Model Analysis on Rice Productivity in Riverina Region, Australia

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Rice production in Australia is focused in the Riverina region of New South Wales (34-36°S, 144-146°E). Rice is grown under fully irrigated conditions and the average industry yield reaches 9.4 t/ha (un-husked rice), which is one of the highest in the world, due to high solar radiation (ca 24 MJm⁻²d⁻¹) and moderate temperature during the growing period (ca 20 °C). Nitrogen management is an essential practice to achieve this high yield level, but it is still not certain whether the rice productivity in the Riverina region is close to the attainable level under the given climatic and nitrogen conditions. The present study therefore was conducted to find the gap between the actual and attainable productivity estimated by the crop growth model based on the photosynthesis and leaf nitrogen relationship

The data provided for the analysis were from nitrogen fertilizer experiments conducted at three paddocks with different cropping history in the Riverina region (Table 1). The cultivar used was ‘Amaroo’, a medium grain variety that is most widely planted in this region. In the current study, we used the actual time courses of LAI and specific leaf nitrogen (SLN) given by the spline function based on periodical sampling, so as to avoid the errors associated with the estimation of these variables. Most of the parameter values were for cv. ‘Nipponbare’ derived from the experiments in Kumamoto and the model was found to give good estimation for rice growth in Kyoto. The extinction coefficient was adjusted to 0.35 for cv. ‘Amaroo’ according to the Williams and Angus. The model simulates the daily changes in total dry matter, but only aboveground biomass was measured in the experiments. We employed an empirical function to convert the simulated total biomass to the above-ground biomass based on the independent data set for ‘Amaroo’ (Williams et al. unpublished). Daily values for developmental index (DVI, a continuous variable for physiological time; 0 at emergence, 1 at panicle initiation, 2 at heading and 3 at maturity) were estimated based on the observations of major the phenological events and degree-days.

Grain yield and final aboveground biomass ranged widely from 3.2 to 13.8 t ha⁻¹ and 700 to 2500 gm⁻² respectively, depending on the paddock history and N management (Table 1 & Fig. 1). The model simulated well the changes in biomass for most of the data sets, but tended to overestimate biomass after the heading stage (around 110 days after sowing) in the plots with large maximum LAI’s. This indicates that rice productivity in the Riverina region is close to the attainable level under given climatic and N conditions, but the constraints other than N exist for dense canopies, which need a further study.

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Table 1. Field surveyed (1995-96)

<table>
<thead>
<tr>
<th>Collaborator</th>
<th>Location and Paddock History</th>
<th>PFN kg ha⁻¹</th>
<th>Maximum LAI</th>
<th>Yield t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. Savage</td>
<td>West Griffith</td>
<td>0</td>
<td>2.0</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Second year rice</td>
<td>75</td>
<td>5.0</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250</td>
<td>8.9</td>
<td>13.1</td>
</tr>
<tr>
<td>G. Condon</td>
<td>West Griffith</td>
<td>0</td>
<td>1.0</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>12 years of continuous rice</td>
<td>75</td>
<td>2.6</td>
<td>5.3</td>
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<tr>
<td></td>
<td></td>
<td>250</td>
<td>7.9</td>
<td>9.0</td>
</tr>
<tr>
<td>D. Newman</td>
<td>Murrami</td>
<td>0</td>
<td>4.1</td>
<td>11.9</td>
</tr>
<tr>
<td></td>
<td>5 years of good clover</td>
<td>75</td>
<td>4.7</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250</td>
<td>5.7</td>
<td>12.3</td>
</tr>
</tbody>
</table>

Source: Williams et al.³

PFN: Pre-flooding nitrogen applied
Yield: un-husked grain at 14% moisture

\[ \text{Model} \]

\[ \text{CGR} = \frac{P \text{can}}{R} \]

\[ R = \text{Gr} \cdot P \text{can} + M_{25} \cdot Q_{10}^{(T/10-2.5)} \cdot W \]

\[ \text{Pcan} = \int_{0}^{\text{LAI}} \int_{0}^{1} P \cdot dF \cdot dt \]

\[ P = \alpha \cdot P_{\text{max}} \cdot \frac{I}{P_{\text{max}} + \alpha \cdot I} \]

\[ I = I_{0} \cdot k \cdot \exp(-k \cdot F) \]

\[ P_{\text{max}} = \frac{P_{m} \cdot \exp(-B \cdot DVI)}{(2/(1+\exp(-A(SLN-Nc))))-1} \]

\[ \text{CGR: crop growth rate} \]

\[ P \text{can}: \text{daily canopy photosynthesis} \]

\[ R: \text{daily respiration} \]

\[ \text{Gr: coefficient for growth respiration} \]

\[ W: \text{total biomass} \]

\[ DVI: \text{developmental index (refer to text)} \]

\[ M_{25}: \text{coefficient for maintenance respiration at 25°C expressed as a function of DVI} \]

\[ Q_{10}: \text{temperature coefficient for maintenance respiration} \]

\[ T: \text{air temperature} \]

\[ P: \text{photosynthetic rate per unit leaf area} \]

\[ \alpha: \text{initial slope of the light-photosynthesis curve} \]

\[ P_{\text{max}}: \text{maximum P at a given SLN and DVI} \]

\[ I_{0}: \text{light intensity above the canopy} \]

\[ I: \text{light intensity per unit leaf area} \]

\[ k: \text{extinction coefficient} \]

\[ F: \text{cumulative LAI from the top of the canopy} \]

\[ P_{m}, A, B, Nc: \text{Parameters for the Pmax function} \]

\[ SLN: \text{specific leaf nitrogen} \]

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Fig. 1. Time courses of actual (symbols) and simulated (line) time courses of biomass.