 99% compared to the previous season (Table 2).

TABLE 2
Weedy rice seed bank estimation in rice field

Method	Seed bank	
	Season 2/04	Season 1/05
Extraction (million seed/ha)	60	34.0
Tray (million seedlings/ha)	1160	1.2

TABLE 3
Mean weedy rice population at 60 and 90 das

Seeding method	Days after sowing (DAS)	
	60	90
	weedy rice panicles m^{-2}	
Season 2/04		
Wet (control)	20^{a}	97^{a}
Water	20^{a}	66^{b}
Season 1/05		
Wet (control)	$14^{a'}$	$21^{a'}$
Water	$7^{b'}$	$10^{b'}$

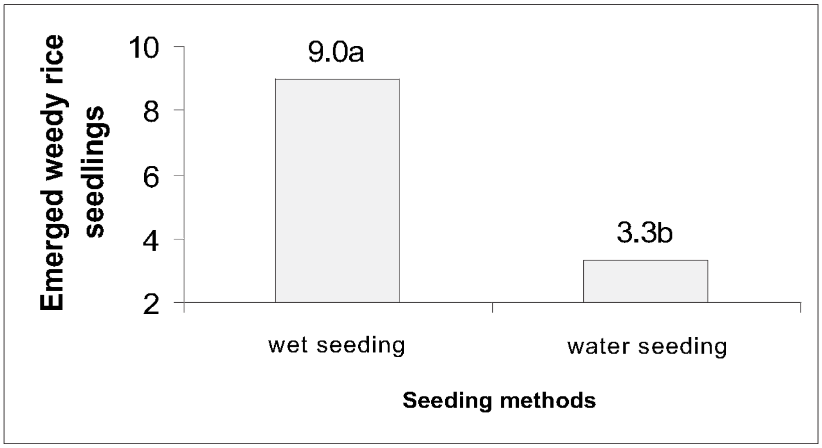
Note: Individual values with different letters in columns are significantly different between means using DNMRT at $P \leq 0.05$.

Viability of weedy rice seeds in the soil for long periods has been reported by Watanabe *et al*. (1996). The weedy rice seedling establishment after prolonged storage reaffirms the severity and threat it poses to subsequent rice cultivation (Azmi *et al*. 2000).

However, the drastic reduction of weedy rice seed bank in season 1/05 compared to season 2/04 is believed to be due to the standard of land preparation and management techniques adopted for rice cultivation, which includes tillage and land leveling operations. The increase in seed bank for the extraction method confirms the dormancy of weedy rice seeds that has been discussed by Watanabe *et al*. (1996). The extraction method was able to identify viable seeds by the triphenyl tetrazolium chloride (TTC) test, thus giving a better estimate of seed bank compared to the tray method.

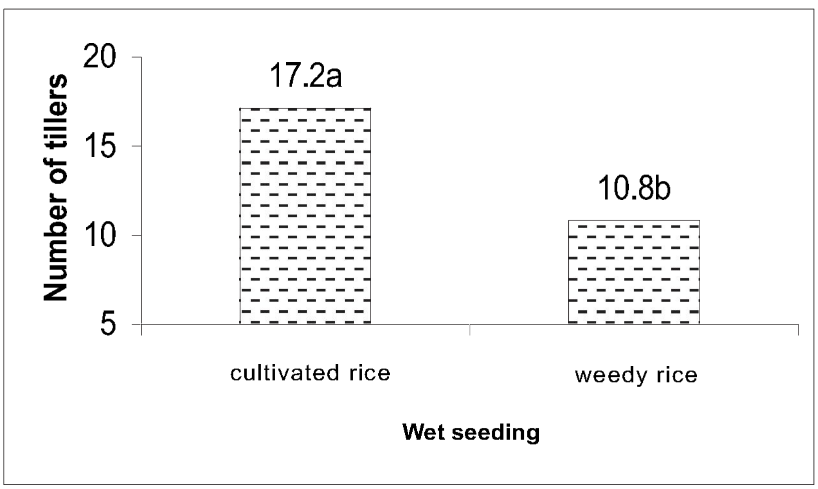
There were no significant differences between wet and water seeding methods for season 2/04 at 60 DAS (Table 3). However, there was a sharp significant decrease in weedy rice population at 90 DAS in the water seeding plot compared to wet seeding, which was almost 32% for season 2/04. The water seeding technique significantly reduced weedy rice population by 50% and 52% at 60 and 90 DAS respectively in season 1/05 compared to wet seeding.

Broadcasting pre-germinated seeds under water at 5-10 cm depth had significant effects on reducing weedy rice population. Muhammad and Azmi (2005) further support this finding as they observed a 93% reduction in weedy rice population in two seasons of planting when water seeding was carried out.



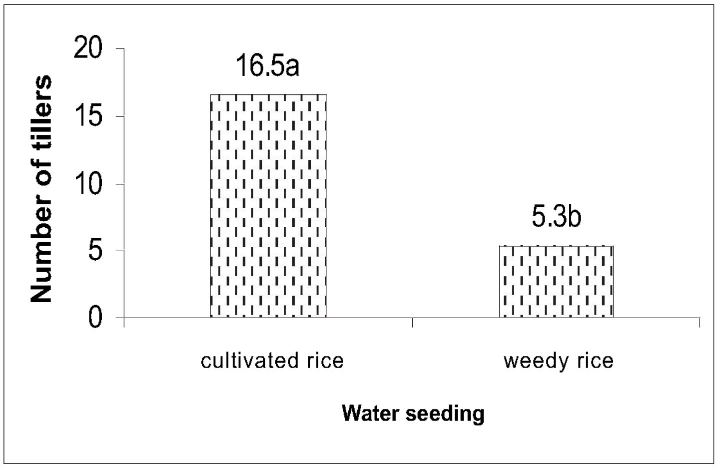
Note: Individual bars with the same letters are not significantly different at P ≤ 0.05 according to DNMRT.

Fig. 1: Effect of seeding method on weedy rice seedling emergence on 14 DAS



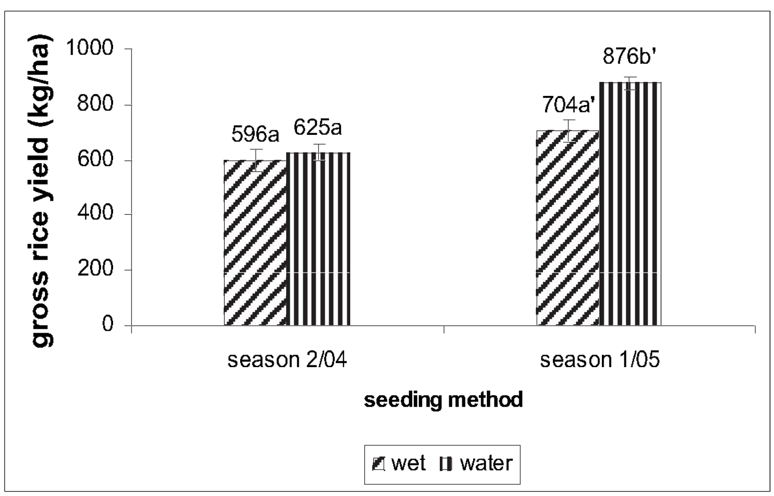
Note: Individual bars with the same letters are not significantly different at P ≤ 0.05 according to DNMRT.

Fig. 2: Number of tillers of cultivated and weedy rice at 45 DAS in wet seeding



Note: Individual bars with the same letters are not significantly different at P ≤ 0.05 according to DNMRT.

Fig. 3: Number of tillers of cultivated rice and weedy rice at 45 DAS in water seeding



Note: Individual values with different letters are significantly different between means using DNMRT at P ≤ 0.05.

Fig. 4: Gross rice yield for each season for wet and water seeding

Their results were substantially higher than that of the present study, probably due to environmental factors (soil type, seasonal variations and rainfall) and crop management practices.

Studies have shown that pre-soaking seeds in dissolved oxygen solutions was effective in breaking seed dormancy of Oryza species (Naredo *et al*. 1998; Syed Omar *et al*. 2004) and improved seedling emergence in flooded soils (Ruan *et al*. 2002). The critical oxygen level for maximum shoot elongation and root elongation was 5% at atmospheric content (Turner *et al*. 1981) and 4 mg kg^{-1} (Ota 1982) respectively. Hence, oxygen supply from ZAPPA-PLUS® had positive effects in enhancing rice seed germination and seedling emergence in field conditions.

There were no significant differences between wet and water seeding in season 2/04 for gross rice yield data (*Fig. 4*). But in season 1/05, the water seeding technique significantly increased rice yield by 25% compared to wet seeding.

The significant rice yield increment in season 1/05 support an initial study conducted in local field trials where yield increments of between 40% and 57% were obtained using pre-treated seeds using the water seeding technique (Syed Omar *et al*. 2004). This further confirms the effectiveness of the water seeding technique in suppressing weedy rice emergence and simultaneously increasing rice yield (*Fig. 4*).

The gross rice yield by machine harvesting recorded for season 2/04 was 5.1 t ha^{-1} for wet seeding and 6.7 t ha^{-1} for water seeding. Season 1/05 recorded 6.6 t ha^{-1} (wet seeding) and 8.1 t ha^{-1} (water seeding). Values by machine harvesting differs from the present study due to estimation of grain moisture content, grain loss during harvesting and other environmental factors.

The significant reduction in weedy rice population and increased rice yield shows that water seeding is an effective method in controlling weedy rice infestation. Hence, it is believed that the use of pre-germinated seeds in flooded soils also improved seedling emergence (Ruan *et al*. 2002), leading to better establishment of cultivated rice and suppressing the emergence of weedy rice.

CONCLUSION

The usage of pre-treated rice seeds with peroxide base material (ZAPPA-PLUS®) in water seeding was able to enhance rice yield in glasshouse and field trials. The increase in rice yield was due to a reduction in weedy rice infestation.

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