Effect of Elevated Temperature on Rice Phenology and Yield

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Abstract

At present in the context of climate change, temperature is one of the most important environmental factors influencing the rice crop growth, development, and yield. The duration of each phenological stage is influenced by temperature which has direct impact on yield. The objective of this study is to provide an overview of the influence of elevated temperature on rice phenology and accumulated growing degree days. The experiment was conducted during Kharif 2012 under temperature control chamber, in which temperature is elevated from the ambient level (2°C and 4°C) for the entire crop growth period. The results showed that the days taken to attain maturity was less under elevated temperature of 4°C (96 days) and 2°C (102 days) when compared to the ambient temperature (108 days). The accumulated growing degree days were higher under elevated temperature of 4°C and nearer value for 2°C viz., 1641 and 1583 respectively from that of ambient. Under elevated temperature of 4°C and 2°C, the grain yield was 23 and 13.3 percent less from the ambient. The highest grain yield is from the treatment under ambient temperature with 6.2 t/ha followed by 5.3 t/ha under 2°C level and 4.7 t/ha at 4°C level. The yield loss under elevated temperature is due to the sterile florets and lesser crop duration.

Keywords: Rice, Elevated Temperature, Phenology, Accumulated Degree Days and Yield.

1. Introduction

Rice is the staple food of over half the world’s population [4]. In India, rice (Oryza sativa L.) is grown under widely varying conditions of altitude and climate, extends from 8 to 35 degree north latitude and as high as 3000 meters from sea level. Global circulation models project that the temperature is likely to increase by 1.1 to 6.4°C by the end of the 21st century [2]. Future projections of climate using regional climate models PRECIS and RegCM3 under A1B scenario have projected an increase in maximum and minimum temperature by 3.1 to 3.7°C and 3.7 to 4.2°C, respectively at the end of the 21st century for Tamil Nadu. The range of reduction in duration of rice ranged from 9 to 14 days at the end of the century [7]. The rise in atmospheric temperature (heat stress) causes detrimental effects on growth, yield, and quality of the rice crop by affecting its phenology, physiology, and yield components [9, 8, 6]. The sensitivity of rice to high temperature varies with growth phase, an increase in day/night temperature and genotype [13, 9, 6] Lalitha et al. [5] stated that daily mean temperature exceeding 26°C restricted the duration of tillering period to five weeks after planting. Ziska et al. [14] found that an increase in temperature by 4°C during the growing season resulted in earlier maturation of the crop by five and six days for wet and dry seasons, respectively.

2. Material and Methods

The experiment was conducted under temperature control chamber created at Agro Climate Research Centre; Tamil Nadu Agricultural University located at 11°N latitude, 77°E longitude and at altitude of 426.7m above sea level during Kharif 2012 with short duration hybrid (CORH3). Two
temperature control chambers were created and adjusted for 2°C and 4°C elevated from the ambient temperature (open) throughout the crop period/season (both day and night). Each control chamber has a total area of 9m² (3m × 3m) with a height of 3.6m attached with weather sensors to record air temperature (°C), relative humidity (%) and soil temperature (°C) inside the chamber and also in the open field. The weather parameters were monitored and recorded by the VR18 PAPERLESS recorder. Weather data was recorded at three minutes interval in both ambient and controlled condition. The phenological stages such as active tillering, panicle initiation, 50 percent flowering and harvest stages were observed. The accumulated heat unit system is based on the design that crops have definite temperature requirements to attain certain phenological stage. The GDD were calculated using the formula given by Iwata [3]. A base temperature of 10°C was adopted for rice as given by Gao et al. [1].

\[
\text{Growing Degree Days} = \frac{T_{\text{max}} + T_{\text{min}}}{2} - T_b
\]

where, \(T_{\text{max}}\) - Total Maximum Temperature (°C), \(T_{\text{min}}\) - Total Minimum Temperature (°C) and \(T_b\) - Base Temperature (°C).

3. Result and Discussion

Phenology of rice hybrid under elevated temperature compared with ambient is presented in Table 1. Results revealed that phenology of crop were influenced by elevated temperature. The various phenological stages like active tillering, panicle initiation, 50 percent flowering and harvest for the crops raised under elevated temperature (4°C and 2°C) was found to be shorter than ambient temperature.

The crop duration was reduced under elevated temperature. The 4°C treatment had a duration of 96 days (12 days earlier than ambient temperature), whereas 2°C had 102 days (6 days earlier than ambient temperature) compared to that of ambient which had a duration of 108 days, similar results were reported by Venkatramanan and Singh [11].

In case of accumulated growing degree days (Table 2), the elevated temperature of 4°C (1641°C day) showed lower accumulated heat units for attaining active tillering to harvest than elevated temperature of 2°C (1583°C day) and ambient temperature, (1523°C day)

The grain yield gets declined at elevated temperature significantly than the ambient. The 4°C treatment recorded a grain yield of 4.7 t/ha, which was the lowest followed by 2°C with 5.3 t/ha compared to ambient 6.2 t/ha. These findings were in corroboration with Sinha and Swaminathan [10]. The yield reduction in rice due to elevated temperature was 13.3 and 23 per cent for 2°C and 4°C treatments respectively (Figure 1) same reported by Weerakoon et al. [12].

4. Conclusion

The elevated temperature on rice crop affects the crop duration by attaining the phonological stages earlier with low accumulated growing degree days. This reduction in grain yield may be due to the direct effect of temperature on rice development especially high temperature at flowering stage leading to spikelet sterility and, therefore, yield loss.

5. References

Table 1. Effect of elevated temperature (2°C and 4°C) over ambient on duration of phonological stages and AGDD during Kharif 2012

<table>
<thead>
<tr>
<th>Date</th>
<th>Total days</th>
<th>Days taken for phonological stage</th>
<th>Date</th>
<th>Total days</th>
<th>Days taken for phonological stage</th>
<th>Date</th>
<th>Total days</th>
<th>Days taken for phonological stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing</td>
<td>May 30</td>
<td></td>
<td>May 30</td>
<td></td>
<td></td>
<td>May 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transplanting</td>
<td>June 18</td>
<td>20</td>
<td>June 18</td>
<td>20</td>
<td></td>
<td>July 7</td>
<td>39</td>
<td>19</td>
</tr>
<tr>
<td>Active Tillering</td>
<td>July 9</td>
<td>41</td>
<td>July 8</td>
<td>40</td>
<td>20</td>
<td>July 20</td>
<td>50</td>
<td>11</td>
</tr>
<tr>
<td>Panicle Initiation</td>
<td>July 21</td>
<td>53</td>
<td>July 20</td>
<td>51</td>
<td>12</td>
<td>August 6</td>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>Flowering</td>
<td>August 8</td>
<td>70</td>
<td>August 7</td>
<td>67</td>
<td>17</td>
<td>August 2</td>
<td>96(C)</td>
<td>31</td>
</tr>
<tr>
<td>Maturity</td>
<td>September 14</td>
<td>108 (A)</td>
<td>September 8</td>
<td>102 (B)</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[D (A-B) = 6 \text{ days}\]
\[E (A-C) = 12 \text{ days}\]

Table 2. Effect of elevated temperature (2°C and 4°C) over ambient on Accumulated Growing Degree Days (AGDD) during Kharif 2012

<table>
<thead>
<tr>
<th>Ambient Temperature</th>
<th>Elevated Temperature (2°C)</th>
<th>Elevated Temperature (4°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Tillering</td>
<td>347.2</td>
<td>367.4</td>
</tr>
<tr>
<td>Panicle Initiation</td>
<td>209.8</td>
<td>214.9</td>
</tr>
<tr>
<td>Flowering</td>
<td>333.5</td>
<td>353.7</td>
</tr>
<tr>
<td>Maturity</td>
<td>633.0</td>
<td>646.8</td>
</tr>
<tr>
<td>AGDD (Transplanting to Harvest)</td>
<td>1523</td>
<td>1583</td>
</tr>
</tbody>
</table>