Effect of Changes of Leaf Water Content on Respiration and Photosynthetic Rate of Tobacco Varieties

Seong Kook Bae*, Ryuichi Ishii** and Atsuhiko Kumura**

葉中水分変化と発酵 品種間 呼吸と 光合成速度の影響

ABSTRACT

The effect of leaf water content on apparent photosynthesis and respiration of tobacco plants (five varieties) was studied under the condition without the irrigation for 10 days after the plants were sufficiently watered on the first day. The wild race \(N. \text{ longiflora}\) among varieties showed highest apparent photosynthesis (AP) and AP had a positive correlation with specific leaf weight. \(N. \text{ longiflora}\) and Andongyeob were different in their AP from the other varieties significantly under the water stress condition. Respiration rate also decreased to be similar to AP except slight increase at early stage of water deficit. The stomatal resistance and the mesophyll resistance increased in the stressed plants. The water stress resistant character seems to be mainly due to open stomata.

INTRODUCTION

Many researchers reported that the reduction of photosynthesis under water stress condition is mainly due to the decrease of stomatal aperture which is closely related to leaf water potential,\(^{2,3,8,9,11,13-14}\) Their conclusions were based on the experimental results where the photosynthetic \(\text{CO}_2\) uptake changes in parallel with transpiration.\(^{1,4}\) On the other hand, Redshaw and Meidner\(^{12}\) found, by the experiment where atmospheric air was forced to pass through the leaf, that water stress depressed not only \(\text{CO}_2\) diffusion process but also process of photosynthesis. Their result showed that air-phase resistances could account for only half the reduction of photosynthesis under water stress.

The effect of leaf water deficit on photosynthesis is not yet clearly characterized in tobacco plant and varietal differences are not well examined. The present investigation was carried out to determine the response of photosynthesis and respiration to different levels of leaf water contents in four varieties of \(N. \text{ tabacum}\) covering local and modern cultivars and \(N. \text{ longiflora}\) as a reference species, dividing the effect to stomatal and mesophyll \(\text{CO}_2\) diffusion resistance.

*Jeonju Exp. St., Korea Ginseng & Tobacco Research Institute, Jeonju 530, Korea (韓國人参烟草研究所 金州試験場）
**Dept. Agrobiology, Faculty of Agriculture, University of Tokyo, Japan (東京大學 農學部 農生物學科）

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Abbreviations: AP, Apparent photosynthesis; WSD, Water saturation deficit; SLW, Specific leaf weight (dry weight per unit leaf area).

MATERIALS and METHODS

The tobacco varieties used in this experiment were Andongyeob, as a local variety, and Bulgaria, Burley 21 and Newton 77, as the modern cultivars, and *N. longiflora*, a wild race of tobacco was also used. The plants were grown in a green house for 20 days after transplanting and then transferred to the growth cabinet controlled at 25°C, 70 ± 5% of R.H. and 12 hours of photoperiod with 450 μE/ m²/s(400-700nm).

After the plants were sufficiently watered on the first day, the water stress treatment was applied by stopping the irrigation for 10 days. Since then, the plants were subjected to the progressive water-stress condition. During the period, photosynthesis was measured on a fully expanded leaf according to Hirata et al.6) The CO₂ concentration and relative humidity in the introduced air was 355ppm and 65% respectively. The leaf temperature was maintained at 25°C by controlling the air temperature in the leaf chamber. The leaf water status was expressed as water saturation deficit (WSD) according to the following equation.

\[
WSD = \frac{\text{saturated leaf weight} - \text{fresh leaf weight}}{\text{saturated leaf weight} - \text{dry leaf weight}} \times 100
\]

The stomatal resistance (RS) and the mesophyll resistance (RM) were determined according to Gaastra,9) using the following equations.

\[
T = \frac{[\text{H}_2\text{O}]_L - [\text{H}_2\text{O}]_A}{\text{RS, H}_2\text{O}}
\]

\[
\text{AP} = \frac{[\text{CO}_2]_A - [\text{CO}_2]_L}{\text{RS, CO}_2 + \text{RM}} = \frac{[\text{CO}_2]_A - [\text{CO}_2]_L}{1.56 \times \text{RS, H}_2\text{O} + \text{RM}}
\]

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant height (cm)</th>
<th>No. of leaves</th>
<th>Measured leaf position</th>
<th>Largest leaf Length (cm)</th>
<th>Width (cm)</th>
<th>SLW* (%)</th>
<th>Dry matter content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>N. longiflora</em></td>
<td>15.0</td>
<td>27.3</td>
<td>11.0</td>
<td>14.8</td>
<td>5.1</td>
<td>49.2(5.17)</td>
<td>10.5</td>
</tr>
<tr>
<td><em>N. tobbacum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>24.8</td>
<td>17.5</td>
<td>10.0</td>
<td>17.7</td>
<td>6.1</td>
<td>28.7(3.21)</td>
<td>11.2</td>
</tr>
<tr>
<td>Andongyeob</td>
<td>14.5</td>
<td>15.7</td>
<td>10.0</td>
<td>11.2</td>
<td>5.5</td>
<td>28.9(4.67)</td>
<td>16.2</td>
</tr>
<tr>
<td>Burley 21</td>
<td>14.2</td>
<td>15.0</td>
<td>10.0</td>
<td>14.4</td>
<td>7.6</td>
<td>35.8(3.76)</td>
<td>10.5</td>
</tr>
<tr>
<td>Newton 77</td>
<td>11.8</td>
<td>15.0</td>
<td>10.0</td>
<td>11.6</td>
<td>5.7</td>
<td>33.4(3.71)</td>
<td>11.1</td>
</tr>
</tbody>
</table>

* SLW: Specific leaf weight (dry weight per unit leaf area)

Where T, transpiration rate; [H₂O]ₐ, saturated vapour pressure in the mesophyll intercellular space at the leaf temperature; [H₂O]ₐ, atmospheric vapour pressure; AP, apparent photosynthesis rate; [CO₂]ₐ, mean CO₂ concentration in the leaf chamber; [CO₂]ₐ, CO₂ concentration in the chloroplast.

RESULTS

Chlorophyll content, AP and respiration were measured in five tobacco varieties before treatment (Table 2). Significant difference of AP and chlorophyll concentration was not observed among the varieties of *N. tobbacum*, but *N. longiflora* showed significantly higher chlorophyll content and AP than *N. tobbacum*. The correlation between AP and stomatal resistance(RS) was not significant but *N. longiflora* of the highest AP showed the lowest RS as 5.88 sec/cm. As shown in Fig. 1. AP had a positive correlation with SLW(r = 0.77 p = 0.05).

AP on the changes of leaf water content in 5 varieties are shown in Fig. 2. AP began to decrease when WSD was over 35% in Andongyeob, and below that in other varieties. The most sensitive variety to leaf water deficit was Bulgaria and its AP began to decrease at 24% of WSD. It was at 53% and 32% of WSD in Andongyeob and Bulgaria.
Table 2. Apparent photosynthesis, respiration, stomatal resistance and mesophyll resistance of 5 tobacco varieties before treatment.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Chlorophyll content (mg/dm²)</th>
<th>AP (°)</th>
<th>RS (sec/cm)</th>
<th>RM (sec/cm)</th>
<th>Respiration (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>N. longiflora</em></td>
<td>7.21</td>
<td>20.7</td>
<td>5.88</td>
<td>3.46</td>
<td>-3.15</td>
</tr>
<tr>
<td><em>N. tobbacum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>3.76</td>
<td>15.5</td>
<td>8.55</td>
<td>2.64</td>
<td>-2.39</td>
</tr>
<tr>
<td>Andongyeob</td>
<td>4.58</td>
<td>16.8</td>
<td>8.69</td>
<td>2.65</td>
<td>-2.86</td>
</tr>
<tr>
<td>Burley 21</td>
<td>4.62</td>
<td>14.2</td>
<td>9.52</td>
<td>3.64</td>
<td>-3.08</td>
</tr>
<tr>
<td>Newton 77</td>
<td>4.88</td>
<td>14.3</td>
<td>9.64</td>
<td>3.08</td>
<td>-2.22</td>
</tr>
</tbody>
</table>

* mg-CO₂/dm²/hr

Fig. 1. Relationship between dry weight per unit leaf area and apparent photosynthesis in tobacco.

Fig. 2. Effect of changes of leaf water content on apparent photosynthesis in 5 tobacco varieties.

Fig. 3. Effect of respiration on changes of leaf water content in 5 tobacco varieties.

Fig. 4. Effect of stomatal resistance and mesophyll resistance on changes of leaf water content in 5 tobacco varieties.

respectively when AP decreased by 50% of the control. Both of AP of *N. longiflora* and Andongyeob were different in their AP from the other varieties significantly under water stress condition.
(Fig. 2). These two varieties continued AP even at the beginning status of apparent wilting. The respiration rate also showed varietal difference in respects of their levels and the location of their peaks (Fig. 3). The peak was observed at 44% of WSD in N. longiflora and 31% in Burley 21. The stomatal resistance and the mesophyll resistance increased in the stressed plants (Fig. 4). The water stress resistant character on AP of N. longiflora and Andongyeob seems to be mainly due to open stomata.

**DISCUSSION**

Improvement of yield would be achieved through the improvement of photosynthesis especially in tobacco. In this paper, the differences of AP were observed between tobacco varieties especially in water stress condition. It is reported that AP of tobacco showed high heritability value in F3 line. Therefore, the selection of varieties or lines would be effective for increasing yield and quality in dry condition. In this paper it was found that the critical WSD for the decrease of AP was higher in Andongyeob, a local variety and N. longiflora, a wild race than in other modern cultivars. However, this doesn't necessarily mean that N. longiflora and Andongyeob are resistant to water stress, because the stomatal resistance of these varieties, compared with other three cultivars, were low in high WSD condition, that is, the stomata of N. longiflora and Andongyeob are still open in low water potential in a leaf (Fig. 4). So, they could photosynthesize with more water loss in low leaf water potential than in other cultivars which were sensitive to the change of leaf water content and stopped photosynthesis before the wilting was apparent. Therefore, from the practical point of view and water management, it could be concluded that the primitive or local varieties of tobacco are insensitive to water status in a leaf, while new cultivars are very sensitive.

**LITERATURE CITED**


