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Genetic Differences in Resistance of Scotch Pine to Eastern Pineshoot Borer

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GENETIC DIFFERENCES IN RESISTANCE OF SCOTCH PINE TO EASTERN PINESHOOT BORER[1]

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Scotch pine (*Pinus sylvestris* L.) is the most common plantation Christmas tree in the northeastern United States. In its large native range, covering much of Europe and Asia, this species is valued highly for timber. Its adaptability to various sites and uses is partly a result of its high degree of genetic variability. For example, varieties differ widely in cold resistance, winter foliage color, growth rate, and needle length.

Unfortunately, however, Scotch pine may be damaged by several insect pests. One of these is eastern pineshoot borer (*Eucosma gloriola* Heinrich). According to Drooz (1960), this insect is native to the area east of the Rocky Mountains in Canada and the northern United States, and attacks many important conifers. Its favorite hosts are Scotch pine and eastern white pine (*Pinus strobus* L.).

Drooz discussed the distribution, life history, and damage caused by the eastern pineshoot borer. The eggs are laid on the needle sheaths of new growth and hatch in late spring. The larvae bore into the expanding new shoots and, once inside, feed on the pith. Normally only one larva occupies a shoot. In mid-summer they emerge to pupate, girdling and nearly always killing the twigs in the process.

The damage inflicted by this insect is easily visible in the autumn and early winter as dead, drooping twigs on the outside of the tree crown. A high incidence of attack results in stem crooks and forks and poor appearance. Wilson (1972) reported that annual height growth of an attacked tree may be reduced as much as two to four inches.

King (1971) found genetic differences within jack pine (*Pinus divaricata* (Ait.) Dumont) in resistance to attack by eastern pineshoot borer. He measured three Wisconsin and Michigan plantations of a provenance test started in 1952. Ten years after planting, the proportion of attacked trees varied from 11 to 35% among the 26 seedlots.

The objectives of the present study were to determine if there are genetic differences within Scotch pine in resistance to attack by this insect and to determine the importance of such differences to Scotch pine growers.

MATERIAL AND METHODS

Attack by eastern pineshoot borer was measured in three lower Michigan plantations of Scotch pine. These were planted in 1961 by the Michigan Agricultural Experiment Station as part of the NC-99 (formerly NC-51) rangewide provenance test of this species. The plantations were established with 2-0 seedlings grown from seed obtained in 112 native stands of Scotch pine. In this study the offspring of a single stand are referred to as a seedlot.

The plantations follow a randomized complete block design with an 8-ft spacing between trees. Each plantation contains 8 to 10 blocks, and each seedlot is represented once in each block by a 4-tree plot. Further details of the history and design of these plantations can be found in Wright and Bull (1963). Plantation descriptions follow.

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Allegan Recreation Area, near Allegan, Michigan. Site level and sandy; plantation well separated from other conifers; survival, 89%; average height in 1971 (age 11 from planting), 13.5 ft. Measured in 1968 (moderate infestation, 32% of trees attacked) and 1970 (heavy infestation, 93% of trees attacked).

Rose Lake Wildlife Experiment Station, 10 miles northeast of East Lansing, Michigan. Site rolling; plantation bordered on one side by a large Scotch pine windbreak; survival, 92%; average height in 1971, 17.2 ft. Measured in 1969 (moderate infestation, 40% of trees attacked) and 1970 (heavy infestation, 83% of trees attacked).

W. K. Kellogg Experimental Forest, 15 miles from Battle Creek, Michigan. Site hilly; plantation surrounded by older plantations of other pine species; survival, 92%; average height in 1971, 17.6 ft. Measured in 1970 (moderate infestation, 39% of trees attacked).

Eastern pineshoot borer began to invade these plantations sometime before 1968. Counts of successful attacks, dead shoots, were made at the above plantations in the years indicated. In all cases presence or absence of attack was tallied for each tree. In addition, the numbers of attacks per tree were counted at all plantations in 1970. Both types of data were analyzed to determine the significance of variety and seedlot-within-variety differences for each plantation.

RESULTS

For convenience the seedlots were grouped according to the taxonomic varieties recognized by Ruby and Wright (in press). There were large differences among varieties in resistance to attack by eastern pineshoot borer—some were attacked more than ten times as much as others in the same plantation. The differences were statistically significant in all three plantations and in every year that they were measured. On the other hand, variation among seedlots within varieties was nonsignificant in most sets of data. Therefore, the genetic variation in resistance can be adequately described by comparing variety means.

Both measurements, attacks per tree and percentage of trees attacked, gave similar results (Table 1), but the ranking of varieties was more consistent among plantations when percentages were used to indicate resistance. This measurement was most reliable in years of moderate attack. When infestation was heavy even relatively resistant trees often had at least one attack, so that many varieties had nearly 100% of their trees attacked (Table 1). Therefore, relative resistance is best expressed as the percentage of trees attacked in each variety, combined for those years in which the respective plantations were moderately attacked (Allegan 1968, Rose Lake 1969, and Kellogg 1970).

DISCUSSION

King (1971) found in jack pine that fast-growing seedlots were most resistant to eastern pineshoot borer and that slow-growing seedlots were least resistant. There is no such linear relationship between growth rate (or height) and degree of resistance in Scotch pine (Table 2). For the most part, short varieties were most resistant and varieties of intermediate height were least resistant. The tall varieties were intermediate in resistance. Consequently, varieties *uralensis* and *armena* were almost equal in height but very different in resistance.

Variety *lapponica* was, by a considerable margin, both the most resistant and the shortest of the varieties. Resistance may have been a function of height in this variety. Those trees were so short (many less than three feet when attacked) that they probably escaped encounter by insects more often than trees in other varieties. But considering all varieties it is unclear what function, if any, height may have in resistance of Scotch pine to attack by eastern pineshoot borer.

Resistance varied noticably with the lattitude of origin of the trees. Northern varieties were most resistant and southern varieties least resistant. The amount of yellow pigment

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Table 1. Differences among Scotch pine varieties in attack by eastern pineshoot borer.

Variety of Scotch pine	Percentage of trees attacked in years of		Attacks per tree, 1970		
	Moderate attack (*)	Heavy attack (†)	Allegan	Rose Lake	Kellogg
	%	%	No.	No.	No.
		Scandinavian Varieties			
lapponica	5	50	.8	.9	.1
septentrionalis	21	87	4.0	3.1	.3
rigensis	31	90	4.1	3.9	.4
		Russian and Siberian Varieties			
mongolica	19	83	2.7	2.0	.3
uralensis	19	82	4.7	2.5	.2
		Central European Varieties			
polonica	37	88	3.0	2.0	1.1
hercynica	41	89	3.6	3.7	.7
carpatica	41	86	2.9	1.7	.6
haguenensis	38	85	2.8	2.6	.6
pannonica	47	93	5.0	5.5	.8
'East Anglia'	36	79	—	3.1	.5
		Western and Southern Eurasian Varieties			
scotica	41	100	—	10.1	.6
iberica	58	96	4.4	9.3	1.3
aquitana	49	96	4.7	7.4	1.0
subillyrica	56	97	—	9.1	1.0
illyrica	44	93	4.5	4.7	1.0
rhodopaea	53	97	5.9	5.6	1.2
armena	51	97	6.0	7.8	1.0

(*) 1968 data from Allegan, 1969 data from Rose Lake, and 1970 data from Kellogg.
(†) 1970 data from Allegan and Rose Lake.

in the foliage during winter also varies with the lattitude of origin of the trees. Consequently, resistance was correlated with winter foliage color ($r = 0.76$, with 67 degrees of freedom). Varieties which have yellow foliage in winter were most resistant to eastern pineshoot borer, and varieties which have green foliage in winter were least resistant (Table 2). In Michigan the color change from yellow to green usually occurs in April, and this insect species oviposits in late April or early May. Thus, it remains uncertain whether winter foliage color is a part of the mechanism of resistance to eastern pineshoot borer.

The time at which shoot growth begins in the spring is another character which varies with the latitude of origin of the trees. In Michigan the adult insect emerges about the same time as Scotch pine is bursting bud, but northern varieties burst bud one to two weeks earlier than southern varieties. This could be the source of variation in resistance if adult insects prefer shoots and young needles of certain lengths for oviposition. Conclusive evidence on this point must await more detailed observations.

Wright *et al.* (1967) and Wright and Wilson (1972), working with the same material used in the present study, found that varieties of Scotch pine differ in resistance to two other insects: European pine sawfly (*Neodiprion sertifer* (Geoff.)) and pine root collar weevil (*Hylobius radicis* Buch.). The varietal resistance patterns to these insects do not conform with the pattern of resistance to eastern pineshoot borer (Table 2). The varieties most susceptible to the other two insects are from central Europe; the varieties most susceptible to eastern pineshoot borer are from southern Europe.

Table 2. Comparison between resistance to attack by eastern pineshoot border and other traits of Scotch pine varieties.

Variety of Scotch pine	Percentage of trees attacked by: Eastern pineshoot borer	European pine sawfly (*)	Pine root collar weevil (†)	Height at age 11 from planting (‡)	Winter foliage color (‡)
	%	%	%	Ft.	1 = yellow 10 = green
		Scandinavian Varieties			
lapponica	5	0	14	8.4	1.0
septentrionalis	21	2	38	13.0	2.6
rigensis	31	6	45	15.1	3.4
		Russian and Siberian Varieties			
mongolica	19	1	30	13.0	1.6
uralensis	19	3	40	16.1	1.2
		Central European Varieties			
polonica	37	19	67	19.0	5.6
hercynica	41	20	44	18.9	7.0
carpatica	41	19	53	19.6	6.5
haguenensis	38	26	65	20.3	8.0
pannonica	47	20	45	18.2	7.3
'East Anglia'	36	26	55	19.7	8.5
		Western and Southern Eurasian Varieties			
scotica	41	6	18	17.1	8.4
iberica	58	11	17	14.5	9.7
aquitana	49	10	12	16.7	9.4
subillyrica	56	12	11	17.6	7.9
illyrica	44	19	10	16.4	7.6
rhodopaea	53	9	19	16.5	8.3
armena	51	7	12	16.2	8.7

(*) Adapted from Wright *et al.* (1967).
(†) Adapted from Wright and Wilson (1972).
(‡) From plantation records at Michigan State University. Color measured at ages 3 to 9.

APPLICATION OF RESULTS

Damage from eastern pineshoot borer is of most importance in the ornamental and Christmas tree industries. For these purposes, moderate growth rate (to avoid the need for excessive shearing) and green winter foliage color are important traits. So the southern and western Eurasian varieties are the ones most commonly planted. Unfortunately, these varieties are also least resistant to eastern pineshoot borer. Of this group, varieties *scotica* and *illyrica* were most resistant, though they lack the best winter foliage color that some less resistant varieties have (Table 2). 'East Anglia' is considered a suitable Christmas tree variety and had a moderate degree of resistance.

No variety is best in all respects and compromises must be made in selecting one to plant. Such decisions are best made if the grower knows which insects are abundant in his area, how easily they can be artificially controlled, and the pattern of genetic variation in the tree species under consideration. Possessing this knowledge, he may then choose the variety which best combines resistance to the most important insect with desirable growth and foliage characteristics.

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SUMMARY

Three lower Michigan plantations of a Scotch pine provenance test have been attacked by eastern pineshoot borer. These plantations were established in 1961 with seedlings originating from 112 native stands distributed throughout the large natural range of this species. Two of the plantations were measured for attack in 1968 and 1969, respectively, and all three were measured in 1970. The proportion of trees attacked varied from 32 to 93%.

The differences among Scotch pine varieties in resistance to this insect were highly significant in all sets of data; in nearly all cases, however, the differences among seedlots within varieties were nonsignificant. Resistance was correlated with latitude of origin and, consequently, with winter foliage color and date of bud burst. Yellow varities from northern regions burst bud earliest and were most resistant; green varieties from southern regions burst bud latest and were least resistant. Resistance was not related to growth rate. The varieties of Scotch pine most suitable for ornamental and Christmas trees in other respects are least resistant to eastern pineshoot borer.

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