NOTES ON FOREST TREE BREEDING IN JAPAN

by

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Table of Contents

FOREWORD

Dr. C. Heimburger, while employed by the Ontario Department of Lands and Forests, maintained an active correspondence and exchange of tree breeding material with tree breeders in Japan. Several Japanese scientists visited the Southern Research Station, Maple, Ontario to see his studies in resistance breeding and in poplar selection and breeding. In 1968, while at the Twelfth International Congress of Genetics at Tokyo, Dr. Heimburger took the opportunity to travel in Japan, to examine the native vegetation, and to visit several tree improvement operations. This report is a direct result of these travels.

Ecologically, northern Japan, especially Hokkaido, is quite similar to parts of the Maritime Region of Canada. Although no tree species are common to both areas, several have ecological equivalents; for example, *Betula alleghaniensis* Brit. and *B. maximowicziana* Reg.; and *Picea rubens* Sarg. and *P. glehnii* Mast. Because of the ecological similarity of the two areas, this report has special significance to tree breeders, ecologists, entomologists, and pathologists in the Maritime Region.

The existence of closely related species from ecologically similar habitats affords an excellent opportunity for the tree breeder to produce improved types by species selection or hybridization. In this report, Dr. Heimburger suggests several instances where such work could be very fruitful.

It will be appreciated that the publication of a report of this length is beyond the capability of most scientific journals. Because of the applicability of much of the information to eastern Canadian forestry, Dr. Heimburger has agreed to publish it as an Information Report of the Maritimes Region, Canadian Forestry Service.

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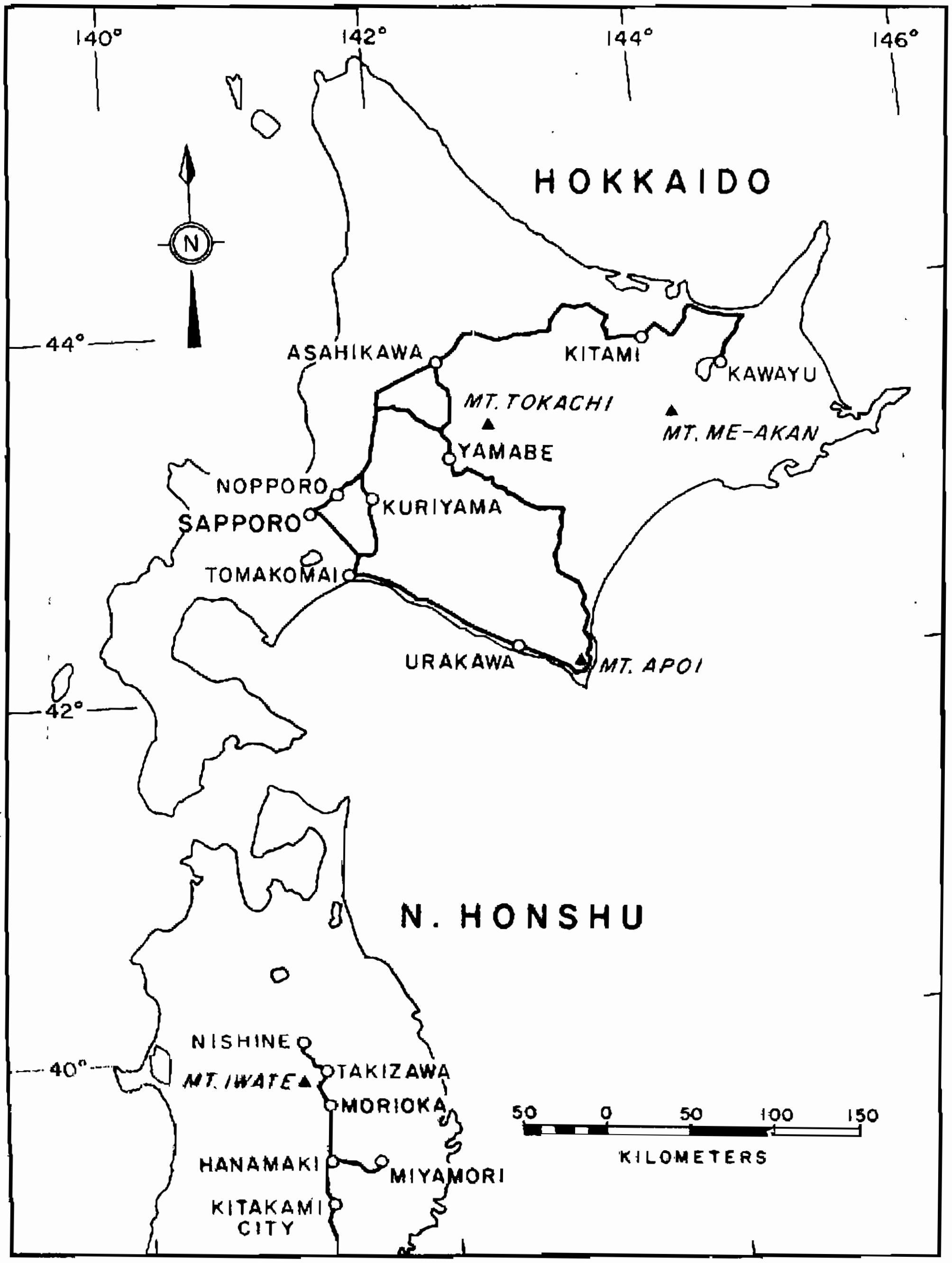

Figure 1. Hokkaido and northern Honshu showing the main places visited.

INTRODUCTION

While in Japan for the Twelfth International Congress of Genetics at Tokyo, 1968, I had the opportunity of making two field trips. The first was to visit the Jujo Paper Manufacturing Company, Limited at Kitakami in northern Honshu and the second was to the Oji Paper Company, Limited at Kuriyama and the Tokyo University Forest at Yamabe, in central Hokkaido (Fig. 1). These organizations are actively engaged in forest tree breeding and have participated in a very productive exchange of breeding materials with the Tree Breeding Unit at Maple, Ontario. The two paper companies were the first to start forest tree breeding on an industrial scale in Japan, about 15 years ago (Lindquist, 1957). The main purpose of the trips was to see some of the tree breeding work in progress, its immediate results in test plantations, and some natural stands of native tree species of interest to our tree breeding work and of possible value to forestry in eastern Canada. Several forest tree genera of interest in this respect have two main distribution areas in Japan, a northern, comprising northern Honshu and Hokkaido, and a southern, in the mountains of central Honshu. The northern distribution area was visited in preference to the southern because of its greater potential importance to forest tree breeding in eastern Canada, based on greater similarity in climate.

I. NORTHERN HONSHU

Before the Congress started, a 3-day trip to northern Honshu was made to visit the main tree breeding activities of the Jujo Paper Mfg. Co. and of the Tohoku Branch Forest Experiment Station of the National Government, at Takizawa, in Iwate Prefecture. Dr. Haruyoshi Saho, of the Faculty of Agriculture, University of Tokyo, kindly made the arrangements and accompanied me on this trip.

One of the aims was to see good Japanese red pine (Pinus densiflora Sieb. & Zucc.). Most P. densiflora grown in North America and Europe are of very poor growth form. This is also the case in Japan and Lindquist (1957) lists Iwate Prefecture as one of the areas with native P. densiflora of superior growth form. This species has been crossed successfully with various forms of Austrian pine (P. nigra Arnold), first by A. F. Blakeslee in 1914 (Austin, 1927), later by Wright and Gabriel (1958), and, more recently, at Maple, Ontario. The resulting hybrids are quite vigorous and of much better growth form than the P. densiflora parent. Some of these hybrids inherited the precocious flowering habit of P. densiflora and were crossed with Scots pine (P. silvestris L.) of northern origin. It was also possible to make the cross P. densiflora x silvestris, as indicated by Wright and Gabriel (1958). These crosses yielded several hybrid seedling populations, mostly P. silvestris-like in appearance but highly variable in other respects. The end results should combine the resistance to the European shoot moth (Rhyacionia buoliana Schiff.) of P. nigra with resistance to sweet fern blister rust (Cronartium comptoniae Arth.), winter hardiness, and site adaptation of P. silvestris. As crosses between P. nigra and P. silvestris are difficult to make, P. densiflora is used as a catalyzer, also contributing additional variability and precocious flowering, which are of possible value to further breeding work with such materials. The aim of this work was to produce new types of hard pines, capable of economically replacing the native red pine (P. resinosa Ait.) beyond its rather limiting climatic and site requirements.

Considerable work in plus tree selection and establishment of seed orchards with selected P. densiflora has been carried out by the Jujo Paper Mfg. Co. and by the Tohoku Station. Mr. Y. Takayama is in charge of tree breeding at the Kitakami Afforestation Centre of the Jujo Paper Mfg. Company. P. densiflora is used here mainly for pulpwood production. A nursery, clone bank, clonal seed orchard, and a large progeny test plantation were seen. In the nursery, the seeds are sown in the spring, seedlings transplanted by hand in the second spring and set out in the field in the third spring, i.e. as 1/1 stock. The soil is a dark, gritty, well-drained silty sand of alluvial origin, originally rather poor in fertility. Materials of excellent growth form were seen in the clone bank and seed orchard. These consisted of grafts of selected trees from all over northern Honshu. The flowering is far less abundant and much more variable than in Canada, but still sufficient for good seed production. It is greatly enhanced by fertilization (Takayama, 1966, 1967) although there is considerable interclonal variation in this. Some of the grafts are topped at about 1.5 m above the ground to facilitate cone picking. This is not as conducive to inbreeding as Fowler (1965) suggests because of dichogamy within clones (Takayama, 1968 a). Some P. silvestris of Swedish origin were also seen. They retain good stem form but are more coarse-branched than in Sweden and are slower growing than the local P. densiflora materials.

The progeny test plantation was most impressive. Crosses were made among the older grafts as soon as these started flowering. The resulting 1/1 plants were set out at Miyamori in blocks of 5 x 5 trees, spaced about 1.5 m apart, in a large cut-over area after thorough cleaning and brush disposal. Lanes about 3 m wide separated the blocks. The blocks differ markedly in height growth, number of branches per whorl, and thickness of branches but there is still considerable variation in these attributes and in branch angle within the blocks. There are also considerable differences in cone production, both within and between the blocks.

Some blocks of P. thunbergii Parl. x densiflora and back-crosses of this hybrid to P. densiflora were also established. This cross can result in considerable hybrid vigour when made in the above direction. The hybrid vigour is probably only temporary, as P. thunbergii seems to be slower in juvenile growth than P. densiflora, i.e. is more of a stayer type.

The planting site originally supported a mixed forest of poor P. densiflora and several intolerant hardwoods, probably of fire origin. Abundant growth of weeds followed clear cutting and brush disposal. Dwarf bamboo (Sasa sp.) and various hardwood sprouts needed at least two mowings per summer during the first few years after establishment to keep the plantation going. At present, most of the trees are about 1.5 m high and need only one mowing per summer. Dwarf bamboo is not as aggressive and persistent here as further to the north in Hokkaido, but still it is of considerable importance in plantation establishment and maintenance.

Seed orchards of P. densiflora were also seen at the Tohoku Branch Forest Experiment Station, of which Mr. S. Umemoto is the Director. This station is situated to the north of Kitakami and almost due east of Mt. Iwate, a large volcano after which the Prefecture is named. The pines have about the same growth form and branching habit as at Kitakami, but are more spindly in growth. The flowering and fruiting are appreciably poorer than at Kitakami, but sufficient to produce satisfactory seed crops. This is not the case with grafted Japanese larch (Larix leptolepis Gord.). These are of much superior growth form than materials usually planted in North America and Europe. Lindquist (1956) made an extensive study of this species in Japan and indicated areas where plus stands could be found. Japanese larch is at present planted very extensively outside its native habitats; seed of good origin is in short supply and clonal seed orchards based on plus trees are widely established. The grafts show surprisingly rapid growth and are often of excellent growth form, but their seed production is very low. The soil is a well-drained, black gritty silty sand of volcanic origin. It is supposed to be very acid and of low fertility, but supports a lush growth of grasses and eutrophic weeds, and excellent vegetative development of the larch grafts.

A natural stand of P. densiflora, on the lower north slope of Mt. Iwate, at Nishine, was also visited. It is about 23 m high at age 60 and appears to be evenaged, probably of fire origin. Most of the trees are reasonably straight, but the branches are rather coarse. The best formed trees are comparable to fair Scots pine. There is a dense undergrowth of deciduous shrubs and climbers, among these Boston ivy (Parthenocissus tricuspidata Planch.). The soil is a fine silty sand with a fine mull and rich ground vegetation, something one would expect under a stand of tulip poplar (Liriodendron) on a rich, sandy site. This stand produces timber of good quality according to local standards. Takayama (1966) made a study of seed weight of P. densiflora in seed orchards of materials of different geographic origin from northern Honshu and classified seeds of this origin as belonging to the heaviest group.

The lower north slopes of Mt. Iwate contain fairly large cut-over areas of mixed P. densiflora and intolerant hardwoods now being re-planted to Japanese larch and P. densiflora. According to Mr. Umemoto, it is more difficult to establish good plantations of the pine than of the larch. This is probably because large pine plants cannot stand transplanting nearly as well as large larch plants. Such plants are needed for satisfactory plantation establishment in the rank weed growth, after clear cutting and brush disposal.

We have, in former years, made several shipments of pollen, seeds, and scions of our two native aspens, Populus grandidentata Michx. and P. tremuloides Michx., to the Kitakami Afforestation Centre and in exchange received pollens of their aspens, P. davidiana Dode and P. sieboldii Miq. Of the various interspecific hybrids produced, P. sieboldii x grandidentata seems the most promising for planting on dry upland sites at Kitakami, while *P. alba* L. x *sieboldii* and *P. grandidentata* x *sieboldii* are the most promising in Canada. The hybrid aspen seeds are, as in Canada, produced on forced branches placed in containers with water in the greenhouse. The seeds are sown in flats in the greenhouse and the seedlings pricked out in rows in the nursery. They are transplanted during the next spring and set out in test plantations as 1/1 stock. After a few years in the test plantation, the plants are evaluated, roots are collected from the best for clonal propagation and root cuttings are made in the spring. The root cuttings are set out in beds in the nursery. During the second spring, the rooted cuttings are lifted, graded, and transplanted to a wider spacing. Early in the second summer, the plants are topped about half-way up. This results in bushy growth, suppressing weed growth. During the third spring, the tops are cut down entirely and a single strong shoot is allowed to grow during the third summer. In the fourth spring, this shoot is topped at about 2 m from the ground, the plants are lifted and set out in test plantations at a spacing of about 2 x 2 m after full cultivation. In the fifth spring, Ladino white clover is sown under the poplars and, in the sixth summer, most of the plants are ready for the first pruning. The land for such upland hybrid aspen plantations is levelled with bulldozers into narrow sloping terraces. Local farmers harvest the clover by hand and remove it when still green for their livestock. This is a good example of multiple land use and the height growth of the aspens is about 5 m in 4 years, i.e. about the same as on rich sites in Canada (Takayama, 1968 b). In time, the clover will probably largely be shaded out. The aspens will require several prunings to produce clear wood suitable for veneer and match stock. The first thinning would probably be unprofitable in Canada because the initial spacing in the plantation is too close, but may not be so in Japan. Time will be required to test the long-term resistance of these hybrid aspen to several diseases and to assess the quantity and quality of their wood production.

Conclusions

Some very good Pinus densiflora were seen on this trip and the introduction of these for breeding work in Canada seems worth while. The poor growth form of P. densiflora is rather strongly inherited in the hybrids with P. silvestris, according to our experience and, as the latter are more promising to the north in Ontario and elsewhere in Canada, a P. densiflora with good growth form becomes increasingly desirable. P. densiflora forma erecta, also supposedly of very good growth form, has shown to be entirely unsuitable to our growing conditions. According to Hyun (1968), it is the result of introgression of P. thunbergii into P. densiflora. P. thunbergii and several P. thunbergii x densiflora hybrids obtained in former years from Japan, have also been unsatisfactory in Canada, because they lack winter hardiness. In a test plantation at Turkey Point, Ontario, we have a small population of P. densiflora from Nagano Prefecture; it is of very good growth form - about comparable to the good ones seen on this trip. However, our trees are rather spindly, in the same manner as those at the Tohoku Station, and suffer much snow damage. This, I was told, is also the case with many P. densiflora planted in Hokkaido, to the north of its natural range. Crosses with northern P. silvestris could, perhaps, add some stiffness and foliage to such materials and contribute to the production of more snow-resistant pines of this kind. Some of these could also be suitable for Christmas tree production in Canada. Hybrids of P. nigra with P. densiflora have been produced in Hokkaido and show some promise (Anon., 1967), although I was told that P. nigra is also subject to snow damage. P. silvestris of southern origin as compared with native materials also suffers much from snow damage when planted in Sweden (Wibeck, 1912). There, snow damage is attributed to poor shoot lignification of the southern materials in a northern climate. Perhaps this also is the case with P. nigra in

Hokkaido and, in part, with P. densiflora. Thus, also from this standpoint, the introduction of genes from a northern strain of P. silvestris would seem desirable.

The mass production of F_1 interspecific hybrids and their direct use in forestry is only of temporary advantage. Rather, the F_1 is more a means to an end. It should consist of potentially valuable materials for still more favourable gene combinations with increased value for forestry in succeeding generations. However, this takes time, and in the meantime it would be important to produce numerous kinds of F_1 hybrids for future work. The rather poor cone production of P. densiflora contrasts strongly with the abundant and often precocious flowering of such materials in North America and Europe. This difference cannot be due to latitude and must be caused by either edaphic or climatic factors, or both. The soil of volcanic origin, found in many areas in Japan, seems conducive to very vigorous vegetative development of the trees, often at the expense of fructification. Under such conditions it may, perhaps, be advisable to select pine biotypes that tolerate such sites, i.e. do not increase branch diameter and decrease shoot ligni-fication and flowering. For this purpose, genes from P. nigra may be useful, as this species is well known to possess higher site requirements than P. silvestris and P. densiflora. Under the climatic and soil con-ditions of Miyamori, there are at least some P. densiflora showing good growth rate and form in combination with reasonably good fructification. Such materials seem promising for further clonal selection and establish-ment of seed orchards with satisfactory seed production.

The most promising clones of hybrid aspen, Populus sieboldii x grandidentata are at present being propagated by means of root cuttings. We had (Heimburger, 1968) a different approach to this, namely crossing with P. alba with good rooting ability from stem cuttings and the breeding of hybrid aspens with such ability, suitable for propagation on an industrial scale. Whether this method will be found more practical in

Japan than propagation from root cuttings remains to be seen. In either case, the good combining ability of P. sieboldii with P. grandidentata, fully confirmed in the reciprocal crosses made in Canada, can be used in the production of additional promising hybrids. As the geographic range of P. grandidentata is much greater than the range of P. sieboldii, the introduction of additional biotypes of P. grandidentata would seem to be promising. As new F_1 hybrids with parents of various geographic origin will be produced, it should be promising to produce several F_2 generations, using unrelated F_1's for this purpose. This will result in large numbers of worthless and indifferent seedlings, and at least some superior seedlings that, by their performance in test plantations, should be able to justify such further breeding work with these materials.

II. HOKKAIDO

After the Congress ended, I made a 12-day trip to Hokkaido to see the tree breeding activities of the Oji Paper Co., Ltd. at Kuriyama, the Tokyo University Forest at Yamabe, and of one National and one Prefectural Forest Experiment Station (Fig. 1). Also, I visited seven National and two Prefectural forest offices and with the help of their staff saw nurseries, plantations, and natural stands of several native tree species. Dr. Shigeru Chiba, Director of the Oji Institute for Forest Tree Improvement, and Mr. Chyuzi Yamakawa, Director of the Hokkaido Tree Breeding Station, kindly made all arrangements for this trip. On the first part of the trip, I was accompanied by Dr. Gustaf W. Hadders of the Institute for Forest Improvement, Uppsala, Sweden, who also attended the Congress in Tokyo. Dr. Seizaemon Satoo, Vice-director of the Oji Institute, supplied transportation and acted as guide during the first part of the trip, and Dr. Chiba was the guide on the second part.

In the past, we had exchanged breeding materials with the Oji Institute and with Tokyo University Forest. These were mostly poplars, pines, and spruces. I was particularly interested in seeing *Picea glehnii* Mast. and *P. jezoensis* Carr. (*P. ajanensis* Fisch.), species that are seemingly closely related to our native spruces, and *Pinus pentaphylla* Mayr. which is of interest to our work with white pine. Besides this, it was possible to obtain some information on breeding work with fir (*Abies sachalinensis* Mast.), larch (*Larix*), birch (*Betula*), and poplars (*Populus*). Work is also in progress with alder (*Alnus*), but this was not seen in detail.

Hokkaido is about the size of Newfoundland, but situated much further south--about the latitude of Boston. It has three climatic areas, a warmer and moister southwestern part, where several more southern tree species, such as beech (*Fagus*) and *Cryptomeria* are native, and a colder, drier northeastern part with mostly a boreal forest. In between, there are vast stretches of mixed forest of Abies, Picea, and northern hardwoods such as Acer, Quercus, and Betula, with alders, poplars, and willows along the water courses. In the mountains, a boreal forest gradually becomes prevalent at higher elevations and, under normal conditions, Pinus pumila Reg., a dwarf soft pine, is found at timber line. Hard pines are not native so far north in Japan. White oaks occur much further to the north than in Canada and several species belong to the northern hardwoods. Our yellow birch (Betula alleghaniensis Brit.) is represented here by B. maximowicziana Reg., which has similar silvicultural requirements. Hurricanes are not as prevalent as further to the south, but one can still see large stretches of forest laid flat, where all wood is carefully salvaged and the area promptly replanted, often to more immediately useful exotic tree species.

The population of Hokkaido is about 5 million and considerably less dense than further to the south. Rice cultivation is possible up to about the middle of the island and all lowlands are used almost exclusively for growing this staple crop. Upland farming has been introduced from the United States of America and is carried out on agricultural land not suitable for rice cultivation. The recent change from charcoal to fuel oil and propane gas has shifted the interest from firewood to timber and pulpwood production.

Dwarf bamboo is a predominant feature on all disturbed soils and persists for at least 50 years under intolerant hardwoods and in some plantations, from timber line right down to sea level. It would be regarded as a most serious weed were it not for its erosion control properties and it is of utmost importance in plantation establishment and maintenance. It also creates a very severe fire hazard in the dry springs that are prevalent here and undoubtedly influences natural forest regeneration in many ways. Under the canopy of dwarf bamboo, voles (Clethrionomys rufocanus bedfordiae Thomas) often have population explosions and cause much damage to natural and artificial regeneration.

The growing of several exotic and otherwise very promising tree species, such as hard pines, Norway spruce, larch, and white pine, is often severely restricted because of their susceptibility to vole damage. Snowshoe hares (Lepus timidus ainu Barrett-Hamilton) are also damaging in this respect, particularly to birches and poplars. Most of the natural forest has, as in Canada, a preponderance of overmature and very young stands. Silviculture for the present consists mainly in selection cutting and thinning to favour the growth of economically more important species. Planting is carried out to about the same extent as natural regeneration. It is done after clear cutting and slash disposal, and as rehabilitation after hurricane damage and fire. At Tokyo University Forest, in the central part of Hokkaido, a kind of group selection cutting and re-planting is practiced. Under such treatment, it was possible to observe promising young Betula maximowicziana.

Birches (B. japonica Winkl., B. ermani Cham., and B. maximowicziana) usually follow fire in dwarf bamboo, resulting in rather open stands. These are very slowly replaced by fir, spruce, and tolerant hardwoods, the only species capable of shading out dwarf bamboo and allowing "normal" ground vegetation to develop.

About 72% of the area is forested, of which 74% is national, prefectural, and municipal forests and 26% private forests. Plantations amount to about 13% of the forested area. Some parts of the national forests are set aside as national parks and protection forests.

Forest nurseries are fairly widespread. Nearly every forest office has one or several nurseries to serve local planting needs. They are usually rather small, about 6 ha, and are fairly uniform in their layout and production methods. A great effort is being expended on soil management. Only the national forest offices can afford the luxury of using soybeans as a soiling crop; the others must save space and use various composts to maintain a high level of soil organic matter.

The seed beds are about 10.5 m wide and are usually enclosed with lumber frames constructed of wide thin boards placed vertically on the ground and supported by steel rods. Black nylon netting is used for shading. This is strung on three wires, one along the centre of the bed supported by stakes and one on each side of the bed. The centre wire is about 15 cm higher than the lateral wires. Shade houses, covered with nylon netting or reeds, are fairly common. They are used for raising grafts, rooted cuttings, etc. and usually are portable, i.e. they can easily be taken apart for storage and reassembled when needed. The same is the case with the lumber frames around the seed beds. Transplanting is usually done into beds by hand at a rate of about 4000 per worker per day. Most of this is done in the spring, although some nurseries are experimenting with August transplanting. Grafting is very widespread and is used to establish local clonal seed orchards with scions supplied by the Hokkaido Tree Breeding Station to most regional, district, and Prefectural forest offices. Selected nursery stock is established in transplant beds, then top-grafted in the spring, with protection of paper bags and shade houses. Plastic strips are used for tying the grafts after cleft grafting. The use of side-grafting on potted stocks in greenhouses was abandoned several years ago. Instead, greenhouses, which are expensive to establish and to maintain, are used for propagation by stem cuttings, with or without mist, several times a year and with several rooting media, some of volcanic origin. The vegetative propagation of Cryptomeria is based on old tradition while that of the more northern tree species is more recent in origin and, seemingly, under rapid development. Air layering is also used rather widely, with softwoods as well as with hardwoods.

Fir

Abies sachalinensis is the most abundant and conspicuous tree in the Sub-frigid Forest Zone of Hokkaido (Anon., 1964). It extends into the boreal forest, but is not as abundant there as balsam fir (A. balsamea (L.) Mill.) is in the Boreal Forest Region of Canada. It is a valuable timber and pulpwood species and can compete successfully with tolerant hardwoods because of its great size and longevity, in marked contrast to balsam fir in Canada. Its seedlings are more shade tolerant than seedlings of the native spruce species and very similar in appearance to seedlings of A. sibirica Ledeb., to which this species may be closely related, perhaps in the same manner that A. fraseri (Pursh) Pair. is related to A. balsamea. The crown is much wider than in balsam fir, and this is probably necessary for its successful competition with tolerant hardwoods. This fir is at present one of the most widely planted tree species in Hokkaido and much improvement work with it is in progress. The seeds are fall-sown in nurseries and seedlings set out as 2/2/1 or as $2/1\frac{1}{2}/1\frac{1}{2}$ stock (transplanting is then carried out in August). Selection in this species is for narrow crown form, rapid juvenile growth, late flushing, and good stem form. In tests for resistance to voles, this fir was found to be markedly more resistant than several exotic species, including balsam fir (Takahashi and Nishiguchi, 1966 a). In order to introduce late flushing, it has been crossed with A. veitchii Lindl., a more southern species in Japan, and the F_1 hybrids found intermediate in time of flushing (Anon., 1967).

The Oji Paper Company is interested in producing trees of about 20-25 cm dbh. as fast as they can and with as high a yield of pulpwood as possible (Anon., 1967). Along with the use of improved silvicultural methods, forest tree improvement is also a means to this end. It is, in this case, an example of selecting a sprinter type of tree out of original material consisting mostly of stayer types, i.e. types with slow juvenile growth but late maturing and long-lived. Also, there is selection for late flushing and a series of other characteristics governing successful survival of artificially raised nursery stock in open plantations competing with dwarf bamboo out of materials originally adapted to natural regeneration under a relatively dense canopy of competing tolerant tree and shrub species.

Moreover, fir and one of the native spruces (Picea glehnii) are the only native species capable of eventually shading out dwarf bamboo and establishing natural regeneration in it. In order to obtain relatively rapid results in fir breeding, I think interspecific hybridization could be applied to advantage. Interspecific hybridization in Abies has thus far shown no incompatibility barriers between species native to widely separated geographic areas (Rohmeder, 1960; Klaehn and Winieski, 1962; Mergen et al., 1964). Eklundh (1943) made the successful cross A. sibirica x veitchii olivacea Shiras. However, very little is known yet about the relative fertility of the resulting hybrids and much basic research in this field remains to be done. A. fraseri is relatively late flushing in Japan (Chiba, 1961), but as far as I know, it has not yet been tested for resistance to voles. Natural hybrids between A. balsamea and A. sibirica are found in abundance at the Arboretum Mustila in Finland (Tigerstedt, 1960). Since A. fraseri is closely related to A. balsamea, it is possible that A. fraseri and A. sachalinensis will yield fertile hybrids, and these would be one means of introducing sprinter-type genes into A. sachalinensis. According to Bukhteeva (1963), A. sachalinensis and its variety mayriana Miyabe and Kudo are native to Hokkaido. In Sakhalin, the var. mayriana is a large dominant tree with a more southern distribution than the typical form, which is a smaller tree. Several intermediate forms have been found also. The introduction of A. sachalinensis may also be of importance in Canada. There are no long-lived Abies species native to eastern North America, capable of successfully competing with tolerant hardwoods and being relatively resistant to heart rot. In areas where balsam fir is being grown for pulpwood, breeding work with this species should eventually gain in importance. Direct introduction of A. sachalinensis could possibly result in northern biotypes going to seed at an early age and southern biotypes not being sufficiently winter hardy under our climatic conditions. This will have to be ascertained empirically and may take time. There are, of course, several other possibilities of introducing long-lived Abies species into eastern Canada, should this become desirable.

Spruce

The two spruce species native to Hokkaido, Picea jezoensis and P. glehnii are next to fir in importance. They grow together with fir in the Sub-frigid Forest Zone and gradually replace it in the Boreal Forest and at higher elevations in the mountains. P. jezoensis is usually the larger in size of the two. At first glance, it is intermediate between sitka spruce (P. sitchensis Carr.) and Engelmann spruce (P. engelmannii Engelm.) in appearance, although the needles are softer. Its ecological requirements appear to be very similar to those of Engelmann spruce, and like the latter, it can reach huge sizes. Chemically, it also seems to be closely related to Engelmann spruce (Schantz and Juvonen, 1966). It usually grows in mixed stands, as does white spruce (P. glauca (Moench) Voss.) in eastern Canada, and reaches its best development on rich soil on well drained slopes. Its juvenile growth is faster than that of P. glehnii and, probably therefore, it was the first native spruce used in planting. A 50-year-old plantation established on a fairly rich tolerant hardwood site after clear cutting and slash disposal at low elevation in central Hokkaido still has a dense growth of dwarf bamboo throughout, although the stand is well closed and in need of thinning. Another planted stand, on rather poor volcanic sand, established after hurricane damage to mixed hardwoods, has a breast height diameter of about 15 cm at age 30 and is beginning to stagnate in height growth. This stand has a ground vegetation indicating good growing conditions for white spruce. Although P. jezoensis is almost as resistant to voles as the fir (Takahashi and Nishiguchi, 1966 a), its use in forest planting has in recent years been curtailed because of susceptibility to late spring frosts. It is also rather weak in competition with dwarf bamboo and open plantings require extensive maintenance. According to Rehder (1940) and Chiba (1961), P. jezoensis var. hondoensis (Mayr) Rehd. is later flushing and more successful. P. jezoensis has a wide distribution in continental eastern

Asia and is known to occur as far west as the Lena-Aldan valley and the east end of Lake Baikal, but does not reach timber line (Suslov, 1961). It is doubtful if provenances of this species available at present will be of immediate interest to forestry in eastern Canada, except in the Maritime Provinces. It has been crossed successfully with black spruce (P. mariana BSP.) and white spruce (Rehder, 1940). The hybrids with white spruce are vigorous and easily produced (Yanagisawa, 1954; Wright, 1955) and may, after testing, become useful in further breeding work with the parent species. The same may be the case with the black spruce hybrids.

The other spruce species native to Hokkaido, Picea glehnii, is at first glance strikingly similar to red spruce (Picea rubens Sarg.). It is a rather slow growing, shade-tolerant species found throughout the Sub-frigid Forest Zone and also in the Boreal Forest. It can form nearly pure stands, similar to the spruce flats and spruce slopes of New England, but is usually mixed with fir, the other spruce species, and hardwoods. It can grow up in the mountains, in a boreal forest, where it is usually mixed with a birch, Betula ermani, and gradually replaced by the shrubby Pinus pumila near timber line. The site requirements are very similar to those of red spruce. It can also grow on somewhat wet ground with a high water table, where in Canada black spruce and balsam fir usually would replace red spruce. It does not grow at as low elevations nor as far south as Picea jezoensis and in those respects differs from the red spruce of the Appalachians. Thus in its climatic requirements it would seem to correspond rather closely to the red spruce of New England and New York (Heimburger, 1934; Heimburger and Holst, 1955). Like P. jezoensis, P. glehnii can reach very large sizes in protected localities, up to 1.2 m in stump diameter, and live up to 300 years. Its terminal buds have subulate scales at base (Rehder, 1940), in this respect being similar to red and black spruce, and its needles are high in bornyl acetate content, as are those of red spruce and black spruce (Schantz and Juvonen, 1966). In crown shape, it is also strikingly similar to red spruce, older trees having pagoda-like crowns as red spruce (Gordon, 1957). This is probably an adaptation to competition with tolerant hardwoods, as in the case of P. jezoensis. It seems to correspond rather closely to red spruce in several morphological and ecological features, and climatic requirements, and is probably one of the corresponding taxa of eastern Asia and eastern North America, having a common origin, but separated since the Tertiary (Li, 1952). In recent years, P. glehnii has been used to quite an extent in forest planting. Because of its late flushing and shade tolerance, it is more resistant to late spring frosts and better able to compete with dwarf bamboo in open plantings than P. jezoensis. It is next to fir in number of plus trees selected and area of seed orchards established in Hokkaido. In resistance to voles, it is about equal to P. jezoensis (Takahashi and Nishiguchi, 1966 a). Narrow crown, good stem form, and rapid growth are the main criteria in the selection of plus trees. This species, as well as P. jezoensis, is usually raised in nurseries as 3/2 stock after fall sowing. August transplanting, as with the fir, is practiced occasionally. Considerable variation in juvenile growth rate was seen in one nursery, where half-sib families of plus trees are being raised for progeny tests. Seedlings of some families were about twice as tall at age 2 as seedlings of other families. There is thus ample variation available within this species, for successful selection of sprinter types, with rapid juvenile growth. The best families in this respect are fully comparable to our good spruce nursery stock of the same age and thus suitable for raising as 2/2 stock or 1½/1½ stock with August transplanting. In a spruce population collection at Tokyo University Forest at Yamabe, a young plantation of P. glehnii was seen with considerable variation in growth form, needle colour (clearly related to number and distribution of stomata rows), and in growth rate. Some of the most striking individuals in this respect resembled P. jezoensis in their foliage and growth form. Unfortunately, there were no cones available to determine whether this variation was due to introgression from P. jezoensis or caused entirely by intraspecific variation inherent in P. glehnii. In any case, such materials appear very promising for further selection and breeding. Rehder (1939) described the hybrid P. notha, (P. glehnii x jezoensis var. hondoensis) raised from seeds of P. glehnii received in 1894 at the Arnold Arboretum, Mass., from the Government Forestry School, Tokyo. Since P. glehnii is not found in Honshu except in a relict stand (Ishizuka, 1961), it is more likely that the seeds were obtained in Hokkaido where both P. glehnii and the typical form of P. jezoensis are native. The hybrid has been raised successfully at the Arnold Arboretum and is fertile. According to a personal communication from Dr. D. Wyman, the present director of the Arnold Arboretum, Picea notha is still growing there and scions of it are available. It is highly probable that the present gene pool of P. glehnii in Hokkaido and Sakhalin is narrower than the combined gene pools of P. rubens and P. mariana in North America. In eastern Canada and adjacent parts of the U.S.A., P. rubens and P. mariana hybridize quite frequently in nature and introgression between these species has been described (Morgenstern and Farrar, 1964). Some introgression from P. mariana has been observed in a plantation of P. rubens at Yamabe and the types found there correspond to those seen in Canada. Because of the great similarity of P. glehnii to P. rubens, it is possible that hybridization between these species will be successful and the resulting hybrids will be, at least partially, fertile and thus suitable for gene transfer. The Appalachian types of P. rubens would then be of particular interest to forestry in Hokkaido, making it possible to produce a more rapidly growing spruce for lower elevations and further to the south. It would then be the task of tree breeding to retain and possibly to increase resistance to voles and climatic adaptation in succeeding generations. P. mariana is represented mostly by sprinter types with precocious flowering in several young plantations in Hokkaido, and thus it should be possible to explore the crossability of this species with P. glehnii. The reciprocal cross, using pollen of P. glehnii, has yielded viable seedlings at Maple, Ontario. Such hybrids should, in part, inherit the precocious flowering of P. mariana and be of potential value to a relatively fast-moving breeding program with P. glehnii, in the same manner as precocious types of Pinus densiflora are being proposed for hard pine breeding. According to Komarov (1934), the occurrence of Picea glehnii is doubtful to the north of latitude 50° in Sakhalin and it is lacking on the Asiatic mainland. The distribution map published by Ishizuka (1961) shows the main occurrence to be in Hokkaido. It is, therefore, rather doubtful if this species can be used directly in forestry in eastern Canada except in southern Newfoundland and the Maritime Provinces, where it will have to compete with native spruce species and with Norway spruce (P. abies (L.) Karst.) in plantations. The main uses of P. glehnii in Canada will be in various hybridization experiments to determine its crossability pattern in relation to other spruce species already used in forest planting. Hybrid vigour could quite possibly result from several such crosses, and this may then be used to advantage in further breeding work.

White Pine

There are two species of Japanese white pine; P. pentaphylla is native only in the southwestern part and in a small area in southern Hokkaido, with the main distribution in northern Honshu, and P. himekomatsu Miyabe and Kudo, found in central Honshu and southward. It was possible to see a natural stand of P. pentaphylla at Urakawa, near Mt. Apoi, in southern Hokkaido. A rocky knoll of diabase with thin soil, mostly of volcanic origin, carried a nearly pure stand of this species and an old landslide nearby had abundant natural regeneration in mixture with fir and hardwoods. Several rocky ridges with thin soil had single trees in mixture with fir and hardwoods. Our P. strobus L. would probably have very similar site requirements there. The growth form is far superior to that of P. himekomatsu seen in various arboreta in Europe and North America, and in parks and gardens in Japan, where it is often planted for decoration and variously modified in form. It is usually raised as 2/2 stock after fall sowing. There is usually no trouble with mice eating the seeds during the winter. Red lead and shooting are used to control seed-eating birds in early spring. Some very successful seed beds and transplant beds of P. pentaphylla and of P. koraiensis Sieb. and Zucc. were seen in several nurseries. The good results are based on much experimentation in soil management and nursery technique. This species is being raised and planted to some extent to the north of its natural range. P. pentaphylla is slower growing than P. strobus but is more vole resistant (Takahashi and Nishiguchi, 1966 a). It has been crossed successfully with P. strobus and some hybrid seedlings were seen in one nursery. Natural hybrids of P. himekomatsu and P. strobus have been found and described in Wellesley, Mass. (Johnson, 1952) and grafted at Maple, Ontario. Many have very good growth form and are faster growing than P. himekomatsu. Some have been found to be quite resistant to blister rust (Cronartium ribicola Fischer). The grafts flower abundantly at Maple, Ontario, but the seed set is very poor. The pollen is also poor, thus making these hybrids rather difficult for further breeding work. Hybrids of P. strobus x pentaphylla are difficult to produce. The seed set and seed germination are low and most of the seedlings succumb to blister rust. However, the few remaining resistant seedlings are showing good vigorous growth and promising stem form. P. himekomatsu has also been crossed successfully with P. griffithii McClelland, P. peuce Griseb., and P. monticola Lamb. The cortex of the shoots, when bruised, has the smell of green tomatoes in P. himekomatsu and all its hybrids with other species obtained thus far. In the population collection of the Tokyo University Forest at Yamabe, some Pinus pumila were seen that in their bud characteristics and smell of bruised cortex reminded one of P. himekomatsu. This may be the result of introgression of P. himekomatsu into P. pumila. According to Ishii (1968), intermediate forms between these species, presumably natural hybrids, are found occasionally in Japan.

P. pumila, usually a timber line species of the mountains, is sometimes planted in rock gardens and parks at lower elevation. At Mt. Yuo, near Kawayu, around a fumarole, P. pumila was found growing well below timber line at the exclusion of all higher plants, except a Ledum species. This appeared to be an exceptional situation where P. pumila could replace all other tree species at low elevation, probably because of its tolerance of sulphur fumes. There are in Ontario two large areas, at Sudbury and Wawa, where sulphur fumes from ore refineries have killed off the forest on a fairly large scale. This is being followed by soil erosion and other undesirable changes in the vegetation. It is possible that the P. pumila at Mt. Yuo has undergone natural selection for resistance to sulphur fumes and thus may be of value in the rehabilitation of such areas around ore refineries. It is also possible that additional areas exist in Japan where trees have acquired resistance to sulphur fumes through long exposure and natural selection. Such types, if found resistant in subsequent tests, may be of value to planting also in areas suffering from industrial smog, which to a great extent is composed of sulphur fumes. If resistance to sulphur fumes is found to have a genetic basis, it may be possible to incorporate it into larger trees of commercial importance through the intermediate forms between P. pumila and P. himekomatsu mentioned above. Forms intermediate between P. pumila and P. sibirica Mayr are known from Siberia (Pozdnyakov, 1952), thus offering another possibility of breeding fume-resistant trees of economic importance. However, the species involved in this are rather distantly related to each other, making breeding work slow and difficult. The direct cross P. pentaphylla x sibirica was not successful in one attempt at Maple, Ontario, although pollination was carried out on a fairly large scale.

Pinus koraiensis is found planted in parks and gardens, and small planted stands of it were seen in the Tokyo University Forest at Yamabe. It is very decorative but slower growing than P. strobus. The growth form is usually about the same as in our plantation of Korean origin at Orono, Ontario.

White pine (Pinus strobus) has been planted in Hokkaido since the turn of this century, as have all the main other exotic conifer species (Picea abies, Pinus silvestris, Larix decidua Mill., and Larix leptolepis, which is native to Honshu). Some of the older plantings of Pinus strobus were seen in the arboretum of the National Forest Office at Asahikawa, in central Hokkaido. Fairly large plantings were established around 1961 in the Tokyo University Forest at Yamabe. Most materials are of Lake States origin and the growth rate is very good, about the same as in the southern Appalachians. No blister rust or weevil damage have been seen to date, although Pissodes strobi Peck is said to have been introduced into Japan around 1925 (Taylor, 1929-30). In spite of lack of weevil damage, the growth form is usually only fair, with rather crooked stems and heavy side branches, as is occasionally seen on very rich and moist sites in Canada. This unsatisfactory condition is probably also caused by poor adaptation to climate. A plantation raised from seeds collected from selected trees at Yamabe has strikingly improved stem form and branch thickness, compared with trees raised from seeds of Wisconsin origin. Were it not for susceptibility to vole damage (Takahashi and Nishiguchi, 1966 a), P. strobus would be one of the most promising exotic forest trees in Hokkaido. Some 40 plus trees of this species have thus far been selected and small seed orchards established in at least four places in Hokkaido. The potential damage from blister rust, if introduced into Japan, does not seem very serious, although climatic factors, notably the usually very wet late summer, would favour its spread and establishment on the pines. Currants and gooseberries are not grown in cultivation, and the few native Ribes seen were similar to R. triste Pall., known to be a poor carrier of blister rust. In view of all this, it seems very strange that the native P. himekomatsu and P. pentaphylla are so resistant to blister rust in North America. Damage by a native weevil, Pissodes nitidus Roelof. (Nishiguchi, 1968) was seen in a young plantation of several exotic species at Yamabe. Picea omorika (Pancic) Purkyne, Pinus griffithii, and P. monticola were heavily attacked and damaged while P. strobus and the native P. pentaphylla and P. koraiensis showed no appreciable damage. This susceptibility to weevil attack may be caused by poor climatic adaptation of the P. monticola materials. The heavy damage to Picea omorika and Pinus griffithii is in line with their susceptibility to Pissodes strobi in North America.

Larch

Japanese larch (Larix leptolepis), originally native in the mountains of Honshu, is the most widely planted forest tree in southern Hokkaido. It is rapidly replacing native species, previously used for fuelwood, especially in private woodlots. One often sees carefully tended nursery stock of this species alongside vegetables on upland soil in small farms, where it is used in reforestation after cutting, fire, landslides, and hurricanes. The ease of nursery stock production and establishment on open land in competition with abundant weeds and rapid juvenile growth were probably the main factors favouring this species in planting. Moreover, seeds were available from plantations established in Honshu, often of excellent growth form and far superior in this respect to anything seen in Europe and North America. Lindquist (1956) initiated and intensive selection of plus trees and plus stands in this species, and subsequently numerous seed orchards and seed production areas were established. However, seed is often in short supply and the few seed orchards flower rather poorly. Some climatic and edaphic factors are probably responsible for this poor flowering and more research seems to be needed in this direction to alleviate this drawback. According to Yanagisawa (1961), materials from the northern part and high elevations of central Honshu show earlier lignification and less early frost damage when planted in Hokkaido than materials from further south and low elevations, while spring flushing is about the same for all provenances. This species is seriously damaged by voles and whole mountain sides of young plantations, almost totally destroyed by voles, were seen. Considerable research is being undertaken and breeding work is in progress to solve this problem. Feeding experiments with captive voles offered twigs of different larch species have shown that Kurile larch (L. gmelini (Rupr.) Litvin. var. japonica (Reg.) Pilger), tamarack (L. laricina (DuRoi) K. Koch.), and Korean larch (L. gmelini var. olgensis (Henry) Ostenf. and Syrach) were resistant, while Japanese larch and European larch (L. decidua) were susceptible (Chiba, 1963; Takahashi and Nishiguchi, 1966 a, b). Chiba (1963) also found a high correlation between resistance of the larch materials tested to voles and to snowshoe hares. Kurile larch is native to the easternmost part of Hokkaido and adjacent Kurile islands. It is a rather slow-growing tree and has been introduced into arboreta and crossed with Japanese larch as soon as its resistance to voles and hares was established, first by direct observations and, more recently, in the feeding experiments cited above. Most of the Kurile x Japanese larch hybrids show hybrid vigour and are about as resistant to voles as Kurile larch. The reciprocal cross has not yielded any appreciable increase in resistance to voles. This may be a case of cytoplasmic inheritance. Experiments are at present under way to mass-produce the hybrid Kurile x Japanese larch in seed orchards. To this end, single tree progenies after open pollination of Kurile larch growing near Japanese larch are scored for the proportion of vigorous hybrid seedlings. The proportion of hybrid seedlings depends, in part, on the time of female flowering of the Kurile larch parent trees in relation to the time of pollen release by the available Japanese larch. The proportion of vigorous seedlings also depends on the genetic loads of the respective parent trees which is a part of their specific combining ability. Japanese larch is well known to exhibit inbreeding depression in respect to growth rate and the same is very likely the case with Kurile larch (Takahashi and Nishiguchi, 1966 b).

Needle cast caused by Mycosphaerella larici-leptolepis K. Ito and K. Sato and shoot blight caused by Guignardia laricina (Sawada) Yamamoto and K. Ito are two important diseases of Japanese larch in Hokkaido. According to Chiba and Nagata (1963), European larch, tamarack, and Japanese larch are slightly injured by needle cast, while Korean larch is severely injured and Kurile larch is moderately susceptible. Kurile larch and Korean larch are highly resistant to shoot blight, while Japanese larch is moderately susceptible and European larch and tamarack are highly susceptible. Yanagisawa and Manabe (1964) also found

Kurile larch to be resistant and Japanese larch susceptible to shoot blight. There is also a great deal of intraspecific variation in resistance to these diseases that is being taken into account in breeding work with larch. Chiba and Ogawa (1965) found Kurile larch to be rather susceptible to root rot caused by the shoestring fungus (Armillaria mellea (Fr.) Quel.) in comparison with Japanese larch when planted on upland sites in the northeastern part of Hokkaido. This is thought to be correlated with the shallower root system of Kurile larch as contrasted with the deeper root system of Japanese larch on such sites. I found considerable interest in our tamarack for breeding purposes. This species is the only exotic conifer showing relatively high resistance to voles. At Yamabe, it is the only larch species regularly flowering on 1-year-old wood, resulting in increased cone production, an important factor for larch in this area. One clone of Kurile larch was also found to flower in this manner. The successful and promising cross of tamarack with Japanese larch effected by MacGillivray (1967) is of particular interest in this connection. Hybrids of Kurile larch with Japanese larch usually show earlier shoot lignification of seedlings than Japanese larch (Hamaya et al., 1968). This would make successful larch cultivation possible in the boreal forest of northern Hokkaido where seedlings of Japanese larch lignify too late. The same would probably be the case with the tamarack hybrids. Some resistance to sulphur fumes has been found in Japanese larch and its hybrids with European larch in tests in Germany (Schönback et al., 1964). Further tests (Börtitz and Vogl, 1965) have shown that Japanese larch generally is more resistant to sulphur dioxide than European and Kurile larches. Intraspecific variation in this resistance within Japanese larch has also been found. With the abundant native materials available in Japan, such tests may be used to find biotypes with superior resistance to sulphur fumes, suitable for growing in industrial areas as suggested earlier for Pinus pumila. Such biotypes would also be of potential value for growing in Canada.

According to Tkachenko (1941), the area stocked with larch in the U.S.S.R. is about equal to the total forested area of Canada. F.A.O. (1966) estimates the potential softwood resources of the U.S.S.R.

to be roughly double those of the rest of the world. The bulk of these resources is situated in eastern Siberia where larch is the principal forest tree species. The wood of larch is well known for its good mechanical properties and resistance to decay, but it is not well suited for lumber because of difficulties in seasoning. It is not as well suited for pulp production as the wood of spruce, fir, or pine, because of more expensive 'cooking' requirements. It is, however, very suitable for piling and harbour construction and in a country like Japan, with a very long coast line, the high potential of larch wood production present in the existing extensive plantations and most probably enhanced in the future by intensive larch breeding programs, is probably well justified. However, it can be reasonably expected that transportation facilities for wood from eastern Siberia will be greatly improved within a foreseeable future and Siberian larch will then be in strong competition on the world market with Japanese larch. This will be particularly true for wood in larger sizes suitable for piling and harbour construction. Attempts will undoubtedly be made to modify the inferior qualities of larch wood by physical and chemical engineering procedures, especially in respect to pulping characteristics. Differences in these have been found to exist between wood of Japanese and European larch and their hybrids (Chowdhury, 1931; Langner and Reck, 1966). At least some of these differences must have a genetic basis and the possibility may thus be at hand to improve the pulping qualities of larch wood by means of breeding. With the excellent experience, good working facilities, and abundant larch breeding materials, Japan could develop a strong competitive position in respect to larch pulpwood production.

Birch

The mill of the Oji Paper Company at Tomakomai, on the south shore of Hokkaido, is using chips of birch and alder for pulp production. The chips are made in the woods and transported by truck to the mill for immediate use. This obviates the somewhat difficult problem of storing pulpwood of these species in the woods or at the mill. The two native birches, Betula ermani and B. japonica, are also grown in plantations nearby for such pulpwood production. There is supposed to be a strong genetic barrier between B. ermani, a high-elevation and slow-growing species, but sometimes of excellent form with good natural pruning ability and strong inherent resistance to voles, and B. japonica, a low-elevation and relatively rapidly growing species of fair form and natural pruning and good resistance to voles. B. ermani is said to be tetraploid and B. japonica diploid (Johnsson, 1945). Some test plantations of both species, raised from seeds of plus trees after open pollination, were seen at Kuriyama. A plantation of B. ermani, of rather slow growth but very good growth form and excellent natural pruning ability was particularly impressive. The desired optimal combination of characteristics of the two species is being attempted by means of indirect crosses, via the diploid B. verrucosa Ehr. from Europe and our B. populifolia Marsh. The crossability of B. japonica with B. verrucosa has been ascertained by Johnsson (1945). B. ermani is at first glance strikingly similar to our B. cordifolia Reg. in ecological requirements and taxonomic features, except that its seeds resemble those of yellow birch more than white birch (Rehder, 1940). B. cordifolia is usually regarded as a variety of B. papyrifera Marsh. and only in recent times (Rosendahl, 1928; Brittain and Grant, 1965, 1967) has it regained its status as an independent species. Most of the materials examined by Brittain and Grant (1965, 1967) were found to be diploid, whereas those used by Stern (1965) were tetraploid This species may well be worth trying out in the current birch breeding programs in Hokkaido. It has been possible to cross the hexaploid paper birch (B. papyrifera) with the hexaploid yellow birch (B. alleghaniensis) according to Johnson and Heimburger (1946) and Clausen (1966). Some definitely intermediate hybrids between these species, made by the Northeastern Forest Experiment Station, were seen at Standing Stone, Pa. in 1964. Therefore, it may also be possible to cross B. cordifolia, which is a white birch, with B. ermani, which has some yellow birch characteristics. The third native birch species, B. maximowicziana is also said to be diploid (Johnsson, 1945). It clearly belongs to the group of yellow birches, is somewhat more tolerant of shade than the two other native species, is often of very good growth form, and is of much more rapid growth. Its site requirements are rather high. Because of its very rapid juvenile growth and shade tolerance, it can compete successfully with dwarf bamboo and grow in mixture with the more tolerant fir and spruce. A young plantation of this species was seen on a medium rich site near Sapporo, where it is being grown for veneer production. After very successful establishment and rapid juvenile growth, the trees are developing large rounded crowns on a very short bole and in this respect resemble the plantation-grown yellow birch in western Quebec. Like yellow birch, this species probably has to be grown in mixed stands to produce reasonably long veneer logs. The wood from natural stands is of excellent quality and is being exported. I saw it being used for flooring in several country inns where it is lighter in colour than our yellow birch wood, but of very similar texture. Because of its very great susceptibility to vole and hare damage, this species is not being used extensively in open plantations. It is very suitable to the group selection method of management in Tokyo University Forest at Yamabe, where some material of very high quality is being grown. The nursery stock production is very similar to that of our yellow birch. If and when an economically feasible silvicultural method for yellow birch is developed in Canada, this species may be worthy of consideration, also in respect to yellow birch breeding.

Poplar

Of the two aspen species native to Japan, *Populus sieboldii* is restricted in Hokkaido to the southwestern part. The other aspen, *P. davidiana*, is found scattered throughout the island, on the edges of woods and in other recently disturbed places. The growth form is usually only fair, about the same as that of trembling aspen (*P. tremuloides*) in southern Ontario. According to Chiba (1966), natural hybrids of planted silver poplar (*P. alba*)with *P. davidiana* are found occasionally. Their growth form seems to be as poor as that of the natural *P. alba* x *tremuloides* in southern Ontario. The *P. alba* seen planted in Hokkaido corresponds almost exactly to the silver poplar planted in Ontario. It consists of female trees only and is most probably of western European origin. Hamaya and Inokuma (1957) also mention intermediate forms between the two native aspens, the *P. sieboldii*-like (pubescent form) occurring in the southern part and at low elevations in Hokkaido, and the *P. davidiana*-like (glabrous form) found more inland at higher elevations. Apparently, the genetic barrier between the two native aspens is not as pronounced in Japan as it is between the native aspens in eastern Canada. The climate of Hokkaido is probably too moist to allow large areas of fir and spruce, with little or no dwarf bamboo in the understory, to be replaced by aspens after a disturbance. Birch is here the pioneer species in secondary succession, in the same manner as it is in areas with a moist (and maritime) climate in eastern Canada where birch-spruce site regions are prevalent, in contrast to areas with a dry (and continental) climate having aspen-white pine site regions. It was possible to see two good stands of the native _P. davidiana_ having their origin after severe spring fires, that completely destroyed, temporarily, the dwarf bamboo rootstocks and thus allowed the aspen seedlings to establish themselves. One of the pure stands of aspens is located on the lower slopes of Mt. Tokachi, in central Hokkaido. It is about 1.2 ha in area and has a dense understory of dwarf bamboo, up to 1.8 m tall, that is suppressing nearly all woody plants with the exception of a few wild raspberries, Hydrangeas, and shrubby _Sorbus_, _Alnus_, and _Aralia_. The ground vegetation under the bamboo is mostly Japanese spurge (_Pachysandra terminalis_ Sieb. and Zucc.) and there are scattered very tall herbs capable of competing with the bamboo. The aspens are about 35 years old and, having started as a very dense stand with later natural thinning, are very spindly but not yet broken by snow. This stand may yet produce match stock and some veneer logs. The other stand is located in the Kitami area, in east-central Hokkaido. It is much larger, about 6.1 ha in area, and older, about 50 years old, and shows signs of decadence. The site is poorer, with lower but still very dense dwarf bamboo as the main understory. Scattered shrubby alder and medium-sized birch are found in the stand. The aspens are of only fair form, many have cankers and heart rot, and some have been broken by ice storms. This stand is suitable only for pulpwood production. Parts of it have been clear-cut recently and are followed by very scattered natural aspen sucker growth, much impeded by dwarf bamboo. One of our main arguments in favour of establishing plantations of hybrid aspens, namely the assurance of an easy second crop from suckers after clear cutting and slash disposal, obviously does not apply here. Will a severe spring fire kill the bamboo rootstocks first, or the aspen roots, or both? A suitable method of establishing aspen stands of sucker origin will in any case be risky and expensive.

A large collection of aspen breeding materials has been obtained from Maple, Ontario and from other sources, and established at the Tokyo University Forest at Yamabe and by the Oji Paper Company at Kuriyama. The collection at Yamabe contains some promising types of P. grandidentata and P. alba x grandidentata, as well as some good P. alba x davidiana of flowering age, but as far as I could see, not much breeding work is in progress. Chiba (1966) has given a detailed account of breeding work with aspens and poplars at Kuriyama, including tests for rooting ability from stem cuttings, for resistance to vole damage and to Malampsora rust. Unfortunately, no P. tremuloides has been used in this work and thus the potential of P. davidiana x tremuloides and of the reciprocal crosses have not yet been exploited. Some promising young test plantings of aspen and of P. alba x aspen hybrids were seen at Kuriyama. Many are approaching flowering age and thus offer ample opportunities for producing second and backcross generations. However, according to observations on the establishment and successional history of natural aspen stands, it will be difficult to establish and to maintain plantations of hybrid aspens in Hokkaido, as far as I can see.

The native balsam poplar (P. maximowiczii Henry) can, on good alluvial soil, develop into large straight trees with form as good as, or better than, our balsam poplar (P. tacamahaca Mill.) in the southern part of the northern Clay Belt. There is the added advantage that its heartwood is not as dark coloured as P. tacamahaca. The wood is also suitable for the production of match stock and pulp. One plantation established some 23 years ago on private land was seen near Yamabe. About 1,000 seedlings/ha were planted and the initial height growth has been very rapid. The plantation has been thinned twice since establishment and at present the height growth is slowing down somewhat, the dominant trees being about 18.3 m tall. It contains many trees of excellent growth form, indicating that this species lends itself very well to selection in this respect. This has been done by the Oji Paper Company and is described in detail by Chiba (1966). Several clonal test plantations were seen at Kuriyama where growth form and growth rate compare favourably with those of the best clones of hybrid cottonwood (P. euramericana (Dode) Guinier). P. maximowiczii has been used in the early poplar breeding work by Stout and Schreiner (1933) and more recently by Bugala and Stecki (1961). Most of its hybrids with European and North American poplars of the cottonwood group (Aegeiros Duby) are very vigorous and have lower site requirements than cottonwoods. The original female clone of P. maximowiczii used in this hybridization roots rather poorly from stem cuttings. Many of the materials selected at Kuriyama have a rooting ability surpassing the best poplar cultivars. As this species also shows high resistance to vole damage and good climatic adaptation, it appears very promising for further breeding work. However, it is highly susceptible to stem cankers caused by Septoria musiva Peck in North America, as are all other Asiatic balsam poplars and their hybrids. Some of our native P. tacamahaca and P. deltoides Marsh. have shown to be highly resistant to Septoria canker and thus may be a good source of resistance. This resistance seems to be recessive in hybrids with Asiatic balsam poplars and therefore F2 and backcross generations will be necessary to produce new resistant materials. This may also apply to Japan, where sooner or later, Septoria may be introduced and cause difficulties in poplar growing. The introduced clones of XP. euramericana are being planted here and there in Hokkaido, but the results are not outstanding. These poplars are subject to several fungus diseases and appear poorly adapted to the moist and cool climate. Natural hybrids of P. nigra L. x maximowiczii have been found and some have been selected and are growing in test plantations at Kuriyama. They look very similar to the early hybrids of Stout and Schreiner with P. maximowiczii parentage and may be promising. However, also in this case resistance to Septoria canker will probably be lacking and may have to be introduced in the course of further breeding work.

Other Species

The botanical garden of Hokkaido University, at Sapporo, is situated on a rich flood plain, long ago cleared and used for rice cultivation elsewhere. It has some native elms of great size and age, with wide crowns and somewhat pendulous branches. This species, Ulmus propinqua Koidz., could possibly be used in elm breeding in North America and may prove resistant to the presently epidemic diseases of our native white elm (U. americana L.). Materials imported from Sapporo may go to seed at an early age in our hot and dry summers and materials from further to the south in Japan may not prove sufficiently winter hardy under our conditions. Considerable selection for climatic adaptation will probably be necessary before they can be used directly in Canada, to replace our white elm. In respect to size, longevity, and general decorative value this species is much superior to the European elms introduced into Canada and to U. pumila L., thus far the only elm species seemingly resistant to the fatal disease of white elm.

Conclusions

The European Scots pine (Pinus silvestris) and Norway spruce (Picea abies) were introduced into Hokkaido some 70 years ago and some of the oldest and best specimens can be seen in the arboretum at Asahikawa. Some fairly extensive provenance tests with Scots pine are in progress at Yamabe and Kuriyama, where young plantations of Norway spruce of various origins can also be seen. The Hokkaido Forest Tree Breeding Station at Nopporo also has provenance tests with these species under way. At all these places the growth rate seems to be fully satisfactory, but most of the trees have rather coarse branching. Norway spruce often suffer from late spring frosts and poor lignification in the fall. Rigid selection for climatic adaptation would appear quite feasible, with the abundant materials of both species already at hand. However, susceptibility to vole damage severely limits the wide use of these two, otherwise very promising, exotics in extensive forest plantations where there is the additional problem of dwarf bamboo. Pinus densiflora, introduced from northern Honshu, is reasonably hardy in southern Hokkaido, but suffers much from snow damage and is also very susceptible to voles. It is possible that P. densiflora from North Korea and P. silvestris from the easternmost parts of its range in eastern Siberia may show some resistance in this respect, when it will be possible to introduce such materials into Hokkaido. Picea koyamai Shiras. has been crossed successfully with Norway spruce at Maple, Ontario and the same may be possible with P. maximowiczii Reg., another species native to the mountains of Honshu. It is still unknown if these species will be sufficiently resistant to voles in Hokkaido, to be used as resistance carriers in breeding projects with Norway spruce. Another possibility is P. obovata Ledeb. from eastern Siberia. This species is said to be closely related to Norway spruce. Chemically, it is also related to P. glehnii, with its high content of bornyl acetate in the needles (Schantz and Juvonen, 1966). Here is a field that needs further exploration, with the aim of incorporating the high productivity of Norway spruce into future hybrid spruces of Hokkaido.

I hope it has been possible, in the course of two short field trips, to obtain some idea of the problems and methods of forest tree breeding in northern Japan. As can be seen, these are in many respects quite different from those in Canada. And yet we have so many important problems in common that the exchange of breeding materials, already well under way, could well be supplemented by further exchanges of ideas and by personal contacts. We also are interested in growing trees for pulpwood production, in short rotations and with built-in wide site and climatic adaptation, easy establishment and maintenance, good wood quality, pest resistance, and high yields. The raw materials for this, namely the native species, often differ markedly in many relevant characteristics and yet many are sufficiently closely related to be used to advantage both in Canada and in Japan. I have indicated some ways in which possible hybridization work could be undertaken to utilize such combined gene pools. Undoubtedly there will be many others.

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