Effect of root trimming and drought on CO_2 gas-exchange and transpiration in *Abies sachalinensis* MAST. and *Picea glehnii* MAST. seedlings*

By

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トドマツ，アカエゾマツ苗木の CO_2 ガス交換と蒸散に与える根切りと乾燥の影響*

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Introduction

Planting stocks are subjected to a rapid change in environmental conditions when they are planted out in the field. By planting out, the seedlings are exposed to much severe conditions as compared with nursery. In addition, during transportation and planting many types of physiological stress may develop. Roots are cut off when the seedling is taken up from the nursery bed. The root tips are damaged to a great extent during transportation, and also roots dry out during transplanting. The fine rootlets often fail to make good contact with the soil particles after planting. These planting shocks produce a water deficit in the seedling after planting. The water deficit will not cease untill new root tips have grown (TRANQUILLINI 1973). Severe planting shock may cause the decrease in the resistance to disease, and result in serious complications later on.

The effects of planting shock on seedling development have been studied mainly through field experiments. Mortality, the decrease in growth, and physiological aspects under severe water stress have also been studied in many tree species. The effect of severe drought on the elongation and the dry weight increment of seedlings was observed over two years after transplanting (TAKAHASHI 1983). The development of long-term water deficits in plants progressively reducing supply of available soil water was typically analyzed by SLATYER (1967). But the long-term effect of planting shock over several months on the physiological aspects has been scarcely studied. The aim of this paper is to study the long-term effects caused by root trimming and drought on transpiration and CO_2 gas-exchange in the seedlings of Todo-fir (*Abies sachalinensis* MAST.) and Akaezo-spruce (*Picea glehnii* MAST.).

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Materials and Methods

Sixty-five five-year-old seedlings of both *Abies sachalinensis* MAST. and *Picea glehnii* MAST. were lifted the nursery almost every month from May 7 to September 27, 1981. Root trimming and root drought treatments were carried out immediately after the seedlings were lifted. Thirty seedlings were root-trimmed using secateurs to a half of their root length and were transplanted into porous clay pots. These potted sedlings were embedded in a nursery bed. Another thirty seedlings were dehydrated under the conditions of 20°C of air temperature, around 50% of air humidity, and 45 Klux (635 $\mu E/m^2 \cdot sec$) for 15 hours in an artificial light cabinet, and xylem water potential (Ψ) before transplanting decreased by around -2.0 MPa in *Abies* and around -2.8 MPa in *Picea*. These dehydrated seedlings were also transplanted into pots and embedded in a nursery bed. As these low values of Ψ induced by the drying treatment were assumed to be a lethal stress for new current shoots in *Picea* from the previous paper (TAKAHASHI 1981), the seedlings lifted on June 25 were dehydrated without artificial lights. The other five potted seedlings served as a control group.

Apparent photosynthetic rate (P), dark respiratory rate (R), light and dark transpiratory rate (T, Tr), and xylem pressure potential (Ψ) were measured at intervals of about a month except during snowy season. These measurements started on May 7, 1981, and ended on August 4, 1982. The measurement of the control late in November was omitted, because the differences between the treatments and the control were presumed to be small.

Five potted seedlings per a treatment were used for each measurement. Current- and one-year-old whorls and also the leading shoot were used for the measurements in P, R, T, and Tr under the condition of 20°C and 30°C (after July, 1981) in the assimilation bags and 25 Klux (355 $\mu E/m^2 \cdot sec$) above the seedlings. The measurements of P, R, T and Tr were carried out using an infrared gas analyzer (Shimazu URA 106) and hygrometer (Vaisala HMP14U, HMI14). Air was forced into assimilation bags and the excessive air was overflowed from the bottom of the bags. The rates of air supply were regulated at 5 l/min, which was enough to keep the turgidity of an assimilation bag, and about 1 l/min was used for the measurement of P, R, T and Tr. The humidity of the air supplied into an assimilation bag was controlled at about 20% by cooling air in order to protect the inside of the bag from getting wet with dew caused by transpiration. Ψ of seedlings was measured with one of one-year-old whorls by using a pressure chamber immediately after the above-mentioned measurements. The state of root regeneration was observed after removing soil by water. Seedlings were dried at 70°C using a desiccator after these measurements and the dry weight of seedlings was measured. This investigation was carried out at the Hokkaido Branch of For. and For. Prod. Res. Inst.

Results

1. Root Trimming

Abies sachalinensis: Fig. 1 and 2 indicated that minimum value of Ψ was -1.26 MPa on May 7 soon after root trimming. Compared with the control, the decrease in Ψ was slightly large soon after roots were trimmed in May and June, but root trimming after 1 August did not induced a decline in Ψ even soon after the treatments. The root-trimmed seedlings developed new white roots in a month and they showed almost no difference from the controls within two months except the seedlings treated late in September. The seedlings with root trimmed in September needed more than two months for the development of new white roots.

Seasonal changes in P and R of the control seedlings followed similar patterns shown by SAKAGAMI & FUJIMURA (1981) and TAKAHASHI (1982). Maximum values of P in root-trimmed seedlings varied between 5.88 mgCO_2 in average in the treatment on August 1, and 3.58 mgCO_2 in the treatment on September 25. Maximum

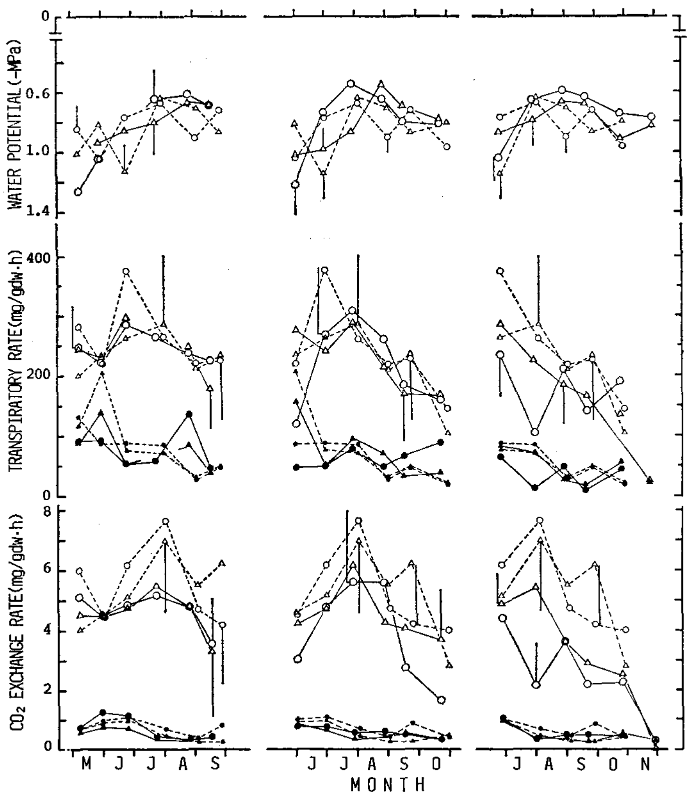

Fig. 1. Seasonal changes of CO_2 exchange rate, transpiratory rate and xylem water potential at 20°C in the seedlings of *Abies* (circles) and *Picea* (triangles) root-trimming in May and June. Open circles and triangles show apparent photosynthetic rate and light transpiratory rates. Solid ones show dark respiratory rates and transpiratory rates. Broken line is the control. Vertical lines are the maximum standard deviations.

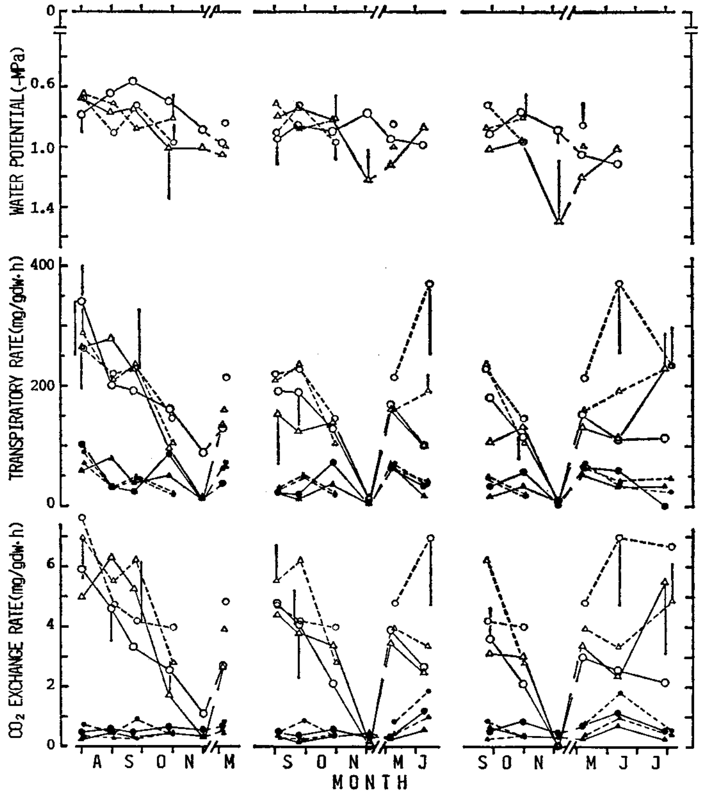

Fig. 2. Seasonal changes of CO_2 exchange rate, transpiratory rate and xylem water potential at 20°C in the seedlings of *Abies* and *Picea* root-trimming in August and September. Symbols are the same as shown in fig. 1.

Table 1. Seasonal changes in relative values of photosynthesis (P) and transpiration (T) in the root-trimmed seedlings of *Abies*

I \ II		7 May	28~31 May	22~28 Jun.	24 Jun. -1 Aug.	24 Aug. -2 Sep.	14~25 Sep.	21~29 Oct.	3~7 May	8~10 Jun.	26 Jul.
7 May	P	85	105	79	67	103	85				
	T	88	101	76	100	108	100				
31 May	P		65	76	73	118	66	45			
	T		86	71	118	120	81	111			
25 Jun.	P			71	28	77	52	56			
	T			62	40	97	63	130			
1 Aug.	T				77	98	80	65	56		
	P				130	92	84	110	61		
2 Sep.	P					101	98	52	80	38	
	T					88	83	87	79	28	
25 Sep.	P						86	53	62	37	32
	T						79	79	72	30	49

I : Time of treatment.
II : Period of measurement.
Figures show the percentages against the control in the same time.

values of T were between also 340 mgH_2O and 180 mgH_2O respectively in the same month as maximum P. The seedlings root-trimmed on June 25 were markedly affected by root trimming (Table 1). In spite of high Ψ of 0.65 MPa, the decrease in P and T of the seedlings root-trimmed in June was noted with under 2 $mgCO_2$ and 105 mgH_2O, about 30% and 40% of the controls respectively, in a month after the treatment. Root trimming on September 2 and 25 depressed P to about 30% of the control even after June of the following year, although Ψ was high around 1.0 MPa.

There was almost no difference in R between the root-trimmed seedlings and the controls. Root trimming did not cause an increase in R from May to June observed in the control, and R in October seemed to increase with delaying the time of root trimming. The values of Tr in each treatment varied more than those in the controls, and seasonal changes in Tr did not always follow the patterns of R. The depression in P and T at 30°C was similar to the patterns shown at 20°C, but the seedlings root-trimmed in September decreased P and T at 30°C more than at 20°C after June of the following year (Fig. 3). The ratios of R or Tr against the control at 30°C rather lower than those at 20°C.

P/T ratios varied between 2.66 $mgCO_2$/100 mgH_2O and 1.03 $mgCO_2$/100 mgH_2O in average (Fig. 4). Top/root ratios were between 3.02 and 1.66 (Fig. 5). Seasonal changes of top/root ratio in all treatments were not so different from those of the control. The seedlings with their root trimmed in September showed slightly higher top/root ratio than the controls because of their poor root development.

Picea glehnii: The values of Ψ in the seedlings root-trimmed between May 8 and August 2 were always over −1.1 MPa in average during this experiment period (Fig. 1, 2). Root trimming on September 3 and on September 26 caused a decline

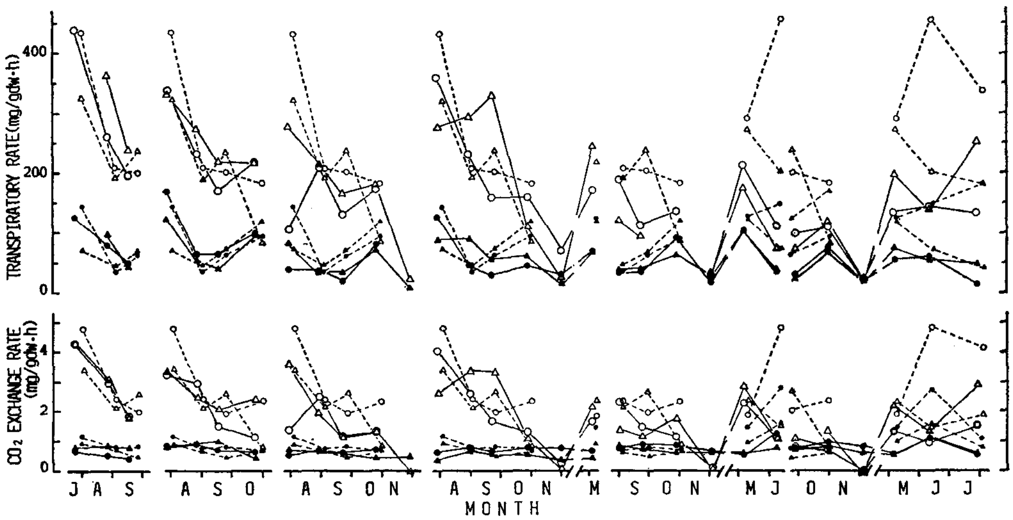

Fig. 3. Seasonal changes of CO_2 exchange rate and transpiratory rate at 30°C in the seedlings of *Abies* and *Picea* root-trimming from May (left) to September (right). Symbols are the same as shown in fig. 1.

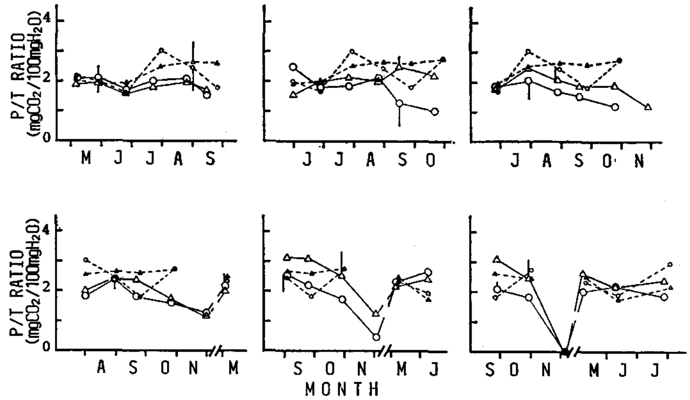

Fig. 4. Seasonal changes of P/T ratio at 20°C in the seedlings of *Abies* and *Picea* root-trimming from May to September. Symbols are the same as shown in fig. 1.

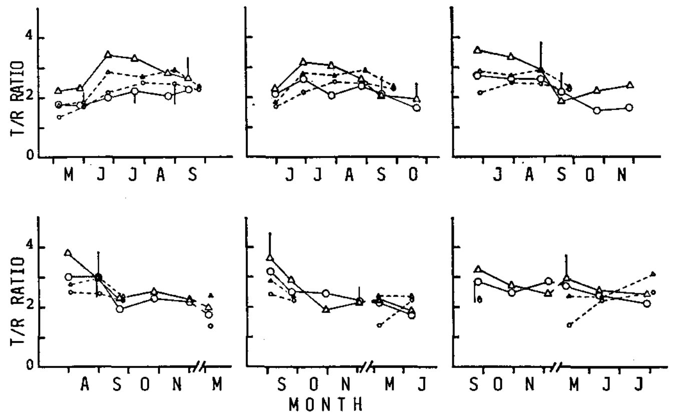

Fig. 5. Seasonal changes of T/R ratio in the seedlings of *Abies* and *Picea* root-trimming from May to September. Symbols are the same as shown in fig. 1.

in Ψ to -1.22 MPa and -1.5 MPa in November respectively, but these low Ψ recovered and reached to over -1.0 MPa in June of the following year. Root-trimmed seedlings developed some new white roots in a month after root trimming and the root system was recovered within two months. However, the seedlings root-trimmed on September 26 did not show the recovery of their root systems until May of the following year.

Seasonal changes in P and T of the control had two peaks and the maximum value of P was 6.97 $mgCO_2$ in July and the maximum T was 288 mgH_2O at the same time. In contrast, the root-trimmed seedlings showed only one peak between 6.31 $mgCO_2$ and 4.39 $mgCO_2$ in all treatments and did not show the second peak observed in the control of September in spite of their high water potential. The maximum values of T were between 298 mgH_2O and 164 mgH_2O. The seedlings root-trimmed early in September showed a decline in T for a month at least after

Table 2. Seasonal changes in relative values of photosynthesis (P) and transpiration (T) in the root-trimmed seedlings of *Picea*

I \ II		8 May	29 May ~1 Jun.	23~28 Jun.	24 Jun. ~2 Aug.	25 Aug. ~3 Sep.	15~26 Sep.	23~30 Oct.	4~8 May	9~11 Jun.	28 Jul.
8 May	P	114	99	93	79	87	54				
	T	121	98	113		117	75				
1 Jun.	P		93	92	89	77	66	133			
	T		116	91	101	102	72	162			
27 Jun.	P			95	77	65	47	91			
	T			109	78	87	70	129			
2 Aug.	P				72	115	85	63	67		
	T				91	131	96	91	83		
3 Sep.	P					80	61	122	88	74	
	T					72	53	136	102	53	
26 Sep.	P						50	108	86	71	114
	T						45	128	82	58	98

I : Time of treatment.
II : Period of measurement.
Figurs show the percentage against the control in the same time.

the root trimming, but their Ψ was higher than others. The depression of P observed in *Abies* did not occur in *Picea* late in July of the following year. The extent of depression in P and T by root trimming of *Picea* seedlings was not so greater than that of *Abies* seedlings (Table 2). The values of P at 30°C in the root-trimmed seedlings varied between 4.26 mgCO_2 and 0.78 mgCO_2 (Fig. 3). The seasonal courses in P, T, R, and Tr at 30°C were almost no different from the patterns at 20°C.

P/T ratios varied between 3.12 mgCO_2/100 mgH_2O and 1.15 mgCO_2/100 mgH_2O except those in November (Fig. 4). P/T ratio showed around 2 mgCO_2/100 mgH_2O almost during the measurement period except late in November or early in December when P decreased by almost 0. P/T ratios over 2 were caused by decreasing in T relatively compared with P. The seedlings root-trimmed early in May and in September showed the narrow range in P/T ratios compared with the other treatments. Top/root ratios were between 3.77 and 1.84 (Fig. 5). Both P/T ratios and top/root ratios in *Picea* showed rather large values compared with those in *Abies*.

2. Dehydration treatment

Abies sachalinensis: Immediately after dehydration treatment, Ψ from May 10 to August 1 was rather low compared with Ψ on September 3 and on September 26 (Fig. 6, 7). But the seedlings dried in May to August recovered Ψ to around -1.0 MPa in one or two months. Some mortalities occurred by the end of experiment, two seedlings in the treatment on June 2 and three in the treatment on August 2. The seedlings dried on June 26 maintained Ψ at a level over -0.9 MPa during experiment period. New white roots began growing in a month after the treatment in all treatments, but the complete recovery of the root system needed two months or more.

Maximum P at 20°C in each treatment varied between 6.92 mgCO_2 in the treatment on May 10 and 2.88 $mgCO_2$ in the treatment on September 26, and maximum T was between 410 mgH_2O and 158 mgH_2O respectively in the same treatments. The declines of P soom after dehydration also became large compared with root trimming, and the dired seedlings could not recover P in the same level as the control during experiment period, even in the treatment less stressed on June 26 (Table 3). The seedlings dried on September 3 and 26 decreased P to 30% of the control after June of the following year, because bud bursting was behind the time and Ψ remained slightly low. Even the seedlings given less water stress in June kept P in a rather low range from 80% of the control in June to 23% late in October. The decrease in R was not so much as that of P and the changes of R followed similar patterns shown by the controls. The low rates of Tr were maintained for one or two months after dehydration treatment.

Seasonal changes in P and T at 30°C followed similar patterns shown at 20°C, the values of P and T at 30°C were down to 40% of the control soon after the treatment, and the low rates of P and T in the treatment after August 1 continued until the end of the experiment (Fig. 8). The seedlings dried after August 1 showed low values of P from about 50% of the control to about 30% in June and July

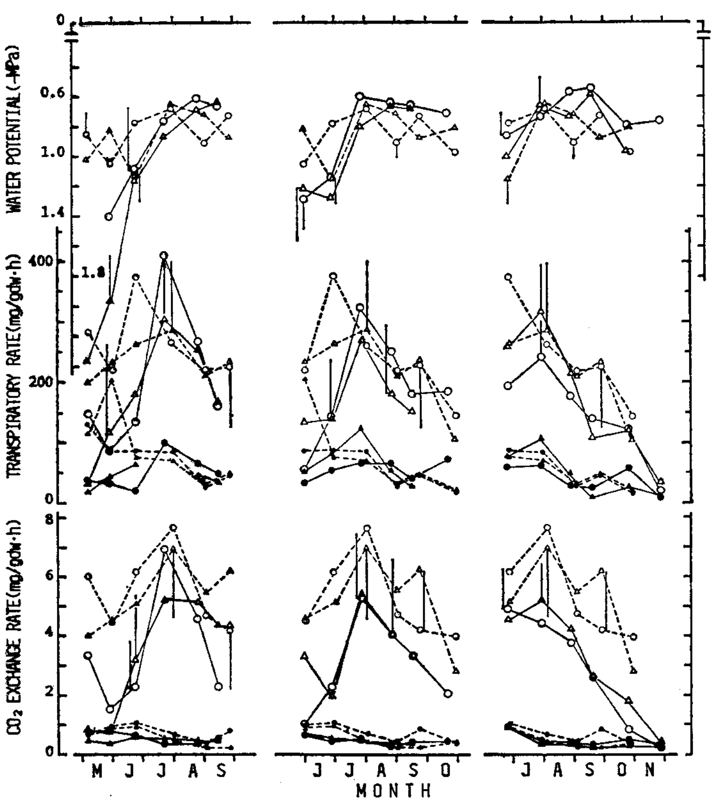

Fig. 6. Seasonal changes of CO_2 exchanges rate, transpiratory rate and xylem water potential at 20°C in the seedlings of *Abies* and *Picea* dehydrating in May and June. Symbols are the same as shown in fig. 1.

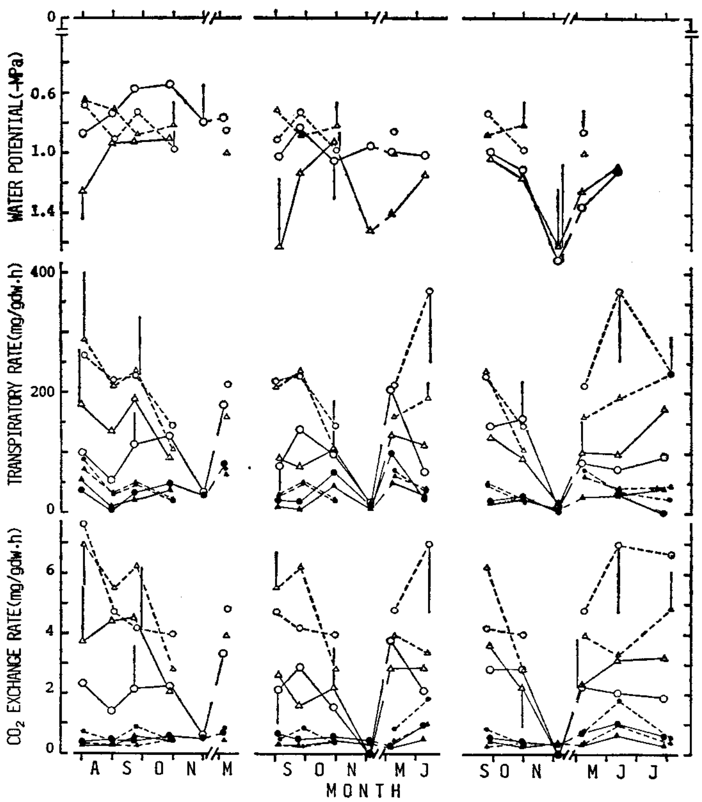

Fig. 7. Seasonal changes of CO_2 exchange rate, transpiratory rate and xylem water potential at 20°C in the seedlings of *Abies* and *Picea* dehydrating in August and September. Symbols are the same as shown in fig. 1.

Table 3. Seasonal changes in relative values of photosynthesis (P) and transpiration (T) in the dehydrated seedlings of *Abies*

I \ II		10 May	29 May ~2 Jun.	23~29 Jun.	25 Jun. ~1 Aug.	25 Aug. ~3 Sep.	15~26 Sep.	20~30 Oct.	3~7 May	8~10 Jun.	27 Jul.
10 May	P	55	33	37	91	97	55				
	T	52	39	37	157	122	70				
2 Jun.	P		23	37	69	86	80	51			
	T		25	38	123	115	80	126			
26 Jun.	P			80	58	79	62	22			
	T			51	92	81	62	83			
1 Aug.	P				30	30	51	57	69		
	T				38	24	50	87	84		
3 Sep.	P					45	69	38	79	30	
	T					35	61	67	96	18	
26 Sep.	P						69	73	47	29	29
	T						65	109	39	20	41

I : Time of treatment.
II : Period of measurement.
Figures show the percentages against the control in the same time.

of the following year.

P/T ratio in each treatment was nearly within the same range as that in the the root-trimmed seedlings (Fig. 9). Top/root ratio of the seedlings dried their roots was on a whole lower than that of root trimmed seedlings, because dehydration treatment did not change amounts of roots (Fig. 10).

Picea glehnii: Immediately after dehydration, the values of Ψ decreased to around -2.4 MPa for the treatment at May 11 and $-1.2\sim-1.6$ MPa for the treatment at June 2 to September 4. However, the xylem water potential were maintained at around -1.0 MPa on June 27, because of the less stressed treatment (Fig. 6, 7). The recovery of Ψ up to around -1.0 MPa needed three months in the seedlings

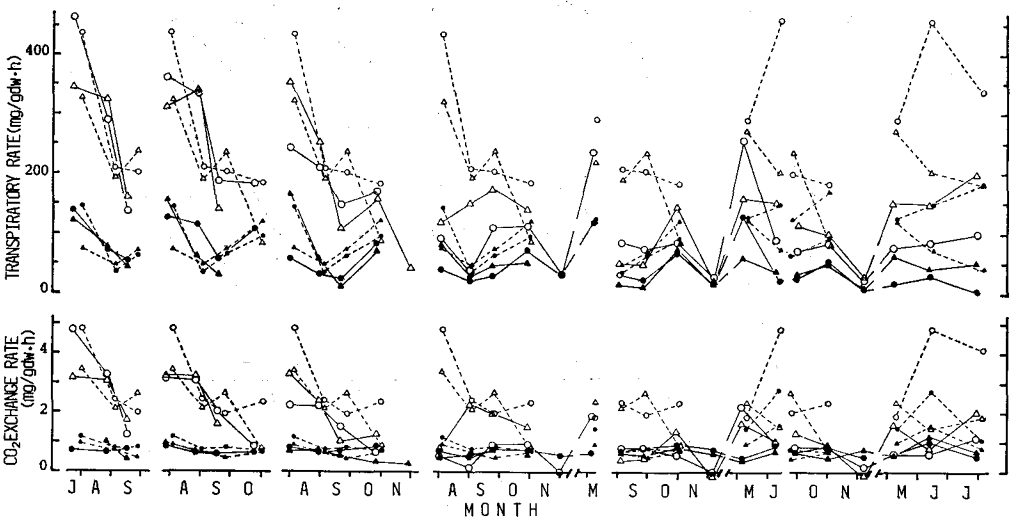

Fig. 8. Seasonal changes of CO_2 exchange rate and transpiratory rate at 30°C in the seedlings of *Abies* and *Picea* dehydrating from May (left) to September (right). Symbols are the same as shown in fig. 1.

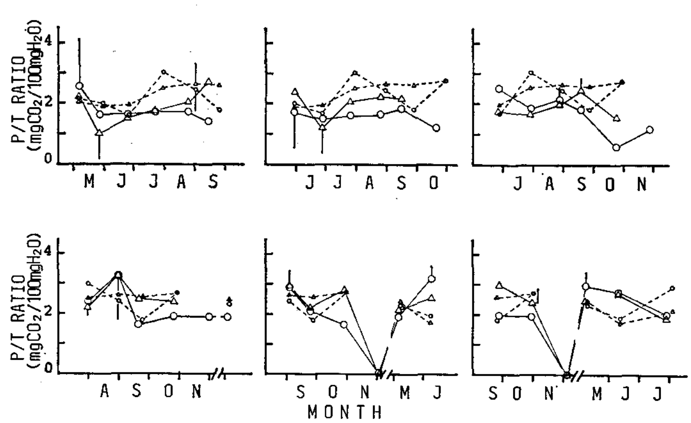

Fig. 9. Seasonal changes of P/T ratio at 20°C in the seedlings of *Abies* and *Picea* dehydrating from May to September. Symbols are the same as shown in fig. 1.

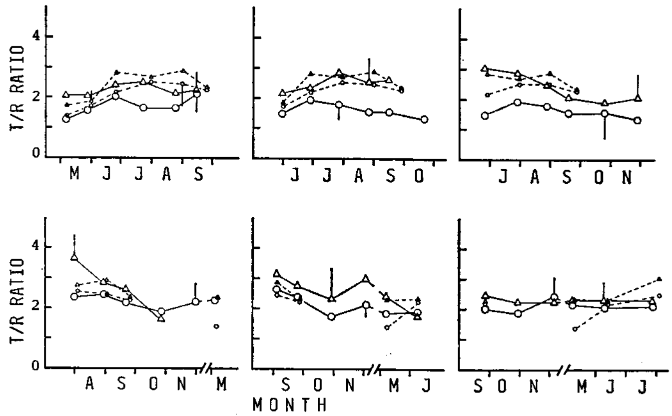

Fig. 10. Seasonal changes of T/R ratio in the seedlings of *Abies* and *Picea* dehydrating from May to September. Symbols are the same as shown in fig. 1.

Table 4. Seasonal changes in relative values of photosynthesis (P) and transpiration (T) in the dehydrated seedlings of *Picea*

I \ II		11 May	30 May ~2 Jun.	24~29 Jun.	25 Jun. ~2 Aug.	26 Aug. ~4 Sep.	16~27 Sep.	25~31 Oct.	6~8 May	9~11 Jun.	29 Jul.
11 May	P	20	16	61	75	93	70				
	T	16	50	69	106	119	71				
2 Jun.	P		72	37	78	73	53				
	T		56	53	94	86	64				
27 Jun.	P			88	75	77	43	65			
	T			98	110	102	46	117			
2 Aug.	P				54	80	74	76			
	T				62	63	79	84			
4 Sep.	P					48	29	78	73	86	
	T					44	33	104	82	60	
27 Sep.	P						43	80	60	94	66
	T						58	84	62	50	74

I : Time of treatment.
II : Period of measurement.
Figures show the percentages against the control in the same time.

dried eary in May and one or two months in the other treatment times. New white roots began growing in a month after dehydration in all treatment, but the number of new roots was less than a half of those in root-trimmed seedlings. Suberized roots in all treatments developed about a month behind the root-trimmed seedlings. Many mortalities were attributable to the dehydration treatments, as fifteen seedlings were counted on August 2, eight on June 2, two on September 4, and one on both June 27 and September 27.

Maximum values of P at 20°C in each treatment varied between 5.45 mgCO_2 in the treatment on June 1 and 2.87 mgCO_2 in the treatment on September 4. The decrease in P soon after the treatment was down to 20% of the control in early

May (Table 4). The low values of P in a month after the treatment were observed in the seedlings dried before early in June and also early in September, because water potentials continued to be low in those periods. Seasonal changes of T in all treatments almost followed the pattern of P. The dried seedlings showed similar ranges of both R and Tr shown by the root-trimmed seedlings.

The seedlings dried after August 2 showed rather low values in P and T at 30°C compared with the root-rimmed seedlings (Fig. 8). Seasonal changes of R and Tr at 30°C followed similar patterns shown by the root-trimmed seedlings.

P/T ratios in a month after the treatment showed low values compared with the controls (Fig. 9). The low P/T ratios were caused by the large decline of P. The low top/root ratios were caused by the less increment of top weight compared with the increment of root weight (Fig. 10).

3. Discussion

Effect of root trimming on P and T appeared most clearly in *Abies* seedlings root-trimmed on June 25, September 2, and September 25. The seedlings with roots trimmed late in June showed great declines in P and T in a month after the treatment. This depression of P and T was not caused directly by water stress because of the high Ψ. On the other hand, the depression of P and T in the seedlings root-trimmed in August and September seemed to be caused by the long-term water stress of around -1.0 MPa in June and July of the following year.

Stomatal opening and closing involve a complex series of processes that are not fully understood (RASCHKE 1975, KRAMER 1983). Several investigators have shown that there is an increase in ABA in the leaves of water-stressed plants, and it has also been shown that application of exogenous ABA to leaves cause stomatal closure in the absence of water stress (HIRON & WRIGHT 1973, DAVIES 1978, WEILER et al. 1982). As the *Abies* seedlings root-trimmed late in June were not water-stressed so much, they may be affected by decrease in a growth regulator, such as cytokinins, supplied from the roots (LIVINE & VAADIA 1972). But there is a question about the role of cytokinins (ASPINALL 1980). *Abies* may be more affected by the unusual synthesis of growth regulators caused by root trimming compared with *Picea*, because of the difference in their root system that the former has a tap root system and the latter has a shallow root system.

The sudden decline in P and T at September were also noted with the seedlings of two species in both root trimming and dehydration treatments. These sudden reduction of photosynthesis on fall seemed to be caused by rapid stomatal control with the maturation of leaf. However, the photosynthetic mechanism in fall seemed to be depressed by the after-effect of root trimming or drought, because the extent of decline in P was larger than that in T at September in both species of each treatment (Table 1～4).

Fig. 1 and 2 showed that the effect of root trimming on *Abies* seedlings did not diminish in five months at least and particularly in the seedlings root-trimmed in late September, the effect of root trimming remained for ten months after treatment. The effect on *Picea* seemed to diminish earlier about a month than that of *Abies*.

Transpiration rates and stomatal resistance of spring-lifted (on March 5) white spruce seedlings were not affected by root pruning in the 6 week period after planting and root prunning did not greatly alter the response to drought (BLAKE 1983). This showed that if root trimming was carried out earlier than May, the effect of root trimming on stomatal aperture would diminish faster.

The mortality counts of seedlings caused by drought indicated that *Abies* was more tolerant than *Picea* as reported by the privious paper (TAKAHASHI 1981). The effect of drought on P and T did not diminish even in ten months in both species.

The effect of planting shock in Scots pine lasted for five weeks at least (HALLMAN et al. 1978). There was no recovery in photosynthesis and a slight recovery in transpiration in five weeks after transplanting.

The recovery of water balance is connected with the degree of root regeneration (TRANQUILLINI 1973, HAVRANEK 1975). As the root-trimmed seedlings recovered faster about a month than the dired seedlings, the difference between root trimming and drought in the recovery of P and T might be caused by the difference in the degree of root regeneration.

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Summary

The purpose of this study is to clarify the long-term effect of root trimming and drought on apparent photosynthesis, respiration, transpiration, xylem water potential and the recovery of root development in five-year-old seedlings of both *Abies sachalinensis* and *Picea glehnii* seedlings. Root trimming and dehydration treatments were carried out at intervals of a month from early May. The roots of root-trimmed seedlings were cut to a half of their length, and dehydration treatment was carried out under the condition of 20°C of air temperature, around 50% of air humidity, and 45 Klux for 15 hours.

CO_2 exchange and transpiration in *Abies* seedlings were affected by root trimming more markedly than those in *Picea*. The decline in photosynthesis and transpiration of *Abies* root-trimmed on 25 June became largest in all treatment times. Photosynthesis and transpiration of the seedlings root-trimmed in September decreased in the following year (Fig. 1, 2, Table 1, 2). These declines were induced by stomatal closing and the stomatal closing on 25 June may be caused by unusual syntheses of growth regulator because of high water potential. The effect of dehydration treatment in both species appeared more clearly than that of root trimming.

Judging from the mortalities in both species, *Picea* was affected by dehydration treatment more severely than *Abies*. But the survived seedlings of *Picea* showed smaller declines in the following year as compared with *Abies* (Fig. 6, 7, Table 3,

4). The root development in the dehydrated seedlings recovered about a month later than that in the root-trimmed seedlings. P/T ratio for all treatment at 20°C varied almost between 1 and 3 ($mgCO^2/100\ mgH_2O$).

The effects of root trimming on *Abies* seedlings were still apparent in five months at least after treatments and remained for ten months in case of the root-trimmed seedlings in late September. The effects of drought on both *Abies* and *Picea* did not diminish even in ten months. The mortality counts of seedlings caused by drought indicated that *Abies* was more tolerant than *Picea*.

Literature cited

ASPNALL, D.: Role of abscisic acid and other hormones in adaptation to water stress. In "Adaptation of plants to water and high temerature stress" (N. C. TURNER & P. J. KRAMER eds). pp. 154–174, Willy, New York, 1980.

BLAKE, T. J.: Transplanting shock in white spruce; effect of cold-storage and root pruning on water relations and stomatal conditioning. Physiol. Plant. **57**: 210–216, 1983.

DAVIES, W. J.: Some effects of abscisic acid and water stress on stomata of *Vicia faba* L. J. Exp. Bot. **29**: 175–228, 1978.

HALLMAN, E., HARI, P., RASANEN, P. K. and SMOLANDER, H.: Effect of planting shock on the transpiration, photosynthesis, and height increament of Scots pine seedlings. Acta Forestalia Fennca **161**: 1–25, 1978.

HAVRANEK, W.: Wasserhaushalt und Zuwachs von Fichten nach versetzung zu verschiedenen Jahreszeiten. Cbl. Ges. Forstw. **92**: 9–25, 1975.

HIRON, R. W. and WRIGHT, S. T. C.: The role of endogenous abscisic acid in the response of plant to stress. J. Exp. Bot. **24**: 769–781, 1973.

LIVINE, A. and VAADIA, Y.: Water deficits and hormone relations. In "Water deficits and plant growth" (T. T. KOZLOWSKI ed.), Vol. 3 pp. 255–275, Academic Press, New York, 1972.

KRAMER, P. J.: Water relations of plants. pp. 320–321, Academic Press, New York, 1983.

RASCHKE, K.: Stomatal action. Ann. Rev. Plant Physiol. **26**: 309–340, 1975.

SAKAGAMI, Y. and FUJIMURA, Y.: Seasonal changes in the net photosynthetic and respiratory rates of *Abies sachalinensis* and *Picea glehnii* seedlings. J. Jap. For. Soc. **63**: 194–200, 1981.

SLATYER, R. O.: Plant-Water Relationships. pp. 275–279, Academic Press, New York, 1967.

TAKAHASHI, K.: Studies on drought resistance of Todo-fir (*Abies sachalinensis* MAST.) and Akaezo-spruce (*Picea glehnii* MAST.) seedlings. Bull. For. & For. Prod. Res. Inst. **313**: 111–160, 1981.

TAKAHASHI, K.: Effect of water stress and change of soil temberature on apparent photosynthesis of Todo-fir (*Abies sachalinensis* MAST.) and Akaezo-spruce (*Picea glehnii* MAST.) seedlings. J. Jap. For. Soc. **64**: 79–86, 1982.

TAKAHASHI, K.: Effect of transplanting on physiological aspects of seedlings (in Japanese). New Technical Information **7**: 1–4, 1983. Hokkaido Branch, For. & For. Prod. Res. Inst.

TRANQUILLINI, W.: Der Wasserhaushalt junger Forstpflanzen nach dem Versetzen und seine Beeinflussbarkeit. Cbl. Ges. Forstw. **90**: 46–52, 1973.

WEILER, E. W., SCHNABL, and HORNBERG, C.: Stress-related levels of abscisic acid in guard cell protoplasts of *Vicia faba* L. Planta **154**: 24–28, 1982.

摘　　要

北海道において気象害を受けた幼齢造林地を調べてみると，植栽木の活着不良やその後作用によると思われる枯死木や生長不良木も少なくない。本報告は，根切りや乾燥がその後の光合成，呼吸，蒸散，樹体の水分状態，根の生長の回復状態などに与える影響を5～10カ月にわたって調べた。根切りおよび乾燥処理は，5月初めからほぼ1カ月ごとに5年生据置苗を掘り取っておこなった。

根切り処理は根長の約1/2を切除後，ただちに鉢植えし，苗床に埋め込んだ。乾燥処理は，20°C，45 kluxの人工光室で15時間乾燥した後，根切り処理と同様に鉢植えにした。6月末の乾燥処理は，新梢の枯死が予測されたので暗黒下で乾燥させた。

光合成と蒸散は，根切り処理や乾燥処理により大きな影響を受けたが，影響の程度や回復状態は処理時期により異なった。

根切り処理による影響は，アカエゾマツよりトドマツで観察された。トドマツにおいて各処理時期別の光合成，蒸散の低下は，6月25日処理のものが最も大きく，9月処理のものでは翌年の光合成，蒸散の低下が大きくなった（図1, 2, 表1, 2)。これらの低下現象は，気孔開度の減少によるものであるが，6月処理では良好な樹体内水分にもかかわらず気孔閉鎖が起きており，水ストレス以外の原因による気孔機能の異常現象と思われる。9月処理では，翌年の－1.0 MPa前後の弱い水ストレスの連続により気孔閉鎖が引き起こされている可能性があり，高温時にさらに気孔閉鎖は強くなっていると思われる。

乾燥処理による影響は，2樹種とも根切り処理より大きく，枯死苗の発生状況等から判断して5月末から9月初めのアカエゾマツが乾燥による影響を強く受けている。しかし，生存個体の翌年の光合成，蒸散の低下はトドマツより小さく，根切り苗と同様の傾向を示した（図6, 7, 表3, 4)。根の回復状態は根切り苗より1カ月程度遅れた。

呼吸と蒸散は，2樹種とも光合成と蒸散ほど低下は示さず，対象苗に近い値を示したが，9月処理苗は根切り，乾燥とも翌年の6月，7月の呼吸が低下した。

PT率（$mgCO_2/100\ mgH_2O$）は，光合成が0に近くなる初冬を除き，多くのものは1～3の範囲で季節変化を示し，根切り処理と乾燥処理は同様の傾向を示した。5月，6月の処理では光合成の低下が蒸散より大きくなるため，対象苗に比べ小さい値を示した。

これらの結果から，トドマツはアカエゾマツに比べ根切りによる影響を受けやすく，アカエゾマツは乾燥による影響を受けやすいことが示され，処理による影響は10カ月後でも消えていないと考えられる。