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RESISTANCE OF SCOTCH PINE VARIETIES TO ZIMMERMAN PINE MOTH (LEPIDOPTERA: PYRALIDAE) AND ITS IMPACT ON SALES IN A CHOOSE AND CUT CHRISTMAS TREE PLANTATION

Clifford S. Sadof[1]

ABSTRACT

Nine varieties of Scotch pine, *Pinus sylvestris*, were assessed for their susceptibility to Zimmerman pine moth, *Dioryctria zimmermani*, in a choose and cut Christmas tree plantation. Trees were examined for wounds to estimate their susceptibility to this pest 7 years after planting in the field. Numbers of trees remaining after seasonal sales in years 7 and 8 were used to estimate marketability of each variety. Infestation rates varied significantly among varieties (11–75%). After sales, proportions of trees remaining also varied significantly among varieties (7–52%). Although Belgian trees were the most moth resistant, they were the least purchased by the public, probably owing to their yellow-colored foliage. Excluding the Belgian variety, proportions of infested trees were positively related to the number of trees remaining after two years of sales ($F=12.7$ $df = 1,22$, $R^2=0.37$, $P<0.002$). This linear relation suggested that in a population of 100 trees, three trees must be wounded to cause one not to be sold. This implies that appearance of advanced damage symptoms such as brown and broken branches have a greater negative impact on sales than the simple presence of wounds.

Zimmerman pine moth, *Dioryctria zimmermani* (Grote) (Lepidoptera: Pyralidae) is a serious pest of Scotch pine, *Pinus sylvestris*, in the midwestern United States (Yonker and Schuder, 1987, Butcher and Carlson 1962). Caterpillars eventually disfigure and discolor trees when they bore into the main stem at the branch whorls, killing branches and terminal leaders. In Christmas tree plantations of Scotch pine, the incidence of wounded trees increases with tree age. Typically, when left untreated, three year old fields have low rates of infestation (2%) increasing to over 20% infested trees by the sixth year (Yonker and Schuder 1987).

This insect winters as first instar caterpillars in shallow hibernaculi located under the bark on the main stem (Rennels 1960, Schuder 1960, Butcher and Carlson 1962, Carlson and Butcher 1967). In northern Indiana, when the weather warms in late spring (mid- April), these caterpillars bore into the base of the lateral branches of the main stem where they feed on the phloem and gummy sap exuding from the tree wound. Feeding continues until pupation occurs some time in late June or July. Accumulations of sap and frass associated with feeding are easily detected after August 1 (Yonker and Schuder 1987). The broad period of adult emergence spans from late June through to the end of August, with a peak in early August. Adult fe-

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males lay most of their eggs near the main stem with a strong tendency to oviposit on previously attacked or wounded trees (Carlson and Butcher 1967, Yonker and Schuder 1987). Caterpillars hatching from these eggs apparently do not feed prior to constructing hibernaculi near the site of egg laying (Carlson and Butcher 1967).

Varieties of *P. sylvestris* vary widely in their susceptibility to *D. zimmermani* (Wright et al. 1975, Ruby and Wright 1976). Previous evaluations of tree susceptibility to this pest have evaluated infestation rates, limb death, and stem shape of unpruned trees. Although these factors are critical to identification of resistant tree varieties they do not accurately reflect commercial conditions in which growers routinely prune and cull trees. In this study, infestation rates of commercially grown Christmas trees were examined in Indiana. Relationships between infestation rates just prior to harvest and the number of trees remaining in a choose and cut plantation after two years of harvesting were evaluated.

MATERIALS AND METHODS

Sources of plants. Nine varieties of *P. sylvestris* were used for this study. Sources and recent European origins of each variety are listed in Table 1 in accordance with established classification schemes (Heit 1969, Ruby and Wright 1976).

Experimental design and site conditions. Two-year-old seedlings of *P. sylvestris* were planted on 2 m centers near Idaville, Indiana in April 1986, on sandy loam soil in a test planting of the Indiana Christmas Tree Growers Association. Three replicate blocks of nine varieties of *P. sylvestris* were planted in a randomized complete block design. Each of the nine plots in each block contained a single variety of 36-42 trees, for a total 1002 trees. Trees were maintained with standard cultural practices by a commercial Christmas tree grower, including annual spring culling of dead and deformed trees. A single application of 1.2 g/l of chlorpyrifos was applied with a mist blower in August 1994.

Plots were examined in August 1993 to determine the number of trees surviving and the number of trees with at least one branch whorl wounded by *D. zimmermani*. Whorls were considered wounded when gummy resin and frass were visible at the whorl junction. Effects of variety on proportions of infested trees in each plot and proportion surviving were compared in a randomized complete block analysis of variance (PROC GLM, SAS Institute 1985). Proportions were arcsin square root transformed prior to analysis (Sokal and Rohlf 1991) Means of each variety were compared using a Waller Duncan K-ratio test (Waller and Kemp 1976)

In August 1995, after trees selected by customers were sold from plots in 1993 and 1994, and the grower completed culling, the number of trees remaining and the number with *D. zimmermani* wounds were counted. Effects of variety on the proportion of trees removed from each plot between 1993 and 1995 were compared in a randomized complete block analysis of variance. Proportions were arcsin square root transformed prior to analysis and varietal means were compared in a Waller Duncan K-ratio test.

RESULTS

After 7 years in the field, Scotch pine varieties varied greatly in survival, and susceptibility to *D. zimmermani* (Table 2). Five varieties had over 90%

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Table 1. Commercial sources and likely European origins of nine varieties of *Pinus sylvestris*.

Variety	Commercial Source	Seed Origin
Belgian	Fair Plains Nursery Greenville, MI	Belgium, Campaigne area (imported by F. W. Schumacher)
Lake Superior Blue *aquitana*[1]	Armintrout Nursery Allegan, MI	France (grower seed orchard)
Pike Lake	Noerby Noeker Nursery Allegan, MI	France, Cassadene Massif (grower seed orchard)
Penn Spanish	Strathmyer Forest Dover, PA	Spain[2]
Land O Pine # 1 *hercynica*[1]	Land O Pines Custer, MI	Germany (grower seed orchard)
Van's # 33	Van's Pines West Olive, MI	Possibly Spain (grower seed orchard)
East Anglia	Hensler Nursery Hamlet, IN	Great Britain, East Anglia (imported)
Clonal East Anglia	Hensler Nursery Hamlet, IN (imported)	Great Britain, East Anglia Alice Holt Lodge
Hensler Orchard	Hensler Nursery Hamlet, IN	East Anglia imported by Mr. Nodwell of Canada (grower seed orchard)

[1]Variety name used in Wilson et al. 1975.
[2] Lineage described in Gerhold 1993.

survival prior to sales whereas 3 varieties had only 74 to 79% of the trees survive. Survival of trees within a variety in 1993 was not related (F=0.02; df = 1,22; R^2=0.02; P<0.89) to the existing rates of *D. zimmermani* infestation. Two varieties, Belgian, and Lake Superior Blue were highly resistant (<15% infested) to this insect while two other varieties Hensler Orchard and Clonal East Anglia were highly susceptible (>60% infested).

There was no significant linear relation (F=0.42 df = 1,22; R^2=0.02, P<0.52) between the proportion of trees remaining in the 27 plots prior to sales in August 1993 and the proportion of these trees that were present after 2 years of sales in August 1995. Belgian plots had the majority of 1993 trees remaining in 1995 (52%). However, only 34% of the Hensler Orchard trees and 29% of the Clonal East Anglia trees present in 1993 remained after 2 years of sales despite >60% rates of infestation in 1993. Lake Superior Blue had the fewest (7%) of the 1993 pre-sale trees remaining in 1995. However, when Belgian plot data were excluded from the analysis, there was a significant relation (F=12.68; df = 1,22, R^2=0.37, P<0.002) between the proportion

Table 2. Percent of *P. sylvestris* remaining in plots and percent infested with at least one wound of D. zimmerani.

Variety	Trees planted in 1986	Trees (%)[2] surviving to 1993 (SEM)	Trees (%)[2] infested with *D. zimmerani* in 1993 (SEM)	Trees (%)[2] in 1993 remaining to 1995 (SEM)	Infested[3] trees (%) present in 1995 (n)
Clonal East Anglia	114	95.3 (±2.4)a[1]	74.8 (±0.7)a	29.2 (±4.7)bc	86.7 (30)
Hensler Orchard	108	74.0 (±9.7)c	61.2 (±7.9)ab	33.6 (±4.7)ab	84.6 (26)
East Anglia	108	94.7 (±02.7)ab	48.9 (±2.6)bc	21.5 (±3.2)bc	87.0 (23)
Van's #33	108	75.0 (±7.3)c	45.4 (±14.2)bc	15.3 (±3.9)cd	53.8 (13)
Land O Pine # 1	108	84.3 (±2.4)abc	36.7 (±10.0)c	22.1 (±1.7)bc	30.0 (20)
Penn Spanish	108	78.7 (± 4.0)c	32.5 (±6.9)c	8.3 (±8.3)d	71.4 (7)
Pike Lake	120	95.8 (±2.2)a	29.7 (±4.5)c	10.8 (±2.7)cd	50.0 (12)
Lake Superior Blue	108	92.6 (±0.9)ab	13.0 (±3.6)d	6.9 (±4.3)d	14.3 (7)
Belgian	120	93.7 (±2.2)ab	10.7 (±1.3)d	51.6 (±4.2)a	20.7 (58)
All Varieties					54.1 (196)
F value, df= 8,16		2.68	9.99	5.91	
P value		0.0386	0.0001	0.0013	

[1]Means followed by the same letter are not significantly different according to the Waller-Dunkan K-ratio test on arcsin square root transformed proportions.
[2]Average of three plots.
[3] Percent of total trees (n) remaining in the three plots of each variety.

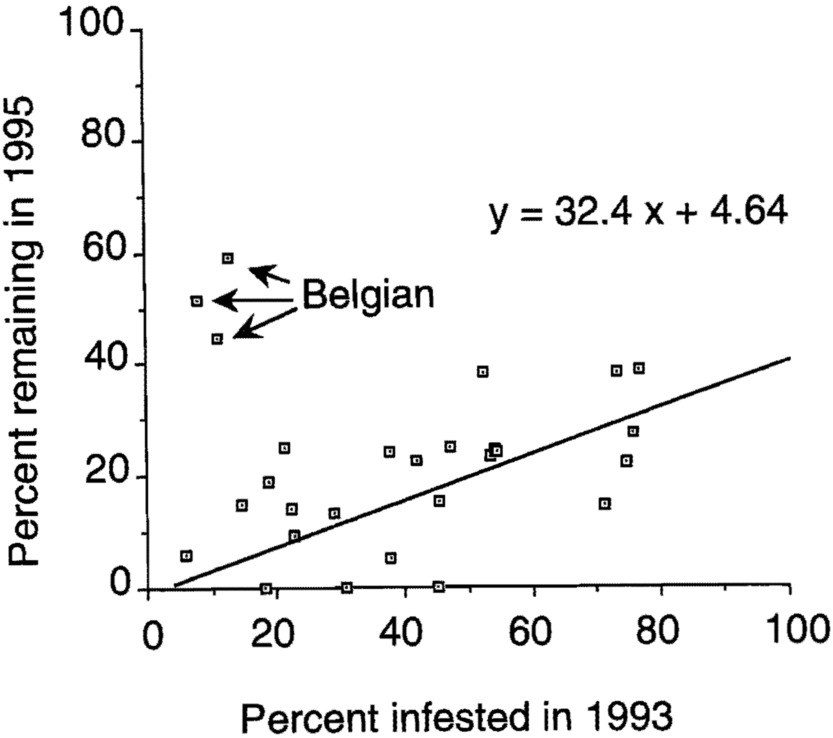

Figure 1. Percent of trees infested with *D. zimmermani* in August 1993 versus the proportion of trees present in 1993 that remained in August 1995 after two years of sales and culling (n=24 plots).

of trees in a plot that were infested with *D. zimmermani* in 1993 and those remaining in plots in 1995 (Figure 1).

Owing to the small and variable number of trees remaining in each plot , data from all three plots of each variety were pooled to report the percent of total trees, and the percent of each variety that were infested in August 1995 (Table 2). More than half of the all trees remaining in the field in 1995 were infested with *D. zimmermani* (Table 2). When the most tolerant varieties, Belgian and Lake Superior Blue were excluded, 83% of the remaining varieties had more than half the trees infested with *D. zimmermani.*

DISCUSSION

Results for this study show that varieties of *P. sylvestris* commonly planted by Christmas tree growers vary widely in rates of survival, and in their susceptibility to *D. zimmermani.* Failure to find a relationship between infestation rates of *D. zimmermani* in seven year old trees and rates of sur-

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vival suggest that factors other than *D. zimmermani* infestation were responsible for the observed tree mortality. Although no attempts were made to identify these factors, low precipitation and extreme heat in 1988 may have been responsible for some of the recorded mortality. Total rainfall between 1 April and 1 September 1988 (32 cm) was the fourth lowest amount in the 102 year period between 1894 and 1996. Average daily temperature for these same months in 1988 (19.83°C) was fifteenth warmest recorded in 102 years (National Climatic Data Center).

Varieties most susceptible to *D. zimmermani* originate from seed collected in East Anglia, Great Britain, whereas less susceptible strains were traced to Belgium, France and Spain. This is consistent with previous findings in plantings of unpruned trees (Wright et al. 1975, Ruby and Wright 1976).

It is important to recognize that although trees could have been sold or culled between August 1993 and August 1995, the majority of the trees removed from plots during this time were sold. Prior to the start of 1993 sales, trees could only be removed from a plot when the grower culled deformed and dead trees. Rates at which trees remained in each plot prior to sales did not predict the rate of trees remaining after the two years of sales and additional culling. Furthermore, although the grower may have increased his rate of culling between 1993 and 1995 in response to increased apparency of *D. zimmermani* injury, he clearly did not removed all the infested trees. More than half the trees remaining in the field in August 1995 showed visible signs of wounding (Table 2). Thus, the positive association between, rates *D. zimmermani* injury and rates of trees remaining in the field in 1995 (Figure 1) suggest that tree wounding had a substantial negative impact on sales.

Injury by *D. zimmermani*, however, was not entirely responsible for the variation in sales among varieties. For example, despite its high level of tolerance to *D. zimmermani*, more trees remained in the Belgian plots after two years of sale than any other variety (Table 2). Belgian varieties of *P. sylvestris* have previously been reported as undesirable to consumers because its foliage often becomes yellow in the fall, prior to the Christmas tree harvest season (Heit 1969). Color has been identified as a one of 5 characteristics that strongly influence customer choice (Florkowski et al. 1992). Even when the Belgian variety is excluded from the analysis, the relationship between injury and sales is somewhat weak. That is, only 37 % of the variation in sales explained by rates of *D. zimmermani* infestation (Figure 1). The slope of the relationship indicates that in a population of 100 trees 3 trees must be injured to reduce sales by 1 tree. This also suggests that consumers purchased a substantial number of trees with exudate surrounding wounded whorls.

Studies of crops valued for their ornamental characteristics indicate that consumers respond negatively to disfigurement and discoloration and not the simple presence of wounds (Sadof and Raupp 1997). Thus, discrepancies between rates of wounding and loss of sales are probably due to a time lag from the initiation of wounding until the expression of aesthetically undesirable symptoms such as needle discolor, or limb breakage. Studies of 4 to 7 year *P. sylvestris* in Indiana with at least one wounded whorl in August have shown that less that half of these trees exhibit needle discoloration or limb breakage in November (Yonker and Schuder 1987). Similar discrepancies in the relationship between simple injury and economic loss have also been reported for Monterey pine (*Pinus radiata* D. Don), where choose and cut customers virtually ignored gummy wounds caused by the pine resin midges (*Cecidomyia* spp.) (Paine et al. 1990).

In conclusion, this study suggests that growers have several highly mar-

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ketable varieties of *P. sylvestris* available that are tolerant to *D. zimmermani*. Despite a wide variation in rates of infestation, *D. zimmermani* was not a significant source of mortality seven years after out planting. In contrast, rates of infestation by *D. zimmermani* had a significant negative impact on sales of 7 and 8 year old trees. This was most likely due to consumers responding to pest-induced changes in tree form and needle color, but not the simple presence of gummy wounds along the tree trunk. Christmas tree management strategies that rely on inspecting trees for wounds would benefit from studies that relate timing of trunk wounding to the expression of symptoms during the cycle of tree production and sales.

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