NOTE

Previous Tip Moth Infestation Predispose Trees to Heavier Attacks in Subsequent Generations[1]

Anthony R. Coody, Christopher J. Fettig, John T. Nowak and C. Wayne Berisford

Department of Entomology, The University of Georgia, Athens, GA 30602 USA

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The Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae), is a common regeneration pest of pine plantations in the southeastern U.S.A. The insect has two to five generations annually depending on climate (Fettig et al. 1999a, USDA For. Serv. Res. Pap., In press). Following oviposition and eclosion, first-instar larvae bore into needles and begin mining between the epidermal layers. Resin from this boring is the first visible sign of tip moth infestation but is often difficult to detect. Second-instar larvae feed at needle and bud axils and produce a web which becomes covered with resin and is the first readily visible sign of attack. Third through fifth instars enter the buds and shoots where their feeding severs the vascular tissue and kills the apical meristem. Pupation occurs in the buds or shoots killed by larval feeding (Berisford 1988, In A. A. Berryman, ed. Dynamics of Forest Insect Populations, Plenum Pub. Corp.).

Tip moth infestations have been shown to reduce tree growth in young loblolly pine (*Pinus taeda* L.) stands (Nowak 1997, M.S. Thesis, Univ. of GA, Athens; Cade and Hedden 1987, South. J. Appl. For 11: 128-133; Stephen et al. 1982, Ark. Farm Res. 31: 10). Chemical control of *R. frustrana* infestations usually consists of three insecticide applications per year in the Piedmont region of Georgia (Gargiullo et al. 1983, Ga. For. Comm. Res. Pap. No. 44). However, it has recently been shown that repeated insecticide applications within a single year may be unnecessary to protect trees from volume losses attributed to tip moth damage (Fettig et al. 1999b, South. J. Appl. For. In press). Fettig et al. (1999b) found a 74.5% increase in volume yield when insecticide applications were limited to the first generation of the first two years following planting. They also observed that previous tip moth attacks appeared to predispose trees to heavier attacks in subsequent generations, and listed this observation as a potential cause or contributor to their findings.

To test this possibility we selected two sites in Oglethorpe Co., GA where three tip moth generations occur annually (Fettig et al. 1999a). As part of a larger study, 80

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three-year-old loblolly pines were sprayed with permethrin (Pounce 3.2® EC) during the first *R. frustrana* generation in 1999 using hand-pump backpack sprayers (Model 425; Solo®, Newport News, VA) at a rate of 0.6 ml of formulated product per liter of water. Applications were made to individual trees on the approximate optimal spray date (Fettig and Berisford 1999, South. J. Appl. For. 23: 30-38) with solid cone nozzles until all foliage was moistened. Trees were not treated with insecticides prior or subsequent to that time. Each insecticide-treated tree was paired with an untreated check in the adjacent row.

The amount of tip moth damage was quantified by three methods: (1) percentage of shoots damaged, (2) amount of volume killed, and (3) percentage of tree volume killed by *R. frustrana* (tree volume reduction). Shoot damage was determined by recording the total number of shoots (>10 linear cm of apical stem containing foliage) and the number of tip moth-damaged shoots for each tree and computing the percentage of damaged shoots. The amount of volume killed was determined by measuring the total length (L) and proximal diameter (D) of each *R. frustrana* damaged shoot and using D^2L (shoot diameter squared times total shoot length) as the volume formula. Tree volume reduction was determined by dividing the total volume killed by the aboveground tree volume. The aboveground tree volume was estimated using the formula of basal diameter squared times height (D^2H) which is a common estimate of aboveground volume (Ross et al. 1990, For. Sci. 36: 1106-1118). All measurements were made during the pupal stage of the second generation (3-14 August 1999). The data were analyzed for each of the three damage estimates using paired t-tests (Sigma Stat 2.0, Jandel Scientific, San Rafael, CA; Sokal and Rohlf 1995, Biometry, 3rd edition).

For all three damage estimates, previously insecticide-treated trees had significantly less damage than untreated trees ($P < 0.001$ in all cases). These data support the initial observations of Fettig et al. (1999b) that previous tip moth attacks predispose trees to heavier attack during the following generation. However, the causes or mechanisms of this phenomenon are currently unknown. Insecticide spray timing provides evidence that the environmental persistence of permethrin and similar synthetic pyrethroid insecticides is limited to a few weeks and is, therefore, not a likely cause (Garguillo et al. 1985, J. Econ. Entomol. 78: 148-154; Nowak, unpubl. data). Bud proliferation from previous attacks, changes in host physiology or females mating and depositing eggs on the same trees they emerged from may be likely causes of this phenomenon. Tip moth infestations cause increased bud and shoot formations which provide additional forage and ovipositional sites. *Rhyacionia frustrana* population levels have been positively correlated with the number of available shoots (Lashomb et al. 1980, Environ. Entomol. 9: 397-402). Previous attacks may cause host stress or other physiological changes that reduce host resistance or tolerance. Resistance is most likely due to high resin flows which cause significant mortality to first-instar larvae (Garguillo and Berisford 1983, Environ. Entomol. 12: 1391-1402). Trees which are stressed by previous *R. frustrana* attacks may not have the necessary reserves to produce sufficient resin flow for resinosis to occur. There are several examples of forest Lepidoptera that deposit all or a large portion of their eggs near their initial emergence site. For example, the spruce budworm, *Choristoneura fumiferana* (Clem.) Freeman (Lepidoptera: Tortricidae), must lay a significant number of eggs before the female can obtain flight (Morris 1963, Mem. Entomol. Soc. Can. 31: 1-332). It is unknown how well gravid tip moth females can fly, but are presumably rather effective fliers considering the rapid colonization rate of newly-planted stands by *R. frustrana.* Further studies are needed to determine the cause of this phenomenon.

These results also have important management implications by providing further evidence that control of the first *R. frustrana* generation provides benefits beyond that generation (Fettig et al. 1999b). Typically, most tip moth control programs repeatedly apply insecticides for each tip moth generation which varies in number depending on geographic location (usually three or four). Our data indicate that by controlling the first *R. frustrana* generation, the second generation is also partially protected, thereby providing an extended benefit. If, by controlling the first generation, we can avoid spraying the second and/or subsequent generations, chemical control of tip moth infestations in forest stands becomes more cost effective.

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