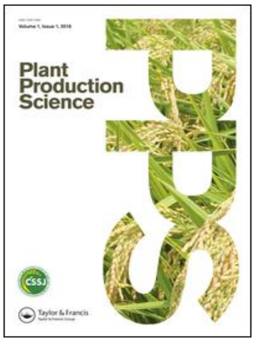

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SHORT REPORT

Effects of poultry manure on soil solution electrical conductivity and early growth of *Monochoria vaginalis*

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ABSTRACT
We investigated the effect of poultry manure (PM) on the occurrence and early growth of *Monochoria vaginalis* in relation to soil solution electrical conductivity (SSEC). PM was applied at rates corresponding to 0 g of nitrogen (N) m^{-2} (PM-0), 1 g N m^{-2} (PM-1), 3 g N m^{-2} (PM-3), and 5 g N m^{-2} (PM-5). At 7 d post-seeding, the soil solution was sampled to measure EC, and also the emergence and growth of *M. vaginalis* were evaluated. The emergence rate of *M. vaginalis* decreased with increasing application rate of PM and SSEC. SSEC was significantly negatively correlated with the emergence rate of *M. vaginalis* seedlings. The average leaf number and length of *M. vaginalis* did not differ between PM-0, PM-1, and PM-3, but were significantly lower in PM-5. In summary, PM would allow to better control the emergence and early growth of *M. vaginalis*.

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CLASSIFICATION
Crop Morphology

Introduction

Monochoria vaginalis (Burm. f.) C. Presl ex Kunth is one of the most abundant and dominant weed species in the rice fields of Japan as well as of east and southern Asia (Breen et al., 1999; Zhang et al., 2009). *M. vaginalis* at a density of 366 m^{-2} has been reported to reduce rice yield by 35% in the Philippines (Lubigan & Vega, 1971), whereas at a density of 150 plants m^{-2} to reduce rice yield by approximately 25% in Indonesia (Guyer & Koch, 1989).

Poultry manure (PM) is widely used as an organic fertilizer that is effective in improving soil properties and crop production (Dikinya & Mufwanzala, 2010). The authors have investigated the effects of PM on growth of organic rice (Watanabe et al., 2011). During these studies we founded that the density of *M. vaginalis* decreased with the increasing application rate of PM. In organic rice farming where no herbicides are applied, rice bran is often used for weed control. The addition of rice bran to the soil increases its electrical conductivity (EC) (Nozoe et al., 2012). The soil solution EC (SSEC) is highly correlated with other soil properties, including the level of organic matter and salinity, which also affect crop productivity (Grisso, 2009). The application of rice bran also increases SSEC, suppressing the germination of *M. vaginalis* (Nozoe et al., 2012). Since PM is also organic matter similar to rice bran, its application may increase SSEC and reduce the occurrence of *M. vaginalis*. However, information on the control of *M. vaginalis* by PM application is limited. The objective of this study was to investigate the effects of PM application on the occurrence of *M. vaginalis* in relation to SSEC. To our knowledge, this is the first report on the suppressive effects of PM on the emergence and early growth of *M. vaginalis*.

Materials and methods

Materials

Mature *M. vaginalis* seeds with no visible signs of disease or insect damage were used in this study. Seeds were stored at 5 °C until the beginning of the experiment. The apparatus for soil solution sampling is shown in Figure 1 (Nozoe et al., 2012).

Experimental treatments and procedures

The experiments were performed as described by Nozoe et al. (2012) with minor modifications. Briefly, 100-g samples of dried Alluvial soil (Gley Lowland soils), which is typical of paddy fields in Japan, were placed into polyethylene vessels (60 × 60 × 85 mm, length × width × height). PM was applied at rates corresponding to 0 g of nitrogen (N) m^{-2} (PM-0), 1 g N m^{-2} (PM-1), 3 g N m^{-2} (PM-3), and 5 g N

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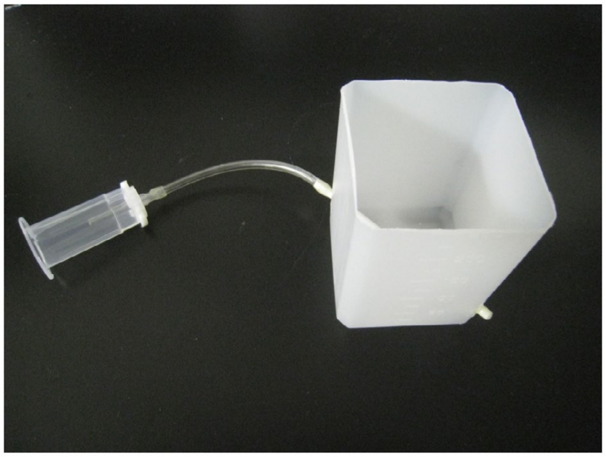


Figure 1. Apparatus for soil solution sampling used in this study.
Note: Soil solutions were placed into 10-ml evacuated collection tubes.

m^{-2} (PM-5). The properties of PM were as follows: total carbon (C), 28.7%; total nitrogen (N), 4.2%; total calcium (Ca), 10.7%; pH (H_2O), 8.7; and carbon-to-nitrogen ratio (C/N ratio), 6.8. Distilled water was added to each vessel and stirred thoroughly to remove all the air from the soil. *M. vaginalis* seeds were planted at a depth of .5 mm, and flooded conditions (1 cm above the soil surface) were maintained throughout the experimental period. All vessels were covered with polyethylene films to prevent desiccation and placed in a growth chamber at 25 °C and 12-h photoperiod with a photosynthetic photon flux of 120 µmol m^{-2} s^{-1}. At 7 d post-seeding, soil solution samples were collected and placed into 10-ml evacuated collection tubes (Figure 1). SSEC was measured using a compact EC meter (B-173; HORIBA, Kyoto, Japan), and the emergence rate of *M. vaginalis* was calculated. A seedling was considered emerged when the cotyledon was raised above the soil.

Statistical analysis

The experiment was arranged as a randomized complete block design with four replications of 25 seeds each. Analysis of variance in conjunction with Tukey's honest significant difference test was performed to identify significant differences among the treatment means. Differences were considered significant at $p < .05$. Statistical analyses were carried out using JMP 4.0 (SAS Institute, Cary, NC, USA).

Results and discussion

PM addition effects on SSEC

PM is considered an excellent alternative to chemical fertilizers, since it markedly improves soil properties and crop production (Dikinya & Mufwanzala, 2010). In the present study, we evaluated the effects of PM on SSEC and the early growth of *M. vaginalis*, which is an important weed in organic rice fields. The results revealed that SSEC significantly ($p < .05$) increased with increasing PM application rate (Figure 2). The highest SSEC was recorded in PM-5 (113.6 ms m^{-1}), whereas the lowest in PM-0 (71.2 ms m^{-1}). In organic rice farming, rice bran is often used for weed control. Our results were in agreement with previous studies that showed an increase in SSEC after the application of rice bran to the soil (Nozoe et al., 2012). Additionally, the range of SSEC in the present study was in agreement with that reported by Tanji et al. (2003) and showed that under field conditions, SSEC varied among and within plots, ranging from 60 to 360 ms m^{-1}.

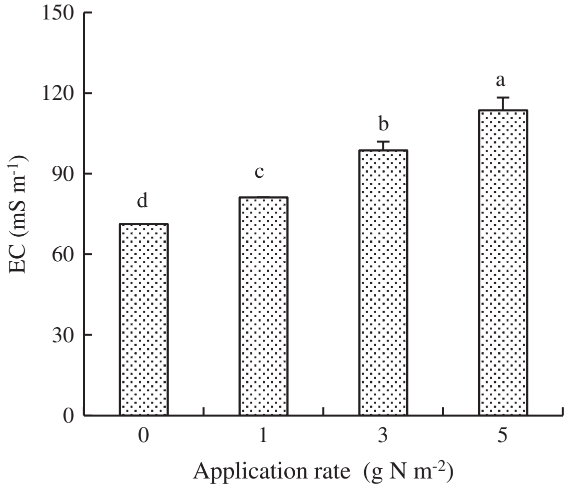


Figure 2. Effect of PM on soil solution electrical conductivity (SSEC).
Note: SSEC was measured at 7 d after the PM application. Data are means ± standard error ($n = 4$). Different letters indicate significant differences at $p < .05$.

PM addition effects on M. vaginalis emergence and early growth

The results showed that the emergence rate of *M. vaginalis* decreased significantly with the increasing PM application rate (Figure 3). The emergence rate in PM-5 was approximately 50% lower than that in PM-0. Additionally, SSEC was significantly ($p < .01$) negatively correlated with the emergence rate of *M. vaginalis* seedlings (Figure 4). Our results were similar to those reported by Nozoe et al. (2012); they showed that SSEC is negatively correlated with the germination percentage of *M. vaginalis*.

The effects of various PM application rates on the leaf number and length of *M. vaginalis* are shown in Figure 5. The leaf number did not differ significantly in PM-1 and PM-3 compared with that in PM-0; however, it was significantly ($p < .05$) higher in PM-5. A similar trend was observed for the leaf length that was significantly ($p < .05$) higher in PM-5 than in the other treatments.

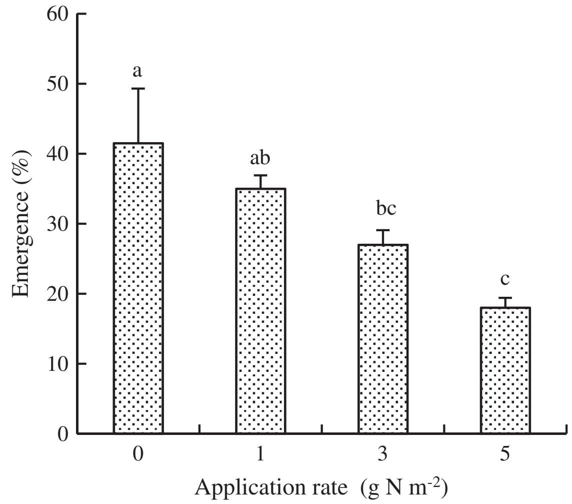


Figure 3. Effect of PM on the emergence rate of *M. vaginalis* seedlings.

Note: Seeds were planted in soils containing different PM rates, and the emergence of *M. vaginalis* seedlings was recorded at 7 d post-seeding. Data are means ± standard error (n = 4). Different letters indicate significant differences at $p < .05$.

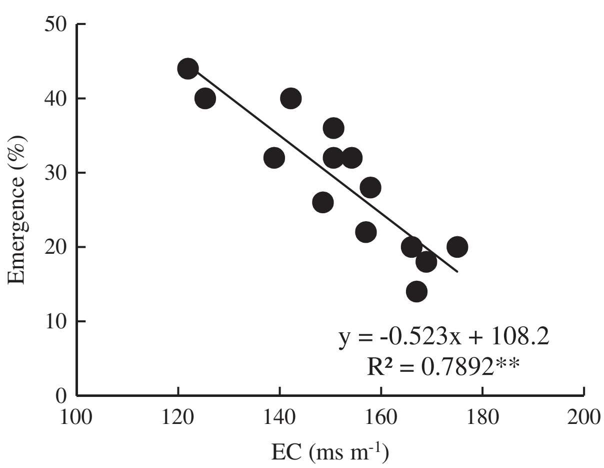


Figure 4. Relationship between the emergence rate of *M. vaginalis* seedlings and soil solution electrical conductivity (SSEC).

**significant at $p < .01$.

Previous studies on organic rice farming have investigated different methods of weed control, including the cultivation of weed-competitive rice varieties (Koarai et al., 1994; Suzuki et al., 2002) and the application of rice bran (Oba, 2002; Xuan et al., 2003). The latter is widely used by organic rice farmers, since it increases SSEC, a factor that suppresses the germination of *M. vaginalis* (Nozoe et al., 2012). Our results also showed that the emergence of *M. vaginalis* was suppressed at relatively high SSEC values (Figures 2 and 3), and a significant negative correlation was identified between these two variables (Figure 4).

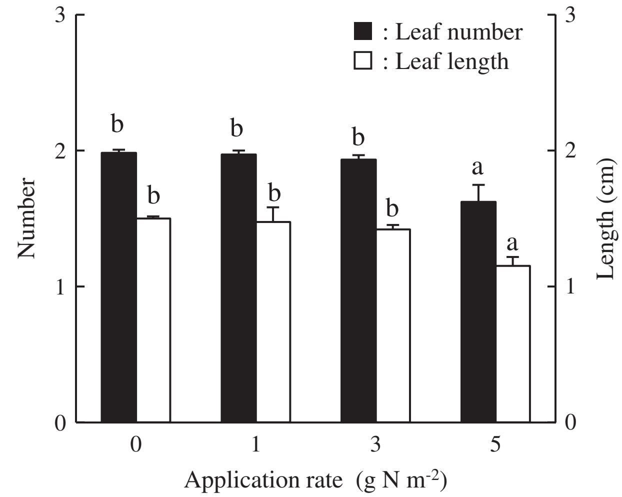


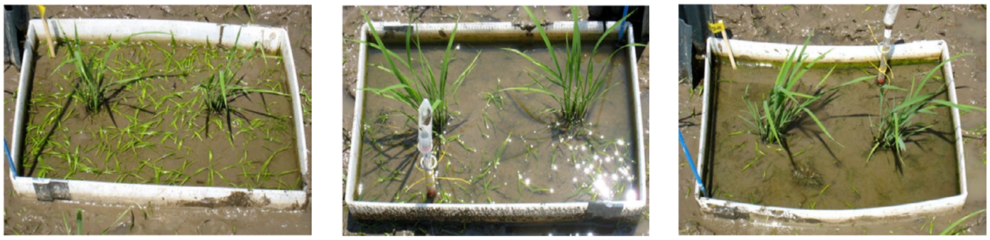
Figure 5. Leaf number and length of *M. vaginalis* seedlings. Data are means ± standard error (n = 4).

Note: Different letters indicate significant differences at $p < .05$.

Many factors could be associated with the increase in SSEC and the decrease in the emergence rate of *M. vaginalis* with the application of PM. PM probably influences the soil physicochemical properties, including soil pH, redox potential (Eh), and the amount of ferrous iron (Fe^{2+}) and organic acids. The addition of PM may increase the soil pH due to relatively high content of Ca (Materechera & Mkhabela, 2002; Sharpley & Smith, 1995; Sharpley et al., 2004). Nozoe et al. (2008, 2012) reported that the increase in SSEC leads to higher rates of Fe^{2+} and organic acids in the soil solution, which probably negatively affect rice growth. However, the effect of PM on soil pH, Eh, and the amount of Fe^{2+} and organic acids needs further study.

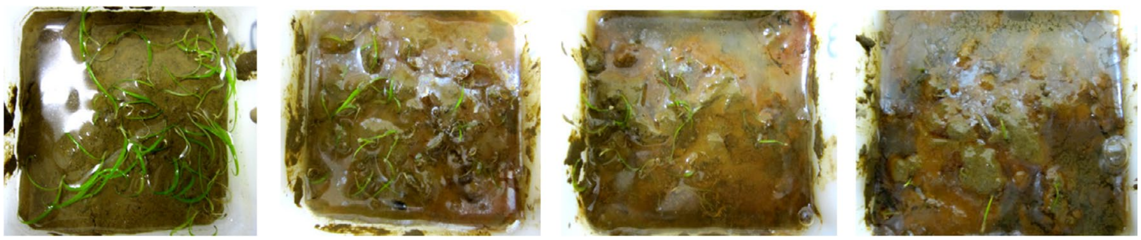
Nakai and Toritsuka (2009) reported that the application of an excess amount of rice bran suppresses the growth of rice seedlings after transplanting. However, older rice seedlings show a better survival rate after the rice bran application, mainly due to the substantial adaptability against highly reduced paddy soil conditions. In the present study, PM application suppressed the occurrence of *M. vaginalis*, and the weed density was the highest in PM-0 and the lowest in PM-5 (Figure 6). Additionally, no visible toxic signs were observed in rice in PM-3 or PM-5, probably because the mature-seedlings with the 6.0–7.0 leaf stage were transplanted in the experiments. However, detailed negative impacts of PM application on rice growth remains to be examined.

Our results showed that PM application could not completely inhibit the emergence of *M. vaginalis* (Figure 2). Additionally, we mainly focused on the relation of PM application and the emergence and early growth of *M. vaginalis*, but on the existence of any competition between rice and *M. vaginalis*. Thus, further studies are needed to investigate



PM-0 PM-3 PM-5

Figure 6. Occurrence of *M. vaginalis* in the organic rice field.
Note: Rice seedlings at the 6.0–7.0 leaf stage were transplanted in soils containing different PM rates.



PM-0 PM-1 PM-3 PM-5

Figure 7. Effect of PM on sediment formation between the overlying water and soil surface.

if higher rates of PM could completely suppress the emergence of *M. vaginalis* or an integrated weed management approach would be more effective, and also to clarify the rice-*M. vaginalis* competition process. Nozoe et al. (2012) reported that the suppressive effects of rice bran on seed germination differ among soil types. Therefore, more research is needed to determine the effects of PM applied to different types of soils on the emergence and early growth of *M. vaginalis* under field conditions.

When organic matter is applied to paddy soil, several biological properties, such as the proliferation of algae and micro-organisms, are activated. During the experiment, dark brown and/or deep green sediment was observed between the overlying water and soil surface in PM treatments; the formation of the sediment might be related directly or indirectly to algae and micro-organisms. Furthermore, the amount of sediment increased with the increasing PM application rate (Figure 7). Several layers of sediment might prevent light from reaching the seeds beneath the soil and suppress their germination. The seed of *M. vaginalis* requires light for its germination (Wang et al., 1996). Thus, insufficient light might suppress the emergence of *M. vaginalis* seedlings. Another possible mechanism of the PM suppression effect on *M. vaginalis* seedlings could be the physical resistance of the sediment. Apparently, these sediments created a thick and light-proof layer on the soil surface (Figure 7).

PM is commonly used as an organic fertilizer that effectively improves soil fertility and rice production. The present study also revealed the inhibiting effect of PM on the emergence of *M. vaginalis* seedlings. Although our experiment was conducted in polyethylene vessels under environmentally controlled conditions, the results provided novel information regarding the application of PM for controlling *M. vaginalis* at the early growth stages.

In summary, PM would allow to better control the emergence and early growth of *M. vaginalis*. Although a few studies have been published on weed control by the application of organic materials, this is the first report on the suppressive effects of PM on the emergence and early growth of *M. vaginalis*. However, further study is needed to better understand the physicochemical mechanism of PM application in relation to SSEC and the early growth of *M. vaginalis*.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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