Water Use Efficiency of Rice (*Oryza sativa* L.) Planted with Organic Planting Ribbon (OPR) in Direct Seeding System

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ABSTRACT

A greenhouse experiment was conducted to study the effect of irrigation interval on the performance rice planted with Organic Planting Ribbon (OPR) as a growth medium in direct seeding system. The experiment also studied the water use efficiency of rice planted with OPR system. The experimental treatments consist of 2 factors, namely: (1) 3 growth medium system (control, close OPR and open OPR), and (2) 5 irrigation interval (I1: one-day, I2: two-day, I3: 3-day, I4: four-day and I5: five-day intervals). The experimental result showed that the open OPR was better (compared to closed OPR) for rice planting in direct seeding system. Rice planted with open OPR had a higher percentage of germinated seeds than the closed OPR (90.42 % for open OPR compared to 55.42 % for close OPR). The rice seedling in open OPR growth better as shown by the higher root dry weight (0.53 g plant-1 for open OPR compared to 0.33 g plant-1 for close OPR), and a highershoot dry weight (0.71 g plant-1 for open OPR compared to 0.50 g plant-1 for close OPR). The use of OPR in direct seeding system increased water use efficiency of the rice plant.

Key words: Conservation farming; conservation tillage; irrigation; water management; sustainable agriculture

INTRODUCTION

With the limitation of water availability, some researchers had promoted direct seeding in rice cultivation [7]. By direct seeding is meant the process of establishment the crops directly from the seed. This is different from the traditional transplanted puddled rice (TPR) system, in which the seeds were germinated in the nursery first, and after which transplanted to the field. Thus direct seeding can save money and time because it eliminates puddling and transplanting. In addition, direct seeding also can conserve water resources, because it do not required maintaining water standing for puddling. Indeed the TPR system has some advantage, such as a good crop establishment, enhance nutrient availability, and weed suppression [25]. However, traditional rice growing system accelerates soil degradation due to soil compaction and soil structure deterioration with intensive soil tillage [27]. Therefore, direct seedling has been widely practice for conservation farming.

Direct seeded rice (DSR) can be done in dry soil by sowing dry seeds into dry soil (called as dry DSR), or by sowing pre-germinated seeds on wet puddle soils called as the wet DSR), or by sowing seeds into standing water(called as the water DSR). Dry DSR is suggested in the area of water availability and widely in most Asian country in the rain fed upland ecosystems. From crop yield point of view, Harada *et al.* [10] showed that in irrigated shallow wetland soil of Japan, direct seeding rice yielded 5.50 t/ha, this was not significantly different with the transplanted rice which yielded 4.40 t/ha. In unfavorable rainfed lowland in India, Sarkar *et al.* [19] showed that direct seeding rice produced a higher yield (3.15 t/ha) compared to the transplanted rice. However, Farooq *et al.* [8], in irrigated soil in Pakistan, showed direct seeding rice produced a lower yield (2.93 t/ha) compared to the transplanted rice.
rice (3.95 t/ha). This lower yield of direct seeding rice might be caused by uneven plant distribution and weed problems as has been suggested by Mann et al. [16]. This might be the reason why a lot of farmers reluctant to practice direct seeding rice.

To overcome this problem, Mustafa et al. [17] developed Organic Planting Ribbon (OPR), a single layer sheet made from natural materials contains lignin and cellulose with thickness varies between 1 – 2 mm, width of 4 – 5 cm, and the length is in accordance with the requirement. At certain distance (usually 25 cm) is filled with 1-2 rice seeds. Djjoyowasito et al. [5], however, observed that the percentage of germinated seed in this system was lower compared to the control (without OPR). It was suggested that the lower germinated seeds in the OPR system was due to the resistance offered by the Organic Planting Ribbon. Djjoyowasito et al. [5] used more rapidly decomposed materials of banana sheath to replace water hyacinth as the raw material of the OPR. The result of their experiment showed that the use of OPR in rice direct seedling did not influence germination percentage and germination rate.

The other reason for the lower germinated seeds in first generation of OPR [17] was thought that the seeds in the ribbon experienced a lack of oxygen and unsuitable soil water content for seed germination. To overcome oxygen problem, in this study we developed two layer OPR with one side (upper side of the seed) left open. We called this organic planting ribbon as s an openorganic planting ribbon (Open OPR). Experiences had shown that the germination of paddy seeds was influenced by the condition of soil water content [9]. They showed that the optimal soil water content for seed germination was at about 50% field capacity. Andoh and Kobata [2] had shown that the length of coleoptiles and seminal roots of paddy sprouts was declined as the soil water potential was lower than -0.23 Mpa. The aimed of the experiment here was to study the performance of the Open Plant Ribbon (OPR) as a medium of rice growth at various interval irrigations. The experiment also studied the water use efficiency of rice planted with OPR method.

**Materials and Methods**

*Organic Planting Ribbon (OPR) preparation:*

The Organic planting ribbon (OPR) was made from two different materials; the upper layer which called as the stable sheet was composed of the water hyacinth (*Eichorniacrassipes* (Mart) Solm) and banana (*Musapparadisiaca*) sheath the ratio (w/w) of 60 : 40, and the lower layer which called as the unstable sheet was composed of the water hyacinth (*Eichorniacrassipes* (Mart) Solm), banana (*Musapparadisiaca*) sheath and *Crotalaria juncea* with the ratio (w/w) of 40 : 40 : 20. The sheet was measured its tensile strength (determined with Brazilian Test method, see Djjoyowasito, et al., [6]), water content (w/w), thickness and Carbon/Nitrogen ratio. The carbon content was determined with the Walkley and Black wet oxidation method [23] and N content was measured by the Kjeldhal method [3]. The characteristics of these two materials were presented in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter</th>
<th>Types of Organic Planting Ribbon</th>
<th>Unstable sheet</th>
<th>Stable sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tensile strength (kg cm⁻¹)</td>
<td>4.24</td>
<td>4.93</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Water content</td>
<td>13.15</td>
<td>9.98</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Thickness(mm)</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Weight (gram m⁻²)</td>
<td>193.6</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>C/N ratio</td>
<td>18.5</td>
<td>39.5</td>
<td></td>
</tr>
</tbody>
</table>

The OPR was made according to the method described by Djjoyowasito et al. [5] and the characteristics of the water hyacinth and banana sheath were similar to that of used by Djjoyowasito et al. [5]. The OPR has a 4 cm width; and rice seed (Inpari-Cidenok cv) was put in between the layer at a distance of 15 cm. For the Open Organic Planting Ribbon (Open OPR), the hole with the size of 2 x 2 cm² was made on the upper layer exactly above the rice seed. Five percent (w/w) of Ammonium Sulfate (AS, [NH₄]₂SO₄) was used as the decomposer of the OPR.

**Experimental treatments and procedure:**

The treatments studied in this experiment included 3 types of growth medium and 5 irrigation interval. The growth medium types were: (i) Closed Organic Ribbon Planting (Closed OPR), (ii) Open Organic Planting Ribbon (Open OPR), and (iii) conventional direct seeding (without OPR) as the control. The interval irrigation tested in this experiment were (i) one- day, (ii) two- days, (iii) 3- days, (iv) four-days, and (v) five-days interval. These 15 treatment combinations were arranged in a Complete Randomized Design with 3 replications.

The experiment was carried out in a glass house of Sekolah Tinggi Penyuluhan Pertanian (University of Agricultural Extension) at Lawang, Malang, East Java, Indonesia. The rice seeds were planted on plastic container of 60 cm (length), 40 cm (wide) and 40 cm (depth). The container was filled with 40 kg of dry soil (passed through 2 mm diameter sieve), and then watered to about 1.2 water content at field capacity (water content at field capacity is 45.25% v/v), after which the rice seeds were planted at a distance of 20 cm (within OPR), or 20 X 15 cm for
the control treatment. The plants were fertilized with 135 kg Urea (46% N), 100 kg super phosphate (36% P₂O₅) and 100 kg Potassium sulfate (50% K₂O) per ha.

Measurement was done for seed germination, soil water content at a depth of 2.5 and 5.0 cm (measured at one day prior to irrigation), shoot and root dry weight, and soil shear strength. The plants were harvested at 42 days after sowing.

Results and Discussion

The experimental result presented in Figure 1 showed that the OPR system prolonged germination time. At 3 days after sowing, in traditional direct seeding method (control) seeds had almost completely germinated, whereas in the OPR system the germinated seeds were only 55% for the Open OPR and 30% for the closed OPR. In the Open OPR, seed germination almost completely within 7 days after sowing. Until 7 days after sowing, the mean germinated seeds in closed OPR were still less than 60%.

The percentage of germinated seeds was significantly influenced by the growth medium and irrigation interval (Table 2). In the control the treatment of irrigation interval did not significantly influence the percentage of germinated seed; which varied between 95.56% to 99.5%. However, in the both of the OPR system irrigation interval significantly influenced the percentage of germinated seeds. In both the both OPR system the increase of irrigation interval, first (form 1 to 2 days interval) increases the percentage of germinated seeds, a further irrigation interval increase, however, tend to decrease the percentage of germinated seeds. In each of irrigation interval the percentage of germinated seeds in the Open OPR was higher compared to that of in the Closed OPR.

Fig. 1: The seed germination pattern (with time) of rice planted with various direct seeding methods.

<table>
<thead>
<tr>
<th>Irrigation interval (days)</th>
<th>The percentage of germinated seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>1</td>
<td>95.62ab</td>
</tr>
<tr>
<td>2</td>
<td>100.00 a</td>
</tr>
<tr>
<td>3</td>
<td>95.00 ab</td>
</tr>
<tr>
<td>4</td>
<td>99.65 a</td>
</tr>
<tr>
<td>5</td>
<td>98.35 a</td>
</tr>
</tbody>
</table>

*mean* followed by the same letters is not significantly different (p=0.05).

The slow of germination (Figure 1) and the lower of the percentage germinated seeds in the OPR system (Table 2) might be caused by a lower oxygen and light supply to seeds similar to the phenomena observed by Nathan and Van Ackher (2004). The suggestion of low oxygen supply for the lower percentage germinated seeds is in agreement with the data which show that the percentage of germinated seeds of the one day irrigation interval treatment were lower compared to that of two days interval irrigation. With daily irrigation, the one day interval irrigation (with water content of 1.2 field capacity) would have a lower oxygen concentration. The suggestion for the lower light supply of the OPR treatment was supported by the result of transparency measurement (measured with light meter which presented in Table 3).
The slow germination speed and lower percentage germinated seeds in closed OPR, of course could be a result of resistant offered by the OPR as suggested by Djjoyowasito et al. [5]. In addition to those three factors, surely the different in the percentage of germination seeds of the treatments was influenced by soil water content. The data in Table 2 show that the highest percentage germinated seeds was obtained by the treatment which received irrigated water with 2 days interval, and then decreased with increasing irrigation interval. The data presented in Table 4 show soil water content at both depth (2.5 cm and 5.0 cm) was only influenced by irrigation interval, and soil water content decreased with increasing irrigation interval. Looking the data given in Tables 4 and 2, it can be concluded that the best soil water content for rice seeds germination was that of closed to the water content at field capacity (2 days irrigation interval).

Table 3: The light transparence in the medium system used in the experiment.

<table>
<thead>
<tr>
<th>Growth system</th>
<th>Light transparence (lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>98.70</td>
</tr>
<tr>
<td>Open OPR</td>
<td>6.87</td>
</tr>
<tr>
<td>Closed OPR</td>
<td>2.30</td>
</tr>
</tbody>
</table>

Table 4: The effect of interval irrigation on soil water content at a depth of 2.5 cm and 5.0 cm.

<table>
<thead>
<tr>
<th>Irrigation interval (day)</th>
<th>Soil water content (% v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5 cm depth</td>
</tr>
<tr>
<td>1</td>
<td>48.86 a</td>
</tr>
<tr>
<td>2</td>
<td>44.46 ab</td>
</tr>
<tr>
<td>3</td>
<td>41.59 bc</td>
</tr>
<tr>
<td>4</td>
<td>37.93 c</td>
</tr>
<tr>
<td>5</td>
<td>36.44 c</td>
</tr>
</tbody>
</table>

1 means followed by the same letters is not significantly different (p=0.05).

Irrigation interval nor the interaction between medium system and irrigation interval did not significantly influence the dry root and shoot weight. The dry root and shoot weight was only influenced by the medium system (Table 5). The highest root and shoot yield were obtained by the plant planted in open organic planting system (0.53 g/plant for root weight and 0.70 g/plant for shoot weight), and the lowest was obtained by closed organic ribbon planting (0.37 g/plant for root weight and 0.37 g/plant for shoot weight).

Table 5: The effect of growth system on root and dry weight of rice planted with direct seeding

<table>
<thead>
<tr>
<th>Growth system</th>
<th>Dry root weight (g/plant)</th>
<th>Dry shoot weight (g/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.42 b</td>
<td>0.56 b</td>
</tr>
<tr>
<td>Open OPR</td>
<td>0.53 a</td>
<td>0.70 a</td>
</tr>
<tr>
<td>Closed OPR</td>
<td>0.37 c</td>
<td>0.47 c</td>
</tr>
</tbody>
</table>

1 means followed by the same letters is not significantly different (p=0.05).

The result in Table 5 indicated that in this experiment the different in irrigation interval had no effect on the growth of rice planted with direct seeding method. Looking the data given in Table 4, this phenomenon was reasonable since soil water content at those irrigation interval was still far higher compared to the wilting point. The lowest soil water content was obtained by 5 days irrigation interval, i.e. 36.44% (at a depth of 2.5 cm) and 37.93% (at a depth of 5.0 cm). These were far higher compared to the water content at wilting point of this soil (24.4% v/v). The difference of root and shoot yield in this experiment, was probably due to the different in the germination speed (Figure 1). This occurred for the closed OPR system which had a lower of root and shoot weight of closed OPR compared to the other two treatments. The higher root and shoot weight of the open OPR (compared to the control) was probably due to the addition of plant nutrient in the OPR. As described above, OPR used ammonium sulfate as the decomposer, and indeed the nitrogen from the decomposer will be used by the plant.

To investigate the possibility of the influence of soil strength on root growth, a vane shear test [4] at 0 – 5.0 cm depth, was done at one day before harvesting. The result in Table 6 shows that soil shear strength was influenced by irrigation interval. However, the increase in soil shear strength in this experiment did not significantly influence root weight. It seems that the highest soil shear strength observed in this experiment (21. kPa) was still not to be the limiting factor for the growth of rice root. The experimental result presented in Figure 2 show that water use efficiency of rice planted in direct seeding system was influenced by the method of direct seeding and irrigation interval. In all interval irrigation treatment, the use OPR increased water use efficiency. For 1 day interval irrigation, the most efficient was obtained by closed design OPR. However, for other irrigation interval water use efficiency of those two OPR design was not significantly different.
Table 6: The effect of interval irrigation on soil shear strength at a depth of 0 - 5.0 cm

<table>
<thead>
<tr>
<th>Irrigation interval (day)</th>
<th>Soil shear strength (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.65 d</td>
</tr>
<tr>
<td>2</td>
<td>8.43 d</td>
</tr>
<tr>
<td>3</td>
<td>13.50 c</td>
</tr>
<tr>
<td>4</td>
<td>17.65 b</td>
</tr>
<tr>
<td>5</td>
<td>21.00 a</td>
</tr>
</tbody>
</table>

Means followed by the same letters is not significantly different (p=0.05).

Fig. 2: The effect of interval irrigation (days) on water use efficiency (l g⁻¹) of various direct seeding methods.

The increase in water use efficiency in the OPR method was probably mainly due to the lower soil evaporation because part of the soil surface was covered by the planting ribbon. Indeed the higher soil temperature due to more sun light in the control treatment (Table 3) would also contributed to the high soil evaporation of the control treatment, and hence decreased water use efficiency.

**Conclusion:**

The experimental result discussed above show that the open OPR was better (compared to closed OPR) for rice planting in direct seeding system. Rice planted with open OPR had a higher percentage of germinated seeds than the closed OPR (90.42% for open OPR compared to 55.42% for close OPR). The rice sowing in open OPR growth better as hown by the higher root dry weight (0.53 g plant⁻¹ for open OPR compared to 0.33 g plant⁻¹ for close OPR), and a higher shoot dry weight (0.71 g plant⁻¹ for open OPR compared to 0.50 g plant⁻¹ for close OPR). The use of OPR in direct seeding system increased water use efficiency of the rice plant.

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