韓作誌(Korean J. Crop Sci.) 30(4): 347~351 (1985)

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

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葉中水分 變化가 잎담배 品種間 呼吸과 光合成速度에 미치는 影響

裵成國*·石井龍一**·玖村敦彦**

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. longiflora*) among varieties showed highest apparent photosynthesis (AP) and AP had a positive correlation with specific leaf weight. *N. longiflora* and Andongyeob were different in their AP from the other varieties significantly under the water stress condition. Respiration rate also decreased to be simillar 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 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 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. tobaccum* covering local and modern cultivars and *N. longiflora* as a reference species, dividing the effect to stomatal and mesophyll CO_2 diffusion resistance.

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〈1985. 6. 19 接受〉

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 nad 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 $\mu E/m^2/s$(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 CO_2 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,[5] using the following equations.

$$T = \frac{[H_2O]L - [H_2O]A}{RS, H_2O}$$

$$AP = \frac{[CO_2]A - [CO_2]L}{RS, CO_2 + RM} = \frac{[CO_2]A - [CO_2]L}{1.56 \times RS, H_2O + RM}$$

Table 1. Agronomic characters of 5 tobacco varieties before the treatment.

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

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

Where T, transpiration rate; $[H_2O]L$, saturated vapour pressure in the mesophyll intercellular space at the leaf temperature; $[H_2O]A$, atmospheric vapour pressure; AP, apparent photosynthesis rate; $[CO_2]A$, mean CO_2 concentration in the leaf chamber; $[CO_2]L$, CO_2 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. tobaccum*, but *N. longiflora* showed significantly higher chlorophyll content and AP than *N. tobaccum*. 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.

Variety	Chlorophyll content (mg/dm^2)	AP (*)	RS (sec/cm)	RM (sec/cm)	Respiration (*)
N. longiflora	7.21	20.7	5.88	3.46	−3.15
N. tobaccum					
Bulgaria	3.76	15.5	8.55	2.64	−2.39
Andongyeob	4.58	16.8	8.69	2.65	−2.86
Burley 21	4.62	14.2	9.52	3.64	−3.08
Newton 77	4.88	14.3	9.64	3.08	−2.22

* $mg \cdot CO_2/dm^2/hr$

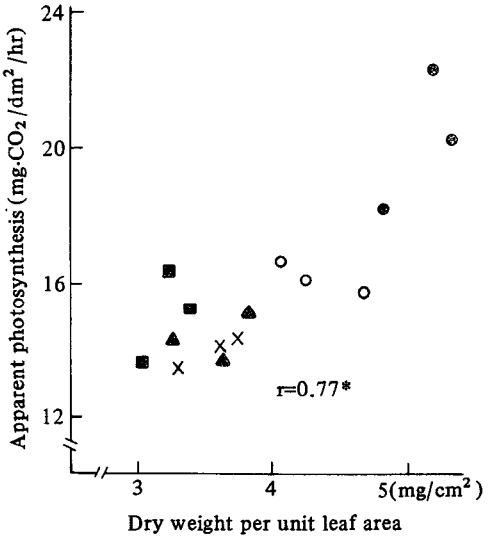

Fig. 1. Relationship between dry weight per unit leaf area and apparent photosynthesis in tobacco.

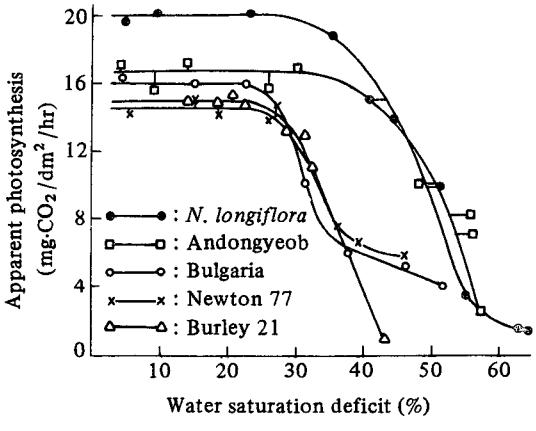

Fig. 2. Effect of changes of leaf water content on apparent photosynthesis in 5 tobacco varieties.

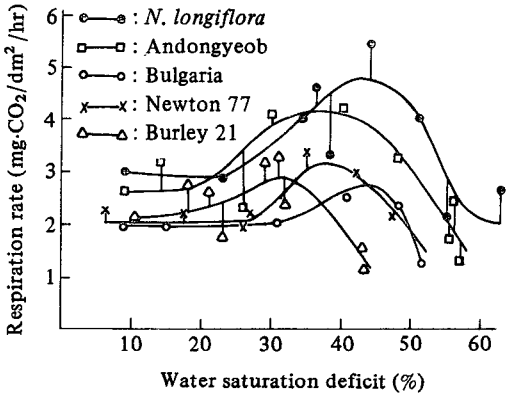

Fig. 3. Effect of respiration on changes of leaf water content in 5 tobacco varieties.

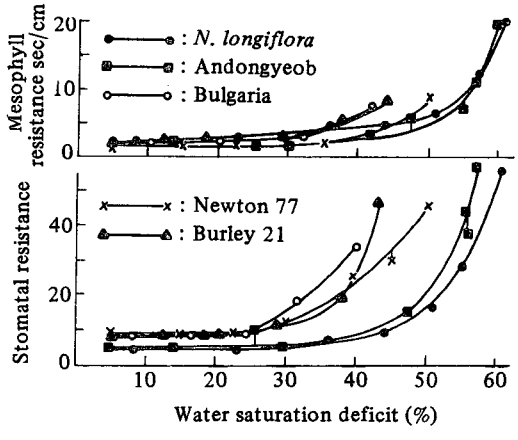

Fig. 4. Effect of stomatal resistance and mesophyll resistance on changes of leaf water content in 5 tobacco varieties.

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 begining 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.[7] 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 F_3 line.[10] 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.

摘　　要

品種間 葉中水分變化에 대한 光合成과 呼吸에 미치는 影響을 밝히기 위하여 溫室에서 자란 잎담배 5品種의 葉中水分含量을 變化시켜서 光-光合成速度, 呼吸速度, 氣孔抵抗 및 葉肉抵抗을 各各 調査한 結果를 要約하면 다음과 같다.

1. 品種間 光合成速度는 *N. longiflora*가 20.7㎎ $CO_2/dm^2/hr$로 제일 컸고 Burley 種이 제일 적었다.

2. 光合成速度와 單位葉面積當 乾物重과는 正의 相關을 보였다.

3. 安東葉은 WSD 53%에서 光合成速度가 50% 程度 減少되었으나 Burley 21은 外觀上으로 萎凋狀態 이전인 WSD 43%에서 光合成能力을 喪失하여 栽培品種은 *N. longiflora*와 安東葉보다 水分敏乏에 의해 光合成 作用이 크게 抑制되었다.

4. 品種間 呼吸速度의 變化는 水分敏乏 初期에 약간 增加하다가 光合成速度와 같은 경향으로 減少하였다.

5. 水分敏乏에 따라 氣孔抵抗과 葉肉抵抗은 增加되었으며 水分敏乏에 의한 光合成速度의 減少는 주로 氣孔이 닫혀지기 때문으로 본다.

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