INTRODUCTION

Rice (Oryza sativa L.) is one of the major staple food in the world, especially in Asia, the region that consumes the most rice (FAO, 2012). Rice farming nowadays is facing many environmental problems caused by input of chemical fertilizers and pesticides. The use of chemical fertilizers and pesticides has led to soil a decline in fertility, ecosystem damage, elimination of soil biota and emergence of resistant pathogens. Therefore the use of eco-friendly biofertilizers should be encouraged. Beneficial microorganisms have been reported to be involved in maintaining agricultural production, protecting the ecosystem and decreasing the use of chemical fertilizers (Adesemoye and Kloepper, 2009).

Seed priming is a pre-germination seed treatment whereby seeds are placed in partially hydrated condition (Bradford, 1986). Seed priming is considered as a method to enhance seedling quality and vigour (Basra et al., 2004). Seed priming is also involved in enhancing rice resistance to environmental stress (Goswami et al., 2013), weed suppressive ability and rice yield (Juraimi et al., 2012). Previous studies have shown that rice seeds respond to seed priming in the early part of the germination stage and revealed that it can increase seed germination, vigour index and germination speed (Anwar et al., 2013; Zarei and Sinaki, 2012). Priming rice seed with plant growth regulators is one of the beneficial treatments that can be used to invigorate rice seed and improve rice seed quality (Farooq et al., 2010).

Plant Growth Promoting Fungi (PGPF) is considered an alternative way to enhance rice growth and yield. The mechanisms by which PGPF act to enhance rice growth and yield includes production of phytohormones, phosphate solubilization, cellulose degradation and siderophore production. PGPF are generally abundant in the soil system and roots. One of the well-known fungi species listed in the PGPF group is the Trichoderma spp. (Doni et al., 2013). Currently, Trichoderma spp. are widely used in industrial processes and agriculture due to their ability to produce enzymes and secondary metabolites (Jiang et al., 2011; Mukherjee et al., 2008). In bio-fertilizer production, Trichoderma spp. is well recognized because of its ability to establish mycorrhizal-like association with plants, control of root and foliar pathogens, change the micro-floral composition in roots, enhance nutrient uptake, enhance root development, increase root hair formation, aid the plant in acquiring systemic resistance, degrade cellulose, solubilize phosphate and produce siderophores (Saravanakumar et al., 2013;...
Saba et al., 2012; Harman et al., 2004; Harman, 2000; Yadidia et al., 1999). Germination stage is reported to be the most critical phase in the plant life cycle, because during this stage, plants have a high vulnerability to injury, disease and environmental stress (Rajjou et al., 2012). Research on the role of Trichoderma spp. in enhancing rice seed germination is very important to be undertaken due to the potential for Trichoderma spp. to act as plant growth regulators. Previous research studies on the effect of Trichoderma spp. on the improvement of seed germination have been conducted for soybean (Tančić et al., 2011). Germination and vigour by growth regulators. Previous research studies on the effect of Trichoderma spp. on the improvement of seed germination have been conducted for soybean (Tančić et al., 2012). Research was carried out to examine the effect of Trichoderma spp. to improve rice seed germination and vigour by Trichoderma spp. to improve rice seed germination and vigour. This research was carried out to examine the effect of Trichoderma spp. on rice (Oryza sativa L.) seed germination and vigour.

**MATERIALS AND METHODS**

*Trichoderma* spp. spore preparation: Isolates of *Trichoderma* spp. namely *Trichoderma* sp., SL1, *Trichoderma* sp., SL2, *Trichoderma* sp., SL3, *Trichoderma* sp., SL4, *Trichoderma* sp., SL5, *Trichoderma* sp., SL6 and *Trichoderma* sp., SL7 were obtained from the Fermentation Technology Laboratory, School of Biosciences and Biotechnology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia. Each isolates were grown separately in potato dextrose agar and incubated for seven days at 30°C. After incubation, spores of the *Trichoderma* spp. were immediately transferred to Erlenmeyer flasks containing sterilized water.

*Rice seed preparation*: Organic rice seeds of the variety MRQ74 were surface sterilized with 70% ethanol, followed by 5% sodium hypochlorite and washed by sterilized distilled water. One hundred rice seed grains were selected for each treatment then soaked in the respective *Trichoderma* spp. in a flask containing 10^7 spores/mL spore suspension for 30 min. Rice seeds soaked in sterilized distilled water served as control. The treated seeds were incubated for 5 days in sterilized petri dishes at 28±2°C fitted with filter paper and each petri dish was irrigated with 10 mL sterilized water.

**Seedling length and weight**: The length of shoot and root seedling by *Trichoderma* spp. were significantly greater than the control (untreated). However, it was not significant on the weight of shoot and root basis (Table 1 and 2). The result revealed that *Trichoderma* sp., SL2 has the highest ability to stimulate seedling root elongation compared to other strains (Fig. 1). The role of *Trichoderma* spp. in the production of auxins and gibberellins is the key factor to enhance rice seedling length (Chowdappa et al., 2013; Martinez-Medina et al., 2011). Gibberellins were first identified as metabolites of *Gibberella fujikuroi* which causes bakanae fungal disease (Bomke and Tudzynski, 2009; Phinney, 1983). Auxins produced by *Trichoderma* spp. are able to stimulate root initiation and cell elongation, while gibberellins are involved in cell division. Production of auxins and gibberellins by *Trichoderma* spp. enhances rice seedling performance during seed germination (Fig. 1). *Trichoderma* spp. which has the ability to promote rice seedling length can be an alternative way to be expressed in grams. All measurements were according to the method used in Dash (2012).

**Seed germination rate**: Germination rate is the average number of seeds that germinate over the 5- and 10-day periods). In this experiment data was calculated on day 5. Germination rate was computed using the formula proposed by IRRI (2011):

\[
\text{Germination} = \left( \frac{\text{Number of seeds that germinated}}{\text{Number of seeds on the tray}} \right) \times 100
\]

**Seed vigour index**: Seed vigour index was examined after five days of incubation using the formula given by Abul-Baki and Anderson (1973) based on the product of germination (%) and seedling length (cm):

\[
\text{S.V.I} = \text{Germination} \times \text{Seedling Length}
\]

**Speed of germination**: Numbers of seedlings emerging daily are counted from day 0 until day 5 of planting. Thereafter a Germination Index (G.I) is calculated by using the following formula as proposed by Gupta (1993):

\[
\text{G.I} = \frac{\text{number of seedlings emerging on day}}{\text{day after planting}}
\]

**Statistical analyses**: All the data were from triplicates and were represented as mean±standard deviation. Further, the variations in the results obtained with respect to different seedling length and seedling weight, as well as different seed germination rate, vigour index and speed of germination were statistically analyzed using one way Analysis of Variance (ANOVA) and tested for significance using Fisher’s protected Least Significant Difference (LSD) at p≤0.05.

**RESULTS AND DISCUSSION**

*Seedling length and weight*: The length of shoot and root seedling by *Trichoderma* spp. were significantly greater than the control (untreated). However, it was not significant on the weight of shoot and root basis (Table 1 and 2). The result revealed that *Trichoderma* sp., SL2 has the highest ability to stimulate seedling root elongation compared to other strains (Fig. 1). The role of *Trichoderma* spp. in the production of auxins and gibberellins is the key factor to enhance rice seedling length (Chowdappa et al., 2013; Martinez-Medina et al., 2011). Gibberellins were first identified as metabolites of *Gibberella fujikuroi* which causes bakanae fungal disease (Bomke and Tudzynski, 2009; Phinney, 1983). Auxins produced by *Trichoderma* spp. are able to stimulate root initiation and cell elongation, while gibberellins are involved in cell division. Production of auxins and gibberellins by *Trichoderma* spp. enhances rice seedling performance during seed germination (Fig. 1). *Trichoderma* spp. which has the ability to promote rice seedling length can be an alternative way to be
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Length of shoot (cm)</th>
<th>Length of root (cm)</th>
<th>Weight of shoot (g)</th>
<th>Weight of root (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trichoderma sp. SL1</td>
<td>4.12 (0.43)</td>
<td>5.00 (1.04)</td>
<td>0.0056 (0.0009)</td>
<td>0.0011 (0.0004)</td>
</tr>
<tr>
<td>Trichoderma sp. SL2</td>
<td>4.48 (0.45)</td>
<td>6.00 (1.85)</td>
<td>0.0084 (0.0032)</td>
<td>0.0048 (0.0036)</td>
</tr>
<tr>
<td>Trichoderma sp. SL3</td>
<td>3.10 (0.48)</td>
<td>3.66 (1.21)</td>
<td>0.0050 (0.0007)</td>
<td>0.0022 (0.0017)</td>
</tr>
<tr>
<td>Trichoderma sp. SL4</td>
<td>3.04 (0.55)</td>
<td>4.36 (1.56)</td>
<td>0.0057 (0.0020)</td>
<td>0.0027 (0.0018)</td>
</tr>
<tr>
<td>Trichoderma sp. SL5</td>
<td>3.72 (0.30)</td>
<td>3.92 (0.74)</td>
<td>0.0066 (0.0016)</td>
<td>0.0024 (0.0012)</td>
</tr>
<tr>
<td>Trichoderma sp. SL6</td>
<td>4.16 (0.68)</td>
<td>3.76 (1.79)</td>
<td>0.0073 (0.0011)</td>
<td>0.0022 (0.0015)</td>
</tr>
<tr>
<td>Trichoderma sp. SL7</td>
<td>3.42 (0.42)</td>
<td>4.40 (0.75)</td>
<td>0.0064 (0.0013)</td>
<td>0.0021 (0.0009)</td>
</tr>
<tr>
<td>Control</td>
<td>2.62 (0.62)</td>
<td>3.30 (0.39)</td>
<td>0.0057 (0.0020)</td>
<td>0.0019 (0.0015)</td>
</tr>
<tr>
<td>LSD</td>
<td>8.15</td>
<td>2.33 ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ns: Not significant; Standard deviations are given in parentheses (n = 40)

Table 2: Comparison of length of shoot, length of root, weight of shoot and weight of root in different treatments (Trichoderma strains)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Length of shoot (cm)</th>
<th>Length of root (cm)</th>
<th>Weight of shoot (g)</th>
<th>Weight of root (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trichoderma sp. SL1</td>
<td>4.12 cdgh</td>
<td>5.00 b</td>
<td>0.0056 h</td>
<td>0.0011 b</td>
</tr>
<tr>
<td>Trichoderma sp. SL2</td>
<td>4.48 cdgh</td>
<td>6.00 acdh</td>
<td>0.0084 cdeh</td>
<td>0.0048 acegh</td>
</tr>
<tr>
<td>Trichoderma sp. SL3</td>
<td>3.10 abf</td>
<td>3.66 bf</td>
<td>0.0050 b</td>
<td>0.0022 b</td>
</tr>
<tr>
<td>Trichoderma sp. SL4</td>
<td>3.04 abef</td>
<td>4.36 b</td>
<td>0.0057 b</td>
<td>0.0027 ns</td>
</tr>
<tr>
<td>Trichoderma sp. SL5</td>
<td>3.72 bdh</td>
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<td>0.0024 b</td>
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<td>4.16 cdgh</td>
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<td>Trichoderma sp. SL7</td>
<td>3.42 abfh</td>
<td>4.40 ns</td>
<td>0.0064 ns</td>
<td>0.0021 b</td>
</tr>
<tr>
<td>Control</td>
<td>2.62 abefg</td>
<td>3.30 b</td>
<td>0.0057 ab</td>
<td>0.0019 b</td>
</tr>
</tbody>
</table>

Means with different small letter was significantly different between treatments at p<0.05; Means with "ns" was not significantly different with all treatment at p<0.05

Fig. 1: *Trichoderma* strains enhance rice seedling growth compared to untreated control

Fig. 2: Relationship between length of shoot and length of root with different treatments (*Trichoderma* strains)
**Fig. 3:** *Trichoderma* sp., SL2 caused better growth compared to control

**Table 3:** Rice seed germination rate, vigour index and speed of germination by different treatments (*Trichoderma* strains) during seed germination

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Germination (%)</th>
<th>Vigour index</th>
<th>Speed of germination (seeds/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Trichoderma</em> sp. SL1</td>
<td>99</td>
<td>902.88</td>
<td>39.26</td>
</tr>
<tr>
<td><em>Trichoderma</em> sp. SL2</td>
<td>97</td>
<td>1016.56</td>
<td>44.75</td>
</tr>
<tr>
<td><em>Trichoderma</em> sp. SL3</td>
<td>97</td>
<td>655.73</td>
<td>40.33</td>
</tr>
<tr>
<td><em>Trichoderma</em> sp. SL4</td>
<td>97</td>
<td>717.80</td>
<td>38.76</td>
</tr>
<tr>
<td><em>Trichoderma</em> sp. SL5</td>
<td>98</td>
<td>748.08</td>
<td>36.85</td>
</tr>
<tr>
<td><em>Trichoderma</em> sp. SL6</td>
<td>99</td>
<td>784.08</td>
<td>36.20</td>
</tr>
<tr>
<td><em>Trichoderma</em> sp. SL7</td>
<td>96</td>
<td>750.72</td>
<td>36.40</td>
</tr>
<tr>
<td>Control</td>
<td>90</td>
<td>532.80</td>
<td>35.86</td>
</tr>
</tbody>
</table>

**Fig. 4:** Relationship between germination rate and vigour index with different treatments (*Trichoderma* strains) during seed germination

**Fig. 5:** *Trichoderma* spp. colonized rice seedling

Rice seed germination rate, vigour index and speed of germination: The results showed that the inoculation of the rice seeds with *Trichoderma* spp. significantly increased rice seed germination rate, vigour index and speed of germination compared to untreated control (Table 3 and Fig. 4). Germination percentages were high in the rice seeds treated with *Trichoderma* spp. to the order of 96 to 99% compared to the untreated control seeds which registered 90% germination. The speed of germination was also high for the rice seeds treated with *Trichoderma* spp. compared to control. The range of germination speed in the rice seeds treated with *Trichoderma* spp. ranged from 36.2 to 44.75 seeds/day compared to the untreated control seeds which registered 35.86 seeds/day. The growth hormone which is produced by *Trichoderma* spp. enhances germination and speed. *Trichoderma* spp. also reduces the growth of pathogenic fungi by colonizing the rice seedlings as shown in Fig. 5. These results are in support of the findings of Jayalakshmi et al. (2009) who reported the biological control potential of *Trichoderma harzianum*. Vigour index was highest in the treatment of *Trichoderma* sp., SL2 followed by *Trichoderma* sp., SL1 *Trichoderma* sp., SL6 *Trichoderma* sp., SL7 *Trichoderma* sp., SL5, *Trichoderma* sp., SL4, *Trichoderma* sp., SL3 and the lowest recorded in the untreated control (Fig. 4). Zheng and Shetty (2000) reported that *Trichoderma* spp. induced phenolic compound production in the plant during seed germination and phenolic compounds produced by *Trichoderma* spp. led to enhancement of seed vigour. Further Cai et al. (2013) reported that a secondary metabolite namely harzianolide produced by *Trichoderma* spp. can influence the early stage of plant development through the enhancement of root length.

**CONCLUSION**

Seed priming has become fashionable among agricultural practitioners in the effort to improve crop stand under normal and adverse conditions. From this study, the higher seed vigour and germination rates of rice seeds treated with *Trichoderma* spp. in comparison to untreated seeds underscores the potential of...
beneficial fungal species such *Trichoderma* spp. as seed priming material to improve rice seed germination. This augurs well with the search for effective biological agents to enhance rice seed quality.

**ACKNOWLEDGMENT**

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**REFERENCES**


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