トドマツ,アカエゾマツ,シラカンバの苗木の蒸散量と乾物生産量に与える庇陰と土壌水分の影響

誌名	日本林學會誌 = Journal of the Japanese Forestry Society
ISSN	0021485X
著者	高橋, 邦秀
巻/号	57巻3号
掲載ページ	p. 95-99
発行年月	1975年3月

論 文

Effects of Shading and Soil Moisture Conditions on Transpiration and Dry Matter Production in Fir, Spruce, and Birch Seedlings

Kunihide TAKAHASHI*

TAKAHASHI, Kunihide: **Effects of shading and soil moisture conditions on transpiration and dry matter production in fir, spruce, and birch seedlings J. Jap. For. Soc. 57: 95～99, 1975** In each species, total transpiration was linearly correlated with dry matter production in all the treatments. *Abies* in the open and *Betula* in the shade used water most efficiently. In the shade, the difference in transpiration ratio among the soil moisture levels was significant only in *Betula*. *Betula* showed the highest growth rate in the moderate soil moisture level. In *Abies* and *Picea*, transpiration and dry matter increment decreased remarkably in the dry soil moisture level, but differences between the wet and the moderate level were not apparent. In the open, with increasing soil moisture the transpiration ratios in *Abies* and *Betula* increased, while in *Picea* the ratio decreased. However, differences among the three soil moisture levels were not significant. *Abies* and *Betula* showed the highest growth rate in the moderate soil moisture level, while *Picea* grew best in the wet one. The effect of soil moisture on the transpiration ratio was not so remarkable as compared with the shading.

高橋邦秀: **トドマツ，アカエゾマツ，シラカンバの苗木の蒸散量と乾物生産量に与える庇陰と土壌水分の影響 日林誌 57: 95～99, 1975** 3樹種の蒸散量と乾物生産量に与える庇陰の有無と土壌水分（過湿，中庸，乾燥）の影響を調べ，特に蒸散比について検討した。各樹種とも蒸散量と乾物生産量の間に正の直線関係が認められた。トドマツは無庇陰下で，シラカンバは庇陰下で他樹種より蒸散比が小さかった。乾燥区の単位蒸散量は低いが，蒸散比に対する土壌水分の影響は庇陰処理ほど著しくなく，庇陰下のシラカンバを除いて，その影響は明らかでなかった。庇陰下ではシラカンバの生長は中庸区の土壌水分で良く，トドマツとアカエゾマツは過湿区と中庸区の差が明らかでなく，乾燥区で生長が劣った。無庇陰下では土壌水分の増加に伴ってトドマツとシラカンバで蒸散比が大きく，アカエゾマツで小さくなる傾向が見られた。トドマツとシラカンバは中庸区で，アカエゾマツは過湿区で良い生長を示した。

Introduction

The distribution of plant species is often limited by water availability as a site factor. There are many experimental studies of the response of growth in plants to water regime in relation to their water consumption. However, most of these works have dealt only with herbaceous agricultural plants or fruit trees.

In this work differences in water requirement were studied among Todo fir (*Abies sachalinensis* MAST.), spruce (*Picea Glehnii* MAST.) and birch (*Betula platyphylla* SUKATCHEV. *var. japonica* HARA). It is well known that the transpiration ratio varies with environmental conditions, and that such variation is caused by the difference in response between transpiration and dry matter increment. The different response of the two functions may be important as a characteristic of each species.

In the previous papers (TAKAHASHI, 1972, 1973) the effects of three different soil moisture conditions on transpiration, growth, and the transpiration ratio in seedlings of five species were reported. In the present study, the effects of shading and three soil moisture conditions on transpiration, dry matter production, and the transpiration ratio in seedlings of *Abies*, *Picea* and *Betula* were observed during the growing seasons in 1972 and 1973. Additional results from 1971 are included in the discussion of differences among the species.

I would like to thank Mr. Y. SAKAGAMI and Mr. K. DOI for their helpful advice, and Mr. A. MANABE

* Hokkaido Branch, Gov. For. Expt. Sta., Sapporo 農林省林業試験場北海道支場

for his advice about statistical analysis of the data. I am very grateful to Dr. E. F. WICKER, Forstry Science Laboratory in Moscow, Idaho, U.S.A., for reading the manuscript.

Materials and Methods

The experiments were conducted in a green house, during the growing seasons in 1972 and 1973, in the same manner as those in 1971. Experimental conditions and number of samples are shown in Table 1. The three levels in soil moisture were wet (W) maintained at 85~75% on dry weight basis, moderate (M) at 60~50% and dry (D) at 35~25%. The moisture equivalent (pF 2.7) of the soil used was 40.1% on a dry weight basis. In the shaded condition, cheesecloth was used for reducing light intensity to three-fourths in the open. Transpiration was measured by the pot weighing method. Temperature and relative humidity in the air were measured by an seven-day hygrothermograph.

Results

There was a total of six treatments in growing conditions; two levels of light intensity, open and shade, and three levels of soil moisture, wet, moderate and dry. Only one level of light intensity was studied in 1971 and 1972 as shown in Table 1. Tests of significance between 1971 and 1973 in the shade or 1972 and 1973 in the open were necessary before the statistical analysis of the effects of treatment was made. The relation between the dry matter production and the total transpiration was linear and the regressions were compared between the years in each level in light intensity. There was no significant difference in the regressions in *Abies* and *Betula* grown in both light intensities and in *Picea* in the shade, but a significant difference occurred with *Picea* in the open. The analysis of co-variance shows that the relations between transpiration and dry matter production were affected by six treatments.

The effects of shading The transpiration ratios in Table 2 show that *Abies* and *Picea* in the open used water more efficiently than those in the shade. However, *Betula* in the shade used water more efficiently. As seen in Table 2, the decrease in dry matter increment in *Abies* was remarkable with the shading, while in *Betula*, transpiration showed the greater decrease. The effect of the shading on *Picea* was not apparent. Figures 1, 2 and 3, and the analysis of co-variance show that the effect of the shading was reflected in the transpiration ratio for *Abies* and *Picea*, but in total transpiration for *Betula*.

The values of top-root ratio in each species were lower in the open than in the shade, especially in *Betula*. The growth rate in the open was higher in *Abies* and lower in *Betula* than in the shade. In the shade, *Betula* used water most efficiently among the three species and showed the highest dry matter production, transpiration and growth rate, and the lowest top-root ratio. In the open, *Abies* used water most efficiently.

The effects of soil moisture In the shade the response of each species to soil moisture was similar to that reported in the previous paper (Table 3). The transpiration per gram of oven dry weight of leaf increased with increasing soil moisture, but the difference between the wet and the moderate level was smaller than between the moderate and the dry level. The top-root ratio of *Abies* or *Betula* was lowest in the dry level, but for *Picea* it was lowest in the wet level. The decline in growth rate of

Table 1. Outline of experiment

Species	Year[1]	Light condition[2]	Saturation deficit[3]	Number of samples W	M	D[4]	Seedling age
Abies sachalinensis	'71	S	997.55	5	5	5	2-2
	'72	O	1403.17	6	7	6	2-2
	'73	S	1609.67	4	4	4	2-2
		O	1743.91	3	4	4	
Picea Glehnii	'71	S	997.55	5	6	6	2-2
	'72	O	1403.17	5	6	5	2-3
	'73	S	1609.67	4	4	2	2-2
		O	1743.91	3	4	2	
Betula platyphylla	'71	S	997.55	4	6	6	1
	'72	O	1317.83	6	8	6	1
	'73	S	1501.04	4	4	3	1
		O	1621.10	4	4	4	

1) Experimental period; May 29-Sep. 15 in 1971, June 1-Sep. 28 (June 1-Sep. 3 only in *Betula*) in 1972, May 15-Sep. 29 (May 15-Sep. 17 only in *Betula*) in 1973.
2) Levels in light intensity; open O, shade S.
3) Total summed up the daily maximum saturation deficit during the experimental period.
4) Levels in soil moisture; wet W, moderate M, dry D.

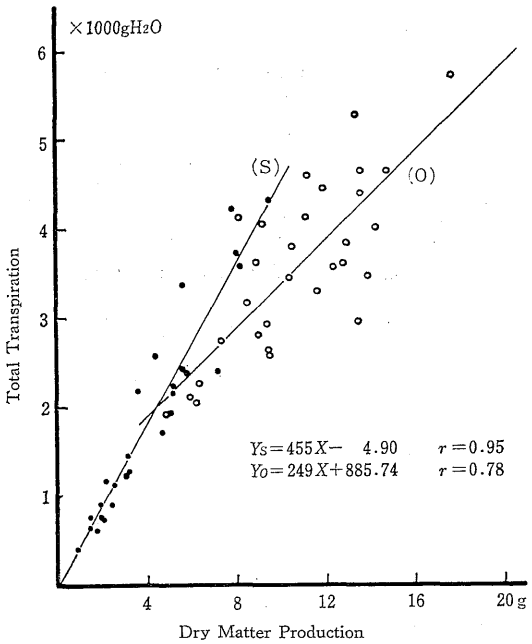

Fig. 1. Total transpiration in relation to dry matter production in each seedling of *Abies* in the open (O) or in the shade (S)

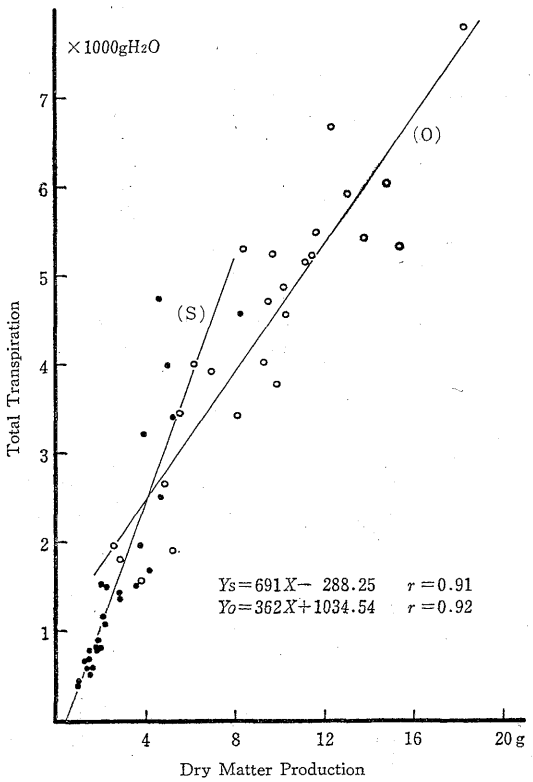

Fig. 2. Total transpiration in relation to dry matter production in each seedling of *Picea* in the open (O) or in the shade (S)

Abies and *Picea* in the dry level was remarkable as compared with *Betula*, but there was no significant difference in the transpiration ratio among the three soil moisture levels in the shade. This may be caused partly by a large variation in the transpiration ratio between the two years. The total transpiration per seedling of *Betula* was significantly affected by soil moisture. *Betula* used water most efficiently among the three species in each of the three soil moisture levels, especially in the dry one. In contrast with *Betula*, *Picea* used water least efficiently.

In the open, the transpiration ratio of *Abies* and *Betula* increased and that of *Picea* decreased with increasing soil moisture (Table 4), but the differences among the levels were not significant. Among the three species, *Abies* used water efficiently in each of the three soil moisture levels, especially in the

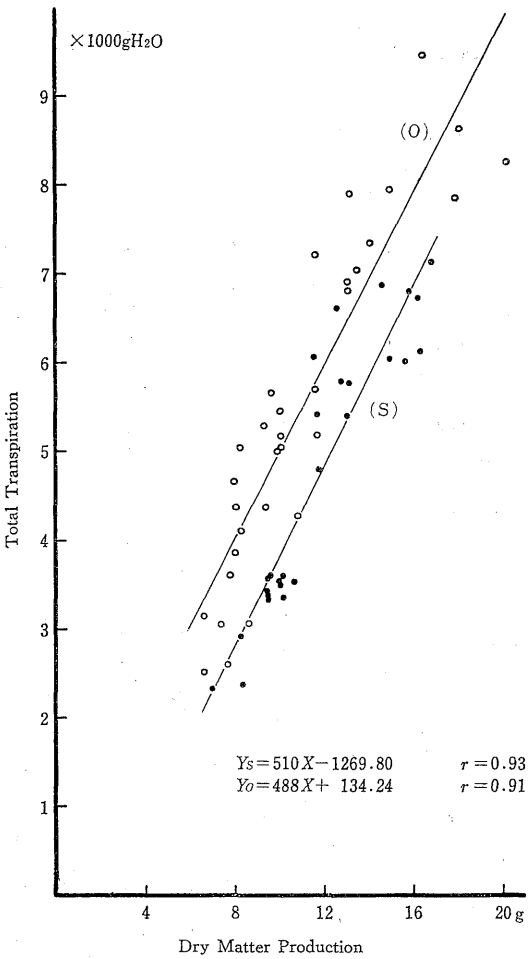

Fig. 3. Total transpiration in relation to dry matter production in each seedling of *Betula* in the open (O) or in the shade (S)

Table 2. Effect of light conditions

Species	Light condition	Transpiration ratio[1]	T-R ratio	Growth rate[2]	Leaf amount[3]
Abies	S	453 (450/1.01)	1.98	0.53	4.25
	O	339 (510/1.55)	1.91	0.89	7.10
Picea	S	543 (391/0.75)	2.78	0.41	4.16
	O	499 (381/0.80)	2.46	0.37	11.75
Betula	S	395 (1,350/3.43)	1.72	7.74	3.48
	O	498 (1,904/3.80)	1.11	7.08	2.90

1) Transpiration in g H_2O per g oven dry weight leaf/Increment g in oven dry weight per g oven dry weight leaf during the experimental period in parenthesis
2) Increment during the experimental period in fresh weight/Fresh weight of a seedling at the beginning of experiment
3) Oven dry weight g per seedling

Table 3. Effect of soil moisture conditions in the shade

Species	Soil moisture	Transpiration ratio	T-R ratio	Growth rate	Leaf amount
Abies	W	483 (501/1.07)	2.16	0.60	4.30
	M	426 (498/1.17)	2.00	0.62	4.44
	D	451 (352/0.80)	1.79	0.36	4.11
Picea	W	535 (456/0.88)	2.60	0.49	4.39
	M	582 (446/0.83)	2.70	0.44	4.47
	D	505 (248/0.52)	3.09	0.21	3.52
Betula	W	422 (1,424/3.40)	1.70	7.12	3.18
	M	421 (1,416/3.36)	1.83	9.47	4.47
	D	343 (1,211/3.53)	1.60	6.36	2.66

Table 4. Effect of soil moisture conditions in the open

Species	Soil moisture	Transpiration ratio	T-R ratio	Growth rate	Leaf amount
Abies	W	362 (490/1.37)	2.10	0.75	7.60
	M	346 (603/1.78)	1.91	1.14	7.01
	D	309 (427/1.47)	1.74	0.74	6.76
Picea	W	442 (413/0.95)	2.49	0.48	11.84
	M	506 (417/0.84)	2.52	0.40	12.26
	D	556 (292/0.56)	2.33	0.20	10.92
Betula	W	555 (2,294/4.14)	1.13	7.07	2.71
	M	511 (2,033/3.99)	1.09	8.27	3.27
	D	427 (1,360/3.24)	1.10	5.64	2.64

Table 5. Difference between years

Species	Light condition	Year	Transpiration ratio	T-R ratio	Growth rate	Leaf amount
Abies	S	'71	438 (463/1.07)	2.03	0.63	2.27
		'73	473 (434/0.95)	1.92	0.40	6.80
	O	'72	306 (543/1.79)	1.93	1.00	7.06
		'73	395 (454/1.14)	1.88	0.69	7.17
Picea	S	'71	459 (396/0.85)	2.91	0.49	2.20
		'73	687 (382/0.59)	2.57	0.26	7.50
	O	'72	461 (368/0.82)	2.43	0.38	13.80
		'73	568 (403/0.75)	2.51	0.35	8.10
Betula	S	'71	377 (1,308/3.48)	1.72	7.00	3.34
		'73	422 (1,411/3.35)	1.70	8.81	3.69
	O	'72	511 (1,847/3.56)	1.12	4.68	2.70
		'73	477 (1,999/4.21)	1.08	11.07	3.22

dry one. *Picea* used water most inefficiently in the dry level and *Betula* in the wet one. The total transpiration per seedling of *Abies* and *Betula* in the open was significantly affected by soil moisture. The total transpiration of *Betula* increased with increasing soil moisture and that of *Abies* was the highest in the moderate soil moisture level. In the shade the difference in transpiration per gram of oven dry weight of leaf among the three soil moisture levels was large in *Betula*, but not in *Abies* and *Picea*. In the dry soil moisture level, growth in the open was better than in the shade in *Abies*, while in *Betula* an inverse relation was shown. Growth in *Picea* was poor in dry soil moisture level both in the open and in the shade. The growth rate in *Abies* and *Betula* was highest in the moderate soil moisture level, but in *Picea* the growth rate was highest in the wet one, both in the open and in the shade.

The difference in the transpiration ratio between the years was not significant except for *Picea* in the open. The significant difference between the years was seen in total transpiration per seedling of *Abies* in the shade and of *Picea* and *Betula* in the open (Table 5).

Discussion

The results of this work show that the transpiration ratios of the three species vary with changing environments. HIRATA and ZINBO (1930, 1931, 1932, 1933) reported that the transpiration ratios were 385～692 in *Cryptomeria japonica*, 301～551 in *Chamaecyparis obtusa*, 703～1598 in *Pinus densiflora*, and 630～996 in *Zelkova serrata*. SHIBAMOTO (1952) observed transpiration ratios of 388～433 in *Cryptomeria* and 361～453 in *Chamaecyparis*. KÔYAMA (1942) reported that the transpiration ratios by the bundle-planted seedlings were 194 in *Pinus densiflora* and 221 in *Zelkova serrata*. These workers studied the effect of only one factor on the transpiration ratios.

The transpiration ratios of the three species studied here are similar to those reported for other tree species, especially of *Cryptomeria* and *Chamaecyparis*. *Abies* in the open and *Betula* in the shade used water efficiently. On the whole, *Abies* had a lower transpiration ratio and *Picea* had a higher one. The top-root ratios differed among the three species. In *Picea*, the root portion was smaller, while in *Betula* it was larger. In *Abies* the dry matter increment was affected more by the shading than the transpiration, while in *Betula* the reverse took place. The transpiration ratio was less affected by the level of soil moisture than the shading, but the transpiration per gram of oven dry weight leaf in each species was reduced in the dry soil moisture condition. Reduction of the growth in the wet soil moisture condition as reported by STAINHILL (1957) was not observed in this experiment. As reported by JARVIS and JARVIS (1963), such reduction was connected with compact sandy and clayey soils, but not with humus-rich soils.

Literature cited

HIRATA, T. & ZINBO, T.: Jumoku no Tsuhatsusuiryo Sokuteishikenseiseki (In Japanese). Shinrin-Chisui-Kisho Iho **10**: 1～46, 1930. **11**: 30～70, 1931. **12**: 1～40, 1932. **13**: 1～50, 1933

JARVIS, P. G. & JARVIS, M. S.: The water relation of tree seedlings (I) Growth and water use in relation to soil water potential. Physiol. Plant. **16**: 215～235, 1963

KÔYAMA, N.: Über die Transpiration der jüngen Bäumchen der Hauptholzarten der Vegetationsperiode (In Japanese with German Summary). J. Jap. For. Soc. **24**: 1～19, 1942

SHIBAMOTO, T.: Sugi, Hinoki, Akamatsu no Eiyo narabini Shinrindojyo no Hiyokudo ni kansuru Kenkyu (In Japanese). 252pp, Rinyacho, Tokyo, 1952

STAINHILL, G.: The effect of differences in soil water status on plant growth: A review and analysis of soil moisture regime experiments. Soil Sci. **84**: 205～214, 1957

TAKAHASHI, K.: Difference among species with respect to the transpiration ratio in different soil moisture conditions. J. Jap. For. Soc. **54**: 373～378, 1972

———: Effects of soil moisture and light intensity on growth and water consumption of birch seedlings. Transact. 84th annual meeting. Jap. For. Soc. (In Japanese). 166～167, 1973

(Received 11 July 1974)