NOTE

Bifenthrin (Capture®) Reduces *Curculio* spp. (Coleoptera: Curculioridae) Damage in Northern Red Oak Acorns[1]

Lisa S. Post, S. E. Schlarbaum, L. R. Barber,[2] Darlene F. Tolman[2] and R. A. Cecich[3]

Department of Forestry, Wildlife & Fisheries, Institute of Agriculture, The University of Tennessee 37901-1071 USA

J. Entomol. Sci. 36(2): 222-225 (April 2001)

Key Words Northern red oak, *Quercus rubra,* acorn, weevil, bifenthrin, seed orchard

Acorn weevils, *Curculio* spp., and other insects have seriously impacted developing acorns in a northern red oak, *Quercus rubra* L., seedling seed orchard (Barber et al., 1995, Proc. 23rd So. For. Tree Improv. Conf., Pp 55-62). Insect predation on acorns causes moderate to severe damage to the cotyledonary tissue (Beck and Olson, 1968, USDA For. Serv. Res. Pap. SE-91, 7 p.), impacting the food supply of the future seedling. *Curculio* spp. cause the greatest loss to acorn yields (Gribko, 1995, USDA For. Serv. Res. Pap. NE-492, 6 p.) and have the potential to reduce the cotyledons entirely to granular frass (Crocker and Morgan, 1983, HortSci. 18: 106-107). Most weevil damage occurs as larvae feed on cotyledons in the last stages of acorn development (Bonner and Vozzo, 1987, USDA For. Serv. Gen. Tech. Rep. SO-66, 21 p.).

An insect diversity study in a northern red oak seedling seed orchard showed differences in weevil numbers between and within different genetic families of northern red oak (Stanton, 1994, M. S. Thesis, Univ. Tenn., Knoxville, 82 p.) suggesting that weevil damage could be confounded with preference for certain tree genotypes. Tree genotype, therefore, may bias insecticide efficacy studies. This study was designed to remove the genetic variability from an insecticide trial by erecting a partition to divide a tree in half. The specific objectives of the study were to determine: (1) presence and types of damage in acorns from sprayed and control halves of two trees; (2) effectiveness of spraying in achieving damage control; and (3) severity of damage to the cotyledons within individual acorns from sprayed and control treatments.

Two trees (A and B) between 10 and 13 m tall with over 1000 post-pollinated flowers were selected for the study. The trees were located on a 7.4-ha seedling seed

[1]Received 20 July 1999; accepted for publication 31 July 2000.
[2]USDA Forest Service, State and Private Forestry, Forest Health, P.O. Box 2680, Asheville, NC 28802 USA.
[3]USDA Forest Service, North Central Forest Experiment Station, 202 ABNR Columbia, MO 65211-7260 USA.

orchard approximately 30 km SW of Mountain City, TN. Polyethylene tarpaulins were stretched vertically on wires through the approximate middle of each tree and attached to 13-m high posts on either side of the tree. The tarpaulins were attached to the trunk of each tree dividing them into two halves for spray (insecticide) and control (unsprayed) treatments. The barrier was erected so that the insecticide, applied only if the wind was less than 16.7 km/h, would not drift to the control side of the tree. Capture® 2EC (bifenthrin, FMC Corp., Agricultural Chemicals Group, Philadelphia, PA) was applied to one-half of each tree at a rate of 7.9 ml per 8.5 l of water using a hand-operated pump-up sprayer. Applications were made from a bucket truck with a 14-m extension boom at approximately 21 d intervals, beginning 24 July 1997 as adult acorn weevils were emerging and ending on 22 Sep 1997 when emergence had ceased.

In mid-September, nets were vertically attached to the bottom of the tarpaulins and anchored to the ground to ensure that the falling acorns were separated by treatment. The acorns were allowed to mature and fall naturally. Upon removal from the nets, the mature acorns were submerged in water (float test), and the floating and sinking acorns were separated (Olson, 1974, USDA For. Serv Agri. Hdbk. 450, 692-703). The viable (sinking) acorns have better germination and nursery growth than acorns that float. The acorns were collected twice a week (15 collection dates total), bagged, labeled, and kept in cold storage at 2°C. For each collection date, 50% of the floating and sinking acorns were cut in half lengthwise and evaluated for type and severity of damage to the cotyledons. Acorns damaged by squirrels were not dissected.

The agent of damage to the cotyledons was identified by various characteristics associated with the damage or larvae as follows: acorn weevil, *Curculio* spp., - weevil larvae and exit holes; filbertworm, *Cydia latiferreana* (Walsingham), - larvae and frass; stony gall wasp, *Callirhytis fructuosa* Weld, - brittle larval tunnels in cotyledons; pip gall wasp, *Callirhytis operator* (Osten Sacken) Beutenmuller, - diamond-shaped scar on the pericarp beneath the acorn cap; an unknown cecidomyid species, Family Cecidomyideae—larvae and brown discoloration of the cotyledons; fungus—white mycelia; and an unidentified disease—yellow-to-brown discoloration of the cotyledons. Air pockets, possibly reflecting damage, were evident inside the acorn as empty spaces between the cotyledons and pericarp. The severity of damage was quantified by estimating the percentage of the cotyledon surface area that was either discolored by disease/fungus or consumed by insects. Acorns without damage were considered to be healthy.

Chi-square analyses were used to evaluate differences in the percentage of floating and sinking acorns between spray and control treatments (SAS Institute, 1996, SAS Inst. Inc., Cary, NC). Analyses were conducted for each tree separately and both trees combined.

Acorn damage was evaluated for the floating and sinking acorns within treatment (spray and control) for individual trees and the trees combined. Damage was scored as either damage present (1) or absent (0) for all analyses. Data were analyzed by use of chi-square tests to detect differences in damage for all pests combined, as well as for the individual damaging agents.

The General Linear Models (GLM) procedure (SAS Institute 1996) was used to conduct an analysis of variance to determine significant differences in the percentage of damaged cotyledons between treatments (spray and control) for each tree and combined trees. Separate analyses were conducted for each damage agent (e.g., acorn weevil) and for all agents combined. Least square means were used to separate the means for each of the seven damage classifications.

The percentage of sinking acorns on Tree A was significantly greater on the spray side (Table 1), but no significant differences were found on Tree B. However, 51% of the acorns on the spray side were classified as sinking acorns, compared to 35% on the control side. Significant differences between the treatments for sinking acorn percentages were found when the trees were combined.

The overall damage to the floating acorns from Trees A and B on the spray treatment was significantly lower than the damage on the control side ($P < 0.0001$). Damage to the sinking acorns from Tree A was significantly greater on the control side ($P < 0.0001$). In contrast, there was no difference in sinking acorn damage on both sides of Tree B ($P = 0.351$). When damage from all agents were combined for both trees, the spray sides had significantly less damage to floating and sinking acorns ($P < 0.0001$).

The amount of damage varied among different damage types. Floating and sinking acorns had significantly less damage by weevils on the spray side on Tree A ($P < 0.0001$). Significant differences in damage were found in floating acorns, but not sinking acorns, on the spray side of Tree B, where only 3% of the floating acorns were damaged, compared with 62% damage on the control side ($P < 0.0001$ and $P = 0.206$, respectively). When data from both trees were combined, there were differences between treatments in weevil damage for both floating and sinking acorns ($P < 0.0001$).

Combined damage, excluding weevil effects, was not different for floating or sinking acorns on either tree or treatment or when the trees were combined. Disease damage was significant to floating acorns only in Tree A spray treatment ($P = 0.049$), while the spray sides of the combined trees were significantly less damaged ($P = 0.037$).

Differences were found between trees for weevil damage ($P < 0.05$), with more damaged occurring on Tree A than Tree B. Treatment effects were significant, with less weevil damage occurring on both spray sides ($P < 0.0001$). The other damage types showed no significant differences between the treatments. Floating acorns had significantly more weevil damage ($P < 0.05$). More floating acorns had weevil damage and stone gall damage than the sinking acorns, and the interaction between treatment and sinkers or floaters was significant for weevil damage ($P < 0.0001$).

Curculio spp. were the most damaging pests of second-year northern red oak acorns, decreasing the proportion of sinking acorns by consuming maturing cotyledonary tissues. Damage from other insects or disease had a negligible effect on

Table 1. Chi-square analysis of spray and control treatments for percentage of sinking acorns of northern red oak by tree and combined trees. Parentheses after percentages indicate the number of acorns evaluated

Tree ID	Test #	Spray (%)	Control (%)	Probability
A	1	56 (359)	23 (222)	>0.001
B	2	51 (301)	35 (189)	0.129
Combined	3	53 (660)	28 (411)	>0.001

acorns in either treatment. However, the insecticide application schedule targeted acorn weevils that emerge in late August, and the effects of other damaging insects could have been underestimated if populations were high and the damaged acorns dropped from the trees prior to acorn collections. Barber et al. (1995) found a progressive drop in acorn numbers from the start of the second year growing season indicating mortality from agents other than *Curculio* spp., so studies extended over the entire growing season are warranted.

Insecticides that control weevils can desiccate cotyledonary tissue (Kearby et al., 1986, Missouri Dept. Conserv. Terrestrial Series 13). Although some acorns had air pockets, there were no significant differences between treatments, indicating that bifenthrin did not cause desiccation.

Acorns protected from insect damage have more cotyledonary tissue for subsequent germination. In northern red oak seedlings, seedling size and vigor are critical to successful regeneration and are proportional to the amount of cotyledonary tissue in an acorn at planting time (Kormanik et al., 1999, Can. J. For. Res. 28: 1-9). Acorn crops protected from insect predation should produce seedlings that develop to their greatest potential under appropriate nursery protocols (Kormanik et al., 1994, Proc. 22^{nd} So. For. Tree Improv. Conf., Pp. 89-98).

Some weevil damage occurred in sprayed acorns, which may be related to the use of a hand sprayer rather than a more effective hydraulic sprayer or too much time between spray intervals. Further tests for effective spray intervals to control weevils need to be conducted. Differences in weevil damage to the acorn crop of each tree agreed with Stanton (1994), indicating preference differences among tree genotypes.

The damage assessment was a quantitative measure, whereas, separating acorns into floating and sinking categories was qualitative. When evaluating the efficacy of different insecticides, small differences in dosage, rate of application, or timing and frequency of application will be detected by a quantitative damage analysis. Meaningful differences from a practical standpoint, however, must increase the number of sinking acorns, which are the only ones that will be planted in a nursery.

We thank C. K. Proffitt, Seed Orchard Manager, Watauga Ranger District, Cherokee National Forest, USDA Forest Service, for assistance with this study.