THE BREEDING OF HARD PINE TYPES RESISTANT TO THE EUROPEAN PINE SHOOT MOTH (*Rhyacionia buoliana* Schiff.)

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ABSTRACT

The susceptibility of hard pines of the Lariciones group to infestation by the European pine shoot moth is postulated by Neugebauer to depend on the amount of resin flow the attacked pines can produce. Abundant resin flow tends to drown out the insect and makes the pines resistant. Warm and moist summers enhance abundant resin flow, cool dry summers retard it. Inherent differences in susceptibility are found between pine species and are suspected at a subspecific level. Variation in degree of infestation is conditioned by possible inherent differences in susceptibility and by the degree of matching of the planting site to the requirements of the materials in respect to summer climate. Breeding possibilities utilizing the resistance found in Japanese black pine and in the Austrian pine group are discussed in relation to the production of improved types of red pine and Scots pine. The possible uses of Japanese red pine and other species as intermediates in such a breeding project are mentioned. The inclusion of breeding for resistance to shoot moth in a general breeding program of hard pines is considered desirable.

The authors of this paper have been much alarmed by the extensive damage caused by the European pine shoot moth to stands of hard pines, not only in Ontario, but also on large areas in the United States (Heimbürger and Holst, 1955). We have felt that our view on this problem might be of interest to foresters concerned with planting hard pines, and we hope to encourage further discussion and new investigations.

The European pine shoot moth was introduced into North America at the beginning of this century on nursery stock. It is now known to occur from Massachusetts south to Virginia and west to Illinois and Michigan. It is also found in Nova Scotia, southern Ontario, and British Columbia. The moth is a serious pest in nurseries and plantations where the larva causes destruction of terminal and lateral buds and hence malformation of the butt log. When the canopy closes and the stand reaches twenty to thirty feet in height, damage usually decreases, but the loss in increment and value may be considerable at this stage.

Low temperatures keep the moth population in check since the larvae are susceptible to sub-zero temperatures. This situation is probably only temporary as the range of this insect in Europe extends into areas with very severe winter climates. Thus, adaptation of the present population of the moth to

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sub-zero temperatures or the introduction of hardier strains are quite possible. Large areas planted with red pine and Scots pine (*Pinus resinosa* Ait. and *P. sylvestris* L.) in southern Ontario and in the United States have mild winters and are at present highly susceptible.

Several means have been suggested for the control of the moth, but all have the weakness of dealing more with prevention than with cure. It is felt that a more biological point of view on the interaction between the insect and the plant material, and between the plant material and site might prove useful. It should be remembered that most of the hard pines have been planted under conditions favorable to the moth, i.e. in open plantations instead of in partial shade, and that several of the pine species used have been planted outside of their natural range.

European investigations indicate that mechanical control, such as collection and destruction of infested twigs, is both useless and expensive. The same holds true of chemical control, because of the short period of flight, and continued infestation from adjacent stands. The manner of feeding in pine buds makes it difficult or almost impossible to control the larva with insecticides. Biological control might prove useful but cannot be depended upon as the only possible solution because only three of eighty species of parasites of this insect in Europe have been established in North America (Craighead, 1950) and parasites in certain areas in Europe are not able to keep the moth population in check.

In an investigation of moth damage on Scots pine, Neugebauer (1952) claims that the main factors controlling the moth population in Europe are those controlling resin production in the pine. In trees with a high resin production the larvae and the moth are drowned out by the abundant resin flow during and after the feeding. Differences in resistance of pine species, and even within races of the same species, are said to be due to variation in resin production. Areas with consistently high moth populations are those with low summer precipitation, causing low turgidity during drought periods, which in turn induces low assimilation, resin production and sap pressure. Trees in such generally dry areas are unable to drown the attacking moths and larvae in resin. Resin production is controlled to a great extent by the environment. More resin is usually produced in a warm and moist climate than in a cool and dry one. When races of pine adapted to a warm climate are planted in a cooler climate, resin production usually decreases. This is illustrated by the fact that German-grown white pine (*Pinus Strobus* L.) is less resinous than in North America because of the lower summer temperatures in Germany, and that *Pinus contorta* Loud. (the coast form) when planted in Europe is highly susceptible to the shoot moth because of the lower precipitation. Of two generally dry areas in Germany, moth damage is much more serious in the cool Arzberg-Bodenwöhr area than in the warmer Rhine-Main plain. We shall later return to this question, as it seems to have some bearing on the direct correlation between moth attack and climate, as well as on the problem of why exotic pine species seem more resistant in some areas than in others.

The concept that resistance to shoot moth and resin production are correlated opens interesting possibilities to the tree breeder. The native red pine is

very low in resin, in spite of its descriptive name (*resinosa*), and we must face the possibility that it may be impossible to locate moth-resistant individuals. The fact that red pine has been planted so widely outside of its native range adds to the severity of the infestations. Scots pine varies in degree of resistance in its native habitat, as reported above. It is low in resin but a careful selection of suitable types might improve this condition. The bad reputation of Scots pine in plantations in North America as regards shoot moth damage may partly be blamed on early optimism and ignorance. Today, Scots pine is one of the most thoroughly investigated tree species in respect to racial composition, and advantage should be taken of this knowledge.

Japanese red pine (*Pinus densiflora* Sieb. & Zucc.) is low in resin and susceptible to the shoot moth in southern Ontario and on Long Island (Heimburger and Holst, 1955). Afanasiev (1949) reports it as being susceptible in Oklahoma to the Nantucket tip moth (*Rhyacionia frustrana* Comst.), a species related to the European pine shoot moth. In other respects this pine species is very promising.

According to Neugebauer (1952), *Pinus tabulaeformis* Car. is quite resistant to the shoot moth in Europe, but we know nothing about its behavior here. *Pinus Mugo pumilio* Zenari is quite resistant in Europe but is here regarded as the worst source of infection. The reason for this is probably that it is native in a rather cool mountain climate while we grow it as an ornamental in warm lowland climates.

The *Pinus nigra* Arnold group offers additional interesting possibilities. Thus Friend (1952) states "Austrian pine is sometimes heavily infested (by the shoot moth), but not so much as the above three species" (red, Mugo and Scots pine). We believe that this statement also applies to southern Ontario.

The variation in susceptibility seems to be caused by (a) possible variation in seed source and (b) degree of matching of the planting site to the site requirements of the planted materials, especially in respect to climate. It should be remembered that Austrian pine in its native habitat grows on dry, shallow limestone soils. The most hardy and continental types are found not in the most northerly area around Wiener Neustadt, as could be expected, but further to the south. "If an Austrian pine adapted to cooler regions or a somewhat moister climate is wanted, it might be found in the more mountainous regions, for example around Gloggnitz or in similar places" (Oksbjerg, 1950). Most seed imported into North America comes from the Wiener Neustadt area and might well have too high summer heat requirements, at least for the New England States.

Keeping the variability of what we summarily call Austrian pine in mind, several cases of resistance to the tip moth have been reported. Higgins (1927) reports "its almost total immunity from tip moth" in Nebraska. Graham and Baumhofer (1930) report high resistance to the tip moth in a more detailed study made in the Nebraska National Forest.

Afanasiev and Ashdown (1951) make the following list of pine species attractive to the tip moth: shortleaf and loblolly pines, both native to Oklahoma and heavily infested; Japanese red, Austrian, Scots, Japanese black and western yellow (*P. ponderosa* Laws.). The authors indicate that the three first

are definitely preferred because they have thin, soft and flexible needles, whereas the other species have more stiff and rigid foliage. An investigation with the above in mind should be promising.

Very little is known about the behavior of Corsican pine (*Pinus nigra* var. *Poiretiana* Aschers. & Graebn.) in these respects. Offhand, we would think it would have trouble with winter hardiness, but it should be possible to find areas with a summer climate almost the same as that found in Corsica at an elevation of 4,000-5,000 feet. The summer precipitation there is very low, only 1.5 inches, but plantations in England, France, and Denmark have reacted favorably to increased precipitation. In its native habitat this species is known to be highly resinous and shoot moth resistant, and in England it has been more resistant than Scots pine (Brooks and Brown, 1936).

The last pine on our list, the Japanese black pine (*Pinus Thunbergii* Parl.) is peculiar in many aspects. It is a seashore species and displays excellent growth and resistance to the shoot moth on the north Atlantic Coast (Littlefield, 1942). We have seen this pine left unaffected on Long Island, while adjacent plantations of Japanese red pine, of unknown origin, and Scots pine, apparently of Continental origin, were heavily infested. It could be expected that Japanese black pine in such a coastal climate would be superior in this respect but other observations indicate that we are dealing with a high degree of resistance under a wide variety of climatic conditions. Thus, this species is known to be relatively free from injury by the Nantucket tip moth in Oklahoma (Afanasiev, 1949; Afanasiev and Ashdown, 1951). The above information is summarized in the table on the following page.

Having surveyed the characteristics of the pine species belonging to the *Lariciones* group with respect to shoot moth and tip moth resistance, the next step would be to investigate the possibility of: (a) improving existing conditions by using plant materials already available and (b) synthesizing types with the desirable qualities by breeding. There is undoubtedly much work to be done in finding suitable races of Scots pine and suitable types within the *P. nigra* group for use in areas where the shoot moth is a serious pest and where more resistant pine types would be desirable. We will leave this as a statement and proceed with the search for possibilities of obtaining this objective through breeding.

If native red pine could be used as basic material, the simplest course would be to breed in possible genes for resistance from other species, such as *P. nigra* and *P. Thunbergii*. Unfortunately, it is not that simple. Red pine has thus far failed to yield hybrids with any other pine species. Several unsuccessful attempts have been made at Chalk River, Ont.; Maple, Ont.; Upper Darby, Penna. (Wright, 1953); and Placerville, Calif. (Duffield, 1952). Work is still in progress with further investigations into crossing compatibilities of red pine. A technique is being tried out at Chalk River, Ont., and Maple, Ont., whereby juvenile scions of one species are grafted into the crown of mature flowering trees of the other species. In time, it may be possible to produce hybrids by crossing the grafted scions with pollen of the tree supporting them.

Scots pine has been crossed successfully with Japanese red, Austrian, and

RESISTANCE OF *Lariciones* PINES
TO THE SHOOT MOTH

Species	Ecological preferences	Hardiness	Growth form	Growth rate	Resistance in native habitat	Resistance in North America
<i>P. Thunbergii</i> Parl.	Coastal pine from Japan and Korea	Good in coastal areas, i.e. Long Island, Nantucket Island, Rochester, N.Y.	Rather poor limby	Rapid	?	highly resistant
<i>P. nigra Austriaca</i> Aschers. & Graebn	Limestone pine; dry sites with high summer precipitation	Good in southern Ontario and Quebec	Straight but rather limby	rather slow	highly resistant	resistant
<i>P. nigra Poiraitiana</i> Aschers. & Graebn	Limestone pine; dry sites with summer dry climates; summer rainfall down to 1.5"	Good in Rochester, N.Y.; Ontario	Excellent fine branches	Rapid	highly resistant	?
<i>P. Mugo pumilio</i> Zenari	Acid soil pine of high elevations with cool, moist climates	Good in Ontario and Quebec	Poor	Slow	highly resistant	susceptible
<i>P. tabulaeformis</i> Carr.	China	Hardy in southern Ontario	Poor	rather slow	resistant	?
<i>P. resinosa</i> Ait.	Inland shore pine acid but not extremely dry soil	Excellent	Excellent rather coarse branches	Rapid	very susceptible	
<i>P. densiflora</i> Sieb. & Zucc.	Japanese low to middle elevation species	Hardy in southern Ontario	Poor	rather slow	susceptible	very susceptible
<i>P. sylvestris</i> L.	Eurasian dry soil pine; many forms	Excellent	(Good) Very variable in North America	Rapid	susceptible	very susceptible

Mugo pine. Of these, it seems that the cross Japanese red x Scots pine is the easiest to make. Several workers have reported failure in the attempts to effect the crosses Scots pine x Austrian pine, and Scots pine x Mugo pine. However, natural hybrids between the first two species have been found in Austria (Wettstein, 1951), and between the last two in Denmark (Syrach Larsen, 1934). If resistance to the shoot moth is found in the Scots x Austrian pine hybrids, backcrosses could be made to desirable types of Scots pine, for the production of a resistant type of Scots pine. As such hybrids are fertile, the way is open for a great number of possible combinations.

Austrian pine deserves attention because it is quite hardy in areas of severe shoot moth infestation in North America. It has rather heavy branches and is slow-growing. The growth form and growth rate could possibly be improved through hybridization with Corsican pine. Such hybrids have already been produced artificially (Richter and Duffield, 1951) and may also be found in Europe where these two species frequently are planted side by side. Wettstein (1951) has reported an Austrian pine yielding 3-4 times more resin than the average tree of this species, and this opens new possibilities for our purpose. This resinous type of Austrian pine could, for example, be crossed with the already existing Austrian x Scots pine hybrids, and the offspring back-crossed to desirable types of Scots pine, according to the formulae:

[resinous Austrian x (Austrian x Scots)] x desirable Scots pine,
[desirable Scots x (Austrian x Scots)] x resinous Austrian pine,
and others.

There is every indication that Japanese black pine is highly resistant to the shoot moth and tip moth, although hardiness and growth form leave much to be desired. The only certain hybrid reported is with Japanese red pine (Saito, 1951; Schreiner, 1949; Wright, 1953). The hybrid Japanese black x Austrian pine listed by Schreiner (1949) has not been confirmed by Wright (1953) reporting on the same material. Work with this species is still in the preliminary stage.

Japanese red pine is highly susceptible to the shoot moth and has no great merit in growth rate nor in growth form. For breeding purposes it might be very useful, as it seems to hybridize quite easily with several other pines. Japanese red pine has been crossed successfully with Austrian pine (Austin, 1927, 1929; Sax & Sax, 1933), with Scots pine (Schreiner, 1949; Wright, 1953), and even with loblolly pine (Nohara, Zinno and Ito, 1951). Species or races capable of producing fertile hybrids with species that are incompatible inter se, have been reported in horticultural and agricultural literature. The Japanese red pine used in the crosses described above seems to belong to this category. It is also suspected of being a rather primitive species. Recent work on oleoresins of pines tends to support this (Mirov, 1953). At the Arnold Arboretum we have seen some Japanese red x Austrian pine derivatives much resembling Scots pine. This material indicates that the ancestral forms of the two parent species, both at present restricted in their ranges, might have intermingled during an earlier period and given rise to the present Scots pine, so rich in climatic races and occupying large areas in Eurasia.

Japanese red pine is, therefore, an important species in tree breeding

work dealing with the *Lariciones* group. It supplies the necessary link between otherwise incompatible species for the transfer of important genes. If future breeding work reveals that hybrids of Japanese black pine carry genes for resistance to the shoot moth, such genes might be transferred to Scots pine and Austrian pine by means of suitable crosses with Japanese red pine. The production of new hardy and resistant inland types, also with new soil requirements, might thus become possible.

The breeding for resistance to shoot moth could easily be included in a breeding program dealing with the *Lariciones* group of hard pines. Such a program would include: (a) further investigation of species compatibilities in interspecific crosses; (b) the collection and testing of a reasonable number of strains of the species concerned; (c) the study of the variation in shoot moth resistance. The extra effort would consist of establishing test plantations in areas with heavy shoot moth infestation, preferably in regions with mild winters.

It is true that resistance to insects and diseases in forest trees seems tricky and difficult to obtain by means of breeding. However, the results already obtained in this respect with other crop plants indicate that it is by no means a hopeless case, especially when it is considered that tree breeding has hardly scratched the surface in this respect.

REFERENCES

- AFANASIEV, M., 1949—Observations of Japanese red and Japanese black pines in central Oklahoma. *Journal of Forestry* 47(9): 723-725.
- AFANASIEV, M. and D. ASHDOWN, 1951—The pine tip moth. Oklahoma Agricultural Experiment Station Bull. No. B-377.
- AUSTIN, L., 1927—A new enterprise in forest tree breeding. *Journal of Forestry* 25(8):928-953.
- AUSTIN, L., 1929—The Eddy tree breeding Station. *Madrono* 1(15): 203-212.
- BROOKS, C. C. and J. M. B. BROWN, 1936—Studies on the pine shoot moth (*Evetria buoliana* Schiff.) Forestry Commission Bull. No. 16.
- CRAIGHEAD, F. C., 1950—Insect enemies of Eastern forests. U.S.D.A. Misc. Publ. No. 657.
- DUFFIELD, J. W., 1952—Relationships and species hybridization in the genus *Pinus*. *Zeitschrift fuer Forstgenetik und Forstpflanzenzuechtung* 1(4): 93-100.
- FRIEND, R. B., 1952—European pine shoot moth. In: Important tree pests of the Northeast. Evans Printing Co., Concord, N.H.
- GRAHAM, S. A. and L. G. BAUMHOFER, 1930—Susceptibility of young pines to tip moth injury. *Journal of Forestry* 28(1): 54-65.
- HEIMBURGER, C. and M. HOLST, 1955—Notes from a trip to the southern United States, January, 1953. *The Forestry Chronicle* 31: 60-73.
- HIGGINS, J., 1927—Facts and figures regarding the Nebraska Planting Project. *Journal of Forestry* 25(8): 1023-1030.
- LITTLEFIELD, E. W., 1942—*Pinus Thunbergii*: a successful exotic on the north Atlantic coast. *Journal of Forestry* 40(7): 566-573.
- MIROV, N. T., 1953—Chemical aspects of *Diploxylon* pines. *Zeitschrift fuer Forstgenetik und Forstpflanzenzuechtung* 2(5): 93-96.
- NEUGEBAUER, W., 1952—Die Bekämpfung des Kiefernrtriebwicklers. *Forstarchiv* 23(8): 159-165.
- NOHARA, Y., Y. ZINNO and T. ITO, 1951—Researches on the heredity of trees. IV. On the artificial crossing of inland Akamatsu and foreign Teidamatsu. *Journ. Jap. For. Soc.* 33(3): 87-93.

- OKSBJERG, E. B., 1950—Oestrigsk og korsikansk fyr. Hedeselskabets Tidsskrift 71(7): 137-150.
- RIGHTER, F. I. and J. W. DUFFIELD, 1951—Interspecies hybrids in pines. Journal of Heredity 62(2): 75-80.
- SAITO, Y., 1951—On several cases of intermediate pine between Japanese black pine and red pine. Trans. 59 Meeting Japanese Forestry Society, Tokyo.
- SAX, K. and H. J. SAX, 1933—Chromosome numbers and morphology in the conifers. Journal of the Arnold Arboretum 14: 356-375.
- SCHREINER, E. J., 1949—Creating better trees. Forest leaves 34(1): 3-4.
- SYRACH LARSEN, C., 1934—Forest Tree Breeding. Royal Vet. & Agr. College Yearbook 1934: 93-113.
- WETTSTEIN, W., 1951—Ueber Bastarde *Pinus nigra* var *austriaca* x *silvestris*. Zeitschrift fuer Pflanzenzuechtung 30: 473-477.
- WRIGHT, J. W., 1953—Summary of tree breeding experiments by the Northeastern Forest Experiment Station 1947-1950. Northeastern Forest Experiment Station, Station Paper N. 56.