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CO_2 CONCENTRATION AND FLUX NEAR GROUND IN MARSH OF THE SANJIANG PLAIN OF NORTHEAST CHINA

Yan Minhua(闫敏华) Ma Xuehui(马学慧) Lu Xianguo(吕宪国)
Changchun Institute of Geography, the Chinese Academy of Sciences, Changchun 130021, P.R.China
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ABSTRACT: There is limited information available on CO_2 concentration and flux over marsh. The objective of this work was to characterize CO_2 concentration and flux within and above marsh plant (*Carex lasiocarpa* Ehrh. and *C. pseudocuraica* F. Schm) canopy at heights 0.5, 1.0 and 1.5 m. CO_2 concentration was measured sequentially every 3 hours by using an infrared gas analyzer. Soil and air temperature, wind speed, net radiation and soil heat flux were also measured simultaneously. Extremely daily minimum and maximum CO_2 concentration ranged from 250 to 754 μmd/mol for the 4-year work. The typical minimum and maximum values ranged from 314 to 464 μmol/mol at the height of marsh plant (about 0.5 m) during the fruiting period and mature date. The seasonal changes in CO_2 concentration show that the minimum CO_2 concentration occurred in the fruiting period and mature date, and both of their minimum values were 314 μmol/mol. This illustrates that CO_2 consumed by photosynthesis was stable during the period. The flux of CO_2 can be thought as a turbulent diffusion phenomenon. By micrometeorological methods, the diurnal CO_2 fluxes were measured in the flowering period, fruiting period, early mature date, late mature date and yellow-ripe stage. Their values were -0.18, 38.15, 24.13, 10.9 and 4.91 μmol/mol respectively.
KEY WORDS: CO_2 concentration, gradient of CO_2 concentration, CO_2 flux, marsh, the Sanjiang Plain

I. INTRODUCTION

In the recent years, the researchers have paid attention to the problems of carbon balance and carbon cycle in the earth ecosystem, with the increase of CO_2 amount in the earth atmosphere. Mire is one of the ecotypes in which carbon accumulation rate is the fastest, and it is the strongest sink for CO_2 (Bramrgd, 1980). But there is limited information available about CO_2 concentration over mire. Some measurements about the temporal and spatial gradient of CO_2 concentration have been made within or above a sugar beet canopy (Brown, 1970), corn canopy (Allen, 1971; Reicosky, 1989), soybean canopy (Allen, 1971; Reicosky, 1989) and wheat canopy (Pearman, 1973; Yu, 1987). These results showed diurnal course and annual course of CO_2 concentration within or above canopies of some crops. The flux of CO_2 from soil was reported by Monteith *et al* (1962; 1964). and Denmead (1969). The measurement methods of CO_2 flux were givenby Rosenberg *et al*. (1983). and Yu Huning. Yu Huning (1987) measured the CO_2 flux from 0.8 to 2.0 m above the ground in a winter wheat field, using a micrometeorological method.

The research was a part of a 4-year project on carbon cycle in peatlands. The objective of this work was to characterize CO_2 concentration and flux within and above marsh plant canopy at heights of 0.5, 1.0 and 1.5 m.

II. EXPERIMENTAL DATA AND ENVIRONMENTAL CONDITIONS

We analyzed a set of CO_2 concentration and micrometeorological data at Marsh Station of Changchun Institute of Geography (latitude 47°35′N, longitude 133°31′E, elevation 56 m) during the period of January – October from 1991 to 1994. The measurements were carried out in the experimental field of the marsh station covered with *C. lasiocarpa* Ehrh. and *C. pseudocuraica* F. Schm marsh, which is the most representative marsh in the Sanjiang Plain. The experimental field was surrounded by marsh, so its advection was weak, air pollution is negligible. CO_2 concentration was measured directly with QGD – 07 and GXH – 305 infrared gas analyzer. Air temperature and relative humidity were observed by using ventilated psychrometers. Wind speed was measured directly with thermoelectric anemoscope. The net radiation was measured with a net radiometer. The above five elements were all measured at heights of 0.5, 1.0 and 1.5 m, respectively. The soil heat flux was observed with heat flux plate at the depth of 0.5 cm. Soil temperature was measured directly with earth thermometer at the depths of 0.5, 10, 15 and 20 cm. All elements were observed sequentially every 3 hours. Unreliable values were excluded, which mostly refer to the situations with rain. By measuring CO_2 concentration, gradients of CO_2 concentration and relatively meteorological factors, the variation rules of CO_2 concentration and CO_2 fluxes as well as some features of marsh plants' photosynthesis are described qualitatively and quantitatively during major growth periods of marsh plants in the Sanjiang Plain.

III. RESULTS AND DISCUSSION

1. The Diurnal and Seasonal Variation of CO_2 Concentration near Ground

The diurnal variations of CO_2 concentration on an overcast day and a following clear day are shown in Fig. 1. On the clear day (day 173 – 174 of 1994), under low wind speed (<2 m/s) conditions, there was apparent diurnal variation of CO_2 concentration at the height of 1.5 m above the marsh. During the daytime, CO_2 concentration was low because photosynthesis of marsh plants consumed CO_2. At night, the respiration of marsh plants released CO_2, so CO_2

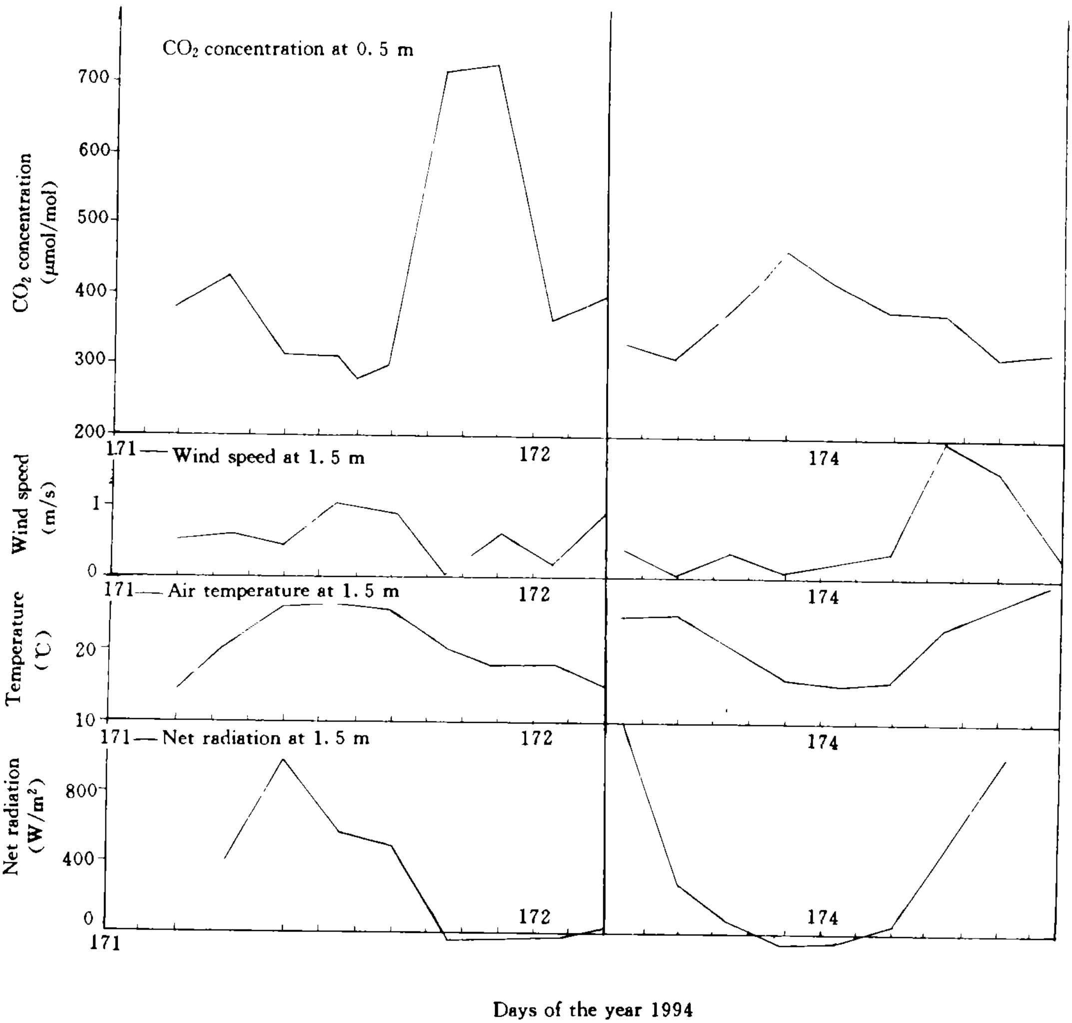

Fig. 1 Example of the CO_2 concentration at 0.5 m, wind speed, air temperature and net radiation at 1.5 m in *C. lasiocarpa* Ehrh. marsh during the 1994 growing season

concen tration gradually reached the peak of a day. The CO_2 concentration was inversely related to the net radiation all day. However, on the overcast day (day 171 – 172 of 1994), it was overcast from the afternoon of day 171, the CO_2 concentration increased suddenly when wind speed was <0.2 m/s at 19:00, and the daily range of CO_2 was as high as 445 μmol/mol.

When stronger photosynthesis by day alternates with stronger respiration at night during the main growth periods of marsh plants, apparent diurnal variation of CO_2 concentration occurred above and within the canopies of marsh plants. For example, in *C. lasiocarpa* Ehrh. marsh (Fig.2) the peak in CO_2 concentration occurred between night and early morning, and the minimum near noon or in afternoon from plant flowéring period to late mature date (from the middle ten days of May to the first ten days of September).

From the fruiting period to mature date, the plant height was ≥0.5 m, the minimum CO_2 concentration was very stable during the daytime, which was 314 μmol/mol. The daily mean CO_2 concentration at the top of the canopy was also stable, which was about 372 μmol/mol. On clear day, the diurnal amplitude of CO_2 concentration fluctuation in autumn was smaller than that in spring and summer (Fig.3). Obviously, the diurnal amplitude of CO_2 con

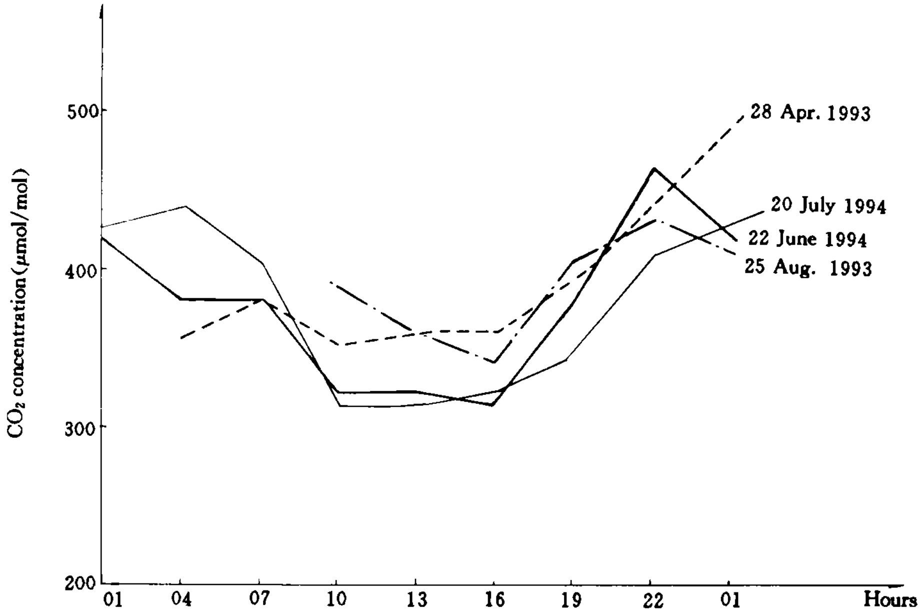

Fig.2 The daily CO_2 concentration of *C. lasiocarpa* Ehrh. marsh at 0.5 m in various growing seasons

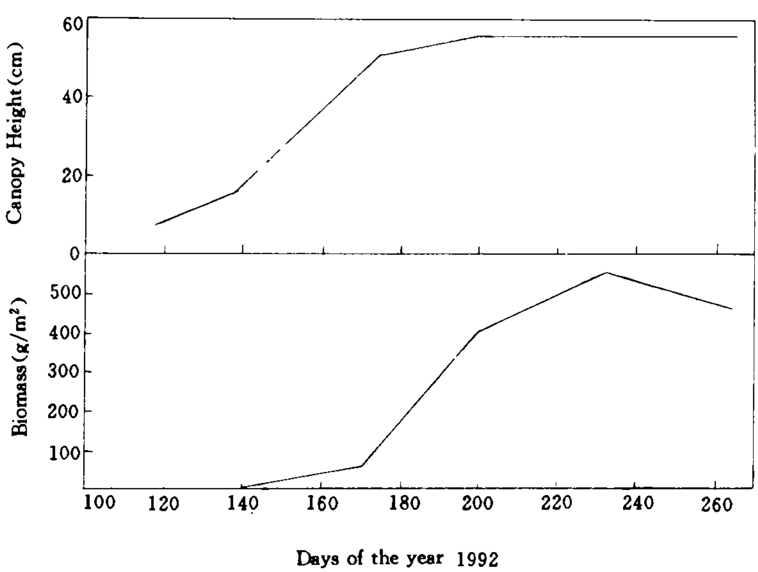

Fig.3 Plant height and biomass for *C. lasiocarpa* Ehrh. for growing season in 1992

centration fluctuation decreased with reducing biomass of marsh plants (Fig. 2, Fig. 3). In winter, CO_2 concentration changes gently because of shortage of stronger CO_2 source and sink.

2. Profiles of CO_2 Concentration near Ground

Growing plant is CO_2 sink during the daytime. The intensity of CO_2 sink mainly depends on both the total area of photosynthesis and the light use efficiency. In the field, respiration of CO_2 is imbibed by photosynthesis of plant from the air by day, all living things on the ground, the decomposition of deciduous leaves respiration of living roots and decomposition of dead roots and organic matter in soil released CO_2 into air all day. The CO_2 used in photosynthesis was more than that released from the other processes. Soils and plants became CO_2 source of the atmosphere at night, and CO_2 concentration in the air near ground was decided by two factors; one is ambient temperature, which affects the CO_2 amount released by plants and soil, the other is wind speed (turbulence), which decides mixing and transferring speed of CO_2 respiration in vertical and tail wind direction.

CO_2 concentration profiles can show clearly the changes of CO_2 source and sink near ground all day. The typical profiles of CO_2 concentration for *C. lasiocarpa* were given in Fig. 4. In the major growing period, CO_2 concentration on the soil surface under plants was the highest. This phenomenon shows that the soil is always a source of CO_2 for the living leaves above it. During the daytime, the CO_2 concentration of the surface was the highest, the CO_2 concentration within the canopy decreased progressively with the rise of elevation and reached the lowest value at a height where photosynthesis was the strongest. Then the CO_2 concentration increased progressively with the rise of elevation. At night, most of CO_2 concentration profiles decreased progressively with the in‹rease of elevation.

From Fig. 4(b), it can be seen that CO_2 concentration profiles above the marsh plants' canopy decreased with the rise of height before sunrise. The soil and the bottom of the plant canopy are CO_2 sources all day. The CO_2 concentration gradient in the canopy was very large because the top of the plant canopy was dense. The received light by the bottom of the plant canopy was far smaller than that for photosynthesis. So the compensation point wasn't reached, the bottom leaves became directly a CO_2 source for the top of the plant canopy.

3. Calculation of CO_2 Flux near Ground in Marsh

Based on aerodynamics theory, the flux of CO_2 (F_C) can be written as:

$$F_C = K_C \frac{\partial c}{\partial z} \tag{1}$$

where K_C is the exchange coefficient of CO_2; $\frac{\partial c}{\partial z}$ is the gradient of CO_2 concentration.

Reynolds' similarity theory thought that the turbulent exchange coefficients for momen

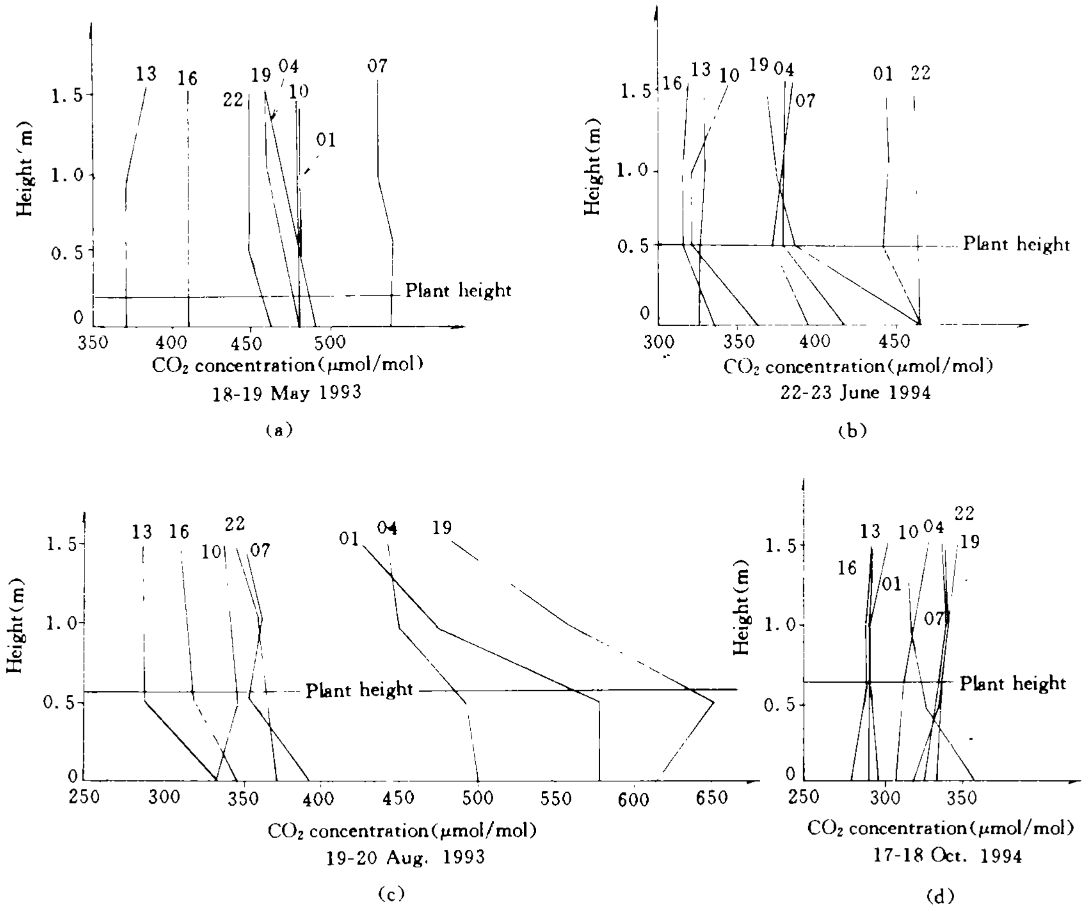

Fig.4 The profiles of CO_2 concentration of *C. lasiocarpa* Ehrh. marsh during marsh plants' growing season

tum, sensible heat, water vapour and CO_2 are equal. Formula (1) can be rewritten as:

$$F_C = f \cdot k^2 \cdot (z - d)^2 \cdot \left(\frac{\partial u}{\partial z}\right)\left(\frac{\partial c}{\partial z}\right)\left(\frac{Kc}{Km} \cdot \Phi_m^{-2}\right) \tag{2}$$

where k is von Karman's constant, z is the elevation above earth's surface, d is the zero plane displacement, u is the mean wind speed at height z, Km is the turbulent exchange coefficient for momentum, Kc is the turbulent exchange coefficient for CO_2, Φm is generally expressed as a function of Richardson number Ri or Z/L (the Monin-obukhov stability parameter), f is CO_2 unit-exchange coefficient.

In W.O. Pruitt (1973) model, the effects of atmospheric stability on the relationship between exchange coefficient under nonneutral conditions are given experimentally, and the functional relationships between Φm and Ri (or Z/L) are precisely defined in stable and unstable conditions. Under unstable condi tions, $Kw / Km = 1.13\,(1 - 60\,\mathrm{Ri})^{0.074}$, $\Phi m = (1.16Ri)^{-1/3}$; under stable conditions, $Kw/Km = 1.13\,(1 + 95\mathrm{Ri})^{-0.11}$, $\Phi m = (1 +$

$16Ri)^{1/3}$(Norman, 1983). Assuming $Kw = Kc$, Kw is the turbulent exchange coefficient for water vapor. From the experimental expressions of Φm and Kw/Km described above, the flux of CO_2 is estimated with equation (2) and measured data between 0.5 m and 1.5 m above *C. lasiocarpa* Ehrh. marsh during various growing seasons from 1992 to 1994 (see Table 1). We assume the direction of Fc is positive from atmosphere to the marsh. Otherwise, the direction is negative. Fc equaling zero expresses CO_2 balance.

In the middle ten days of May, flowering period of *C. lasiocarpa* Ehrh., CO_2 flux was very small all day, Fc was in the state of balance by day and negative value during the period after sunset or before sunrise. In the middle or last ten days of June, the fruiting period of the plant, during the daytime, Fc increased gradually after sunrise and reached the peak at noon. After that, CO_2 reached balance. The direction of Fc became negative and the absolute value of Fc was very small from sunset to midnight. In the last ten days of July or early ten days of August, mature date of the plant, Fc began to diminish. F_C reached the maximum before noon. There was a net release of CO_2 to atmosphere after midnight. In late August, yellow ripe stage of the plant, the flux of CO_2 became weak. Fc was positive value by day and negative value at night. In early september, only before sunset there was a weak release of CO_2 to air, the flux of CO_2 almost equaled zero all day.

Obviously, the direction and value of Fc changed notably with plant maturity. Diurnal Fc value decreased and diurnal amplitude of Fc wave declined gradually after the fruiting stage of *C. lasiocarpa* Ehrh. with the plant growing. The direction and value of Fc could indicate whether the plant was a CO_2 source or a CO_2 sink because Fc represented CO_2 transport amount and direction.

IV. CONCLUSION

(1) There were similar daily variation curves of CO_2 concentration near ground in the various growing seasons of marsh plants. Cn a day, the minimum value of CO_2 concentration occurred at 10:00 – 16:00 hours, the maximum value occurred at 22:00 – 4:00 hours.

(2) Both the daily lowest and daily mean CO_2 concentration are very stable for full growing marsh plant during certain period.

(3) The profiles of CO_2 concentration demonstrated that the CO_2 concentration reached the lowest value at centain height within the canopy by day. The profiles decreased progressively with elevation at night.

(4) The direction of CO_2 flux varied notably with marsh plant growing. This shows that the situation of marsh plant canopy as a CO_2 source or sink also changed accordingly.

(5) The diurnal amplitude of CO_2 flux fluctuation attenuated continually with marsh plant maturity.

Table 1 CO_2 flux near ground in *C. lasiocarpa* Ehrh. marsh during various growing periods

Date	Period of marsh plant	CO_2 fluxes (μmol/(m²·s))								Diural CO_2 flux (0.5 – 1.5 m) (μmol/(m²·s))	Daily mean wind speed at height of 1.5 m (m/s)	Daily mean temperature at height of 1.5 m (℃)
17-18 May 1993	Flowering	16:00 0.00	19:00 −0.23	22:00 0.00	1:00 0.46	4:00 −2.3	7:00 0.00	10:00 0.00	13:00 0.00	−0.18	1.07	15.25
22-23 June 1994	Fruiting	4:00 0.23	7:00 −77.74	10:00 6.44	13:00 386.17	16:00 0.00	19:00 0.00	22:00 −0.69	1:00 −0.00	38.15	0.48	21.18
20-21 July 1994	Mature	7:00 −0.46	10:00 272.78	13:00 31.97	16:00 0.92	19:00 −0.00	22:00 −0.00	1:00 −85.1	4:00 −0.00	24.13	1.21	24.63
26 Aug. 1992	Mature	1:00 0.00	4:00 0.00	7:00 1.15	10:00 43.47	13:00 48.99	16:00 −6.67	19:00 −0.00	22:00 −0.23	10.9	1.63	19.49
5-6 Sept. 1992	Yellow-ripe	7:00 0.00	10:00 −2.07	13:00 0.00	16:00 −37.49	19:00 −0.00	22:00 0.00	1:00 0.00	4:00 0.00	−4.91	1.00	17.8

REFERENCES

Allen L H, 1971. Variations in carbon dioxide concentration over an agricultural field. Agric. Meteorol., 8:5 – 24.

Bramrgd T, 1980. The role of peatlands for the global carbon dioxide balance. In: Proceeding of 6th International Peat Congress of International Peat Society, Duluth.

Brown K W, Rosenberg N J, 1970. Concentration of CO_2 in the air above a sugar beet field. Mon. Weather Rev., 98:75 – 82.

Denmead O T, 1969. Carbon dioxide exchange in the field: Its measurement and interpretation. In: proceedings of WMO Seminar on Agricultural Meteorology.

Monteith J L, 1962. Measurements and interpretation of carbon dioxide fluxes in the field. Neth J. Agric. Sci., 10: 334 – 346.

Monteith J L, Szeicz G, Yabuki K, 1964. Crop photosynthesis and the flux of carbon dioxide below the canopy. J. Appl. Ecol., 1:321 – 337.

Norman J Rosenberg *et al.*, 1983. Microclimate: The Biological Environment. Chapter 4, 142 – 143, Chapter 8, 293 – 299. New York: Jhon Wiley & Sons, Inc.

Pearman G I, Garratt J R, 1973. Carbon dioxide measurements above a whear crop. I. Observations of vertical gradients and concentrations. Agric. Meteorol., 12:13 – 25.

Reicosky D C, 1989. Diurnal and seasonal trends in carbon dioxide concentrations in corn and soybean canopies as affected by tillage and irrigation. Agric, and Forest Meteoral., 48:285 – 303.

Weng Duming *et al.*, 1979. Microclimate and agricultural microclimate. Beijing: Agriculture Press. (in Chinese)

Yu Huning, 1987. The Research on the CO_2 flux in the field ecological system. The Study of Energy Transfer and Matter Exchange in Agro-Ecosystems. Beijing: Meteorology Press. 171 – 179. (in Chinese)