Yield contributing characters effect of submerged water levels of boro Rice (Oryza sativa L.)

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A B S T R A C T

The field experiment was conducted at the Field Laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka in boro season with a view to find out the influence of water level and seedling number hill⁻¹ on growth and yield of boro rice. The entire yield component was significantly unaffected by seedlings number hill⁻¹ but percent filled grains was decreased with increasing seedling number hill⁻¹. Grain yield was significantly influenced by seedling number hill⁻¹ but straw yield as well as biological yield was unaffected. The highest grain yield (6.49 t ha⁻¹) was found with 2 seedlings hill⁻¹ which was similar to 1 and 3 seedlings hill⁻¹ and the lowest grain yield (6.00 t ha⁻¹) was at 4 seedlings hill⁻¹. Interaction effect of water level and seedling number hill⁻¹ had significant effect on growth as well as yield contributing characters except duration of flowering, effective tillers hill⁻¹ and 1000 grain weight. Among the yield contributing characters total grains panicle⁻¹, filled grains panicle⁻¹ and percent filled grains were significantly lowest at saturated condition with 4 seedlings hill⁻¹ compared to other treatments. Significantly the highest grain yield was recorded from 1 to 3 seedlings hill⁻¹ irrespective of their water level and the lowest grain yield was at 4 seedlings hill⁻¹ under continuous saturation as well as submerged condition. Field water use efficiency was significantly higher (6.10 kg ha⁻¹ mm⁻¹) at continuous saturated condition and lower (4.57 kg ha⁻¹ mm⁻¹) at submerged condition.

Key words: Submerged, Interaction, Harvest index, Water economy, yield, Boro Rice (Oryza Sativa L.)

Introduction

Rice (Oryza sativa L.) is the primary food for half the people in the world. In many regions it is eaten with every meal and provides more calories than any other single food. Rice is a nutritious food, providing about 90 percent of calories from carbohydrates and as much as 13 percent of calories from protein (Anon., 2005). Rice contributes more than 70% of total production and 60-94% of daily calorie intake in China, India, Pakistan, Bangladesh and Nepal (Prasad et al., 1999).

Rice is the 1st ranking cereal crop in terms of area and production in Bangladesh though the average yield of 2.82 t ha⁻¹ is very low as compared to that of Egypt (8.4 t ha⁻¹) and USA (6.6 t ha⁻¹) (BBS, 2010). There are many reasons for this low yield. The important one is use of unsuitable aged seedlings and different water levels by farmers. The combined effect of these factors usually produces high seedlings mortality just after transplanting. Seedlings age at transplanting is an important factor for uniform stand of rice and regulating its growth and yield (Bassi et al., 1994). Tiller dynamics of the rice plant greatly depends on the age of seedlings at transplanting (Pasuquin et al., 2008). Tilling and growth of rice proceed normally when optimum aged seedlings are transplanted at the right time (Mobasser et al., 2007). Though about one-third of the country’s land area is submerged by monsoon flood in a normal year, no boro crop can be grown without irrigation (Das, 2005). On the other hand, inefficient water use not only increases cost of irrigation, but declines the water table, increases arsenic contamination and may emit the greenhouse gases from submerged rice field that lead to climate change in the world (Wang et al., 2002). Most farmers maintained standing water in the rice crop to control weeds, but this benefit comes at the expense of substantial water loss by percolation and seepage. The gap between the “true need” and “current use” of water producing rice is very large (Bhuiyan, 1999).

Irrigated area can be extended from its current one-third of the cultivated area to more than one-half. But water is costly resource and its efficient use means bringing additional area under irrigation without making extra investments (Das,
Materials and Methods

The field experiment was conducted at the Field Laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka in boro season during the period from January 2013 to May 2013 with a view to find out the influence of water level and seedling number hill\(^{-1}\) on growth and yield of boro rice. The experiment was carried out in split-plot design with 3 replications having two levels of water in main plot and 4 levels of seedling number hill\(^{-1}\) in the sub plot. There were 8 treatment combinations. The total numbers of unit plots were 24. The size of unit plot is 5 m x 3 m. The distances between plot to plot and replication to replication were 1 and 1.5 m respectively. The water levels were continuous saturated (S\(_1\)) & continuous submerged (S\(_2\)) condition as well as seedling numbers were 1 (T1), 2 (T2), 3 (T3) & 4 (T4) seedlings hill\(^{-1}\).

Recording of data of crop growth characters: Plant height (cm) at 15 days interval, Number of tillers hill\(^{-1}\) at 15 days interval, Leaf area index at 15 days interval, and Time of flowering. The data collected on different parameters were statistically analyzed to obtain the level of significance using the IRRISTAT (Version 7.2, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Table 1. Influence of water level and seedling number hill\(^{-1}\) on yield contributing characters of boro rice

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Effective tillers hill(^{-1}) (No.)</th>
<th>Panicle length (cm)</th>
<th>Grains/panicle (No.)</th>
<th>Filled grains/panicle (No.)</th>
<th>Unfilled grains/panicle (No.)</th>
<th>Unfilled grains (%)</th>
<th>1000-grain weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water level</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>S(_1)</td>
<td>12.28</td>
<td>28.10</td>
<td>153.16</td>
<td>137.20</td>
<td>15.96</td>
<td>10.50</td>
<td>19.86</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Seeding number hill(^{-1})</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T(_1)</td>
<td>12.37</td>
<td>28.40</td>
<td>157.02</td>
<td>143.04</td>
<td>13.98</td>
<td>8.90</td>
<td>19.89</td>
</tr>
<tr>
<td>T(_2)</td>
<td>12.40</td>
<td>28.23</td>
<td>161.45</td>
<td>146.08</td>
<td>15.37</td>
<td>9.52</td>
<td>20.08</td>
</tr>
<tr>
<td>T(_3)</td>
<td>12.25</td>
<td>28.10</td>
<td>156.53</td>
<td>140.62</td>
<td>15.92</td>
<td>10.17</td>
<td>19.64</td>
</tr>
<tr>
<td>T(_4)</td>
<td>13.38</td>
<td>28.31</td>
<td>154.16</td>
<td>135.37</td>
<td>18.79</td>
<td>12.37</td>
<td>19.41</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>2.33</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Interaction of water level and seedling number hill(^{-1})</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>S(_1) T(_1)</td>
<td>11.80</td>
<td>28.15</td>
<td>157.65</td>
<td>145.59</td>
<td>12.07</td>
<td>7.65</td>
<td>19.93</td>
</tr>
<tr>
<td>S(_1) T(_2)</td>
<td>12.33</td>
<td>28.06</td>
<td>154.97</td>
<td>139.00</td>
<td>15.97</td>
<td>10.23</td>
<td>20.02</td>
</tr>
<tr>
<td>S(_1) T(_3)</td>
<td>12.30</td>
<td>27.72</td>
<td>162.18</td>
<td>145.85</td>
<td>16.33</td>
<td>10.06</td>
<td>20.16</td>
</tr>
<tr>
<td>S(_1) T(_4)</td>
<td>12.70</td>
<td>28.47</td>
<td>137.82</td>
<td>118.36</td>
<td>19.46</td>
<td>14.12</td>
<td>19.32</td>
</tr>
<tr>
<td>S(_2) T(_1)</td>
<td>12.93</td>
<td>28.64</td>
<td>156.38</td>
<td>140.48</td>
<td>15.90</td>
<td>10.17</td>
<td>19.86</td>
</tr>
<tr>
<td>S(_2) T(_3)</td>
<td>12.20</td>
<td>28.47</td>
<td>150.88</td>
<td>135.38</td>
<td>15.50</td>
<td>10.28</td>
<td>19.12</td>
</tr>
<tr>
<td>S(_2) T(_4)</td>
<td>14.07</td>
<td>28.16</td>
<td>170.50</td>
<td>152.38</td>
<td>18.12</td>
<td>10.62</td>
<td>19.47</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>ns</td>
<td>1.11</td>
<td>28.62</td>
<td>23.66</td>
<td>7.10</td>
<td>3.30</td>
<td>ns</td>
</tr>
<tr>
<td>CV (%)</td>
<td>12.3</td>
<td>2.2</td>
<td>10.2</td>
<td>9.4</td>
<td>24.9</td>
<td>18.1</td>
<td>4.9</td>
</tr>
</tbody>
</table>

2005). Seedling(s) per hill is an important factor for the growth and yield of rice. Optimal population density and leaf area influences the availability of sunlight and nutrients for growth and development. Competition within the hill is an integral part of the physical environment and the competition by neighbors often create the complexity. Obulamma et al. (2002) recorded the highest grain yield, crop growth rate and net assimilation rate from one seedling hill\(^{-1}\). Panda et al. (1999) found that grain yield was highest with 4 seedlings hill\(^{-1}\). Biswas and Salokhe (2001) revealed similar yield of rice by planting 2-4 vegetative tillers per hill. Because of these conflicting reports about the effect of water level and population density on growth and yield of boro rice, a study has under taken with the following objectives to find out the effect of water level and seedling number hill\(^{-1}\) on growth and yield of boro rice, to identify the optimum water level and seedling(s)/hill for boro rice cultivation and to find out the water use efficiency.
Number of effective tiller hill$^{-1}$ was not significantly influenced by seedlings number hill$^{-1}$ (Table 1). The higher number of effective tiller hill$^{-1}$ (13.38) was counted at 4 seedlings hill$^{-1}$ that followed by other treatments. The findings are in agreement with those stated by BRRI (1999) and Shah et al. (1991) who reported that effective tillers significantly unaffected by the variation of seedlings numbers per hill.

Number of effective tillers hill$^{-1}$ was insignificant by the interaction of water level and population density. Maximum and minimum effective tiller hill$^{-1}$ was recorded at continuous submergence with 4 seedlings hill$^{-1}$ (14.07) and saturation with 1 seedlings hill$^{-1}$ (11.80) though the difference was statistically similar (Table 1).

Results and discussion

Number of effective tillers hill$^{-1}$

The number of effective tillers hill$^{-1}$ obtained with submerged condition was (12.92) and with continuous saturated condition was 12.28 (Table 1). The results agreed with Chowdhury (1988) also revealed the highest number of effective tillers m$^{-2}$ with continuous flooding that was significantly different from that obtained with continuous saturation.

Panicle length

The panicle length was not varied significantly due to water levels. The maximum (28.42 cm) and minimum (28.10 cm) panicle length was obtained under submerged and saturated condition respectively which was statistically similar (Table 1). The similar length of panicle under saturated and submerged condition due to adequate supply of water and nutrients might be resulted from similar flag leaf which ultimately caused equal photosynthesis that supplied equal assimilates. Bhuiyan (2001) also reported that rice plant did not suffer from water stress if soil was saturated and there was no standing water.

Panicle length was statistically unaffected by the number of seedlings hill$^{-1}$. The longest (28.40 cm) and shortest (28.10 cm) panicle was observed in 1 and 3 seedlings hill$^{-1}$ respectively though the value did not differ significantly (Table 1). The results are conformity with Hushine (2004), BRRI (1999) who stated that panicle length was unaffected by the number of seedlings hill$^{-1}$.

The interaction between water level and seedling number hill$^{-1}$ was significantly influenced the panicle length (Table 1). The longest panicle length (28.64 cm) was obtained under continuous submerged condition with 1 seedlings hill$^{-1}$ and that followed by other treatment combination except saturated condition with 3 seedlings hill$^{-1}$ which gave significantly shortest panicle length (27.72 cm).

Number of grains panicle$^{-1}$

The number of grains panicle$^{-1}$ significantly unaffected due to the different water levels. Plants grown under continuous standing water (S$\text{s}_2$) showed 161.42 grains panicle$^{-1}$, whereas plants under continuous saturated (S$\text{s}_1$) condition gave 153.16 grains plant$^{-1}$ (Table 1). The number of grains panicle$^{-1}$ was 5.39% higher under submerged condition compared to saturated condition. The result was dissimilar with Joseph & Havagni (1988) who showed that number of spikelets per panicle under standing water was superior than that’s of under saturated condition. They found 8.21% more spikelets per panicle over saturated to submerged condition.

Number of grains panicle was not significantly influenced by the number of seedlings hill$^{-1}$. The maximum (161.45) and lowest (154.16) of grains panicle$^{-1}$ was obtained with 2 and 4 seedling hill$^{-1}$ respectively which was statistically similar (Table 1). The result was agreement with Shah et al. (1991) who stated that total grains per panicle was unaffected by the number of seedlings hill$^{-1}$ and number of grain panicle$^{-1}$ increased with decrease in seedling number hill$^{-1}$.

Total grains per panicle was significantly influenced by the interaction effect of water levels and seedling number hill$^{-1}$. Continuous submergence showed higher grains panicle$^{-1}$ irrespective of their seedling number hill$^{-1}$ but in case of in case of saturated condition higher seedling number hill$^{-1}$ resulted the lowest grains panicle$^{-1}$.

Filled grains panicle$^{-1}$

The filled grains panicle did not differ significantly for water levels. The maximum number of filled grains (145.35) was found in submerged condition and the minimal number (137.20) of grains panicle$^{-1}$ at saturated condition (Table 1). The percent filled grain was 89.50 and 90.05 of total grains under saturated and submerged condition respectively.

Number of filled grains panicle$^{-1}$ did not differ significantly at different seedling number hill$^{-1}$. The maximum number of filled grains panicle$^{-1}$ (146.08) was found at 2 seedlings hill$^{-1}$ and the lowest (135.37) at 4 seedlings hill$^{-1}$ (Table 1). The percent filled grain was significantly influenced by seedling number hill$^{-1}$ (Table 1). Filled grain percentage was highest at 1 seedling hill$^{-1}$ (91.10%) which was statistically similar with 2 seedlings hill$^{-1}$ (90.48%) and it was followed by 3 seedlings hill$^{-1}$.
Comparatively maximum (8.03 t ha\(^{-1}\)) straw yield was found under irrigation applied at submerged condition and saturated condition respectively (Table 2). The result was in conformity with that of Patel (2000), who reported significantly unaffected straw yield straw yield under saturated and submerged condition.
Table 2. Yield of boro rice as influenced by water level and seedling number hill$^{-1}$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (t ha$^{-1}$)</th>
<th>Straw yield (t ha$^{-1}$)</th>
<th>Biological yield (t ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water levels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S$_1$</td>
<td>6.16</td>
<td>7.69</td>
<td>13.86</td>
</tr>
<tr>
<td>S$_2$</td>
<td>6.44</td>
<td>8.03</td>
<td>14.47</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Population density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T$_1$</td>
<td>6.29</td>
<td>7.26</td>
<td>13.56</td>
</tr>
<tr>
<td>T$_2$</td>
<td>6.49</td>
<td>7.86</td>
<td>14.35</td>
</tr>
<tr>
<td>T$_3$</td>
<td>6.42</td>
<td>8.21</td>
<td>14.63</td>
</tr>
<tr>
<td>T$_4$</td>
<td>6.00</td>
<td>8.11</td>
<td>14.11</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.43</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>CV %</td>
<td>5.4</td>
<td>20.6</td>
<td>12.3</td>
</tr>
</tbody>
</table>

S$_1$= Saturated (No deficit or stagnation of water), S$_2$= Submerged (Continuous 2-5 cm standing water), T$_1$= 1 seedling hill$^{-1}$, T$_2$= 2 seedlings hill$^{-1}$, T$_3$= 3 seedlings hill$^{-1}$, T$_4$= 4 seedlings hill$^{-1}$

Straw yield was not significantly influenced by the different level of population density. The maximum straw yield (8.21 t ha$^{-1}$) was found with 3 seedlings hill$^{-1}$ and the minimum straw yield (7.26 t ha$^{-1}$) was at single seedling hill$^{-1}$ (Table 2). Rajarathinam and Balasubramanuyan (1999) also revealed no significant difference of straw yield due to different levels of seedlings hill$^{-1}$.

**Biological yield**

Biological yield was not significantly varied for the water levels. The maximum biological yield (14.47 t ha$^{-1}$) was obtained from continuous submerged condition which was statistically similar (13.86 t ha$^{-1}$) to saturated condition (Table 2). Statistically similar biological yield might be due to the similar grain yield and stray yield under different water levels.

Biological yield was not significantly influenced by seedling numbers hill$^{-1}$. Maximum biological yield (14.63 t ha$^{-1}$) was observed with 3 seedlings hill$^{-1}$ whereas minimum biological yield (13.56 t ha$^{-1}$) was found with planting single seedling hill$^{-1}$ (Table 2).

**Harvest index**

Harvest index was not statistically influenced by the water levels. However, the maximum (45.03 %) harvest index was found from irrigation applied at submerged condition and the minimum harvest index (44.65) was at saturated condition (Figure 1). The result was in agreement with the findings of Raju (1980) who reported that treatment having continuous flooding did not improve the harvest index.

![Figure 1. Influence of water level on harvest index of boro rice](image)

Seedling number variation had no significant effect on harvest index. However, One seedling hill$^{-1}$ produced the highest harvest index (46.77%) and the lowest (42.87%) was in 4 seedlings hill$^{-1}$. The increase of harvest index was more prominent in less population density and it was decreased with increasing planting density (Figure 2). The result was in agreement with the findings of Shah et al. (1991) and Zhang and Huang (1990) who reported that harvest index was unaffected by the number of seedlings hill$^{-1}$ but Shrirame et al. (2000) reported significantly higher harvest index with one seedling hill$^{-1}$.  

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Water economy

The applied water was measured as per Islam (1997). It was found that higher amount of water (1410 mm) was required for continuous submerged (2-5 cm standing water) condition where as continuous saturated condition needed 1010 mm water. Similar water requirement in submerged and saturated condition was also reported by IRRI (1995), BRRI (1988), Jaggi et al. (1985), and Iruthyaraj (1981) who stated that continuous flooding needed more water than saturated condition. The percent reduction of total water requirement from submerged to saturation was 28.37%. Sattar and Bhuiyan (1994) also reported that under continuous saturated condition, 26-30% water was saved during normal irrigation period over the amount used in farmer’s water management practice with continuous 5-7 cm standing water without any significant yield reduction.

Field water use efficiency
Effect of water levels

Field water use efficiency was significantly influenced by irrigation water levels. It was evident that significantly higher (6.10 kg ha\(^{-1}\) mm\(^{-1}\)) and lower (4.57 kg ha\(^{-1}\) mm\(^{-1}\)) water use efficiency was recorded with continuous saturated condition (No deficit or stagnation of water) and submerged condition respectively (Figure 3). The result was in agreement with those stated by Patel (2000), Gowda (1995), Maity and Sarkar (1990) who observed the highest water use efficiency in saturated condition than that’s of submerged condition.

The maximum percentage of water use efficiency was estimated under 2 seedlings hill\(^{-1}\) at continuous saturation (15%) and minimum percentage (10%) was recorded at submerged condition with 4 seedlings hill\(^{-1}\) (Figure 4).
Conclusions

From the overall results it may be concluded that transplanting of younger seedlings in combination with intermittent submerge performed the best in tiller production, growth dynamics, yield contributing characters and produced more productive tillers hill⁻¹. Intermittent submerge was suitable for exploring the physiological potentials of rice seedlings on effective tillers for increasing grain yield.

References

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