Urban Micro Environment and Photosynthesis of Street Trees

TAKAGI, Masahiro, GYOKUSEN, Koichiro, SAITO, Akira

都市環境と街路樹の光合成

高木正博・玉泉幸一郎・齋藤 明

Summary

Micro meteorological factors and leaf photosynthesis of *Ilex rotunda* were investigated on a median strip in a commercial district to clarify characteristics of the urban micro environment for street trees and the acclimation of leaf photosynthesis to the environment. Diminished sunlight, high air temperature and soil drought in summer were characterized as urban micro environment.

Photosynthetic rate of street trees was lower than for suburban trees from July to September and higher from October to March. High photosynthetic rate in autumn and winter depended on high carboxylation efficiency, and low photosynthetic rate in summer might depend on air pollution. Intrinsic water use efficiency was higher in street trees because of the high carboxylation efficiency and, especially in summer 1994, the low stomatal conductance. The results suggest that these photosynthetic characteristics of street trees represent the acclimation to the urban micro environment.

1. Introduction

Photosynthesis is one of the most important physiological functions regulating plant growth. Photosynthetic rate is regulated by response of photosynthetic capacity, as potential capacity of leaf, to environmental factors such as light intensity, air temperature and soil water content. Photosynthetic capacity itself is acclimated to environmental factors (Jones ; 1992, Seiler and Johnson ; 1985). Urban street trees grow under many stresses, including diminished sunlight due to interception by buildings, high air temperature (i.e., heat-island), and water stress (Bassuk and Whitlow ; 1987, Kjelgren and Clark ; 1992, Krizek and Dubik ; 1987, Whitlow and Bassuk ; 1988). Therefore, photosynthetic capacity of urban street trees is considered to be acclimated to urban micro environment.

Urban micro environment is quite different from that in forest, so it is difficult to extrapolate from morphological, physiological and biochemical data obtained from trees growing in a forest to trees growing in an urban environment (Krizek and Dubik ; 1987). Therefore, knowing the urban micro environment and the reaction of street trees, a new managing schedule can be designed for urban street trees. However, there are few studies on the effects of the urban micro environment on street trees

Key words: Street tree, Urban micro environment, Photosynthesis, Seasonal course, Acclimation, *Ilex rotunda*.

キーワード：街路樹，都市環境，光合成，季節変化，順化，クロガネモチ

Faculty of Agriculture, Kyushu University

九州大学農学部

(Bassuk and Whitlow ; 1987, Whitlow and Bassuk ; 1988). To clarify urban micro environment and acclimation of leaf photosynthetic capacity of street trees, environmental factors and photosynthesis of detached shoots were measured independently because photosynthetic capacity of *in situ* attached shoots could not separate from *in situ* environmental factors.

2. Materials and methods

2.1 Study sites

The study was carried out on the median strip of the prefectural highway in Tenjin in Fukuoka, a central commercial district in western Japan. This highway runs north to south and is 45 m in width. Buildings of 30–40 m heights have been constructed on both sides of the street. The median strip is 5.5 m in width and 55 m in length along the street and is enclosed by concrete pit. There is an underground shopping center under the street. Twelve trees of *Ilex rotunda* Thunb. of about 7 m heights and many *Raphiolepis umbellata* var. *integerrima* Rehder, as shrub, of about 50 cm heights were planted 20 years ago. A control study site was set up in the Kyushu University nursery in Hakozaki, Fukuoka, a residential district 5 km north of Tenjin (Fig. 1).

2.2 Environmental factors

Photosynthetic photon flux density (*PPFD*), air temperature (T_a) and soil water potential (*SWP*) were measured at both study sites. *PPFD* was measured by *PPFD* sensors (Koito, IKS-25-10), and T_a by thermistors at 10 minutes intervals. These sensors were set 7.5 m and 5.0 m above the crown of *Ilex rotunda* at Tenjin and Hakozaki, respectively. *SWP* was measured by tensiometers (Koito, KDC-S5) at hourly intervals. Depth of sensors was 50 cm at both study sites. Data was recorded by dataloggers (KONA system, Kadec series).

PPFD and T_a were measured from July 1, 1993 to July 29, 1994 at Tenjin and from July 21, 1993 to July 29, 1994 at Hakozaki. *SWP* was measured from July 19, 1993 to July 29, 1994 at both study sites. *PPFD* and T_a data was not available from January 31 to March 8 at Tenjin and from February 18 to March 8 at Hakozaki. *SWP* data was not collected from February 18 to March 8 only at Hakozaki.

2.3 Gas exchange

Responses of photosynthetic rate and stomatal conductance to various *PPFD* and CO_2 concentration in the air were measured for leaves of *Ilex rotunda* Thunb. planted at both study sites. A sampled tree at Tenjin was planted in the south edge of the median strip, faced a crossing, and 7.3 m in height and 22.0 cm in diameter at breast height. A control tree planted in the nursery at Hakozaki was single isolated one and 4.9 m in height and 12.5 cm in diameter at breast height.

Photosynthetic rate (P_n) and stomatal conductance (g_s) of a single leaf were measured by an assimilation chamber in the laboratory every month from July 1993 to July 1994. Sampled shoots were cut in 50 cm lengths from the south side of the middle of the crown before sunrise, and ends of the shoots were cut

Fig. 1 Study sites in Fukuoka, Japan. Colored areas are commercial districts. Solid lines are railways and open squares are stations.

diagonally in distilled water three times. Response of P_n and g_s to various *PPFD*s was measured by controlling *PPFD* using shading films. Using the same leaf, response of P_n and g_s to various CO_2 concentrations in the air was measured by controlling CO_2 concentration of inflow air to the chamber. Each measurement was repeated three times for each site.

Leaf temperature was measured using a copper-constantan thermocouple and was controlled by varying air temperature in the chamber, in which temperature was controlled using a thermo cooler (NIPPON BLOWER Co. Ltd, SAMOL SL-4FF). Air humidities of inflow and outflow air to the chamber were measured using humidity sensors (VAISALA, HMP113Y) and that of the inflow air was controlled by dew point temperature using a water temperature regulator (SHIMAZU, CTE-240). CO_2 concentration of inflow air was controlled using a massflow controller (KOJIMA, Kofloc MODEL 2203) mixing CO_2 gas evaporated from liquid CO_2 and CO_2 free air through sodalime. CO_2 concentrations of inflow and outflow air were measured using an infrared gas analyzer (SHIMAZU, IRA-102). Light was supplied by metal halide lamps (OSRAM, HQI-TS 70W/NDL) and measured using a *PPFD* sensor (LI-COR, LI-190SB) set in the chamber. Leaf temperature was kept 25°C in July and August 1993 and July 1994, 20°C in October 1993 and May and June 1994, 15°C in November 1993 and April 1994, and 10°C from December 1993 to March 1994. Vapor pressure deficit was kept between 1.0 and 2.0 kPa. Response curves of P_n and g_s to CO_2 concentration in the air were measured at $1000 \mu\text{mol m}^{-2} \text{s}^{-1}$ in *PPFD*. Response curves of P_n to *PPFD* were measured at arbitrary CO_2 concentrations in the air, and, after measurement, adjusted to 35 Pa using the response curve of P_n to CO_2 concentration in the air.

P_n , g_s and intercellular CO_2 concentration (C_i) were calculated after von Caemmerer and Farquhar (1981). The P_n and g_s under the condition of $1000 \mu\text{mol m}^{-2} \text{s}^{-1}$ in *PPFD* and 35 Pa in CO_2 concentration in the air were used for analysis and called P_{n1000} and g_{s1000} , respectively. The slope of the initial linear portion of the response curve of P_n to C_i was defined as the carboxylation efficiency (K_c) (Farquhar and Sharkey; 1982). The ratio of P_{n1000} to g_{s1000} was defined as the intrinsic water use efficiency (*IWUE*) (Zhang *et al.*; 1993).

3. Results

3.1 Urban micro environment

Weekly average of diurnal integrated *PPFD* ($\text{mol m}^{-2} \text{day}^{-1}$) measured at Tenjin was lower at Hakozaki throughout the year and the annual averaged ratio of Tenjin to Hakozaki was 64.6% (Fig. 2). The diurnal *PPFD* at Tenjin was limited by adjacent buildings, which intercepted direct sunlight in the early morning and late afternoon. The window period, when direct sunlight irradiated the sensor, was between 9 and 14 h on July 12 near the summer solstice and 10 and 13 h on December 29 at near the winter solstice. Maximum *PPFD* of a day was also lower at Tenjin: the ratio of Tenjin to Hakozaki was 65.5% on December 29, 1993 and 88.1% on July 12, 1994 (Fig. 3). The annual average ratio was 78.2%.

Weekly averaged maximum and minimum T_a of a day at Tenjin was higher than at Hakozaki throughout the study period (Fig. 2). Annual averaged differences of maximum and minimum T_a between study sites were 0.42°C and 1.43°C, respectively. There were only six days when minimum T_a at Tenjin was lower than at Hakozaki during the study period. In the late afternoon after the sunlight shut out by buildings, T_a at Tenjin was often lower than at Hakozaki on sunny days: 3.7°C on December 29, 1993 and 1.6°C on July 12, 1994 on average two hours after sun set, that is, 13 to 15 p.m. and 15 to 17 p.m., respectively (Fig. 3).

Daily average *SWP* from July 1993 to April 1994 changed around -0.01 MPa . After May 1994, soil was dehydrated and *SWP* was often outside the available range (-0.063 MPa) of the sensor at both study sites due to the low precipitation: 48%, 58% and 7.2% precipitation compared with the monthly averaged precipitation over 10 years in May, June and July 1994, respectively (Fukuoka Districts Meteorological Observatory; 1994). *SWP* at Tenjin was outside the range on June 2, and again on July 6 at Tenjin and on July 5 at Hakozaki following rainfall on June 18. Soil was usually more dehydrated at Tenjin than at Hakozaki (Fig. 4).

Fig. 2 Seasonal courses of weekly average of photosynthetic photon flux density (PPFD) and of maximum (thin) and minimum (bold) air temperature at Tenjin (solid lines) and Hakozaki (dashed lines) study sites.

Fig. 3 Diurnal courses of photosynthetic photon flux density (PPFD) and air temperature at Tenjin (solid lines) and Hakozaki (dashed lines) study sites in July 7, 1993, and December 29, 1993, near the summer and winter solstice, respectively.

Fig. 4 Seasonal courses of soil water potential (SWP) at Tenjin (solid lines) and Hakozaki (dashed lines) study sites, SWP difference between both study sites (Tenjin minus Hakozaki) and precipitation.

Fig. 5 Seasonal courses of photosynthetic rate (P_{n1000}), stomatal conductance (g_{s1000}), carboxylation efficiency (K_c), and intrinsic water use efficiency (IWUE) for detached shoots of *Ilex rotunda* at Tenjin (solid lines, open circles) and Hakozaki (dashed lines, solid circles) study sites. Each value is a mean, $\pm$ SE, $n=3$.

3.2 Gas exchange

P_{n1000} , g_{s1000} and K_c at Tenjin were lower than at Hakozaki from July to September 1993 except for K_c in August. These parameters decreased slowly at Tenjin, and rapidly at Hakozaki from September to October 1993. From October 1993 to March 1994, P_{n1000} and K_c were higher at Tenjin but g_{s1000} was almost equal. P_{n1000} and K_c of newly flushed leaves in April became higher following leaf expansion. However, g_{s1000} did not become the same level as last summer, especially at Tenjin. $IWUE$ was higher at Tenjin from October 1993 to July 1994. From July to September 1993, there was no difference between study sites (Fig. 5).

4. Discussion

4.1 Urban micro environment

Diurnal integrated $PPFD$ at Tenjin was lower than at Hakozaki due to interception of direct sunlight by adjacent buildings. This is a characteristic of light environment in an urban canyon, and was also reported by O'Rourke and Terjung (1981) and Kjellgren and Clark (1992).

The maximum $PPFD$ of a day was lower at Tenjin than at Hakozaki. Fujimoto (1974) reported air pollutants in urban areas reduced maximum solar radiation about 10% on sunny days at Tokyo. In this study, the annual average reduction ratio (100-the ratio of maximum $PPFD$ of Tenjin to that of Hakozaki) was 21.8%. This reduction ratio was higher than the reported values. In this study, the sensor was left above the crown for six months, so dust deposited on the sensor at Tenjin might have reduced radiation (e.g., December 29, 1993). However, the maximum $PPFD$ at Tenjin just after setting the sensor was lower than at Hakozaki: the reduction ratio for 10 days just after setting sensor in July 1993 was 11%. Therefore, $PPFD$ at Tenjin was considered to be reduced by air pollutants as well as dust deposited on the sensor.

T_a at Tenjin was higher than at Hakozaki, particularly for minimum T_a at night. This is an evidence of the heat island effect. However, T_a in the late afternoon at Tenjin was lower on sunny days, because direct sunlight was intercepted by buildings. This lower T_a is the cause of the cool island effect. The monthly average maximum and minimum T_a of a day at Tenjin were higher than those recorded at the Fukuoka district meteorological observatory (e.g., 1.72°C and 0.64°C in January 1994, and 1.28°C and 0.38°C in July 1994, respectively) (Fukuoka District Meteorological Observatory; 1994). The same result that T_a in a street canyon was higher than at a weather station was also reported by Bassuk and Whitlow (1987).

SWP of both sites changed between -0.01 MPa and -0.0039 MPa during the measurement period except after May 1994. SWP of this range is generally observed and is suitable for plant growth. After May 1994, the soil was dehydrated due to very low precipitation. Soil water under -0.063 MPa is hardly available for plants. In this period, the soil at Tenjin was under the severe dry condition than at Hakozaki. The reason for the difference in SWP between study sites is probably that, in addition to very low precipitation, water was not supplied from low layers of soil cut off by concrete, and more transpiration of bigger trees at Tenjin might deplete the soil water. However, our data was unique because precipitation from May to June 1994, was 36% of the average year (Fukuoka Districts Meteorological Observatory; 1994). To ascertain general SWP for summer at Tenjin, measurement should be carried out in the summer with average precipitation.

On the other hand, flooding has been pointed out as the urban environmental stress (Bassuk and Whitlow; 1987, Krizek and Dubik; 1987). Just after rainfall, SWP at Tenjin was lower than at Hakozaki. However, there was only one day (May 12, 1994) when SWP at Tenjin was above field capacity (-0.0063 MPa) while Hakozaki was below it. Therefore, in spite of summer precipitation in 1993 1.7 times higher than in an average year (Fukuoka Districts Meteorological Observatory; 1993), there was no instance when the soil at Tenjin was wetter for longer than at Hakozaki.

Fig. 6 Dependence of photosynthetic rate (P_n) on intercellular CO_2 concentration of leaves of *Ilex rotunda* at Tenjin and Hakoziaki study sites in August (circles) and November (triangles) 1993. Each regression line (solid lines) are demand function and dashed lines are supply function. Arrows represent measured and presumed P_{n1000} and intercellular CO_2 concentration when ambient CO_2 was 35 Pa.

4.2 Photosynthesis acclimated to the urban micro environment

4.2.1 High P_{n1000} in autumn and winter

P_{n1000} from October 1993 to May 1994 was higher at Tenjin. K_c was also higher. However, g_{s1000} was almost the same at both study sites. Therefore, higher K_c may account for higher P_{n1000} at Tenjin. The dependence of P_{n1000} to g_{s1000} and K_c from summer to winter can be distinguished using response curves of P_n to C_i for August and November after Bauer *et al.* (1985) (Fig. 6).

In the case of Hakoziaki, when CO_2 concentration in the air was 35 Pa, P_{n1000} and C_i were $12.7 \mu\text{mol m}^{-2} \text{s}^{-1}$ and 23.1 Pa in August and $1.6 \mu\text{mol m}^{-2} \text{s}^{-1}$ and 28.9 Pa in November, respectively. If the decrease in P_{n1000} depended on only a decrease in K_c , P_{n1000} ought to be $1.9 \mu\text{mol m}^{-2} \text{s}^{-1}$, that is the intersecting point of dashed line (supply function) of August, which slope is equal to negative of g_{s1000} , and real line (demand function) of November, which slope is equal to K_c . However, P_{n1000} decreased to $1.6 \mu\text{mol m}^{-2} \text{s}^{-1}$, so the $0.3 \mu\text{mol m}^{-2} \text{s}^{-1}$ in the decrease depended on g_s . The dependence of P_{n1000} to K_c was 97.3% at Hakoziaki and 66.2% at Tenjin.

P_n , g_s and mesophyll conductance (K_c) decreased following senescence, independent of changing environmental conditions (Nelson; 1985). In this study, the decrease in P_{n1000} largely depended on a decrease in K_c and the degree of dependence of P_{n1000} on K_c at Tenjin was less than at Hakoziaki. Curtis and Teeri (1992) reported autumnal decline of P_n for *Populus grandidentata* under natural conditions was almost entirely due to a decrease in K_c . Bauer *et al.* (1985) reported about 75% of chill-induced reduction of CO_2 uptake for *Coffea arabica* was due to impairment of carboxylation efficiency and 25% to reduced stomatal aperture. These reports show that low temperature reduces K_c and, in fact, Sawada *et al.* (1974) showed low temperature reduced *in vitro* ribulose biphosphate carboxylase efficiency. Therefore, higher minimum T_a in autumn and winter at Tenjin probably moderated the decrease of K_c and caused higher P_{n1000} . Higher P_{n1000} is probably result of the acclimation to higher minimum T_a .

4.2.2 High IWUE in summer with less precipitation

IWUE in July 1993 was not different between study sites. In June and July 1994, however, it was higher

at Tenjin than at Hakozaki because of lower g_{s1000} and higher K_c at Tenjin. *Pinus taeda* and *Populus deltoides* grown under water-stressed conditions had a lower transpiration rate or g_s and higher water use efficiency under sufficient soil water conditions in comparison with plants grown under non-stressed conditions. This high water use efficiency was the result of water stress preconditioning (Gebre and Kuhns 1993; Seiler and Johnson; 1985, 1988). In June and July 1994, the sampled tree at Tenjin was probably under greater water stress than at Hakozaki, because the soil at Tenjin was more dehydrated. In this study, the gas exchange rates were measured with well watered detached shoots. Therefore, in comparison with July 1993, lower g_{s1000} and higher $IWUE$ in 1994 was probably the result of acclimation to dehydrated soil.

4.2.3 Low P_{n1000} in summer

In August and September 1993, P_{n1000} were lower at Tenjin. The sample tree at Tenjin was planted in the street with heavy traffic. Traffic over a 12 hour daytime period on this road in March 1994 consisted of 31012 cars (City of Fukuoka; 1994). SO_2 , NO_x and dust concentration in the air at Tenjin were higher than in suburbs like Hakozaki (Fukuoka Prefecture; 1994). Air pollutant is indicated as factors reducing photosynthesis, for example, exhaust from cars (Kammerbauer *et al.*; 1987), dust (Thompson *et al.*; 1984) and heavy metals (Carlson and Bazzaz; 1977, Lamoreaux and Chaney; 1978). Therefore, impairment by air pollutants is a possible explanation of low P_{n1000} at Tenjin. In July 1994, however, P_{n1000} was higher at Tenjin. This was probably due to acclimation to dehydrated soil (4.2.2).

5. Conclusion

In this study, less sunlight, high air temperature and soil dehydration in summer were characterized as the urban micro environment for street trees at Tenjin study site. The hypothesis that photosynthetic capacity of the urban street tree was acclimated to the environment was empirically confirmed. The high minimum air temperature reduced carboxylation efficiency moderately and caused high photosynthetic rate in winter. Dehydrated soil probably reduced stomatal conductance and caused high intrinsic water use efficiency. Low photosynthetic rate in summer 1993 might be impairment of air pollution. The heat island effect and air pollution are phenomena observed on "city scale" and are reported for many cities (Kawamura; 1979). Dehydrated soil in the concrete pit is phenomenon observed on "street scale." Therefore, high photosynthetic rate in winter and low photosynthetic rate in summer may be observed commonly in many cities. In contrast, soil water condition may change every pit. In fact, flooding has been pointed out for urban concrete pits. Gas exchange acclimation of urban street trees to soil water condition should be studied at many urban concrete pits.

References

- BASSUK, N. and WHITLOW, T.(1987) Environmental stress in street trees. *Acta Horticulturae* **195**: 49-57.
 BAUER, H., WIERER, R., HATHEWAY, W.H. and LARCHER, W.(1985) Photosynthesis of *Coffea arabica* after chilling. *Physiol. Plant.* **64**: 449-454.
 CARLSON, R.W. and BAZZAZ, F.A.(1987) Growth reduction in American sycamore (*Plantanus occidentalis* L.) caused by Pb-Cd interaction. *Environ. Pollut.* **12**: 243-253.
 CITY OF FUKUOKA (1994) Statistical Yearbook of City of Fukuoka. No. 32, pp. 146. Fukuoka.(in Japanese)
 CURTIS, P.S. and TEERI, J.A.(1992) Seasonal responses of leaf gas exchange to elevated carbon dioxide in *Populus grandidentata*. *Can. J. For. Res.* **22**: 1320-1325.
 FARQUHAR, G.D. and SHARKEY, T.D.(1982) Stomatal conductance and photosynthesis. *Ann. Rev. Plant Physiol.* **33**: 317-345.
 FUJIMOTO, F.(1974) Influence of atmospheric pollution on the solar radiation measured on the ground (I). *Geophys. Mag.* **37**: 1-48.
 FUKUOKA DISTRICTS METEOROLOGICAL OBSERVATORY (1993, 1994) Monthly Weather Report of Fukuoka Prefecture. The Fukuoka headoffice of Japan weather society, Fukuoka.(in Japanese)
 FUKUOKA PREFECTURE (1994) Environmental White Paper of Fukuoka Prefecture. pp.395-409. Fukuoka.(in Japanese)

- GEBRE, G.M. and KUHN, M.R. (1993) Effects of water stress preconditioning on gas exchange and water relations of *Populus deltoides* clones. Can. J. For. Res. **23**: 1291-1297.
- JONES, H.G. (1992) In: *Plants and microclimate*. pp. 197, 242. Second edition. Cambridge University Press, Cambridge.
- KAMMERBAUER, H., ZIEGLER-JÖNES, A., SELINGER, H., RÖMMELT, R., KNOPPIK, D. and HOCK, B. (1987) Exposure of Norway spruce at the highway border: Effects on gas exchange and growth. *Experientia* **43**: 1124-1125.
- KAWAMURA, T. (1979) introduction. In: *Science of atmospheric environment 3. Atmospheric environment of cities*. (eds. Kawamura, T.) pp. 1. University of Tokyo Press, Tokyo. (in Japanese)
- KJELGREN, R.K. and CLARK, J.R. (1992) Photosynthesis and leaf morphology of *Liquidambar styraciflua* L. under variable urban radiant-energy condition. Int. J. Biometeorol. **36**: 165-171.
- KRIZEK, D.T. and DUBIK, S.P. (1987) Influence of water stress and restricted root volume on growth and development of urban trees. J. Arboriculture. **13**: 47-55.
- LAMOREAUX, R.J. and CHANEY, W.R. (1978) The effect of cadmium on net photosynthesis, transpiration and dark respiration of excised silver maple leaves. *Physiol. Pl.* **43**: 231-236.
- NELSON, N.D. (1985) Photosynthetic life span of attached poplar leaves under favorable controlled environmental condition. For. Sci. **31**: 700-705.
- O'ROURKE, P.A. and TERJUNG, W.H. (1981) Relative influence of city structure on canopy photosynthesis. Int. J. Biometeorol. **25**: 1-19.
- SAWADA, S., MATSUSHIMA, H. and MIYACHI, S. (1974) Effects of growth temperature on photosynthetic carbon metabolism in green plants. III. Difference in structure, photosynthetic activities and activities of ribulose diphosphate carboxylase and glycolate oxidase in leaves of wheat grown under varied temperatures. *Plant Cell Physiol.* **15**: 239-248.
- SEILER, J.R. and JOHNSON, J.D. (1985) Photosynthesis and transpiration of loblolly pine seedlings as influenced by moisture-stress conditioning. For. Sci. **31**: 742-749.
- SEILER, J.R. and JOHNSON, J.D. (1988) Physiological and morphological responses of three half-sib families of loblolly pine to water-stress conditioning. For. Sci. **34**: 487-495.
- THOMPSON, J.R., MUELLER, P.W., FLUCKIGER, W. and RUTTER, A.J. (1984) The effect of dust on photosynthesis and its significance for roadside plants. *Environ. Pollut. (Ser. A)* **34**: 171-190.
- VON CAEMMERER, S. and FARQUHAR, G.D. (1981) Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves. *Planta* **153**: 376-387.
- WHITLOW, T.H. and BASSUK, N.L. (1988) Ecophysiology of urban trees and their management-The North American Experience. *HortScience* **23**: 542-546.
- ZHANG, J., MARSHALL, J.D. and JAQUISH, B.C. (1993) Genetic differentiation in carbon isotope discrimination and gas exchange in *Pseudotsuga menziesii*. *Oecologia* **93**: 80-87.

(Accepted April 21, 1996)

要 旨

都市街路樹の植栽環境、および街路樹の光合成特性の都市環境への順化の程度を明らかにすることを目的として、福岡市天神地区を対象に日射、気温及び土壌水分の各環境因子と、中央分離帯に植栽されているクロガネモチ (*Ilex rotunda* Thunb.) の切り枝の光合成速度を1年間測定した。その結果、都市特有の植栽環境として、少ない日射量、高い気温および夏期の土壌乾燥が明らかになった。また都市内に植栽されたクロガネモチの最大光合成速度は、郊外に植栽されている個体に比較して夏期に低く、秋期から冬期に高い値を示した。秋期から冬期の高い最大光合成速度は高いCO₂固定効率に依存していた。夏期の低い光合成速度は大気汚染の影響の可能性が考えられた。1994年夏期の高い水利用効率は乾燥した土壌に起因したものと思われた。この様に都市街路樹の光合成特性は、都市環境に順化したものであることが示唆された。