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Effects of artificial water treatment on the growth and leaf characteristics of *Fraxinus rhynchophylla* and *Fraxinus mandshurica*

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Abstract. Although the result of the tree height growth after water treatment, *Fraxinus rhynchophylla* has little affection by the artificial water treatment, the growth showed decreased tendency as the soil moisture decreased, and *F. mandshurica* showed high growth in relatively high soil moist 78~90% treated area. The growth of root collar diameter of *F. rhynchophylla* and *F. mandshurica* also showed decreased tendency as soil moisture decreased. The changes of biomass according to dry weight of root, stem, leaves of *F. rhynchophylla* demonstrating statistical significance as moisture contents of soil is lower showing decreased biomass tendency and in the treatment of 78%~90%(A) moisture content showed more than double the higher biomass compare to the treated area of 18~30%(D) moisture contents. Also *F. mandshurica* showed statistical significance in A and D treatment demonstrating differences among each treatment. This can be purported to have physiological effects like weakening of seedling and softening of tissues including leaves as soil moisture decreased. Ultimately it is regarded to the main reason of unsatisfactory growth for *F. rhynchophylla* and *F. mandshurica* that are weak to drought resistance. SLA, which is one of the special traits of leaf area of *F. rhynchophylla*, didn't show statistical significance between moisture process, it demonstrated decreased tendency as the moisture content interval is minimal. LAR and LWR showed increased tendency while moisture content didn't show statistical significance between treatments as they are minimal.

Key words : *dry weight,* Fraxinus mandshurica, Fraxinus rhynchophylla, *growth, leaf characteristics, water treatment*

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Introduction

In the forest ecosystem, water is reckon as one of the most lacking factors including light among many kinds of the inorganic environment influencing growth of trees. A tree would slowdown its growth even in a region with appropriate temperature and nutrient soil status depends on amount of rainfall and its distribution. To that extent, moisture deficiency will influence every physiological development concerning a tree's growth, and distribution of geological forest has close correlation to water supplying (Currie and Paquin, 1987). While spring and autumn are dry season in Korea, amount of rainfall is concentrated in the summer season due to its excess rain climate. In addition, not only the depth of forest soil and organic matter content are insufficient, the forest soil in hilly regions suffer serious moisture stress, owning to periodic and constant insufficient moisture during growing period of trees. Moisture is reckon as the essential factor for physiological activity of a tree as solvent for all sorts of fertilizers, maintaining turgor pressure, controlling osmotic pressure of cells and as raw materials for photosynthesis while forming the greater part of a plant (Ashton and Berlyn, 1994; Bahari et al. 1985; Cole and Newton, 1986; Elias and Masarovicova, 1985; Frensch and Schulze, 1988; King, 1994; Kramer, 1983). Consequently, the size of leaves become smaller as they experience moisture stress and reduce transpiration rate due to the growth in the stem was inactive. This would ultimately hinder ability to photosynthesis, which was a final product of metabolism. Studies of home and abroad were constantly being published in order to investigate physiological and ecological affect on moisture of trees. However, it was difficult to apply the study findings obtained from abroad as was on the forest of Korea where species and environment of forest are diverse thus, details of study results on tree species particularly applied for the environment were required(Choi, 2001; Kwon and Lee, 1994; Kim, 1987; Kim,1988; Han and Kim, 1989; Han and Sim, 1989).

Hence, in order to analyze the special growth characteristics that fluctuate depending on moisture environment, the study focused its analysis on *Fraxinus rhynchophylla* and *F. mandshurica* which its value is expanding thanks to broad-leaved tree resource.

Materials and Methods

Experiment sites

The study was carried out in the facilitate greenhouse site of Wonkwang University (college of natural science) from early April to September in 2006.

Water treatments and soil characteristics

The amount of moisture variables of growing media container saved in moisture environment process of *Fraxinus rhynchophylla* and *Fraxinus mandshurica* are as Fig. 1. As a result of irrigation process of 1 day, 3 days, 6 days and 9 days increments, the water content of growing media container was uniformly decreased. The treatment A displayed 78~90% in 1 day increment, 58~70% in treatment B in 3 days increment, 38~50% in treatment C in 6 days increment and 18~30% ranges in treatment D in 9 days increment.

The physical and chemical analysis result on the growing media used for the experiment is as the Table 1. pH, one of the chemical traits of the growing media that combines Vermiculite, Peat Moss and Perlite in 1 : 1 : 1 ratio were 6.0 subject to the pH 5.6~6.0 (Korea Forest Service, 2000) which is proposed as the broad-leaved tree

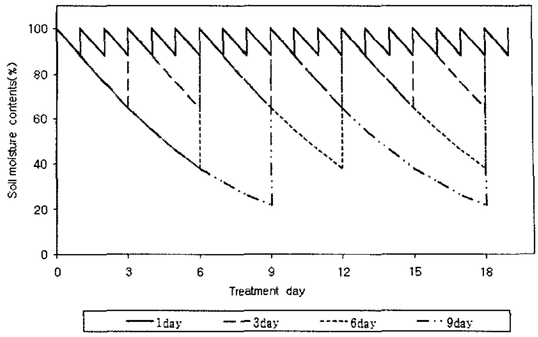

Fig. 1. Daily changes of soil moisture contents in each of dry and wet soil moisture regimes.

nursery bed soil. E.C. was 0.1 ds/m, Ca^{++} was 40.0 $c \cdot mol^{+}/kg$, NO_3 was 0.1 mg/kg, P_2O_5 was 123.0 mg/kg, K^{+} was 4.0 $c \cdot mol^{+}/kg$, Mg^{++} was 7.0 $c \cdot mol^{+}/kg$ and cation exchange capacity (C.E.C.) was 17.0 $c \cdot mol^{+}/kg$.

Tree Materials and Analysis

A-year-old *F. rhynchophylla* and *F. mandshurica* seedlings were obtained from Northern Regional Forest Service and transplant the seedling into an ordinary plastic container (15 cm × 18 cm × 12 cm). To exclude growth affect of seedlings in accordance with nutrient, the study used vermiculite, peat moss and perlite of culture soil of early April by mixing them up in a 1 : 1 : 1 ratio as growing media. And to minimize stress accompany by the transplanting, the seedling have been rooted until the early part of June to reinstate their normal physiological condition and selected 80 seedlings respectively for experimental measure. The analysis of used growing media was analyzed by soil chemical analyzing method. The element contained in growing media essentially required for a tree to grow is the minimum. Therefore, the study irrigated nutrient solution of Sachs'(Sachs, 1860) in four weeks increment to supplement essential nutrient needed for growth as the Table 2.

The water treatments were executed in four steps starting from the early part of June in 1day, 3 days, 6 days

Table 1. The physical and chemical properties of the growing media.

Physical elements (%)		Chemical characteristics			
peatmoss	33.0	pH (1 : 5, v/v)	6.0	P_2O_5 (mg/kg)	123.0
vermiculite	33.0	E.C (ds/m)	0.1	K^{+} ($c \cdot mol^{+}/kg$)	4.0
perlite	33.0	Ca^{++} ($c \cdot mol^{+}/kg$)	40.0	Mg^{++} ($c \cdot mol^{+}/kg$)	7.0
etc.	1.0	NO_3 (mg/kg)	0.1	C.E.C. ($c \cdot mol^{+}/kg$)	17.0

Table 2. Sachs' of nutrient solution.

(g/l)

Major elements		Minor elements	
KNO_3	1.00	H_3BO_3	0.60
$Ca_3(PO_4)_3$	0.50	$CuSO_4 \cdot 5H_2O$	0.05
$MgSO_4 \cdot 7H_2O$	0.50	$MnCl_2 \cdot 4H_2O$	0.40
$CaSO_4$	0.50	$H_2MoO_4 \cdot 4H_2O$	0.02
NaCl	0.25	$ZnSO_4$	0.05
$FeSO_4$	some		

and 9 days increments. The soil moisture contents were calculated as following method after drying fixed amount of wet soil in an oven at 100-105°C temperature and the measuring was carried out 10 times per each treated area (Lee and Choi, 2001).

Soil moisture content (%)=(Dry soil volume (g)/Raw soil volume (g))×100

Growth rates and leaf characteristics

To measure seedling height, root collar diameter and proximal growth in accordance with moisture process, respective tree species and treatments on seedling height and root collar diameter measured 3 times on 15 samples in the middle of May and September. In addition, each dry weight of leaves, stem and roots measured by sampling a seedling during the middle of September, which the season was determined to slowdown the growth of a tree. For growth situation, comparison was compared using Relative Growth Rate (RGR).

The leaf area measured using a leaf area meter (Li-3100, Li-cor, Inc.). With the leaf area and dry weight measuring result, RGR of seedling, distribution ratio of seedling dry weight and T/R ratio, SLA (Specific leaf area=leaf area/leaf dry weight), LAR (leaf area ratio= leaf area/total dry weight), LWR (leaf weight ratio=leaf dry weight/total dry weight) was estimated.

All the statistic analyses were carried out with multiple range test of Ducan utilizing the PC SAS program Ver. 8.0 (SAS, 2000).

Results and Discussion

Growth characteristics

The growth of leaves, stem and roots of a tree influenced the cells expansion in accordance with moisture absorption and increment of the cells. When water deficiency occurs to the tree due to deficiency of soil moisture, it decreases capacity of the tree and growth of each organ, which would significantly decrease or hinder (Kozlowski, 1984). Table 3 shows growth performances of *F. rhynchophylla* and *F. mandshurica* in accordance with artificial water treatments.

While the tree height RGR of *F. rhynchophylla* demonstrates slowdown growth as it moves to the D treatment from the A treatment which has high soil moisture content, the tree height RGR showed difference in the order of A>B>C> and D. The RGR of root collar diam-

Table 3. The growth of height and root collar diameter in the seedlings of *Fraxinus rhynchophylla* and *Fraxinus mandshurica* subjected to artificial watering treatments.

Treatment	Height (cm)		Relative growth rate (%)	Root collar diameter (mm)		Relative growth rate (%)
	May	Sep.		May	Sep.	
			Fraxinus rhynchophylla			
A	37.6±0.6	45.2±0.8	120.2±3.6	5.4±0.2	6.3±0.3	116.7±7.5
B	37.1±1.1	42.7±0.9	115.1±3.7	5.0±0.2	5.6±0.1	112.0±7.1
C	36.2±1.2	39.3±1.1	108.6±5.7	5.7±0.1	6.1±0.4	107.0±6.1
D	37.0±1.4	39.8±3.6	107.6±10.1	6.1±0.3	6.4±0.2	104.9±5.4
			Fraxinus mandshurica			
A	15.7±1.0	23.9±0.8	152.2±9.4	4.2±0.3	4.8±0.2	114.3±10.6
B	15.7±0.7	21.3±0.7	135.7±4.5	4.1±0.3	4.6±0.2	112.2±7.7
C	14.8±1.3	18.1±0.7	122.3±13.2	3.8±0.2	4.2±0.2	110.5±3.3
D	16.2±0.8	18.3±0.7	113.0±9.4	4.0±0.3	4.2±0.4	105.0±12.4

Relative soil water; A : 78~90% B : 58~70% C : 38~50% D : 18~30%.

Table 4. Effect of artificial watering treatment on the dry weight of *Fraxinus rhynchophylla* and *Fraxinus mandshurica.*

Treatment	Dry weight (g)			T/R ratio
	Leaves	Shoot	Root	
		Fraxinus rhynchophylla		
A	5.32a†	10.17a	19.43a	1.34a
B	4.66a	8.29ab	14.13b	2.41b
C	3.86ab	5.32bc	12.22b	2.72b
D	2.92b	3.94c	11.77b	3.16b
		Fraxinus mandshurica.		
A	1.77a†	2.11a	10.23a	2.87a
B	1.52ab	2.08a	8.48ab	4.89ab
C	1.50ab	2.06a	8.01ab	4.52b
D	1.01b	1.64a	5.87b	5.06b

Relative soil water; A : 78~90% B : 58~70% C : 38~50% D : 18~30%
†: Means with the same letter within a column are not significantly different at 5% level by Duncan's multiple range test.

eter displayed higher growth rate as it contained much more moisture similar to the tree height growth rate. The moisture process per treatment showed in the order of A > B > C > and D however, while the C and D treatments didn't show much difference, the higher RGR of root collar diameter were showed at the A treatment.

While the tree height RGR of *F. mandshurica* showed similarities in the order of A > B > C > and D treatment, *F. mandshurica* showed overall higher growth rate than *F. rhynchophylla* and the higher the moisture content, the higher growth rate tendency were demonstrated.

Moreover, the RGR of root collar diameter showed the largest RGR in the A treatment which has the high moisture content in the order of A > B > C > and D, and the C and D treatment displayed similar tendency. While *F. rhynchophylla* and *F. mandshurica* are species that have low drought resistance and high adaptability to damp soil (Lee, 2006), they showed seedling growth even at the low soil moisture content condition. On the other hand, *F. mandshurica* showed significantly higher growth rate compare to *F. rhynchophylla* in a same environment. According to findings, this result were due to lower moisture potential in accordance with the absorption difference in the cells of cell elongation according to moisture stress, suspending cell elongation cause of low root pressure and develops embolism in xylem owning to moisture stress, filling the xylem with air instead of water which hinders functions of moisture circulation path in which constrain the growth of plants (Milburn, 1993). The decrease of root collar diameter when the fewer the moisture content is purported to one of the protect mechanisms (Winkle and Rambal, 1993) that suspends growth in order to fight the moisture stress period by using synthetic compounds generated by the minimum photosynthesis under moisture stress. When a tree receives excess watering, the diameter growth would be accelerated or decreased due to nutrient of moisture (Kozlowski, 1984). In case of flood-tolerant tree, it either dry out or the diameter growth would decrease during long-term process however, watering process during short period time would rather accelerate the diameter growth(Bahari et al, 1985).

Since the moisture processing on *F. rhynchophylla* and *F. mandshurica* was not a long-term experiment, the observation was not distinct on difference of excess moisture and deficiency in case of the root collar diameter growth. Therefore, it is determined that there could be sufficient data on excess moisture and deficiency if detail studies are further carried out on the soil moisture that influences growth traits.

Dry weight and leaf characteristics

Dry weight of *F. rhynchophylla* and *F. mandshurica* seedling showed decreased tendency in every treated areas as the moisture content of soil decreased.

In exploring the changes of biomass according to moisture process, dry weight of leaves of *F. rhynchophylla* were 5.32 g, 4.66 g, 3.86 g and 2.92 g according to

Table 5. Effect of artificial watering treatment on the leaf area, SLA, LAR, and LWR of *Fraxinus rhynchophylla* and *Fraxinus mandshurica.*

Treatment	Leaf area(cm^2)	SLA	LAR	LWR
		Fraxinus rhynchophylla		
A	759.21a†	173.82a	22.89a	0.15a
B	668.74ab	151.02a	24.74ab	0.16a
C	581.61bc	145.35a	25.07ab	0.17a
D	473.73c	145.26a	25.77b	0.17a
		Fraxinus mandshurica		
A	244.28a†	191.62a	17.59a	0.11a
B	214.08a	144.11b	17.92a	0.12a
C	204.54a	140.81b	18.34a	0.12a
D	183.22a	134.39c	20.87a	0.14a

Relative soil water; A : 78 ~ 90% B : 58 ~ 70% C : 38 ~ 50% D : 18 ~ 30%
†: Means with the same letter within a column are not significantly different at 5% level by Duncan's multiple range test.

A, B, C and D treatments and the dry weight of stems were 10.17 g, 8.29 g, 5.32 g and 3.94 g and the dry weight of roots were 19.43 g, 14.13 g, 12.22 g and 11.77 g, demonstrating statistical significance as moisture content of soil is lower showing decreased biomass tendency and in the A treatment of 78 ~ 90% moisture content showed significantly higher biomass compare to the D treatment. As *F. mandshurica* showing a same tendency to *F. rhynchophylla* the dry weight of leaves of *F. mandshurica* were 1.77 g, 1.52 g, 1.50 g, 1.01 g according to A, B, C and D treatment and the dry weight of stems were 10.17 g, 8.29 g, 5.32 g, 3.94 g and the dry weight of roots were 19.43 g, 14.13 g, 12.22 g and 11.77 g moisture content of soil is lower showing decreased biomass tendency. Though *F. mandshurica* has a very low decrease range of dry weight, it showed statistical significance in A and D treatment demonstrating differences among each treatments.

The changes of dry weight according to *F. rhynchophylla* and *F. mandshurica*'s moisture process demonstrate decreased tendency with dry weight as the soil moisture ratio decreased and the main reason for the cause would be due to intense moisture deficiency and in which affects the two species, *F. rhynchophylla* and *F. mandshurica* that are weak to drought resistance. While *F. rhynchophylla* and *F. mandshurica* grow well in the high soil moisture condition, their biomass declined as the moisture of soil decreased.

Table 5 shows a result that analyzed leaf characteristics of two tree species according to moisture process. In case of *F. rhynchophylla*, the leaf area showed 759.21 cm^2 in the A treatment, 668.74 cm^2 in the treatment B, 581.61 cm^2 in C, 473.73 cm^2 in D area and with *F. mandshurica*, the treatment A showed 244.28 cm^2, 214.08 cm^2 in B, 204.54 cm^2 in C and 183.22 cm^2 in the treatment D, which demonstrate relatively higher leaf area with *F. rhynchophylla* per moisture process tree compare to *F. rhynchophylla* and the both species demonstrated higher leaf area value when soil water content is higher and as soil water content decrease, the value of leaf area also decreased. SLA, which is one of the special traits of leaf area of *F. rhynchophylla*, didn't show statistical significance between moisture process, it demonstrated decreased tendency as the moisture content interval was minimal.

As the characteristic of leaf area of *F. mandshurica* had a same tendency to *F. rhynchophylla*, SLA didn't show statistical significance among each water treatment but relatively showed statistical significance in A and D treatments and it demonstrated decreased tendency as the moisture content interval is minimal. LAR and LWR showed increased tendency while moisture content didn't show statistical significance between each processing interval as they are minimal.

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Literature citied

1. Ashton, P. M. S. and G. P. Berlyn. 1994. A comparison of leaf physiology and anatomy of *Quercus*(section Erythrobalnus-Fagaceae) species in different light environments. Am. J. Bot. 81(5):589-597.
2. Bahari, Z. A., S. G. Pallardy. and W. C. Parker. 1985. Photosynthes is, water relation, and drought adaptation in six woody species of oak-hickory forest in central Missoury. For. Sci. 31:557-569.
3. Choi, J. H. 2001. Effects of artificial shade treatment on the growth performances, water relations, and photosynthesis of several tree species. Chungnam university. Korea. 152pp.
4. Cole, E. C. and M. Newton. 1986. Nutrient, moisture, and light relations in 5-year-old douglas-fir plantations under variable competition. Can. J. For. Res. 16: 727-732.
5. Currie, D. J. and Paquin, V. 1987. Large-scale biogeographic patterns of species richness of trees. Nature (London) 329: 326–327.
6. Elias, P. and E. Masarovicova. 1985 Chlorophyll content in leaves of plants in oak-hornbeam forest(IV)-Amouts per stand area unit. Photosynthetica 19(1):49-55.
7. Frensch, J. and E. D. Schulze. 1988. The effect of humidity and light on cellular water relations and diffusion conductance of leaves of *Tradescantia virginiana* L. Planta 173:554–562.
8. Han, S. S. and H. S. Kim. 1989. Effects of light, temperature, and water stress on the photosynthesis and respiration rates of leaves in four oak species. J. Kor. For. Soc. 78(2):151-159.
9. Han, S. S. and J. S. Sim. 1989. Characteristics of photosynthesis and respriration in *Fraxinus rhynchophylla* Hance and *Fraxinus mandshurica* Rupr. leaves. J. Kor. For. Soc. 78(3):280-286.
10. Kim, G. T. 1987. Effects of simulated acid rain on growth and physiological characteristics of *Ginkgo biloba* L. seedlings and on chemical properties of the tested soil. . Leaf surface area, visible leaf injury, leaf chlorophyll content and photosynthetic ability of the leaf tissue. J. Kor. For. Soc. 76(3):230-240.
11. King, D. A. 1994. Influence of light level on the growth and morphology of saplings in a Panamanian forest. Am. J. Bot. 81(8):948-957.
12. Korea Forest Service. 2000. Forest & Forestry Technique . Korea Forest Service. 509p.
13. Kozlowski, T. T. 1984. Response of woody plants to flooding. Flooding and plant growth. Academic, Orlando, Florida. 129-164.
14. Kramer, P. J. 1983. Water Relations of Plants. A. P. N. Y. 489p.
15. Kwon, K. W. and J. H. Lee. 1994. Ecophysiological studies on the water relations of economic tree species - Temporal changes of stomatal responses to soil moisture regimes and exogenous abscisic acid in oaks and ash-. Jour. Kor. For. S. 83(3):410-423.
16. Lee, C. Y. and K. Choi. 2001. Traditional knowledge for soil erosion control in the republic of Korea. Korea Forest Research Institute. 110p.
17. Lee, K. J. 2006. Tree physiology. Seoul National University Press. 536p.
18. Milburn, J. A. 1993. Cavitation. A review: past, present and future. *In* M Borghetti, J Grace, A Raschi, eds, Water Transport in Plants under Climatic Stress. Cambridge University Press. p. 14-26.
19. Sachs, J. 1860. Kristallbildung beim gefrienen und auftauen saftiger pflanzenteile, mitgeteilt von W. Hofmeister. Berichte Verhandlung Sachs. Akademie der Wissenschaften 12: 1-50.
20. SAS Institute. 2000. SAS/STAT software: Changes and Enhancements through release 8.0. SAS Institute, Cary, NC. 1100pp.
21. Winkel, T and S. Rambal. 1993. Influence of water stress on grapevines growing in the field: from leaf to whole-plant response. Australian Journal of Plant Physiology 20:143-157.

인위적인 수분처리가 물푸레나무와 들메나무의 생장과 엽형특성에 미치는 영향

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적 요. 인위적인 수분처리에 대한 묘고생장 결과 물푸레나무는 수분처리의 영향을 크게 받지는 않았으나, 토양수분이 감소할수록 생장이 감소하였고, 들메나무는 상대적으로 토양수분이 높은 처리구(78~90%)에서 높은 생장을 보였다. 물푸레나무와 들메나무의 근원직경 또한 토양수분이 감소할수록 생장이 감소하는 경향을 보였다. 물질생산량의 변화는 물푸레나무의 경우 잎, 줄기, 뿌리 등 건중량이 각 처리구별로 토양내 수분이 낮아질수록 통계적으로 유의성을 보이면서 감소하는 경향을 나타냈으며, 토양수분이 78~90%(A)인 처리구에서는 상대적으로 18~30%(D)처리구에 비해 약 2배 이상 높은 물질 생산량을 나타냈다. 들메나무도 각 처리구간에 차이를 보이면서 A처리구와 D의 처리구에서는 통계적으로 유의성을 보였다. 이는 토양수분이 묘목의 수세 약화 및 잎을 포함한 조직의 연화 등 생리적인 부분에 영향을 미치는 것으로 생각된다. 물푸레나무와 들메나무의 엽 특성중 SLA는 토양수분처리에 따라 통계적으로 유의성을 보이진 않았지만 처리구간 수분함량이 적을수록 감소하는 경향을 나타냈다. 그러나 LAR과 LWR의 경우에는 각 처리구간 토양내 수분함량이 적을수록 통계적으로 유의성은 나타나지 않았지만 증가하는 경향을 나타냈다.

주제어 : 물푸레나무, 들메나무, 수분처리, 생장, 건중량, 엽특성