Rice Bran Application under Deep Flooding Can Control Weed and Increase Grain Yield in Organic Rice Culture

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Abstract

Rice bran application just after transplanting has been increasingly practiced as a herbicide-substitute for organic rice production in Korea. However, this practice is frequently reported to be unsatisfactory in weed suppression. An experiment with five treatments that combine flooding depth (shallow and deep), rice bran application level (low and high), and herbicide application was carried out in the paddy field to evaluate whether rice bran application under deep flooding can lead to successful weed control in compensation for the single practice of rice bran. Rice bran was broadcasted on the flood water surface just after deep flooding of 8 to 10 cm that was started at seven days after transplanting. Six weed species were recorded in the shallow flooding plot without herbicide: Monochoria vaginalis, Echinochloa crus-galli, Ludwigia prostrata, Cyperus amuricus, Aneima keisak, and Bidens tripartite. Among the first four dominant weed species, deep flooding significantly suppressed the occurrence of Echinochloa crus-galli and Cyperus amuricus, while it did not suppress the occurrence of Monochoria vaginalis and Ludwigia prostrata. On the contrary, rice bran application under deep flooding significantly suppressed Monochoria vaginalis and Ludwigia prostrata, while didn’t exert an additional suppression of Echinochloa crus-galli and Cyperus amuricus compared to deep flooding alone. Rice bran application and deep flooding suppressed complimentarily all six weed species to a satisfactory extent except for Monochoria vaginalis for which suppression efficacy was 31.9%. Deep flooding substantially reduced the panicle number by inhibiting the tiller production, increased the spikelet number per panicle slightly, and led to a lower rice grain yield compared to shallow flooding with herbicide. Rice bran application under deep flooding mitigated the panicle reduction due to deep flooding, increased the spikelets per panicle significantly, and thus produced even higher grain yield in the rice bran application of 2000 kg ha⁻¹ as compared to the shallow flooding treatment with herbicide. In conclusion, it would be advisable to implement rice bran application under deep flooding as an integral practice for an organic rice farming system.

Key words: rice, rice bran, deep flooding, weed suppression, grain yield, compost

Introduction

The conventional farming systems that have relied on heavy input of agrochemicals and pursued high productivity have provoked poignant problems such as escalated production costs, heavy reliance on non-renewable resources, reduced biodiversity, water contamination, chemical residues in food, soil degradation, and health risks to farm workers handling pesticides (Drinkwater et al. 1998; Matson et al. 1997; Tillman 1999). With increasing interest in sustaining economically-viable crop production with minimal environmental impacts, organic farming without synthetic fertilizers and pesticides has been increasingly adopted as an alternative agricultural practice (Kirchmann and Thorvaldsson 2000; Reganold et al. 1993). Despite concerns on the sustainability and profitability of organic farming systems (Avery 1999; Trewavas 1999), the organic food industry is one of the fastest growing businesses (Greene 2000; Kirchmann and Thorvaldsson 2000) because market and social forces have created price premiums on a wide variety of organic foods (Reganold et al. 2001). Organic rice farming has also been rapidly adopted in response to increasing customer demands and government policy initiatives in Korea (MAF 2005). Weed management is a very important and labor-intensive practice in organic farming systems compared to conventional methods utilizing herbicide. Ducks, golden apple snail (GAS) and rice bran have...
been widely adopted for biological weed control in organic rice farming in Korea (MAF 2005). Duck-rice farming is known to be very effective for controlling paddy weeds except for Echinochloa crus-galli. In rice-duck farming the cost of rice farming expenses by 54-77% compared to conventional rice farming since duck breeds and feed should be purchased, and it is easier to control rice weeds (Cho et al. 1999).

Duck-rice farming is gradually forsaken by Korean farmers (MAF, 2005). GAS-rice farming also has the problem of expenses and sales. Furthermore, there is widespread concern of the fact that GAS- rice farming is a best of the rest of the rice plant and other aquatic crops in the tropics (Jochi R.C. et al. 2005). Could over winter in the Korean climate and imperil the plant and other aquatic crops in the tropics (Jochi R.C. et al. 2005)

Weed occurrence as affected by rice bran application and water depth in rice (Yong-Feng Yan et al. 2017).


dat the effect of flooding, but no suppression effect on Weed occurrence as affected by rice bran application and water depth in rice field (Yong-Feng Yan et al. 2017). In the present study, we have to check this possibility in weed control and evaluate the influence on yield performance in organic rice farming system employing rice bran application under deep flooding management.

Materials and Methods

This experiment was conducted at the Experimental Farm of Seoul National University at Suwon, Korea in 2005. The experimental field had a soil texture of sandy clay loam, pH of 5.4, CEC of 12.7 cmol(+)/kg, organic matter of 20.2 g kg(-1), total N of 11.6 g kg(-1), and available P of 35.8 mg kg(-1). Five treatments combining flooding depth, application dose of rice bran, and herbicide use included (1) shallow flooding of 3 to 5 cm and no weed control (SF, control), (2) deep flooding of 8 to 10 cm and weed control (DF), (3) shallow flooding of 3 to 5 cm and herbicide application (SH+HB), (4) deep flooding of 8 to 10 cm and rice bran application of 1000 kg ha(-1) (DF+LRB), and (5) deep flooding of 8 to 10 cm and rice bran application of 2000 kg ha(-1) (DF+HB). The experiment was laid out in a randomized complete block design using three replications. Each plot size was 2 m x 7.5 m. An auto-water-supply system equipped with a ball cock in each plot was used to keep the flooding depth constant. To prevent side-seepage between plots with different flooding and fertilization regimes, corrugated plastic sheets were installed down to a depth of 30 cm, which was well below the top of hardpan. The experimental field was fertilized with the compost (fermented from a mixture of swine dung, sawdust, plant residue, and zeolite, and containing 31.5% of O.M., 1.36% of T-N, and 0.51% of P2O5, 0.27% of K2O) of 12,000 kg ha(-1) that is equivalent to 130 N ha(-1), plowed, and puddled 4 days before transplanting. Rice seedlings grown for 30 days were transplanted with machine transplanter at a spacing of 15 cm x 30 cm on 27th of May in 2005. For the deep flooding plots, deep irrigation was started at seven days after transplanting (DAT) and lasted for 30 days. Except for the deep flooding period, water level was kept at 3 to 5 cm depth in as the shallow flooding treatments. In the case of plots with rice bran application, rice bran was broadcasted on the flood water surface to be at 2 JG 80%, 50%, and 20% and C, K content of rice bran used in the present experiment were 3.2, 1.7, and 1.9%, respectively. The fermented compost of 3.0 kg rice farming system experiment was prepared by deep flooding (Bhan 1983; Pons 1982; Raju and Reddy 1987; Sahid and Hossain 1995). As reviewed above, rice bran application and deep flooding seemed to have complimentary suppression effects on some weed species; the deep flooding suppresses the occurrence of Echinochloa crus-galli effectively but not the occurrence of Monochoria vaginalis, and vice versa for the rice bran application. Therefore, rice bran application in combination with deep flooding would be more effective to rice bran application and herbicide application and to be a better method of weed control. The present study aimed to confirm this possibility in weed control and evaluate the influence on yield performance in organic rice farming system employing rice bran application under deep flooding management.

Results

Weed occurrence

Six weed species were recorded in the control plot (SF) with no herbicide and rice bran application under shallow flooding (Table 1). Four weed species such as Monochoria vaginalis, Echinochloa crus-galli, Cyperus serotinus, and Cynodon dactylon were dominant as found in the common paddy field of Korea. Herbicide treatment (SF+HB) controlled most of the weeds effectively, with the exception of Ludwigia amuricus (weed suppression efficacy of only about 30%). Deep flooding (DF) and rice bran application under deep flooding (DF+LRB and DF+HB) suppressed Annelina keisak and Bidens tripartita completely, while showing differential suppression effect depending on the species of the four dominant weeds. Deep flooding without rice bran application (DF) decreased the occurrence of Echinochloa crus-galli and Cyperus amaricus significantly, showing suppression efficacy of 84.0 and 72.4%, respectively, while it did not suppress the occurrence of Monochoria vaginalis and Ludwigia prostrata (Tables 1 and 2). On the contrary to the deep flooding treatment, rice bran application showed significant suppression effect on Monochoria vaginalis and Ludwigia prostrata but no suppression effect on Echinochloa crus-galli and Cyperus amaricus (Table 2).

Deep flooding and rice bran application showed complementary suppression effect on the dominant four weed species. Thus, the combined treatment of deep flooding and rice bran application showed effective suppression in more weed species than the treatment of any one of them. Although it was not higher than herbicidal rice bran application, rice bran application under deep flooding showed satisfactory suppression efficacy for the dominant weed species except Monochoria vaginalis. Monochoria vaginalis was significantly suppressed by rice bran application under deep flooding, but not to a satisfactory degree, and showed a suppression efficacy of only about 30%.

Dissolved oxygen of flood water

Dissolved oxygen (DO) dropped to the lowest level on the next day of deep flooding and rice bran application at 7 DAT and thereafter increased steadily until around 20 DAT (Fig. 1). Manually on the next day of the deep flooding (DF), compared to shallow flooding (SF and SF+HB) DO of DF treatment (3.1 mg L(-1)) was nearly half of the SF (5.7 mg L(-1)) and SF+HB (6.8 mg L(-1)) treatment at 8 DAT and the difference was narrowed rapidly thereafter until 19 DAT. Because deep flooding deterred O2 diffusion and rice bran decomposition consumed a lot of O3, rice bran application under deep flooding (DF+LRB and DF+HB) showed much lower DO level than the other treatments until 19 DAT. DO level was lower in the highest dose of rice bran (DF+HB) than in the lower dose (DF+LRB).
and to a substantial degree. Deep flooding in combination, but had no suppression effect on the was not significantly affected by submergence (Pons (Catizone 1983; Mukhopadhyay 1983; were level at 30 DAT, and then dropped to the minimum level before applied three days before transplanting, reached the maximum the top soil increased rapidly since fermented compost was lower level in rice bran application under deep flooding Compared to deep flooding (DF), soil Eh dropped to much same level with shallow flooding (SF and SF+HB) at 14 DAT. Fig. 2. Temporal changes in redox potential at 2 cm depth of paddy soil as affected by rice bran application and water depth. The abbreviations for treatment codes are the same as described in the footnote of Table 1.

Soil redox potential
As shown in Fig. 2, the redox potential (Eh) of soil (2 cm below soil surface) was lowered drastically one day after deep flooding at 7 DAT and subsequently increased, reaching the same level with shallow flooding (SF and SF+HB) at 14 DAT. Compared to deep flooding (DF), soil Eh dropped to much lower level in rice bran application under deep flooding (DF+LRB and DF+HRB).

Soil mineral nitrogen
Soil mineral nitrogen (NO₃-N and NH₄-N) concentration in the top soil increased rapidly since fermented compost was applied three days before transplanting, reached the maximum level at 30 DAT, and then dropped to the minimum level before the additional dressing of compost at 55 DAT (Fig. 3). There was no difference in soil mineral nitrogen concentration between shallow flooding (SH and SH+HB) and deep flooding (DF). However, rice bran application increased it significantly compared to the treatments without rice bran application.

Rice growth and yield
Tiller production
As in Fig. 4, tiller number was the highest in shallow flooding with herbicide application (SF+HRB). Deep flooding (DF) significantly decreased tiller number compared to SH+HB. However, the tiller number in deep flooding with rice bran application (DF+LRB and DF+HRB) was much higher than in deep flooding without rice bran application (DF) and was almost to the same as that in SF+HB especially in the later growth stage. The tiller number in shallow flooding without weeding treatment (SF) was the lowest.

Discussion
Effect of rice bran application under deep flooding on weed occurrence
In the experimental field, six weed species occurred in the plot subjected to shallow flooding and no herbicide application (Table 1). Among these, four species, Echinochloa crus-galli, Cyperus amaricus, Monochoria vaginata, and Ludwigia prostratae, were dominant as reported by Kim et al. (2001) in the same province. It is well known that flooding hinders weed germination and suppresses the weed population of already emerged weeds, depending on the nature of weed flora. Among the four dominant weed species, deep flooding (8-10 cm) effectively suppressed the two weed species: Echinochloa crus-galli and Cyperus amaricus, but had no suppression effect on the other two species: Monochoria vaginata and Ludwigia prostratae (Tables 1 and 2). These results are in good agreement with other reports that continuous submergence considerably suppressed Echinochloa crus-galli and pratetica (Kwon et al. 1996), and Monochoria vaginata was not significantly affected by submergence (Pons 1982). On the contrary to deep flooding, rice bran application suppressed Monochoria vaginata and Ludwigia prostratae to a substantial degree, but not the other two species (Table 2). Similarly, Kim et al. (2001) reported that rice bran application had little suppression effect on Echinochloa crus-galli, but suppressed Monochoria vaginata, Scirpus juncoides, and Cyperus serotinus to a substantial degree. Deep flooding in combination with rice bran application significantly suppressed the occurrence of all six weeds including the four dominant weeds (Table 1). Weed suppression efficacy of Echinochloa crus-galli, Cyperus amaricus, Ludwigia prostratae, and Monochoria vaginata were 72, 73, 75, and 31%, respectively. These results suggested that deep flooding and rice bran application had differential suppression effects depending on weed species, and thus the combined treatment of deep flooding and rice bran application could suppress weed complementarily, resulting in better weed control. When soils are flooded, the ratio of carbon dioxide to oxygen typically increases and can have detrimental effects on seed germination and seedling emergence (Forcella et al. 2000). One day after deep flooding, dissolved oxygen levels in flood water just over the soil surface dropped to almost half compared to shallow flooding, which deterred diffusion of oxygen and also redox potential (Eh) of top soil was reduced to much lower levels. Rice bran application under deep irrigation further lowered DO and Eh levels and maintained low DO and Eh longer compared to deep flooding alone. As mentioned above, Echinochloa crus-galli and Cyperus amaricus was significantly suppressed by a single treatment of deep flooding and there was no additional suppression effect on them due to rice bran application under deep flooding. And Monochoria vaginata and Ludwigia prostratae were substantially suppressed by rice bran application under deep flooding but not by single deep flooding treatments. These results suggested that rice bran

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Table 3. Effect of flooding depth and rice bran application on plant nitrogen concentration and content at harvest.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrogen concentration (g kg⁻¹)</th>
<th>Nitrogen content (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Straw</td>
<td>Stalk</td>
</tr>
<tr>
<td>SF</td>
<td>2.97a</td>
<td>2.12a</td>
</tr>
<tr>
<td>SF+HB</td>
<td>2.97a</td>
<td>2.12a</td>
</tr>
</tbody>
</table>

Table 4. Effect of flooding depth and rice bran application on grain yield and yield components.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Panicle Number per Plant</th>
<th>Spikelet Number per Panicle</th>
<th>Total Spikelet Number</th>
<th>Ripened Grain Percentage</th>
<th>Grain Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(No. m⁻²)</td>
<td>(No. m⁻²)</td>
<td>(No. m⁻²)</td>
<td></td>
<td>(g m⁻²)</td>
</tr>
<tr>
<td>SF</td>
<td>422b</td>
<td>355d</td>
<td>355d</td>
<td>0.4674NS</td>
<td>0.6135*</td>
</tr>
<tr>
<td>SF+HB</td>
<td>422b</td>
<td>355d</td>
<td>355d</td>
<td>0.4674NS</td>
<td>0.6135*</td>
</tr>
</tbody>
</table>

Table 5. Correlations between weed numbers recorded at 40 days after transplanting and yield components.

<table>
<thead>
<tr>
<th>Item</th>
<th>Panicle Number per Plant</th>
<th>Spikelet Number per Panicle</th>
<th>Total Spikelet Number</th>
<th>Ripened Grain Percentage</th>
<th>Grain Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0.4674NS</td>
<td>0.5181*</td>
<td>0.7736**</td>
<td>0.7766**</td>
<td>0.6210*</td>
</tr>
</tbody>
</table>

Table 6. Correlations between nitrogen concentrations in the top soil of 15 cm depth at 30 days after tillering stage and yield components.

<table>
<thead>
<tr>
<th>Item</th>
<th>Panicle Number per Plant</th>
<th>Spikelet Number per Panicle</th>
<th>Total Spikelet Number</th>
<th>Ripened Grain Percentage</th>
<th>Grain Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0.4674NS</td>
<td>0.5181*</td>
<td>0.7736**</td>
<td>0.7766**</td>
<td>0.6210*</td>
</tr>
</tbody>
</table>

References


Greene C. 2000. US organic agriculture gaining ground, Agricultural Outlook. 270: 9-14


Acknowledgement

This work was funded by the Korea Meteorological Administration Research and Development Program under Grant CATER 2006-4301.