Korean J. Ecol. 27(6): 363∼367, 2004

Changes in Understory Vegetation of a Thinned Japanese Larch (*Larix leptolepis*) Plantation in Yangpyeong, Korea

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ABSTRACT : Photosynthetically active radiation (PAR) beneath the forest canopy, understory species richness and diversity, and biomass were measured in a *Larix leptolepis* plantation seven years after thinning in Yangpyeong. Four different thinning intensities (control, 10%, 20% and 40% stocking reduction) were applied in 1997. The current PAR values were lower than those measured four years after thinning, and PAR at the heavy thinning plots was significantly higher than that of other thinning intensities. A total of 23 species including 9 tall-trees and 14 shrubs were found for the high layer while a total of 82 species including 10 tall-trees, 29 shrubs, and 43 herbs for the low layer. Species richness and diversity generally increased with thinning intensities, and the trends were more evident for the low layer. Aboveground biomass significantly differed among thinning intensities for both shrubs and herbs. Also there was a negative correlation between biomass and the current number of stems per hectare. The current study suggested that the effects of thinning on light conditions at the forest floor, species richness and diversity and production of understory vegetation continued seven years after the treatment.

Key words : Biomass, *Larix leptolepis*, Photosynthetically active radiation (PAR), Species diversity, Species richness, Thinning

INTRODUCTION

Larix leptolepis has been extensively planted throughout the country and thinning is commonly applied at an age of 15~20 years for the species. The purpose of thinning is to increase growth on high-value trees and there are some reports on the effects of thinning on environmental conditions related to tree growth (Son et al. 1999, 2004a, 2004b). However, it is not clear whether these effects would still be evident in the longer term. Furthermore, more information is needed to understand the relationship between thinning and understory vegetation, which plays an important role in ecological functions for *L. leptolepis*. The objectives of the current study were 1) to examine the light condition under overstory canopy, and 2) to investigate total number of species, species diversity and biomass of understory vegetation seven years after thinning in a 22-year-old *L. leptolepis* plantation in Yangpyeong, Korea.

MATERIALS AND METHODS

The study was conducted at the Korea University Yangpyeong Experiment Forest (37°30' N, 127°42' E, elevation 160m). A detailed description on the area was provided by Son and Lee (1997) and Son et al. (1999). A 15-year-old *L. leptolepis* plantation was selected and four levels of thinning were applied in April of 1997 [no thinning (control, 2250 stems per hectare), light thinning (T10, 10% thinning, 2000 stems per hectare after thinning), moderate thinning (T20, 20% thinning, 1750 stems per hectare after thinning), and heavy thinning (T40, 40% thinning, 1200 stems per hectare after thinning)] (Son et al. 1999, 2004a, 2004b). The stand density of October of 2004 (number of trees per hectare) was 1575 for control, 1525 for T10, 1350 for T20, and 1100 for T40, respectively.

Photosynthetically active radiation (PAR, 400~700nm, in micromoles/m^2/sec) was measured using a Decagon Sunfleck Ceptometer (Model SF-80) beneath the forest canopy between 11 AM and 1 PM on July 24, 2004 (Stohlgren et al. 1998). PAR was measured at two different heights (30cm and 1m above ground levels) and five readings were taken at four cardinal directions within each thinning treatment plot.

Understory vegetation was separated into two layers; high layer (vegetation growing at 60~150cm above ground level) and low layer (vegetation growing up to 60cm above ground level). Five square subplots (4m × 4m for the high layer and 2m × 2m for the low

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layer) were randomly located within each thinning treatment plot and a vegetation survey was conducted in July 2004. All plants within subplots were identified to species (nomenclature sources: Lee 1982), and understory plant species were classified into three life forms of tall-tree, shrub, and herb (including grasses, sedges and ferns) (Nagaike 2002). Plant cover was visually estimated for each species. After identification, all plants were harvested for above-ground biomass estimation. Plant samples for biomass were separated into shrubs and herbs, dried at 70℃ until constant weight, and weighed. The species richness and diversity were calculated using the number of species and the Shannon's index (Swindel et al. 1986).

Analysis of variation was used to test for the differences in PAR, and species richness and diversity, and biomass of understory vegetation among thinning intensities. Means were separated using Tukey's honestly significant difference test ($p<0.05$). Simple linear regression was used to evaluate the relationships of thinning intensities (number of stems per hectare after thinning) to PAR, species richness and diversity, and understory biomass (SAS 1988).

RESULTS AND DISCUSSION

Intercepted PAR (µmole/m^2/sec) at 30cm and 1m above ground levels was 76.1 and 77.2 for control, 62.1 and 65.0 for T10, 75.1 and 74.9 for T20, and 94.7 and 114.9 for T40, respectively. For T40 PAR was higher at 1m than at 30cm above ground level. PAR was significantly higher for T40 compared to other thinning intensities at both measuring heights. However, there were no significant differences in PAR among control, T10, and T20 at both heights. The current PAR values were lower than those measured four years after thinning at two measuring heights (Son et al. 2004b). Although a significant correlation between mean annual intercepted PAR and the number of stems after thinning was reported in 2001 (Son et al. 2004b), we found no correlation between PAR and the number of stems at 30cm and 1m above ground levels in 2004 ($p>0.05$). It appeared that the overstory canopy rapidly expanded since 2001 and resulted in low PAR values. Also the understory vegetation seemed to influence light interception (see below). The high PAR at T40 compared to other thinning intensities might be attributed to heavy removal of stems and/or canopy might be still expanding.

A total of 23 species including 9 tall-trees and 14 shrubs were found for the high layer while a total of 82 species including 10 tall-trees, 29 shrubs, and 43 herbs for the low layer (Table 1). Total number of species was similar to that recorded in 2001, however, the composition ratio for life forms changed; the number of shrubs decreased while the number of herbs increased (Son et al. 2004b). It was possible that these changes resulted from decreased PAR

Table 1. Understory plant species recorded in July 2004 for different thinning intensities in a *L. leptolepis* plantation

Species	Thinning intensity			
	Control	T10	T20	T40
High layer				
Tall-trees				
Acer ginnala	○	○		○
Castanea crenata	○	○	○	○
Fraxinus rhynchophylla	○	○	○	○
Kalopanax pictus	○			
Morus alba		○	○	○
Quercus aliena	○			
Quercus dentata	○	○	○	○
Quercus serrata	○	○	○	○
Quercus variabilis				○
Shrubs				
Aralia elata	○	○	○	
Callicarpa japonica			○	
Corylus heterophylla var. *thunbergii*	○		○	○
Corylus heterophylla				○
Ligustrum obtusifolium				○
Lindera obtusiloba		○		
Lespedeza maximowiczii	○			
Rhus trichocarpa	○	○	○	○
Rubus crataegifolius	○	○		
Rubus coreanus		○		○
Staphylea bumalda		○	○	○
Stephanandra incisa	○			
Symplocos chinensis for. *pilosa*	○	○	○	○
Zanthoxylum schinifolium	○	○	○	○
Low layer				
Tall-trees				
Acer ginnala		○		○
Castanea crenata	○		○	○
Cornus controversa				○
Fraxinus rhynchophylla		○	○	○
Morus alba		○		○
Pinus koraiensis			○	
Quercus acutissima	○		○	
Quercus dentata	○	○	○	○
Quercus serrata	○	○	○	○
Quercus variabilis	○		○	
Shrubs				
Actinidia arguta	○	○	○	○
Aralia elata	○	○	○	○
Callicarpa japonica		○	○	
Celastrus orbiculatus		○		○
Clematis apiifolia				○
Clematis mandshurica			○	○
Cocculus trilobus	○	○	○	○
Corylus heterophylla var. *thunbergii*			○	○
Euonymus alatus	○	○	○	○

Table 1. Continued

Indigofera kirilowii				○
Ligustrum obtusifolium			○	
Lindera obtusiloba	○		○	○
Lespedeza maximowiczii			○	
Lonicera japonica	○			○
Menispermum dauricum			○	
Paederia scandens		○		○
Prunus japonica var. *nakaii*	○			○
Rhus trichocarpa	○	○	○	○
Rosa multiflora			○	
Rubus crataegifolius	○	○	○	○
Rubus coreanus				○
Rubus parvifolius				○
Smilax sieboldii	○	○	○	○
Staphylea bumalda				○
Stephanandra incisa	○			
Spiraea prunifolia for. *simpliciflora*			○	
Symplocos chinensis for. *pilosa*		○	○	○
Vitis thunbergii var. *sinuata*				○
Zanthoxylum schinifolium	○	○	○	○
Herbs				
Angelica decursiva	○	○	○	○
Aster scaber	○	○	○	○
Astilbe chinensis var. *davidii*			○	○
Athyrium conilii	○	○	○	○
Atractylodes japonica	○	○	○	○
Carex lanceolata	○	○	○	○
Cephalanthera erecta	○	○		○
Commelina communis	○		○	○
Convallaria keiskei				○
Dennstaedtia wilfordii				○
Dioscorea batatas	○	○	○	○
Disporum smilacinum				○
Dryopteris bissetiana	○	○	○	○
Echinops setifer		○	○	
Eupatorium chinense var. *simplicifolium*		○	○	○
Gentiana scabra var. *buergeri*	○	○		○
Hemerocallis fulva		○	○	
Iris nertschinskia		○	○	○
Isodon inflexus		○		
Lilium tsingtauense	○	○		○
Liparis kumokiri				○
Lysimachia clethroides	○	○	○	○
Melampyrum roseum		○		○
Milium effusum	○	○	○	○
Oplismenus undulatifolius	○	○	○	○
Persicaria senticosa	○			
Phryma leptostachya var. *asiatica*		○		○
Polygonatum odoratum var. *pluriflorum*	○	○	○	○
Potentilla freyniana	○	○	○	○
Ranunculus sceleratus		○		
Rubia akane	○	○		
Sanguisorba officinalis	○	○	○	

Table 1. Continued

Smilacina japonica				○
Smilax riparia var. *ussuriensis*	○	○	○	○
Veratrum maackii var. *japonicum*		○	○	○
Vicia nipponica	○	○	○	
Viola accuminata			○	
Viola albida	○	○	○	○
Viola collina		○		
Viola dissecta var. *chaerophylloides*			○	
Viola dissecta var. *takahashii*			○	
Viola mandshurica	○	○	○	
Youngia denticulata		○		

since 2001 (Nagaike 2002, Rankin and Tramer 2002). Harrington and Edwards (1999) suggested that light availability was the dominant factor affecting herbaceous responses in a thinning study. In the high layer, vegetation cover gradually increased with thinning intensities (15% for control, 29% for T10, 35% for T20, and 48% for T40). Dominant plant species varied depending on thinning intensities; *Rhus trichocarpa*, *Quercus serrata*, and *Q. dentata* for control, *R. trichocarpa*, *Q. serrata*, and *Lindera obtusiloba* for T10, *R. trichocarpa*, *Castanea crenata*, and *Fraxinus rhynchophylla* for T20, and *Corylus heterophylla*, *R. trichocarpa*, and *Zanthoxylum schinifolium* for T40, respectively. In general, *R. trichocarpa* was more dominant at control or low thinning intensities compared to heavy thinning. In the low layer, vegetation cover did not show any trend with thinning intensities; 34% for control, 46% for T10, 53% for T20, and 46% for T40, respectively. *Dryopteris bissetiana* was the most dominant species throughout all thinning treatments. Shade tolerant species such as *D. bissetiana*, *Carex lanceolata*, *Oplismenus undulatifolius*, *Athyrium conilii*, *Smilax riparia* var. *ussuriensis*, *S. sieboldii* were more common at control and light thinning plots compared to moderate and heavy thinning plots. These patterns were similar to those investigated in 2001 (Son et al. 2004b), and seemed to be a relatively short-term effect of thinning (He and Barclay 2000).

Species richness and diversity of understory vegetation were presented in Table 2. These values were higher than those calculated in 2001 (Son et al. 2004b). Species richness and diversity were higher for the low layer than for the high layer. And these indices generally increased with thinning intensities, and the trends were more evident for the low layer. Consequently, a correlation between species richness or diversity and the number of stems was significant for the low layer ($p<0.05$, $r=0.97$), but not significant for the high layer ($p>0.05$). Moore and Allen (1999) concluded that thinning operations might help increase vegetation diversity because

Table 2. Species richness and diversity for different thinning intensities in a *L. leptolepis* plantation. The figures in parentheses are standard errors. Means followed by the same letter in a given treatment do not differ at *P*=0.05

	Thinning intensity			
	Control	T10	T20	T40
High layer				
Species richness				
Total	5.6(0.7)ba	5.0(0.3)b	6.2(0.8)ba	7.4(0.9)a
Tall trees	2.6(0.7)a	1.8(0.6)a	3.2(0.4)a	3.2(0.8)a
Shrubs	3.0(1.0)a	3.2(0.4)a	3.0(0.4)a	4.2(0.2)a
Species diversity[a]				
H'	1.54(0.09)ba	1.33(0.12)b	1.62(0.13)ba	1.70(0.10)a
Low layer				
Species richness				
Total	17.2(1.5)c	21.0(1.5)bc	23.4(1.4)b	28.2(1.0)a
Tall-trees	1.8(0.5)a	1.6(0.6)a	2.4(0.4)a	2.6(0.7)a
Shrubs	4.6(0.4)c	4.8(0.7)c	8.0(0.6)b	10.0(0.5)a
Herbs	10.8(0.8)b	14.6(1.8)a	13.0(0.7)ab	15.8(0.5)a
Species diversity				
H'	2.24(0.07)d	2.48(0.11)c	2.77(0.09)b	3.07(0.05)a

[a] Based on the equation of Ludwig and Reynolds (1998).

of more sunlight inputs and microclimatic variation in temperature and moisture. Sunlight seemed to be the principal environmental factor determining understory species composition (but see Hanley and Brady 1997). Based on the current study, thinning appeared to increase species richness and diversity of understory vegetation (Bailey et al. 1998, Brunet et al. 1996, Thomas et al. 1999). Plant life forms were in the order of shrubs > tall-trees in the high layer while herbs > shrubs > tall-trees in the low layer. In general, the number of tall-trees, shrubs, and herbs was higher at control and low thinning plots than that at moderate and heavy thinning plots.

Understory aboveground biomass (kg/ha) of herbs and shrubs for the high and low layers was 186 and 415 for control, 327 and 531 for T10, 528 and 1173 for T20, and 716 and 1376 for T40, respectively (Fig. 1). Aboveground biomass significantly differed among thinning intensities for both plant types (shrubs and herbs). Also there was a negative correlation between biomass and the current number of stems ($p<0.05$, $r=0.97$ for herbs, $p<0.05$, $r=0.95$ for shrubs, figures not shown). Previous studies reported that the

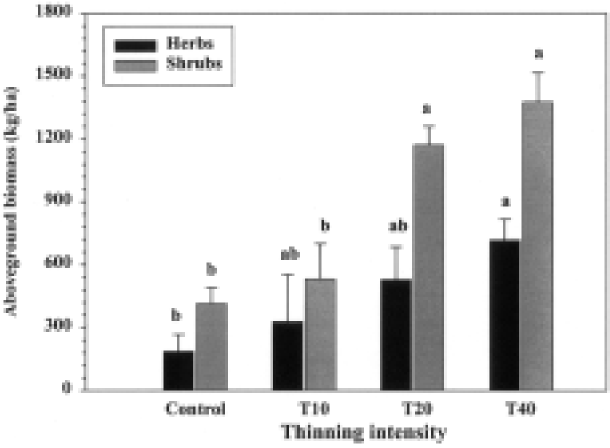

Fig. 1. Understory aboveground biomass for thinning intensities in a *Larix leptolepis* plantation in Yangpyeong. Vertical bars represent standard errors. Same letters indicate no significant difference within a plant type (p>0.05).

amount of sunlight at the forest floor was the primary influencing factor for understory production (Bisbee et al. 2001, Harrington and Edwards 1999, Martinez Pastur et al. 2002). More sunlight input at moderate and heavy thinning plots appeared to increase understory vegetation production in this study. Total biomass (herbs plus shrubs, kg/ha) was 601 for control, 856 for T10, 1701 for T20, and 2092 for T40, respectively, and significantly different among thinning intensities. These values constituted to 1~3% of total aboveground biomass of 15-year-old *L. leptolepis* (Yim et al. 1981). Biomass of understory vegetation was at least five times higher than those reported in 2001. The rapid growth of understory shrubs and herbs appeared to decrease PAR. The current study suggested that the effects of thinning on light conditions at the forest floor, species richness and diversity and production of understory vegetation continued seven years after the treatment. However, more studies are needed to clarify the long term effects of thinning on light condition and understory vegetation in the region (Battles et al. 2001, He and Barclay 2000, Ito et al. 2003).

ACKNOWLEDGEMENTS

This research was supported by the Korea University Grant. We thank Dr. Y.J. Yun and two anonymous reviewers for providing helpful comments on earlier drafts.

LITERATURE CITED

Bailey, J.D., C. Mayrsohn, P.S. Doescher, E. St. Pierre, and J.C. Tappeiner. 1998. Understory vegetation in old and young Douglas-fir forests of western Oregon. Forest Ecology and

Management 112: 289-302.

Battles, J.J., A.J. Shlisky, R.H. Barrett, R.C. Heald, and B.H. Allen-Diaz. 2001. The effects of forest management on plant species diversity in a Sierran conifer forest. Forest Ecology and Management 146: 211-222.

Bisbee, K.E., S.T. Gower, J.M. Norman, and E.V. Nordheim. 2001. Environmental controls on ground cover species composition and productivity in a boreal black spruce forest. Oecologia 129: 261-270.

Brunet, J., U. Falkengren-Grerup, and G. Tyler. 1996. Herb layer vegetation of south Swedish beech and oak forests- effects of management and soil acidity during one decade. Forest Ecology and Management 88: 259-272.

Hanley, T.A. and W.W. Brady. 1997. Understory species composition and production in old-growth western hemlock-Sitka spruce forests of southeastern Alaska. Canadian Journal of Botany 75: 574-580.

Harrington, T.B. and M.B. Edwards. 1999. Understory vegetation, resource availability, and litterfall responses to pine thinning and woody vegetation control in long leaf pine plantations. Canadian Journal of Forest Research 29: 1055-1064.

He, F. and H.J. Barclay. 2000. Long-term response of understory plant species to thinning and fertilization in a Douglas-fir plantation on southern Vancouver Island, British Columbia. Canadian Journal of Forest Research 30: 566-572.

Ito, S., M. Nakagawa, G.P. Buckley, and K. Nogami. 2003. Species richness in sugi (*Cryptomeria japonica* D. DON) plantations in southeastern Kyushu, Japan: the effects of stand type and age on understory trees and shrubs. Journal of Forest Research 8: 49-57.

Lee, T.B. 1982. Illustrated flora of Korea. Hangmoonsa, Seoul, Korea (in Korean).

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical ecology. Wiley Interscience, New York.

Martinez Pastur, G., P.L. Peri, M.C. Fernandez, G. Staffieri, and M.V. Lencinas. 2002. Changes in understory species diversity during the *Nothofagus pumilio* forest management cycle. Journal of Forest Research 7: 165-174.

Moore, S.E. and H.L. Allen. 1999. Plantation forestry. *In* M.L. Hunter (ed.) Maintaining biodiversity in forest ecosystems. Cambridge University Press, Cambridge, pp 400-433.

Nagaike, T. 2002. Differences in plant species diversity between conifer (*Larix kaempferi*) plantations and broad-leaved (*Quercus crispula*) secondary forests in central Japan. Forest Ecology and Management 168: 111-123.

Rankin, W.T. and E.J. Tramer. 2002. Understory succession and the gap regeneration cycle in a *Tsuga canadensis* forest. Canadian Journal of Forest Research 32: 16-23.

SAS. 1988. SAS/STAT user's guide, 6.03 ed. SAS Institute, Cary, North Carolina.

Son, Y. and I.K. Lee. 1997. Soil nitrogen mineralization in adjacent stands of larch, pine and oak in central Korea. Annals of Forest Science 54: 1-8.

Son, Y., W.K. Lee, S.E. Lee, and S.R. Ryu. 1999. Effects of thinning on soil nitrogen mineralization in a Japanese larch plantation. Communications in Soil Science and Plant Analysis 30: 2539-2550.

Son, Y., Y.C. Jun, Y.Y. Lee, R.H. Kim, and S.Y. Yang. 2004a. Soil CO_2 evolution, litter decomposition, and nitrogen availability 4 years after thinning in a Japanese larch plantation. Communications in Soil Science and Plant Analysis 35: 1111-1122.

Son, Y., Y.Y. Lee, Y.C. Jun, and Z.S. Kim. 2004b. Light availability and understory vegetation four years after thinning in a *Larix leptolepis* plantation of central Korea. Journal of Forest Research 9: 133-139.

Stohlgren, T.J., R.R. Bachand, Y. Onami, and D. Binkley. 1998. Species-environment relationships and vegetation patterns: effects of spatial scale and tree life-stage. Plant Ecology 135: 215-228.

Swindel, B.F., L.F. Conde, and J.E. Smith. 1986. Successional changes in *Pinus elliottii* plantations following two regeneration treatments. Canadian Journal of Forest Research 16: 630-636.

Thomas, S.C., C.B. Halpern, D.A. Falk, D.A. Liguori, and K.A. Austin. 1999. Plant diversity in managed forests: understory responses to thinning and fertilization. Ecological Applications 9: 864-879.

Yim, K.B., K.D. Kim, K.J. Lee, Y.S. Kim, I.H. Park, T.H. Kwon, S.H. Lee, and H.S. Park. 1981. Biomass study of a 15-year-old *Larix leptolepis* stand. Journal of Korea Forestry Energy 1: 4-12. (in Korean with English abstract)

(*Received November 19, 2004; Accepted November 26, 2004*)