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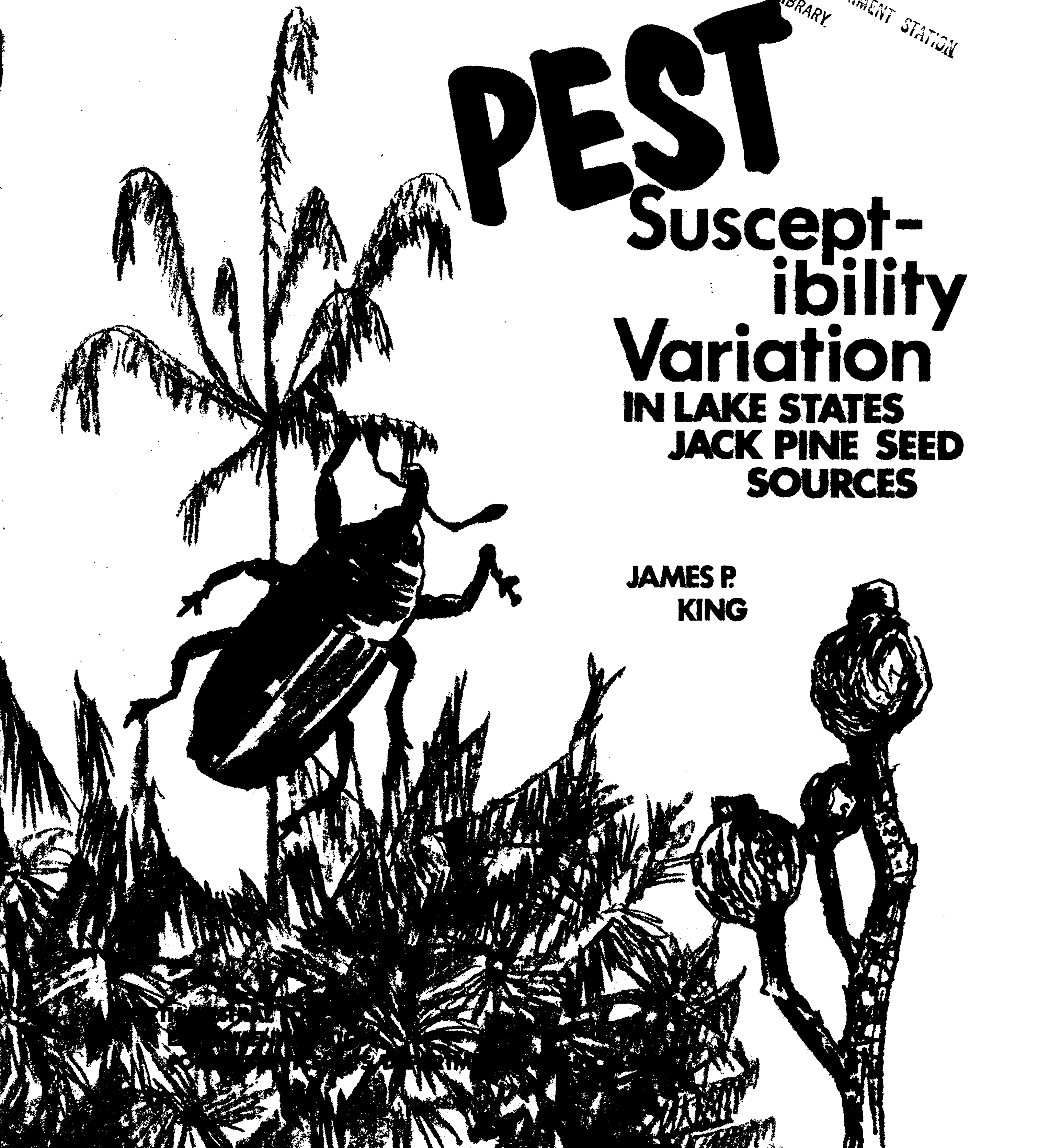

PEST Susceptibility Variation IN LAKE STATES JACK PINE SEED SOURCES

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CONTENTS

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PEST SUSCEPTIBILITY VARIATION IN LAKE STATES JACK PINE SEED SOURCES

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Development of pest-resistant tree varieties in a species can be undertaken only after useful levels of genetic variation have been shown to exist. The North Central (then Lake States) Forest Experiment Station and the University of Minnesota initiated a provenance study of Lake States jack pine (*Pinus banksiana* Lamb.) in 1951. Various Federal, State, and private forestry agencies collected seed from natural stands in Minnesota, Wisconsin, and Michigan. The seedlings were used to establish 17 permanent test plantations in the three States. Data from these plantations have shown jack pine to vary genetically in resistance to some, but not all, of the pests encountered.

PREVIOUS WORK

Three reports on insects or diseases in some of these plantations have already been published. Batzer (1962) described differences among seed sources in incidence of white-pine weevil (*Pissodes strobi* (Peck)) on the Chippewa and Superior National Forests in northern Minnesota. He measured weeviling incidence in 1958 and 1959 on the Chippewa and in 1960 and 1961 on the Superior. On the Chippewa National Forest, trees from the following seed sources showed significantly more weeviling than those from the local source: Pine County (1595, 1596), Minnesota; Douglas (1604), Burnett (1608), Marinette (1609), Oneida (1610), and Wood (1611) Counties, Wisconsin; and Gogebic (1612) County, Michigan. On the Superior National Forest trees from the following sources were more weeviled than those from the local source: Cass (1589, (1600), Pine (1595), and Becker (1597) Counties, Minnesota; and Douglas (1604), Burnett (1608), Marinette (1609), Oneida (1610), and Wood (1611) Counties, Wisconsin.

Arend *et al.* (1961) measured three test plantations in Lower Michigan 5 years after planting and found differences among provenances in susceptibility to white-pine weevils, bark beetles (*Pityophthorous* spp.) and the red-headed pine sawfly (*Neodiprion lecontei* (Fitch)).

There were striking similarities in weevil incidence in Michigan (Arend *et al.* 1961) and in Minnesota (Batzer 1962). The 7 most weeviled sources in the Michigan plantings were among the 8 most weeviled sources on the Chippewa and the 12 most weeviled sources on the Superior.

Provenance differences in jack pine needle cast (*Hypodermella ampla* Dearn.) infection in a southern Wisconsin and a western Upper Michigan planting were described by King and Nienstaedt (1965). Trees from Lower Michigan seed sources showed the least infection and those from northeastern Minnesota sources the most.

METHODS

Seed was collected in 1951 from 29 jack-pine stands in Minnesota, Wisconsin, and Michigan. Each collection was made from dominant and codominant trees in a stand considered good for its locality.

In the spring of 1952, seed from all 29 stands was sown in both the General Andrews State Nursery at Willow River, Minnesota, and in the Hugo Sauer Nursery at Rhinelander, Wisconsin.

Two-year-old seedlings were used to establish 17 test plantations throughout the three States. Seedlings from the General Andrews Nursery were used in the six Minnesota plantings and two western Wisconsin plantings, while seedlings from the Hugo Sauer Nursery were used to establish four Wisconsin and five Michigan plantations.

A four-replicated, randomized, complete-block design was used at each location. Each replication contained trees from each experimental seed source, plus trees from a local source furnished by a commercial nursery in the area of the plantation. Each seed source was represented by a square 64 tree plot in each replication. Because of shortages within various seedlots, substitution had to be made in several plantings. Nevertheless, there were still 26 sources (fig. 1) common to all plantings.

In the fall of 1958, trees in all the plantations were measured for total height, d.b.h. and causes of loss or current injury. All 64 trees on each plot were measured. Trees in 11 test plantations (fig. 1) were again scored in 1963 for total height, d.b.h., form, and the presence or absence of seven insects and two diseases. The 1963 measurement included only 16 trees per plot,

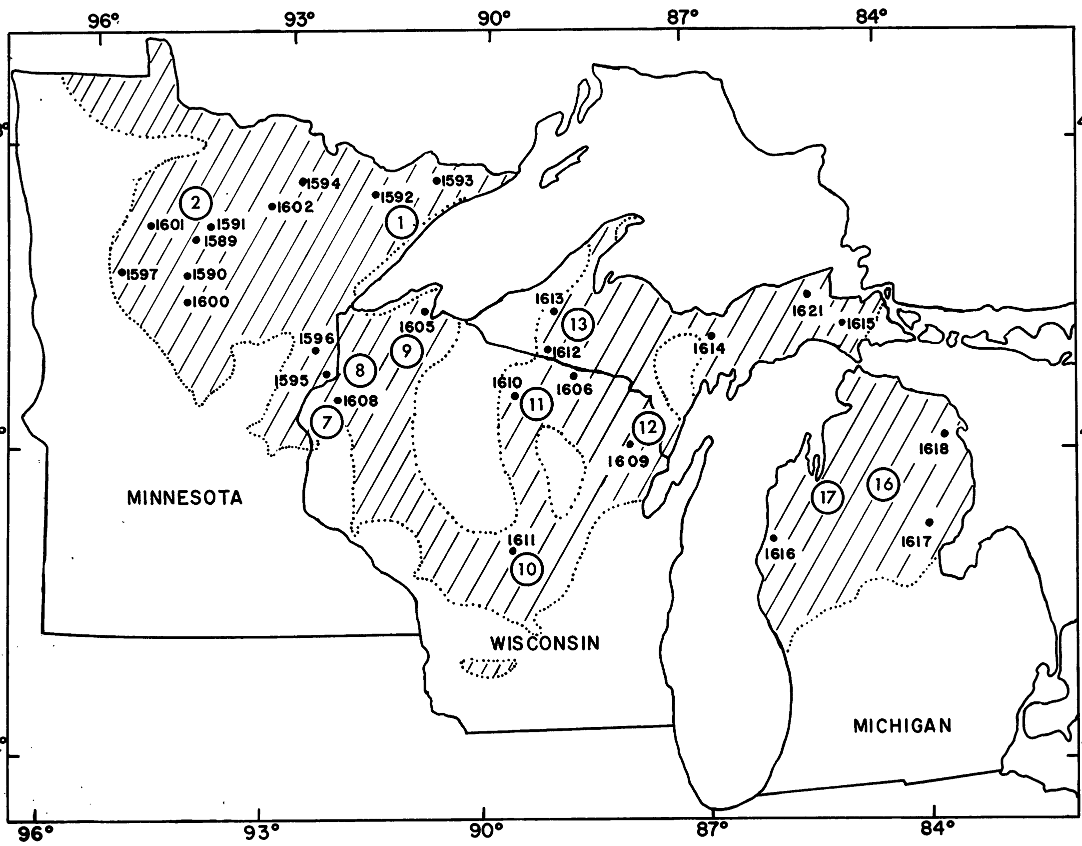

Figure 1.—Location of seed sources and plantations used in regional study. Dots show seed source locations; encircled numbers show plantation locations. Shaded areas show natural range of jack pine.

which were systematically selected and measured. Results of the 1963 height-growth measurements have been reported by King (1966).

Only the 16 trees per plot and the 11 plantings that were measured in both 1958 and 1963 were used in this analysis. Moreover, only the 26 sources common to the 11 plantings are discussed.

ANALYSES

Insect or disease incidence was often low. As a result, many of the plot mean distributions were badly skewed. Few transformations were tried as most of the skewness was due to the large number of zero values for plot means.

When infestations were such that 20 percent or more of all the measured trees within a planting were attacked, the plot mean distribution tended to be normal or nearly so, and analysis of variance was used.

When between 5 and 20 percent of all measured trees were infected, only the seed source totals over all replications were used in the analyses. In this situation the seed source totals from several plantings were combined into a single analysis, using the normally distributed seed source totals as the basic data. This provided a valid test of seed source differences when the seed source x plantation terms were used as the estimate of error variance. However, no within-planting error terms were available for testing the significance of the seed source x plantation interaction.

When less than 5 percent of all the trees in a planting were damaged, the data were not analyzed.

RESULTS

White-Pine Weevil

After five growing seasons in the field, more than 20 percent of the measured trees in three plantings had been attacked by white-pine weevil (table 1). These plantings were at Burnett County Forest, Wisconsin; Au Sable State Forest, Michigan; and Fife Lake State Forest, Michigan. Seed source differences in weeviling incidence could be found at the Burnette and Au Sable plantings, but not at the Fife Lake planting (table 2). When the data from the Burnett County and the Au Sable plantings were combined, highly significant seed source differences were found, but the seed source x plantation interaction was not significant. Significant seed source differences in 5-year height were also noted and the seed source x plantation height growth interaction was nonsignificant. The correlation between seed source tree height at 5 years and weeviling incidence was positive, but just short of significant at the 5-percent level (calculated $r = 0.375$; tabular r for $0.05 = 0.388$ with 24 degrees of freedom (d.f.)).

Even though the height-weeviling correlation was not significant, trees from the five least-weeviled sources were all below average in height and those from the four most-weeviled sources were all above average in height. Thus, the 5-year data suggest that height differences do make a small contribution to weeviling differences but factors other than height are primarily responsible for weeviling differences at that age.

Table 1.—Incidence of white-pine weevil on jack pine in 11 test plantations 5 and 10 years after establishment

Plantation number	Name and location	Percent of trees attacked in	
		1958	1963
1	Superior National Forest Minnesota	1.4	8.1
2	Chippewa National Forest Minnesota	5.6	6.3
7	Burnett County Forest Wisconsin	23.5	2.5
8	Mosinee Industrial Forest Wisconsin	4.4	7.2
9	Chequamegon National Forest Wisconsin	6.7	1.3
10	Nepco Industrial Forest Wisconsin	1.3	1.0
11	Argonne Experimental Forest Wisconsin	6.7	1.0
12	Marinette County Forest Wisconsin	8.4	1.6
13	Ottawa National Forest Michigan	3.8	1.0
16	Au Sable State Forest Michigan	32.2	49.5
17	Fife Lake State Forest Michigan	23.1	7.3

Table 2.—Incidence of white-pine weevil on jack pine in 1958 and 1963

Seed source	State	1958		1963				Au Sable and Fife Lake (combined)	
		Burnett	Au Sable	Superior	Chippewa	Au Sable	Fife Lake	1963 height	1963 weeviling (Adjusted for height)
		Percent	Percent	Percent	Percent	Percent	Percent	Feet	Percent
1589	Minn.	27	27	3	3	47	8	10.5	24.2
1590	Minn.	19	38	8	6	52	5	10.4	25.9
1591	Minn.	14	22	8	5	47	6	10.2	26.5
1592	Minn.	3	25	5	5	38	5	9.9	23.3
1593	Minn.	9	23	2	0	34	3	9.6	24.5
1594	Minn.	23	38	8	2	27	0	9.2	22.8
1595	Minn.	30	22	11	5	56	13	10.5	31.1
1596	Minn.	20	31	5	11	63	8	10.2	34.9
1597	Minn.	20	31	5	5	50	2	10.1	25.9
1600	Minn.	32	25	5	5	52	8	10.0	31.6
1601	Minn.	22	23	9	3	39	8	10.6	19.6
1602	Minn.	17	34	6	5	36	8	9.8	25.2
1605	Wisc.	28	39	3	6	53	11	9.7	36.3
1606	Wisc.	20	22	6	5	36	3	9.8	22.6
1608	Wisc.	30	55	16	16	59	9	10.5	31.5
1609	Wisc.	41	38	17	16	52	20	10.1	36.4
1610	Wisc.	41	42	20	8	55	5	10.6	25.2
1611	Wisc.	56	27	14	13	67	17	10.1	43.1
1612	Mich.	23	38	13	13	52	19	10.0	37.1
1613	Mich.	17	23	9	9	56	3	9.7	33.8
1614	Mich.	19	45	6	5	41	3	9.4	29.2
1615	Mich.	14	28	8	9	45	6	9.6	31.6
1616	Mich.	30	44	2	0	61	9	11.6	21.4
1617	Mich.	20	41	13	6	59	6	11.2	22.5
1618	Mich.	14	39	5	3	56	2	11.6	15.2
1621	Mich.	20	22	6	2	56	3	9.5	35.6
Seed source F value		4.94	1.86	1.80	2.05	1.88	1.94	--	--

The sources from Lower Michigan seem to be the most notable exceptions to the height-weeviling relationship. Sources 1617 and 1618 were two of the three sources producing the tallest trees, and yet both were slightly below average in weevil incidence. Trees from source 1616 were the tallest in the plantings, but were the sixth most weeviled. Trees from source 1605 (northeastern Wisconsin), on the other hand, were the next to the shortest in the planting but the fifth most weeviled.

In the 1963 measurements, only one of the plantings, Au Sable State Forest, showed a high degree of weevil infestation —about 50 percent of the tree were attacked (table 1). The differences among sources were highly significant. (table 2).

Incidence of white-pine weeviling in the two Minnesota plantings was low (table 2). When weeviling incidence from both Minnesota and Michigan plantings are combined, there is a significant seed source x planting interaction between the Minnesota and Michigan plantings.

In most cases differences in weeviling incidence between the Minnesota plantings and the Michigan plantings paralleled height growth differences. For example, trees from two of the Lower Michigan seed sources (1616 and 1618) were among the fastest growing in the Michigan plantations and among the slowest growing in the Minnesota plantations. They were well above average in weeviling incidence in Michigan but below the plantation average in Minnesota. In other words, changes in white-pine weeviling incidence could be accounted for mainly by changes in height growth.

In the Minnesota plantings where the weeviling incidence was low there was no correlation between 10-year height and 10-year weeviling. But in the Au Sable, Michigan, planting there was a significant correlation ($r = .53$ with 24 d.f.). Covariance analysis established that there were weeviling differences independent of height. Moreover, in the Minnesota plantations, sources 1606, 1589, and 1616 averaged 3 percent of their trees weeviled, while sources 1609 and 1611 averaged 15 percent weeviled trees. Yet these five sources did not differ significantly in the 10-year tree height growth. Clearly not all differences in weeviling are the result of height growth differences.

If 10-year weevil incidence in the two Lower Michigan plantings is adjusted for height differences (via linear covariance), trees from source 1618 and source 1601 are taller and relatively less weeviled in the Lower Michigan plantings. Tree from sources 1609, 1611, and 1610 had the highest (adjusted) weevil incidence although these made about average height growth.

In the Minnesota plantings trees from sources 1609 and 1611 were below average in height, but were among the most heavily weeviled. Trees from a number of other sources were low in weeviling incidence, and no source could be singled out as showing exceptional resistance to weeviling in the Minnesota plantings.

There was no obvious relationship between weeviling and seed source latitude. This same lack of geographic pattern in weevil incidence has been reported for eastern white pine (*Pinus strobus*)by Garrett.[1]

In summary, it is clear that there are real differences among seed sources in white-pine weevil resistance. But these differences can be and are often obscured by the varying height growth among seed sources. Trees from the southernmost Wisconsin seed sources showed a consistently high incidence of weeviling, both in this study and in those reported by Batzer (1962) and Arend *et al.* (1961). Trees from the northern Minnesota seed sources show a consistently low incidence of weeviling, but trees from these sources are usually the slowest growing in the Wisconsin and Michigan plantations. When a statistical adjustment is made for seed source tree height differences, the Lower Michigan sources appear quite low in weevil preference. Because trees from these Lower Michigan sources (1616, 1617, and 1618) are the fastest growing in Wisconsin and Michigan (King 1966), they would appear to be the best sources to use as a starting point in a white-pine weevil resistance breeding program.

Eastern Pine-Shoot Borer

Eastern pine-shoot borer (*Eucosma gloriola* Heinrich) was found in 8 of the 11 plantations after five growing seasons in the field (table 3). Although the incidence of this insect in the plantations ran as high as 38 percent, no significant seed source differences could be shown.

Table 3.—Incidence of eastern pine-shoot borer on jack pine in 11 test plantations 5 and 10 years after establishment

Plantation number	Name and location	Percent of trees attacked in: 1958	1963
1	Superior, Minn.	0.4	2.1
2	Chippewa, Minn.	10.0	2.7
7	Burnett, Wisc.	10.6	4.9
8	Mosinee, Wisc.	6.5	23.5
9	Chequamegon, Wisc.	21.4	2.9
10	Nepco, Wisc.	37.9	20.9
11	Argonne, Wisc.	5.3	18.8
12	Marinette, Wisc.	.6	1.2
13	Ottawa, Mich.	.0	24.8
16	Au Sable, Mich.	.0	1.3
17	Fife Lake, Mich.	.0	1.2

[1] *Garrett, Peter W. Resistance of eastern white pine (Pinus strobus L.) provenances to the white-pine weevil (Pissodes strobi Peck). (Manuscript in preparation for publication.)*

In the 1963 measurements some shoot borer damage was found in all the plantings. Of the four most heavily attacked plantings, seed source differences were found at the Nepco Industrial Forest, Argonne Experimental Forest, and the Ottawa National Forest but not at the Mosinee Industrial Forest (table 4).

When the insect data from the Nepco, Argonne, and Ottawa were combined into a single analysis, a significant seed source x plantation interaction was found. And while there was a negative correlation (r = –.67 with 24 d.f.) between shoot borer incidence and 10-year height over the three plantings, a linear covariance analysis showed that variation in shoot borer incidence could not be entirely attributed to height growth variation.

Based on the three-plantation average and on a covariance adjustment for 10-year height, trees from sources 1609, 1596, 1612, and 1616 showed the lowest overall shoot borer incidence (table 4). Trees from sources 1592, 1597, and 1615 had the highest incidence.

Sources contributing most of the seed source x plantation interaction were 1606 and 1621, which had relatively higher insect incidence at the Argonne Experimental Forest than at the Nepco or Ottawa plantings; sources 1595 and 1610, which had relatively high insect incidence at the Ottawa National Forest; and sources 1592 and 1614, which both responded differently at the Nepco than at either of the other two plantings.

Table 4.—Incidence of eastern pine-shoot borer on jack pine in 1963

Seed source	State	Nepco	Argonne	Ottawa	All three plantings combined: Mean height	All three plantings combined: 1963 incidence (adjusted for height)
		Percent	Percent	Percent	Feet	Percent
1589	MN	19	17	19	13.5	20.5
1590	MN	25	17	33	12.9	25.3
1591	MN	27	25	22	12.4	22.8
1592	MN	20	39	44	12.0	31.1
1593	MN	33	34	39	11.5	25.0
1594	MN	20	19	25	11.7	16.9
1595	MN	17	16	33	12.9	22.1
1596	MN	8	9	25	12.5	12.7
1597	MN	22	33	39	12.9	31.5
1600	MN	19	25	25	12.9	23.2
1601	MN	28	19	30	13.0	26.0
1602	MN	25	19	36	12.6	25.7
1605	WS	27	16	22	12.6	20.5
1606	WS	13	22	16	12.5	16.7
1608	WS	16	13	14	13.7	17.1
1609	WS	11	6	17	13.1	12.4
1610	WS	13	13	28	13.7	20.8
1611	WS	25	16	27	12.4	20.7
1612	MC	17	8	11	13.5	14.4
1613	MC	17	16	22	12.8	17.8
1614	MC	33	17	22	12.9	24.0
1615	MC	31	36	28	12.7	31.0
1616	MC	14	5	13	14.0	14.9
1617	MC	20	6	17	13.4	16.8
1618	MC	19	5	19	13.8	17.7
1621	MC	25	39	22	12.1	25.7
Seed source F value		1.87	4.05	2.91	--	--

The heights of the trees in each seed source may be the most important factor in shoot borer incidence. In 1958, when seed source tree height averaged 4 to 6 feet, the insects showed no seed source preferences. By 1963, when the mean height of the test plantation trees exceeded 12 feet, the insects preferred the seed sources with shorter trees. However, the fact that height variation could not entirely account for variation in shoot borer incidence suggests that other unknown factors may also play a role in insect resistance, and possibly these factors are not present in younger trees.

There was a tendency for trees from the more northerly seed sources to have a higher level of pest incidence than those from the southern seed sources. That is, there was a positive correlation between eastern pine-shoot borer incidence and the latitude of the seed source. However, this is probably a reflection of the fact that the trees from Minnesota sources were shorter than those from the Michigan sources in these plantations. That is, insect resistance appears related to latitude only because height growth is related to latitude.

Eastern Gall Rust

In the 5-year plantation measurements 15 percent of the trees in the Mosinee Industrial Forest plantation and 14 percent of the trees in the Chequamegon National Forest planting had eastern gall rust (*Cronartium quercum* (Berk.) Miyabe Ex Shirai) cankers (table 5). Gall rust was also found in the Superior National Forest, Chippewa National Forest, Burnett County Forest, and Nepco Industrial Forest and the Au Sable State Forest plantings, but in none of these was the overall rust incidence greater than 3 percent. There were significant differences in rust incidence among seed sources on both the Mosinee Industrial Forest and Chequamegon National Forest (table 6).

In the 10-year measurements gall rust cankers were found in every test plantation. There were significant seed source differences in every planting where more than 15 percent of the trees were infected (table 6).

Table 5.—Incidence of eastern gall rust on jack pine in 11 test plantations 5 and 10 years after establishment

Plantation number	Name and location	Percent of trees attacked in: 1958	1963
1	Superior, Minn.	0.1	3.1
2	Chippewa, Minn.	.4	26.1
7	Burnett, Wisc.	3.3	38.8
8	Mosinee, Wisc.	14.7	80.8
9	Chequamegon, Wisc.	14.1	70.4
10	Nepco, Wisc.	2.4	32.8
11	Argonne, Wisc.	.0	.7
12	Marinette, Wisc.	.0	1.1
13	Ottawa, Mich.	.0	2.8
16	Au Sable, Mich.	.7	44.7
17	Fife Lake, Mich.	.0	15.1

There was a significant negative correlation between 1963 height and 1963 rust incidence in some of the more heavily infested plantings ($r = -.66$ with 24 d.f.). But height differences alone could not account for all the differences in rust incidence and vice versa.

A combined analysis of the 10-year data showed significant seed source x plantation interaction. When the 5- and 10-year data from the Mosinee and Chequamegon plantings were used in a combined analysis, a significant year x seed source interaction was indicated. However, these interactions arose mainly from large between-plantation differences in the overall level of infection rather than from increased (or decreased) susceptibility of any seed source. The ranking of the seed sources between plantations and years remains quite consistent, with very few exceptions.

Trees from seed source 1611 (Wood County, the southernmost source in this test) had the lowest rust incidence in both the Mosinee and Chequamegon plantations at age 5. At age 10, trees from this source had the lowest rust incidence in five of the seven plantations showing significant seed source differences, and were never significantly poorer than the best in any of the plantings. Sources 1595, 1600, and 1608 were also consistently among the five sources having the lowest incidence.

Table 6.—Incidence of eastern gall rust on jack pine in 1958 and 1963

(Percent of trees infected)

Seed source	State	1958				1963				
		Mosinee	Chequamegon	Chippewa	Burnett	Mosinee	Chequamegon	Nepco	Au Sable	Fife Lake
1589	MN	3	11	16	13	75	63	22	28	11
1590	MN	2	8	22	34	89	58	19	28	8
1591	MN	20	6	30	50	86	77	30	42	13
1592	MN	49	25	39	59	100	80	59	58	20
1593	MN	27	17	41	44	97	92	45	56	16
1594	MN	33	39	55	64	97	92	75	63	31
1595	MN	3	3	19	17	66	33	11	20	5
1596	MN	11	13	23	42	84	77	19	39	9
1597	MN	9	5	30	44	75	53	20	25	16
1600	MN	2	6	13	20	70	53	28	19	2
1601	MN	17	14	36	38	83	80	19	44	11
1602	MN	30	19	52	67	94	88	67	75	27
1605	WS	6	8	13	36	69	55	11	27	9
1606	WS	20	17	44	38	91	80	42	69	23
1608	WS	3	13	8	17	56	45	11	28	5
1609	WS	6	9	13	27	72	55	19	14	2
1610	WS	23	31	33	36	98	89	38	59	28
1611	WS	2	3	14	3	22	28	3	14	8
1612	MC	28	23	25	47	95	92	39	56	27
1613	MC	6	23	17	50	88	88	47	39	19
1614	MC	23	11	23	52	92	86	36	66	16
1615	MC	33	27	39	63	100	92	52	61	27
1616	MC	9	8	14	30	70	52	13	42	11
1617	MC	6	14	14	28	59	69	42	64	16
1618	MC	14	13	22	34	80	67	30	63	17
1621	MC	17	11	27	58	92	89	55	64	20
Seed source F value		3.69	2.65	2.98	6.65	14.75	11.36	6.81	6.98	3.22

Within the portion of the jack-pine range that was sampled in this study, trees from the northernmost sources showed the highest rust incidence, while those from the southern sources showed the lowest rust incidence. It seems possible that the seed sources from the southern portion of the range have been subjected to more intense gall rust infections, and hence have developed some resistance to it, while sources from the more northernly areas (where the alternate hosts are not as plentiful) have not been subjected to as severe selection for resistance.

Anderson (1965) has reported both eastern gall rust and western gall rust (*C. coleosporioides* Arth.) in the Lake States. These two rusts are morphologically indistinguishable, and it is possible that some plantings were infested with eastern gall rust, and others with western gall rust. If this was the case, the consistent variation pattern throughout the planting suggests that resistance to both rust species is governed by the same factors.

Assuming that various races of these rusts may have developed, the consistent performance of the sources also suggests that a source possessing resistance to one race of eastern gall rust will possess resistance to other races of rust.

Other Pests

The northern pitch-blister moth (*Petrova albicapitana* (Busck.)) was found in all of the plantations in either 1958 or 1963. The Nepco Industrial Forest plantation was the most heavily attacked. In both years about 20 percent of all the trees showed symptoms of this insect. And yet, significant differences among sources were not found in any of the plantings. Moreover, Arend *et al.* (1961) reported 30 percent of the trees damaged in an identical planting (not covered in this paper) in Lower Michigan without finding seed source differences. If genetic variation in resistance to this insect exists in the material studied, it could not be detected by this test.

Pine tortoise scale (*Toumeyella numismaticum* (Pettit and McDaniel)) was present in the 1963 examination on 25 percent of the trees in the Argonne Experimental Forest planting. No significant seed source differences were found. Although the insect was found in several plantings, at no other planting did the overall incidence exceed 4 percent.

In 1958 other insects and diseases noted in the plantings included: Aphids, Saratoga spittlebug (*Aphrophora saratogenis* (Fitch)), pine root-collar weevil (*Hylobius radicis* Buchanan), jack-pine sawfly (*Neodiprion pratti banksianae* Rohwer), red-headed pine sawfly, pine webworm (*Tetralopha robustella* Zeller), jack-pine budworm (*Choristoneura pinus* Freeman), Zimmerman pine moth (*Dioryctria zimmermani* (Grote)), jack pine needle cast and sweetfern rust (*Cronartium comptoniae* Arth.).

In 1963 the presence of jack-pine sawfly, jack-pine budworm, Saratoga spittlebug and sweetfern rust were also noted.

None of these pests occurred on more than 1 percent of the trees in any plantation. No seed source differences could be detected for any of these pests.

DISCUSSION

The results showed that trees from a particular seed source may grow faster than average and be less susceptible to several forest pests, but are not necessarily resistant to all pests. Sources 1609 (Marinette County, Wisconsin) and 1611 (Wood County, Wisconsin) showed a higher than average incidence of white-pine weeviling in the study as well as in Batzer's (1962). Yet these same two sources showed a relatively low incidence of eastern pine-shoot borer. Source 1611 was also among the lowest in eastern gall rust incidence.

// Certainly a breeding program intended to produce resistant varieties should not be confined to only a single insect or disease. For in doing so one may increase resistance to one pest while increasing susceptibility to another. On the other hand, if a pest resistance breeding program tries to take into account the full spectrum of forest insects and diseases, the program may be diluted to the point where no progress is made in increasing resistance to any pest. Thus, the tree breeder, in close consultation with forest entomologists and pathologists must carefully limit the choice of insects and diseases to be considered in a resistance breeding program.

Not a good general premise

Pests that do not have an important economic impact on forest productivity should be ignored. The tree breeder must accept the presence of forest pests that do not reach epidemic proportions or that cause essentially aesthetic damage to forest stands. Pests that can be controlled through silvicultural means should also be ignored. Obviously, any insects or diseases that do not occur in the areas where the resistant varieties are to be used commercially should not be considered.

In this and other studies (Arend *et al.* 1961, Garrett[2]), the relationship between the geographic location of the seed origin and pest incidence has been random. It is not possible to predict the sources that will produce the least susceptible trees. Thus, a resistance breeding program should begin with a range-wide seed source study of the tree species in question. If a seed source study already exists, then the breeder might begin by either selecting parents from trees that are part of the existing study or by returning to the areas of the faster growing provenances and selecting several hundred new parents for more intensive studies of resistance.

Comparing the present pest data with 10-year height growth variation (King 1966), it is evident that the height growth ranking of the seed sources is little affected by the presence of heavy pest infestations. This is probably the result of the laterals in jack pine quickly assuming dominance w~~t~~hen the terminal shoot is damaged. Thus, there is little loss in height growth

[2] *Ibid.*

from white-pine weevil or eastern pine-shoot borer attack. There would, therefore, be little natural selection either for or against insect resistance. This may account for the random nature of the geographic distribution of resistance to these two insects.

The insect and disease incidence reported in this study was entirely the result of natural infestations. If the trees could have been artificially infested, a more uniform level of pest incidence could probably have been achieved. This would have increased the precision of the test and probably revealed a greater number of statistically significant seed source differences. This has already been demonstrated with white-pine weevil (Soles and Gerhold 1968). Moreover, as noted in this study, insect attack was often influenced (either positively or negatively) by relative tree height. It could not be determined from the present data whether the relationship between tree height and insect incidence was due to a direct link between growth rate and insect success or whether growth rate merely affected the availability of the tree to the insect. Clearly, the development and use of controlled infestation techniques is a prerequisite to an efficient pest resistance breeding program.

CONCLUSIONS

1. Jack pine seed source variation in incidence of white-pine weevil, eastern pine-shoot borer, and eastern gall rust has been demonstrated.

2. Resistance to one pest does not imply resistance to other pests. New improved varieties must be tested against several carefully chosen destructive pests. A thorough understanding of host-pathogen relationships will be needed to insure that selection for resistance to one pest does not increase suspectibility to other pests.

3. Insect attack can be strongly influenced, either positively or negatively, by relative tree height. In an insect resistance breeding program, artificially inducing insect attack through caging or carrying live insects to every tree may help to eliminate the confounding effect on growth rate. But in any case, more must be known about factors influencing movement, oviposition, dispersal and feeding habits of each pest.

LITERATURE CITED

Anderson, Gerald W. 1965. The distribution of eastern and western gall rusts in the Lake States. Plant Dis. Rep. 49(6): 527-528.

Arend, John L., Smith Norman F., Spurr, Stephen H., and Wright, Jonathan W. 1961. Jack pine geographic variation – 5-year results from Lower Michigan tests. Proc. Mich. Acad. Sci., Arts, and Letters 46: 219-238.

Batzer, Harold O. 1962. White-pine weevil damage differs significantly by seed source on two northern Minnesota jack pine plantations. USDA Forest Serv., Lake States Forest Exp. Sta. Tech. Note 618, 2 p.

King, James P., and Nienstaedt, Hans. 1965. Variation in needle cast susceptibility among 29 jack pine seed sources. Silvae Genet. 14: 194-198.

King, James P. 1966. Ten-year height growth variation in Lake States jack pine. *In* Joint Proc. Second Genetics Workshop of the SAF and the Seventh Lake States Forest Tree Improvement Conference. USDA Forest Serv. Res. Pap. NC-6, N. Cent. Forest Exp. Sta., St. Paul, Minn.

Soles, Robert L., and Gerhold, Henry D. 1968. Caged white pine seedlings attacked by white-pine weevil, *Pissodes strobi*, at five population densities. Ann. Ent. Soc. Amer. 61(6): 1468-1473.

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