SELECTION AND BREEDING EASTERN COTTONWOOD FOR RESISTANCE TO FOLIAGE DISEASES 1/

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ABSTRACT.--The incidence and effects of Melampsora leaf rust and Marssonina leaf spot on eastern cottonwood in the central United States are discussed. Yield at age 15 in an Illinois plantation was related to means of leaf-rust scores observed in September of the second and third growing season. An increase of 1 rust score class on a 5-point scale (f=light infection. ...5=severe infection) reduced yield by about 20 percent. The need for selection and breeding for resistance is stressed and methods for attaining resistance are presented.

Intensive culture of eastern cottonwood, Populus deltoides Bartr., is becoming commonplace on the Mississippi Delta and is viewed with increasing interest in the Midwest and elsewhere in the United States. Early results have been sufficiently encouraging to uphold the promise of high yields over short rotations, such as are attained in Europe with selected clones. Nevertheless, it is unlikely that expectations will be fully realized with our natural species--most of which do not warrant intensive culture at wide spacings mainly because of their susceptibility to numerous stem and foliage diseases.

Schreiner's (1963) assessment that "poplars, if not the most pest-ridden of the world's important timber species, certainly rank high in this respect" has been largely unheeded in our quest for superior clones of eastern cottonwood. Resistance to specific diseases must be a primary goal rather than a fortuitous result of breeding and selection.

IMPORTANT FOLIAGE DISEASES

Two diseases meriting primary consideration in the central United States are leaf rust caused by Melampsora medusae Thum. and leaf spot caused by Marssonina brunnea (Ell. et Ev.) P. Magn. Although the

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effects of the latter disease are obscured by and have been confused with the effects of the better known leaf rust, the two diseases are easily distinguished. Leaf rust is recognized by the presence of yellow-to-orange pustules of urediospores on the upper and often on the lower surfaces of infected leaves. Irregular, dark brown necrotic areas, which may include the entire leaf, and rumpling of the leaf blade are characteristic of leaf-rust infection. Leaf-spot infection is manifest within a few weeks after leafing as discrete reddish brown to purple discolorations on both leaf surfaces. These develop into dark brown lesions that are seldom over 1 mm in diameter. The release of light-colored macroconidia from acervuli in the middle of a dark lesion produces a characteristic ringlike structure. Elongated dark lesions on the veins and petioles are also characteristic. Infected leaves turn yellow to bronze in color and remain flattened in contrast to rusted leaves that darken and rumple. Both diseases progress acropetally in the crown and normally do not reach the tip of the tree until late in the growing season.

INCIDENCE AND EFFECT

Melampsora leaf rust occurs throughout the natural range of eastern cottonwood. The incidence of Marssonina leaf rust is less well known. Recent studies suggest that it is particularly severe in the central United States.

The incidence and severity of Melampsora leaf rust and Marssonina leaf spot on unselected clones of eastern cottonwood of varying geographic origin has been studied in an east-central Illinois plantation on Drummer silty clay loam (Typic Haplaquoll). Rust infection was scored on the following rating system (Jokela 1966):

Class 1. Pustules not apparent or rare.
Class 2. Pustules present but not prevalent; little or no leaf drop.
Class 3. Pustules prevalent on most leaves but not abundant; some leaf drop.
Class 4. Pustules prevalent and abundant on many leaves; considerable leaf necrosis and leaf drop in the lower portion of the crown.
Class 5. Pustules so abundant as to appear coalesced; over 50 percent leaf drop.

Leaf spot was scored on a similar rating system except that it was based on the presence of lesions rather than pustules and on the yellowing or bronzing rather than necrosis of the foliage.

Trees were scored on September 24, 1974 (table 1). Each plotted point above the blocks on the diagonal or equality line represents a clone more severely attacked by leaf spot than by leaf rust. Most clones of

Table 1.-- Incidence of Melampsora leaf rust and Marssonina leaf spot on clones of eastern cottonwood of southern, central, and northern seed origins in a 5-year-old plantation, September 24, 1974, Urbana, Illinois

Leaf-spot score	Mississippi (*)						So. Illinois (•) and Missouri (+)						No. Illinois (x) and Minn.-Wisc. (0)					
	Leaf-rust score					Percent of clones	Leaf-rust score					Percent of clones	Leaf-rust score					Percent of clones
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
5						-						-						39
4						28						21						49
3						43						51						12
2						29						28						-
1						-						-						-
Percent of clones	28	43	29	-	-	100	7	12	39	16	26	100	5	29	41	20	5	100
Basis	7 clones (11 trees)						43 clones (67 trees)						41 clones (67 trees)					

northern origins are in this category, whereas most trees of central origin are more severely infected with leaf rust. Observations made over several years have shown that clones of southern origin are not severely attacked by either pathogen until late in the growing season.

The primary effect of either disease is premature defoliation. In Illinois this may occur 2 months before the end of the normal growing season and is sufficiently extensive and severe to virtually preclude the development of yellow autumn coloration on eastern cottonwood. Premature defoliation caused by leaf rust has been associated with loss in vigor, lessened winter hardness in colder climates (Nagel 1949, Meiden and Vloten 1958, Peace 1952), a predisposition to attack by other pathogens (Nagel 1949, Schreiner 1959), and root starvation.3/

The economic impact of foliage diseases has not yet been thoroughly evaluated in American plantations because until recently there has been little interest in intensive culture of poplars. The contention that leaf rust infection occurs too late in the growing season to affect growth is unfounded. Wilcox and Farmer (1967) found high negative correlations between first-year rust reaction and second-year growth in height and diameter in a Mississippi plantation of eastern cottonwood. Chiba and Nagata (1973) found similar correlations in P. maximowiczii between rust scores made in the nursery and height at 8 years of age.

The cumulative effect of annual rust infections on growth and survival is being studied in a clonal and seedling plantation established in 1960 on a bottomland site in east-central Illinois for the purpose of studying heritable variation in eastern cottonwood. Only results obtained in the seedling planting are reported here. This plantation was established with 20 1-year-old seedlings selected at random from each of 22 progenies of southern Illinois origin, 38 progenies of west-central Illinois origin, and 32 progenies of east-central Illinois origin.

All trees were scored for rust infection in early September of the second growing season and again in late September of the third growing season. Subsequent growth and survival measurements have been correlated with the means of these two rust scores. Significant differences in height and survival that were related to mean rust scores were already present at 7 years of age when the first height and survival measurements following rust ratings were made. These differences have increased with age and have been most pronounced on the trees of southern Illinois origin and least pronounced on trees of east-central Illinois or local origin.

3/ Personal communication with C. W. S. van Kraayenoord.

The relation between mean rust score and diameter squared x height, a relative measure of tree volume, at 15 years of age is shown in figure 1. The solid line shows the relation for trees that survived through the 15th growing season following planting. The relation shown by the broken line is a better indicator of yield because it accounts for mortality. Accumulated mortality to age 15, which averaged about 15 percent of the trees in the lower three rust score classes, increased to 33 percent of the trees in rust class 4 and to 50 percent in rust class 5. The essentially linear relation between D^2H and rust score suggests that an increase in one rust score class reduced yield at age 15 by about 20 percent.

Information on the economic impact of Marssonia disease on eastern cottonwood in American plantations is not presently available. Premature defoliation caused by this disease occurs earlier and is at least as extensive in the central United States as that caused by leaf rust, hence there is reason to expect that economic losses may be as serious as those caused by leaf rust. Marssonina leaf diseases have caused severe economic losses on euramericana poplars in Europe (Meiden 1962, Castellani and Cellerino 1964).

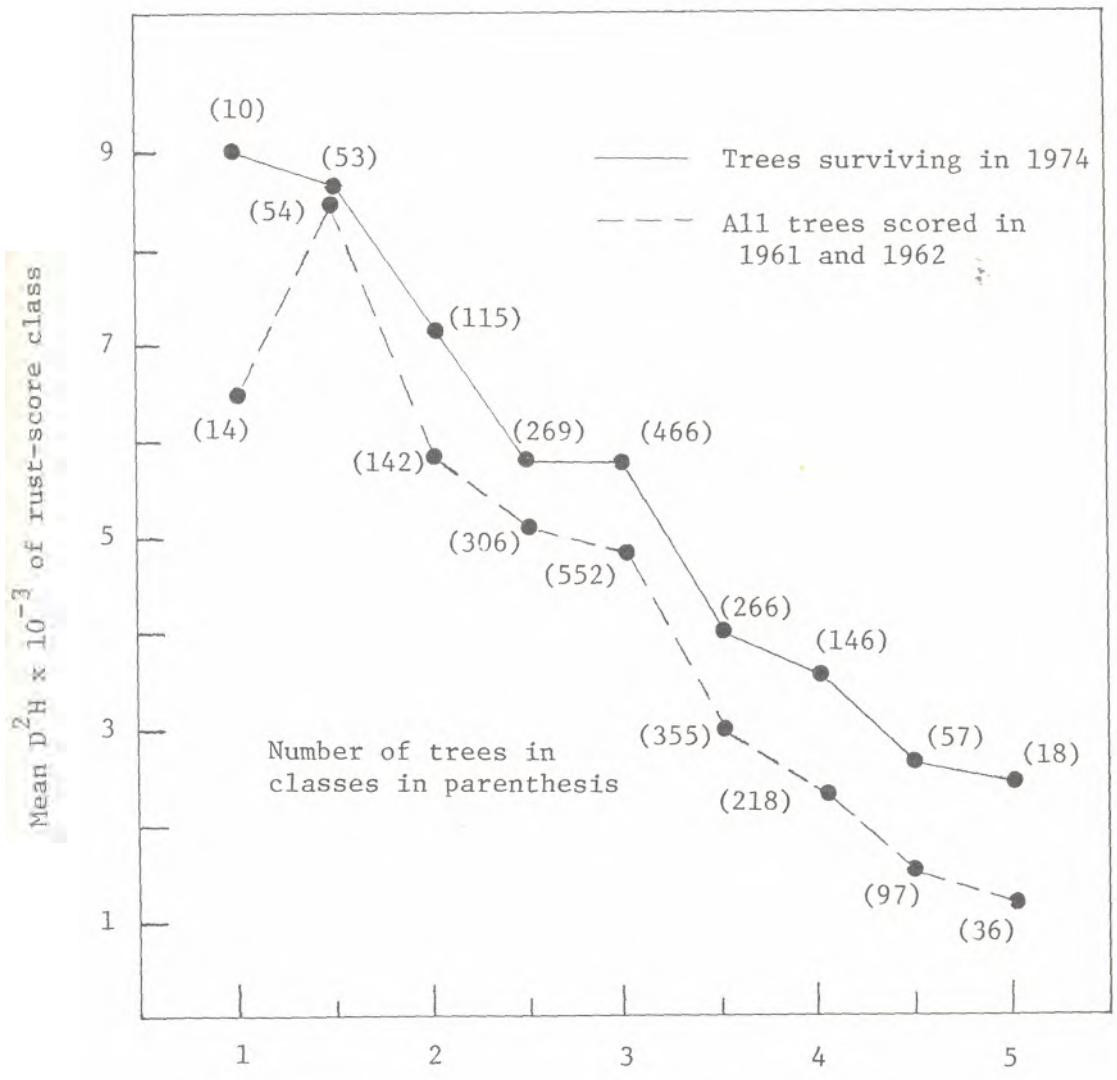
SELECTION AND BREEDING

The wide range of resistance to Melampsora leaf rust among geographic origins, progenies, and clones of eastern cottonwood, and the reliable and rapid assessment of rust reaction argues well for the development of resistant clones and varieties.

Geographic Origin Tests

Evidence from NC-99 tests suggests that utilization of geographic variation is one approach to obtaining rust resistance. In the Ohio test (Thielges and Adams 1975), trees of Missouri origin were more resistant than were trees of local or other midwestern origins. In the Illinois test most clones of Louisiana or Mississippi origin remained practically rust free until very late in the growing season. Correspondence with world-wide recipients of eastern cottonwood seed distributed by the Poplar Council suggests that seed from certain origins has yielded large numbers of resistant trees. This type of uniform resistance appears to be due to an interaction between seed origin and environment and it may be specific to the locations of the planting. Northward movement of seed enhances rust resistance but incurs the risk of planting trees where they are not winter hardy. Because a reliable assessment of winter hardiness requires many years. NC-99 test plantings, which are already 10 years old, are a logical place to search for this type of resistance. Resistance to Marssonina might be selected for simultaneously. We have selected a number of clones of Mississippi and southern Illinois origins that are field

Figure 1.--Relation between Melampsora leaf-rust score and diameter squared x height of trees of Illinois seed origin in a 15-year-old plantation in central Illinois



resistant to both diseases, are rapid growers, and appear to be hardy in central Illinois.

Progeny Tests

Observations of numerous open-pollinated progenies do not support the idea that seed collections from untested, rust-resistant wild trees will necessarily yield rust-resistant progenies. This is not to say that differences among open-pollinated progenies do not exist. On the contrary, we have found progenies that are mostly field resistant but we have never been able to demonstrate a correlation between the resistance of the female parents and the progeny means.

Results of a test of open-pollinated progenies are given in table 2. All progenies are of southern Illinois origin with the exception of those from seed collections made in the central Illinois counties of Vermilion, Henderson, and Hancock. Most trees in Progeny 73-002, which had the lowest mean rust scores on both dates that scorings were made, were field resistant (i.e., rust scores of 1 or 2 on September 6). More than 50 seedlings with a rust score of 1 could have been selected in this progeny and Progeny 73-001, which had the next lowest mean rust score. Less than 20 rust-resistant seedlings were found in the remaining 20 progenies.

The tendency for progenies to be either lightly or heavily rusted suggests that progeny screening tests conducted in the nursery would be useful in selecting parents that yield a high proportion of resistant individuals. Fifty to 100 seedlings per progeny, with 3 replications, would be sufficient to identify resistant progenies. On the basis of observations reported in table 2, one might expect 1 to 3 percent of the progenies to contain sufficient numbers of resistant individuals to warrant large seed collections from their parents in subsequent years.

A small to moderate size program such as this should yield hundreds of resistant individuals for establishing clonal tests to assess growth and other traits. A major drawback, however, is that Marssonina infections appear to be too light in the nursery or in 1 or 2-year-old plantings on new sites to allow reliable assessment of resistance to this disease.

Controlled Pollination

Hybridization studies begun by Muhle-Larsen (1970) and continued by Steenackers (1972a, 1972b) show great promise for obtaining resistance to several diseases.

Table 2.--Mean rust scores on September 6 and October 4, 1973, of open-pollinated progenies sown in Union State Tree Nursery, Jonesboro, Illinois, on June 20, 1973

Progeny (UIFG No. 73-)	Seed origin: Nearest town	Seed origin: County	Mean rust score[1/]: Sept. 6	Mean rust score[1/]: Oct. 4
001	Golconda	Pope	3.0	3.4
002	Golconda	Pope	1.0	1.4
003	Joppa	Massac	2.8	3.0
005	Grand Chain	Pulaski	3.0	3.6
006	Grand Chain	Pulaski	3.5	4.6
008	Thebes	Alexander	3.8	4.8
011	Georgetown	Vermillion	1.5	2.4
012	Oquawka	Henderson	3.0	4.1
013[2/]	Carthage	Hancock	3.5	4.1
014	Brookyln	Schuyler	3.0	4.7
016	Chester	Randolph	3.0	3.4
017	Rockwood	Randolph	3.0	4.1
018	Jones Ridge	Jackson	3.2	4.0
019	Valmeyer	Monroe	3.5	5.0
020	Valmeyer	Monroe	2.8	3.1
021	Rockwood	Randolph	3.8	4.4
022	Rockwood	Randolph	3.2	4.0
024	Grand Tower	Jackson	3.0	4.1
026	Ware	Union	3.5	4.0
027	Reynoldsville	Unioon	3.2	4.3
028	McClure	Alexander	3.8	4.4
029	Cache	Alexander	4.0	4.7
All sources			3.1	3.9

1/ Means for September 6 and October 4 are averages of 4 and 7 plot means, respectively, 50 to 200 trees per plot.

2/ UIFG-68-J18-00. Selected in 1968 for resistance to Melampsora and Marssonina.

Assortative matings of Melampsora resistant and susceptible eastern cottonwood were studied by Lovett (1975). He found significant differences among mating types. However, these differences were not as large or in the direction one would expect if resistance was largely controlled by additive genes. The results supported Jokela's (1966) heritability studies, which suggested that much of the genetic variation in susceptibility to Melampsora within eastern cottonwood was non-additive. Controlled pollinations will be useful and necessary in

combining resistance and other desirable traits. Until more is known about the inheritance of specific traits and of general and specific combining abilities, however, selection of wild types appears to be a more practical approach.

Selection of Resistant Phenotypes

The most promising approach to obtaining resistant clones for immediate use is to select phenotypes from natural stands in midfall just before the first killing frost. At this time trees highly resistant to both Melampsora and Marssonina diseases are strikingly conspicuous because only they will have a full complement of healthy green foliage. This method also allows simultaneous selection for tree form and, to a limited extent, growth rate.

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