GENETIC IMPROVEMENT OF SIBERIAN LARCH FOR PRAIRIE SHELTERBELTS

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Abstract .--The tree improvement program at the PFRA Tree Nursery emphasizes studies aimed at developing superior tree and shrub species for planting in prairie shelterbelts. In the past several years considerable attention has been focused on genetic improvement of Siberian larch (*Larix sibirica*). The project has included seed collection from the native range of the species in the Soviet Union; establishment of provenance tests; selection of plus trees from existing plantations; development of breeding techniques, including pollen handling and controlled pollination; and investigations on methods of sexual as well as asexual propagation.

Additional keywords: *Larix sibirica*, botanical description reproduction, improvement program, pollination

Introduction

Shelterbelt plantings have been carried out in the Canadian prairies for the past 85 years. The selection of trees and shrubs for shelterbelts depends not only on adaptability and hardiness of the species but also growth characteristics that allow for optimum wind reduction and shelter.

In the past 80 years numerous species have been evaluated for shelterbelt planting. Historically common caragana (*Caragana arborescens* Lam.) and green ash (*Fraxinus pennsylvanica* var *subintegerrima* [Vahl.] Fern.) have been used for field shelterbelts in the prairies. Over the years several alternative species, including Scots pine (*Pinus sylvestris* L.), Siberian elm (*Ulmus pumila* L.), Manitoba maple (*Acer negundo* L.) and Siberian larch (*Larix sibirica* Ledeb.) have been evaluated. Of these, Siberian larch appears to have considerable potential for shelterbelt planting in the prairies. This paper describes the biological characteristics of Siberian larch in regard to the genetic improvement of the species for use in prairie shelterbelts.

Natural Range

The natural range of Siberian larch includes the territory of central and western Siberia with a total area of approximately 3.3 million km^2 (Abaimov etal, 1980). To the west, Siberian larch is replaced by Sukuchev's larch (*Larix sukaczewii* Dyl.), to the east and northeast by Dahurian larch (*Larix gmelinii* [Rupr.] Rupr. ex Kuzen.). According to Rozhkov (1966) hybrid forms of larch are abundant at the point of contact where the ranges of these species overlap. Siberian larch is the principal forest forming species in regions of the Soviet Union with harsh continental climates (Bobrov, 1972).

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Siberian larch was introduced to North America in the early 1800s (Rehder, 1977), however it has never been considered a viable forestry species because of extensive native stands of tamarack (Larix laricina [DuRoi] K. Koch), alpine larch (Larix lyalli Parl.) and western tamarack (Larix occidentalis Nutt.) as well as the superior performance of European larch (Larix decidua Mill.), Japanese larch (Larix kaempferi [Lamb.] Carriere) and their hybrids (Reimenschneider and Nienstaedt, 1983).

The first Siberian larch accession recorded at the PFRA Tree Nursery were obtained from the western portion of the natural range near the Ural mountains. This original plantation was established in 1908 and has been the principal source of seed for Siberian larch plantings in the prairies.

Botanical Description

Siberian larch is a slender, pyramidal shaped deciduous conifer. The leaves are needle—like and approximately 2.5 to 3.0 cm in length. They are borne in clusters on spur—like branches or singly on new growth. The bark is rough, scaly and dark grayish brown. The fruit is a cone, approximately 2.0 to 3.0 cm long and is borne upright on the branch.

Rozhkov (1966) explained that in its natural environment, Siberian larch is outstanding among local trees for its longevity. He reported that under the best conditions 600 to 700 year old larches are common. Mature stands growing under prairie conditions are limited, however, the Indian Head plantation is approaching 80 years of age and is still healthy and vigorous.

Growth rate of Siberian larch is rapid compared to other coniferous species in the prairie region. Reimenschneider and Nienstaedt (1983) noted an annual growth rate of 0.82 m from the age of 5 to 8 years and with a mean height of 4.30 m after 8 years. After five growing seasons, Siberian larch planted in a shelterbelt in south eastern Saskatchewan had a mean height of 3.6 m. Height of larch was significantly greater than height of other coniferous species in the planting. In trials at Indian Head, Saskatchewan, a block planting of Siberian larch was 20 m in height with a 23 cm DBH 56 years after planting.

Siberian larch is characterized by an upright, pyramid shaped growth habit. During the first fifty years, Larch maintains a dense pyramidal form. Forty year old larch shelterbelts at Indian Head have maintained exceptional density with little loss of lower branches.

Siberian larch is well adapted to harsh climates (Mironoz and Levin, 1986). Plantings at Indian Head have shown no evidence of winter injury, however, young foliage may be damaged by late spring frosts. Rozhkoz (1966) noted that the ability of Siberian larch to survive in harsh climates was not only due to its deciduous nature but also to a very active assimilation process that allows it to thrive in regions with short growing seasons. According to Rozhkoz, larch's rate of carbon assimilation was 2.5 times higher than spruce and almost 1.5 times higher than pine.

Siberian larch is characterized by deep primary roots and a poorly developed adventitious root system (Nikitin, 1968). Root excavations at the PFRA Tree Nursery revealed that Siberian larch was characterized by large "anchor" roots which give the trees good wind resistance. Verzunoz (1978) noted that the root system does not have great plasticity and as a result root development is severely affected by hardpan layers below the soil surface.

In the native range of Siberian larch, approximately 130 foliage and seed insects have been recorded (Rozhkoz, 1966). In the prairie region of Canada, the larch sawfly (Pristiphora erichsonii Hartig.) has been the most destructive insect affecting Siberian larch. During the 1930s epidemic populations of sawfly severely affected larch plantings in western Canada. It is noteworthy that Fedorova and Gugulaeva (1976) reported that resistance to sawfly attack appeared to be related to phenol content in needles.

Reproductive Development

Siberian larch is a monoecious species that normally reaches sexual maturity at 10 years of age (Rudolf, 1974). Vegetatively propagated (grafted) trees at Indian Head, produced ovulate cones the third year after planting. There are no reports in the literature on attempts to decrease the age—to—flowering of Siberian larch by mechanical or chemical means.

Cone morphogensis of Siberian larch was studied at Indian Head in 1986-1987. Flowers are initiated in August—September of the year preceding cone development. Flower buds are generally larger than leaf buds and a glossy yellow on top. It is difficult to visually distinguish between male and female buds at this time, however, if the buds are sectioned differentiation is simple and rapid. The axis of male buds is rounded, while the axis of the female buds is cone shaped. Using these characteristics, male buds can be distinguished from female buds with the aid of a lens or by the naked eye.

The development of the ovulate flower and the shedding of pollen are to a certain degree dependent on meteorological conditions and may be delayed a week or more by cold and moist weather. In 1987, anthesis occurred in late April, two weeks earlier than normal.

Male flowers are scattered along the twig together with ovulate cones. During pollination, male flowers are turned downwards and female inflorescences are upright. At pollination the bracts of the female inflorescence open and remain receptive for up to two weeks. When receptive, the stigmatic flaps are swollen and the bracts are heart shaped. After pollination the flaps collapse and are hidden behind the bracts which have become rectangular in shape.

The cones increase rapidly in size. By late August, a change from green to brown color, specific gravity less than one and a lowered seed moisture content indicate cone maturity. Cones are considered to be mature when specific gravity reaches 0.80 to 0.88.

Good cone crops at Indian Head are produced at intervals of 5 to 7 years with light crops in most intervening years. Annual variation in the number of ovulate cones initiated, freezing of female flowers and insect damage are the major factors in periodicity of mature cone crops.

The number of viable seeds per cone averages about 33 and varies from 20 to 40. In most years 40 to 60% of seeds are damaged by insects resulting in a high percentage of empty seeds. Cleaned seed averages 20,000 per kilogram and ranges from 14,000 to 33,000 (Rudolph, 1974). Under natural conditions cones open while on the tree during warm autumn days. According to Rozhkov (1966), although seed may be disseminated up to 200 metres, the effective range is not much more than half of the tree height.

Controlled Pollination

Studies at Indian Head have indicated that when male flowers were collected earlier than one to two days prior to anthesis, the flowers dried and yielded very little pollen. To test for readiness—to—pick, male flowers were macerated between the thumb and forefinger. If the contents were dry (mealy) and yellow in color anthesis was near. If the contents were watery and clear it was too early to collect pollen. Once the male flowers are judged to be near anthesis, branches are cut and placed in water. Within two days at room temperature pollen grains are visible on the surface of the flower. The branches are gently tapped over paper and the pollen funneled into vials. Any drying method that prevents contamination and does not subject the pollen to extremes of temperature is satisfactory. Pollen can be stored dry at +2°C until used. Conditions for long term pollen storage have not been determined, however, it is probable that fresh pollen can be stored with little loss in viability at —18°C for periods up to one year.

The stages of ovulate cone development have been described earlier. All ovulate cones do not reach maximum receptiveness at the same time. The shape of the bracts and the protrusion of the stigmatic flaps from behind the bracts are a reliable indicator of receptiveness. Female inflorescences should be covered with isolation bags and male flowers removed as early as possible. Bags should not be removed until two weeks following anthesis. White kraft windowed pollination bags are superior to sausage casing as heat buildup in the latter reduces fertilization. If possible, at least three pollinations should be conducted at intervals of two days from the beginning of the receptive period until the inflorescence close.

Improvement Programs

Siberian larch tree improvement programs are a rarity in North America and western Europe. In the Soviet Union, because of the extensive native stands of this species and low utilization, reforestation programs are nonexistant. Consequently, improvement programs for Siberian larch have not received high priority. Provenance testing has been carried out and seed orchards established in the European portion of the Soviet Union. Classical work in this area was conducted by Timofeev (1977) and Sukachev (1924). In recent years, Siberian larch has become increasingly popular in the Soviet shelterbelt program. In view of this, tree improvement programs aimed at developing a strain of larch adapted to dry steppe conditions are underway

(Pavloski etal. 1983). The programs concentrate on selection of individual trees with desirable phenotypes from existing shelterbelts. The selected trees are vegetatively propagated and planted in clonal archives, from which progeny tests originate.

At Indian Head, genetic improvement of Siberian larch was initiated in 1983 (Schroeder, 1985). Seed was obtained from seven locations throughout the native range of Siberian larch. In addition, a seed collection mission in 1985 provided seed from an additional five Siberian sources. The current project has dual objectives: establishment of a base population for advanced generation breeding and development of open pollinated seed orchards from which genetic information can be obtained and production of significant quantities of seed incorporating some genetic improvement. Genetic gains are to be obtained through selection among provenances and ultimately establishment of progeny tested clonal seed orchards.

Summary

With the increased popularity of shelterbelt planting and the need for alternate species, a continued effort in Siberian larch tree improvement is required. In the past five years significant advances have been made in nursery culture and planting techniques for Siberian larch, however further studies examining the biology of the species, especially as it pertains to insect resistance and vegetative propagation, will be necessary. Continued contact and cooperation with Soviet scientists and geneticists will undoubtedly enhance our understanding of the biology and genetics of this species.

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