BRIEF COMMUNICATION

# Gas exchange characteristics of the flue-cured tobacco (*Nicotiana tabacum* L.) cultivars grown under two production systems

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## Abstract

The net photosynthetic rate ($P_N$), intercellular $CO_2$ concentration ($C_i$), stomatal conductance ($g_s$), transpiration rate ($E$), water use efficiency (WUE), and leaf biomass production of four American flue-cured tobacco (*Nicotiana tabacum* L.) cultivars K 326, K 358, and Speight G 28 were compared with three local Indian cultivars 16/103, Special FCV, and PCT-7, during 1994 and 1995 crop seasons under irrigated and rainfed production systems (Northern light soils, NLS, and Karnataka light soils, KLS) in India. By comparison, the American tobacco cv. K 326 showed the highest $P_N$ and $g_s$. A positive correlation was found between $P_N$ and biomass production in all the varieties tested ($r$ = 0.55 in NLS and 0.73 in KLS). The American cultivars were superior than the local cultivars in their biomass production and $P_N$ under Indian farming conditions.

*Additional key words*: intercellular $CO_2$ concentration; leaf biomass; net photosynthetic rate; stomatal conductance; transpiration rate; water use efficiency.

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Tobacco is one of the important commercial crops of India. The flue-cured tobacco is grown under irrigation in Northern light soils (NLS) located 16°20'N, 81°33'E and also as a rainfed crop in Karnataka light soils (KLS) situated between 11°30' to 12°N and 76°05' to 77°55'E of India. The yields of flue-cured tobacco cultivars have been attributed to variable climatic conditions. The cured leaf yields depend on the leaf photosynthesis.

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*Abbreviations*: $C_i$ – intercellular $CO_2$ concentration; Chl – chlorophyll; $E$ – transpiration rate; $g_s$ – stomatal conductance; $g_m$ – mesophyll conductance; $I$ - irradiance; KLS – Karnataka light soils; NLS – Northern light soils; $P_N$ – net photosynthetic rate; WUE – water use efficiency.

Attempts to breed crop cultivars with higher net photosynthetic rates ($P_N$) have met with no success although considerable variation in $P_N$ exists in several crop species including tobacco and positive correlation between leaf $P_N$ and productivity has been reported (Delgado *et al.* 1992). $P_N$ and chlorophyll (Chl) content were higher in air-cured tobacco cultivars having cylindrical plant type with erect leaves than the other types (Matsuda 1978). Higher transpiration rate ($E$) in tobacco hybrids is attributed to larger number of stomata (Dubranek *et al.* 1987). The amount and course of $E$ in the prilep cultivar depend upon the mineral nutrition and water holding capacity of soil (Filiposki 1987). The water content and water use efficiency (WUE) of tobacco leaves change as they expand (Šesták 1985, Čatský and Šesták 1997) and are greatest under good nutrition and poorest at low irradiance ($I$) (Rawson and Woodward 1976). The yields of flue-cured tobacco are affected by nutrient status and total rainfall during crop growth period (Janardhan *et al.* 1990).

The studies on $P_N$ and its contribution to the entire carbon economy in flue-cured tobacco cultivars in two agroclimatic regions are rare. Therefore, we compared $P_N$, $E$, WUE, intercellular $CO_2$ concentration ($C_i$), stomatal conductance ($g_s$), and leaf biomass production of four American flue-cured tobacco cultivars and three local Indian cultivars in two geographical locations during two crop seasons.

Field experiments were laid during flue-cured tobacco (*Nicotiana tabacum* L.) growing season from September 1994 to March 1995 in Northern light soils (NLS) which represents the irrigated production system at Cherukumilli Village, West Godavari District, Andhra Pradesh, India. The surface soil in the experimental location at NLS was sand about 22 cm deep with a sandy clay subsoil. The soils are friable, well drained soil types with low organic matter and phosphorus, medium in potash, and acidic in reaction. Similar field experiments were also done during flue-cured tobacco season from May to September 1995 in Hunsur, which represents the Karnataka light soil (KLS) flue-cured tobacco growing area under rainfed production system in the Karnataka State, India. The surface soil was sandy loam about 15 cm deep with a sandy clay loam subsoil. The soils are characterised by acidic reaction, low nitrogen, and low to medium phosphorus and potash status. The crop management practices were those recommended for the respective regions (Anonymous 1989). The field crops thus grown at each location were divided into 4 replications and 200 plants were maintained in each replication. The values were recorded by selecting 10 plants in each replication for $P_N$ measurements. The analysis was a completely randomised design, where the F-test for significance and a protected LSD statistical analysis were conducted at 95 % confidence level on all experimental values using the GLM procedure in SAS (Statistical Analysis Software, *SAS Institute*, Cary, NC, USA).

A portable open gas exchange measuring system (model *LCA-3, ADC*, Herts, England) was used for rapid simultaneous determination of $CO_2$ and water vapour exchange in attached leaves under field conditions. The portable measuring system was equipped for recording basic values and instantaneous computation as well as storage of leaf gas exchange characteristics, namely $P_N$, $g_s$, $C_i$, and $E$. All leaf gas exchange measurements were made between 10:00 and 11:30 h (IST) on sunny and generally cloud-free days throughout the experimental period. For measuring $P_N$ and

Table 1. Gas exchange characteristics of flue-cured tobacco cultivars grown in Northern light soils (NLS) and Karnataka light soils (KLS): Net photosynthetic rate ($P_N$) [μmol($CO_2$) $m^{-2}$ $s^{-1}$], intercellular $CO_2$ concentration ($C_i$) [$cm^3$ $m^{-3}$], stomatal conductance ($g_s$) [mol $m^{-2}$ $s^{-1}$], transpiration rate ($E$) [mmol($H_2O$) $m^{-2}$ $s^{-1}$], and water use efficiency (WUE) [g($CO_2$) $kg^{-1}$($H_2O$)] were measured on fully expanded 5th leaves. Cured leaf biomass [g $plant^{-1}$]. Means of 5 measurements. LSD = least significant difference ($p = 0.05$). Values of $r = 0.55$ for NLS and $r = 0.73$ for KLS.

| | Cv. | $P_N$ | $C_i$ | $g_s$ | $E$ | WUE | Biomass |
|---|---|---|---|---|---|---|---|
| NLS | K 326 | 8.48 | 199 | 0.13 | 2.97 | 0.159 | 130.6 |
| | K 346 | 7.31 | 187 | 0.10 | 2.23 | 0.178 | 129.6 |
| | K 358 | 7.08 | 196 | 0.10 | 2.41 | 0.173 | 131.0 |
| | Speight G 28 | 5.93 | 210 | 0.10 | 2.29 | 0.144 | 106.9 |
| | 16/103 | 5.10 | 176 | 0.06 | 1.47 | 0.207 | 98.1 |
| | LSD | 0.68 | 16 | 0.02 | 0.39 | 0.067 | 14.3 |
| KLS | K 326 | 18.08 | 198 | 0.43 | 3.65 | 0.103 | 144.4 |
| | K 346 | 12.17 | 222 | 0.34 | 3.27 | 0.087 | 120.4 |
| | K 358 | 12.12 | 212 | 0.24 | 3.32 | 0.123 | 132.7 |
| | Special FCV | 11.55 | 217 | 0.26 | 2.41 | 0.108 | 100.5 |
| | PCT-7 | 11.70 | 236 | 0.32 | 3.39 | 0.089 | 131.7 |
| | LSD | 1.18 | 8 | 0.04 | 0.30 | 0.032 | 10.0 |

$E$ in light, photosynthetic leaf chamber (model *PLC-3 (B)*, *ADC*, Herts, England) was clipped onto the selected attached leaf which had been exposed to natural sunlight. The chamber was held at such an angle that the enclosed leaf surface directly faced the sun to avoid shading inside the cuvette. The $I$ at the upper surface of leaf chamber was measured by a calibrated sensor (filtered silicon photocell, *ADC*, Herts, England) mounted on the same surface of leaf chamber; it was 1200-1300 μmol $m^{-2}$ $s^{-1}$ during most $P_N$ measurements. Atmospheric air drawn from 3 m height through a telescopic mast was flown through the leaf chamber in order to avoid fluctuations in $CO_2$ concentration of the ambient air which could otherwise arise due to the addition of respired $CO_2$ by the researcher(s) at the time of the measurements. Atmospheric air containing ambient concentrations of $CO_2$ (345 $cm^3$ $m^{-3}$) and $O_2$ (21 %) passed through the photosynthetic chamber at 5 $cm^3$ $s^{-1}$ without changing its relative humidity. The $P_N$ and $g_s$ became stable within 2 min after clipping the chamber on the selected attached leaf experiencing saturated solar irradiance and the values of $P_N$ gas exchange were then recorded. Measurements were repeated on at least ten different plants on the 5th leaf from the stem apex. The WUE was calculated as a ratio of $P_N/g_s$.

Among the flue-cured tobacco cultivars grown under the two agroclimatic regions (Table 1), $P_N$ was significantly higher in cultivars K 326, K 346, and K 358 than in the other cultivars. The $C_i$, $g_s$, and $E$ were directly proportional to $P_N$ and flue-cured leaf biomass production in all the three American cultivars. In cv. Speight G28, the $P_N$ was associated with low WUE and cured leaf biomass production while the $C_i$, $g_s$, and $E$ were much higher than those in cv. 16/103. Similarly, the local cvs. Special FCV and PCT-7 showed lower $P_N$ associated with lower biomass production than the

American cultivars. The WUE of cv. Special FCV was higher with biomass lower than in PCT-7 although the $C_i$, $g_s$, and $E$ were lower.

Besides genetic variability, the $P_N$ of tobacco cultivars depends on environmental and edaphic factors (Tatemichi 1970, Ben-Zioni and Itai 1972). Improvement of WUE was often associated with reduced dry matter accumulation and yield (Matus *et al.* 1995). Thus the genetic variability in WUE may be predominantly controlled by stomatal factors in several crop species such as *Triticum* (Farquhar *et al.* 1988), *Phaseolus* (White *et al.* 1990), and *Gossypium* (Lu *et al.* 1996).

In $g_s$-dependent cultivars, the $g_s$ is invariably lower, resulting in lower $E$. WUE is predominantly regulated by the $g_s$ and/or mesophyll resistance ($g_m$) that regulate $CO_2$ uptake. On the other hand, $E$ is predominantly controlled by differences in $g_s$ at a given water vapour pressure difference. Since $g_s$ is strongly related to water vapour pressure and size of mesophyll intercellular spaces, the total water used and WUE become interdependent (Condon *et al.* 1990). This interdependence becomes stronger when intercellular partial pressure of leaf is high and hence the WUE is predominantly regulated by $g_s$. In such cultivars, increase in WUE results in lower $E$ and hence in lower total cured leaf biomass.

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