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Physiological Characteristics of Paper Mulberry in Experimental Plot

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ABSTRACTS

Paper mulberry, Si Satchanalai (Broussonetia papyrifera) and Kozo (Broussonetia kazinoki) cultivars were grown in the experimental field of Kamphaeng Saen campus. The light response and CO_2 compensation were measured for mature leaves of 24 days old. The photochemical efficiency, α, is in the range of 0.060-0.063 mol mol^{-1}, and the P_m values are 25.6-31.6 μmol m^{-2} s^{-1}, with light saturation of about 880 μmol m^{-2} s^{-1}. The CO compensation is 61 μmol mol^{-1}, and the carboxylation conductance is in the range of 107-111 mmol m^{-2} s^{-1}. The parameters indicate no distinct difference in the photosynthesis apparatus between the two cultivars. The similar light reaction rate is further confirmed by the measurement of chlorophyll fluorescence. The average quantum yield of dark-adapted leaf (Fv/Fm) is 0.822 for SS and 0.808 for KZ. The reaction centers of paper mulberry employed a photoprotection mechanism when the PPF intensified during the course of the day.

One measurement of diurnal change in gas exchange and water potential was made on leaves of 30 days old of 8 month-old plants in September, 2000. The matric potential of active root zone of 30 cm, was low at –53 kPa at the start of the day. So the root was in mild water stress. The sky was overcast, with only 2 hours of strong radiation during 10-12 hr. Kozo showed consistently higher rates of net photosynthesis (A), transpiration (E) and greater stomatal conductance (g_s). The peak A was only half of P_m, which was the result of both low PPF and lower g_s under stress. The g_s of KZ was more responsive to change in total potential (ψ_t) of the leaf and was higher than SS's at the same level of ψ_t. The solute concentration of leaf sap changed following the rate of A, which was higher for KZ. Averaged over the day, KZ leaves were at lower total potential, but the higher solute concentrations enabled the leaves to gain slightly higher turgor than the SS's. The biomass determination of each plant at 5 months old showed that KZ plant had more dry mass. We propose from this study that the faster growing rate of KZ does not come from the higher performance of the potential photosynthesis, but from the more dynamic opening of stomata, thus the higher rates of gas exchange under the field conditi

Keyword: Si Satchanalai (Broussonetia papyrifera) and Kozo (Broussonetia kazinoki)

Introduction

Paper mulberry grows better under a forest canopy. Cultivating the plant in farmer's field results in low yield. The plant is prone to damage caused by unfavorable soil water regime.

Objectives: We set up the study of paper mulberry in the experimental plot to measure primarily the basic process of its gas exchange rate. The data would shed more light to the understanding of the relations of environmental factors and the gas exchange process of the plant.

Materials and Methods

Two cultivars of paper mulberry are under study: Si Satchanalai (SS), a local cultivar, and Kozo (KZ), a cultivar from Japan. The planting spacing was 2 □2 m^2, for a number of 20 trees of each cultivar. The soil is Kamphaeng Saen soil series (Typic Haplustalfs), with pH in the range of 6.5-7.5, and high in phosphorus and potassium content.

Light response function and carbon dioxide compensation point

Measurement of net photosynthesis is by portable photosynthesis open system (LI 6400 by Licor, Nebraska, U.S.A). Conditions inside the leaf chamber were RH at 60%, leaf temperature of 32-33C, leaf-air vapor pressure deficit (VPD) of 1.3-1.8 kPa, photosynthetic photon flux (PPF) ranging from 0 - 2,000 □ mol m^{-2} s^{-1}, and CO_2 concentration ranging from 0-400 □mol mol^{-1}. Two mature leaves of each cultivar were selected at the age of 24 days.

Diurnal changes in the chlorophyll fluorescence, gas exchange and water potential

On 28 September 2000, when the trees were 8 months old, we carried out an hourly measurement of leaf chlorophyll fluorescence, gas exchange and water potential. The day was overcast with bright sunshine only during the hour of 10-12. Altogether about 20-23 mature, healthy leaves, of 30 days old, from about 10 trees of each cultivar were selected. The round started with the measurement of dark-adapted followed by light chlorophyll fluorescence (Mini-PAM by Heinz Walz, Germany). After the leaf was exposed to light for no less than 15 minutes, we made the measurement of transpiration and photosynthesis with portable photosynthesis close system (LI-6200 by Licor, Nebraska, U.S.A.). The last step was to excise the leaf for the measurement of total potential using the pressure chamber (SoilMoisture Equipment, Santa Barbara, U.S.A). The leaf tissue was submerged in the liquid nitrogen, which was later used in the measurement of sap solute potential with the dewpoint microvoltmeter (HR-33T by Wescor, Logan, U.S.A).

Results and Discussion

Light response function and carbon dioxide compensation point

The data is fitted to a non-rectangular hyperbola function (Thornley and Johnson, 1990) of: $\sqrt{(\alpha I + P_m)^2 - 4\theta\alpha I P_m}$

where A is net photosynthesis; I is photosynthetic photon flux; P_m is maximum net photosynthesis rate; R_d is dark respiration rate; □ is quantum or photochemical

efficiency; and is the curvature factor. The parameters are shown in Table 1. The ratio of diffusive to carboxylation conductance (g_d/g_c) can be derived from the value.

The higher ratio of g_d/g_c indicates that the leaf has a higher diffusive conductance. The higher conductance gives higher P_m. CO compensation for SS was 61.1, and 61.8 molCO mol^{-1} for KZ. The carboxy-lation (mesophyll) conductances were 111 and 107 mmol m^{-2} s^{-1}, respectively. Since both the light and dark reactions in the leaves of the two cultivars are of the same rates, the difference in the net photosynthesis rate between the two cultivars is a function of the magnitude of stomatal conductance.

Table 1 Parameters for light response function for 4 mature leaves, 24 days old, of Si Satchanalai and Kozo cultivars of paper mulberry.

Parameters	Si Satchanalai		Koz	
	Leaf 1	Leaf 2	Leaf 1	Leaf 2
, mol mol^{-1}	0.0632	0.0601	0.0601	0.0635
	0.6101	0.5827	0.6268	0.4624
P , mol m^{-2} s^{-1}	29.3443	29.1204	25.6481	31.6458
R , mol m^{-2} s^{-1}	1.4683	1.7456	1.6375	1.6931
g_d/g_c	0.6391	0.7160	0.5954	1.1627
I , mol m^{-2} s^{-1}	24	30	28	27
I , mol m^{-2} s^{-1}	853	898	799	967

Diurnal changes in the chlorophyll fluorescence, gas exchange and water potential

chlorophyll fluorescence

The dark-adapted quantum yield (=Fv/Fm), or the photosynthetic efficiency was relatively the same for the two cultivars. The average for the day was 0.822 for SS and 0.808 for KZ. The maximum, Fm, and minimum, Fo, fluorescence under dark adaptation was also very similar between the two cultivars. The light quantum yield varies in response to the intensity of radiation. The decrease in Fm' with increasing PPF indicates that the PSII has engaged a photoprotection mechanism, which is mostly associated with the xanthophyll zeaxanthin cycle at LHCII (Epron *et al*., 1992; Angelopoulos *et al*., 1996). The chlorophyll fluorescence study indicates that the PSII reaction center of paper mulberry uses PPF at high efficiency, with light saturation level at around 600 mol m^{-2} s^{-1}. The reaction center also employs a photoprotection mechanism when the PPF intensifies.

Transpiration (E) and net photosynthesis (A) of the leaves

The pattern of diurnal gas exchange is shown in Figure 1. The E rate was within the range obtained in the light response study. The obvious difference was in the net photosynthesis rate. The present values reached the peak of only half of the potential (P_m). This may be due partially to the low PPF and stomatal conductance(g_s).

The g_s of SS was very high before 9 hr., then stomates seemed to close abruptly and remained partially close afterwards. The KZ leaves had higher g_s,

mostly in the morning session. The partial closure of stomates in the afternoon was caused by the low radiation of the day. Strong sun lasted only 2 hours from 10-12 hr. During this period, the leaf-air VPD increased to the level of 2-3.5 kPa. That the stomates did not open fully, even though the atmospheric condition was mild, was because the water potential of the active root zone was low. The top 30 cm of root zone had the matric potential in the range of –52 to –80 kPa during the daytime. So the water stress in the root zone could contribute to the partial closure of the stomates.

Si Satchanalai seemed to be effected by the soil water stress more than the Kozo. With the closing down of the stomates, the ratio of water loss to net CO_2 gain (E:A) was relatively low for paper mulberry for the day. KZ leaves carried out higher rates of both E and A, making its E to A ratio comparable to that of SS.

Water potential

The response of total potential to atmospheric condition is apparent during the day. The initial values in the early morning were at –200 for SS and –500 kPa for KZ. During high PPF and leaf-air VPD, there was a corresponding sharp drop in the total potential to –1,400 kPa for both cultivars.

The change in KZ potential was greater than SS. Averaged throughout the day, the total potential for SS was –789 kPa and –820 kPa for KZ.

The average solute potential was –1,437 for SS and –1,495 kPa for KZ. The solute concentration (C_i) of KZ sap is more concentrated, with the corresponding values being 580 and 604 mol m^{-3}. The change in solute concentration of leaf sap seems to follow closely the photosynthesis process.

The turgor potential shows that KZ leaf was in a better water status than SS during the morning session, but then it lost its turgor more severely than SS in the afternoon. There is a temporarily lapse of water supply to meet the demand. KZ regained its turgor quite late in the day, at 16 hr.

Stomatal conductance

High PPF is the cause of high leaf temperature. For KZ, the threshold of 35C seems to lead to partial closure of stomata. At leaf-air VPD higher than 3-3.5 kPa, the g_S decreased. Under all factors, g_S of KZ leaf was consistently higher than SS's. The factor that has the most impact seems to be the leaf water potential.

The changes of g_S indicate that KZ's stomates are more dynamic than SS's. The conductance of SS remains at constantly low level once the stress progresses and does not recover fully. KZ shows a greater degree of stomatal closure and reopening during the day.

Conclusion

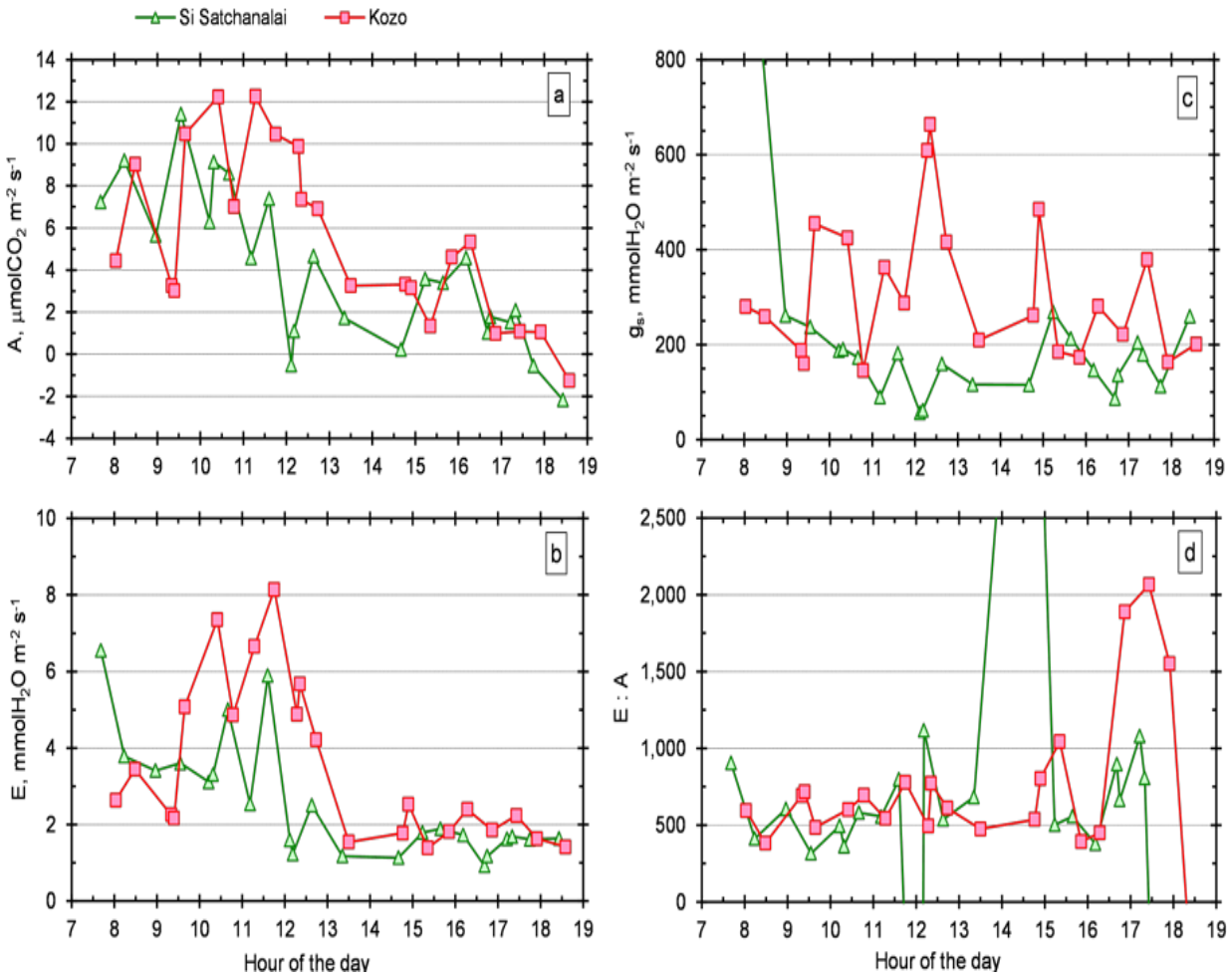
There is no distinct difference in the photosynthesis apparatus between the two cultivars. The similar light reaction rate is confirmed by the measurement of chlorophyll fluorescence. The reaction centers of paper mulberry employed a photoprotection mechanism when the PPF intensified during the course of the day.

One measurement of diurnal change in gas exchange and water potential was made on leaves of 30 days old of 8 month-old plants in September, 2000. The

root was in mild water stress. Kozo showed consistently higher rates of net photosynthesis (A), transpiration (E) and greater stomatal conductance (g_S). The peak A was only half of P_m, which was the result of both low PPF and lower g_S under stress. The g_S of KZ was more responsive to change in total potential (ψ_t) of the leaf and was higher than SS's at the same level of ψ_t. The solute concentration of leaf sap changed following the rate of A, which was higher for KZ. Averaged over the day, KZ leaves were at lower total potential, but the higher solute concentrations enabled the leaves to gain slightly higher turgor than the SS's. We propose from this study that the faster growing rate of KZ does not come from the higher performance of the potential photosynthesis, but from the more dynamic opening of stomata, thus the higher rates of gas exchange under the field condition.

Literature Cited

Angelopoulos, K., B. Dichio and C. Xiloyannis. 1996. Inhibition of photosynthesis in olive trees (*Olea europaea* L.) during water stress and rewatering. J. Exp. Bot. 47: 1093-1100.



petraea (Matt.) Liebl.] during drought under field conditions: diurnal course of net CO_2 assimilation and photochemical efficiency of photosystem II. Plant, Cell and Environ. 15: 809-820.

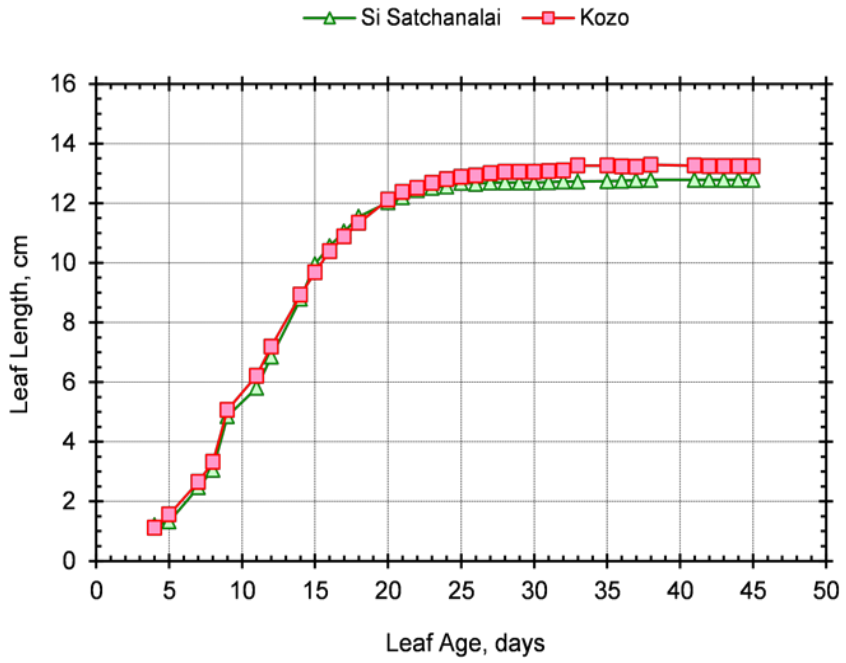
Figure 1 The change in gas exchange rates during the day of paper mulberry leaves. (a) the net photosynthesis, A; (b) the transpiration, E; (c) the stomatal conductance to vapor, g_S; and (d) the ratio of E to A. Kozo showed consistently higher values in allparameters.Materials and Methods

Two cultivars of paper mulberry are under study to obtain basic data on their physiological behavior. They are Si Satchanalai (SS), a local cultivar, and Kozo (KZ), a cultivar from Japan. The seedlings, provided by KAPI are transplanted into the experimental plot of the Tropical Vegetable Research Center in Kamphaeng Saen campus starting from January of 2000. The planting spacing was 2×2 m^2, and there were 20 trees of each cultivar. The soil in the field is Kamphaeng Saen soil series (Typic Haplustalfs), which is neutral with pH in the range of 6.5-7.5, and high in phosphorus and potassium content. The field has high water table in the rainy season,
which can be as high as 30 cm from the soil surface. Several basic data are obtained with details as follow.

Growth rate of the leaf

The development of leaf is based on 3 leaves from 3 trees of each cultivar. Leaf age is the number of days since budbreak. Length was measured everyday when leaf length reached 1 cm until the leaf reached 45 days.

Result is shown in Figure 1. Leaves of both cultivars have similar rate of development, with a rapid length extension from days 4-20 since budbreak. Growth rate for SS is 0.775 cm d^{-1}, and 0.755 cm d^{-1} for KZ. During the period of 21-25 days, length growth started to slow down and stopped after 25 days. Leaf growth was complete after 25 days. Averaged maximum length of SS is 12.7 cm, while of KZ is 13.0 cm



One hundred mature and healthy leaves of each variety were selected to

determine the leaf area, length and width with a leaf area meter (CI-203CA by CID, U.S.A), then they were weighed to obtain the fresh mass. The leaf statistics and the relations between parameters are shown in Table 1.Literature Cited

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