Time-course of Respiration and its Relation to Water Conditions in Various Plant Species*

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Abstract : The time-courses of respiratory CO₂ evolution of fourteen plant species were examined to elucidate interspecific difference in respiration under the same environmental conditions. The effects of water deficiency and water logging on respiration were also examined in several plant species.

The change in respiration rate with time were almost the same in all plant species examined, though the levels of respiration rate were relatively higher in five C₄ plants than in three C₄ plants and six C₃ plants. They decreased after the onset of dark period followed by the temporary increase at midnight and declining again from 8 to 12 hours after the onset of dark period.

Both water deficiency and water logging conditions strongly and immediately affected the time course of respiration rate. The temporary rise of the rate at midnight disappeared within one day in both cases. In plants sensitive to flooded conditions the second decrease of respiration rate around 8 to 12 hours after the onset of dark period also disappeared by water logging for 7 days. From these results, it was concluded that the internal processes relating to the change in respiratory CO₂ evolution with time were similar among fourteen plant species, and that respiration rate sensitively and quickly reflected the plant growth response to water conditions, which differed among species.

Key words : Diurnal change of respiration, Interspecific difference, Respiration, Water deficit, Water logging.

呼吸の経時変化およびその水分条件との関係における種間差 : 山岸順子・秋田重誠†・高梨純一† (東京大学農学部・†農業研究センター)

要 旨 : 同一条件下で栽培した 14 種の植物の呼吸による CO₂ 放出速度を経時的に測定し、呼吸の種間差について検討した。さらに、数種について、水分欠乏あるいは湛水条件が呼吸におよぼす影響について検討を加えた。

呼吸速度は 5 種 (全て C₄ 植物) で他の 9 種 (C₄ 植物 3 種, C₃ 植物 6 種) よりも比較的高かったが、呼吸速度の経時変化は用いた全種においてほぼ等しく、暗期開始後低下するが、その後一時的に上昇し、暗期開始 8—12 時間後に再び低下開始し、以後低下し続けた。

水分欠乏と湛水条件は呼吸の経時変化に対し強くかつ直ちに影響をおよぼした。夜間の呼吸の一時的上昇はいずれの条件下でも一日のうちに消失した。また、湛水条件に弱い植物では、7 日間の湛水処理により暗期開始後 8—12 時間後に開始する呼吸速度の低下もみられなくなった。

以上より、用いた全種において呼吸による CO₂ 放出の経時変化に関係する体内要因が共通のものであること、および、呼吸は水分条件に対する植物の生長反応を敏感にかつ直ちに反映することが結論された。

キーワード : 経時変化, 呼吸, 種間差, 水分欠乏, 湛水。

It has been reported in various plant species that the respiration rates in the dark change with time^{2,3,4,5,6,7,8,10,11,12,13}. Though some of these showed continuous decreases of respiration rate with time during the dark period^{2,4,5,10}, the others showed temporary

increases of respiration rate following an initial decrease for a few hours^{3,6,9,12,13}. This temporary increase of respiration rate was called midnight rise of respiration (MRR) in soybean plant¹². We examined the time-course of respiratory CO₂ evolution in fourteen plant species including monocotyledons and dicotyledons, summer plants and winter plants, and C₃ plants and C₄ plants under the same environmental condition to elucidate the interspecific difference in respiration. These plant species also included those resistant to water deficiency but sensitive to water logging, as corn and wheat, and those resistant to

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Table 1. List of plants examined.

Species (Scientific name)	Plant type	Growing season
Rice (<i>Oryza sativa</i> L.)	C ₃	Summer
Soybean (<i>Glycine max</i> Merr.)	C ₃	Summer
Sunflower (<i>Helianthus annuus</i> L.)	C ₃	Summer
Italian ryegrass (<i>Lolium multiflorum</i> Lam.)	C ₃	Winter
Orchardgrass (<i>Dactylis glomerata</i> L.)	C ₃	Winter
Wheat (<i>Triticum aestivum</i> L.)	C ₃	Winter
Corn (<i>Zea mays</i> L.)	C ₄	Summer
Sorghum (<i>Sorghum bicolor</i> Moench)	C ₄	Summer
Job's tears (<i>Coix lacryma-jobi</i> L. var. <i>frumentacea</i> Makino)	C ₄	Summer
Bahiagrass (<i>Paspalum notatum</i> Flugge)	C ₄	Summer
Green panicgrass (<i>Panicum maximum</i> Jacq. var. <i>trichoglume</i> Eyles)	C ₄	Summer
Rhodesgrass (<i>Choris gayana</i> Kunth)	C ₄	Summer
Common millet (<i>Panicum miliaceum</i> L.)	C ₄	Summer
Finger millet (<i>Eleusine coracana</i> Gaertn)	C ₄	Summer

water logging but sensitive to water deficiency, as rice and Job's tears. The fact that plant growth is strongly affected by these water conditions suggests a similar relationship with respiration rates. The present study also examined the effect of water deficiency and water logging on the time-course of respiration rate of several plant species.

Materials and Methods

1. Plant materials Fourteen plant species (Table 1) were grown in small plastic pots (10cm diameter, 5cm depth) with artificial soil containing base fertilizer (Kumiai ryuujou baido K, Kumiai, Japan) in a growth cabinet at the National Institute of Agrobiological Resources. Air temperature was 25/20°C (day/night) and relative humidity was 70%. Light intensity was 1000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ and length of day and night was 12 hours each. The plants were watered two times a day. The number of plants per pot are : 2 with soybean, sunflower, and corn ; 5 with sorghum, Job's tears and green panicgrass ; 8 to 10 with wheat, bahiagrass, rhodesgrass and common millet ; and about 15 with rice, Italian ryegrass, orchardgrass and finger millet. When 6 foliage leaves of monocotyledons were fully emerged and when 1 or 2 foliage leaves of dicotyledons were fully expanded, the respiration rates of the whole plants were measured.

2. Measurement of respiration rate The measurement of the CO₂ exchange rate of whole

plant started at the onset of the dark period and continued for 22 hours under dark conditions. One pot was set in an acrylic chamber (10×10×30 cm) with a fan to circulate the air. CO₂-free air was introduced to the chamber. The CO₂ concentration of the sample air was determined by an infrared CO₂ gas analyzer (ZAP, Fuji Electric, Japan). Each species has 4 to 12 replications and almost the same results were obtained.

The respiration rate was also measured after withholding water for one day in seven species, rice, soybean, orchardgrass, wheat, corn, Job's tears and common millet. Four species, rice, corn, wheat and Job's tears were subjected to flooding conditions (5mm in water depth on the soil surface) for seven days. The respiration rate was measured 1, 2, 4 and 7 days after water logging treatment was applied.

Results

Time-course changes of respiration rates in fourteen plant species were shown in Fig.1. The trends of changes in the respiration rates of all plant species were almost identical in all plant species. They decreased after the onset of dark period followed by a temporary increase at midnight, decreasing again from 8 to 12 hours after the onset of dark period. In all plant species except rhodesgrass, respiration rates started to increase 2 to 4 hours after the onset of dark period. In the case of rhodes-

Fig. 1. Time-courses of respiration rate of fourteen plant species in the continuous dark. Horizontal axis shows the time from the onset of dark period.

grass, this increase started earlier than in other species.

Based on the level of respiration rate throughout the measurement period, the fourteen species were classified into 2 groups. One group consisted of plants with high respiration rates, such as corn, sorghum, bahiagrass, greenpanicgrass and rhodesgrass. The other group included Job's tears, common millet, finger millet and all C₃ plants. Almost no difference was observed in the level of respiration rates among C₃ plants.

Time-course changes of respiration rates of plants exposed to water deficit were quite different from those of well-watered plants

(Fig. 2), though no wilting symptoms appeared in these plants. Respiration rate suddenly decreased within 1 to 2 hours after the onset of the dark period, followed by a gradual decline, and the temporary increase of the rate at midnight completely disappeared.

Under flooded conditions, two types of time-course changes in the respiration rate were observed (Fig. 3). One, occurring in rice and Job's tears, showed almost the same trends of respiration rate 1, 2, 4 and 7 days after the start of treatment. After a sharp decrease of respiration rate for 1 or 2 hours, an almost constant level was kept for around 10 hours, and the temporary rise of respiration at mid-

Fig. 2. Time-courses of respiration rate in the continuous dark of the plants exposed to water deficiency for one day. Horizontal axis shows the time from the onset of dark period.

night was reduced. After that, the respiration rate gradually decreased until the end of measurement period. The other type was observed in corn and wheat. The fluctuation of the respiration rate became unclear with days of treatment and, on the 7th day, the rate was maintained at almost a constant level throughout the measurement period.

Discussion

In our results, no difference was observed in the change of respiration rate with time in fourteen plant species irrespective of monocotyledons or dicotyledons, C_3 or C_4 plants, and winter or summer plants. It suggested that the internal processes relating to the fluctuation of respiratory CO_2 output with time were basically common in these plants. Our results also showed that these internal processes were quite sensitive to the water conditions. It was reported that in soybean leaves the change in the respiration rate with time was reflected on the protein synthesis¹⁴⁾. Furthermore, it was known that protein synthesis was immediately suppressed by the water deficiency¹⁾. These reports suggested that the sensitivity of respiration rate to water deficiency was through the protein synthesis in the plants.

Under flooded conditions, the time course changes of respiration rate in corn and wheat

became unclear with days of treatment. This was quite similar to the case of nitrogen-depleted soybean plants¹²⁾. It is assumed that this unchanged respiration rate reflected the disturbance of normal growth. This coincided with the fact that corn and wheat can not grow under flooded condition. In contrast, with rice and Job's tears, which can grow in the flooded field, time-course changes of respiration rate were almost the same for 7 days of water logging treatment, although the mid-night rise of respiration was reduced.

From these results, it was concluded that the time-course changes in the respiration rate of various species were basically the same, and that they sensitively and quickly reflected the different growth response to water conditions among plant species.

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Fig. 3. Time-courses of respiration rate in the continuous dark of the plants exposed to water logging for one day (—), two days (---), four days (·····) and seven days (—•—).

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