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THE INFLUENCE OF SEED PRIMING ON WEED SUPPRESSION IN AEROBIC RICE

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ABSTRACT

Aerobic rice refers to growing dry direct seeded rice in non-saturated soils without any standing water layer. Aerobic rice cultivation is a promising approach to cope with water scarcity. However, this method of cultivation has suffered from increased problems due to weeds and from poor stand establishment. Seed priming (controlled moisture addition technique allowing seeds to be hydrated partially without radicle emergence) reduces emergence time, boosts germination percentage and favors synchronized emergence, this might have a great influence on weed suppression, seedling stand and yield. The present study was, therefore, designed to explore the possibility of adopting seed priming technique for suppressing weeds in aerobic rice. The experiment was conducted at Universiti Putra Malaysia, Malaysia with aerobic rice germplasm AERON 1 with four priming techniques: hydropriming, hardening, Zappa® priming and untreated control; and two levels of weed control: weed free and weedy. Seed priming significantly improved germination attributes, weed suppressive ability and yield of rice, whilst unprimed control exhibited inconsistent germination, poor seedling establishment and less weed competitiveness resulting lower yield. Priming increased germination percentage by 6% and reduced mean germination time by 2 days. Priming enhanced the germination index and seedling vigor index to a great extent. Reduction in weed dry matter due to priming ranged from 22 to 27 % compared to control. A positive influence of priming was also reflected in rice yield. Weed inflicted relative yield loss was curtailed by 10% as a consequence of seed priming. Among different priming techniques, priming with Zappa® solution was the best and thus may be considered as a pragmatic tool for sustainable weed management in aerobic rice.

Key words: Seed invigoration, Zappa®, seedling vigor and weed competitiveness

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INTRODUCTION

Rice is the largest user of fresh water consuming one third of world freshwater utilization (Barker *et al.,* 1999). Traditionally, rice has been cultivated in flooded conditions mostly for higher yield and better weed management (Bouman, 2003). In the last few decades, sustainability of global water resources has been a major concern (Juraimi *et al.,* 2010), and declining water availability has endangered flood-irrigated rice system (Anwar *et al.,* 2010). It is, therefore, crucial to find alternate ways of rice cultivation with limited water input. Among different water wise technologies, aerobic rice is considered to be the most promising one. Aerobic rice refers to growing dry direct seeded rice in non-saturated soils (aerobic soil) without any standing water layer (Bouman, 2003), which minimizes water use and boosts up water productivity compared to lowland rice. Poor emergence along with uneven crop stand and high weed infestation are amongst the major constraints to aerobic rice cultivation (Balasubramanian and Hill, 2002). Lack of a 'head start' and the absence of standing water layer to suppress weeds make aerobic rice highly vulnerable to weeds, causing severe yield loss (Zhao *et al.,* 2007). Therefore, developing a sustainable weed management approach has been a challenge for widespread adoption of aerobic rice technology.

Seed priming refers to a carefully-controlled moisture addition technique, where seeds are allowed to be hydrated partially to that point where germination-related metabolic activities occur, but seeds do not reach the irreversible point of radicle emergence (Bradford, 1986). Beneficial effects of seed priming includes increased germination rate, higher germination uniformity, better allometric (changes in growth of plant parts over time) attributes and faster emergence of seedlings (Farooq *et al*., 2007); as well as early germination and better stand establishment, priming led to crops growing faster, flowering earlier and yielding higher (Du and Tuong, 2002).

Seed priming can improve the traits closely associated with weed competitiveness of rice include early height, growth rate, early crop biomass and early vigor. Various priming techniques have been employed to improve speed and synchrony of seed germination. Common techniques include pre-soaking, hardening, hormonal priming, hydropriming, halopriming, osmoconditioning, and ascorbate priming (Farooq *et al*., 2009).

Harris *et al.* (2002) reported that due to seed priming rice seedlings could compete more successfully with weeds. Clark *et al.* (2001) revealed that seed priming improved the competitive ability of maize against weed, and faster emergence along with increased vigor of a primed stand are the key factors for tolerating weeds. A robust

seedling stand obtained from primed seeds enhanced weed competitiveness of wheat against weed and improved tolerance to environmental stress (Ghiyasi *et al*., 2008). Du and Tuong (2002) also observed a positive influence of seed priming on weed suppression in direct seeded rice at low seeding rate. Zhao *et al*. (2007), on the other hand, did not find any effect of seed priming on weed suppression and grain yield in aerobic rice. Therefore, it may be hypothesized that seed priming might influence the weed suppressive ability of crop.

Several studies have reported the influence of seed priming on the weed competitiveness of different crops. So far, however, there has been a little discussion on aerobic rice. Therefore, the objectives of the present study were to explore the possibility of adopting seed priming technique as a tool for weed management and to assess effects of seed priming on germination behavior, seedling vigor, phenology and yield performance of rice under aerobic soil conditions.

MATERIALS AND METHODS

A trough experiment was conducted at the Plant House, Universiti Putra Malaysia, Malaysia (3^{o} 02' N, 101^{o} 42' E; elevation 31 m) during April to June 2010. The local climate is hot-humid-tropic with plentiful rainfall. The troughs were filled with soil having clayey texture with pH 4.8. The experiment was organized in a randomized complete block design with four replicates comprising four seed invigoration techniques: (a) unprimed seed (control), (b) hydropriming (soaking seeds in tap water at room temperature for 48 h and redrying back to original moisture content), (c) hardening (soaking seeds in tap water at room temperature for 24 h and re-drying back to initial moisture content and cycle was repeated one more) and (d) Zappa® priming (soaking seeds in Zappa® solution for 24 h followed by air drying for 12 h); and two levels of weed control: (a) weed free and (b) weedy.

Aerobic rice germplasm AERON 1 was used as the plant material in the study. Rice seeds were dry seeded following 25 cm × 15 cm spacing with 7seeds/hill in troughs containing non-saturated soil. Troughs were irrigated as necessary to maintain around field capacity throughout the growing period. Different intercultural operations and plant protection measures were conducted following standard practices.

Data were collected on germination attributes, yield, relative yield loss and phenology of rice. Weed rating was done; weed density and weed dry matter were recorded. Data were subjected to Analysis of Variance (ANOVA) conducted by Statistical Analysis System (SAS 9). Significant differences among means were adjudged using Fisher's protected Least Significant Differences (LSD) test at $P \geq 0.05$.

RESULTS

Germination behavior and seedling vigor

Seed priming treatments exhibited significant effect on germination of AERON1 (Table 1). Germination percentage and germination index were higher, while mean germination time (MGT) and days to 50% germination (T_{50}) were lower with primed seeds compared to control. Maximum germination percentage and germination index were obtained from the seeds subjected to Zappa® priming, followed by hydropriming. Lowest MGT and T_{50} also were noted with Zappa® priming.

Seed priming with Zappa® increased germination percentage by 6 % and reduced emergence time by more than 2 days. Germination index was three times higher in Zappa® primed seeds compared with unprimed seeds. All the priming treatments increased seedling vigor (Table 1). These treatments also produced the most vigorous seedlings with 50% more vigor index compared to unprimed seeds.

In terms of seedling shoot and root lengths, seeds treated with Zappa® performed the best. Seedling dry weight was greatly enhanced by priming treatment; compared to unprimed control, seedling dry weight was increased by almost 110, 60 and 35% due to Zappa® priming, hardening and hydropriming, respectively.

Table 1. Germination behavior and seedling vigor of AERON1 as influenced by seed priming.

Priming technique	Germination behavior		Seedling vigor					
	Germination %	Mean germination time (days)	Days to 50% Germination	Germination index	Seedling vigor index	Shoot length (cm)	Root length (cm)	Dry matter (g)
Unprimed	85.88c	4.37a	3.59a	18.67 c	15.56c	17.9c	1.77c	0.14d
Hydropriming	88.75b	2.59b	2.06b	37.14 b	23.13a	25.7a	2.20b	0.19c
Hardening	86.01c	2.41c	1.79c	38.27 b	18.41b	21.8b	2.26b	0.22b
Zappa® Priming	91.80a	1.95d	1.55d	50.73 a	23.08a	25.7a	2.83a	0.29a
LSD	1.222	0.046	0.168	1.511	2.151	2.529	0.167	0.005

Within a column means sharing same alphabets are not significantly different at P≥0.05.

Weed suppression

Seed priming showed a positive influence on weed suppression (Table 2). Weed ratings were lower in priming treatments compared with unprimed control. In rice stand obtained from unprimed seeds,

weed infestation was high and was rated >7, while weed ratings were < 6 in the unprimed stand, though there were no significant differences among priming treatments. Weed dry matter also was reduced due to seed priming.

On average, priming treatments reduced 25% weed dry matter compared with unprimed control. In contrast, seed priming effect on weed density was not significant. Weed inflicted relative yield loss was lower with primed stand compared to that of unprimed one (Table 2). Relative yield loss was reduced by around 10% due to priming, but reduction was not significant among priming treatments.

Table 2. Seed priming effect on weed suppressive ability and phenology of AERON1.

Priming techniques	Weed suppressive ability				Phenology	
	Weed rating (1 to 9 scale)	Weed dry weight (g/m^2)	Weed density ($no./m^2$)	Relative yield loss over weed free control (%)	Days to flowering	Days to maturity
Unprimed	7.25a	185.23a	226.00	30.88a	51.00a	80.50a
Hydropriming	5.50b	143.29b	210.50	20.87b	48.75c	77.13c
Hardening	5.25b	143.67b	208.75	19.68b	50.12b	78.50b
Zappa®priming	5.25b	135.45b	205.75	19.95b	48.25c	76.13d
LSD	0.854	34.69	30.78	6.56	0.627	0.918

Within a column means sharing same alphabets are not significantly different at P≥0.05.

Phenology and yield performance

Earlier flowering and maturity occurred in primed stands, compared with the unprimed one (Table 2). Days to flowering and maturity were delayed in the control treatments. Among the priming treatments, Zappa® priming required the least time to mature.

All the priming treatments were better than unprimed control in terms of yield and biomass production (Figure 1). Zappa® priming topped the list followed by hardening and hydropriming in terms of yield. The total dry matter production also was highest with Zappa® priming followed by hardening.

DISCUSSION

Our study demonstrated that seed priming promoted the growth of the rice plant through early ontogeny and increased its competitive ability against weeds. Seed priming enhanced seed vigor, which improved the speed and rate of seedling emergence, as indicated by higher germination percentage and germination index,

and lower MGT and T_{50}. Faster emergence of primed seeds might be due to the completion of pre-germination metabolic activities, while higher and synchronized emergence was the consequence of reduced physiological non-uniformity in the seed bulk due to priming.

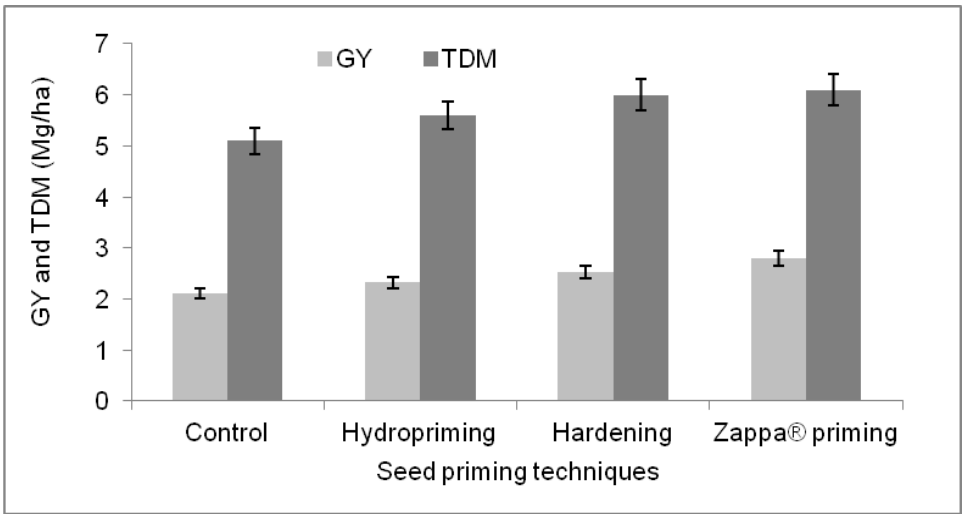

Figure 1. Seed priming effect on grain yield (GY) and total dry matter (TDM) of AERON 1.

In our study, primed stand of rice was more competitive against weed than unprimed stand as reflected by lower weed rating and weed dry matter. Faster and higher emergence rate, along with vigorous stand, resulting from priming might offer rice plants a preliminary advantage to outcompete weeds (Clark *et al*. 2001; Ghiyasi *et al*. 2008). In contrast, less vigorous and poor stands of unprimed seed encouraged weed growth resulting higher weed rating and weed dry matter. There are several reports that seed priming can increase weed competitiveness of crop (Du and Tuong 2002; Harris *et al*. 2002).

However, at the same time conflicting findings have also been reported by Zhao *et al.* (2007). Seed priming led to improved phenological features of rice. Primed plants enjoyed a vigorous start, grew faster and matured earlier than unprimed counterparts.

The enhanced phenology due to priming might be attributed to rapid emergence and reduced imbibitions period. Higher number of panicle bearing tillers due to low mortality of seedlings (data not shown) resulted in increased grain yield in primed stand compared to unprimed stand. Increased rice yield due to priming has also been reported by many researchers (Harris *et al.* 1999; Farooq *et al.* 2009).

In conclusion, this study substantiates our hypothesis that seed priming can increase the weed suppressive ability of rice, and consequently, employing seed priming may help increase grain yield of direct seeded aerobic rice by reducing the risks of poor stand establishment and crop losses due to weeds.

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