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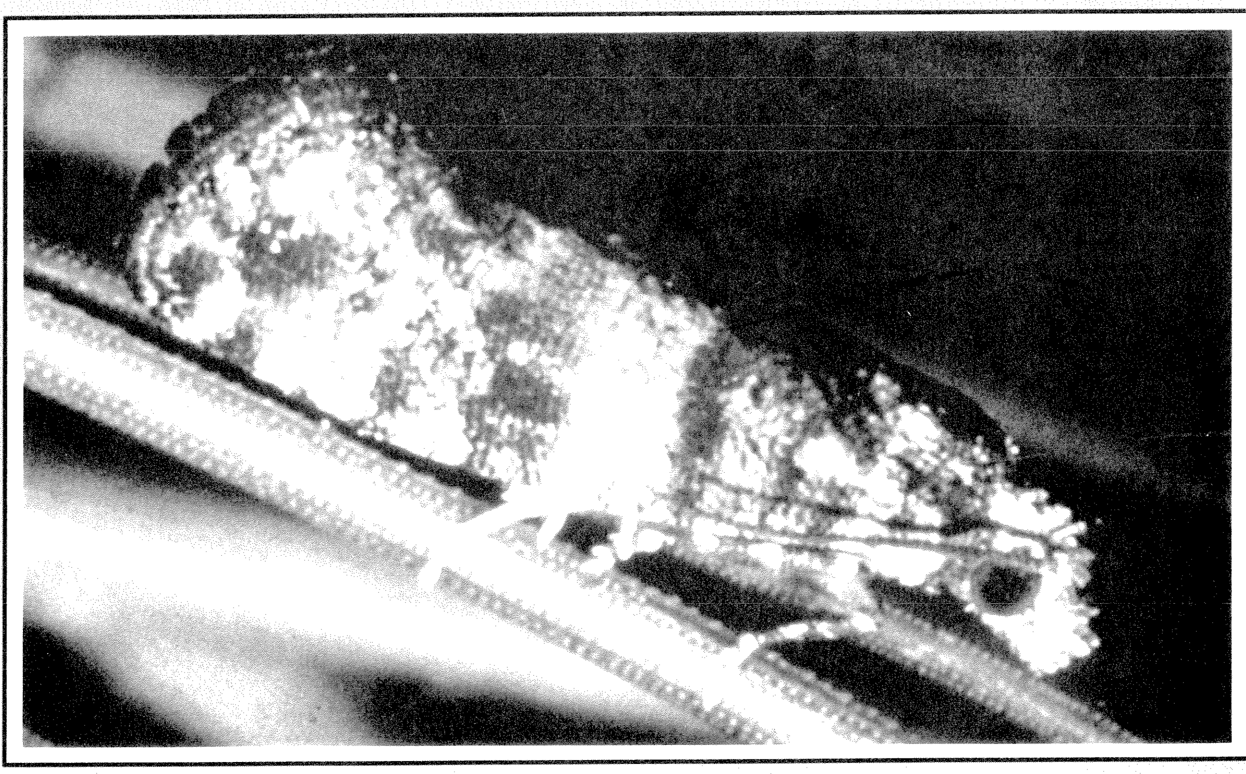
Nantucket Pine Tip Moth Phenology and Timing of Insecticide Spray Applications in Seven Southeastern States

Christopher J. Fettig, Mark J. Dalusky, and C. Wayne Berisford



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Abstract

The Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae), is a common pest of Christmas tree and pine plantations throughout much of the Eastern United States. The moth completes two to five generations annually, and insecticide spray timing models are currently available for controlling populations where three or four generations occur. The thermal requirements for the Nantucket pine tip moth to complete a generation were obtained from published data and used along with historical temperature data to produce maps indicating the number of annual generations predicted to occur throughout seven Southeastern States. Spray timing prediction values were also obtained from published data and used to predict optimal spray periods based on 5-day increments for each location where either three or four generations occurred. Approximately 80 percent of the predicted optimal spray periods were within one optimal spray period of previously field-determined spray dates. Land managers who use contact insecticides, such as synthetic pyrethroids, may find the predicted optimal spray periods useful in optimizing spray effectiveness.

Keywords: Chemical control, Nantucket pine tip moth, phenology, *Rhyacionia frustrana*, spray timing.

Introduction

The Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae), is a common pest of Christmas tree and pine plantations in the Eastern United States (Berisford 1988). Females deposit eggs singly on needles and shoots with a significantly greater proportion being laid on needles (McCravy and Berisford 1998). The first visible signs of attack are small droplets of resin exuding from needle bases where the first instar larvae have bored entrance holes (Berisford 1988). Second instars construct silken webs, which increase in size as the larvae develop. Later larval instars enter the lateral and terminal shoots where their feeding severs the vascular tissue and kills the apical meristem. Fifth instars pupate within the damaged shoots. Larval feeding can cause shoot mortality and tree deformity (Berisford and Kulman 1967), height and volume reductions (Cade and Hedden 1987, Stephen and others 1982), compression wood increases (Hedden and Clason 1980), and occasional tree mortality (Yates and others 1981). Damage is most severe on seedlings and saplings <5 years old (Berisford 1988). In the Southeastern United States, preferred hosts include loblolly (*Pinus taeda* L.), shortleaf (*P. echinata* Mill.), and Virginia (*P. virginiana* Mill.) pines. Slash (*P. elliottii* Engelm.) and longleaf (*P. palustris* Mill.) pines are considered resistant to attack (Berisford 1988, Yates 1960).

Within the natural range of the Nantucket pine tip moth, the life cycle is synchronized to produce a new generation of egg laying adults during each growth flush of the primary host. Two to five generations occur annually depending on the prevailing climate (Berisford 1988). Where the moth has been studied extensively, boundaries delineating moth phenology, i.e., number of generations annually, have been well established, while in other areas this information is limited. Two generations have been reported for parts of the Mountain Province of Virginia (Berisford and Kulman 1967). Three generations occur in much of the Piedmont Plateau and Coastal Plain of Virginia (Berisford and Kulman 1967, Fettig and Berisford 1999), the Mountain Province and Piedmont Plateau of Georgia (Berisford 1974, Berisford and others 1992, Gargiullo and others 1983), and parts of North Carolina (Fettig and Berisford 1999). Four generations have been reported for the Coastal Plain of Georgia and South Carolina (Berisford and others 1992, Gargiullo and others 1985, Moreira and others 1994). Apparently, five generations occur in extreme southeastern Georgia (Ross and others 1989), the Gulf Coast, and northern Florida (Yates and others 1981). A more detailed description of Nantucket pine tip moth phenology within the range of commercially important *Pinus* species would be useful for both management and research purposes.

The number of thermal units required to complete a generation varies somewhat among studies and locations and ranges from 580 to 818 degree-days °C (33.7 to 47.6 days assuming a daily mean temperature of 26.7 °C) (Fettig and Berisford 1999, Gargiullo and Berisford 1983, Gargiullo and others 1985, Haugen and Stephen 1984, Ross and others 1989). Assuming that development is largely controlled by climate, possible sources of variation include sampling intensity, temperature data acquisition, computational methods, and genetic and diet effects (Mawby and Rock 1986, Ross and others 1989). However, Ross and others

(1989) determined that division of the annual number of cumulative degree-days by 754 degree-days °C, using lower and upper developmental thresholds of 9.5 and 33.5 °C, resulted in phenology predictions that correlated well with known Nantucket pine tip moth phenologies throughout Georgia.

Insecticide applications are a viable control method if attacks cause substantial pine growth or form losses (fig. 1). Spray timing models have been developed to predict optimal spray dates where either three (Dalusky, unpublished data)[1] (Fettig and Berisford 1999, Gargiullo and others 1983) or four generations occur annually (Fettig and others 1998, Gargiullo and others 1985). Degree-days are accumulated commencing on the date of an average of one moth caught per trap per day in pheromone-baited traps (fig. 2) and continuing until an experimentally determined sum, based primarily on moth phenology and insecticide properties, is attained for each generation (Gargiullo and others 1983, 1985). This sum

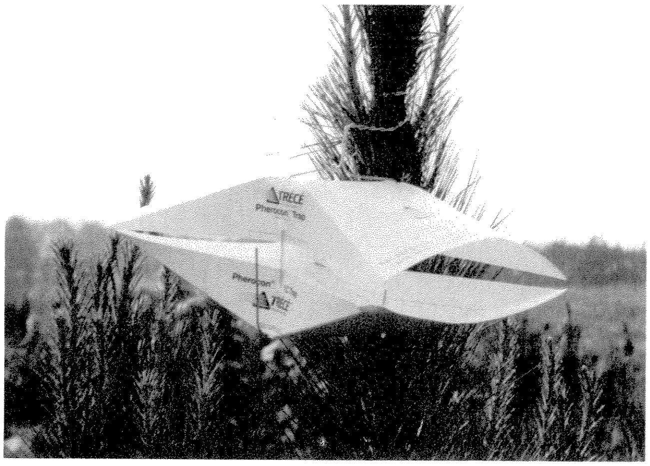

Figure 2—A pheromone-baited wing trap used to determine male moth emergence.

indicates the optimal spray date for each generation and correlates with an abundance of susceptible life stages in the field (Berisford and others 1984). Spray timing models have helped increase insecticide efficacy, reduce application frequency, and decrease the growth and form losses associated with late instar larval feeding.

Figure 1—An applicator using a hand-pump backpack sprayer to control Nantucket pine tip moth infestations in a 3-year-old loblolly pine plantation.

The objectives of this study were to (1) identify the number of Nantucket pine tip moth generations occurring annually based on data from weather stations located in a seven–State region of the Southeastern United States and (2) estimate optimal spray periods for each generation in locations where three or four generations occur annually.

Materials and Methods

Mean maximum and minimum temperatures for each day of the year were obtained online (http://www.water.dnr.sc.us; Southeast Regional Climate Center, South Carolina Department of Natural Resources, Columbia, SC) for selected weather stations in Virginia ($n = 49$), North Carolina ($n = 58$), South Carolina ($n = 45$), Georgia ($n = 70$), Alabama ($n = 54$), Mississippi ($n = 52$), and northern Florida ($n = 26$). The distribution of weather stations was chosen to provide a complete description of the climates that occur in each State. In most cases, mean temperature data are based on >40 years of climatic data. Weather stations with <15 years of data were excluded from analyses.

Daily mean maximum and minimum temperatures for each weather station were placed in a spreadsheet program (Microsoft Excel®, Microsoft Corp., Seattle, WA) and then

[1] Dalusky, M.J. October 17, 1986. Unpublished data on spray timing for esfenvalerate in the Georgia Piedmont. 4 p. Unpublished report. On file with: Department of Entomology, The University of Georgia, Athens 30602.

transferred to a degree-day computational program (Degree-Day Utility, University of California Statewide Integrated Pest Management Program, Davis, CA). Degree-days were accumulated using the single-sine, intermediate cutoff computation method (Seaver and others 1990) with lower and upper developmental thresholds of 9.5 and 33.5 °C, respectively (Haugen and Stephen 1984). The annual number of degree-days accumulated at each station was divided by 754 degree-days °C and rounded to the next lowest whole number to provide an estimate of the number of Nantucket pine tip moth generations occurring annually at that location (Ross and others 1989). The weather station locations and the numbers of corresponding generations were then mapped for each State.

The length of winter diapause and the precise conditions required to break it are unknown for the Nantucket pine tip moth, and temperatures above the lower developmental threshold may occur throughout the year. Therefore, spray timing prediction values were accumulated from an arbitrarily established biofix of January 7 where four generations occur annually and March 1 where three generations occur annually. These dates are based on the average male moth emergence periods for the first generation that were determined during previous studies. Although actual emergence dates vary from year to year (typically ± 7 days), the effect on spray date determinations should be minimal. Maximum temperatures are typically at or near the lower developmental threshold and few degree-day accumulations occur initially.

Three different sets of spray timing values were used to determine optimal spray dates depending on geographic location. In portions of Virginia and North Carolina where three generations occur annually, the values were 188, 784, and 1,472 degree-days °C (Fettig and Berisford 1999). In remaining portions of the Southeast where three generations occur annually, the values were 204, 968, and 1,787 degree-days °C (see footnote 1). In locations where four generations occur annually, the values were 237, 899, 1,757, and 2,513 degree-days °C (Fettig and others 1998). Spray timing values are not available for controlling populations with two or five annual generations and, therefore, are not provided for such locations (tables 1–7). Degree-days were accumulated continuously for each weather station from the assigned biofix until the appropriate spray prediction value was reached for each generation. The corresponding date was designated the optimal spray date. Each optimal spray date was then located in an optimal spray period established by dividing the calendar year into 5-day increments.

To test the validity of spray period predictions, the predictions were compared to 44 spray dates determined at 16 different field sites during 1996–98. The field-determined spray dates were determined on site by monitoring moth flight with pheromone-baited sticky traps (Pherecon 1 C®; Trece Inc., Salinas, CA) and accumulating degree-day totals from the initiation of moth flight for each generation with a continuously recording biophenometer (Model TA51; Dataloggers Inc., Logan, UT). During this period, mean temperatures were generally normal (1996), below normal (1997), and above normal (1998) (Athens, GA, June departure from normal: -0.06 °C, -2.33 °C, and 2.06 °C, respectively) throughout most of the Southeastern United States.

Results and Discussion

Our phenology predictions indicated that the Nantucket pine tip moth would complete one to five generations annually in this region. The number of generations generally increased from northern to southern latitudes and from higher to lower elevations but was apparently subject to variations in local topography that affect climate. The Nantucket pine tip moth is typically reported to have two to five generations annually throughout its native range (Berisford 1988). However, at Big Meadows, Virginia (elevation: ≈1100 meters), only one generation was predicted (station 7, fig. 3). It is unlikely that one generation would occur in Virginia because two generations are reported to occur in the Northeastern United States (Yates 1960, Yates and others 1981). It is more likely that the thermal requirements to complete a generation that were established in more southerly latitudes at lower elevations are no longer accurate in this environment. Phenology studies conducted in northern portions of the Southeastern United States have generally reported reduced thermal requirements to complete a generation (Fettig and Berisford 1999, Haugen and Stephen 1984). Therefore, we conclude that two to five generations occur annually in the Southeastern United States.

Virginia

Two to three generations were predicted to occur throughout Virginia (fig. 3). The prediction of two generations for the Mountain Province agrees with other studies conducted in southwest portions of the Mountain Province (Berisford and Kulman 1967, Lewis and others 1970), northern Virginia (Craighead 1950), and adjacent Maryland (Lashomb and others 1978). Three generations were predicted for much of the Piedmont Plateau and throughout the Coastal Plain (fig. 3). Studies limited to the southern portions of these regions also found that three

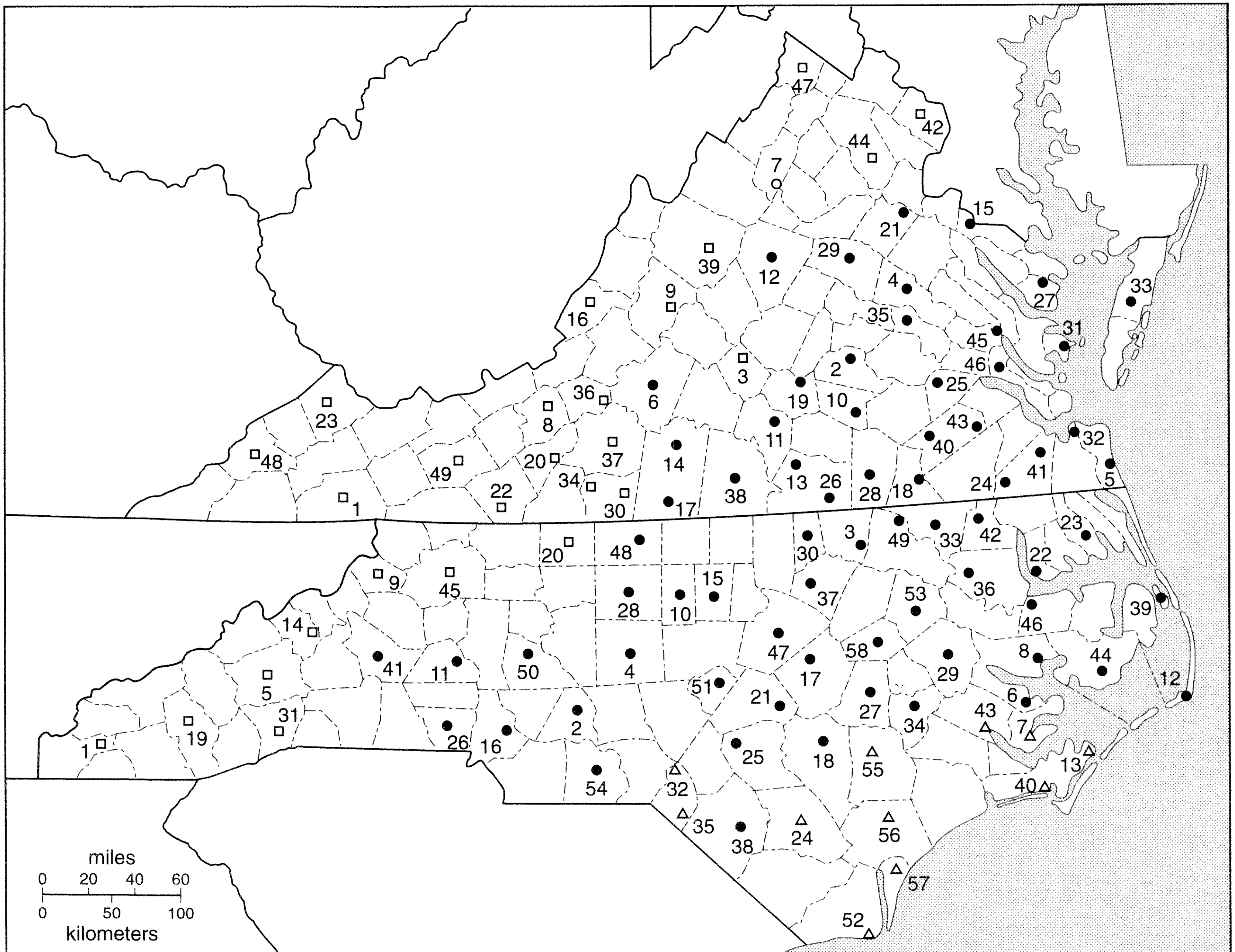

Figure 3—Weather station locations and corresponding number of predicted Nantucket pine tip moth generations per year in Virginia and North Carolina. Open circle (○) denotes one generation, open squares (□) denote two generations, closed circles (●) denote three generations, and open triangles (△) denote four generations per year. (Numbers correspond to weather station locations in tables 1 and 2.)

generations occurred annually (Berisford and Kulman 1967, Fettig and Berisford 1999). Appomattox, VA, (station 3, fig. 3) is presumed to be an outlier because only two generations were predicted to occur there. This station is located in the Piedmont Plateau and is not associated with any particular topographic feature that would explain its cooler temperatures relative to adjacent stations. It is unknown whether this location represents a real cold pocket or whether errors have occurred at the recording station. In locations with three generations, the predicted first generation spray periods generally occurred in late April, the second in mid- to late June, and the third in early August (table 1).

North Carolina

Two to four generations were predicted to occur in North Carolina (fig. 3). Two generations were predicted for the Mountain Province, and three generations throughout the Piedmont Plateau and northern two-thirds of the Coastal Plain. Fettig and Berisford (1999) identified three generations in extreme northeastern portions of the Piedmont Plateau and Coastal Plain. Four generations were predicted for a small area located in the southeastern corner of the Coastal Plain (fig. 3). The distribution of a fourth generation phenology appears to reach its northern limit in this region (Gargiullo and others 1984). Although Lumberton, NC, (station 38, fig. 3) appears to be an outlier, its temperatures agree with those of adjacent station 19 located in South Carolina (fig. 4). The location presumably indicates an actual cold pocket. Where three generations occur annually, the predicted first generation spray period generally occurred in mid-April, the second in mid-June, and the third in late July (table 2). In the few locations where a fourth generation was predicted, the first generation spray period was predicted in early to mid-April, the second in early June, the third in late July to early August, and the fourth in mid-September (table 2).

South Carolina

Two to four generations were predicted to occur in South Carolina (fig. 4). Two generations were predicted for a single location (station 8) in the extreme northwest portion of the Mountain Province (fig. 4). Three generations were predicted for much of the Piedmont Plateau, while a fourth generation occurred in most of the Coastal Plain. Four generations have previously been reported for portions of the Coastal Plain (Moreira and others 1994). Calhoun Falls and Clarks Hill, SC, (stations 9 and 14, respectively, fig. 4) appear to be outliers relative to adjacent stations where three generations were predicted. However, their warmer climates could be attributed to the western proximity of Russell and J. Strom Thurmond Lakes, which may moderate temperature extremes early and late in the growing season. In locations with three generations annually, the predicted first generation spray period generally occurred in mid-April, the second in mid- to late June, and the third in early August (table 3). Where a fourth generation occurs, the predicted first generation spray period typically occurred in late March to early April, the second in late May to early June, the third in mid- to late July, and the fourth in late August to mid-September (table 3).

Georgia

Two to five generations were predicted to occur in Georgia (fig. 4). Two generations were predicted for a single location (station 11) at one of the highest elevations in the Mountain Province (fig. 4). Berisford and others (1992) found three generations occurred throughout the Mountain Province. This study did not include the higher elevations because they lacked significant Nantucket pine tip moth infestations. Ross and others (1989) predicted that two generations would occur throughout a more extensive area of northeast Georgia. Three generations were predicted for much of the Piedmont Plateau and Mountain Province, which agrees with numerous studies on Nantucket pine tip moth phenologies in these regions (Berisford 1974; Berisford and others 1984, 1992; Canalos and Berisford 1981; Gargiullo and Berisford 1983; Gargiullo and others 1983; Kudon and others 1988). Four generations were predicted for most of the Coastal Plain except the extreme southern portions of the State where a fifth generation was predicted (fig. 4). These results are also supported by several previous studies (Berisford and others 1992, Gargiullo and others 1985, Moreira and others 1994, Ross and others 1989). Where three generations occur annually, the predicted first generation spray period generally occurred in mid-April, the second in mid- to late June, and the third in early August (table 4). In locations where a fourth generation occurs, the predicted first generation spray period typically occurred in mid- to late March, the second in late May, the third in mid-July, and the fourth in mid-August to early September (table 5).

Northern Florida

Investigations were limited to regions north of Ocala, FL, (figs. 4 and 5). To the south of this region susceptible southern pine species (loblolly and shortleaf pines) become increasingly rare and an associated species of tip moth, the subtropical pine tip moth (*Rhyacionia subtropica* Miller), becomes increasingly dominant. The limit of the natural range of the Nantucket pine tip moth occurs in central Florida (Berisford 1988, Yates and others 1981).

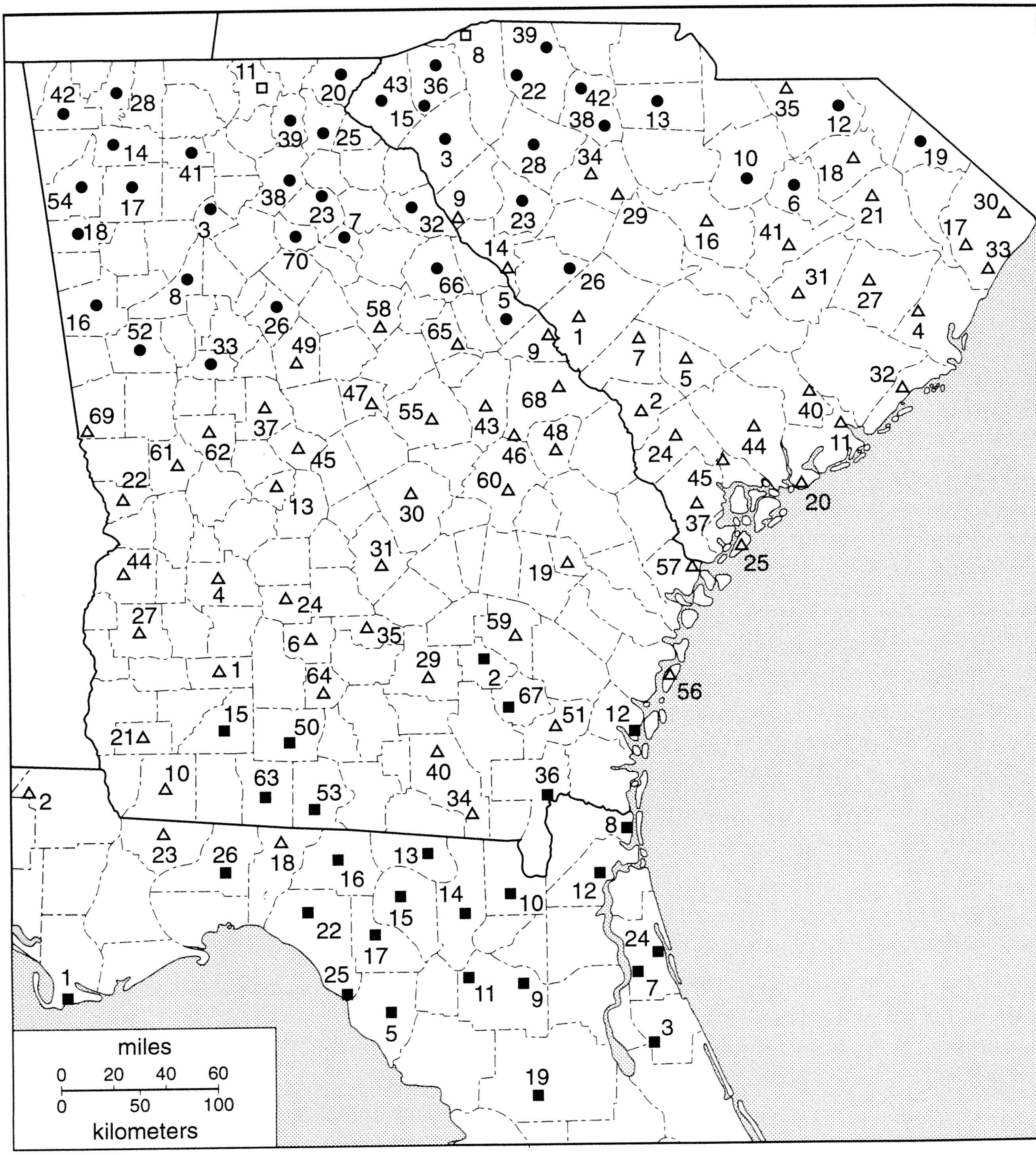

Figure 4—Weather station locations and corresponding number of predicted Nantucket pine tip moth generations per year in South Carolina, Georgia, and northern Florida. Open squares (□) denote two generations, closed circles (●) denote three generations, open triangles (△) denote four generations, and closed squares (■) denote five generations per year. (Numbers correspond to weather station locations in tables 3, 4, and 5.)

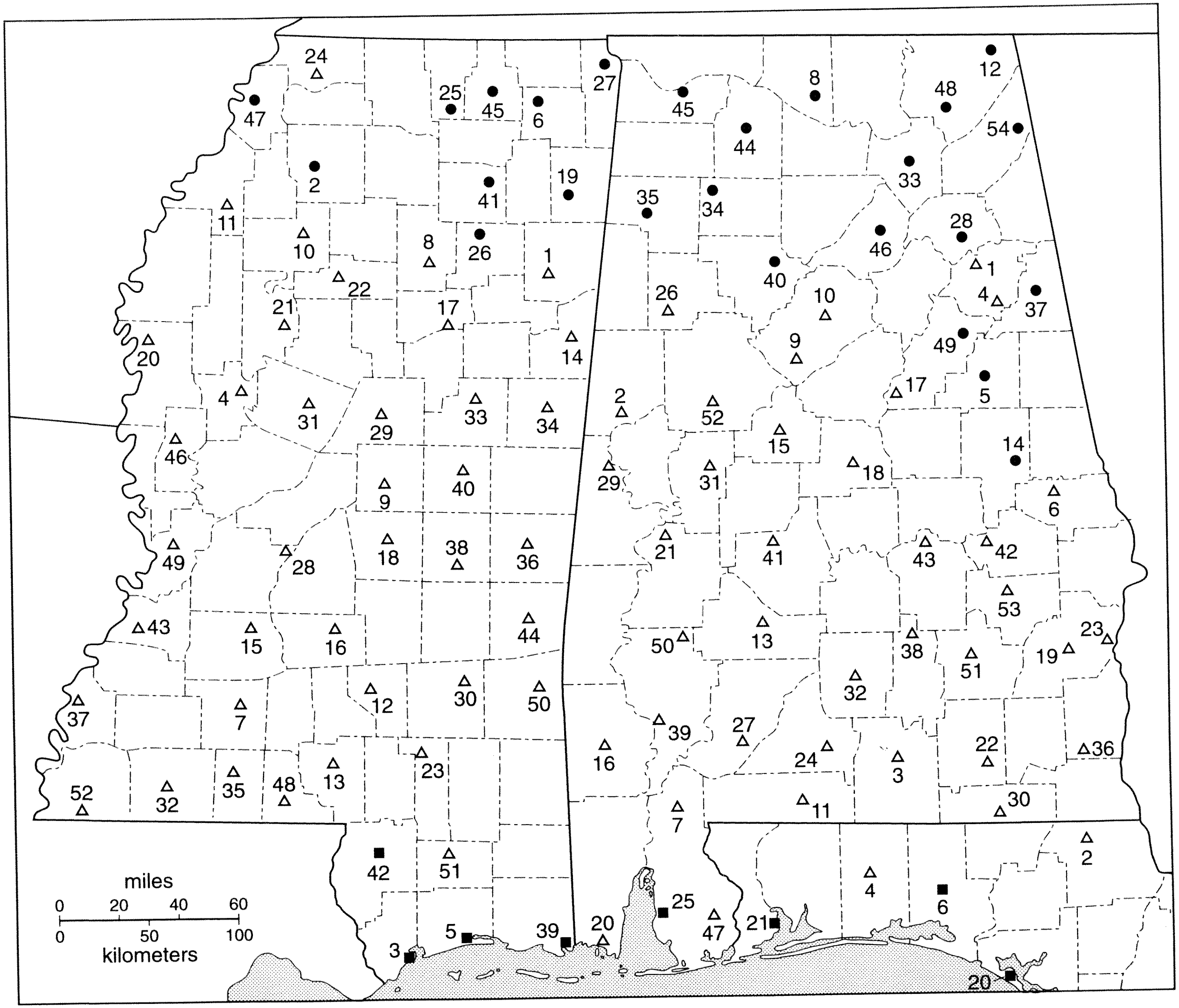

Figure 5—Weather station locations and corresponding number of predicted Nantucket pine tip moth generations per year in northwestern Florida, Alabama, and Mississippi. Closed circles (●) denote three generations, open triangles (△) denote four generations, and closed squares (■) denote five generations per year. (Numbers correspond to weather station locations in tables 5, 6, and 7.)

Four to five generations were predicted to occur in northern Florida (figs. 4 and 5). Four generations were predicted for several locations in the western panhandle, while remaining areas appear to have five generations (figs. 4 and 5). Recent pheromone trapping programs have not revealed definitive differences in emergence patterns among the third, fourth, and possible fifth generations, making it difficult to conclude how many generations actually exist.[2] Yates and others (1981) suggested that five generations occur throughout most of northern Florida. Where four generations were predicted, the first generation spray period was predicted in mid-March, the second in mid-May, the third in mid-July, and the fourth in mid-August (table 5).

Alabama and Mississippi

Three to five generations were predicted to occur in both Alabama and Mississippi. Three generations were predicted for northern portions of each State, and a fourth generation throughout much of the remaining Coastal Plain (fig. 5). Alexandria and Anniston, AL, (stations 1 and 4, respectively, fig. 5) appear to be outliers relative to surrounding stations with three generations. These stations are not associated with any particular topographic features that would explain their warmer temperatures relative to adjacent stations. They may represent actual warm pockets or errors in data acquisition at the recording stations. Based on the close proximity of these sites (15 kilometers), the phenology predictions are probably accurate. Hernando, MS, (station 24, fig. 5) is also an outlier when compared to surrounding stations where three generations were predicted, but no particular topographic features explain its warm temperatures. A fifth generation was predicted for extreme southern portions of each State (fig. 5). Yates and others (1981) suggested that a fifth generation occurs in southern portions of the Gulf States.

In locations of Alabama and Mississippi where three generations occur annually, the predicted first generation spray period generally occurred in mid-April, the second in mid- to late June, and the third in early to mid-August (tables 6 and 7). In locations with a predicted fourth generation, the first generation spray period typically occurred in late March to early April, the second in late May to early June, the third in mid- to late July, and the fourth from late August to early September (tables 6 and 7).

[2] Personal communication. 1998. J. Foltz, Professor, Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611-0620.

Validity of Predictions

Fourteen (31.8 percent) of the predicted spray periods agreed with field-determined spray dates, 21 (47.7 percent) differed by 1 spray period, 6 (13.6 percent) differed by 2 spray periods, and 3 (6.8 percent) differed by 3 spray periods (table 8). Six (66.7 percent) of the spray predictions that differed by two or three periods occurred during the first Nantucket pine tip moth generation and may reflect discrepancies between the arbitrary biofix date and the actual initiation of moth flight at these locations. Spray timing values are typically determined experimentally by applying insecticide sprays at specified degree-day intervals, assessing damage levels for each spray, and using second degree polynomial regressions (parabolas) to determine optimal spray timing values. Although an optimal value exists, approximately 105 degree-days occur around the optimal value in which little or no variation in damage levels is observed (Gargiullo and others 1985). Assuming a typical mean daily temperature of 15.5 °C for the first generation, 17.5 days would pass during the 105 degree-day interval. Therefore, a large spray efficacy window exists during the first generation, and spray timing is often less critical.

Management Implications

Although largely effective, improper use of Nantucket pine tip moth spray timing models have occasionally led to errors in spray date predictions. These models require a detailed knowledge of moth biology; proper pheromone trap deployment (placement, spacing, and timing); intensive trap monitoring; knowledge of degree-day calculations, conversions, and utility; and the ability to acquire daily maximum and minimum temperatures on or near the site (Gargiullo and others 1985). Although the collection of data required to use timing models is costly and laborious to obtain, these costs can be mitigated by increased insecticide efficacy and reduced application frequency. However, scheduling problems may still arise from short-term advance notice of approaching optimal spray dates or inclement weather patterns that limit insecticide spray opportunities.

When considering the difficulties associated with using spray timing models, the spray period predictions presented here are a viable alternative to determining optimal spray dates in the field. Land mangers who apply contact insecticides, such as synthetic pyrethroids, and are unable to run the appropriate moth trapping and degree-day accumulation model can locate the closest weather station to their pine plantation (figs. 3-5) and use the optimal spray periods to time their insecticide applications accordingly (tables 1-7). During extended periods of inclement weather, land managers may choose to adjust the spray period predictions by one period, depending on the prevailing temperature deviations from normal.

Acknowledgments

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Literature Cited

Berisford, C.W. 1974. Comparisons of adult emergence periods and generations of the pine tip moths, *Rhyacionia frustrana* and *R. rigidana*. Annals of the Entomological Society of America. 67: 666–668.

Berisford, C.W. 1988. The Nantucket pine tip moth. In Berryman, A.A., ed. Dynamics of forest insect populations: patterns, causes, and implications. New York: Plenum Publication Corporation: 141–161.

Berisford, C.W.; Canalos, C.G.; Godbee, J.F., Jr.; Yates, H.O., III. 1992. Occurrence and seasonal activity of pine tip moth in Georgia. Georgia For. Comm. For. Res. Pap. 87. Macon, GA: Georgia Forestry Commission. 11 p.

Berisford, C.W.; Gargiullo, P.M.; Canalos, C.G. 1984. Optimum timing for insecticidal control of the Nantucket pine tip moth (Lepidoptera: Tortricidae). Journal of Economic Entomology. 77: 174–177.

Berisford, C.W.; Kulman, H.M. 1967. Infestation rate and damage by the Nantucket pine tip moth in six loblolly pine categories. Forest Science. 13: 428–438.

Cade, S.C.; Hedden, R.L. 1987. Growth impact of pine tip moth on loblolly pine plantations in the Ouachita Mountains of Arkansas. Southern Journal of Applied Forestry. 11: 128–133.

Canalos, C.G.; Berisford, C.W. 1981. Seasonal activity of two sympatric *Rhyacionia* species determined by pheromone traps. Journal of the Georgia Entomological Society. 16: 219–222.

Craighead, F.C. 1950. Insect enemies of eastern forests. Misc. Publ. 657. Washington, DC: U.S. Department of Agriculture. 679 p.

Fettig, C.J.; Berisford, C.W. 1999. Nantucket pine tip moth phenology in eastern North Carolina and Virginia: implications for effective timing of insecticide applications. Southern Journal of Applied Forestry. 23: 30–38.

Fettig, C.J.; Berisford, C.W.; Dalusky, M.J. 1998. Revision of a timing model for chemical control of the Nantucket pine tip moth (Lepidopetra: Tortricidae) in the southeastern Coastal Plain. Journal of Entomological Science. 33: 336–342.

Gargiullo, P.M.; Berisford, C.W. 1983. Life tables for the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), and the pitch pine tip moth, *Rhyacionia rigidana* (Fernald) (Lepidoptera: Tortricidae). Environmental Entomology. 12: 1391–1402.

Gargiullo, P.M.; Berisford, C.W.; Canalos, C.G. [and others]. 1984. Mathematical descriptions of *Rhyacionia frustrana* (Lepidoptera: Tortricidae) cumulative catches in pheromone traps, cumulative egg hatching, and their use in timing of chemical control. Environmental Entomology. 13: 1681–1685.

Gargiullo, P.M.; Berisford, C.W.; Canalos, C.G.; Richmond, J.A. 1983. How to time dimethoate sprays against the Nantucket pine tip moth. Georgia For. Comm. For. Res. Pap. 44. Macon, GA: Georgia Forestry Commission. 11 p.

Gargiullo, P.M.; Berisford, C.W.; Godbee, J.F., Jr. 1985. Prediction of optimal timing for chemical control of the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae), in the southeastern Coastal Plain. Journal of Economic Entomology. 78: 148–154.

Haugen, D.A.; Stephen, F.M. 1984. Development rates of Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae) life stages in relation to temperature. Environmental Entomology. 13: 56–60.

Hedden, R.L.; Clason, T. 1980. Nantucket pine tip moth impact on loblolly pine wood and product quality. For. Res. Rep. 1979. Homer, LA: Louisiana State University Agricultural Experiment Station. 90 p.

Kudon, L.H.; Berisford, C.W.; Dalusky, M.J. 1988. Refinement of a spray timing technique for the Nantucket pine tip moth (Lepidoptera: Tortricidae). Journal of Entomological Science. 23: 180–186.

Lashomb, J.H.; Steinhauer, A.L.; Douglass, L. 1978. Impact studies of Nantucket pine tip moth populations on loblolly pine. Environmental Entomology. 7: 910–912.

Lewis, K.R.; Kulman, H.M.; Heikkenen, H.J. 1970. Parasites of the Nantucket pine tip moth in Virginia with notes on ecological relationships. Journal of Economic Entomology. 63: 1135–1139.

Mawby, W.D.; Rock, G.C. 1986. Effects of food, strain, and sex on estimating thermal requirements for nondiapause larval and pupal development of tufted apple bud moth (Lepidoptera: Tortricidae). Environmental Entomology. 15: 210–215.

McCravy, K.W.; Berisford, C.W. 1998. Parasitism by *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) in relation to Nantucket pine tip moth (Lepidoptera: Tortricidae) egg density and location. Environmental Entomology. 27: 355–359.

Moreira, A.F.C.; Berisford, C.W.; Hedden, R.L.; Silva, J.A.A.D. 1994. Methodology for rating *Pinus taeda* stands for pine tip moth, *Rhyacionia* spp. infestation (Lepidoptera: Tortricidae). Anais da Sociedade Entomologica do Brasil. 23: 227–236.

Ross, D.W.; Pickering, J.; Berg, J.D.; Berisford, C.W. 1989. Mapping Nantucket pine tip moth (Lepidoptera: Tortricidae) phenology in Georgia. Journal of Entomological Science. 24: 405–412.

Seaver, D.; Strand, J.; Strawn, A.J. 1990. Degree day utility-user's guide. Version 2. Davis, CA: University of California. 86 p.

Stephen, F.M.; Wallis, G.W.; Colvin, R.J. [and others]. 1982. Pine tree growth and yield: influences of species, plant spacings, vegetation, and pine tip moth control. Arkansas Farm Research. 31: 10.

Yates, H.O., III. 1960. The Nantucket pine tip moth: a literature review. Stn. Pap. 115. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 19 p.

Yates, H.O., III; Overgaard, N.A.; Koeber, T.W. 1981. Nantucket pine tip moth. For. Insect and Dis. Leafl. 70. Washington, DC: U.S. Department of Agriculture, Forest Service. 7 p.

Table 1—Site number, location, and optimal spray period predictions for 49 weather stations located throughout Virginia

Site no.	Location	Spray period[a] 1	2	3
1	Abingdon	—	—	—
2	Amelia	April 26–30	June 25–29	Aug. 9–13
3	Appomattox	—	—	—
4	Ashland	April 26–30	June 20–24	Aug. 9–13
5	Back Bay	April 26–30	June 20–24	July 30–Aug. 3
6	Bedford	April 26–30	June 25–29	Aug. 9–13
7	Big Meadows	—	—	—
8	Blacksburg	—	—	—
9	Buena Vista	—	—	—
10	Camp Pickett	April 26–30	June 25–29	Aug. 9–13
11	Charlotte Court House	April 26–30	June 25–29	Aug. 9–13
12	Charlottesville	April 26–30	June 20–24	Aug. 9–13
13	Chase City	April 21–25	June 15–19	July 30–Aug. 3
14	Chatham	April 26–30	June 25–29	Aug. 9–13
15	Colonial Beach	April 26–30	June 20–24	July 30–Aug. 3
16	Covington	—	—	—
17	Danville	April 21–25	June 15–19	July 30–Aug. 3
18	Emporia	April 26–30	June 20–24	July 30–Aug. 3
19	Farmville	April 21–25	June 20–24	Aug. 4–8
20	Floyd	—	—	—
21	Fredricksburg	May 1–5	June 25–29	Aug. 4–8
22	Galax	—	—	—
23	Grundy	—	—	—
24	Holland	April 21–25	June 20–24	July 30–Aug. 3
25	Hopewell	April 16–20	June 10–14	July 25–29
26	J. Kerr Dam	April 26–30	June 20–24	July 30–Aug. 3
27	Kilmarnock	April 26–30	June 25–29	Aug. 4–8
28	Lawrenceville	April 21–25	June 20–24	July 30–Aug. 3
29	Louisa	April 26–30	June 20–24	Aug. 9–13
30	Martinsville	—	—	—
31	Mathews	April 26–30	June 20–24	Aug. 4–8
32	Norfolk	April 26–30	June 15–19	July 30–Aug. 3
33	Painter	May 1–5	June 25–29	Aug. 9–13
34	Philpott Dam	—	—	—
35	Richmond	April 26–30	June 20–24	July 30–Aug. 3
36	Roanoke	—	—	—
37	Rocky Mount	—	—	—
38	South Boston	April 26–30	June 20–24	Aug. 4–8
39	Staunton	—	—	—
40	Stony Creek	April 21–25	June 15–19	July 30–Aug. 3
41	Suffolk	April 21–25	June 15–19	July 30–Aug. 3
42	Vienna	—	—	—
43	Wakefield	April 26–30	June 20–24	July 30–Aug. 3
44	Warrenton	—	—	—
45	West Point	April 21–25	June 15–19	July 25–29
46	Williamsburg	April 21–25	June 20–24	July 30–Aug. 3
47	Winchester	—	—	—
48	Wise	—	—	—
49	Wytheville	—	—	—

[a] — refers to spray periods that are not applicable to spray timing because models have not been developed for populations with two annual generations.

Table 2—Site number, location, and optimal spray period predictions for 58 weather stations located throughout North Carolina

Site no.	Location	Spray period[a] 1	2	3	4
1	Andrews	—	—	—	—
2	Albemarle	April 16–20	June 10–14	July 25–29	
3	Arcola	April 21–25	June 15–19	July 30–Aug. 3	
4	Asheboro	April 16–20	June 10–14	July 25–29	
5	Asheville	—	—	—	—
6	Aurora	April 16–20	June 5–9	July 20–24	
7	Bayboro	April 11–15	June 10–14	July 30–Aug. 3	Sept. 18–22
8	Belhaven	April 16–20	June 10–14	July 20–24	
9	Boone	—	—	—	—
10	Burlington	April 21–25	June 15–19	July 25–29	
11	Catawba	April 16–20	June 10–14	July 25–29	
12	Cape Hatteras	April 21–25	June 15–19	July 25–29	
13	Cedar Island	April 16–20	June 10–14	July 30–Aug. 3	Sept. 18–22
14	Celo	—	—	—	—
15	Chapel Hill	April 21–25	June 15–19	July 30–Aug. 3	
16	Charlotte	April 16–20	June 10–14	July 20–24	
17	Clayton	April 16–20	June 10–14	July 20–24	
18	Clinton	April 11–15	June 5–9	July 20–24	
19	Cullowhee	—	—	—	—
20	Danbury	—	—	—	—
21	Dunn	April 11–15	June 10–14	July 20–24	
22	Edenton	April 16–20	June 10–14	July 20–24	
23	Elizabeth City	April 16–20	June 10–14	July 25–29	
24	Elizabethtown	April 6–10	June 10–14	July 30–Aug. 3	Sept. 18–22
25	Fayetteville	April 11–15	June 5–9	July 20–24	
26	Gastonia	April 11–15	June 5–9	July 20–24	
27	Goldsboro	April 11–15	June 5–9	July 15–19	
28	Greensboro	April 21–25	June 15–19	July 30–Aug. 3	
29	Greenville	April 16–20	June 10–14	July 20–24	
30	Henderson	April 21–25	June 15–19	July 30–Aug. 3	
31	Hendersonville	—	—	—	—
32	Hoffman	April 1–5	June 5–9	July 25–29	Sept. 8–22
33	Jackson	April 16–20	June 15–19	July 25–29	
34	Kinston	April 16–20	June 10–14	July 25–29	
35	Laurinburg	April 6–10	June 5–9	July 25–29	Sept. 8–22
36	Lewiston	April 16–20	June 10–14	July 25–29	—
37	Louisburg	April 21–25	June 15–19	July 30–Aug. 3	—
38	Lumberton	April 11–15	June 5–9	July 20–24	—
39	Manteo	April 16–20	June 10–14	July 25–29	—
40	Morehead City	April 11–15	June 10–14	July 30–Aug. 3	Sept. 18–22
41	Morganton	April 16–20	June 15–19	July 30–Aug. 3	

continued

Table 2—Site number, location, and optimal spray period predictions for 58 weather stations located throughout North Carolina (continued)

Site no.	Location	Spray period[a] 1	2	3	4
42	Murfreesboro	April 21–25	June 15–19	July 30–Aug. 3	
43	New Bern	April 11–15	June 10–14	July 30–Aug. 3	Sept. 18–22
44	New Holland	April 11–15	June 10–14	July 20–24	
45	N. Wilkesboro	—	—	—	—
46	Plymouth	April 16–20	June 10–14	July 25–29	
47	Raleigh	April 16–20	June 10–14	July 25–29	
48	Reidsville	April 26–30	June 20–24	Aug. 4–8	
49	Roanoke Rapids	April 26–30	June 20–24	July 30–Aug. 3	
50	Salisbury	April 21–25	June 20–24	Aug. 4–8	
51	Sanford	April 11–15	June 10–14	July 25–29	
52	Southport	April 11–15	June 10–14	July 30–Aug. 3	Sept. 18–22
53	Tarboro	April 16–20	June 10–14	July 20–24	
54	Wadesboro	April 16–20	June 5–9	July 20–24	
55	Warsaw	April 11–15	June 10–14	July 30–Aug. 3	Sept. 18–22
56	Willard	April 6–10	June 5–9	July 30–Aug. 3	Sept. 18–22
57	Wilmington	April 6–10	June 10–14	July 30–Aug. 3	Sept. 18–22
58	Wilson	April 16–20	June 10–14	July 25–29	

[a] — refers to spray periods that are not applicable to spray timing because models have not been developed for populations with two annual generations.

Table 3—Site number, location, and optimal spray period predictions for 45 weather stations located throughout South Carolina

		Spray period[a]			
Site no.	Location	1	2	3	4
1	Aiken	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
2	Allendale	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
3	Anderson	April 16–20	June 20–24	Aug. 9–13	
4	Andrews	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
5	Bamberg	March 27–31	May 26–30	July 20–24	Sept. 3–7
6	Bishopville	April 16–20	June15–19	Aug. 4–8	
7	Blackville	March 27–31	May 26–30	July 20–24	Sept. 3–7
8	Caesars Head	—	—	—	—
9	Calhoun Falls	April 11–15	June 10–14	July 30–Aug. 3	Sept. 13–17
10	Camden	April 16–20	June 20–24	Aug. 9–13	
11	Charleston	March 27–31	May 26–30	July 15–19	Aug. 24–28
12	Cheraw	April 16–20	June 20–24	Aug. 4–8	
13	Chester	April 16–20	June 20–24	Aug. 9–13	
14	Clarks Hill	April 6–10	June 5–9	July 30–Aug. 3	Sept. 13–17
15	Clemson	April 16–20	June 20–24	Aug. 9–13	
16	Columbia	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
17	Conway	April 1–5	May 31–June 4	July 20–24	Sept. 3–7
18	Darlington	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
19	Dillon	April 16–20	June 20–24	Aug. 4–8	
20	Edisto Island	April 6–10	May 31–June 4	July 20–24	Sept. 3–7
21	Florence	April 11–15	June 5–9	July 25–29	Sept. 13–17
22	Greenville–Spartanburg Airport	April 16–20	June 25–29	Aug. 14–18	
23	Greenwood	April 16–20	June 20–24	Aug. 9–13	
24	Hampton	March 17–21	May 21–25	July 15–19	Aug. 24–28
25	Hilton Head Island	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
26	Johnston	April 16–20	June 20–24	Aug. 4–8	
27	Kingstree	April 1–5	May 31–June 4	July 20–24	Sept. 3–7
28	Laurens	April 16–20	June 20–24	Aug. 4–8	
29	Little Mountain	April 6–10	June 5–9	July 25–29	Sept. 8–12
30	Loris	April 6–10	June 5–9	July 30–Aug. 3	Sept. 18–22
31	Manning	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
32	McClellanville	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
33	Myrtle Beach	April 1–5	June 5–9	July 25–29	Sept. 13–17
34	Newberry	April 6–10	June 5–9	July 25–29	Sept. 13–17
35	Pageland	April 11–15	June 10–14	July 30–Aug. 3	Sept. 18–22
36	Pickens	April 16–20	June 20–24	Aug. 14–18	
37	Ridgeland	March 17–21	May 21–25	July 15–19	Aug. 24–28
38	Santuck	April 11–15	June 15–19	Aug. 4–8	
39	Spartanburg	April 16–20	June 20–24	Aug. 9–13	
40	Summerville	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
41	Sumter	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
42	Union	April 16–20	June 25–29	Aug. 14–18	
43	Walhalla	April 21–25	June 25–29	Aug. 19–23	
44	Walterboro	March 22–26	May 26–30	July 20–24	Aug. 29–Sept. 2
45	Yemassee	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2

[a] — refers to spray periods that are not applicable to spray timing because models have not been developed for populations with two annual generations.

Table 4—Site number, location, and optimal spray period predictions for 70 weather stations located throughout Georgia

Site no.	Location	Spray period[a] 1	2	3	4
1	Albany	March 17–21	May 21–25	July 10–14	Aug. 19–23
2	Alma	—	—	—	—
3	Alpharetta	April 21–25	June 30–July 4	Aug. 24–28	
4	Americus	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
5	Appling	April 11–15	June 20–24	Aug. 9–13	
6	Ashburn	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
7	Athens	April 16–20	June 20–24	Aug. 4–8	
8	Atlanta	April 16–20	June 15–19	Aug. 4–8	
9	Augusta	April 1–5	May 31–June 4	July 20–24	Sept. 3–7
10	Bainbridge	March 12–16	May 21–25	July 10–14	Aug. 19–23
11	Blairsville	—	—	—	—
12	Brunswick	—	—	—	—
13	Byron	April 1–5	June 5–9	July 25–29	Sept. 8–12
14	Calhoun	April 16–20	June 25–29	Aug. 14–18	
15	Camilla	—	—	—	—
16	Carrollton	April 16–20	June 20–24	Aug. 14–18	
17	Cartersville	April 16–20	June 20–24	Aug. 9–13	
18	Cedartown	April 16–20	June 20–24	Aug. 9–13	
19	Claxton	March 22–26	May 26–30	July 20–24	Aug. 29–Sept. 2
20	Clayton	April 26–30	July 5–9	Sept. 8–12	
21	Colquitt	March 12–16	May 16–20	July 10–14	Aug. 19–23
22	Columbus	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
23	Commerce	April 16–20	June 25–29	Aug. 14–18	
24	Cordele	March 17–21	May 21–25	July 10–14	Aug. 19–23
25	Cornelia	April 21–25	June 30–July 4	Aug. 29–Sept. 2	
26	Covington	April 11–15	June 15–19	Aug. 4–8	
27	Cuthbert	March 17–21	May 21–25	July 10–14	Aug. 19–23
28	Dalton	April 21–25	June 25–29	Aug. 14–18	
29	Douglas	March 17–21	May 21–25	July 15–19	Aug. 24–28
30	Dublin	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
31	Eastman	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
32	Elberton	April 11–15	June 20–24	Aug. 14–18	
33	Experiment	April 16–20	June 20–24	Aug. 9–13	
34	Fargo	March 12–16	May 16–20	July 10–14	Aug. 19–23
35	Fitzgerald	March 17–21	May 21–25	July 10–14	Aug. 24–28
36	Folkston	—	—	—	—
37	Forsyth	April 1–5	June 5–9	July 25–29	Sept. 13–17
38	Gainesville	April 21–25	June 25–29	Aug. 14–18	
39	Helen	April 21–25	July 5–9	Aug. 29–Sept. 2	
40	Homerville	March 12–16	May 16–20	July 10–14	Aug. 24–28
41	Jasper	April 21–25	June 30–July 4	Aug. 24–28	
42	La Fayette	April 21–25	June 25–29	Aug. 19–23	
43	Louisville	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
44	Lumpkin	March 22–26	May 26–30	July 20–24	Sept. 3–7

continued

Table 4—Site number, location, and optimal spray period predictions for 70 weather stations located throughout Georgia (continued)

Site no.	Location	Spray period[a]			
		1	2	3	4
45	Macon	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
46	Midville	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
47	Milledgeville	April 6–10	June 5–9	July 25–29	Sept. 13–17
48	Millen	March 17–21	May 26–30	July 15–19	Aug. 24–28
49	Monticello	April 6–10	June 5–9	July 25–29	Sept. 13–17
50	Moultrie	—	—	—	—
51	Nahunta	March 7–11	May 16–20	July 10–14	Aug. 24–28
52	Newnan	April 11–15	June 15–19	Aug. 4–8	
53	Quitman	—	—	—	—
54	Rome	April 16–20	June 20–24	Aug. 9–13	
55	Sandersville	April 1–5	June 5–9	July 25–29	Sept. 8–12
56	Sapelo Island	March 17–21	May 21–25	July 10–14	Aug. 24–28
57	Savannah	March 17–21	May 21–25	July 10–14	Aug. 19–23
58	Siloam	April 6–10	June 5–9	July 30–Aug. 3	Sept. 13–17
59	Surrency	March 12–16	May 21–25	July 10–14	Aug. 29–Sept. 2
60	Swainsboro	March 22–26	May 26–30	July 15–19	Aug. 24–28
61	Talbotton	March 27–31	May 31–June 4	July 25–29	Sept. 8–12
62	Thomaston	March 27–31	May 31–June 4	July 25–29	Sept. 8–12
63	Thomasville	—	—	—	—
64	Tifton	March 17–21	May 21–25	July 10–14	Aug. 24–28
65	Warrenton	April 6–10	June 5–9	July 25–29	Sept. 8–12
66	Washington	April 16–20	June 20–24	Aug. 9–13	
67	Waycross	—	—	—	—
68	Waynesboro	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
69	West Point	April 1–5	June 5–9	July 25–29	Sept. 8–12
70	Winder	April 16–20	June 20–24	Aug. 14–18	

[a] — refers to spray periods that are not applicable to spray timing because models have not been developed for populations with two or five annual generations.

Table 5—Site number, location, and optimal spray period predictions for 26 weather stations located throughout northern Florida

Site no.	Location	Spray period[a] 1	2	3	4
1	Apalachicola	—	—	—	—
2	Chipley	March 12–16	May 16–20	July 10–14	Aug. 19–23
3	Crescent City	—	—	—	—
4	Crestview	March 12–16	May 16–20	July 10–14	Aug. 19–23
5	Cross City	—	—	—	—
6	DeFuniak Springs	—	—	—	—
7	Federal Point	—	—	—	—
8	Fernandina Beach	—	—	—	—
9	Gainesville	—	—	—	—
10	Glen Saint Mary	—	—	—	—
11	High Springs	—	—	—	—
12	Jacksonville	—	—	—	—
13	Jasper	—	—	—	—
14	Lake City	—	—	—	—
15	Live Oak	—	—	—	—
16	Madison	—	—	—	—
17	Mayo	—	—	—	—
18	Monticello	March 12–16	May 16–20	July 10–14	Aug. 19–23
19	Ocala	—	—	—	—
20	Panama City	—	—	—	—
21	Pensacola	—	—	—	—
22	Perry	—	—	—	—
23	Quincy	March 12–16	May 16–20	July 10–14	Aug. 24–28
24	Saint Augustine	—	—	—	—
25	Steinhatchee	—	—	—	—
26	Tallahassee	—	—	—	—

[a] — refers to spray periods that are not applicable to spray timing because models have not been developed for populations with five annual generations.

Table 6—Site number, location, and optimal spray period predictions for 54 weather stations located throughout Alabama

Site no.	Location	Spray period[a] 1	2	3	4
1	Alexandria	April 6–10	June 5–9	July 30–Aug. 3	Sept. 13–17
2	Aliceville	April 11–15	June 10–14	July 30–Aug. 3	Sept. 13–17
3	Andalusia	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
4	Anniston	March 22–26	May 31–June 4	July 25–29	Sept. 8–12
5	Ashland	April 16–20	June 25–29	Aug. 14–18	
6	Auburn	April 6–10	June 5–9	July 25–29	Aug. 19–23
7	Bay Minette	March 12–16	May 16–20	July 5–9	Aug. 19–23
8	Belle Mina	April 16–20	June 20–24	Aug. 9–13	
9	Bessemer	April 6–10	June 5–9	July 25–29	Sept. 13–17
10	Birmingham	April 6–10	June 5–9	July 25–29	Sept. 13–17
11	Brewton	March 12–16	May 21–25	July 15–19	Aug. 24–28
12	Bridgeport	April 21–25	June 25–29	Aug. 19–23	
13	Camden	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
14	Camp Hill	April 16–20	June 20–24	Aug. 9–13	
15	Centreville	April 6–10	June 5–9	July 25–29	Sept. 8–12
16	Chatom	March 17–21	May 21–25	July 15–19	Aug. 24–28
17	Childersburg	April 1–5	June 5–9	July 25–29	Sept. 8–12
18	Clanton	April 6–10	June 5–9	July 25–29	Sept. 13–17
19	Clayton	March 22–26	May 26–30	July 20–24	Sept. 3–7
20	Coden	March 17–21	May 21–25	July 10–14	Aug. 24–28
21	Demopolis	April 1–5	June 5–9	July 25–29	Sept. 8–12
22	Enterprise	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
23	Eufaula	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
24	Evergreen	March 22–26	May 26–30	July 20–24	Aug. 29–Sept. 2
25	Fairhope	—	—	—	—
26	Fayette	April 11–15	June 10–14	July 30–Aug. 3	Sept. 18–22
27	Frisco City	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
28	Gadsden	April 16–20	June 20–24	Aug. 9–13	
29	Gainesville	April 6–10	June 5–9	July 25–29	Sept. 8–12
30	Geneva	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
31	Greensboro	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
32	Greenville	March 17–21	May 21–25	July 10–14	Aug. 24–28
33	Guntersville	April 16–20	June 20–24	Aug. 4–8	
34	Haleyville	April 21–25	June 25–29	Aug. 14–18	
35	Hamilton	April 16–20	June 25–29	Aug. 14–18	
36	Headland	March 22–26	May 21–25	July 15–19	Aug. 29–Sept. 2
37	Heflin	April 21–25	June 25–29	Aug. 19–23	
38	Highland Home	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
39	Jackson	March 17–21	May 21–25	July 10–14	Aug. 24–28
40	Jasper	April 16–20	June 20–24	Aug. 14–18	
41	Marion Junction	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
42	Milstead	March 27–31	June 5–9	July 25–29	Sept. 8–12
43	Montgomery	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
44	Moulton	April 16–20	June 20–24	Aug. 9–13	

continued

Table 6—Site number, location, and optimal spray period predictions for 54 weather stations located throughout Alabama (continued)

Site no.	Location	Spray period[a] 1	2	3	4
45	Muscle Shoals	April 16–20	June 20–24	Aug. 9–13	
46	Oneonta	April 21–25	June 25–29	Aug. 14–18	
47	Robertsdale	March 12–16	May 26–30	July 15–19	Aug. 29–Sept. 2
48	Scottsboro	April 16–20	June 20–24	Aug. 9–13	
49	Talladega	April 11–15	June 15–19	Aug. 4–8	
50	Thomasville	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
51	Troy	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
52	Tuscaloosa	April 1–5	May 31–June 4	July 20–24	Sept. 3–7
53	Union Springs	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
54	Valley Head	April 26–30	July 5–9	Aug. 24–28	

[a] — refers to spray periods that are not applicable to spray timing because models have not been developed for populations with five annual generations.

Table 7—Site number, location, and optimal spray period predictions for 52 weather stations located throughout Mississippi

Site no.	Location	Spray period[a] 1	2	3	4
1	Aberdeen	April 6–10	June 5–9	July 25–29	Sept. 8–12
2	Batesville	April 16–20	June 15–19	Aug. 4–8	
3	Bay Saint Louis	—	—	—	—
4	Belzoni	April 6–10	May 31–June 4	July 20–24	Aug. 29–Sept. 2
5	Biloxi	—	—	—	—
6	Booneville	April 21–25	June 20–24	Aug. 9–13	
7	Brookhaven	March 22–26	May 31–June 4	July 20–24	Sept. 3–7
8	Calhoun City	April 6–10	June 5–9	July 30–Aug. 3	Sept. 13–17
9	Carthage	April 6–10	June 5–9	July 25–29	Sept. 8–12
10	Charleston	April 11–15	June 10–14	July 25–29	Sept. 13–17
11	Clarksdale	April 11–15	June 5–9	July 20–24	Sept. 3–7
12	Collins	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
13	Columbia	March 12–16	May 16–20	July 5–9	Aug. 19–23
14	Columbus	April 6–10	June 5–9	July 25–29	Sept. 3–7
15	Crystal Springs	March 22–26	May 21–25	July 15–19	Aug. 24–28
16	D Lo	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
17	Eupora	April 6–10	June 5–9	July 25–29	Sept. 8–12
18	Forest	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
19	Fulton	April 11–15	June 15–19	Aug. 4–8	
20	Greenville	April 6–10	May 31–June 4	July 20–24	Aug. 29–Sept. 2
21	Greenwood	April 6–10	May 31–June 4	July 20–24	Sept. 3–7
22	Grenada	April 11–15	June 5–9	July 25–29	Sept. 8–12
23	Hattiesburg	March 17–21	May 21–25	July 10–14	Aug. 24–28
24	Hernando	April 16–20	June 10–14	July 30–Aug. 3	Sept. 13–17
25	Hickory Flat	April 16–20	June 20–24	Aug. 4–8	
26	Houston	April 16–20	June 20–24	Aug. 9–13	
27	luka	April 21–15	June 25–29	Aug. 14–18	
28	Jackson	March 27–31	May 31–June 4	July 20–24	Aug. 29–Sept. 2
29	Kosciusko	April 6–10	June 5–9	July 25–29	Sept. 13–17
30	Laurel	March 27–31	May 26–30	July 15–19	Aug. 29–Sept. 2
31	Lexington	April 6–10	June 5–9	July 25–29	Sept. 8–12
32	Liberty	March 27–31	May 26–30	July 20–24	Aug. 29–Sept. 2
33	Louisville	April 6–10	June 5–9	July 25–29	Sept. 8–12
34	Macon	April 6–10	June 5–9	July 25–29	Sept. 8–12
35	McComb	March 22–26	May 26–30	July 15–19	Aug. 24–28
36	Meridian	March 27–31	May 31–June 4	July 20–24	Aug. 29–Sept. 2
37	Natchez	March 17–21	May 21–25	July 10–14	Aug. 24–28
38	Newton	April 1–5	May 31–June 4	July 25–29	Sept. 8–12
39	Pascagoula	—	—	—	—
40	Philadelphia	April 6–10	June 5–9	July 25–29	Sept. 8–12
41	Pontotoc	April 16–20	June 20–24	Aug. 4–8	
42	Poplarville	—	—	—	—
43	Port Gibson	March 27–31	May 26–30	July 20–24	Aug. 29–Sept. 2
44	Quitman	March 27–31	May 31–June 4	July 20–24	Sept. 3–7
45	Ripley	April 21–25	June 20–24	Aug. 9–13	
46	Rolling Fork	April 6–10	June 5–9	July 20–24	Sept. 3–7
47	Tunica	April 16–20	June 15–19	Aug. 4–8	
48	Tylertown	March 17–21	May 21–25	July 10–14	Aug. 24–28
49	Vicksburg	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
50	Waynesboro	March 22–26	May 26–30	July 15–19	Aug. 29–Sept. 2
51	Wiggins	March 17–21	May 21–25	July 10–14	Aug. 19–23
52	Woodville	March 17–21	May 21–25	July 10–14	Aug. 24–28

[a] — refers to spray periods that are not applicable to spray timing because models have not been developed for populations with five annual generations.

Table 8—Comparisons between optimal spray dates determined on site at 16 field locations throughout the Southeastern United States during 1996–98 and predicted optimal spray periods

			Generation			
Location	Year	Weather station location[a]	1 Spray	2 Spray	3 Spray	4 Spray
Alabama						
Escambia Co.	1996	Brewton (30 km ESE)	0[b]	1	NA[c]	NA
Georgia						
Athens	1997	Athens (5 km SW)	3	1	3	—
Jefferson Co.	1997	Louisville (8 km W)	3	1	1	2
	1998	Louisville (7.5 km W)	0	0	2	NA
Oglethorpe Co.	1998	Athens (3 0.5 km WNW)	2	1	1	—
Taylor Co.	1998	Talbotton (37 km WNW)	NA	1	NA	NA
North Carolina						
Chowan Co.	1996	Edenton (9.5 km S)	2	1	1	—
Connarista	1996	Lewiston (13.5 km SW)	2	1	1	—
Halifax Co.	1996	Roanoke Rapids (21 km E)	0	0	1	—
Hertford Co.	1998	Murfreesboro (16 km SW)	0	1	NA	—
Pleasant Hill	1996	Emporia, VA (22.5 km N)	0	0	0	—
South Carolina						
Almeda	1997	Hampton (17 km NW)	2	0	1	1
Virginia						
Brunswick Co.	1996	Lawrenceville (13 km WSW)	1	0	1	—
Isle of Wight Co.	1996	Wakefield (30.5 km WNW)	1	1	1	—
Southampton Co.	1998	Holland (22.5 km ENE)	0	0	NA	—
Sussex Co.	1998	Emporia (5 km W)	1	0	NA	—

NA = data not available; — = data not applicable.

[a] Approximate distance and coordinate from field site to weather station location.

[b] Numbers refer to the differences between dates in terms of 5–day optimal spray periods.

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The Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae), is a common pest of Christmas tree and pine plantations throughout much of the Eastern United States. The moth completes two to five generations annually, and insecticide spray timing models are currently available for controlling populations where three or four generations occur. The thermal requirements for the Nantucket pine tip moth to complete a generation were obtained from published data and used along with historical temperature data to produce maps indicating the number of annual generations predicted to occur throughout seven Southeastern States. Spray timing prediction values were also obtained from published data and used to predict optimal spray periods based on 5-day increments for each location where either three or four generations occurred. Approximately 80 percent of the predicted optimal spray periods were within one optimal spray period of previously field-determined spray dates. Land managers who use contact insecticides, such as synthetic pyrethroids, may find the predicted optimal spray periods useful in optimizing spray effectiveness.

Keywords: Chemical control, Nantucket pine tip moth, phenology, *Rhyacionia frustrana*, spray timing.