ダイズ植物体の生理的条件と呼吸速度との関係(1)

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Respiration of Soybean Plants in Relation to Their Physiological Conditions

I. The effects of nitrogen supply and plant age on the behavior of respiration in the dark period*

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Abstract : The time course of respiration in soybean plants was examined under different physiological conditions to elucidate the mechanism of the determination of respiration rate.

Respiratory CO_2 evolution per unit dry weight (RPW) decreased after the onset of the dark period and showed a temporary acceleration around midnight, called the midnight rise of respiration (MRR) in this paper, reaching a constant level at about 48 hours after the initiation of the dark. Throughout this time course, RPW was high in younger and nitrogen-supplied plants, and low in the aged or nitrogen-depleted plants. Furthermore, MRR disappeared in the aged or nitrogen-depleted plants.

From the results obtained, it was hypothesized that the time course of RPW, especially the existence of MRR, was determined by the demand for the energy and metabolic products which could be derived from respiration.
Key words : Diurnal change of respiration, Growth respiration, Nitrogen metabolism, Plant age, Respiration, Soybean.

ダイズ植物体の生理的条件と呼吸速度との関係　I. 窒素供給およびエイジが呼吸の経時変化に及ぼす影響：山岸順子・石井龍一・玖村敦彦（東京大学農学部）

要　旨：異なる生理的条件の下で測定したダイズ個体の呼吸速度の経時変化から，呼吸速度の決定機構を検討した．

暗期中の単位乾物重あたり CO_2 放出速度（RPW）は，暗期開始直後には低下するが，数時間後，一時的に増加し（Midnight Rise of Respiration, MRR），その後，再び低下し続けるという経時変化を示した．このような経時変化を示す RPW は，全般的に植物体が若く，窒素供給を行なった場合に高く，MRR も顕著であったが，成熟の進んだ個体あるいは窒素供給を停止した個体では MRR が見られなくなった．

これらのことより，ダイズ個体においては，RPW の大きさおよび MRR を特徴とする RPW の経時変化は，呼吸により生成されるエネルギーおよび中間代謝産物に対する植物体自身の需要度によって決められると考えられた．
キーワード：エイジ，呼吸，呼吸の経時変化，生長呼吸，ダイズ，窒素条件．

Diurnal changes of respiration have been examined in various plant species[1,3,4,6,8,9,10,12]. The initial rate of respiration at the start of darkness usually depends on the photosynthetic rate in the preceding light period, and as a general trend, the respiration rate continuously decreases with time during the dark period. This behavior of respiration could be the result of the change in the level of photosynthetically produced carbohydrate. It could therefore be said that the rate of respiration is determined by the level of its substrate. However, we can find several papers suggesting that the rate of respiration is not necessarily controlled only by the level of substrate. For an example, a temporary increase of respiration in the course of continuous decrease during the dark period has been observed in several species[4,8,12]. From this, we could speculate that respiration can be accelerated in accordance with the plant requirement of energy supply for the fulfillment of metabolic performance, as suggested by Beevers[2]. Furthermore, it has also been reported that high nitrogen plants have a high respiration rate, suggesting that high nitrogen levels in a plant necessitates more respiratory products[13,14,15,16,17].

In this report, we examined the diurnal

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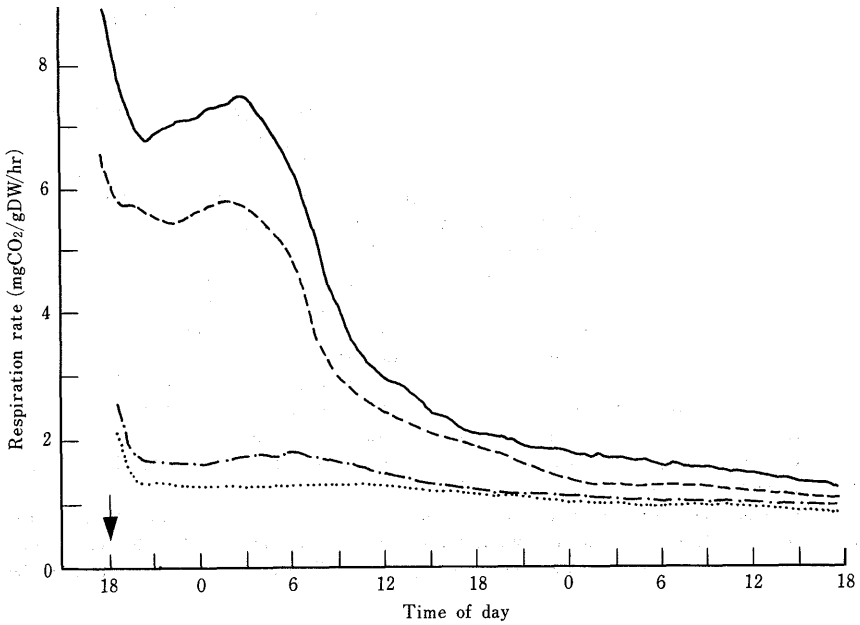

Fig. 1. Time course of respiration rate under continuous dark condition at the different growth stages.

Arrow shows the onset of the dark. Air temperature, humidity and light intensity were 25°C, 21°C as the dew point and 610 μeinstein/cm^2/s (PAR).

————: 5th foliage leaf fully expanded.

— — —: 6th foliage leaf fully expanded and flowering started.

—•—•—: First pod, the length of which reached 2 cm, appeared on the top four internodes on the main stem.

.....: Yellow pod appeared on the main stem.

change in the respiration in soybean plants under different environmental or physiological conditions, aiming to elucidate the mechanism of the determination of respiration rate.

Materials and Methods

Plant materials; Soybean plants (*Glycine max* (L.) Merr. cv. Koganedaizu and cv. Tsurunoko) were grown in 2.2 liter pots with Kasugai solution in a glass room at the Center of Environment Regulation System for Biology (CERES), the University of Tokyo, where the temperature and humidity were maintained at 25/20°C (day/night) and 70% respectively. The solution was changed every other day. The plants were transferred to a growth cabinet when they have 4 to 7 fully expanded foliage leaves on the main stem. In the growth cabinet, the air temperature, relative humidity, and light intensity were maintained at 25°C, 70% and 610 μeinstein/cm^2/s (PAR) with 12 hours light period respectively.

Measurement of CO_2 exchange rate; CO_2 exchange rate (CER) was measured with the system previously reported[7]. One plant was set in each of acrylic chambers (40×50×60 cm). The culture solution was aerated with the air in the acrylic chamber. Therefore our measurement was made on the over-all CER by whole plant. The sample air from each assimilation chamber was introduced into an infrared CO_2 gas analyzer (Fuji electric, ZAP) every four minutes alternately, and CO_2 concentration was measured continuously for about 48 hours.

Results

Fig. 1 shows the time course of respiration rate per unit dry weight (RPW) in whole soybean plants of different ages. The younger plants, which have 5 or 6 fully expanded foliage leaves on the main stem, were distinguished from the older ones in that a fast decrease soon after the onset of darkness was

followed by a temporary increase before the continuous decrease through the dark period. In this paper, we call this temporary increase of RPW observed around the midnight, the midnight rise of respiration, abbreviated as MRR. MRR was not found in the old plants, which have yellow pods on the main stem.

The time course of RPW characterized by MRR was maintained even in the plants which experienced low light intensity in the preceding light period, although the general value of RPW through the darkness was low (Fig. 2). This suggests that MRR is independent from the amount of carbohydrate available for respiration.

However, if nitrogen is removed from the culture solution, MRR disappeared on the 6th day of the treatment (Fig. 3).

When RPW was measured under 35°C, it showed remarkably higher values than that under 25°C. However, the time when MRR occurred did not change (Fig. 4). This suggests that the metabolic change relating to MRR takes place at an almost constant time after initiation of darkness.

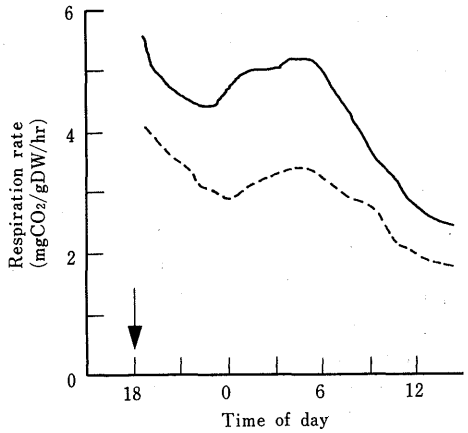

Fig. 2. Time course of respiration rate under continuous dark, following 12 hours light period of different light intensity.
Arrow shows the onset of dark. Light intensities in the preceding light period were 610 μeinstein/cm^2/s (PAR) (————) and 260 μeinstein/cm^2/s (PAR) (— — —).

Discussion

If we take the assumption proposed by McCree[10] that the RPW during 12 hours after the initiation of dark period subtracted by maintenance respiration, RPW at the end of the extended darkness, is corresponding to the growth respiration, the present paper clearly showed that growth respiration was strongly influenced by the plant age and nitrogen level, although the maintenance one showed small response to those factors. This means that the growth respiration is maintained at high levels under the conditions of young plant age and high nitrogen level. Furthermore, under those conditions, MRR was observed at an almost constant time after the dark period started.

A similar trend in the diurnal change of RPW was reported with cucumber[4], tomato[8] and *Chenopodium* species[12]. In addition, the diurnal change of not only respiration rate but also several enzymatic activities was observed with *Chenopodium* species, and this diurnal

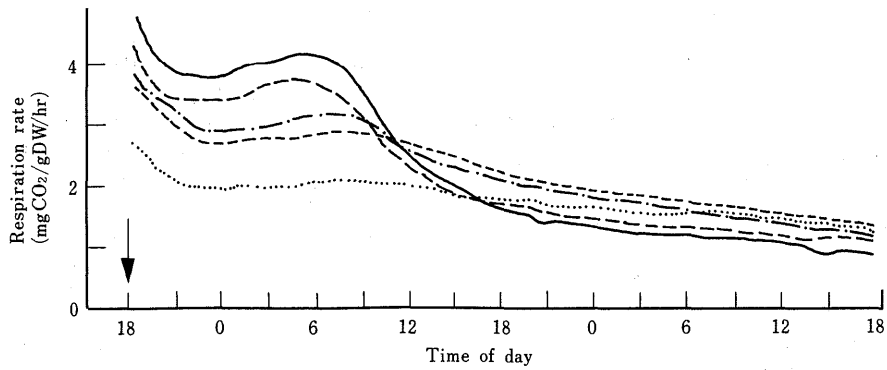

Fig. 3. Time course of respiration rate with nitrogen-depleted plants under continuous dark.
Arrow shows the onset of dark. ————: zero day, — — —: one day, —•—•—: 2 days, ----------: 4 days, ·····: 6 days after the removal of nitrogen.

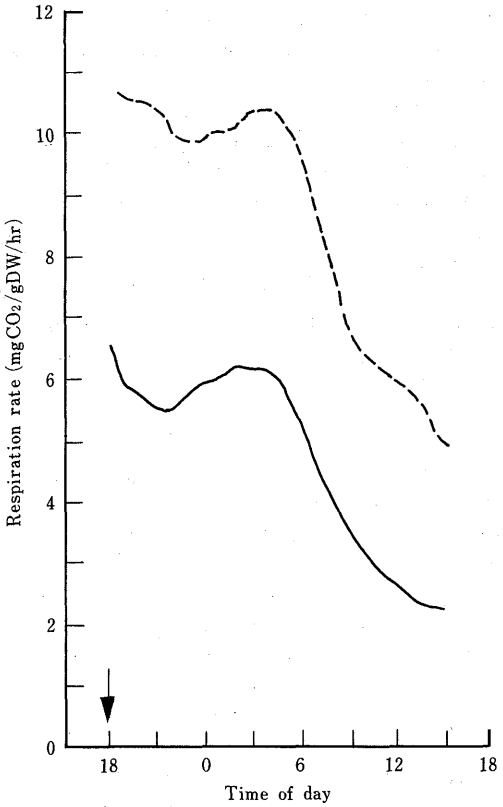

Fig. 4. Time course of respiration under continuous dark at different air temperatures, ————: 25°C, — — —: 35°C. Arrow shows the onset of the dark. The air temperature in the preceding light period was 25°C.

change is assumed to be circadian rhythm in plant[5]. In this paper, however, RPW showed no repeating rhythmic behavior during the continuous darkness. Challa[4] observed a temporary increase of respiration rate at midnight similar to our MRR, and speculated that this increase might be caused by the processes of carbon incorporation into structural carbohydrate and of protein redistribution. Our results also support the idea of Challa, because RPW showed no MRR in the nitrogen-depleted or the aged plants which were presumably inactive in nitrogen metabolism. Furthermore, it was also observed in this study that the existence of MRR was not affected by CO_2 concentration or light intensity in the preceding light period, or night temperature[4,8]. This implies that the amount of the respiratory substrate is not the cause of the occurrence of MRR and the followed decrease of respiration. It could be concluded, therefore, that soybean plants accumulate sufficient substrate required for respiratory performance in normal night period. This agrees with the idea that a plant possesses a comparatively large pool of carbohydrate or other organic compounds under normal physiological or environmental conditions[11].

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