MEMOIRS OF THE FACULTY OF SCIENCE, KYOTO UNIVERSITY, SERIES OF BIOLOGY
Vol. IV, pp. 130-138, March 1970

Root Habit of Japanese Birches (*Betula*)*

By

Hideo TABATA

Laboratory for Plant Ecological Studies, Faculty of Science,
Kyoto University

(Received January 18, 1971)

ABSTRACT The root habit of Japanese *Betula* species was investigated in connection with their mode of life. They were compared in root features and root distribution. As *Betula platyphylla* var. *japonica* has a wide habitat preference (Tabata, 1963, 1964, 1966), correspondence between its root system and edaphic conditions was studied in various habitats.

The investigation on the root bears out my previous studies made from the viewpoint of evolutionary ecology and morphology. The root system of *Betula platyphylla* var. *japonica* is full of variety reflecting its diverse habitats. It suggests that abundance of the species fairly depends on its flexible nature. On the other hand, the other species are poor in variety of the root habit and more or less specialized. Especially the most specialized are the species of the subsection Nanae.

The suckering ability is discussed in connection with mode of life. In the subsection Albae the ability may be referred to as neotenic one related with advanced mode of life, while in the subsection Nanae as 'deviation' leading to the specialization of life.

Introduction

The life of species must be better understood when studies of the root system are involved in the investigation. In an ecological study of the root system it is firstly important to investigate features which are concerned in the mode of life of a species. It was reported in my previous paper (1966) that special root features are closely related with the life under severe environmental conditions.

It has been reported that each plant species has its specific root habit, and also that distribution and development of roots vary in connection with environmental conditions, especially edaphic factors (Cannon, 1911, 1955; Haasis, 1921; Holch, 1931; Laitakari, 1934; Yeager, 1935; Yoshioka, 1936-1937; Weaver, 1938; Numata, 1947; Karizumi, 1957; Yano, 1960). And these facts have been of

* Contribution No. 9 from the Laboratory for Plant Ecological Studies.

great value in forestry, horticulture and so on, as, for example, furnishing an index for deciding fit or unfit sites for plantation (Büsgen, 1927; Hilf, 1927; Dengler, 1930; Rogers, 1933; Miyazaki, 1942; Yamada, 1955).

Laitakari reported that *B. verrucosa* and *B. odorata* are more variable than pine species in several features of the root system depending on soil conditions. However, there have been few comparative studies on root systems of trees from the viewpoints of both ecology and taxonomy.

Some authors reported on mycorrhizae of birch species (Melin, 1923; Laitakari; Salyaev (Саляев), 1962).

This paper will deal with mycorrhiza distribution and root habit variation of *B. platyphylla* var. *japonica*, Japanese white birch, which widely distributes and inhabits in various edaphic conditions. Comparative studies on root habits of Japanese birch species will also be reported.

The distribution of mycorrhizae and fine roots was investigated on a soil profile at a distance of 50cm from the stump. The profile, 1m deep and 2m wide, was divided into smaller sections, 5cm by 10cm, and the root abundance was evaluated by the sum of fine root index in each section : 3, fine roots abundant; 1, fine roots rare; 2, intermediate between 3 and 1. By fine root are meant here roots less than 0. 2cm in diameter.

Comparative investigation was carried out chiefly at the most typical habitat of each species as reported in my previous papers (1963, 1964, 1966).

With reference to Omasa, brown forest soils are classified into six types: B_A, dry brown forest soil (steep slope type); B_B, dry brown forest soil (gentle slope type); B_C, fairly dry brown forest soil; B_D, moderately moist brown forest soil; B_E, fairly moist brown forest soil; and B_F, wet brown forest soil.

Result

1. *The root system of Japanese white birch*

B. platyphylla var. *japonica* is one of the most thriving birch species. It can inhabit under various habitat conditions and has a wide distribution range, although rather prefers moderately moist brown forest soil on gentle mountain slopes and in plains, where it often forms pure stands. Root system of a species may present typical features in its favorite habitat. And it is also necessary to study root systems in other habitats and compare them with the former case.

Fig. 1 shows the root system in a moderately moist forest soil on a gentle mountain slope (B_D). This species is characterized by well developed horizontal roots and mycorrhizae. Fine roots grow upwards from horizontal roots extending into the upper part of A horizon, and most root tips are infected by mycorrhizal fungi in the lower Ao and the upper A horizons (Fig. 2a). Especially in moist leaf mold of Ao horizon the mycorrhizae branch in the same plane. On the other hand, in dry soils of B_A or B_B type rich in loose granular structure, mycorrhizae are poorly developed, but long and branched fine roots exclusively occur (Fig. 2b).

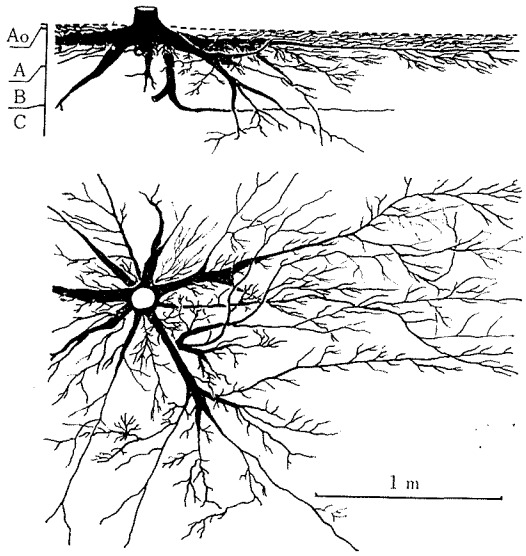

Fig. 1. Root system of *B. platyphylla* var. *japonica* in Bd soil, having much branched horizontal roots (Akigami, Gifu Prefecture).

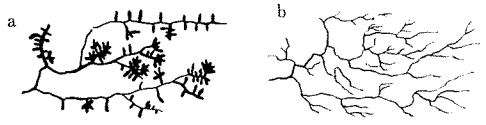

Fig. 2. Fine roots of *B. platyphylla* var. *japonica*. a, mycorrhizal roots in a Bd soil; b, non-mycorrhizal roots in a Ba soil.

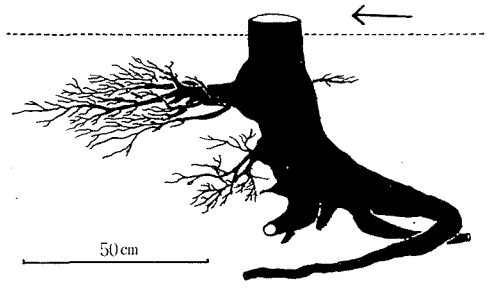

Fig. 3. Root system of *B. platyphylla* var. *japonica* in a undeveloped volcanic ash soil where alluvial deposits are being formed. Rain water flows in the direction of the arrow (Kawayu, Hokkaido).

Distribution of roots is extremely varied in habitats where alluvial deposits are being formed. In the plant depicted in Fig. 3, the site of rooting has shifted upwards on the stem for twenty-six years as deposits increased. Deeply buried roots seem to have begun to lose their function and to be decomposed.

The species is often found in extremely wet peat bogs, which is unfavorable for it, and often forms birch forests along streams in bogs, but it grows poorly at the central part of peat bogs with dead water. The water table is situated near the surface, and the roots run very shallowly. Horizontal roots grow along the moor knoll surface (Fig. 4). Fine

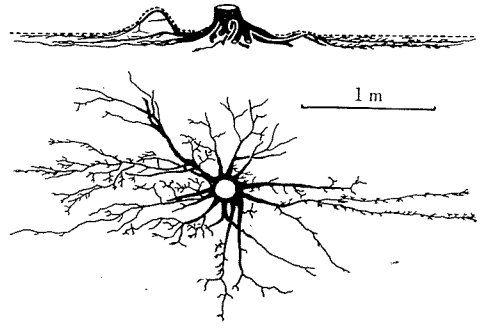

Fig. 4. Root system of *B. platyphylla* var. *japonica* in a peat bog (Sarabetsu, Hokkaido).

roots are very scrubby, and the root branching may be referred to as the 'stunted type' in comparison with the ordinary root branching. These short roots seem to grow and then lose their function one after another in this kind of habitat. This type of root branching is also found in compact and

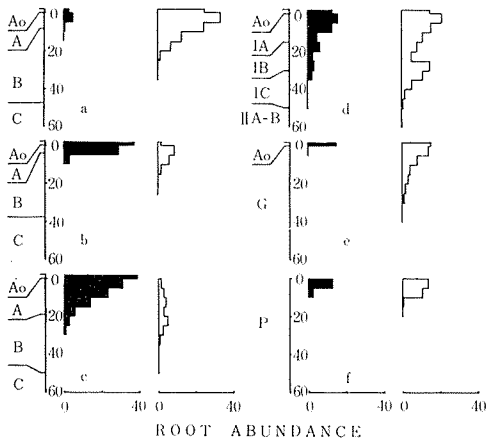

Fig. 5. Abundance of fine roots and mycorrhizae in various soils. Black area, mycorrhizae; white area, non-mycorrhizal roots; ordinate, horizons and depth in cm from soil surface; abscissa, abundance of fine roots and mycorrhizae (sum of index values). a, B_B soil; b, B_C soil; c, B_D soil; d, B_D soil; e, Glei; f, peat.

massive soils.

In a boggy habitat, a fairly large cavity is formed beneath the trunk, and the trunk is supported from the water table by lateral roots suggesting prop roots. This root habit is also observed in *Picea Glehnii* Mast. growing under similar conditions.

Fig. 5 illustrates the relationship between mycorrhizae and ordinary fine roots in various habitats. The two kinds of roots seem to compensate each other, since trees can reach their full growth without mycorrhizae. The formation of mycorrhizae may depend on the conditions effective on mycorrhizal fungi, i. e. soil moisture and air permeability. In a volcanic ash soil mycorrhizae occur even in C horizon owing to good air permeability of scoria (Fig. 5d). Deeply distributed roots are being decomposed in Glei.

2. *Root systems of birch species*

It is difficult to distinguish specific characters from the modification caused by environmental conditions. It is also impossible to compare each species as to the response of root system to the same conditions, as all species do not grow at a site. These problems, however, may be resolved to some degree by comparative studies under various habitats. Especially suggestive are the root systems of the species which sporadically occur near one another in a birch forest — under almost the same conditions.

B. apoiensis and *B. tatewakiana* of the subsection Nanae have bushy habit, the former especially being from 15cm to 50cm high in its adult form. My previous paper has reported that they possess conspicuously developed suckering parts consisted of clusters of buds. Even when the aerial parts are of much vigor, some suckers often grow to be etiolated as a consequence. Though *B. tatewakiana* occurs at the peripheral part of Sarabetsu peat bog, Hokkaido, and *B. apoiensis* grows only on the serpentine stony slope of Mt. Apoi, Hokkaido, they bear a striking mutual resemblance in main root, root branching and sucker formation (Fig. 6).

The suckering parts or bud burls are formed as the plant grows. In the experimental field of the university they began to be formed 4-5 years after germination (Fig. 7).

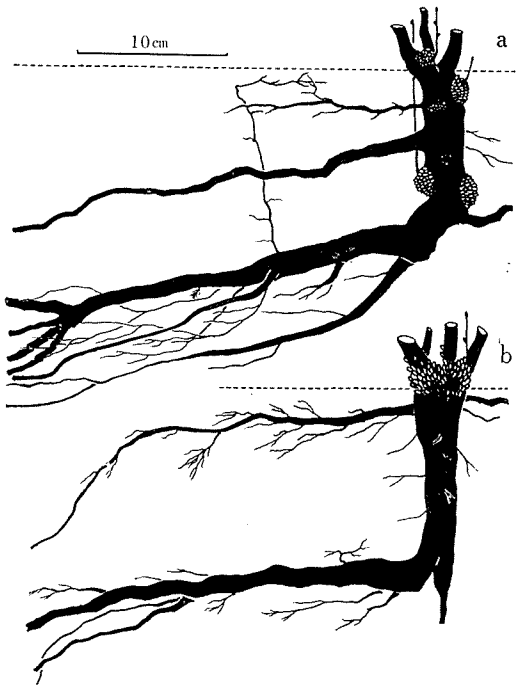

Fig. 6. Root systems of *B. tatewakiana* (a) and *B. apoiensis* (b).

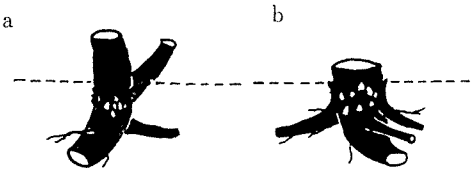

Fig. 7. The suckering parts formed 4-5 years after germination : *B. tatewakiana* (a) and *B. apoiensis* (b).

It may be said that the species other than those of the subsection Nanae resemble more or less one another in the root habit, though vigorous sucker formation of adult trees is practically restricted to the subsection Albae. In various habitats *B. platyphylla* var. *japonica* remarkably develops horizontal roots which are profusely branched. *B. ermanii* is hardly distinguished from *B. platyphylla* var. *japonica* in the root distribution. *B. maximowicziana* differs from them, having characteristic oblique rope-like roots which are 0.5cm in diameter and scarcely branch (Fig. 8). The tree seems to have a tendency to develop these rope-like roots better in dry soils rather than in moist soils. These characteristic roots run zigzag in such a compact soil as B horizon of Bc soil. It has a tendency to bear long rods of mycorrhizae.

B. davurica is characterized by its oblique roots. Lateral roots branch off from a thicker root at sharp angles and develop straight (Fig. 9). These characteristics are found wherever the trees grow.

The other species bear no specific characteristics. *B. nikoensis* has a likeness to its closely related species, *B. ermanii*. *B. globispica* in rare cases bears remarkably sinuous roots, with the tree growing vigorously. This form of roots does not seem to be caused by such conditions as stones in soil and compactness of soil. *B. chichibuensis* was not studied, since it exists only on the outcrop of limestone.

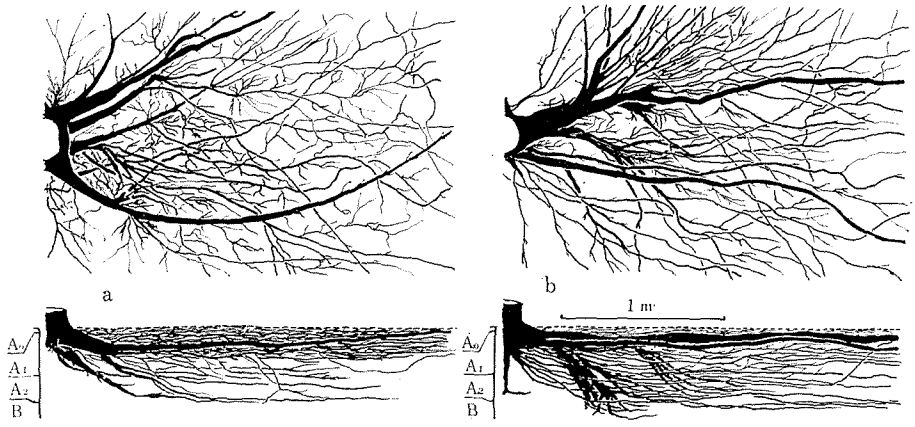

Fig. 8. Root system of *B. platyphylla* var. *japonica* and *B. maximowicziana* in the same soil. a, *B. platyphylla* var. *japonica*, roots running shallowly; b, *B. maximowicziana*, rope-like roots distributing comparatively deeply (Shintoku, Hokkaido).

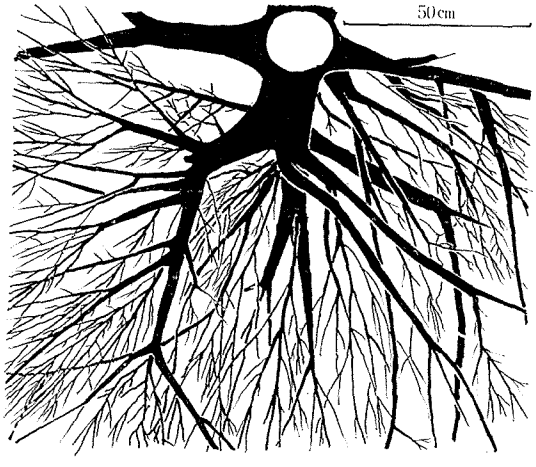

Fig. 9. Root system of *B. davurica*. Root branching occurs at acute angles (Honbetsu, Hokkaido).

Conclusion and Discussion

Two Japanese species of the subsection Nanae conspicuously resemble each other in the root habit, though they grow under quite different habitat conditions. As reported in my previous papers, the sucker formation of these species is favorable for the life in severe habitats, ensuring descendants even after

the death of aerial parts. Fedorov (Федоров) *et al.* (1962) reported that such sucker formation occurs also in other species of this subsection, *B. fruticosa*, *B. humilis* and *B. nana*. Polosova (Полосова) (1966) also described the same features as a characteristic of *B. nana*. Though the subsection Nanae is not fully represented by these species, it may be conjectured that this characteristic prevails among the species of the subsection. The suckering ability has indispensable and adaptive meaning to the life of these species under extremely severe conditions, as these species readily reproduce vegetatively after the damage of aerial parts. The bud burl formation of these species may correspond to 'deviation in the middle stage of development' (Sewertzoff, 1931; Takhtajan, 1954), as Fig. 7 shows. On the other hand, in the subsection Albae the mode of sucker formation without bud burls may be regarded as 'neoteny' in substance, retention of juvenile property in adult stage, since all Japanese birch species and some foreign species so far as examined have this ability in young stage. It has been reported that the bud burls are formed in *B. odorata* (*B. pubescens* subsp. *odorata*), *B. populifolia* and *B. tortuosa* (Laitakari, 1934; Stone and Cornwell, 1968; Vaarama, 1970), but Vaarama has suggested the origin of *B. tortuosa* by hybridization.

B. platyphylla var. *japonica* and the species of the subsection Costatae are alike each other in general aspects of root systems, but there is a difference between them. The root system of the former is full of variety reflecting its diverse habitats. On the other hand, the species of the subsection Costatae are poor in variety of the root habit owing to their narrow habitat preference.

B. davurica differs from another species of the subsection Albae, *B. platyphylla* var. *japonica*, in the root characteristics as well as in the features of catkin arrangement, fruits and habitat preference as reported previously. The section Davuricae was formerly discriminated from and has lately been combined with the white birch group. But reexamination of the classification may be necessary in view of these differences.

B. maximowicziana of the section Betulaster differs from the species of the section Eubetula in a external feature of mycorrhizae.

The root habit seems to be roughly conformable to the classification of subsections. And it may also be argued that *B. platyphylla* var. *japonica* is regarded as the least specialized species among Japanese birches. It is of deep significance that these agree with the results previously reported (1966).

Acknowledgment

I wish to express my thanks to Emeritus Professor Joji Ashida for his valuable criticisms and also to Professor Isao Hatakeyama for his support and encouragement. I am indebted to the members of Regional Forestry Offices of Ministry of Agriculture and Forestry, the members of the Experimental Plantation of Tokyo University and the members of the Forestry Department of Hokkaido Government.

References

1) Büsgen, M., Bau und Leben unserer Waldbaüme. Fischer, Jena, 1927
2) Cannon, W. A., Root habits of desert plants. Carnegie Inst. Wash. Publ., 1911
3) ——, A note on the grouping of lateral roots. Ecol., **35**, 293-295, 1955
4) Dengler, A., Waldbau auf ökologischer Grundlage. Springer, Berlin, 1930
5) Fedorov, A. A., M. E. Kirpichnikov and Z. T. Artyushenko (Федоров, А. А., М. Э. Кирпичников и З. Т. Артюшенко), Атлас по описательной морфологии высщих растений. Изд-во АН СССР, Москва-Ленинград, 1962
6) Haasis, F. W., Relations between soil and root form of western-yellow pine seedlings. Ecol., **2**, 292-303, 1921
7) Hilf, H. H., Wurzelstudien an Waldbaümen. Schaper, Hanover, 1927
8) Holch, A. E., Development of roots and shoots of certain deciduous tree seedlings in different forest sites. Ecol., **12**, 259-298, 1931
9) Karizumi, N., Studies on the form and distribution habit of the tree root (in Japanese with English summary). Bull. Govern. For. Exp. St., **94**, 1-205, 1957
10) Laitakari, E., Koivum juristo (with English summary). Acta For. Fenn., **41**, 1-205, 1934
11) Melin, E., Experimentelle Untersuchungen über die Birken- und Espenmykorrhizen und ihre Pilzsymbionten. Svensk Bot. Tidskr., **17**, 479-520, 1923
12) Miyazaki, S., On the relation between the forest vegetation and the soil morphology of Shikoku (in Japanese). Korinkai, Tokyo, 1947
13) Numata, M., On the reproductive type of plants (in Japanese). Seibutsu, **2**, 121-123, 1947
14) Omasa, M., Forest soils of Japan. Report 1 (in Japanese). Govern. For. Exp. St., Tokyo, 1951
15) Polosova, T. G. (Полосова, Т. Г.), Корневая система карликовой березки *Betula nana* L. в восточноевропеиской лесотундре. Бот. жур., **49**, 387-395, 1964
16) Rogers, W. S., Root studies III. Pear, gooseberry and black currant root systems under different soil fertility conditions, with some observations on root stock and scion effect in pears. Jour. Pomol. Hort. Sci., **11**, 1-18, 1933
17) Salyaev, R. K. (Саляев, Р. К.), Физиология древесных растений. Изд-во АН СССР, Москва, 1962
18) Sewertzoff, A. N., Morphologische Gesetzmässigkeiten der Evolution. Fischer, Jena, 1931
19) Stone, E. L. and S. M. Cornwell, Basal bud burls in *Betula populifolia*. For. Sci., **14**, 64-65, 1968
20) Tabata, H., Topography and soil type for the occurrence of Japanese white birch. Mem. Coll. Sci. Univ. Kyoto (B) **30**, 15-19, 1963
21) ——, Vessel element of Japanese birches as viewed from ecology and evolution. Physiology and Ecology, **12**, 7-16, 1964
22) ——, A contribution to the biology of Japanese birches. Mem. Coll. Sci. Univ. Kyoto (B) **32**, 239-271, 1966
23) Takhtajan, A. L. (Тахтаджян, А. Л.), Теория филэмбриогенеза А. Н. Северцова и эволюционная морфология растений. Проб. бот. **1**, 222-231, 1950
24) —— : Пути приспособительной эволюции растений. Бот. жур., **36**, 231-239, 1951
25) ——, Essays on the evolutionary morphology of plants. AIBS, Wash., 1959
26) Vaarama, A., Induced mutation and polyploidy in birch, *Betula* spp. V. Univ.

of Turku, Finland, 1970
27) Weaver, J. E., Root distribution of trees in relation to soil profile. Ecol., **19**, 155-156, 1938
28) Yamada, M., Forest physiographical studies on the microtopographical analysis (in Japanese with English summary). Rin-ya kyosaikai, Tokyo, 1955
29) Yano, N., Ecological studies on the subterranean organ of higher plants in various soil types. Ann. Rep. Sotokugakuen, **1**, 1-65, 1960
30) Yeager, A. F., Root systems of certain trees and shrubs grown on prairie soils. Jour. Agric. Res., **51**, 1085-1092, 1935
31) Yoshioka, K., On the underground organs of the plants on Mt. Hakkoda (in Japanese). Seitaigakukenkyu, **2**, 121-131, 211-222, 319-324 (1936), ibid., **3**, 47-60, 1937