Study on Silvicultural Operations for Natural Regeneration in Natural Forest Management: Effects of brush cutting on natural todo-fir (*Abies sachalinensis*) seedling

by

Katsutoshi KOSHIKA

天然林施業における更新補助作業の研究

ートドマツ天然生稚樹に対する刈りだし作業の効果ー

小 鹿 勝 利*

Abstract

After the brush cutting of sasa grasses which had suppressed the growth of natural todo-fir (*Abies sachalinensis*) seedlings in a natural forest in northern Hokkaido, the growing process of seedlings, as well as methods and effects of brush cutting, were continuously examined. It was found that brush-cutting contributed to some extent to improvement of conditions for the generation and ecesis of new seedlings. The todo-fir seedlings began to increase faster in tree height 3 or 4 years after brush cutting; their annual height growth increased 4 times over that before the brush cutting. Moreover, synergetic effects of the improvement of light conditions in forests by the crown release of predominant trees at the brush cutting site were observed. Recent years, however, have seen the height growth of seedlings dwindle due to increased competition among seedlings and high crown density of the predominant trees. Density control of seedlings and crown release of predominant trees are essential to maintain growth of seedlings. Furthermore, it was confirmed that brush cutting should be conducted more than once in combination with other tending methods, such as improvement cutting of seedlings and crown release of predominant trees.

Key words: natural forest management, silvicultural operations for natural regeneration, brush cutting, natural todo-fir seedling

Introduction

The importance of natural forest management which utilizes the forces of nature

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*Laboratory of Forest Management, Department of Forest Science, Faculty of Agriculture, Hokkaido University, Sapporo 060

北海道大学農学部森林科学科森林施業計画学講座

has recently been emphasized, reflecting growing needs for diversified afforestation, cultivation of broad-leaved trees and environmental preservation. Although natural forest management has long been carried out in Hokkaido, careless management (e. g. felling without replanting), has prevailed and regeneration work has not been sufficiently conducted. As a result, natural forests have severely deteriorated in quality and decreased in stand volume (KOSHIKA, 1995).

In Hokkaido, natural regeneration is often difficult due to heavy growth of sasa grasses and accumulated fallen leaves or other ground-covering substances. Therefore, when carrying out natural forest management, we cannot depend solely on natural regeneration. Instead, it is necessary to carry out manual silvicultural operations for natural regeneration, such as: securing succeeding trees through supplementary planting and surface scarification, or brush cutting of floor vegetation which suppresses advance seedlings.

Effects of brush cutting as a means of silvicultural operations for natural regeneration have been presented (HIBINO *et al.*, 1941; FUKUCHI *et al.*, 1980). Few, however, have reported the effects and methods of brush cutting based on long-term research. This paper discusses the effects and methods of brush cutting, based on the analysis of the growth process of natural todo-fir seedlings over 20 years after carrying out brush cutting in natural forest.

Survey Site and Methods

The survey was conducted at compartment No. 182 of Hokkaido University's Nakagawa Experiment Forest, a natural forest located 150 m above sea level on a slope facing southeast, where both todo-firs and deciduous broad-leaved trees grow.

Compartments 178 to 185, including No. 182, were designated in 1971 as management experimental forest. Since then, forest management in 8-year circulation periods has been executed there. The silvicultural system has been selected selection cutting system to improve the quality and quantity of the timber resource, and felled trees were mainly minus trees. Table 1 shows the record of cultural operations which was carried out for compartment No. 182. The first selection cutting was conducted in February 1976, and brush cutting of sasa grasses (*Sasa senanensis*), which hindered seedlings from growing, was conducted in September of that year in a 0.44-ha area where regeneration of natural todo-fir seedlings was conspicuously observed. Later, brush cutting was carried out according to the restoration of sasa grasses in 1977, 1978, 1980 and 1985. The second selection cutting was conducted in February 1984. In brush cutting, sasa grasses were cut at their roots with a sickle and then brought out of the compartment. A total of 52.5 people participated in the 5 occasions of brush cutting.

Table 1 Record of cultural opereations in surveyed area

Years	Operations
1976	1st selection cutting
	1st brush cutting (42)*
1977	2nd brush cutting (8)*
1978	3rd brush cutting (4)*
1980	4th brush cutting (3)*
1984	2nd selection cutting
1985	5th brush cutting (5.5)*

*: The total number of man-days for each brush cutting work.

The survey was conducted in July 1977 by establishing an experimental plot (5×20 m) in the brush cutting site. Trees within the plot with heights of 3 m or greater were examined regarding species, diameters at breast height, tree heights, bole heights, locations and branch spread. For trees shorter than 3 m, only species and tree heights were examined. Measurements were conducted 4 times: in July of 1977, 1982 and 1990, and in May 1996. In October 1983, the year previous to the second selection cutting, a 20×40 m section, which included the experimental plot, was established in the brush cutting site, to examine all trees with diameters at breast height of 8 cm or more, regarding their species, diameters at breast height, tree heights, bole heights, locations and branch spreads, with the aim of investigating changes in crown density before and after the selection cutting. Also, in October 1996, 10 todo-fir seedlings of different heights were sampled from the brush cutting site for stem analysis.

Survey Results and Discussion

Outline of surveyed forest stand

Table 2 shows that the forest stand where the experimental plot was established consisted of broad-leaved trees, with predominant trees being oaks (*Quercus mongolica var. grosseserrata*), birches (*Betula ermanii*) and caster aralias (*Kalopanax pictus*), with almost complete crown cover density. Oaks were predominant in terms of number and stand volume, followed by birches which had a stand volume of 362 m^3 per ha. Such broad-leaved stands with high stand volumes were sporadically distributed in compartment No. 182, which as a whole was a mixed forest with coniferous and broad-leaved trees. Predominant trees observed at the experimental plot (5×20m) included 4 oaks, 2 birches and 1 maple (*Acer mono*) (tree height: 16-23 m). Of the lower-story trees, which were taller than sasa grasses (average height: 150 cm), 2 todo-firs (tree height: 1.7-3 m), 2 japanese cucumber trees (*Magnolia obovata*) (tree height: 2-7 m), and 2 *Acanthopanax sciadophylloides* (tree height: 2-3 m), were observed. Natural seedlings, mainly todo-firs, were observed regenerating gregariously in the sasa grasses, which grew thickly on the forest floor.

In this forest stand (20×40 m), 2 oaks and 2 birches were cut in the first selection cutting (1976) and 6 birches, 2 oaks, 4 maples and 1 todo-fir in the second selection cutting (1984). These felled trees were all minus trees.

Table 2 Outline of investigated stand condition (20×40 m, 1983)

Species	Number	Mean brest height daimeter (cm)	Mean height (m)	Stand volume (m^3)
Abies sachalinensis	3	28	15	1.43
Betula ermanii	12	28	22	8.25
Quercus mongolica var. grosseserrata	26	27	20	17.39
Acer mono	5	21	15	1.39
Kalopanax pictus	3	26	18	1.39
Total	49			29.85

Table 3 Number of seedling (5×20 m)

Species	Years			
	1977	1982	1990	1996
Abies sachalinensis	315	1502	647	577
Picea jezoensis		10		
Betula ermanii		14		
Quercus mongolica var. grosseserrata	76	309	67	12
Magnolia obovata	4	12	5	1
Prunus maximowiczii		10	1	1
Sorubus commixta	1	50	20	10
Phellodendron amurense		24		
Acer mono	53	2243	491	128
Tilia japonica		2	2	
Acanthopanax sciadophylloides	7	9	7	5
Kalopanax pictus	1	5	5	
Total	457	4190	1245	734

Changes in seedling population

Table 3 shows changes in the population of seedlings after brush cutting of sasa grasses. Six lower-story trees taller than the sasa grasses (shorter than 7 m) were also included among the seedlings and all were examined together.

After the first brush cutting in 1977, 7 species of 457 seedlings (45,700 trees/ha) were observed. Of them, 69% were todo-firs, while broad-leaved trees consisted mainly of oaks and maples.

In 1982, 2 years after the fourth brush cutting, 5 new species were identified: yezo-spruce (*Picea jezoensis*), birch, cherry (*Prunus maximowiczii*), amur corktree (*Phellodendron amurense*) and basswood (*Tilia japonica*); the total species number rose to 12 and the total population increased 9 times over the 1977 figure. Population of each species observed in 1977 increased: todo-firs and oaks respectively increased by 4 and 5 times, while the population of maples increased remarkably, 42 times. The reason for such a sharp increase in the number of species and population is presumably the fact that ideal conditions for germination were established after 4 brush cuttings, which caused sasa grasses to almost completely disappear and exposed soil, allowing light intensity on the forest floor to rise.

Three species identified in 1982 (yezo-spruce, birch and amur corktree) disappeared by 1990, reducing the total number of species to 9. For that year, populations of almost all species decreased: maples decreased by 78%, oaks by 79% and todo-firs by 57%. The population of trees declined to 1,245, or 29% of the 1982 figure. The population decrease was especially conspicuous among coniferous trees with heights of 10 cm or shorter, and broad-leaved trees 20 cm or shorter, which may be attributed to the fact that seedlings which regenerated after the brush cutting had disappeared due to poor survival of roots, drying and damage by animals. Also noted was the disappearance of lower-story trees such as japanese cucumber tree and *Acanthopanax sciadophyl-*

loides, which were higher than the sasa grasses before the brush cutting.

In 1996, 20 years after the first brush cutting, the number of species decreased by 2 from 1990 to 7, the same number observed in 1977. The population of trees was nearly halved to 734, or 56% of the 1990 figure. The reduction rate was generally higher among broad-leaved trees, at 73%: oaks were reduced by 83% and maples by 74%, while todo-firs were reduced by 16%. Broad-leaved seedlings 30 cm or shorter were conspicuously reduced in number, the reason for which was probably the fact that todo-firs, dominant even before the brush cutting, continued to grow, causing the disappearance of seedlings due to suppression and lowering light intensity available to the floor.

Though changes in generation or disappearance of seedlings after brush cutting of sasa grasses were significant, as shown above, the population of trees eventually increased 1.6 times over 20 years. In forests, generation and disappearance of seedlings are repeated until certain conditions conducive to seedling ecesis are ensured (MORI, 1991). However, brush cutting is thought to have some effects in improving conditions to allow generation and ecesis of new seedlings.

The height growth of todo-fir natural seedlings

This section first discusses the height growth of todo-fir seedlings within the experimental plot, referring to Table 4 and Figure 1.

The average todo-fir seedlings height in 1977 was 48 cm. Most ranged in height from 31 to 100 cm, with 11 seedlings 101 cm or higher, and the maximum tree height being 250 cm.

In 1982, newly generated seedlings led to a reduction in the average tree height to 19 cm, while the number of trees 101 cm or higher had increased to 56, with the maximum tree height being 278 cm. The distribution pattern of tree heights showed 2 peaks, with 6.3 cm the most frequently observed height among the new seedlings after the brush cutting, and 100 cm among the advance seedlings before the brush cutting.

Many of the new seedlings disappeared in 1990, increasing the average tree height to 62 cm. The number of trees with tree heights of 101 cm or greater increased to 157, and 8 were 301 cm or higher, with the maximum tree highest being 417 cm. The tree height distribution for that year showed the same pattern as seen in 1982. The tree height most frequently observed among the new young seedlings was 16 cm and 250 cm among the advance seedlings. The growth of the latter group was especially remarkable.

In 1996, the average tree height increased to 84 cm. Although the number of trees

Table 4 Number of todo-fir seedling in each tree height class

Years	height class (cm)						Total
	0～10	11～30	31～100	101～200	201～300	301～	
1977	30	25	249	10	1		315
1982	1206	35	205	54	2		1502
1990	106	311	73	106	43	8	647
1996	40	300	89	65	40	43	577

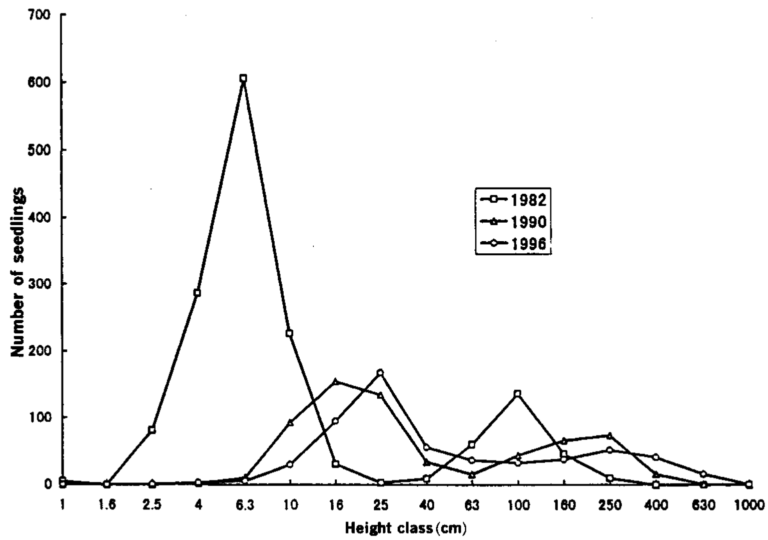

Fig 1 Frequency distribution of height (*Abies sachalinensis* seedlings) in 1982, 1990 and 1996

101 cm or higher was almost the same as in 1990, the number of trees of 301 cm or higher increased to 43, with the maximum tree height being 683 cm. The tree height distribution closely resembled 1 peak, with 25 cm the most frequently observed tree height. Tree heights varied among the advance seedlings.

Figures 2 and 3 show the result of stem analysis conducted for 9 todo-fir seedlings (note: among 10 seedlings collected, 1 was excluded as it was regenerated after brush cutting).

When the first brush cutting was conducted in 1976, the average age of the todo-fir seedlings was 16 years (7-20 years). The average tree height was 62 cm (33-91 cm). The average annual height growth was 4.1 cm (2.4-4.9 cm). In the 20 years after the brush cutting, the average annual height growth increased to 15 cm (7.4-27.2 cm), 3.6 times higher than the figure before the brush cutting, and the average tree height reached 362 cm (147-544 cm). The height growth pattern varied among individual trees. Generally, however, trees grew slowly immediately after the brush cutting and began to grow faster over the next 3 or 4 years. The reason for this is thought to be that, upon being relieved of suppression, the growth of seedling roots took place first in response to sharp increases in transpiration loss, followed by increase in tree height (YAMAUCHI, 1948). Seedlings under suppression do not begin to grow immediately upon relief of suppression, sasa grasses quickly regenerate, which indicates single brush cuttings have great possibilities that seedlings may be again subjected to suppression from sasa grasses where grasses thickly grow.

Also, the comparison of average annual height growth before and after the second selection cutting in 1984 showed the average tree height increased from 9.5 cm to 17.5 cm, presumably due to the improvement of light intensity after the selection cutting, as well as the disappearance of sasa grasses which suppressed todo-fir seedlings.

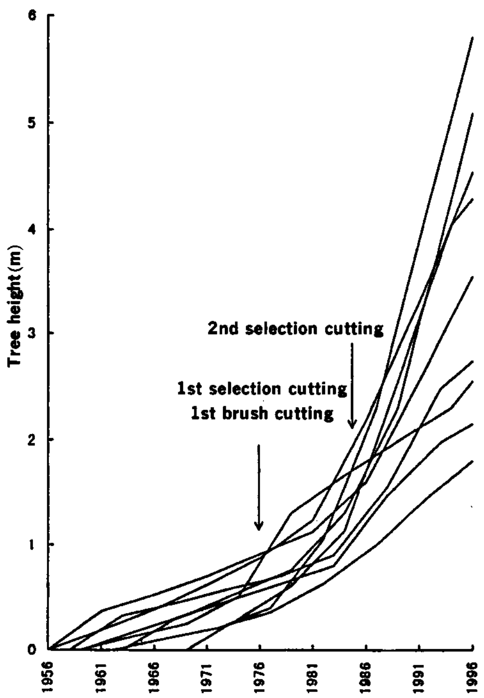

Fig 2 Height growth curves of sample trees (*Abies sachalinensis*)

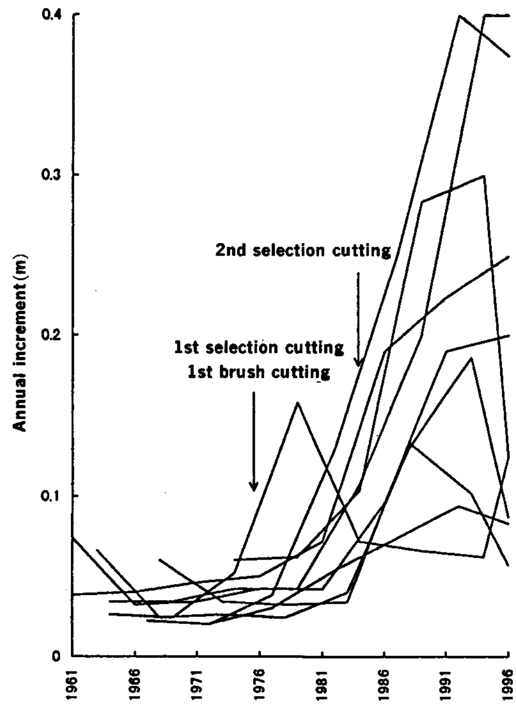

Fig 3 Annual increment of height growth of sample trees (*Abies sachalinensis*)

On the other hand, recent years have seen the height growth of seedlings decline, due to the intensifying competition between seedlings because of high tree density per m^2 (6 trees/m^2), as well as a decrease in light intensity, caused by the advanced crown density among the predominant trees over the 12 years after the second selection cutting.

Conclusion

The growth of natural todo-fir seedlings was surveyed over 20 years after brush cutting, which is one method for silvicultural operations for natural regeneration. Due to its promoting the disappearance of floor vegetation, brush cutting showed an extent of effectiveness in improving conditions for generation and ecesis of new seedlings. The average annual height growth of todo-fir seedlings after brush cutting increased 3.6 times, proving that brush cutting greatly contributes to the growth of seedlings. Moreover, synergetic effects of improvement of lighting conditions by the crown release of predominant trees at the brush cutting site were observed. Recently, however, height growth has begun to decrease, indicating increased competition among seedlings.

The process of height growth after brush cutting showed that trees grow slowly just after brush cutting and then begin to develop faster several years later. Therefore, single brush cuttings are not enough, as possibilities exist that seedlings will be again subjected to suppression from regenerated sasa grasses. It is necessary to conduct brush cutting several times to ensure its effectiveness, in accordance with regeneration of sasa grasses and seedling growth. Table 1 indicates that, although the first brush cutting requires considerable manpower, subsequent brush cuttings require minimal amounts. In addition to brush cutting, crown release of predominant trees and improvement cutting of seedlings should be carried out at the brush cutting site, in accordance with the seedling growth.

Many natural forests in Hokkaido have forest stands where naturally regenerated seedlings are suppressed by sasa grasses, or where the seedlings do not fully regenerate. Therefore, forest reconnaissance should precede forest management so as to accurately understand the regeneration conditions and ensure effective silvicultural operations for natural regeneration according to situations in each forest stand. It is impossible to ensure the effectiveness of such assistance only by simple treatment. It is essential to continuously carry out tending most pertinent to forest conditions, such as appropriate tending or density control of predominant trees according to the growth of seedlings.

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要　　約

現在自然環境の保全や多様な森林造成の必要性から，自然力を活用した天然林施業が再評価されつつある。しかしこれまでの天然林施業は伐採後の林地は放置される等，更新作業が伴わない粗放な施業が多く，その結果森林資源内容は質・量両面の劣化が進行した。特に北海道ではササの繁茂や地被物の堆積により天然更新が困難なことが多く，持続的に森林の維持・再生産を図るためには補助造林や地表処理作業，刈りだし作業等の更新補助作業が不可欠である。本報告では北海道北部の天然林で更新補助作業の一種であるトドマツ天然生稚樹の刈りだし作業を実施し，20年間の稚樹の成長測定をもとに刈りだし作業の効果とその実行方法について検討した。刈りだし作業はササの回復状況に応じて５回実施した。刈りだし作業後，稚樹の発生，消失の変化は大きいが，20年間で稚樹個体数は1.6倍に増加するなど，刈りだし作業は新たな稚樹の発生，定着の条件改善に一定の効果が見られた。トドマツ天然生稚樹は初回の刈りだし作業後３～４年目前後から樹高成長は増加し，刈りだし作業後20年間の年平均成長量は実施前の約４倍に増加し，樹高１ｍ以上の個体数も11本から148本に増加するなど，成長促進

の効果は大きくあらわれた。また刈りだし地の上層木疎開による林内光環境改善の相乗効果もみられた。しかし最近数年間では稚樹間の競争激化や上層木の樹冠うっ閉のため樹高成長は低下しつつある。刈りだし作業後の天然生稚樹の成長経過から判断すると，刈りだし作業実行には次のような考慮が必要と考えられる。①1回限り作業実行ではササの回復により再び被圧される可能性が大きいため，ササの回復を抑えるため複数回の実行。②刈りだし作業単独でなく作業地内の上層木の疎開伐等の併行。③天然生稚樹の成長に対応した除間伐など，継続的な保育作業の実行。