RECENT ADVANCES IN RESEARCH OF SOME PEST PROBLEMS OF HYBRID POPULUS IN MICHIGAN AND WISCONSIN

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Abstract.--Hybrid *Populus* clones were examined for impact from and resistance to attack from several insects and diseases. Cottonwood leaf beetle, poplar-and-willow borer, and Septoria canker were most injurious. The spotted poplar aphid and poplar-gall saperda, even when abundant, caused only minor impact. The tarnished plant bug, a newly identified pest of *Populus*, injured young trees near agricultural areas. Hybrid clones show a wide range of susceptibility to pests and provide exceptional breeding material for pest-resistant trees.

Hybrid *Populus* plantings are proving to be particularly vulnerable to insect and disease pests. At least 150 insects and 50 or more diseases are potentially injurious. The insect pests are mostly native ones that feed on aspens and cottonwoods but are equally at home on hybrids grown for intensive culture. For nearly 10 years, the North Central Forest Experiment Station has conducted or supported research on several insects and diseases of hybrid poplars at the Harshaw Farm, Rhinelander, WI; at the Boscobel Nursery and the University of Wisconsin at Madison; and on land owned by the Packaging Corporation of America at Manistee, MI. Results of some of these studies were summarized in an earlier report (Wilson 1979).

Since the last report we have been studying some of the same pests and a few new pests. The most investigated pests include: poplar-and-willow borer (*Cryptorhynchus lapathi* L.), cottonwood leaf beetle (*Chrysomela scripta* Fab.), tarnished plant bug (*Lygus lineolaris* Palisot de Beavois), Septoria leaf spot and canker (*Septoria musiva* Peck), poplar-gall saperda (*Saperda inornata*, Say), and spotted poplar aphid (*Aphis maculatae* Oestlund). We have summarized these studies and a study on simulated insect injury in this report, emphasizing the results during 1979-1982.

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RESEARCH RESULTS

Poplar-and-Willow Borer

The poplar-and-willow borer is the most important boring insect in intensive culture hybrid poplar plantings in the Lake States. It readily attacks young sapling and pole-size trees. Heavy attacks can cause growth loss, stem breakage, tree deformity, and mortality.

The most heavily attacked planting we have studied so far is in a stand of Raverdeau and NE-353 poplars in Benzonia Co., MI, owned by Packaging Corporation of America (PCA). The Raverdeau was established from rooted stock and planted in rows adjacent to NE-353 established from 40 cm cuttings the same year.

Both the Raverdeau and NE-353 clones were attacked by the borer, but the Raverdeau was injured first and more severely. This probably occurred because Raverdeau trees were faster growing and reached a diameter susceptible to attack quicker than NE-353. Morris (1980) and Moore *et al*. (1982a) found that trees were usually free from attack until they grew to 2.0 cm at the base. All first-year attacks, as a consequence, tended to be within 30 cm of the base. But, as trees aged, borers attacked more often and higher on the tree.

After three growing seasons, nearly half of the Raverdeau and a quarter of the NE-353 trees were attacked. By then only 10 out of 1,400 trees had died or broken over. Data from other locations, however, indicate that more damage is possible because borer-infested trees are particularly susceptible to breakage from wind or ice (Morris 1980).

We examined poplar-and-willow borer attacks in a stand at three levels of Populus biomass densities at Rhinelander, WI, in 1981. The clone densities were at 5,000, 10,000, and 15,000 T/ha. Poplar-and-willow borer was counted on three P. x euramericana clones: NC 5323, 'Canada Blanc'; NC-5326, 'Eugenei'; and NC-5377, 'Wisconsin #5' at these three densities. The preliminary data (table 1) were too variable to indicate whether or not density is related to borer attack.

Table 1.--Poplar-and-willow borer attacks on three P. x euramericana clones at three biomass densities

Clone	Mean attacks at densities (T/ha) of: 5,000	10,000	15,000	All
'Canada Blanc'	7.2	1.8	15.6	8.2
'Eugenii'	4.8	2.8	4.8	4.1
'Wisconsin #5'	9.0	3.6	7.0	6.5
Mean Total	7.0	2.7	9.1	6.3

Cottonwood Leaf Beetle

In recent years, the cottonwood leaf beetle has become the number one defoliator in certain Wisconsin and Minnesota plantings of hybrid Populus. Hybrid selections of 12 standard clones and tissue-cultured subclones of P. x euramericana grown at the Boscobel Nursery in Wisconsin gave us an opportunity to study the insect in greater detail.

Cooperators at the University of Wisconsin set out to study the beetle's biology and ecology, to determine its host preference for feeding, and to study the subsequent utilization of Populus tissues as a nutrient source for its growth and development.

The cottonwood leaf beetle (CLB) is a highly prolific insect--females produce an average of 510 eggs (Burkot and Benjamin 1979). In southern Wisconsin four generations occurred between May and September, each generation appearing at about 20-day intervals. After the last generation the adults overwintered in the leaves and debris beneath the host trees.

Larvae, soon after hatching, fed gregariously and skeletonized the foliage. As they aged, they spread out and devoured entire leaves. When food became scarce, the beetles consumed young bark of shoots on the tree tops. Adult beetles also fed on the foliage, adding to the injury.

Life-table studies suggest that predators and parasites kill many CLB's but not enough to keep the population below economic thresholds. The most significant biological control agents found were: Coleomegilla maculata DeGeer, which consumed 25 percent of the eggs; and Shizonatus latus Walker, a pteromolid parasite which destroyed 26 percent of the pupae. The pentatomids Podisus maculiventris Say and Perillus bioculatus Fab., and lacewing and syrphid flies accounted for a small percentage of the young-larval mortality. Few natural enemies attacked the larvae mainly because of the defensive secretion they emit when disturbed or attacked.

Starvation was another main cause of death; four generations of beetles quickly over-ran their hosts and rapidly defoliated them. Population increases showed a potential in excess of 25, 18, and 8 times for the first three generations respectively, which produced millions of beetles in the nursery each season.

Taxonomically the genus Populus is subdivided into five sections. The three major ones are Leuce, Aigeiros, and Tacamahaca. In host preference tests between clones of these three sections, CLB adults would not feed on hybrid clones from the Leuce section (table 2).

Table 2.--Populus clones and CLB feeding preference

Clone	Defoliation Level[1/] (percent)	Sectional Composition[2/]
'Crandon'	0	100% Leuce
NE-1	22	50% A., 50% T.
NE-299	33	50% A., 50% T.
DN-21	41	100% Aigeiros
NC-5260	47	100% Tacamahaca
NE-298	49	50% A., 50% T.
NE-372	51	25% A., 75% T.
NE-387	52	25% A. 75% T.
'Wisconsin #5'	65	100% Aigeiros
NE-252	66	50% A., 50% T.
NE-386	68	25% A., 75% T.
NE-375	78	100% Aigeiros

1/ Level of defoliation reported by Caldbeck et al. (1978).

2/ A. = Aigeiros; T. = Tacamahaca

We expected the beetle to reject the Leuce foliage because the aspens and white poplars in this section are not normally hosts of the CLB

(Harrell et al. 1981). Beetles occasionally nibble these hosts but barely injures them because the foliage was generally unsuitable for their development (Caldbeck et al. 1978, Wilson 1979).

The adults showed an intermediate preference for Aigeiros clones and a high preference for all clones with Tacamahaca parentage. Leaf extractions and bioassays indicated that one or more sugars may be responsible for these preferences. Such differences suggest that increasing the Aigeiros component in future hybrids might make them more resistant to the CLB.

By examining CLB's when exposed to a single tissue-cultured clone (P. x euramericana 'Wisconsin #5'), cooperators found that moisture content and foliage affected the beetles' development and behavior (Harrell et al. 1982). Larvae fed equally on all leaves with water contents greater than 73 percent but did not feed on leaves with less than 70-percent water. In the latter case, the larvae fed on the shoots instead of the leaves. Adults, however, prefered the more succulent, high-water content leaves in the upper crown (table 3).

Table 3.--Adult cottonwood leaf beetle feeding preference with respect to P. x euramericana leaves of different maturity

Leaf position on stem	Mean leaf water content	Mean leaf consumption
	(percent)	($mm^2 \pm$ S.E.)
1 (youngest)	80.9	57.1 $\pm$ 10.33
2	80.2	32.7 $\pm$ 11.80
3	76.8	2.1 $\pm$ 1.01
4 (oldest)	75.2	0.6 $\pm$ 0.33

Larvae were affected by foliage. They developed in an average of 13.5 days on immature foliage and in 14.6 days on mature foliage. Of even greater significance was insect size relative to foliage maturity. Larvae reared on immature foliage yielded prepupae weighing 42.3 mg in contrast to the prepupae weighing 33.5 mg from those reared on mature foliage.

These results suggest that leaf water content or some other leaf constituent that varies with water content has an important influence on the feeding of CLB's and the damage these insects cause. Other plant factors that may be important in reducing CLB feeding and development on the more mature leaves include a lower nitrogen content and higher amounts of fiber and tannins. Additional studies are needed to determine the importance of each of these plant factors so that the information can be utilized in developing resistant poplar clones.

Tarnished Plant Bug

In 1978 an unknown agent began injuring young hybrid Populus trees planted on the Harshaw Forestry Research Farm near Rhinelander, WI. Each summer thereafter, lesions developed on the stems and occasionally on short branches, growing tips, and leaf petioles of certain clones of newly planted and 1- and 2-year old Populus grown from cuttings. The stem lesions occurred in the middle or upper portion of young trees; the injured areas sometimes calloused over but frequently stems were girdled or broken above the injury. The injured area was technically a split-stem lesion and when fully formed consisted of an irregular elongate split with a swollen flared area of necrotic bark and xylem tissues around the stem (fig. 1). Mature lesions ranged from less than 0.5 cm to 5 cm long.

Figure 1.--Split-stem lesion on Populus caused by tarnished plant bug

Initial dissections of lesions for insects and isolations for pathogens provided no clue to the cause of the injury (Sapio et al. 1982). A possible insect and disease association, however, was indicated after the application of malathion, which eliminated most insects at the spray site. New lesions continued to form in an unsprayed area after the treatment but only a few formed in the treated area. In 1981 we set out to determine the causal agent of the lesion, incidence of injury among various Populus clones, and the best ways to prevent it.

Many field and greenhouse tests ultimately identified the causal agent as the tarnished plant bug, normally a destructive pest of agricultural and fruit crops such as alfalfa, cotton, beans, apple, and peach. Though many lygus bugs closely related to the tarnished plant bug (TPB) transmit pathogenic fungi to plants, the TPB did not appear to induce the lesions by vectoring pathogens. Instead, it may have caused lesions through enzymatic activity from its saliva.

TPB's fed on and caused lesions on various clones of hybrid poplar as well as quaking and big tooth aspen. An examination of 20 clones at the Harshaw Farm revealed that NE-298, NE-386, NE-387, and NC-9921 appeared to be consistently the most susceptible. Clones NE-299 and NC-9922 appeared totally resistant in a clonal trial, but were moderately lesioned in other locations. We suspect this may have been because the TPB preferred these clones over less desirable ones or because it lacked other suitable food sources nearby. All clones are probably somewhat susceptible to TPB injury when food choice is limited. For instance, clone NE-375 which appeared highly resistant, developed lesions when caged with TPB's. In fact, it developed more lesions than susceptible clone NC-9922.

Field tests further suggested that Populus resistance is tempered somewhat by the trees' proximity to preferred food sources such as horseweed and fleabane--two weeds common at Harshaw Farm. Also, when white dutch clover was used as a cover crop, it seemed to attract the TPB's and prevent injury to Populus. White dutch clover is one of the TPB's favorite hosts and apparently highly preferred over Populus.

During the first two growing seasons after planting, Populus hybrids showed the highest risk for the TPB lesion. TPB's rarely fly more than 2 m above the ground, so the succculent tissue of the mainstem of Populus is usually well out of reach after the second growing season. The TPB may also feed on the lower twigs but its impact is inconsequential to Populus growth and biomass production.

Cover cropping may minimize TPB injury if properly used or integrated with pesticides. Studies on the management of horseweed, white dutch clover, alfalfa, and other associated treatments are still needed before conclusions can be drawn. Horseweed is somewhat resistant to glyphosate herbicide and its presence seems to be beneficial in lowering incidence of lesions. Perhaps some flowering weeds should be maintained near Populus plantings to entice TPB's away from the trees. Such weeds also encourage parasites that are drawn to the pollen to feed.

The TPB can be suppressed by one or more applications of suitable insecticides. Ultra-low volume malathion has been successful at 9.7 oz. actual insecticide per acre when used in alfalfa fields. It appears to be useful only for short-term suppressions, however, because emigrating adults quickly repopulate an area. Also, there are at least three generations of the TPB in Wisconsin, which further complicate matters.

All in all, perhaps an early season spray integrated with an appropriate weed-management program might successfully control the tarnished plant bug in young Populus stands.

Septoria Leaf Spot and Canker

Septoria is a serious disease on the leaves and stems of hybrid poplars of all ages. This fungus causes small necrotic spots on the leaves; heavy infection usually causes premature leaf drop. Cankers form on the mainstem and branches. Coalescent cankers reduce growth, cause stem breakage, and kill trees. Spores of this disease are carried by wind and rainsplash to leaves, stems, and branches where infection occurs.

In 1979 some nursery stock and a Populus plantation adjacent to the PCA nursery were infected by Septoria. Becoming heavily cankered, the plantation was cut in 1980 for firewood and the stumps were allowed to resprout. In 1981, these sprouts were also cankered and additional nursery stock was infected.

To study Septoria, we set out to determine the severity and site of Septoria infection of first-year coppice and to determine the most susceptible clones in the nursery stool beds.

After coppicing, there were an average of 34 sprouts per stump (range 2-84), and 52 percent of these sprouts were infected in the fall of 1981. All but one of the 75 stumps examined had at least one cankered sprout. Septoria canker was more prevalent on lower stems at leaf petioles and buds as compared to elsewhere on the stems. Densely spaced sprouts encouraged Septoria infection by trapping infected leaves and retaining a moist micro-environment ideal for infection. Infected leaf debris around the stumps also contributed to pathogen retention, spread, and disease severity (Moore et al. 1982b). The severe Septoria infection in the plantation was the result of planting highly susceptible clones.

Nursery stool beds may be even more vulnerable to Septoria than plantations because they are more closely spaced and thus retain higher moisture. Overhead irrigation probably further increases infection. Nearly two-fifths of the clones in the nursery were heavily infected with Septoria. All the P. maximowiczii crosses were heavily infected. This group has been highly susceptible in inoculation tests (Waterman 1954), and cankers also have been found on this species in the eastern U.S. As the male parent, P. trichocarpa appeared in 11 of the 19 highly susceptible crosses at PCA and in none of the resistant clones, indicating that it may contribute to clonal vulnerability to Septoria. P. trichocarpa crosses (as the male parent) have been rated more susceptible to Septoria than P. deltoides (as the female parent) (Waterman 1954). Six of our infected P. deltoides crosses were ones with P. trichocarpa and were among the heaviest cankered.

This study indicates that Septoria canker and leaf spot is certainly one of the most damaging diseases of hybrid poplars in Michigan and, unless managed, can limit the usefulness of susceptible clones. Nursery stock and plantation coppice are infected by spores from infected leaf debris in early spring. Removing this debris is one way to control Septoria. However, local screening of clones for resistance and planting these resistant clones is the most promising long term control strategy in areas where Septoria is known to be a problem. Until this screening is complete, land managers should be aware of the potential hazard from Septoria, if highly susceptible clones are planted. Hybrid poplars with P. trichocarpa, P. laurifolia, or P. maximowiczii as one of the parents were the most susceptible to Septoria and probably should not be planted where this fungus is known to be present.

Poplar-gall Saperda

The poplar-gall saperda attacks the stems and branches of natural and hybrid Populus. Larval feeding forms a swelling that weakens the stems and branches, sometimes causing them to break or die.

During our investigations in PCA plantings in Michigan, we had an opportunity to study the incidence of saperda attacks and the insect's impact in an outplanting of 5-foot tall Populus whips of mixed clones planted in the spring of 1979. The planting was set out in a clearing surrounded by saperda-infested aspens that apparently permitted rapid infestation of the whips.

In the first season of attack, more than 60 percent of the whips were galled by the beetle. Average attack was nearly 2 galls per tree (range 0-12 galls/tree). By the end of the season, 2.6 percent trees died from galls near the base of the trees. Another 7.5 percent were top-killed from galls higher on the stem. Attacks the second year gave the tree another two galls per tree, but nearly 30 percent were on the branches. By the end of the second season, mortality rose by 0.2 percent to 2.8 percent and top-kill increased by 1.5 percent to 9.0 percent. Height differences between galled and ungalled trees were statistically insignificant after the second year.

These data suggest that the poplar-gall saperda does not appear to be a threat to young trees up to the attack level of an average of four galls per tree. Mortality of 2.8 percent after 2 years is not much more than might be expected from most other causes and certainly only a minor concern for biomass production. Almost no additional trees died after the second year mainly because old-galled areas become overgrown by the tree. This also minimized breakage as the tree is strengthened by the new growth. Most top-killed trees resprouted new shoots and quickly regained most of the lost height the following season, suggesting that breakage has little impact on biomass production. So far, this insect has not proved to be a destructive pest and further research is needed with many Populus clones under variable growing conditions before its real impact can be determined.

Spotted Poplar Aphid

The spotted poplar aphid feeds on the terminal shoots of various species of Populus. Clustering in tightly nested colonies, these aphids en masse often cover the entire growing tip and first two or three ranks of leaves during mid and late summer.

This insect has been a perennial pest in the PCA nursery in recent years. We rated all the clones in the nursery according to their susceptibility to this aphid and examined its impact on growth. We also tested two insecticides for controlling the aphid.

Clones of Populus x jackii were the most susceptible to the aphid, having the most numerous attacks and largest aphid colonies. The five next most susceptible clones were NE-19, NE-41, NE-209, NE-298, and NE-360. Resistant clones were NE-19, D-38, I-4551, NE-375, NE-224, and NE-238. None was attacked in the nursery. All other clones were attacked by at least a few colonies and varied from a trace to a moderate infestation. When heavily infested stool-bed suckers were compared to non-infested ones within clones of P. x jackii, we found no significant growth differences at the end of the growing season.

Two insecticidal soaps were tested on aphid colonies on four *Populus* clones at recommended full strength (1.0%) and half-strength (0.5%) dosages. The chemicals tested were Safer insecticidal soap concentrate containing 50.5 percent potassium salts of fatty acids, and a 10 percent mono-L-pesticide developed in the Department of Biomechanics at Michigan State University. The treatments were tested at the PCA nursery and at Morin's Nursery at Manistee, MI.

Both insecticides and dosages controlled the aphids about equally on three of the clones--DN-22, DN-28, and Raverdeau (table 4). Control was slightly less effective on DN-55 colonies.

Table 4.--Control of spotted poplar aphid on cottonwood clones with insecticidal soaps

Populus clone	Insecticide	Dosage	Aphids controlled
		(percent)	(percent)
DN-22	Safer	0.5	88
	Safer	1.0	91
	MSU	0.5	89
	MSU	1.0	94
DN-55	Safer	0.5	76
	Safer	1.0	77
	MSU	0.5	86
	MSU	1.0	84
DN-28	MSU	0.5	96
	MSU	1.0	91
Raverdeau	MSU	0.5	93
	MSU	1.0	88

We concluded from these tests that the insecticidal soaps gave sufficient control to disrupt the colonies for the remainder of the season. However, we would not recommend MSU's formula because it caused some burning of foliage when applied on sunny days, although it controlled adequately.

Insect Damage Simulation

Cooperators at Michigan State University completed tests on the effects of simulated insect damage of hybrid *Populus* in a study planting at Rhinelander, WI (Bassman *et al.* 1982). Insect defoliation and girdling/boring was simulated to assess potential growth impact under nursery conditions. Partial defoliation in several patterns was tested both early and late in the growing season. Clones tested were: NE-298 (*P. nigra* var. *betulifolia* x *P. trichocarpa*); NC-5260 (*P. tristis* x *P. balsamifera*) and NC-5351 (*Populus* sp.).

Trees that had defoliation levels of 40 percent were identical in height growth to non-defoliated trees showing that moderate defoliation is not cause for concern even in such young trees. Further, the young trees appeared to sustain 2 years of 40-percent defoliation without significant growth loss as long as favorable growing conditions were maintained. Defoliation levels of 75 to 80 percent, however, consistently produced significant height growth reductions on the order of 20 percent. Complete defoliation was not tested because normal practice would be to apply insecticides if defoliation appeared likely to become that severe.

Timing of defoliation in the growing season did not seem to be particularly important for growth of trees defoliated 40 percent. Late-season defoliation, however, can be more deleterious than earlier defoliations that allow time for subsequent recovery before bud set in the fall. Location of defoliation on the tree was insignificant to growth loss, indicating that an insect preferring new foliage would do no more damage than one preferring old foliage.

Effects of basal injury by girdling and boring followed a pattern somewhat similar to that of defoliation. Damage had to be severe enough to weaken the stem almost to the point of collapse before there was significant growth loss. Basal injuries healed rapidly in vigorous stock and caused no lasting effects. We should point out that such wounds, however, may be infection sites for pathogens that could kill the trees.

We should also note that these tests did not encompass direct damage to leaders. Several modes of insect attack result in leader damage, and these are difficult to simulate mechanically. In particular, the feeding of aphids does not lend itself to investigation by simulation. Experiments with caged insects are needed in this regard.

DISCUSSION

Since research has begun on *Populus* pests in the North Central Region, the cottonwood leaf beetle has been the predominant defoliator with the greatest impact. Because we now know a great deal about the behavior of this insect as well as much about the physical factors of the host trees, the next appropriate step for research is to examine the chemical cues in *Populus* that repel or attract and safeguard the insect once on the tree. Research will need to interrelate the physical and chemical factors in order to understand host resistence mechanisms. For instance, we will need to learn what concentrations of nitrogen and other nutritional components of the foliage relate to the feeding behavior and growth of the cottonwood leaf beetle. Also, allelopathic chemicals in the host that are certain to provide further mechanisms of host resistence. Populus is ideal for such research because it has a wide range of resistance and susceptibility to this beetle. Because of this and because the cottonwood leaf beetle is the most important defoliator in the region, it might be considered first in pest-resistent breeding programs.

Two insects we investigated--the spotted poplar aphid and the poplar-gall saperda--which are potentially destructive pests of nursery stock and 2- to 3-year old planted trees, caused only minor impact, even when abundant. This suggests that these two insects have been overrated as pests of poplars. For instance, aphid colonies exceeding 800 insects only slightly deformed a few leaves on the tips of some sprouts. Growth differences were insignificant as compared to unattacked sprouts. Similarly, saperda caused a few trees to break over or die-back, but most of those trees resprouted the following year and nearly caught up in height within 2 years. The saperda may have more injury potential under unusual circumstances. High winds or ice storms, for example, might precipitate greater stem breakage. Two or 3 years after outplanting, however, most poplars in our study were nearly immune to stem-injury from saperda.

Septoria canker is the worst disease organism investigated on Populus in both the nursery and plantations. Because many otherwise favorable clones are attacked, this disease will require further and immediate research for its prevention and control.

The poplar-and-willow borer is potentially the worst boring insect so far encountered in the region mainly because it can destroy sapling-size trees. Research will need to continue on this pest in the next few years in order to learn the full extent of its impact. Cultural practices, such as fertilization and thinning, should be tested further to learn how they modify the weevil's behavior.

Cultural practices should also be researched on the tarnished plant bug and Septoria canker, especially where 1-to 2-year old trees need protection. Cover cropping, the role of weeds, and variables related to moisture also need to be studied.

All these studies suggest further that we need to change how we perceive control of some Populus pests--particularly the insects. The poplar-gall saperda and the spotted poplar aphid are two good examples in which damage potential appears to be high but control may rarely be needed. The damage simulation tests further show that Populus can tolerate much defoliation and boring injury before control treatments are needed. Defoliation at 50- to 60-percent levels for 2 or more consecutive years seems to be nearly inconsequential to growth and biomass production. Similarly, borers need to literally riddle a stem before economic thresholds are reached and control is needed.

In conclusion, it appears that if proper pest-preventive measures are taken before and during the growing of Populus hybrids, reasonably resistant trees are planted, and good cultural treatments are adhered to, many Populus pests should be kept at sufficiently low levels to maintain full biomass production.

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