TENDING TECHNIQUES OF FORESTRY IN JAPAN

Takao FUJIMORI*

Introduction

Along the eastern seaboard of the Eurasian continent, the Japanese archipelago extends slenderly from north to south. Although the area covered by Japan itself is not so large, the distance from the northernmost to the southernmost part is considerably large, that is, more than 3,000km, and the climatic and topographical conditions are very complicated. As all parts of the land in Japan are blessed with abundant rainfall throughout the year, they are covered with forests in natural condition and the various forest zones are found there mostly according to variations in temperature conditions. The principal forest zones are subarctic and subalpine coniferous, cool-temperate broad-leaved deciduous, warm-temperate broad-leaved evergreen, and subtropical broad-leaved evergreen. In the cool and warm temperate forest zones which cover large areas and occupy main part of Japan, various coniferous tree species including *Cryptomeria japonica* (Sugi) and *Chamaecyparis obtusa* (Hinoki) are found intermingled with broad-leaved trees in natural condition.- One of the most characteristic points about forestry in Japan is that the man-made pure forests of *Cryptomeria* and *Chamaecyparis* have been established and regenerated by planting in the area whose climax is represented by broad-leaved forests. There, abundant species of plants thrive luxuriantly and inter-specific competition is severe.

As *Cryptomeria* and *Chamaecyparis* have been the most important tree species for timber production in Japan, their pure man-made stands have been widely established. The ratio of man-made forests in 1976[12] was 35% in area, 98% of which consisting of coniferous stands. The ratios of the area where *Cryptomeria* and *Chamaecyparis* were planted against the whole plantation area of coniferous species are 37% and 32% respectively[12]. Thus the tree species which are to be discussed here will chiefly be *Cryptomeria* and *Chamaecyparis*.

Properties of *Cryptomeria* and *Chamaecyparis*

Cryptomeria belongs to the family *Taxodiaceae*. The stem tends to grow straight and to attain a full body if the conditions are appropriate. The wood quality is appreciated for its appearance, touch, and smell as well as for its physical properties. This species prefers wet soils as compared with *Chamaecyparis*.

Chamaecyparis belongs to the family *Cupressaceae*. Its growth rate is smaller than that of *Cryptomeria* but its wood quality is considered to be superior to that of *Cryptomeria*.

Use of timber in Japan

Tending techniques cannot be fully discussed without fixing the objectives of the timber production. Thus the use of timber in Japan will be briefly outlined here. As Japanese culture has been referred to as a culture of wood, living and cultural patterns in Japan are closely related to the use of wood. Recently, various raw materials have replaced wood in many cases, but wood is still widely used and firmly demanded. As the taste of Japanese people for wood is pronounced, there is a tendency for the range of timber price to be considerably wide according to the quality of the wood even in the same species. Another important point about forestry in Japan is that the wood quality has been largely controlled by tending techniques as well as other techniques in forestry.

According to the standards on timber authorized by the Ministry of Agriculture, Forestry, and

---

* Chief, 2nd Silviculture Laboratory, Silviculture Department, Forestry and Forest Products Research Institute; Ministry of Agriculture, Forestry and Fisheries, Kunizaki, Inashiki, Ibaraki, Japan.

Fisheries of Japan, the main conditions for obtaining high quality timber are stipulated as follows:
(1) Fewer and smaller knots (especially dead or rotten knots)
(2) Better colour and luster
(3) Uniformity and adequate range (less than 6mm) of annual rings
(4) Less disturbance and inclination of fiber strike
(5) Less rot, discolouration, and other particularities

To satisfy condition 4 and to increase the yield percentage of sawing, tapering of the stem should be avoided and stems should be round and straight, especially in the case of the production of smaller size logs.

History and present situation of tending techniques in Japan

In Japan there are many forestry areas known for their own products and techniques, some of which are shown in Fig. 1. According to the records,[11] the oldest plantations for the production of timber in Japan date back to at least the 1600s in many forestry areas. The advanced forestry areas have developed and consolidated their tending techniques through years in association with the use of timber. Table 1 shows the aims of production and the corresponding tending types in the historical forestry areas of Japan. Table 1 was drawn with the view of stressing the historical particularities of Japan's forestry. Recently however, there is a tendency for the range in the number of planting trees to become smaller in the various areas while the cutting period is becoming relatively longer. Also pruning is being more widely performed. The reduction in the range of the number of planting trees must have been caused by the decrease in the demand for smaller size logs such as scaffoldings or large size and tapering logs such as timber for shipbuilding. Therefore the optimum range in the number of planting trees has been fixed in taking into account economic and ecological factors.

Fig. 1 Forestry areas known for characteristic (tending) technique

In this report, an example of the tending system in the National Forest and typical tending system in Yoshino area (private forests) will be introduced here (Table 2). Most of the timber products in the National Forest are common timber and the management is comparatively simple. On the other hand, as the production in Yoshino aims at high quality timber, the management is intensive. In Yoshino the number of planting trees per given surface area and the number of thinnings is larger, also pruning is conducted more positively when compared with that in the National Forest. The number of weedings in Yoshino is smaller than that in the National Forest and vine cutting is seldom necessary in Yoshino. This tendency must be ascribed to the difference in the stand density between both areas. A comparison between the number of planting trees in both areas, as illustrated in Table 2, shows that in Yoshino the number used to be larger (10,000/ha or

Table 1 Main tending types and objectives of timber production in Japan

Stand density	Thinning	Cutting period	Pruning	Main uses of production	Forestry areas
Close	Frequently conducted from early stage	Long	Conducted	Large size high quality timber for board and other uses	Yoshino
	Frequently conducted from early stage	Short	Frequently conducted	Small size polished log for pillars	Kitayama
	Conducted	Short	Conducted	Square timber for pillars	Nishikawa Oome
Intermediate	Conducted	Long	Conducted	Large size high quality timber for board and other uses	Chizu
	Conducted	Medium ~ Long		Common timber	National Forest
Sparse	Conducted to promote the growth of individual trees	Long		Shipbuilding timber	Obi
	Seldom conducted or loosely conducted	Short		Common timber, Telegraph pole timber	Tenryu, Hita, Oguni, Kitoo

Comment: This table was made after modifying the table drawn by Sakaguchi.[3]

Table 2 Examples of current tending systems applied in Japan

	Species	Number of planted trees per ha	Weeding	Vine cutting	Salvage cutting	Pruning	Cutting period	Objectives of the production
National Forest	*Cryptomeria japonica*	3000~5000	From the planted year to 5~7 years after	Once or twice	Once or twice	No	40~50	Common timber
	Chamaecyparis obtusa	3000~4000	From the planted year to 5~7 years after	Once or twice	Once or twice	Twice	50~55	Common timber
Yoshino	*Cryptomeria* or mix of *Cry. & Cha.*	6000~8000	From the planted year to 4~5 years after	No	Twice	Three or four times	60~70	High quality timber

more) while that in the National Forest used to be smaller (3,000/ha), that is, the difference in the number of planting trees between both areas has become smaller recently. Such tendency is becoming increasingly conspicuous in many forestry areas in Japan for the reasons outlined above.

Significance and role of each tending technique in Japan

Almost all of the forest management in *Cryptomeria* and *Chamaecyparis* has been centered on the clear cutting system. And it could be said that the management by the clear cutting method has been successful although several of its defects have not been eliminated or corrected. The greatest shortcoming is that it usually brings about more or less the reduction of site quality and in the worst case, land devastation. To avoid such shortcomings and make use of the advantage of multi-storied forests, methods aiming at omitting clear cutting have been studied, tried and in some places practically adopted. However, there are still problems to be solved to establish such systems successfully. The methods omitting clear cutting, as mentioned above, include the establishment of two-storied forests as well as selection forests of *Cryptomeria* and *Chamaecyparis*.

Main tending techniques in the clear cutting method and procedures omitting clear cutting in Japan are shown in Table 3. Among the tending techniques in the clear cutting method weeding and vine cutting are essential techniques to produce and maintain stands composed of planted trees. In making a pure coniferous stand in the warm-temperate and cool-temperate zones in Japan (Fig. 2), planted trees will not be able to grow up to form the stand unless they are protected from interspecific competition and weeding and vine cutting should be performed.

Thinning is not absolutely necessary to produce and maintain a healthy stand. As a result of thinning, the remaining trees are healthier and the understorey vegetation can develop and grow vigorously, which is important for the maintenance or recovery of the soil fertility (Fig. 2). In forest

Table 3 Main tending techniques and their significance in Japan

		Weeding	Vine cutting	Salvage cutting	Stand density control (thinning)	Pruning	Fertilization
Clear cutting system	Essential technique for the production and maintenance of a stand	◎	◎	○	◎		
	Technique for the control of wood quality	○	○	○	◎	◎	○
	Technique for the promotion of growth	○	○	○	○		◎
Omission of clear cutting system	Essential technique for the production and maintenance of a stand	○	○	○	◎	◎	
	Technique for the control of wood quality	○	○	○	○	◎	
	Technique for the promotion of growth	○	○	○	○		◎

Comment: ◎ indispensable or important technique
○ useful technique

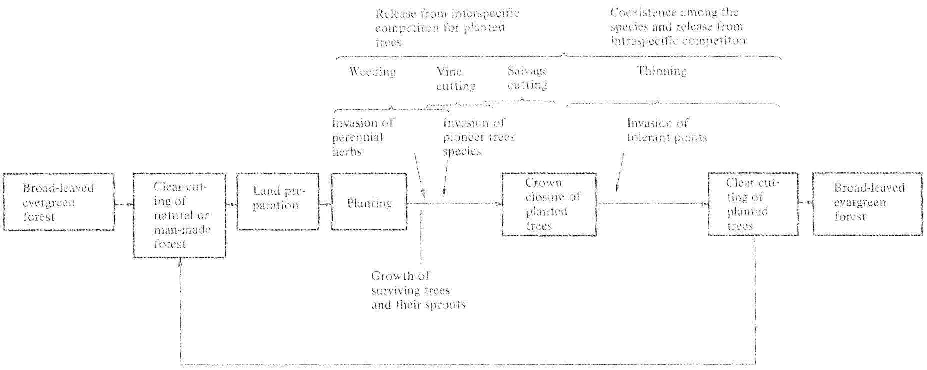


Fig. 2 Position of man-made forests in plant succession in the warm-temperate zone of Japan and essential tending techniques for their production and maintenance

Comment: As for plant succession in man-made forests in Chiba prefecture, a model like this one was shown by Ooga and Sakura.[8)]

management for the production of timber, thinning (stand density control) is important for the control of the wood quality in a stand. The quantity of wood in a stand can also be monitored by stand density control to a certain extent. Pruning is not necessary for the production and maintenance of a stand, but when it comes to the production of high quality wood, pruning is essential.

In the case of methods omitting clear cutting, thinning including selection cutting and pruning are essential techniques to produce and maintain a multi-storied forest. In order to produce and maintain a multi-storied forest of *Cryptomeria* or *Chamaecyparis*, distribution of sunlight to the lower strata by thinning or selection cutting and pruning is absolutely necessary (Table 3). On the other hand, weeding and vine cutting techniques which are essential in the clear cutting method are not so important when the clear cutting method is omitted.

The significance of fertilization should be evaluated independently from the techniques mentioned above. The principal purpose of fertilization is to increase or restore land productivity or stem growth. If there is no need to improve land productivity, fertilization is not essential for either clear cutting method or method omitting clear cutting.

Among the techniques surveyed above, stand density control (thinning) appears to be the most important technique in any case. Pruning is also important for the effective production of high quality timber and intensive forest management with pruning is one of the most characteristic forms of forest management in Japan. These two techniques will be discussed in this report in relation of the clear cutting system from a theoretical angle and as an opportunity to present the results of studies carried out in Japan.

Techniques and theoretical considerations

1. Weeding

In general, weeding is performed once a year (from the middle of June to the middle of July) during 5—8 years after planting, in other words, it is continued until the height of the planted trees reaches 1.5 times that of other plants. In the more intensive management, weeding is performed twice a year (June and August) during the first three years or so. Weeding is operated by hand with a sickle or a brush cutter, and herbicides are used in some areas. Vine cutting and salvage cutting follow weeding and are conducted generally once or twice (Fig. 2).

2 Stand density control (Thinning)

If the stands belong to the same species and are of the same age, if the grounds are in the same condition, and if only the stand density varies, such effects as indicated in Table 4 have been recognized in connection with the relation between the growth of tree and stand density.[1) 6)] The relationship between stand density and stem configuration is shown in Fig. 3,[6) 2)] while the effect of the density in relation to the weight of each component of trees in a stand is shown in Fig. 4.[6)].

When the stand density is considered, one of the most important factors is the relationship between the growth of each tree and that of a stand per given area. The theories of intraspecific competition and stand density control which have been worked out in Japan [7) 1) 6)] will be introduced here.

Table 4 Stand density effects

As stand density increases, each factor responds as follows:	
Mean height of dominant trees	Moderate decrease
Mean diameter of stem	Decrease
Non-tapering of stem	Increase
Ratio of clear length	Increase
Density of annual rings	Increase
Mean stem volume	Decrease
Total stem volume per definite area	Increase to a certain extent

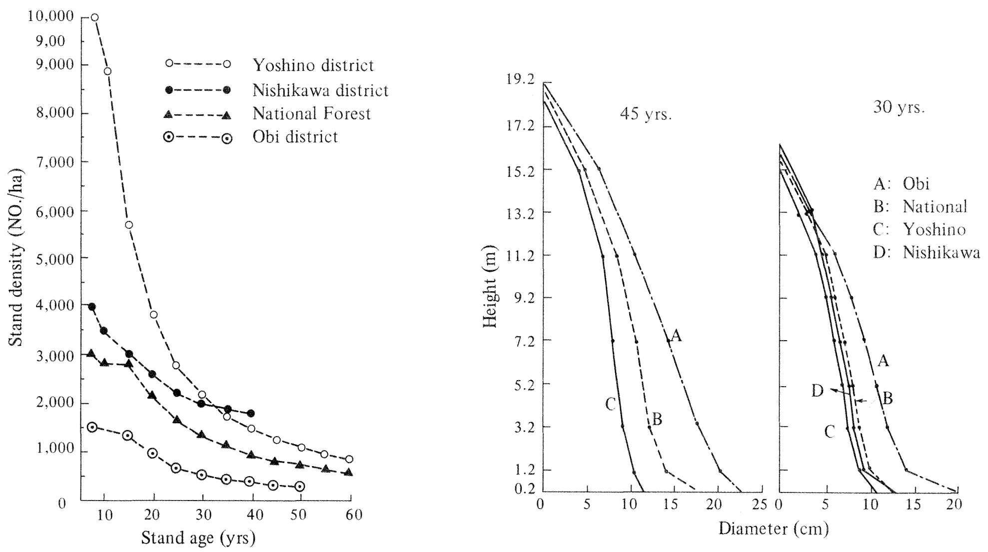


Fig. 3 Relation between stand density control and stem shape in *Cryptomeria japonica* stand (Andoo et al., 1968)

When the following conditions are satisfied, that is, 1) Conditions for growth are identical except for stand density 2) Seeds are sown or seedlings are planted under various stand density, 3) The growth of the all stands starts at the same time, the relation between the mean weight (w) and the number of the individual trees (ϱ) after a certain period of time is as follows:

$$1/w = A\varrho + B \,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\, (1)$$

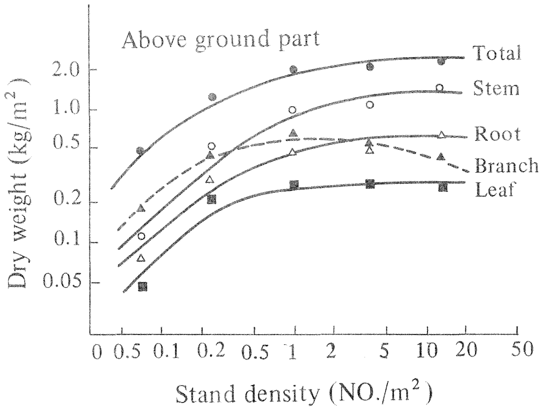


Fig. 4 Stand density effect in relation to the weight of each component of trees in *Larix leptolepis* stands (Hatiya, 1964)

Here, the coefficients A and B are a function of time (t). This relation is called Competition-Density effect (C-D effect), and Equation (1) is called reciprocal equation of the C-D effect. As there is a relation between the weight per definite area (y) and stand density, namely

$$y = w \times \varrho$$

Equation (1) becomes

$$1/y = A + B/\varrho \;\ldots\ldots\; (2)$$

This relation is called the Yield-Density effect (Y-D effect), and Equation (2) is called the reciprocal equation of the Y-D effect. The C-D and Y-D effects apply to both herbaceous plants and trees, and in the case of trees, they correspond not only to the whole weight but also to the stem weight (volume or even basal area of stem). The C-D and Y-D effects in connection with stem volume of *Cryptomeria* are shown in Fig. 5.

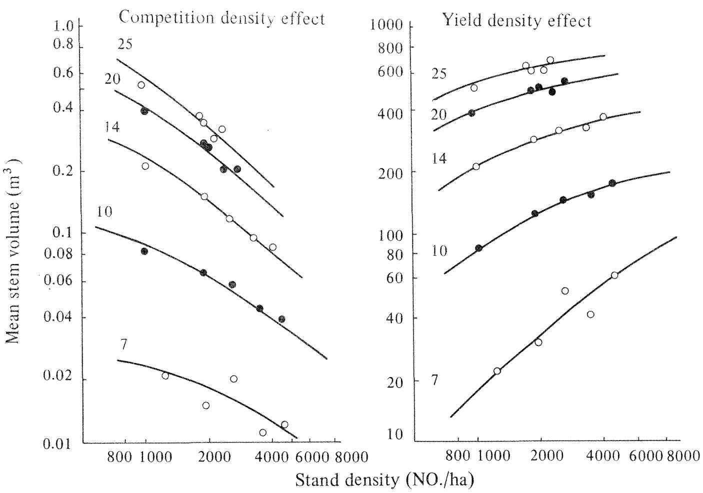


Fig. 5 Stand density effects in connection with stem volume in *Cryptomeria japonica* stands (Figured after Syuu by Andoo, 1962)

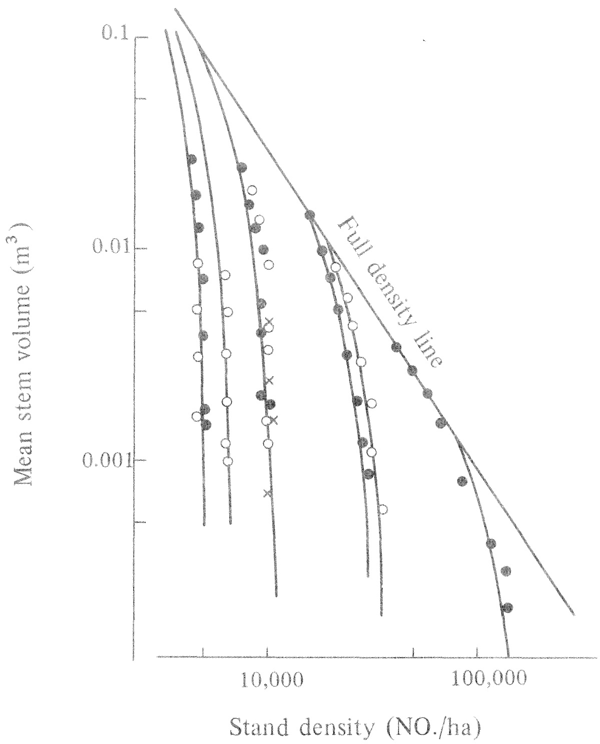


Fig. 6 Process of self-thinning and full density curve in *Pinus densiflora* stands (Hatiya, 1967)

In a stand there is a limit in the number of trees which can coexist in each growing stage. In a stand, as the growing stage advances, competition among individuals becomes severe and the phenomenon of self-thinning occurs. Consequently, there is an upper limit in the number of trees in each growing stage of each species. In a closed stand in which self-thinning is taking place, the following relations are found among stand density (ϱ_f), mean individuals (w), and the yield per definite area (y).

$$w = k\varrho_f^{-a} \quad \ldots\ldots\ldots\ldots (3)$$

$$y = k\varrho_f^{1-a} \quad \ldots\ldots\ldots\ldots (4)$$

Here, k and a are the coefficients characteristic of each species. The curve drawn according to Equation (3) or (4) is called the full-density curve. Fig. 6 shows the process of self-thinning and full-density curve according to the growing stage in a natural stand of *Pinus densiflora*. The curve of self-thinning is expressed by the following equation:

$$1/\varrho = A'v + B' \quad \ldots\ldots (5)$$

Here, ϱ, v, and A', B' express the stand density at a certain time, the mean stem volume, and coefficients corresponding to the full-density curve and initial planting density.

The laws on the density effects mentioned above have been applied to the tending technique in forestry. The stand density control diagram was worked out on the basis of the fundamental laws on density effect. Fig. 7 is an example applying to *Cryptomeria*. The diagram can be interpreted as follows:

Equivalent mean height line: Each line which runs from the left lower part to the right upper part expresses the relation between stand density and stem volume per ha according to the mean height of the dominant trees.

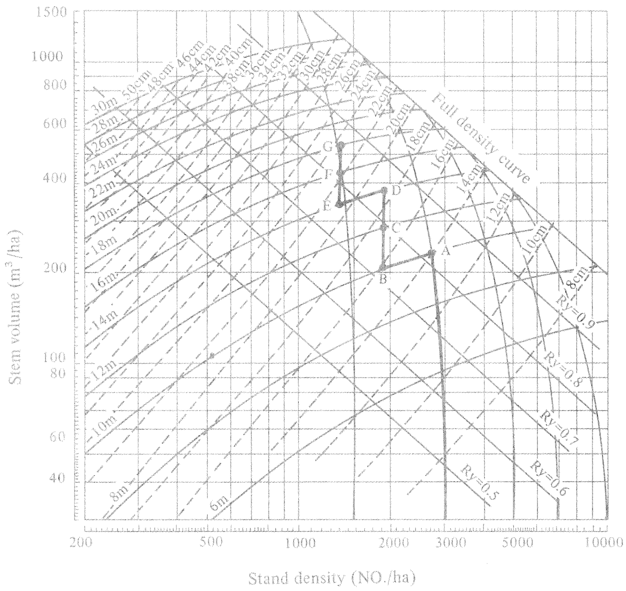


Fig. 7 Example of stand density diagram of *Crytomeria japonica* (Hatiya, 1970)

Full-density line and self-thinning line: Oblique line of right upper part is the full-density curve (it is expressed by a straight line on log-log graph). Each line which runs from the base upward with a slight incurvation is the self-thinning curve.

Equivalent mean diameter line: Each dotted line which runs from the full-density curve to the left lower part of the diagram expresses the mean diameter in connection with mean height and stand density.

Yield index line: Each line which runs parallel to the full-density curve expresses the yield index (Ry) which corresponds to the ratio of the stem volume of a stand at a certain density against that at full density when mean tree heights of the stands are identical.

A stand density control diagram can be drawn in combining these lines on a log-log graph (Fig. 7). On this diagram, various relations among stand density, stem volume, mean tree height, and mean diameter of a stand can be read at a time and the future growth condition of the stand can be estimated in connection with stand density control.

The following example illustrating density control will be demonstrated using the diagram (Fig. 7). Three thousand trees per ha are planted, and in 30% of them thinning is performed when the mean tree height reaches 10m and 14m. The final cutting is undertaken when the tree is 18m high. This process is indicated by the thick line on Fig. 7. First thinning is performed at point A which is at the intersection of the self-thinning line which started from 3,000/ha and the tree height (10m). It can be seen that at point A the tree number has been reduced to 2,700/ha, and the stem volume and mean stem diameter are 230m³/ha and ca. 14cm, respectively. When 30% thinning is performed at point A, the result is seen at point B, that is, the remaining tree number is ca. 1,900/ha, the remaining stem volume is ca. 210m³/ha, and mean stem diameter is ca. 16cm. In this case, smaller trees are mainly removed. At point D, the second thinning is performed, and the tree number, stem volume, and mean stem diameter move to point E. Final cutting is performed at point G, where the tree number is ca. 1,350/ha, mean stem diameter ca. 24cm, and ca. 530m³/ha stem volume is harvested.

The stand age is not taken into account in the stand density control diagram. When information about the stand age is required, it can be obtained using the general yield table for the same area of the stand density control diagram. In the yield table, mean tree height, mean diameter, tree number per ha, and stem volume per ha on each site index can be determined according to stand age.

The way to select the cutting trees in a stand which is an important technique will be omitted owing to lack of space in the present report.

3 Pruning

Pruning effects which have been clarified are summarized in Table 5.[5] These effects can be applied to forest management. The principal objectives of pruning are as follows:

1) Production of high quality timber (especially knot-free timber), 2) Control of the fluctuation in the size of individual trees in a stand, 3) Prevention of the damage by blight and harmful insects, 4) Prevention of the damage by snow covering the crown or strong winds (for the trees whose crowns are asymmetrical), 5) Distribution of sunlight to the lower strata in a stand.

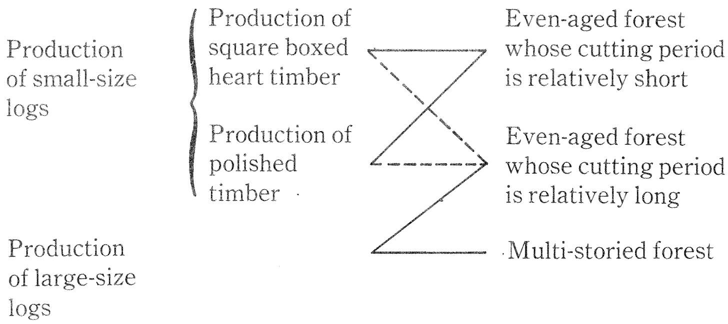
Table 5 Pruning effects

			Pruning of living branches	Pruning of dead branches
Stem growth	Height growth		Decrease (Smaller in comparison with diameter growth)	No change
	Diameter growth		Decrease	No change
	Stem shape		Non-tapering increase	No change
Formation of knots	Number of knots		No change	No change
	Size of a knot	Length	Decrease	Decrease
		Thickness	Decrease	No change
	Distribution of knots	Vertical direction	No change	No change
		Horizontal direction	Decrease	Decrease
Light intensity in the lower strata in a stand			Increase	Increase to a certain extent
Crown shape			More symmetrical	No change
Discolouration of stem wood			Prevents the discolouration around a dead knot. (Rough operation causes opposite effect)	Prevents or decreases the discolouration around a dead knot. (Rough operation causes opposite effect)
Deviation of the size of individual trees in a stand			Decrease or increase	No change

Among them, as the production of high quality timber has been the most important objective, the explanation of the pruning technique will be outlined in association with the production of high quality timber, in this report.

By the removal of branches, the range of the horizontal distribution of knots in a stem can be controlled and the absence of tapering of a stem becomes enhanced. These procedures are also effective for the density effect. Thus the tending system for the production of high quality timber usually combines the density control system and pruning system. But only the pruning technique enables to control most exactly the horizontal range of the knots.

The production of knot-free timber involves two types, that is, small-size logs for poles and large-size logs for the boards and other uses.



Broken lines on the diagram illustrate harvesting by thinning.

The objective of the pruning for the production of square boxed heart timber is the effective production of timber whose surface is knot-free. Fig. 8 represents the relation between the size of a square timber (y), the diameter of the log within which pruning should be conducted to make the surface of the square timber knot-free (x), and the diameter of the log over which sawing can be carried out to produce the square timber (z).[10]

When the surface of the square timber whose side measures $y$cm is required to be knot-free, the surface of the stem should be knot-free when the diameter of the stem attains $y$cm. Thus the stem diameter within which pruning should be performed (x) is:

$$x \leqslant y - 2l$$

Here, l indicates the length needed for the occlusion of a branch stub.

When the log is bent, the equation becomes:

$$x \leqslant y - 2l - b$$

Here, b indicates the length of the bending of a bucked log.

In Japan, the most common size of square timber is 10.5cm × 10.5cm × 3m. The maximum length for the occlusion of branch stub is ca. 1cm when pruning is carefully conducted, and 1 or 2cm bending for a 3m length is common.[11][10][4] Thus it can be said that when aiming at producing square boxed heart timber without knots and measuring 10.5cm in side, pruning should be conducted until the diameter reaches 7cm.

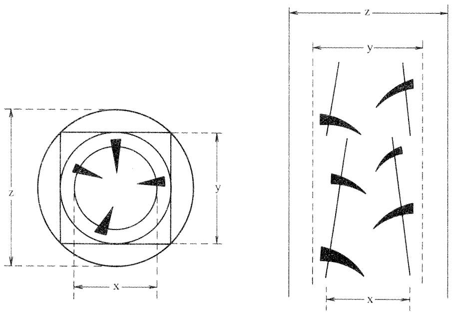


Fig. 8 Size in relation to pruning and product (Takeuchi et al., 1977)

y: Length of one side in square boxed heart timber without knots

x: Stem diameter just below the lowest branch at the time of pruning

z: Minimum stem diameter (z) needed for the production of timber of which the length of one side is y $z = \sqrt{2} \cdot y$

The appearance of dead knots is one of the worst shortcomings. As the dead knots usually appear in the sapwood which is the most valuable part of a log, the pruning for the removal of dead knots is important for the production of high quality large-size logs. In the case of the production of large-size logs, it is not necessary for the size within which pruning should be conducted to be as strictly defined as in the case of small-size logs, but it is necessary for the range in which knots appear to be as small as possible.

Fig. 9 illustrates a pruning control diagram in association with stand density control.[4] As shown in Fig. 9, the aim is to produce knotless timber both of large and small size. The interpretation of Fig. 9 is as follows:

1) The horizontal and vertical lines indicate tree age and tree height respectively.

2) The solid line on top represents the tree height. Each solid line below the tree height line is the equivalent line indicating the stem diameter without bark at certain height depending on tree age. The values 7 and 9cm express the stem diameter within which pruning should be conducted to obtain square boxed heart timber without knots measuring 10.5 and 12cm in side respectively. The values 16 and 18cm express the minimum diameter at the top end of the bucked log enabling to obtain square timber measuring 10.5 and 12cm in side respectively. The value 28cm expresses the minimum diameter at the top end of the bucked log for a large-size log.

3) Each of the four solid lines which are parallel to the horizontal line indicates the length of each bucked log or the sum of several of them. (3.5m means 3m log plus 0.5m base which is not used and removed; 6.5m means 2 bucked logs 3m long plus 0.5m base.)

4) The line with dots separated by dash shows the height under which stunted branches appear.

5) The solid line which runs from the left upper part to the right lower part shows the stand density. The tending system indicated in Fig. 9 is frequently applied in Japan in the most intensive management. Although the areas where such tending system can be adopted are limited, this type of management is characteristic of Japanese forestry.

Pruning, in Japan, is performed by hand with a hatchet, sickle, and saw, among which the hatchet is the instrument most commonly used.

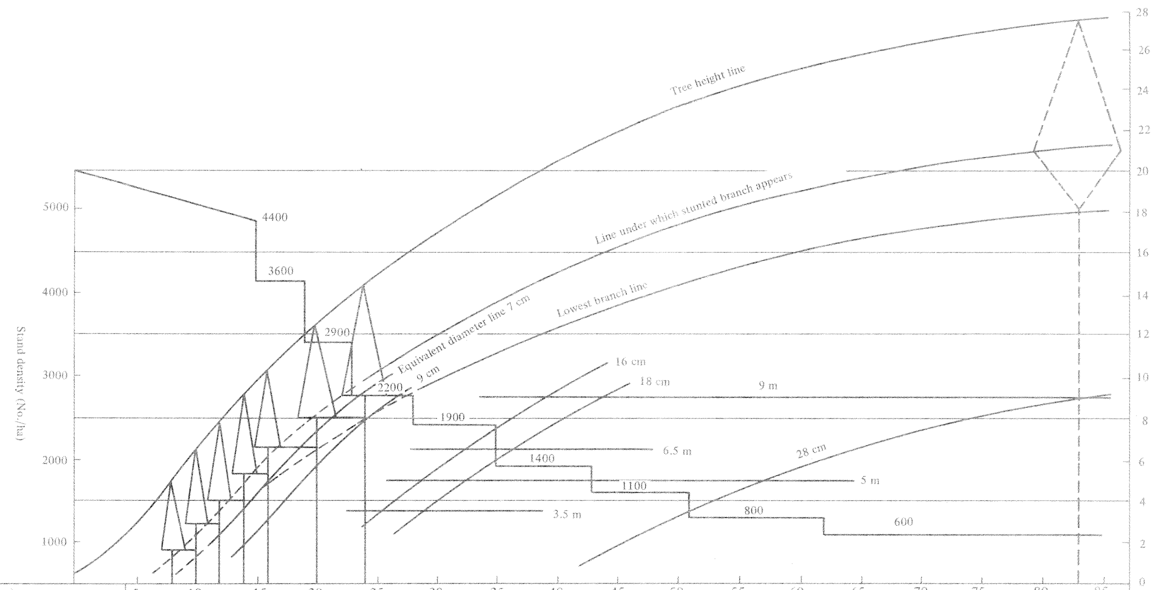
4 Fertilization

Forest fertilization has been tried and used partially in Japan since the 1960s. It goes without saying that the principal purpose of fertilization is to increase land productivity or stem growth. However, as far as production and forest management are concerned, the significance of fertilization is not definite. For example, to produce high quality wood or to produce as much volume as possible on condition that the quality does not decrease, fertilization should be done mainly in the latter part of the growing stage to make the width of annual rings uniform. Recently the significance of this aspect has been recognized. It should be also pointed out that the unnecessary reduction of the stem growth after pruning is compensated by the effect of fertilization. As such, the significance of fertilization can be enhanced by its combination with other techniques. Meanwhile, fertilization can play an important role for the improvement or recovery of the productivity of land.

Tending techniques in the deep snow area

In the deep snow area in Japan, tending techniques to cope with heavy snow are very important. Attempts to establish a tending system have been made but many problems still remain to be solved. Details about the tending techniques in the deep snow area will be omitted here, although their importance must be emphasized.

The climatic and topographical conditions in Japan are very complicated. For example, during the summer it is hot and humid like in the tropical countries and abundant species of plants thrive luxuriantly. During the winter, it is considerably cold and the damage caused by the cold itself as well as by cold winds is often important. We often have strong winds and typhoons with torrential rains bringing about great damage. We also have heavy snow along the Japan Sea coast area and wet snow which prevent normal growth of the planted trees and cause various damage.



Stand age (year)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Mean d.b.h. (cm)	3.3	6.3	9.9	13.6	17.1	20.2	24.4	26.6	29.7	31.9	33.0	34.1	35.0	35.5	35.9	36.3	36.6
Mean tree height (m)	2.7	6.3	9.6	12.5	14.8	16.8	18.8	20.3	21.8	23.0	24.0	24.9	25.7	26.3	26.8	27.1	27.4

Pruning								
Frequency	1	2	3	4	5	6	7
Tree height (m)	4.8	6.3	7.6	9.0	10.2	13.4	14.6
Clear length (m)	1.5	2.8	3.0	5.2	6.5	8.0	9.0

Harvesting of knot free square: One of 10.5 x 3; Two of 10.5 x 3; Two of 12 x 4; Two of 12 x 4

Harvesting of large size log: One of 4 m; Two of 4 m

Thinning								
Frequency	1	2	3	4	5	6	7	8
Number of removed trees	800	700	600	400	500	300	300	200
Ratio of removed trees	18	19	21	17	26	21	27	25
Yield	Small square			Square box timber for pillar				Multiple uses

Multiple uses

Weeding →

Fig. 9 Example of pruning control diagram in association with other tending techniques in *Cryptomeria japonica* stands (Fujimori, 1976)

Under such conditions, careful management and tending techniques are needed to produce and maintain healthy man-made forests. It goes without saying that we should make efforts to improve the tending techniques and establish better and multifarious tending systems adapted to the changes in natural conditions.

References

1) ANDOO, T. (1968): Ecological studies on the stand density control in even-aged pure stand. *Bull. Gov't For. Exp. Sta.*, **210**, 1-153.
2) ANDO, T., HATIYA, K., KATAOKA, H., KATOO, Y., and SAKAGUCHI, K. (1968): Studies on the system of density control of *Cryptomeria japonica* stand. *Bull. Gov't For. Exp. Sta.*, **209**, 1-76. (Japanese with English Summary)
3) FUJIMORI, T (1975): Studies on the technical system of pruning. *Bull. Gov't For. Exp. Sta.*, **273**, 1-74. (Japanese with English Summary)
4) ———— (1976): Pruning and its theory. Jap. For. Tech. Associ., 75 pp. (In Japanese)
5) ———— (1977): Objectives of timber use and pruning. Print for the Symposium at 28th Kansai Meet. Jap. For. Soc., 51—59. (In Japanese)
6) HATIYA, K. (1970): Laws of density effect and stand density control diagram, Selection of 33 new techniques in forestry. National Forestry Extension Associ., 164-195. (In Japanese)
7) KIRA, T. et al. (1953—1963): Intraspecific competition among higher plants I—XI. *J. Inst. Polytech.* Oosaka City Univ.
8) OOGA, N. and SAKURA, A. (1975): Forest vegetation in Chiba prefecture (4), Influence by human agency (Secondary forests and man-made forests). Flora in Chiba pref., Chiba Biol. Soc., 83-102. (In Japanese)
9) SAKAGUCHI, K. (1971): Studies on basic factors in thinning. *Bull. Gov't For. Exp. Sta.*, **131**, 1-95. (In Japanese)
10) TAKEUCHI, I. and HATIYA, (1977) K.: Studies on occlusion after artificial pruning. *Bull. Gov't For. Exp. Sta.*, **292**, 161-180. (Japanese with English Summary)
11) Jap. For. Tech. Associ. (1972): History of forestry techniques I. 727pp. (In Japanese)
12) Survey of the statistics in forestry, (1977): Rinya Kyosaikai, 235pp. (In Japanese)

Discussion

Choob K. (Thailand): Since most of your man-made forests are located on slopes, to avoid severe soil erosion and public pressure, how big should be the cutting area you consider to be economically feasible in clear felling? What criteria should be considered in allocating the size of the plot?

Answer: The smaller the area and the longer the cutting period, the better from the ecological and economic point of view. We prefer to plant seedlings prior to carrying out clear cutting.