Studies on the Photosynthetic Characteristics of Ginger

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Abstract

The results of this experiment showed that the photosynthetic rate of "Laiwu Big Ginger" was higher than that of "Laiwu Small Ginger"; the photosynthetic rate of leaves at 11th-12th nodes was higher than that of the leaves at 3rd-4th nodes, and it was lowest at top leaves. The dynamic of photosynthetic rates of single leaf and canopy showed mono-peak curves during the whole growth stage of ginger. The heavy midday depression of photosynthesis was observed in single leaf at both leaf vigorous growth stage and rhizome vigorous growth stage. However, no mid-day depression of canopy photosynthesis was noted at rhizome vigorous growth stage, maximum photosynthetic rate occurring around 13:00, but midday depression of canopy photosynthesis occurred at leaf vigorous growth stage. The results also indicated that the optimal PFD of photosynthesis for single leaf was about 1290 μmol·m^{-2}·s^{-1}, but 1950 μmol·m^{-2}·s^{-1} for canopy. Nevertheless, CO_2 concentration for single leaves and canopy photosynthesis of ginger was similar, about 1500 μl·l^{-1}. Moreover, the optimal temperature and soil water content for photosynthesis of ginger were 25-30 C^o and75 %, respectively.

INTRODUCTION

Ginger (*Zingiber officinale Rosc.*) originated from the tropical rain forest region. For a long time, people always thought that the ginger was a shade-loving light-hating plant, and that ginger needed to be shaded in the field (He, Q.W. et al. 1990, Wang, S.H., 1999). However, as we have noted in recent years, by mulching ginger with straw in field, neither yield nor photosynthetic rate (Pn) decreased. On the contrary, Pn declined in shaded fields (Xu, K., 1999, 2000). These results disagree with conventional opinions. Known to all, crop yield is closely related to plant density and photosynthetic rate (Pn) in the leaves. Therefore, understanding the factors that influence photosynthesis and the photosynthetic rate is essential to make reasonable cultural practices, enhance growth, and promote yield of ginger. For this problem, the relation between environmental factors and photosynthesis of ginger was studied in order to regulate environmental conditions more efficiently, provide better cultivation measures, and further promote the yield and quality of ginger.

MATERIALS AND METHODS

The experiment was done with Laiwu big ginger and Laiwu small ginger in the vegetable testing station of Shandong Agricultural University from 1997 to 1999. The plant density was 20 × 60 cm in field. The photosynthetic rate of single leaf and plant colony, and diurnal or seasonal changes of photosynthesis were recorded in this treatment. Until leaf vigorous growth began, the ginger, which planted in pots (50 cm high x 35 cm in diameter) were transferred to psychrometric room, to regulate the temperature, light, and CO_2 concentration automatically. Water content of soil in pots was regulated by weighting during natural desiccation. The response of photosynthesis to environmental factors (temperature, PFD and CO_2) was measured in the psychrometric room. The measuring leaves were the 11th-12th node leaves from bottom on main stem. All measurements were made after steady-state conditions were achieved (about 30 min after an environmental factor was changed). Each experiment was repeated for 4-6 times.

All data were measured with the CIRAS-1 Portable Photosynthesis System (PP System, UK). The data were analyzed by Duncan's shortest significant range test to determine differences between treatment means.

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RESULTS

Effect of Different Species and Different Node Leaves on Photosynthetic Rate

At the vigorous growth stage of ginger, the photosynthetic rates (Pn) of different node leaves and two species ("Laiwu big ginger" and "Laiwu small ginger") were measured. The results showed that the Pn of top (17^{th}-18^{th}) leaves，middle (11^{th}-12^{th}) leaves and low (3^{rd}-4^{th}) leaves of Laiwu big ginger were 21.24 %, 13.01 %, 16.94 % higher than that of "Laiwu small ginger" respectively, (Table 1). Usually, the photosynthetic ability increases with increased chlorophyll content (Zheng, G.H., 1980). Compared with "Laiwu small ginger", the leaves of "Laiwu big ginger" were larger and thicker, the color of leaves was deeper and chlorophyll content was higher.

Photosynthetic Rate at Different Growth Stages of Ginger Leaves

The photosynthesis of ginger gradually increased with plant growth. In middle September photosynthesis climaxed and then gradually decreased. The photosynthetic rate of single leaf varied little at early stage, however, decreasing rapidly at later stage, relative to environmental conditions and plant age. The leaves of ginger were tender at seedling the stage and the photosynthetic ability was low. Once the leaves were growing stronger and the suitable climate was coming, the photosynthetic ability of leaves became higher at the vigorous growth stage. And at later growth stage, though the rhizomes grew rapidly, with the temperature dropping and the leaves becoming decrepit, the photosynthesis declined. As for the collective photosynthetic rate (CPn), it increased rapidly at early stage, which was determined by two factors: the increase of Pn in single leaf and the rapid expansion of the plant colony. For this reason, adopting proper cultivation measurements, hastening shoot and leaf development, prolonging photosynthesis time, and keeping leaves from senescing, have an important meaning for the production of ginger.

Diurnal Changes of Photosynthetic Rate of Ginger Leaves

The diurnal changes of Pn and CPn were measured at vigorous growth stage of leaves and rhizomes. Both Pn and CPn displayed asymmetry double-peak curves at leaf vigorous growth stage (Fig.2, Fig.3). The first peak of Pn appeared at around 9:00, and that of CPn appeared at around 11:00. After 11:00, both the Pn and CPn dropped and reached the lowest point at 13:00. After this, the Pn and CPn rose gradually and reached subaltern-peak at 15:00. This indicated apparent "midday depression of photosynthesis." The diurnal changes of Pn and CPn were the results of internal and external factors. At 7:00, low temperature and weak light contributed to the low photosynthetic rate. At 9:00-11:00, with the suitable temperature and light, the photosynthetic rate was high. The occurrence of a midday depression of photosynthesis could be partly attributed to unfavorable environmental conditions. For instance, high temperature, low moisture, and strong light decreased stoma conductivity. However, the diurnal changes of Pn and CPn at rhizome vigorous growth stage were different from that of leaf vigorous growth stage. The Pn also showed as a double-peak curve, in which there was apparent midday depression of photosynthesis, while the CPn, with no midday depression, was a mono-peak curve. Which was relevant to the great colony at rhizome vigorous growth stage, though top leaves were exposed in strong light and high temperature, the middle and low leaves were exposed in suitable light intensity.

Effect of Temperature and Soil Water Content on Photosynthesis of Ginger Leaves

Exposed in certain light (1200 $\mu mol \cdot m^{-2} s^{-1}$) and CO_2 (340 $\mu l \cdot L^{-1}$), the Pn of pot cultured plants were measured under different temperatures at leaf growth vigorous stage. The results (Fig.4) indicated that Pn increased rapidly with temperatures rising below 25 °C; between 25-30 C^o Pn was highest. But when temperature was over 30 C^o Pn dropped rapidly, indicating that the suitable temperature for photosynthesis of ginger was 25-30 C^o.

The soil water content affected the Pn of ginger leaves significantly (Fig.5). When the soil water content was reduced from 98 % to 75 %, Pn changed little, about 13 $\mu mol \cdot m^{-2} \cdot s^{-1}$; but as soil water content continued to decrease, the Pn dropped rapidly. The Pn were 8.38 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 2.12 $\mu mol \cdot m^{-2} \cdot s^{-1}$ as the soil water content reduced to 60 % and 41.2 %. Compared with the maximum Pn (80 % soil water content), which declined 36.13 % and 83.84 % , respectively.

Effect of Light Intensity and CO_2 Concentration on Pn and CPn of Ginger Leaves

By controlling light intensity manually, the light-response to Pn and CPn were measured. The results (Fig.6) showed that the Pn increased rapidly with the light intensity increasing in the scope of 900 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Over 900 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the trend slowed. The trend of CPn was similar with that of Pn, but the CPn increased nearly linearly under PFD 1200 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Over this point, the trend slowed, even reaching PFD 1600 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the CPn still increased, which apparently exceeded the light saturation point of single leaves. According to the experimental data and computer imitation, the light compensation point and saturation point of Pn and CPn were 28.5 $\mu mol \cdot m^{-2} \cdot s^{-1}$, 1293 $\mu mol \cdot m^{-2} \cdot s^{-1}$, 106.8 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 1950 $\mu mol \cdot m^{-2} \cdot s^{-1}$, respectively, indicating the light adaptability of the ginger colony was far higher than that of single leaf.

Response to CO_2 concentration Pn and CPn was similar with the same light intensity (Fig.7). In the scope of 600 $\mu l \cdot l^{-1}$, the photosynthetic rate increased as a linear line almost with the CO_2 concentration rising. Then the trend slowed. When the CO_2 concentration reached 1500 $\mu l \cdot l^{-1}$, the photosynthetic rate tended to be steady. With computer imitation, the CO_2 compensation point and saturation point were obtained. The CO_2 compensation point and saturation point of Pn and CPn were 61.7 $\mu l \cdot l^{-1}$, 1514.7 $\mu l \cdot l^{-1}$, 65.9 $\mu l \cdot l^{-1}$ and 1462.8 $\mu l \cdot l^{-1}$, respectively. Therefore, the CO_2 utilization ability of single leaf and colony of ginger was similar.

DISCUSSION AND CONCLUSIONS

Adaptability to Light Intensity of Ginger

According to the results of the experiment, the light compensation point and saturation point of the single leaf were 28.5 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 1293 $\mu mol \cdot m^{-2} \cdot s^{-1}$, while the light compensation point and saturation point of colonial photosynthesis were 106.8 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 1950 $\mu mol \cdot m^{-2} \cdot s^{-1}$, respectively. So this experiment confirmed that the ginger should be a light-loving and shade-tolerating plant, its normal growth had strong adaptability to light. The experiment confirmed that the soil water content and temperature had remarkable effect on the growth of ginger, so it should be emphasized especially in cultivation.

The Relation of Leaf Age to the Photosynthesis of Ginger

The Pn was lower when the leaves were at early stage. It increased gradually as leaves growing until reaching a peak and then dropped gradually as leaves senesced. This is because the photosynthesis takes place in chloroplast when lamella construction play an important role in Pn. The lamella construction of chloroplast had not fully developed when the leaves were younger, so photosynthetic ability was poor. It increased as the lamella construction developed and then decreased as the lamella construction was destroyed because of the decrepitude of leaves.

Colonial Photosynthetic Characteristic and Light-Required Regulation of Ginger

The experiment showed that the seasonal changes of CPn showed as a mono-peak curve, which was similar to that of Pn, while the diurnal changes of CPn were different at different growth stages. At leaf vigorous growth stage, it showed as a double-peak curve and indicated an apparent midday depression of photosynthesis, which was the result of internal and external conditions. At this stage, high temperature, strong light intensity, low humidity and small colony size leaded to this phenomena. But at the rhizome vigorous growth stage, the colony was large and green leaves distributed at different layers. Because of the high temperature, strong light intensity and low humidity, the Pn of top leaves may become lower, while the middle and low leaves were likely to exposed to favorable environmental conditions. Therefore, the diurnal changes of CPn showed a mono-peak curve and its tiptop was at 11:00-13:00.

Light is a very important resource for the photosynthesis and every crop has its light saturation point. When the light to which crops were exposed was over, the light saturation point, the superfluous light would depress the photosynthesis, i.e photo-prohibition and even photo-oxidation (Demming-Adams B., Adams III WW., 1992, Gilmore, A.M., 1997, Demming-Adams, B. and Daniel, L. et al. 1998, Powls, S.B., 1984). However, plants dissipated the superfluous light and prevent the photosynthetic organ from being destroyed in different ways (Zhao, S.J., 1999 and Guo, L.W., et al. 1996). For long time, people thought of ginger as a shade loving plant, and it was shaded in ginger field (He, Q.W. et al. 1990, Wang, S.H., 1999). The light-response to photosynthesis regulation under field conditions showed that, when light intensity reached around 1500 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the CPn still increased; indicating that the colony of ginger required higher light intensity, especially at vigorous growth stages and with larger colony. The result also provided the theoretical basis for cultivation measurements of ginger, with the ginger at early growth stage was shaded and np shading applied at later growth stages. It can be drawn from production practices that ginger colonies need a higher light intensity than single leaf. Therefore, it was more practical to guide the ginger production by rule of requirement light in community.

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Tables

Table 1. The photosynthetic rate of different ginger varieties.

Item	Laiwu big ginger			Laiwu small ginger		
	Low leaves	Middle leaves	Top leaves	Low leaves	Middle leaves	Top leaves
Chlorophyll Content ($mg \cdot g^{-1}Fw$)	3.83c	3.59b	2.68a	3.01c	2.89b	2.13a
Photosynthetic rate ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	9.87b	13.46c	7.42a	8.44b	11.91c	6.12a
Photo flux density ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	876a	1310b	1778c	893a	1285b	1756c

*Test temperature 28.3-31.1°C, CO_2 concentration 331-346$\mu l \cdot l^{-1}$.
Values of the same variety within a line followed by different letters are significantly different at 5% level.

Figures

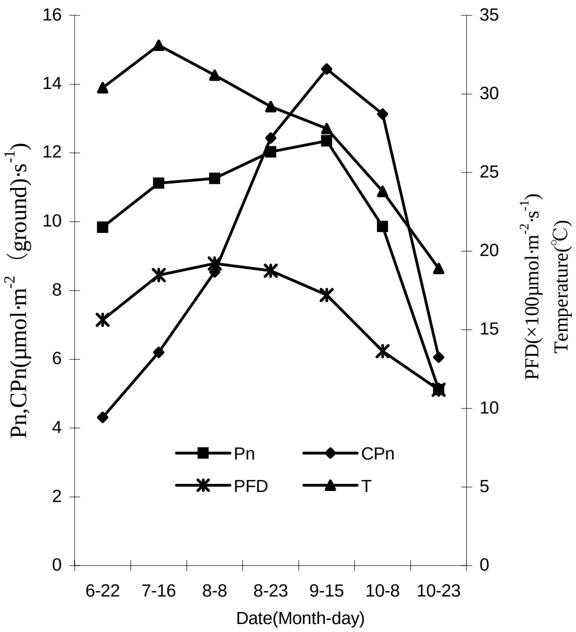

Fig. 1. The photosynthetic rate of ginger at different growth stages

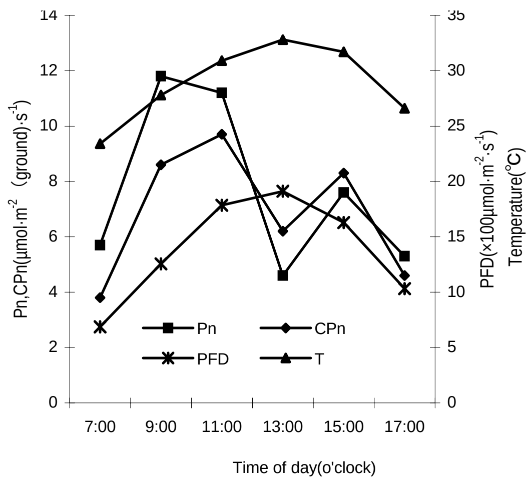

Fig. 2. Diurnal changes of photosynthetic rate of ginger at leaf vigrous growth stage

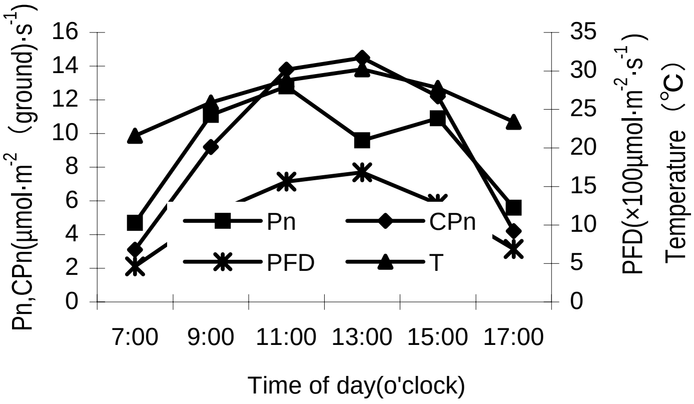

Fig. 3. Diurnal changes of photosynthetic rate of ginger at rhizome vigorous growth stage.

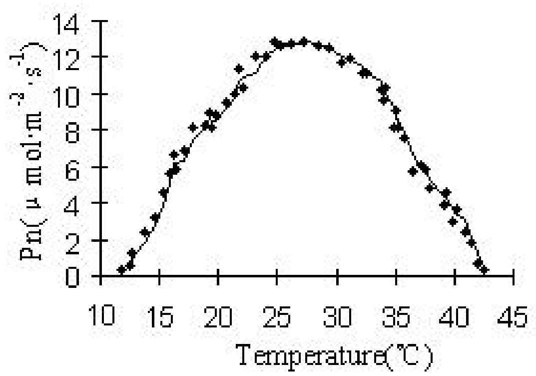

Fig. 4. Effects on temperature on PN in ginger leaves.

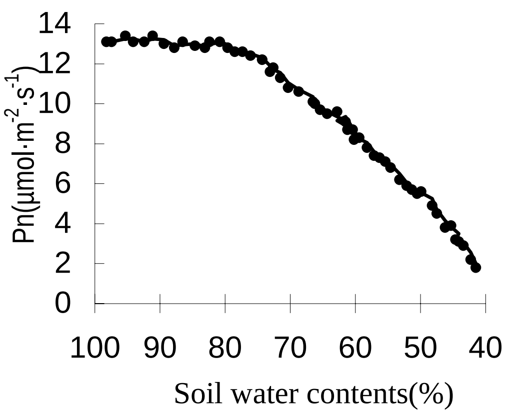

Fig. 5. Effects of soil water contents on Pn in ginger leaves.

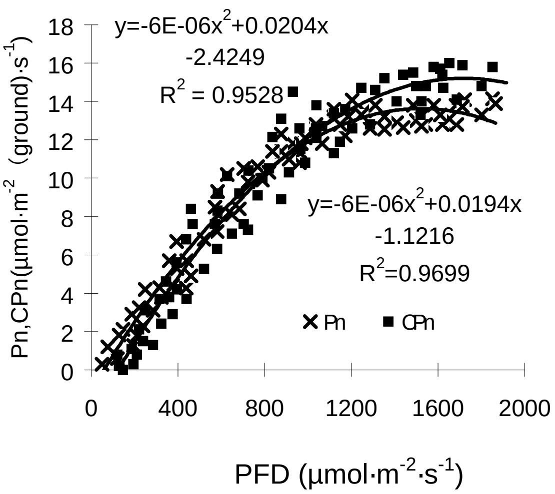

Fig. 6. The response of PFD to photosynthetic rate of ginger.

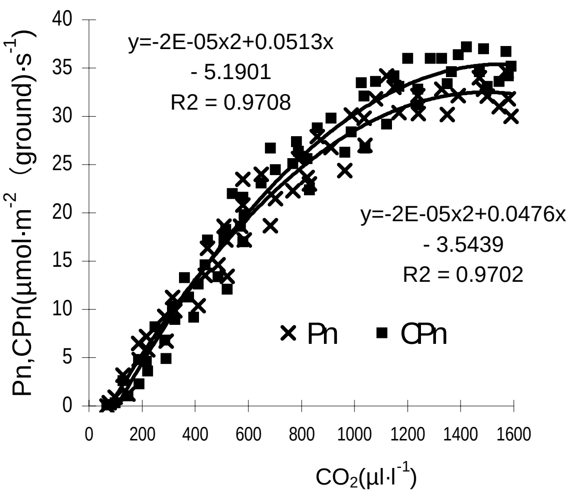

Fig. 7. The response of CO_2 to photosynthetic rate of ginger.