韓國林學會誌 85(3) : 524-531. 1996
Jour. Korean For. Soc. 85(3) : 524-531. 1996

Factors Affecting the Early Natural Regeneration of *Pinus densiflora* S. *et* Z. after Forest Works at Mt. Joongwang Located in Pyungchang-gun, Kangwon-do[1*]

Pil Sun Park[2] and Don Koo Lee[2]

江原道 平昌郡 中旺山에서 山林作業 後 소나무의 初期 天然 更新에 미치는 要因[1*]

朴必善[2] · 李敎求[2]

ABSTRACT

The objective of this study was to determine the important factors affecting the early natural regeneration of *Pinus densiflora* S. et Z. Seed germination, survival and height growth of the pine seedlings were examined at four experimental plots of *P. densiflora* forests including forest roadside. Plots I and III were thinned in 1992, plot II was treated with hexazinone in 1993 after seed tree method was applied in 1982 and 1989. Seedlings emerged after thinning and the rate of their emergence depended on forest floor conditions. Seedling survival was related with light conditions, herbaceous vegetation, and degrees of rainfall. More seedlings emerged in forest hauling roads than within the forest because soil scarification due to logging provided better conditions for seed germination and seedling growth. Seed supply was enough, but germination rate was very low in the forest compared with that in the greenhouse because micro-environments such as organic layer and herbaceous plant acted as limiting factors. Weed control was needed for 4 to 5 years until seedlings grew upto about 50cm in height which was similar to that of herbaceous plants. But 10-40% coverage of herbaceous vegetation was needed to protect small seedlings from heavy rain. Forest works such as thinning and logging, over 40% of light were important factors to help the pine regeneration. However, over 70% coverage of herbaceous vegetation, and heavy rain inhibited rather survival and growth of pine seedlings.

Key words : Pinus densiflora S. et Z., *seed germination, seedling growth, early natural regeneration, thinning, herbaceous vegetation, canopy coverage*

요 약

소나무의 초기 천연 갱신에 영향을 미치는 중요한 인자가 무엇인지를 알아보기 위하여 강원도 평창군 중왕산 지역에서 이 연구를 수행하였다. 3개의 조사지와 1개의 임도 지역에 시험구를 설치하여 소나무의 발아와 치수의 묘고, 여름을 지나는 동안의 생존율을 조사하였다. 조사지 I과 III은 1992년에 간벌을 실시한 곳이고, 조사지 II는 1982년과 1989년에 모수림 작업을 시도한 후, 1993년까지 헥사지논으로 지피 식생 처리를 한 곳이다. 세 조사지는 서로 다른 시기에 산림 작업의 형태로 교란이 일어난 곳이다. 소나무 치수는 간벌이 일어난 후에 나타났으며, 치수의 발생은 지피 식생이 적은 곳에서

[1] 接受 1996年 5月 10日 Received on May 10, 1996.
[2] 서울대학교 농업생명과학대학 산림자원학과 Department of Forest Resources, Seoul National University, Suwon 441-744, Korea
* 이 연구는 산림청 지원 "국유림 경영 산학협동 실연연구"의 일부 결과이다.

잘 나타났다. 특히 산림 작업에 의해 토양이 드러난 곳인 작업로에 소나무 치수의 발생이 많았으며, 상층 수관의 울폐도가 낮은 곳에서 생장이 좋았다. 하층 식생은 소나무 치수의 발생과 생장에 제한 요소로 작용하나 약 10~40%의 초본류는 소나무 치수를 보호하기 위하여 필요하다. 여름철의 집중 호우는 주위에 초본이 없는 경우 완전히 뿌리를 내리지 못한 소나무 치수를 비에 떠내려가게 하는 역할을 하였다. 소나무 치수가 잘 성장하기 위해서는 묘고가 초본류의 높이인 약 50cm에 달하는 4~5년까지 제초 작업이 필요하다. 이 지역에서 소나무 천연 갱신에 주요한 영향을 미치는 요인 중 갱신을 도와주는 요인은 간벌과 집재 등의 산림 작업과 40% 이상의 광이었으며, 피도 70% 이상의 지피식생과 집중 호우 등은 오히려 소나무 묘목의 생존과 생장에 방해가 되었다.

INTRODUCTION

Pinus densiflora Sieb. et Zucc. is the representative, native species to Korea. This pine is widely distributed from Korea to eastern Manchuria and adjacent Russia, on the Shantung Peninsula of China, and in Japan from northern Honshu to Yaku Shima, south of Kyushu (Critchfield and Little, 1966) and usually appeares southern part of the mountain. It grows till 35m high and 1.8m diameter(Lee, 1982), even though it is considered pioneer species, however, it is one of the best timber species. But the species has been genetically degraded, because most of the natural stands were destroyed under the Japanese ruling period (1910-1945) and during the Korean war(1950-1953) (Kim and Zsuffa, 1994). An additional problem to this pine was damage from pine gall midge, *Thecodiplosis japonensis*(Park and Hyun, 1983). The infection has been so severe that dying forest can be found all over the country, even in remote areas of Kangwon-do. Various attempts have been made to control this pest, but there has been no noticeable success(Forest Genetics Research Institute, 1993). Pine forests damaged by pine gall midge have been cut especially in Kangwon-do.

The total number of these pines planted since 1953 is 94,907,000 seedlings and 84,938,000 trees survived, which occupies about 29,534ha(1.3% of the total forest areas)(Forestry Administration, 1994). Artificial plantings become expensive due to high labor cost, thus forestation through natural regeneration has been favored.

The regeneration of *P. densifora* in thinned forest areas provides the opportunity to understand factors influencing its establishment. Some factors that affect regeneration immediately after disturbance such as cutting and soil instability may differ from those that inhibit subsequent tree establishment. Initial and subsequent tree establishment at high elevation is affected by several climatic factors including snow accumulation and timing of snow melt(Wardle, 1968), summer and winter desiccation(Cui and Smith, 1991), extreme air and soil temperatures(Munn *et al.*, 1982). Tree regeneration may be influenced also by non-climatic factors, such as bare mineral soil for germination, competition with herbaceous vegetation and such microsite moderators as woody debris.

Distribution of *P. densiflora* was a consequence of species differences in growth as well as in time recruitment and *P. densiflora* regenerated abundantly after certain fires because their seedlings needed bare mineral soil and plentiful sunlight to become established. The regeneration and growth patterns of *P. densiflora* seemed to depend mainly on the forest fire (Jo, 1994).

This pine forest has a strong ability of natural regeneration and is very adapted to the ecological conditions which are very poor(Wang and Zhou, 1984).

Regeneration studies after tree harvesting have been typically conducted for surveys. Available thinning has provided useful information concerning regeneration composition and structure under different thinning regimes, but gives limited insight into the ecological process that drives the response. There is a need for integrated studies that examine species population dynamics and the underlying processes under different regimes. With this knowledge, silvicultural treatment can be designed to produce the desired results. Differences in regeneration patterns were related to regeneration strategies(Roberts and Dong, 1993).

Natural regeneration can be significant after harvesting but is highly variable because it is controlled by a large number of interacting biological, climatic and edaphic variables. For example, harvesting and forest floor disturbance directly affect seed availability, receptivity of the seedbed, and the environmental factors such as temperature, light, moisture and soil that control seed germination and seedling survival. In addition, disturbance affects survival of advance regeneration and vegetative reproduction which compete with seedlings(Winsa and Berstein, 1994; Boucher *et al.*, 1994).

This study was designed to examine seed germination, seedling survival, and height growth of *P. densiflora* during 3- to 13-year period after different forest work practices and seedling population dynamics at the areas which three types of thinning treatment were applied. The specific objectives of the study were 1)to determine what the important factors affecting the early natural regeneration of *P. densiflora* are, 2)to determine the effect of forest work on seed germination and seedling survival, and 3)to suggest the proper method for early natural regeneration of *Pinus densiflora*.

MATERIALS AND METHODS

Study area

Three *P. densiflora* stands after thinning had been practised were selected for study area at Mt. Joongwang in Pyungchang-gun, Kangwon-do. It was recorded that the mother trees were directly seeded in 1928~1929. The first plot (Ⅰ) is located at western boundary of Mt. Joongwang (Da-subcompartment in compartment number 164, compartment number was designated by Pyungchang Regional Office), the second plot (Ⅱ) is north of first plot(Sa-subcompartment in compartment number 164), and the third plot (Ⅲ) at most north among the three plots(Na-subcompartment in compartment number 163)(Table 1). Plots Ⅰ and Ⅱ are located in steep slope (20~70%) and plot Ⅲ in flat. All the plots face south. Forest road has been constructed since 1988. Seedlings are recently regenerating at plots Ⅰ and Ⅲ, but plot Ⅱ shows several age classes of saplings. The plot Ⅰ was thinned strongly in 1992. The plot Ⅱ was treated by seed tree method and thus seedlings or saplings were regenerating normally well. Trees in plot Ⅱ were cut except mother trees in 1982 and seed tree method was retried in 1989. Soil preparation and weed control with hexazinone had been done in every August from 1989 to 1993. Plot Ⅲ was dominated by *P. densiflora* in overstory, *Abies holophylla* and *Picea koraiensis* seedlings were planted in 1994 under *P. densiflora*. It was made as two-storied forest with *P. densiflora* in overstory, and *Abies holophylla* and *Picea koraiensis* in understory.

Shrubs and herbs were similarly composed among all study plots. *Carex* spp., *Chrysanthemun* spp. and *Lespedeza* spp. were common herb species appearing in the plots. In the plot Ⅰ, *Quercus mongolica* and *Quercus accutissima* increased. *Cocculus trilobus* was consistently present and wild strawberry plants were also prevalent. In the plot Ⅱ, wild strawberry was dominant species and *Betula costata* and *Q. mongolica* seedlings

Table 1. General characteristics for study plots

Descriptive variables	Study plot		
	Ⅰ	Ⅱ	Ⅲ
Latitude (N)	37° 27′ 29″	37° 27′ 41″	37° 28′ 19″
Longitude (E)	128° 29′ 35″	128° 29′ 03″	128° 29′ 50″
Altitude (m)	684	896	910
Aspect	South	South	Southeast
Slope (%)	60 ~ 70	20 ~ 30	0 ~ 10
Mean vegetation coverage (%)	10 ~ 60	70 ~ 80	10 ~ 80
Forest work	Thinning was practised in 1992	Trees were cut for seed tree method between 1989 and 1993	Trees were planted in 1994

appeared. In the plot Ⅲ, wild strawberry plants were also dominant species, and logs and snags as thinning residuals were present.

Seed germination, scarification and organic layer removal experiment

In the greenhouse, 100 pine seeds were sown to both pots containing same soil media as field situation and those containing sand with 3 replicates for each soil media to examine seed germination by various soil depths.

The small quadrats(1m×2m) were established inside forest stands and areas harvested to examine the effects of light and soil conditions on the germination of pine seeds. Two treatments(one is only removal of organic layers and the other, organic layer removal and scarification of soils) with 10 replications were applied to each of the small quadrats before seeding. The 100 pine seeds were directly seeded on each of the treatments. Thus the experiment was a randomized block design.

Germinated seeds and survived seedlings at each of the quadrats were recorded on August 14 and 31, 1995 and compared between the two treatments.

Quadrat set, data collection, measurement and data analysis

The 10×10m quadrats were randomly established within each of the study plots. Five quadrats were randomly set for each of the plots Ⅰ and Ⅱ, and 7 quadrats for plot Ⅲ. Five 2×5m quadrats were established along forest road from 684m to 910m from sea level. Pine seedlings regenerated naturally were marked with about 30cm steel stick in spring and observed again in autumn. The number of pine seedlings and their height by age for these quadrats were measured and compared with those occurring at forest roadside. Seedling ages were determined by counting annual rings in basal disc or bud scar. The number of seedlings and saplings and the number of seedlings survived during summer in each of the quadrats were counted.

Canopy coverage was caculated with combining crown width and density of mature trees in each of the plots. Vegetation coverage was the percent of the area covered by vegetation in the quadrat to quadrat area.

Soil was digged with 30×30×5cm in volume, and seeds buried in soil were observed.

Student t-test was used to compare the treatment means using the SPSS.

RESULTS AND DISCUSSION

Seedling emergence in relation to forest works

Pine seedlings appeared suddenly after thinning of mature trees. In plot Ⅰ, there were two 7-year-old seedlings and three 5-year-old seedlings for all quadrats. The 4-year-old seedling, however, was none. Seedlings have increased since 1993 (Fig. 1). It resulted from thinning which was done in 1992 in plot Ⅰ. In plot Ⅱ there were many seedlings at various ages. After thinning for seed tree method in 1982, site preparation and weed control during 1983~1985, seed tree method retried in 1989, and site preparation and weed control were done during 1989~1993. It explained sudden increases in 6-year-old seedlings and decreases in seedlings aged of 1-, 2- and 3-year-old. Four-age class appeared in plot Ⅲ.

The result which many aged seedlings occurred after forest works was similar to that reported by Peal *et al.*(1991) who mentioned that conifer regeneration is generally excessive after logging. Thinning of young stands on upland sites appears to benefit understory conifers, which rapidly expand to fill in the available growing space. Heavy thinning in older stands promotes dense germination of understory conifers making it difficult for other understory plants to become established(Deal and Farr, 1994). Especially this pine seedlings could emerge more after thinning or disturbance which provided the space supplying sufficient light.

The number of mature trees differed among the plots Ⅰ, Ⅱ and Ⅲ(Table 2). But the number of 1-year-old seedlings was the most in plot Ⅰ whereas the least in plot Ⅲ. Tree height in plot Ⅰ was the greatest. Plot Ⅰ was located at the lowest altitude and plot Ⅲ at the highest. So

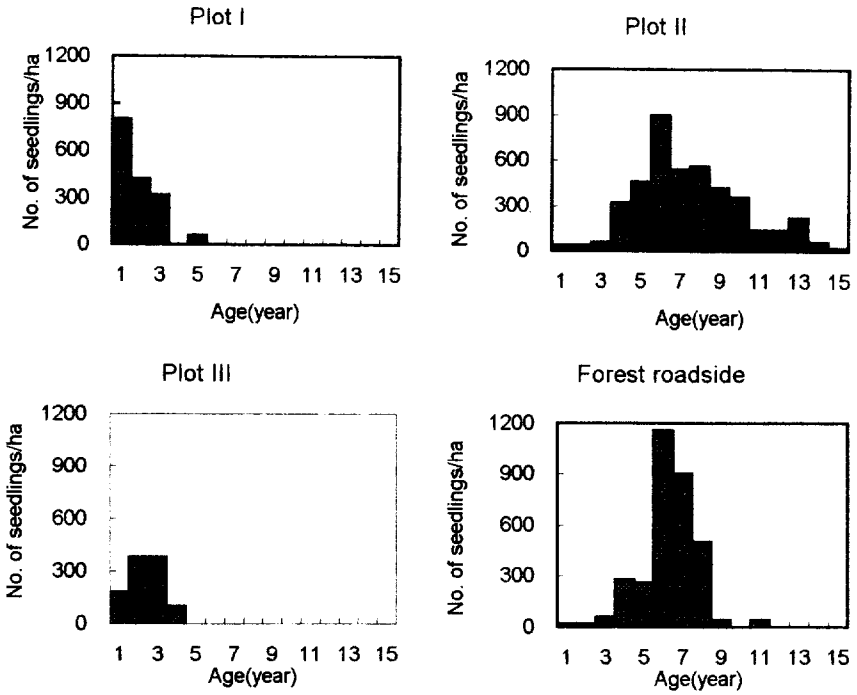

Fig. 1. Distribution of pine seedlings by age for three study plots and forest roadside. Plot I : thinned in 1992; Plot II : seed tree system was applied in 1982 and 1989 and treated with hexazinone in 1993; Plot III : thinned in 1992 and two-storied forest was established in 1994.

Table 2. Mature tree age, number of mature trees per ha, average mature tree height, number of seeds buried in soil per ha, dry weight of herbaceous vegetation biomass, herbaceous plant height, average organic layer for all of the study plots.

	Plot I	Plot II	Plot III	Forest roadside
Mature tree age (years)	63	50-60	62	-
Mature trees/ha	289	22	300	-
Mature tree height (m)	22	20	18.4	-
Volume (m^3/ha)	219	33	187	-
No. of seeds buried in soil per ha	1,667,000	264,000	500,000	-
No. of one-year-old seedlings per ha	1,540	340	180	40,000
Dry weight of herbaceous vegetation biomass (tons/ha)	22.15	22.50	21.60	-
Herb height (cm)	30	50	5	-
Organic layer (cm)	3	3	1	-

trees seemed to grow better at lower altitude. The diameter of mature trees were similar as about 500cm between all three plots. Dry weight of herbaceous vegetation was similar among the three plots. Even though in same plots, the amount of herbaceous plants was different. Herb heights were about 30cm in plots I and III, and about 50cm in plot II.

A sufficient number of well distributed seed trees per unit area must be present for a good potential cone production. The trees must be healthy and windfirm and have well developed crowns. However, a good seed fall will not be sufficient. Suitable microsite and favorable weather conditions are also essential for a good germination and seedling establishment. In plot II, only 22

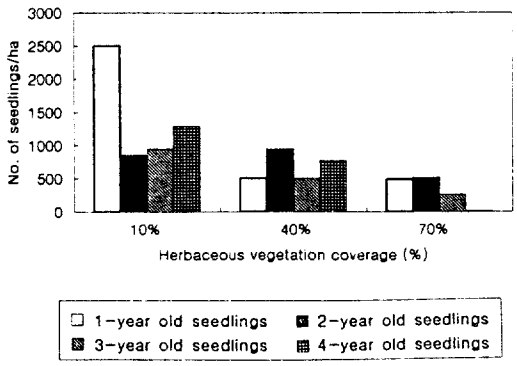

Fig. 2. Seedling density of *P. densiflora* by vegetation coverage

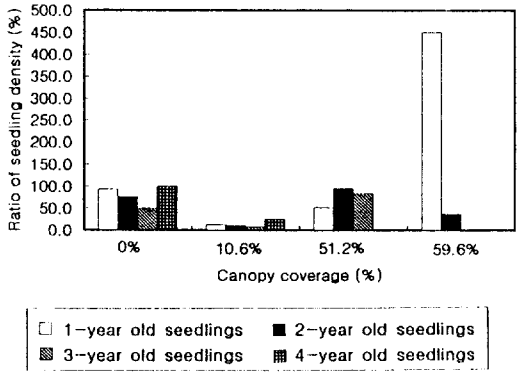

Fig. 3. Survival rate of *P. densiflora* seedlings by canopy coverage (0%: forest roadside; 51.2%: plot I; 10.6%: plot II; 59.6%: plot III).

mature trees per ha produced about 4,000 seedlings. Thus, it was considered that about 20 trees per ha were sufficient for successful natural regeneration of pines.

Seedling survival related to vegetation and canopy coverage

Seedling density by vegetation coverage explained how vegetation affected seedling survival(Fig. 2). In vegetation coverage of about 10%, many small pine seedlings appeared and survived until age 4. But in vegetation coverage of 70%, there were few 4-year-old seedlings in comparison with vegetation coverages of 10% and 40%. Herb patches play a major role in determining the density and distribution of seedlings of leading tree species, and that the distribution of herb patches is significantly affected by both tree canopy foliage and other herb patches(Maguire and Forman, 1983).

Canopy coverage was important to seedling growth. Pine seedlings could grow when enough light reached and its growth was strongly affected by overstory coverage. Tree growth was the best in plot II where canopy coverage was 10.6%.

Seedling survival by canopy coverage showed different results from seedlings density by herb coverage(Fig. 3). Seedling survival rate reached almost 100% when canopy coverage was 0%, but it was the lowest when canopy coverage was 10.6% in plot II. In plot II, there were many herbaceous plants and their height was tall, which inhibits pine seedling growth. Even though overstory was open to supply enough light, pine seedlings were difficult for survival if understory was closed. The unusual survival rate of 1-year-old seedling in canopy coverage 59.6% was caused by delayed germination. There were few 1-year-old seedlings when counted in spring. However, some seeds were germinated after surveying in spring, indicating that their survival rate rather increased in fall.

Effect of scarafication and organic layer removal on seed germination and seedling survival

Germination rate tested in the greenhouse was above 70%. Pine is one of the highest seed-germinating species. But, germination rate in the study plots was very low even though seed supply was enough. In the germination experiment by burying depth, seedlings emerged till 2cm burying depth, but no more seedlings emerged deeper than 2cm.

In the experiment to understand the effect of light and scarification, germination did not seem to be affected by light(Table 3). On August 14, 1995 when seeds were just germinated, there were no differences between the number of seedlings at open area and in the forest. On August 31, 1995, however, those in the forest hardly survived. At open area, the number of seedlings in scarification differed between August 14 and August 31 on. In the litter removal treatment,

Table 3. Germination rate(%) between litter removal and scarification treatment at open area(0% canopy coverage) and in the forest (90% canopy coverage) on August 14 and August 31, 1995.

Treatment \ date		August 14	August 31
At open area	Litter removal	2.1[A]	2.1
	Scarification	4.0*[A]	2.1*
In the forest	Litter removal	2.9	0
	Scarification	3.7	0.2

* and [A] indicate significant differences between August 14 and August 31 in scarification treatment at open area, and between litter removal and scarification treatment at open area on August 14 at 5% level, respectively.

herbaceous plants somewhat appeared. In scratched treatment, about 4 seedlings per square meters decreased to about 2 seedlings per square meters. Every possibilities like insects, disease to explain the decrease of seedlings would be guessed. In this case rain took an important role. From August 24 to August 30, there was heavy rainfall-about 101mm per day(Korea Meteorological Administraion, 1995). In scarification treatment, there were few herbaceous plants to protect pine seedlings from water flowing. Rain hit the bare soil. Therefore, many small seedlings were lost. Herbaceous plants shade pine seedlings and derive them of light to die. But their small amounts helped pine seedlings survive and seedlings could stand shade to some degrees.

Pine trees grew slow till they were 4- or 5-year-old(Fig. 4). Reaching that age, they started growing fast, because tree height at ages 4 or 5 became about 50cm, which was the average height of herbaceous plants in this area. It is possible that pine seedlings lose the competition of light with herbaceous plants. It explained the extremely low survival rate of pine seedlings in plot II. There was weed control with hexazinone from 1989 to 1993 in plot II. There were many 4- to 7-year-old seedlings, but there were few 1-, 2- and 3-year-old seedlings in plot II because many herbaceous plants invaded again and outgrew pine seedlings. Canopy coverage made an important role in seedling emergence and growth. Pine seedlings could grow when enough light reached and its growth was strongly affected by overstory coverage. Tree growth was the best in plot II where canopy coverage was 10.6%.

The establishment, survival and growth of

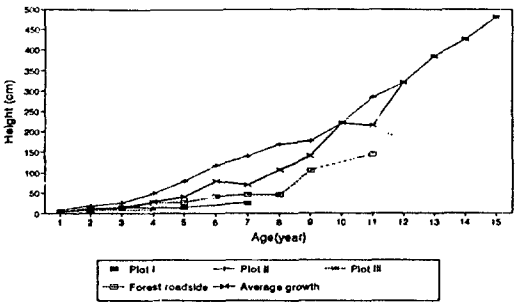

Fig. 4. Height growth of *P. densiflora* seedlings by age for all the study plots

forest seedlings are strongly influenced by the microsite conditions. Soil preparation could modify the climate near the ground to a certain extent. (Lundmark and Hällgren, 1987).

CONCLUSION

Germination rate in the greenhouse was above 70%, but many other micro-environments acted limiting factors for seed germination in the field. Thus seed germination on the field situation was only 2 to 3%.

For early natural regeneration of *P. densiflora*, overstory disturbance like thinning was indispensible to supply enough light for seedling emergence and survival. Even though overstory was open, over 70% coverage of herbaceous vegetation prevented the growth of seedlings and shaded them to die.

Soil scarafication during forest works such as logging helped pine seedling emergence and growth about 4 times better than those growing without scarification.

The scratching by logging operations and slash dispersal were advised to prepare the ground for initial natural regeneration of *P. densiflora*. Weed control was advised till pine seedlings became 4 -to 5-year-old when their height reached about 50cm to outgrow herbaceous plants, but about 10 to 40% coverage of herbaceous plants may be good to protect the growth of pine seedlings from heavy rain. Light, herbaceous plant, canopy coverage and heavy rain were the main factors affecting the early natural emergence of *P. densiflora* seedlings.

LITERATURE CITED

1. Boucher, D.H., J.H. Vandermeer, M.A. Mallona, N. Zamora and I. Pergecto. 1994. Resistence and resilience in a directly regenerating rainforest : Nicaraguan trees of the Vochysiaceae after Hurricane Joan. For. Eco. Manag. 68 : 127-136.
2. Critchfield, W.B. and E.L. Little, Jr. 1966. Geographic distribution of the pines of the world. USDA Forest Service Miscellaneous Publication 97, 991pp.
3. Cui, M. and W.K. Smith. 1991. Photosynthesis, water relations and mortality in *Abies lasiocarpa* seedlings during natural establish -ment. Tree Physiol. 8 : 37-46.
4. Deal, R.L. and W.A. Farr. 1994. Composition and development of conifer regeneration in thinned and unthinned natural stands of western hemlock and sitka spruce in southeast Alaska. Can. J. For. Res. 24 : 976-984.
5. Forest Administration. 1994. Statistical Year Book of Forestry 24. 536pp.
6. Forest Genetics Research Institute. 1993. Development of pines resistant to pine gall midge by use of biotechnology. 41pp.
7. Jo, J.C. 1994. Stand structure and growth pattern of *Pinus densiflora* S. et Z. and their relationship to forest fire in Sokwang-Ri, Uljin-Gun. Ph. D. dissertaton, Seoul National University, Suwon.
8. Kim, K.H. and L. Zsuffa. 1994. Reforestation of south Korea : The history and analysis of a unique case in forest tree improvement and forestry. The Forestry Chronicle 70(1) : 58-64.
9. Korea Meteorological Aministration. 1995. Monthly Weather Report. 48pp.
10. Lee, C.B. 1982. Illustrated flora of Korea. Hyangmoonsa. Seoul. 990pp.
11. Lundmark, T. and J-E Hällgren. 1987. Effects of frost on shaded and on exposed spruce and pine seedlings in the field. Can. J. For. Res. 17(10) : 1197-1201.
12. Maguire, D. and R.T.T. Forman. 1983. Herb cover effects on tree seedling patterns in a mature hemlock hardwood forest. Ecology 64(6) : 1367-1380.
13. Munn, L.C., B.A. Buchanan, and G.A. Nieson. 1978. Soil temperatures in adjacent high elevation forests and meadows of Montana. Soil Sci. Soc. Am. J. 42 : 982-983.
14. Park, K.N. and J.S. Hyun. 1983. Studies on effect of the pine needle gall midge, *Thecodiplosis japonensis* S. et Z. (II). Growth impact on red pine. J. Kor. For. Soc. 62 : 87-95.
15. Peal, R.C., C.D. Oliver and B.T. Bormann. 1991. Reconstruction of mixed hemlock-spruce stands in coastal southeast Alaska. Can. J. For. Res. 21 : 643-654.
16. Roberts, M.R. and H. Dong. 1993. Effects of soil organic layer removal on regeneration after clear-cutting a northern hardwood stand in New Brunswick. Can. J. For. Res. 23 : 2093-2100.
17. Wang, R. and G. Zhou. 1984. Natural regeneration and prospect of Japanese red pine forest in Shandong Peninsula. J. Ecology. China 8(2) : 18-22, 25.
18. Wardle, P. 1968. Engelmann spruce (*Picea engelmannii* Parry) at its upper limits on the Front Range, Colorado. Ecology 49 : 483 -495.
19. Winsa, H. and U. Bergstein. 1994. Direct seeding of *Pinus sylvestris* using microsite preparation and invigorated seed lots of different quality : 2-year results. Can. J. For. Res. 24:77-86.