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Rate of Soil Respiration at Black Locust (*Robinia pseudo-acacia*) Stands in Jinju Area

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ABSTRACT: The rate of soil respiration to varying stand ages was studied in four *Robinia pseudoacacia* stands (18-, 23-, 28- and 35-year old) throughout one year from September 1998 to August 1999. Soil temperatures showed a pronounced seasonal pattern, in contrast to soil moisture. The highest rate of soil respiration was generally found in August when soil temperatures were the highest, and the lowest in January. The daily rate of soil respiration amounted to 5.51 (g $CO_2 \cdot m^{-2} \cdot day^{-1}$) for 18-year old stand, 5.28 for 23-year old stand, 8.29 for 28-year stand, and 2.67 for 35-year old black locust stand, respectively. The Q_{10} values were ranged between 1.63 and 1.66, averaging 1.65 for the *R. pseudoaca'cia* stands. The results indicate significant correlation between soil temperature and soil respiration for all four stands (r=0.96 to 0.97). Among the study stands, the annual rate of soil respiration was the highest (3.03 kg $CO_2 \cdot m^{-2} \cdot yr^{-1}$) for 28-year old stand.

Key words: Q_{10} value, *Robinia pseudo-acacia*, Soil respiration, Stand development.

NTRODUCTION

Black locust (*Robinia pseudoacacia*) was planted extensively for erosion control and honey production during past one century in Korea, because of its rapid juvenile growth and high adaptability on poor site with N-fixing capacity from atmosphere. However, Yun *et al.* (1999) pointed out negative effects of black locust on growth, natural regeneration, and effective silvicultural work of native species.

On the other hand, evolution of CO_2 from the soil to the atmosphere is an important process in the flow of carbon in forest ecosystem. Large amounts of carbon are released to the atmosphere as CO_2 during decomposition of organic matter such as litter added to soil from aboveground and belowground sources. Measurements of the soil respiration from decomposing substrate has been recognized as an useful index of decomposition of organic matter and soil nitrogen processes of mineralization (Ewel *et al.* 1987, Gilmour*et al.* 1985, Mathes and Schriefer 1985, Schlentner and Van Cleve 1985, Tewary 1982), nitrification (Keeney *et al.* 1985), and denitrification (Reddy at al. 1982). Although, attempts to partition soil respiration into soil microbial activity and root respiration for the purpose of estimating forest productivity have been problematic (Minderman andVulto 1973), soil respiration provides an useful index of relative biological activity and has been used in many comparative studies (Weber 1985). Therefore, estimates of soil respiration have been made in a variety of forest ecosystem (Raich and Nadelhoffer 1989, Raich and Schlesinger 1992).

However, no studies have been directed towards understanding the pattern of soil respiration according as stand development at various forest ecosystem in Korea. It is necessary to understand the relative soil biological activity by measuring soil respiration at various forest ecosystems (Moon 2000). The purpose of this study was to investigate annual cycles of CO_2 evolution, and to relate CO_2 evolution to stand development, as well as to the effect of the abiotic factors of soil temperature and moisture content on CO_2 evolution from mineral soil of four black locust stand.

MATERIALS AND METHODS

Study area

The study was conducted at four black locust stands in Chinju area, Gyeongnam Province, Korea. All study stands consisted of a pure stand of black locust. Annual precipitation in this area is about 1502 mm, with about a half this falling in the summer months. The mean annual temperature is 13.4℃, with mean monthly temperatures ranging from 0.2℃ in January to 26℃ in August.

The four study stands were chosen and named the study stand A, B, C, and D by tree age, respectively. Tree ages of

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each stand were determined by an increment borer of the five trees of black locust. The understory vegetation at each study stand is dominated by *Smilax sieboldii* for A (18-year old stand), *Smilax china* for B (23-year old stand), *Phytolacca esculenta* for C (28-year old stand), and *Rosa multiflora* for D (35-year old stand), respectively. The characteristics and soil properties of the study stands were shown in Tables 1 and 2, respectively.

Soil analysis and respiration measurements

Soil samples were collected from 0-10 cm depth at mineral soils in each stand. Before analysis, soil samples were ground and passed through a 2-mm sieve. Soil moisture content was measured by drying to a constant weight at 105℃. Soil pH (H_2O) was measured by using a glass electrode in a 1:2.5 mixture of soil:deionized water. Soil organic matter was estimated by ignition loss at 450℃ for 4hr. The total N content was measured by using a C-N corder (MT-1600, YANACO). Available P in soil was extracted by 0.002N H_2SO_4 and determined colorimetrically by molybdate blue method. Exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na+ were extracted from soil with 1N CH_3COONH_4 buffered to a pH of 7.0. Among them, Ca^{2+}, Mg^{2+} and Na^+ were determined by an atomic absorption spectrophotometer, and K^+ was determined by flame-photometric procedure (SPCA-626D, SHIMADZU).

Soil respiration was measured from September 1998 to August 1999 using an alkali absorption method (Kirita 1971). Cylinder of 15 cm in diameter and 22 cm in height was used as CO_2 isolation chamber. Seven cylinders in each study stand were inserted 5 cm deep into the soil while taking precautions to minimize soil disturbance. Absorbant (25ml of 1N KOH) in sponge was placed within the cylinder on a simple wire in each study stand. The cylinder was shielded from direct sunlight by covering it with aluminum foil. Soil respiration rates were measured over 24hr. After 24hr, collected sponges were refrigerated at 4℃ for transport to the laboratory. In the laboratory, 5 ml of solution collected from the sponge was titrated with 0.1N HCl using phenolphthalein andmethylorange as indicators. Soil temperature was measured hourly with a thermo recorder (TR-71, T AND D) throughtout the study period.

The influences of soil temperature and moisture content on soil respiration rate were determined by regression analysis. All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 7.5).

Table 1. Observed stand characteristics of black locust stands

Parameters	Stand age (yr)			
	18(A)	23(B)	28(C)	35(D)
Plot size(m^2)	400	400	400	400
Aspect	E	ES	ES	NE
Slope(°)	5~8	6~10	0~5	3~10
Mean height(m)	7.2	7.6	8.5	9.6
Mean DBH.(cm)	11.2	12.9	14.7	16.8
Dominant species of understory	*Smilax sieboldii*	*Phytolacca esculenta*	*Smilax china*	*Rosa multiflora*

RESULTS

Fig. 1 show the soil temperature and moisture content throughout the study period in each study stand, respectively.

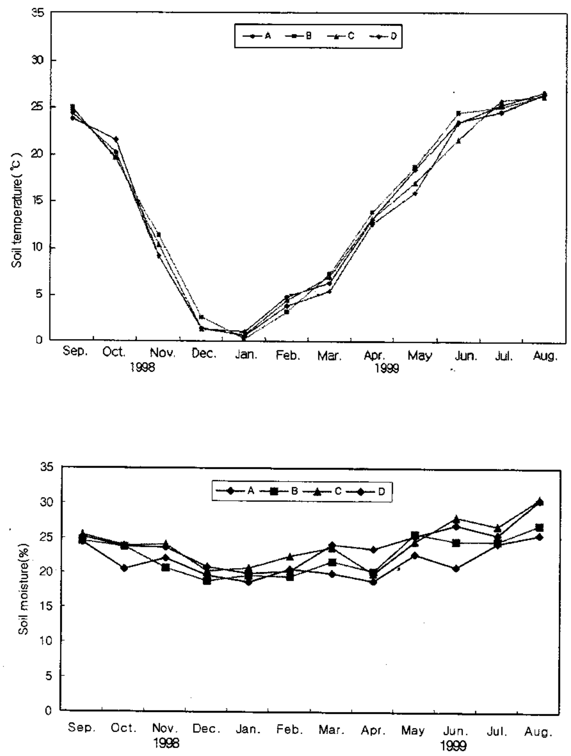

Fig. 1. Soil temperature (℃) and moisture content (%) on the four black locust stands during study period.

Table 2. Soil properties of four black locust stands

Stand type	pH (H_2O)	O.M. (%)	T.N. (%)	P (ppm)	Exch.(me/100g)			
					Ca^{2+}	Mg^{2+}	K^+	Na^+
A	4.8	2.4	0.15	36.2	0.61	0.14	0.05	0.02
B	5.2	2.9	0.16	28.1	0.60	0.18	0.06	0.02
C	5.1	3.2	0.19	39.7	0.73	0.17	0.06	0.03
D	5.2	3.1	0.19	36.9	0.75	0.17	0.06	0.02

Soil temperature in the four stands changed slightly during the growing season, probably due to differences in stand structure. Throughout the study period, average of soil moisture content were slightly higher in 35-year-old black locust stand than those of the other stands.

The seasonal changes of soil respiration in each study stand were shown in Fig. 2. In all study stands, seasonal changes of soil respiration rates were similar pattern, being high at growing period and low at dormancy period. The highest rates of soil respiration in all study stands were measured in August when soil temperatures were highest, and the lowest in January. There were slight differences in the rate of soil respiration between all study stands. Soil respiration rates in the 28-year old black locust stand tended to show higher rates than those in the other stands.

The relationships between the mean daily soil temperature and the soil respiration are shown in Fig. 3. An exponential equation (Eq. (1)) best described the relationships between soil temperature and soil respiration. The regression coefficient of following equation for each study stand are shown in Table 3.

$$\text{Log SR} = a + bT \quad (1)$$

Where Log SR is the daily soil respiration rate (g $CO_2 \cdot m^{-2} \cdot day^{-1}$), T is the mean daily soil temperature, and a and b are the regression coefficients, respectively.

As was shown in Fig. 3, there was significant correlation between soil temperature andsoil respiration for all four stands (*r* between 0.96 and 097). However, effect of soil moisture on soil respiration rate was not observed.

The Q_{10} values, with gives the rate of increase of soil respiration with a 10°C increase in soil temperature, varied between all study stands (Table 3). The Q_{10} values ranged between 1.63 and 1.66, averaging 1.65 for the black locust stand, respectively.

Table 3. The relationships between soil respiration rates and mean daily soil temperature for mineral soils in four black locust stands

Stand type	Estimated parameters		r	Q_{10} value
	a	b		
A	0.1956	0.0378	0.97	1.66
B	0.1878	0.0363	0.96	1.66
C	0.2663	0.0457	0.96	1.63
D	0.2188	0.0418	0.97	1.66

The annual rate of soil respiration was calculated from daily mean soil temperature using soil temperature-soil respiration regression analysis. The results are shown in Table 4. The annual rate of soil respiration amounted to 2.01 (kg $CO_2 \cdot m^{-2} \cdot yr^{-1}$) for 18-year old stand, 1.93 for 23-year old stand, 3.03 for 28-year old stand, and 0.97 for 35-year old black locust stand, respectively.

DISCUSSION

In general, soil respiration rate measured in this study, regardless of site condition, are also within the acceptable range of respiration rates encountered in other temperate forest worldwide (Singh and Gupta 1977), although comparability is interfered by thelack of standard methodology of soil respiration.

The steep increases in soil respiration occurring during early spring period in 29-year old black locust stand could indicate one of the following: (i) litters that had sojourned over the winter

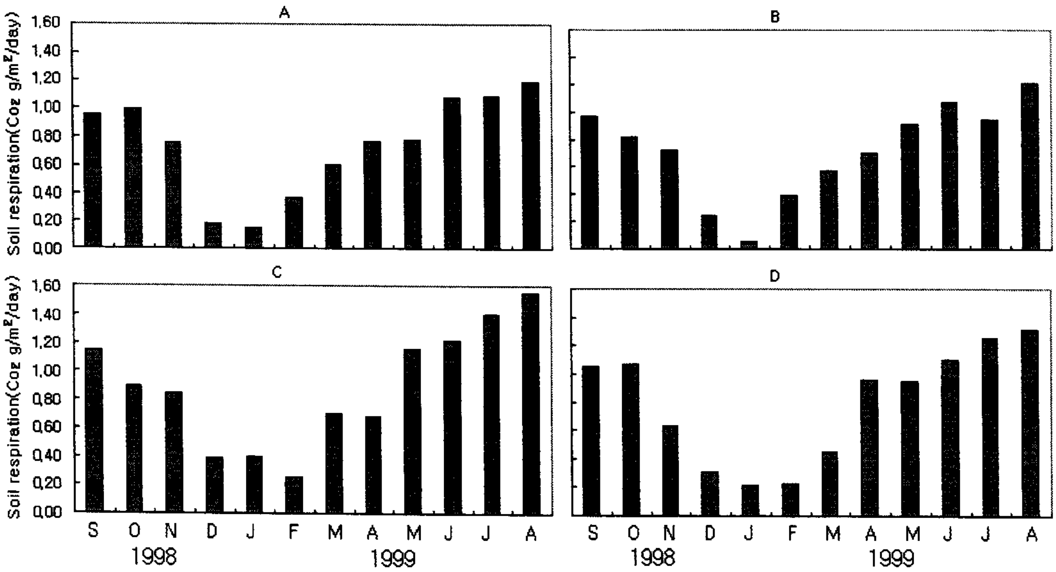

Fig. 2. Seasonal patterns of soil respiration rates for the four black locust stands.

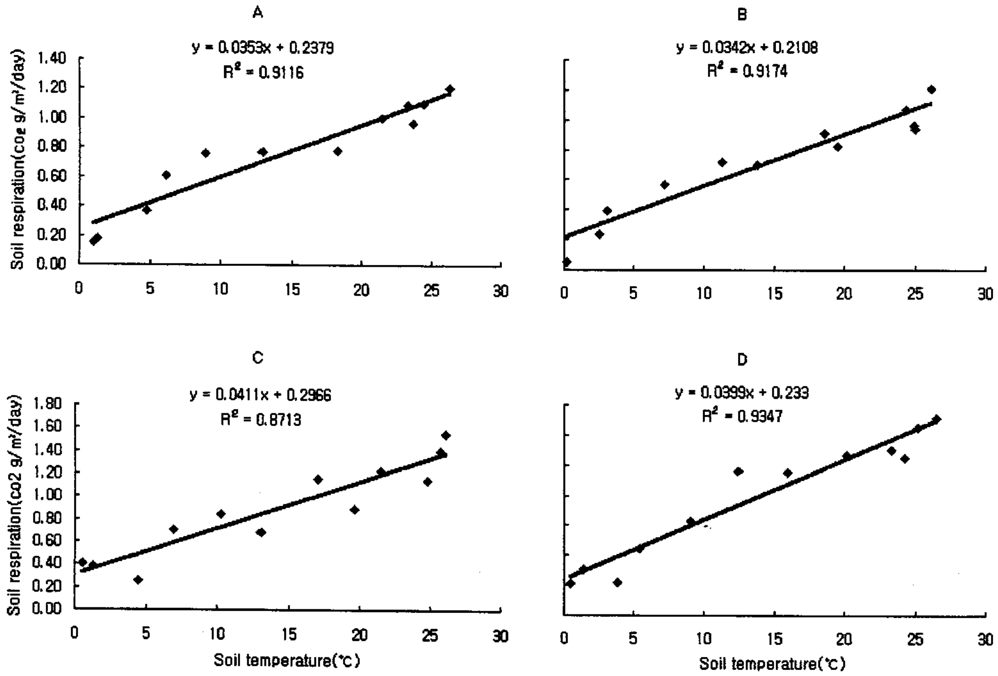

Fig. 3. The relationships between mean daily soil temperature and rates of soil respiration on mineral soils for the four black locust stands.

Table 4. Daily and annual rates of soil respiration in four black locust stands

Stand type	Daily respiration ($g\ CO_2 \cdot m^{-2} \cdot d^{-1}$)	Annual respiration ($kg\ CO_2 \cdot m^{-2} \cdot yr^{-1}$)
A	5.51	2.01
B	5.28	1.93
C	8.29	3.03
D	2.67	0.97

period provided a suitable substrate for microbial decomposition with the approach of warmer weather consequent increase in soiltemperature (Moon 1999), (ii) active root respiration of understory vegetation including herbaceous plants following winter dormancy.

Although live root biomass was not measured in this study, the increase in soil respiration rate in the 28-year old stand was primarily due to the increase in live root respiration. The difference in the rates of soil respiration between stands may be related to the development of root biomass, as the proportion of soil respiration contributed by the roots is variable in different plant communities and depends on the degree of development of the root system. Some studies have been reported on the relationship between root respiration and total soil respiration. As Coleman (1973) already pointed out, precise estimations of the contribution of plant root respiration is problematic due to difficulties in the separation of the roots and microbes from the soiland rhizosphere, respectively. Kucera and Kirkman (1971) estimated that 60% of the total soil respiration was derived from microbial processes in turnover of organic matter and the remaining 40% was attributed to root metabolism. And Wiant (1967) summarized that root respiration comprises at least one-third of total soil respiration inforest ecosystems. Therefore, the highest soil respiration rate observed in 28-year old stands is most likely attributable to roots activity of understory vegetation including herbaceous plants. Actually, *Smilax china* spread out all over the surface on understory in 28-year old black locust stand, respectively. Root removal in field disturbs the soil, possibly stimulating soil respiration, and thus may not be a valid estimate of root respiration.

The most commonly used abiotic variables explaining observed soil respiration patterns are soil temperature and soil moisture (Davidson *et al.* 1998, Howard andHoward 1979, Orchard and Cook 1983, Salonius 1983), as these two abiotic variables exert their influence by having a direct effect on CO_2 evolution and also by indirectly altering other abiotic parameters such as gaseous diffusion. However, the effects of these two variables differ temporally within a particular forest ecosystem and also between different forest ecosystems. Exponential relationships between CO_2 evolution and temperature justify the use of the classical Vant Hoff's equation, $Q_{10}=K_{t+10}/K_t$, where K_t is the reaction rate at a particular temperature. However, the majority of published Q_{10} values show that soil moisture content is not a limiting factor for soil respiration appear more direct than those of soil moisture. Actually, soil moisture content clearly have no effect on the soil respiration rates observed in this study. Under such conditions it is reasonable to hypothesize that the Q_{10} quotient will vary with moisture content. Although there have been some reports on the effects of soil moisture contenton soil respiration (Buchmann *et al.* 1997, 1998, Caryle and U Ba Than 1988, Conant *et al.* 1998, Wildung *et al.* 1975), the results could be concluded that soil respiration rate was constrained by high and low soil moisture. The Q_{10} values computed from this data were 1.63°≠1.66. Monteith *et al.* (1953) obtained a Q_{10}=3 for bare soil. And, Moon (2000) reported that Q_{10} values were 1.31~1.52 for various stand which established after volcanic eruption. Boone *et al.* (1998) reported significantly higher Q_{10} values for root respiration than for soil respiration.

All four black locust followed the same seasonal trend, even though they varied in age and stand structure. However, the rate of soil respiration is not necessarily increase according to stand development, which soil respiration was highest in 28-year old stand and was lowest in 35-year old stand. Buchmann (2000) studied soil respiration rates in four *Picea abies* stands (47-, 87-, 111- and 146-year old stand), and it could be concluded that soil respiration rates were highest in 111-year old stand and were lowest in 146-year old stand. We may, therefore, reasonably conclude that soil respiration rates were not consistent with stand development.

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