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Biomass and Productivity of *Betula papyrifera* near Its Climatic Limit in Northwestern Canada[1]

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Abstract Measurements of biomass and estimates of net primary productivity were made on a stand of birch (*Betula papyrifera*), 8 km southeast of Inuvik (68°18′N, 133°29′W) in northwestern Canada, near the climatic limit of the species. A partially destructive sampling technique was used. Total biomass was estimated at 74.5 t/ha, with 1.7 in leaves, 57.8 in stem and 15.0 in branch. Net primary productivity of above-ground parts was estimated at 2.16 t/ha•year with only 0.06 in the branches and 0.42 in the stems, compared with 1.68 in the leaves. The high proportion of productivity in the photosynthesis organ seems to be characteristic of trees growing near their climatic limit. The results probably represent nearly minimal values for deciduous woodlands.

Introduction

Productivity studies on woodland ecosystems have been mainly confined to temperate and tropical regions with little information on the productivity of woodlands near their climatic limit. Elkington and Jones (1) reported biomass and primary productivity of a scrub woodland of *Betula pubescens* in Equaluit Bay (61°06′N), southwestern Greenland, about 30 to 40 km south of the northern limit of the species (1). At Equaluit, individual trees lack trunks, their procumbent branches being ascending or horizontal, forming a dense, interlacing network. The results probably represent nearly minimal values for deciduous woodland. Inuvik, in northwestern Canada, is located in a transitional zone between dense spruce forests and treeless tundra (5). Paper birch (*Betula papyrifera*) is the only predominant deciduous species growing on the uplands near Inuvik, with tree heights reaching nearly 10 m, though both *Populus tremuloides* and *P. balsamifera* grow only on floodplains near Inuvik. This study was carried out to determine the characteristics of biomass and productivity of deciduous trees occurring on permafrost near their climatic limit.

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Materials and Methods

1. *Description of study area*

Studies were carried out at a stand of *Betula papyrifera*, located about 8 km southeast of Inuvik (68°18′N, 133°29′W, 60 m alt.). An uniform birch stand containing a few conifers was selected for study. A plot of 100 m^2 was located on a south-facing slope with 10° gradient. This stand is a secondary forest established after a fire about 100 years ago. Clumps of up to three stems sprouted from the fire-killed trees. In most clumps, however, only one or two trees remained alive and other trees had decayed (Fig. 1). Earth hummocks (40 to 50 cm height) developed on the forest floor and most trees grew on the side or in interhummock troughs (5, 6). The permafrost table is within 50 cm of the surface. The ground vegetation is dominated by feathermosses on the hummock tops and *Sphagnum* in troughs. The dwarf shrubs consisted mainly *Vaccinium vitis-idaea* and *V. uliginosum*. *Rosa acicularis* is main lower shrub.

The soil is mainly clay and pH (H_2O) is 5.91. The soil temperature was 5.0 and 1.8°C at 5 and 12 cm from the surface in the troughs, respec-

Fig. 1. Surveyed plot of *Betula papyrifera* near Inuvik
Tree age: about 100 years, mean height: 9 m

Table 1. Meteorological

	Jan.	Feb.	Mar.	Apr.
Mean temperature (°C)	−29.3	−29.4	−23.9	−14.6
Mean maximum temperature (°C)	−24.1	−23.9	−17.7	−7.9
Mean minimum temperature (°C)	−34.5	−35.0	−30.0	−21.2
Number of day sub-zero temperature	31	28	31	30
Mean precipitation (mm)	20.3	10.4	16.5	13.9

1941–1970, Warmth index: 18.4

tively. The mean thickness of thawed soil on July 5th, 1974 was 30 and 12 cm on the tops and in the troughs of hummocks, respectively. Meteorological data is presented in Table 1.

2. *Field sampling*

Field sampling was carried out on July 5th and 13th, 1974. A sample area of 100 m^2 was delimited, and DBH and heights of trees were measured. Three trees were elected and felled. After recording of DBH, height, the fresh weights of stem bole, branches, and leaves were separately determined according to the stratified clipping technique using one meter interval per stratum. Stem discs of each sample were taken at one meter intervals along the stem bole and just below the lowest living branch for stem analysis. Small samples of respective tree components were also taken for determination of oven-dry weight and leaf area. All weight values were expressed in dry weight. Leaf area index was caluculated from the leaf biomass data and from dry weight of leaf discs. The biomass on the plot area was estimated by assuming that the rate in biomass of the total sum of sample trees per plot to that on the whole plot area is equal to the rate in respective basal areas.

Results

Total growth, mean annual increment, and 10-year periodic mean annual increment of tree height of *Betula papyrifera* are shown in Fig. 2. Growth rate of tree height increased abruptly between 17 to about 35 years and reached maximum at 35 to 40 years, and then abruptly decreased to about 70 years.

The biomass, estimated biomass, and annual productivity of birch at Inuvik are summarized in Tables 2 and 3 together with those of birch in northern Hokkaido (about 44°30′N) estimated by Takahashi *et al.* (3). The total biomass (74.5 t/ha) of the Inuvik material is much greater than that of the birch in Greenland (54.9 t/ha) (1). Leaf biomass is considerably higher in the Hokkaido material, the value of 2.6 t/ha estimated by Takahashi *et al* (Table 3), being about 50% above that of the Inuvik material (1.7t/ha) (3). The leaf biomass in the Inuvik material is, however, much higher than

data of Inuvik

May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
−0.8	9.8	14.5	10.3	2.7	−7.2	−20.6	−27.7	−9.7
3.9	16.0	19.2	15.5	6.8	−3.8	−16.5	−22.0	−4.5
−5.6	3.7	7.4	5.0	1.7	−10.7	−24.7	−32.0	−14.9
26	7	1	3	21	30	30	31	269
17.5	12.9	34.3	46.2	21.1	33.8	14.7	18.5	260

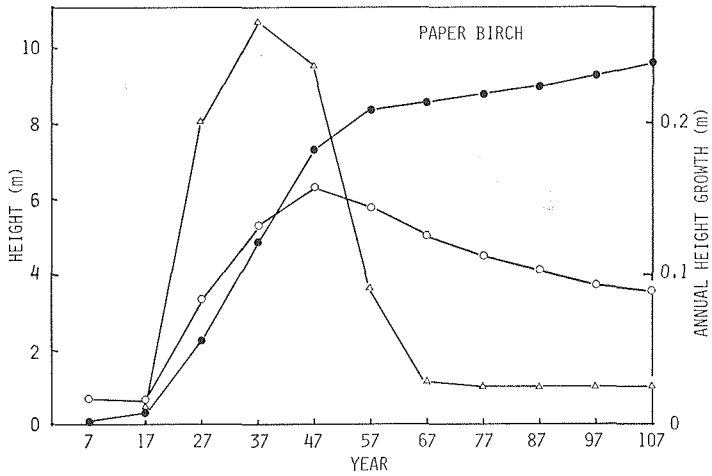

Fig. 2. Total growth (●), mean annual increment (○), and 10-year periodic mean annual increment of tree height (△) of *Betula papyrifera* near Inuvik
Tree age: 109 years

Table 2. Biomass and other properties of survey stand of *Betula papyrifera* near Inuvik

Number of tree (no/ha)	3000
Tree age (year)	107
Mean tree height (m)	8.6
Mean DBH (cm)	8.5
DBH range (cm)	4.4～14.0
Basal area at DBH (m^2/ha)	19.1
Stem volume (m^3/ha)	98.5
Production in the last 10 years (m^3/ha)	7.7
Stump number (no/ha)	1830
Mean tree number each stump	1.6

Survey area: 300 m^2, July 5th and 13th, 1974
Three trees were felled.

in the Greenland material (1.2 t/ha). Total net primary productivity in the Inuvik stand (2.16 t/ha•year) is nearly the same as that of the Greenland material (1.98 t/ha•year), which is very low when compared to that of northern taiga fir forest (3 t/ha•year) and of stunted firs near the timber line in Japan (4. 2 t/ha•year) (2).

The low values for both biomass and productivity, which probably present near minimum values for deciduous woodlands, are clearly related to the severe climate of arctic regions. In the birch trees in Inuvik, the annual production was very low and 78% of the products was apportioned to the

Table 3. Comparison of biomass and annual productivity of birches at Inuvik and Nayoro, northern Hokkaido (3)

	Betula papyrifera (Inuvik)	*Betula platyphylla* var. *japonica*** (Hokkaido)
Total biomass (t/ha)	74.5 (100)*	145.9 (100)
Stem (t/ha)	57.8 (78)	126.4 (87)
Branch (t/ha)	15.0 (20)	16.9 (11)
Leaf (t/ha)	1.7 (2)	2.6 (2)
Leaf area (ha/ha)	3.3	5.2
Net productivity (t/ha·year)	2.16 (100)*	10.2 (100)
Stem (t/ha·year)	0.42 (20)	6.7 (66)
Branch (t/ha·year)	0.06 (2)	0.9 (9)
Leaf (t/ha·year)	1.68 (78)	2.6 (25)
Leaf productivity/Leaf area (t/ha)	0.65	
Net productivity/Leaf productivity (t/ha)	1.28	

Abbreviation, tonne : t
* Percentage distribution in different organs
** Tree age : 50 to 60 years ; height 20 m

leaves of trees. In the Greenland birch, 60% of the annual net production was apportioned to leaves (1). The same trend was observed in the forest of *Abies veitchii* which grows under a heavy snow deposit near the timber line in central Japan (2). These trees were 4 to 5 m in height and the trunks were very stocky. The annual production of 3 plots ranged from 1.2 to 3.9 t/ha·year and about 60% of the products was apportioned to the leaves. It seems clear, therefore, that in trees growing near their climatic limit most of the products occurs in the organs of photosynthesis.

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Literature Cited

1) Elkington, T. T. and B. M. G. Jones 1974 Biomass and primary productivity of birch (*Betula pubescens* S. Lat.) in southwest Greenland. *J. Ecol.*, **62** : 821–830.
2) Oohata, S. and C. Onishi 1974 Some discussions on tree form and dry-matter production of a fir stand at Tonohara of Mt. Onaka. *Bull. Kyoto Univ. Forests*, **46** : 51–57.
3) Takahashi, Y., T. Asai and K. Kikuzawa 1974 On biomass estimation of *Betula platyphylla* var. *japonica* forest stand in Nayoro. *Bull. Hokkaido Forest Exp. Stat.*, **12** : 29–37.

4) Zoltai, S. C. and W. W. Pettapiece 1973 Terrain, vegetation and permafrost relationships in the northern part of the Mackenzie valley and northern Yukon. Environ. -Soc. Program, N. Pipelines, Task Force N. Oil Develop., Gov. Canada, Rep. 73-4, 105 pp.
5) ——— 1973 Tree distribution on perennially frozen earth hummocks. *Arc. Alp. Res.*, 6: 406-411.
6) ——— 1975 Structure of subarctic forests on hummocky permafrost terrain in northwestern Canada. *Can. J. Forest Res.*, 5: 1-9.