広葉樹幼齢林の林分構造と生長量

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Structure and growth of young deciduous hardwood forest stand in Hokkaido

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北海道の広葉樹二次林の多くは山火後に再生したものであると考えられている。それらについては現在までに，カンバ類を主とする数林分での現存量調査についての報告があるが，まだその実態が十分に把握されているとは言い難い。特に，林木の枯死・生長・再生等を含む林分の動態は，一回の現存量調査では把握され得ないためにまだよく知られていない状態にある。

この研究は山火後に一斉に再生したと考えられる広葉樹幼齢林に固定試験地を設定して反復調査を行なったものである。試験林の林分構造・現存量・生長量について報告する。

調査地と調査方法

調査地は，オホーツク海沿岸の興部町に所在する道有林興部経営区 14 林班内にある。標高は約 120m，西向斜面で傾斜は中である。調査林分は 1952 年の山火後に一斉に再生したものといわれている。観察によれば，更新のしかたは萌芽によるものであったようだ。主要な構成樹種はシラカンバ，ミズナラ，アズキナシ，ハクウンボク，イタヤカエデ，ハウチワカエデなどである。林分の最大樹高は約 8mに達するが，6～8mの上層をシラカンバの優勢木が占め，2～6mの下層をシラカンバの劣勢木および他の樹種が占めている。

1973 年に，林内にプロットを 2 個とった。プロット 1 は 20m×20m，プロット 2 は 10m×10mの方形区である。プロット内に含まれる樹高 2m以上の全立木にナンバーテープでしるしをつけ，胸高位置には赤ラッカーでしるしをつけ，胸高直径を測定した。プロットの付近から 5 本の標本木を選んで伐倒し，幹・枝・葉に切り分けて各部分重量を測定した。2 年後の 1975 年に再測定を行なった。全立木の胸高直径を再測し，枯損木を記録した。付近から標本木を１本選定し，伐倒調査した。

結 果 と 考 察

林 分 構 造

標本木の樹幹解析から求めた樹高生長曲線（Fig. 1）を見ると，多くは年数 20 年前後であり，この林分が 1952 年の山火後にほぼ一斉に再生したことを示している。樹高生長速度はシラカンバが最大であり，つづいてミズナラ，ハクウンボク，ハウチワカエデとなっている。

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ヘクタール当りの本数は，プロット 1 では 11,900 本，プロット 2 では 22,600 本であった。Fig. 2 には直径階別の本数分布を示した。全本数を見ると，プロット 1 では 2〜4cm のクラスのものが多く，プロット 2 では 0〜2cm クラスのものが多い。主な樹種毎にみると，プロット１ではシラカンバが多いのに対して，プロット 2 ではアズキナシ，イタヤカエデ，ミズナラなどの方が多い。黒くぬりつぶした部分は期間中の枯損数である。Fig. 3 には生産構造図を示した。葉の量は上から 4 層目，すなわち 4.3〜5.3mに最も多い。すなわち葉は比較的下層にまで幅広く分布しているものといってもよい。

現存量と生産量

伐倒した標本木の資料を用いて，アロメトリー（Fig. 4）を用いて現存量を求めた（Table 1)。1973 年度の現存量は 2 つのプロット間でほとんど差がない。葉の現存量は約３トン/ヘクタールに達している。これは落葉広葉樹林における平均的な値と考えられる。地上部全現存量は約 40 トン/ヘクタールであった。1975 年には現存量は増加しているが，2 年間の増加量はプロット 2 の方がプロット 1 よりも大であった。次に，主な樹種についてその幹現存量を比較した（Fig. 5)。2 つのプロットともに，ミズナラの現存量が最大であった。特に，プロット 1 で個体数の最多であったシラカンバの現存量がミズナラのそれより少ないことが注目される。これは Fig. 2 にも示したように小径木が多く，また期間中の枯損木も多かったことによる。

地上部の純生産量を Table 2 に示した。プロット 1 では 4.7 トン/ヘクタール・年，プロット 2 では 8.7 トン/ヘクタール・年であった。プロット 2 の値は，従来報告されている落葉広葉樹林の純生産量の平均的な値であるが，プロット 1 の値はやや少ない。

幹現存量および増加量の直径階別の配分をしらべた。最大直径階からある直径階のものまでの積算現存量（Y_8（D)）および積算増加量（ΔY_8（D）を示した（Fig. 6)。現存量は中間の 4〜7cm の直径階で最大である。増加量は 4cm 以下の小径木階では減少するか（プロット 1)，またはごく僅かに増加する（プロット 2)。このことは，小径木階のものは全体の増加量に対してほとんど寄与していないことを示している。

結　　論

この林分が山火後に一斉に萌芽更新して成立したことは，観察および Fig. １に示す年齢数から明らかである。現在の林分はシラカンバがその初期生長のはやさと個体数の多さによって，他の樹種より優占しているようにみえる。しかし，現存量や生長量はシラカンバよりもミズナラの方が大である。すなわち，この林分がシラカンバ優占型から，ミズナラの優占する混交林型へと移行していく過程にあるものと結論される。

葉の現存量やプロット 2 における生産量は，落葉広葉樹林の平均的な値を示した。このことから，条件さえよければ 20 年生程度の幼齢林でも，最大に近い乾物量を生産しうるものと結論できる。

INTRODUCTION

Development and growth of deciduous hardwood forests in Hokkaido, many of which are considered to regenerate after fires have been known insuffciently, though biomassestimations of forest stands were conducted by several authors based on data of sample trees collected from stands TADAKI *et al.* 1961, SATOO. 1974）. We also made a biomassestimation of birch stand at Nayoro （TAKAHASHI *et al.* 1974）. Sampling trees alone, however, could not provide sufficient informations especially about mortality and growth of the trees during the period concerned. Repeated observations as well as collecting sample trees are requi red to obtain reliable data. In this paper we would report firstly the structure and biomass of a young deciduous hardwood forest stand in Hokkaido. Secondly, growth amounts and mortalities, or net production of the stand, which were estimated by repeated observations on the permanent plots in the stand will be reported. Based on the results, development of the stand, especially regeneration and successive trend would be discussed.

SURVEY SITE AND METHOD

The survey site is located in Okoppe town which is on the coast of the Okhotsk Sea and is situated at 44°50′ north latitude and at 143° east longitude. It is located at the middle of a slope faced to the west, and at about 120m above the sea level. It is considered that the standing trees sprouted simultaneously from stools after a fire in 1952. The main tree species constituting the stand were birch (*Betula platyphylla var. japonica*) ,oak (*Quercus mongolica var. grosserrata*) maples (*Acer mono and A. japonica*) sorbus (*Sorbus alnifolia*) ,styrax (*Styrax obassia*) and so on. Heights of these trees were from 2 to 8 m in 1973, the time of the first survey. Dominants of birch attained higherlevel of 6 to 8 m while suppressed trees of birch and other trees constituted the lower, 2〜6 m. The number of trees in terms of per hectare was about 10,000〜20,000. On the forest floor, there were a few shrubby species such as *Vaccinium hirtum* and herb species such as *Cornus canadensis and Maianthemum dilatatum*.

Two permanent plots, plot l and 2, were delimited in the stand in August of 1973. Plot 1 was 20 m by 20 m square, which contained 476 standing trees. Plot 2 was 10 m by 10 m square which contained 226 trees. The trees higher than 2 m were numbered with numbering tape, and the breast height of them was marked utilizing red lacquer. Utilizing a diameter tape, trees were measured for diameter at breast height (*D*) along the red mark. Five sample trees chosen near the plots were felled. After measuring the height and diameter of each sample tree, they were cut into stratum each 1 m depth but the lowest one (0〜0.3m) .Of each stratum, stem boles, branches and leaves wereweighed separately. Small samples of each part and stem cross sections of each tree were carried back to the laboratory to obtain dry weight and to make stem analysis.

In August of 1975, two years after the first survey, the second survey was conducted. Ascertaining the number tape attached to each tree, the diameters were measured. Onesample tree was felled, its diameter and height were measured, a stem bole was weighed and the stem analysis was made.

RESULTS AND DISCUSSION

1.Structure of the Stand

Height growth curves against tree ages obtained by stem analysis of sample trees were shown in Fig.1. The curves of three sample trees of birch were similar to eachother, so only a representative one was employed in the Figure. The ages of sample trees were 20 to 21 years at the time of the first survey in 1973 except for one sample tree of styrax, in which only 16 annual rings could be recognized because of rottencentral core. These observations support the presumption that the trees of the stand regenerated simultaneously after the fire in 1952. As for tree heights, birch was the highest in the stand, and was foll owed by oak and by styrax and maple as shown in Fig. 1, which was reflected by differences in growth rates not in tree ages.

The number of tree species was 16 and 18 in plot l and 2, respectively. The number of standing trees in 1973 was 11,900/ha in plot l and 22,600/ha in plot 2, respectively. Frequency distributions of tree numbers of each diameter class were shown in Fig. 2. As for total tree numbers, trees of 2 to 4 cm diameter class were numerous in plot 1, while those of 0 to 2 cm class were extremely abundant in plot 2. In plot 1, birch was nu-merous among tree species while in plot 2 individual numbers of other tree species such as sorbus, maple and oak were more than those of birch. Among them the number of sorbus was higher in 0 to 2 cm diameter class than the number in lager diamete

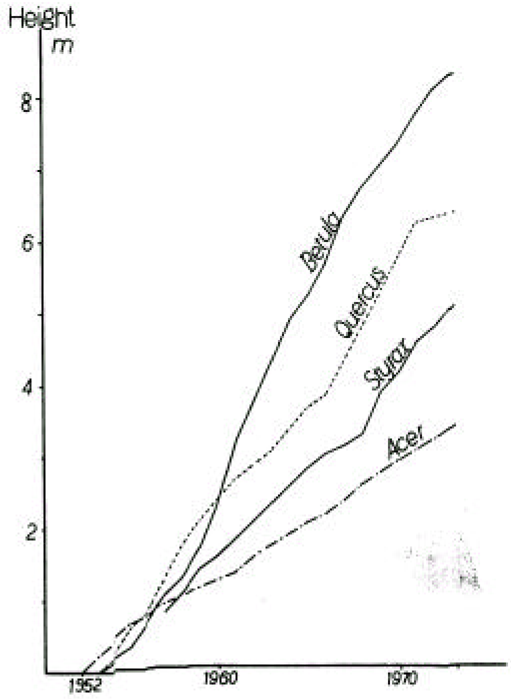

Fig.1. Height growth curves of sample trees.

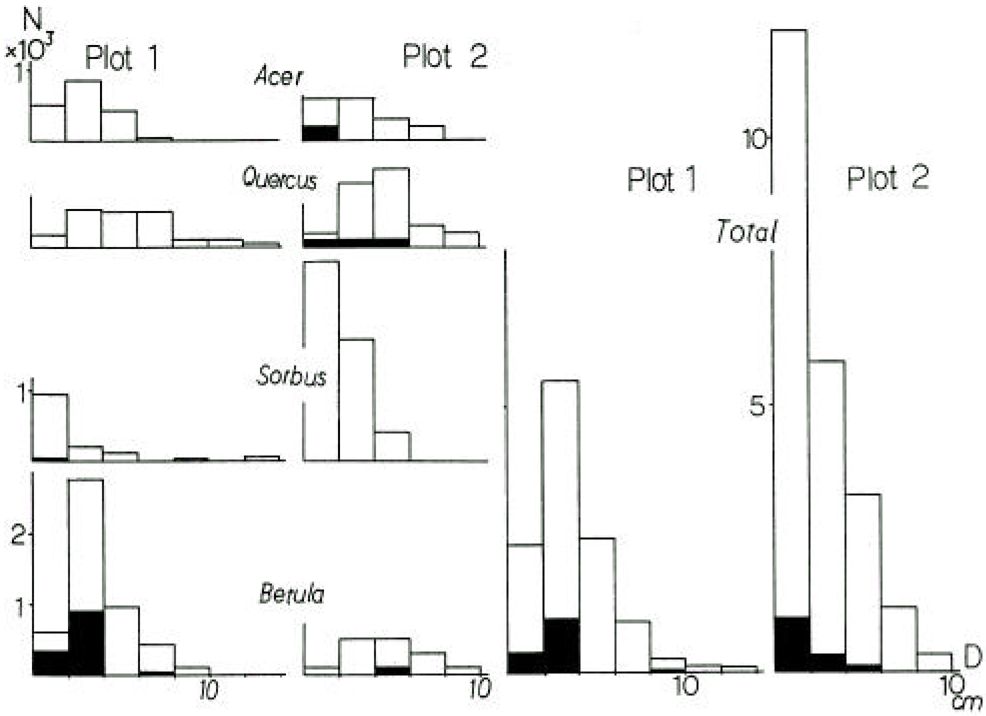

Fig.2. Frequency distributions of tree numbers of each diameter class ; filled bars indicate mortalities from 1973 to 1975.

r classes. The filled bars in Fig. 2 represent the mortalities from 1973 to 1975, which would be discussed in the next section.

The vertical distributions of stem and branch weight and leaf weight, or productive structure diagram of the stand were shown in Fig. 3. The leaf weight attained the maximum at the fourth stratum (4.3～5.3m) from the uppermost one, showing that it was distributed relatively widely from the upper to the lower stratum. That is to say, though the stand was as young as 20 years, it comprised a somewhat complex crown structure which was refiected by the differences in growth rates among species. The vertical distribution of branch weight was similar to that of leaf. The stem weight decreased with ascending strata.

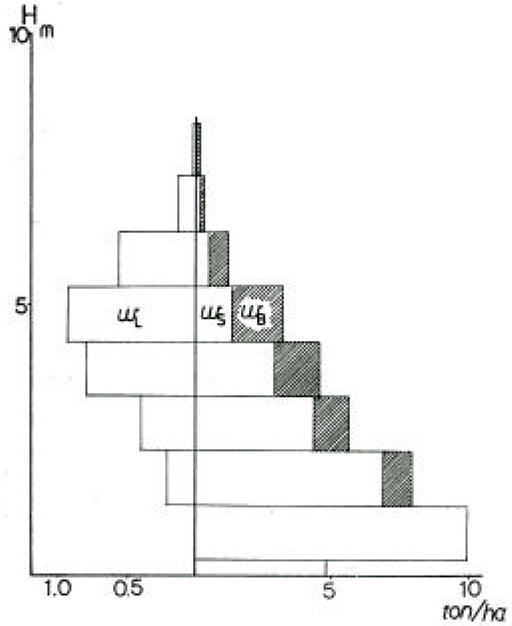

Fig.3. Vertical distributions of stem (W_S), branch (W_B) and leaf weight (W_L).

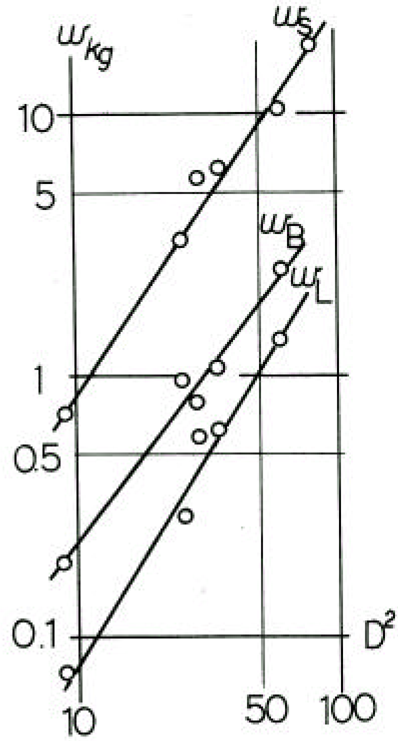

Fig.4. Allometries of stem (W_S), branch (W_B) and leaf weight (W_L) against square of diameter (D^2)

2.Biomass, Mortality and Net Production

A11ometric relation between stem dry weight (W_S: kg) and tree diameter (D: cm) were shown on a double logarithmic scale in Fig. 4. The regression equation between the two was ;

$$W_S = 0.0285D^{2.93} \qquad (1)$$

Substituting the values of tree diameters measured in the plots into D in equation (1) ,we get stem biomass values of the two plots. These values, in turn, were converted to those per hectare. Similarly, allometric relations between leaf dry weight (W_L: kg) and diameter and between branch dry weight (W_B: kg) and diameter were also shown in Fig.4. These regression equations were;

$$W_L = 0.00176D^{3.21} \qquad (2)$$

$$W_B = 0.0110D^{2.60} \qquad (3)$$

Leaf and branch biomasses in terms or ton per ha were obtained respectively utilizing these two formulae. The above three formulae were utilized for biomass estimation in 1975 as well as in 1973. It is believed, however, that allometric relation itself changes with increase of stand ages (TADAKI 1963). It is probable, therefore, that biomassesestimated by utilizing these formulae in 1975 are somewhat over-estimation especially in leaf and branch biomasses.

The biomasses of two plots in two survey years, thus obtained, were shown in Table 1. There were little differences in the biomasses between the two plots in 1973. Leaf biomasses attained about 3 ton/ha, which are considered to be an average value of the leaf biomass of deciduous hardwood forest stand (TADAKI 1963). These leaf biomassvalues of the stand are higher not only than 1.2 ton/ha of young birch stand obtained by TADAKI *et al.* (1961) but also than 2.6ton/ha of 40 years stand of the same species (TAKAHASHI *et al.* 1974) or 1.8 to 2.6 ton/ha of 47 years *Betula maximowicziana* stands by SATOO (1974).

Table 1. Biomass of the Stand

	year	number of trees/ha	Biomass ton/ha			
			stem	branch	leaf	tital
Plot 1	1973	11,900	29.3	6.1	3.1	38.5
	1975	10,500	31.3	6.4	3.4	41.1
Plot 2	1973	22,600	30.8	6.7	3.1	40.6
	1975	21,100	39.3	8.2	4.1	51.6

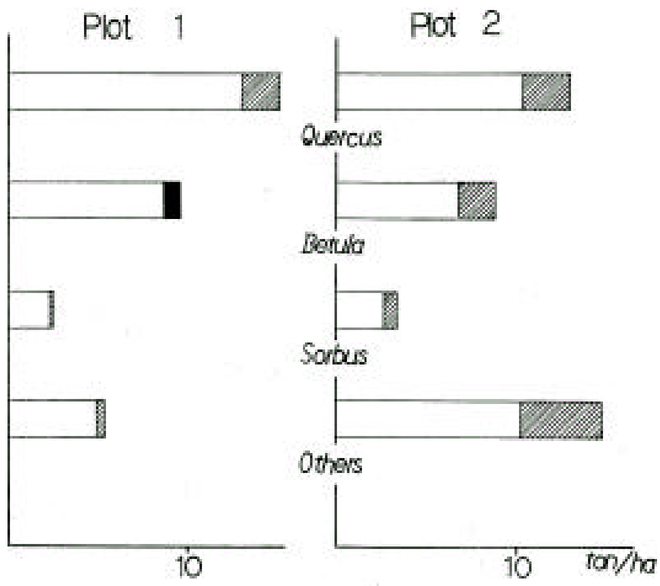

Fig.5. Stem biomasses of main tree

Open bars indicate biomasses in 1973, hatched bars indicate biomass increments from 1973 to 1975, filled bar indicates biomass decrement during the same period.

This may suggest that mixed stand could contain larger amounts of leaves than pure birch stand. Further consideration would be required along these lines. Stem biomasses were about 30 ton/ha. The biomasses of the two plots increased during the two years interval. The amount of biomass increment was much greater in plot 2 than in plot 1. Total biomass of plot 1 in 1975 was 41.1 ton/ha, which had increased by 2.6 ton/ha during two years, while that of plot 2 was 51.6 ton/ha, which had increased by 11.0 ton/ha.

The stem biomasses of main tree species were compared with each other in Fig.5. Oak biomasses were the largest among species in both two plots. It seems to be characteristic that in plot 1 the biomass of birch which had the highest individual number among species was smaller than that of oak,and moreover, it decreased a little during the two years. This biomass decline in birch may be due to high mortalities and high ratio of small diametered trees as shown in Fig.2. In plot 2, the biomass of oak was larger than that of sorbus which had the highest individual numbers among species in this plot. Oak biomass increments in both two plots also showed the largest values among species, resulting that the biomass allocation among species in 1975 showed the similar trend to that in 1973. From the results mentioned above it would be concluded that the stand concerned is in a transitional stage from birch dominant to oak dominant mixed forest stand.

Mortalities, or the number of dead trees during the two years, were 1400/ha•2 years in plot 1 and 1500/ha•2 years in plot 2, respectively. Though there were little differences in mortalities between the two plots, mortality rate was higher in plot 1 than in plot 2, since the number of standing trees was higher in plot 2 than in plot 1. Mortality rates per year were 5.9% and 3.3% in plot 1 and 2 respectively. As shown in Fig. 2, dead trees were exclusively found in 0 to 4 cm diameter classes. Of all mortalities, those of birch showed the greatest percentage in plot 1. While in plot 2 mortalities were allo-cated to several species. The stem weight of dead trees were 0.8 ton/ha in plot 1 and 0.7 ton/ha in plot 2, respectively,which amounted to few percentages of the total stem biomasses.

As shown in Table 1, the biomasses increased during the two years. The apparent biomass increments are not net productions in the strict sense. As a net production, matters produced during the period must be counted up. Net production estimations in the stand were made according to the following procedure. As a stem net production, stem biomass increment and stem weight of dead trees during the period were summed. Strictly speaking, stem weight increments of the dead trees during the period must be added to them, which however were considered to be negligibly small. Branch biomass increment and branch weight of dead trees during the period were also summed to provide branch net production. This procedure is considered to give an under estimation since the turn over of twigs during the period was not counted up. It has been widely accepted that leaf biomass gives immediately an annual leaf production, since leaves of deciduous trees turn over annually (TAKAHASHI *et al.* 1974). Also in this paper, therefore, this procedure was employed. This is considered usually to give somewhat under estimation especially in a stand where leaf biomass is increasing.

Net productions thus obtained were shown in Table 2 in terms of ton per ha per year. Total above gr

Table 2. Net Production of the Stand

	Net production ton/ha • year			
	stem	branch	leaf	total
Plot 1	1.4	0.2	3.1	4.7
Plot 2	4.7	0.9	3.1	8.7

ound production were 4.7 ton/ha•year and 8.7 ton/ha•year in plot 1 land 2 respectively. The production value of plot 2 was higher than 5.5〜7.2 ton/ha•year of 47 years birch stands obtained by SATOO (1974), though it was somewhat smaller than 10.2 ton/ha•year of 40 years birch stand obtained by us (TAKAHASHI *et al.* 1974). The net production estimate of plot 1 was somewhat smaller than plot 2. Though this may be due partially to the high mortality ratio in this plot, it is assumed also that there may be several differences in site conditions between the two plots. Further examinations would be required.

Lastly biomass and its increment of trees of each diameter class were examined. In Fig.6, abscissa indicates diameter classes and ordinate is the stem biomass (Y_S (D)) of trees whose diameter is in the range from the maximum ($D_{\max}$) to a certain diameter (D_i) (HOZUMI 1968). Stem weight increment summed from the maximum diametered tree to a certain diametered one (ΔY_S (D)) is also shown as hatched area in Fig.6. Namely, Y_S (D) and ΔY_S (D) are expressed as follows;

$$Y_S(D) = \sum_{D_i}^{D_{\max}} W_S(D) \tag{4}$$

$$\Delta Y_S(D) = \sum_{D_i}^{D_{\max}} \Delta W_S(D) \tag{5}$$

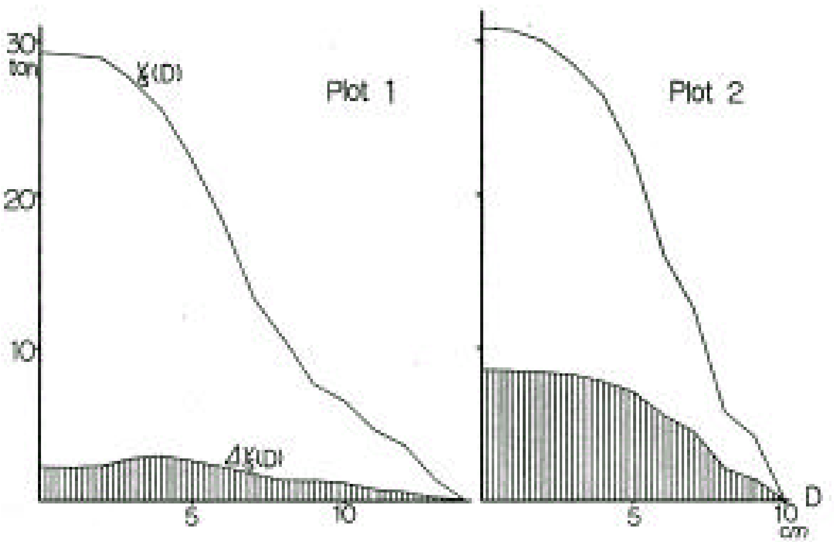

Fig.6. Cumulative amounts of stem biomass and those of stem biomass increment against diameter slasses.

D : diameter

Y_S (D) : cumulative stem biomass

ΔY_S (D) :cumulative stem biomass increment where D_i and D_{max} indicate the i-th diameter class and the maximum diameter of the stand respectively. W_S (D) and ΔW_S (D) are stem weight and its increment respectively of individual tree whose diameter is D. As shown in Fig.6 the cumulative biomasses against diameter classes showed somewhat inverse sigmoid curve and gradients of the curves were the steepest during 4 to 7 cm diameter classes in both two plots. That is to say, the partial biomass of these diameter classes constituted a large percentage of the total. Biomass of smaller diametered classes contributed little to the total, though individual numbers of these classes were the highest of all. In plot 1, cumulative biomass increment curve declined in the ranges of diameter classes smaller than 4 cm, which indicates that individual trees of these classes played a role to decrease total biomass increment. This is apparently due to high mortalities of these classes as well as little stem increment of survived trees. In plot 2, the cumulative biomass increment curve became flattened in these classes, though it did not decrease as plot 1, indicating little contributions of these classes to total biomass increment. In both two plots, individuals of 5 to 7 cm diameter classes constituted a large percentage of total biomass increments.

CONCLUSION

It is probable that the stand regenerated simultaneously after the fire, presumably as sprouts from stools. At present birch seems to be dominant because of its higher growth rate and individual number. However, the mortality rate was higher in birch than other tree species especially in plot 1 where birch was extremely numerous. On the other hand, biomass and its increment were the highest in oak among tree species in both two plots. These observations indicate that the stand is in a transitional stage from birch dominant to oak dominant mixed stand.

In 1973, there were little differences in biomasses between the two plots. The stand retained about 3 ton/ha leaf biomass, which was larger than those of pure birch stands. In plot 2 annual net production was 8.7 ton/ha•year, which could be comparable to that in mature stand. That is, though the stand was as young as twenty years, it attained nearly maximum production. While in plot 1, production was lower than that in plot 2. The reason to make these differences other than high mortality was not clarified.

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SUMMARY

1. The structure of a young deciduous hardwood forest stand, which was presumed to have regenerated simultaneously after a fire from stools as sprouts, was examined. The age of the stand was about 20 years. Birch, oak, maples, sorbus, and styrax constituted main tree species of the stand. Birch attained higer level in tree height of 6〜8 m, while suppressed brich trees and other trees constituted the lower.

2. Two permanent plots were taken in the stand in August of 1973. Standing trees were measured for diameter. The trees were re-measured in 1975. Sample trees chosen near the plots were felled. The bi

omass of the stand was estimated utilizing these sample data.

3. There were little differences in the biomasses between the two plots in 1973, showing about 3 ton/ha of leaf biomass and about 40 ton/ha of total above ground biomass. Above ground total net productions were 4.7 and 8.7 ton/ha•year in plot 1 and 2, respectively. Low net production in plot 1 was due partially to high mortality rate in this plot. Large percentage of stem biomass and its increment were constituted by individuals of 5〜7 cm diameter classes.

4. Though birch seemed to be dominant because of its high growth rate and individual number, its mortality was also the highest of tree species. On the other hand, the highest biomass and its increment were observed in oak. From these observations it would be concluded that the stand is in a transitional stage from birch dominant to oak dominant mixed stand.

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