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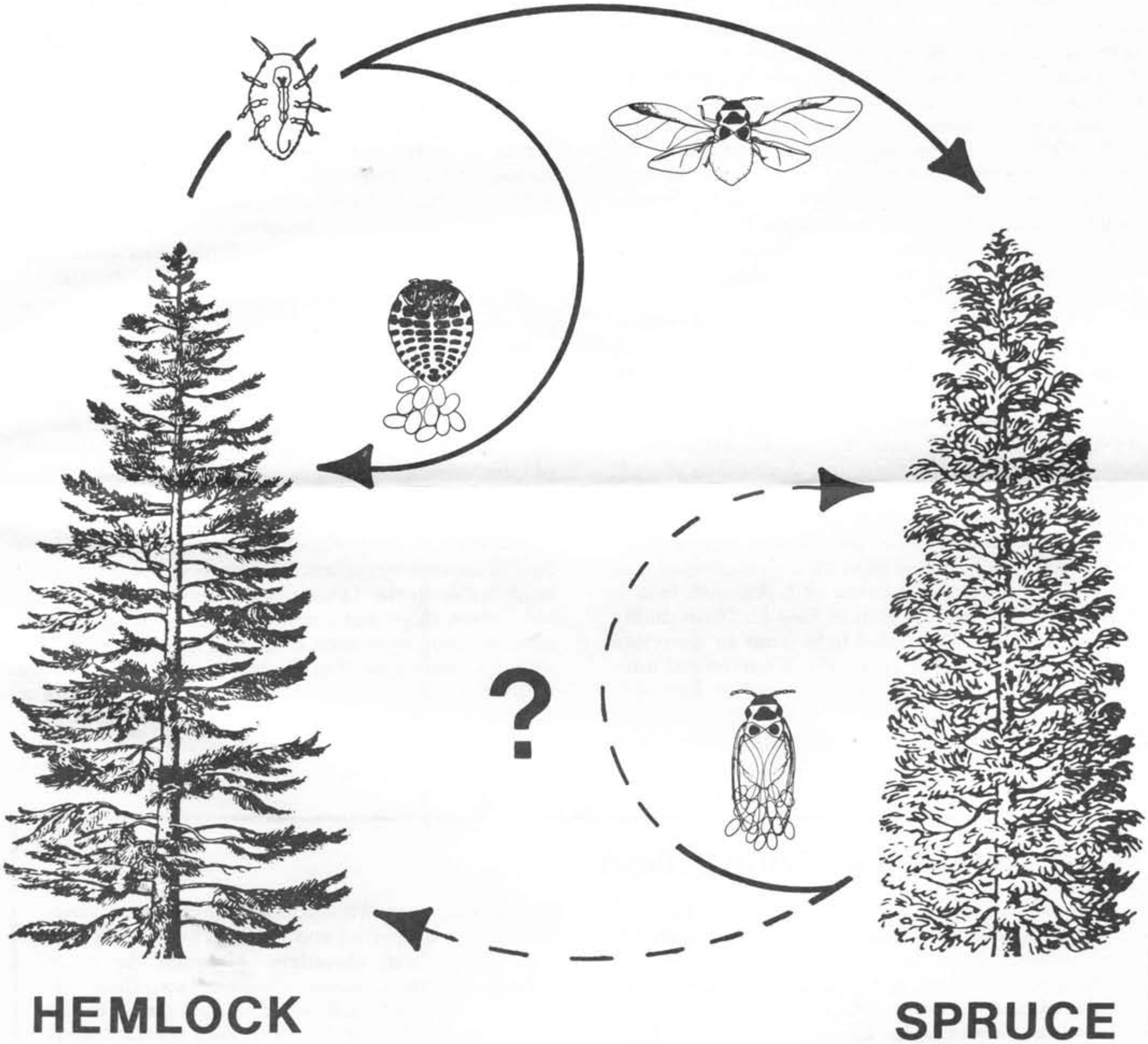

Life cycle of the hemlock woolly adelgid. See page 7.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION NEW HAVEN

Lyme disease: a tick-related problem increasing in importance

By Louis A. Magnarelli and John F. Anderson

With growing public concern over ticks and Lyme disease, we have been studying blood-seeking arthropods, spirochetes, mammals, and birds for the past 5 years to estimate the extent of infection in Connecticut. Our main objectives are to identify new areas where the Lyme disease agent, *Borrelia burgdorferi*, occurs and to determine which animals harbor this bacterium and serve as hosts for the tick vector, *Ixodes dammini*.

Ticks were removed from mammals and birds in the field, and blood samples were taken for analyses. In the laboratory, we removed internal tissues from the ticks and smeared them on glass microscope slides. Special reagents applied to these tissues made *B. burgdorferi* visible under a fluorescence microscope. Blood samples from mammals were tested for antibodies to *B. burgdorferi* by immunofluorescence procedures or enzyme-linked assays. The test on tick tissues detected the pathogen, while analyses of blood provided immunologic evidence of present or past infection by the Lyme disease agent in mammals.

Immatures and adults of *I. dammini* feed on a variety of vertebrate hosts. We found this tick on white-footed mice, chipmunks, meadow voles, short-tailed shrews, and more than 30 species of passerine birds. The latter include American robins, gray catbirds, black-capped chickadees, common yellowthroats, and swamp sparrows. There can be many ticks on a given animal. For example, we removed 74 larvae of *I. dammini* from a white-footed mouse captured in East Haddam during August 1980 and 19 nymphal ticks from an American robin at this same site during 1983. White-footed mice and other rodents are important because they harbor *B. burgdorferi* for several months, including the winter months, and serve to maintain these spirochetes in or near woodlands. Birds transport infected ticks to new sites and have probably had an important role in expanding the geographic range of *B. burgdorferi*.

It was important to determine if the larvae that emerge from eggs were already infected with *B. burgdorferi*. We tested 2,297 larvae, which were reared from eggs deposited in the laboratory, and found that less than 2% were infected. Therefore, passage of Lyme disease spirochetes to the eggs (transovarial transmission) and larvae is inefficient. We concluded that larval ticks acquire *B. burgdorferi* spirochetes when they feed from infected hosts, such as rodents, and pass them to the next life stage — the nymph. The spirochetes are subsequently transmitted to other mammals or birds when the nymphs feed. Most human infections of Lyme disease are acquired during the summer, when the nymphs are most abundant.

We also needed to know if the prevalence of infected ticks was increasing in areas known to be highly endemic for Lyme disease. We tested 262 *I. dammini* adults that had been removed from white-tailed deer in East Lyme during fall hunting seasons. The proportion of infected ticks was 13% in 1982, 23% in 1983, and 14% in 1984. Thus, it does not appear that infection rates are increasing in ticks at this locality.

Presence of antibodies to *B. burgdorferi* indicates past or current infections. Our studies revealed immunoglobulins to the Lyme disease spirochete in white-tailed deer, chipmunks, white-footed mice, gray squirrels, raccoons, opossums, dogs, and horses at numerous sites in Connecticut (Fig. 1). In our collaborative work with veterinarians in Connecticut, we learned that 19 of 52 dogs with antibodies to *B. burgdorferi* had limb or joint disorders that caused lameness. This clinical

Lyme disease in Connecticut

Lyme disease was first described as a form of arthritis in 1975. It was named after Lyme, Connecticut because of a geographic clustering of children with joint disorders in this and adjoining towns. Lyme disease occurs in at least 24 states and is now known to be a complex illness that is caused by a recently discovered spirochete (bacterium) named *Borrelia burgdorferi*. A tick, *Ixodes dammini*, transmits this infectious agent to mammals and birds.

Within 30 days after a tick bite, people may develop expanding skin lesions with accompanying flu-like symptoms. Without antibiotic treatment, these infections may persist and result in cardiac, neurologic, or arthritic disorders. Although the exact number of human cases is unknown, Lyme disease is the most prevalent arthropod-related illness in the United States. During 1984 and 1985, the Connecticut Department of Health sent 5,408 human serum samples to The Connecticut Agricultural Experiment Station for analyses. Results of serologic tests indicated that 1,173 specimens from 1,006 persons had antibodies to the Lyme disease spirochete.

manifestation occurs less frequently in horses. Therefore, the majority of dogs and horses with immunologic evidence of *B. burgdorferi* lacked signs of illness.

Although little is known about how *B. burgdorferi* affects wildlife, we have isolated this disease organism from the blood or other tissues of white-footed mice, chipmunks, meadow voles, raccoons, and a bird (veery). This means that these animals are probably serving as reservoirs of infection and that ticks could acquire *B. burgdorferi* from a multitude of hosts in nature.

Ixodes dammini is the primary vector of the Lyme disease agent, but we wondered if other arthropods harbored this bacterium. We found *B. burgdorferi* in internal tissues of fleas, deer flies, horse flies, and mosquitoes. Infection rates were usually less than 10% but were as high as 21% for females of a deer fly species collected in Norwich. Our findings clearly establish the presence of Lyme disease spirochetes in several arthropod species, but we do not know if the fleas or bloodsucking flies can efficiently transmit *B. burgdorferi*. Studies are underway to clarify their role in the epidemiology and ecology of Lyme disease.

The geographic range of *I. dammini* and *B. burgdorferi* appears to be expanding, and because of the wide host range of this tick, the potential for further spread of the pathogen is high. We attribute the relatively large number of human cases to elevated infection rates in ticks and to the close association between people and ticks in or near woodlands.

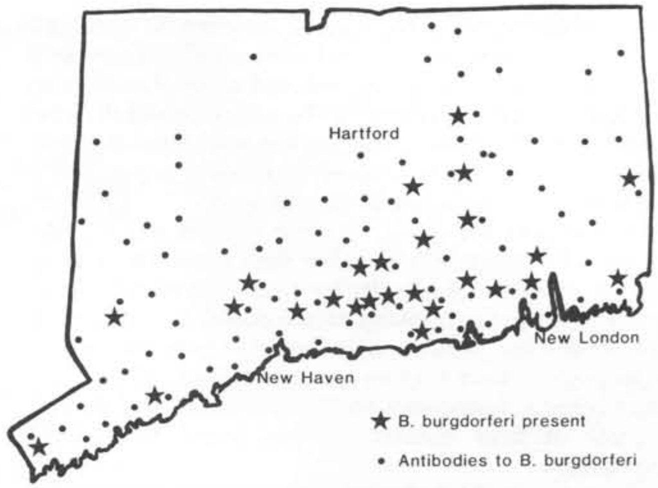

Figure 1. Geographic distribution of *B. burgdorferi* in tick and wildlife populations. Antibodies were detected in horses, dogs, white-footed mice, and white-tailed deer during 1982-1986.

To read about Lyme disease in Connecticut, the following recent journal articles are suggested:

Anderson, J.F., and Magnarelli, L.A. 1984. Avian and mammalian hosts for spirochete-infected ticks and insects in a Lyme disease focus in Connecticut. Yale Journal of Biology and Medicine 57:627-641.

Anderson, J.F., Johnson, R.C., Magnarelli, L.A., et al. 1985. Identification of endemic foci of Lyme disease: isolation of *Borrelia burgdorferi* from feral rodents and ticks (*Dermacentor variabilis*). Journal of Clinical Microbiology 22:36-38.

Anderson, J.F., Johnson, R.C., Magnarelli, L.A., et al. 1986. Involvement of birds in the epidemiology of the Lyme disease agent *Borrelia burgdorferi*. Infection and Immunity 51:394-396.

Magnarelli, L.A., Anderson, J.F., Kaufmann, A.F., et al. 1985. Borreliosis in dogs from southern Connecticut. Journal of the American Veterinary Medical Association 186:955-959.

Magnarelli, L.A., Anderson, J.F., Apperson, C.S., et al. 1986. Spirochetes in ticks and antibodies to *Borrelia burgdorferi* in white-tailed deer from Connecticut, New York State, and North Carolina. Journal of Wildlife Diseases 22:178-188.

Magnarelli, L.A., Anderson, J.F., and Barbour, A.G. 1986. The etiologic agent of Lyme disease in deer flies, horse flies, and mosquitoes. Journal of Infectious Diseases 154:355-358.

Steere, A.C., Grodzicki, R.L., Kornblatt, A.N., et al. 1983. The spirochetal etiology of Lyme disease. New England Journal of Medicine 308:733-740.

Analyzing wine and beer coolers for calories and alcohol

By Lester Hankin

Since their introduction in 1981, sales of wine coolers have grown to nearly $1 billion per year. Their appeal is likely their flavors derived from the blend of wine with fruit juice, carbonation, and their perceived lower caloric and alcohol content. Other products, such as beer coolers and wines with reduced alcohol are also being marketed. Because the state levies taxes on alcoholic beverages, the Department of Revenue Services sent samples of these products to the Experiment Station for determination of their alcohol content.

According to Connecticut Statutes, wine contains not less than 3.2% alcohol and is taxed at 30 cents per gallon. Beer must contain more than one-half percent alcohol and is taxed at 10 cents per gallon. Wine coolers are taxed at 30 cents per gallon and beer coolers at 10 cents per gallon. Products containing less than one-half percent alcohol are not taxed.

According to the U.S. Department of the Treasury, wine coolers contain a base of standard wine to which is added concentrated or unconcentrated juice, flavoring, water, citric acid (for tartness), sugar, and carbon dioxide. Addition of water and other components reduces the alcohol content of the wine to less than 7%. Although the alcohol content of standard wine usually preserves it from microbial action, the reduced alcohol content in coolers requires preservatives be added to stabilize the product and prevent secondary fermentation after bottling. Sulfiting agents, sodium benzoate, or potassium sorbate, or a combination may be used.

Beer coolers are similar to wine coolers, except that the base beverage is beer rather than wine. There is no specific standard of identity for beer coolers. Flavoring is added before processing of the cooler is completed. Spokesman for the beer cooler industry state that, unlike wine coolers, beer coolers are pasteurized. Also unlike wine coolers, statements on the label about the alcohol content of beer coolers are prohibited by federal regulations.

Wines from which alcohol has been removed are usualy advertised as "wine without alcohol." No regulations pertain to such products.

In addition to alcohol, wine and beer coolers may contain sugars such as fructose, glucose, and sucrose. Sugars and alcohol contribute calories, a subject of concern to many. Thus, we tested the coolers not only for their alcohol content but also for sugars and determined calories. Table wine, for example, with about 12% alcohol, contains about 7% sugars and averages 24 calories per ounce. Beer contains about 4% sugars, averages 4.5% alcohol, and contains about 13 calories per ounce. Hard liquor, on the other hand, ranges from 65 to 83 calories depending on its alcohol content.

We tested 67 wine coolers, six beer coolers, and three wines without alcohol. Alcohol content was determined by gas chromatography and glucose, fructose, and sucrose by high performance liquid chromatography. Calories were calculated from alcohol and sugar values.

Table 1 shows the results of our tests. The average percentage of alcohol in the wine coolers was 5.7% with a range from 2.9 to 7.0%. The average percentage of alcohol in the beer coolers was 4.8% with a range from 3.7 to 5.2%. Wines without alcohol averaged 0.05% alcohol. Alcohol in the wine coolers averaged 104% of guarantee, but ranged from 81 to 123%.

All products contained fructose and glucose, but only six contained sucrose, probably added as a separate ingredient. The fructose and glucose were probably from the juices added as flavoring. Generally the wine coolers contained about 8% sugars, the beer coolers 7%, and the wine without alcohol, 4%.

Calories in coolers primarily are derived from sugars and alcohol. The wine and beer coolers averaged 19 and 17 calories per ounce, respectively. The wines without alcohol had fewer calories, averaging four per ounce, since the alcohol was removed. Beer coolers have about the same alcohol content as regular beer but about 30% more calories per ounce. Wine coolers contain about half as much alcohol as ordinary table wine.

The results of analyses of all products listed by brand name are detailed in Bulletin 840 and is available free from Publications; The Connecticut Agricultural Experiment Station; P.O. Box 1106; New Haven, CT 06504.

Table 1. Alcohol, calories, and sugar in wine and beer coolers and wine without alcohol.

Beverage	No. Samples	Alcohol, % Avg.	Alcohol, % Range	Calories, No./oz. Avg.	Calories, No./oz. Range	Sugars, % Avg.	Sugars, % Range
Wine coolers	67	5.7	2.9-7.0	19	13-23	8	3.7-13.9
Beer coolers	6	4.8	3.7-5.2	17	15-19	7	6.2-8.5
Wine without alcohol	3	0.05	0.04-0.06	4	3-5	4	2.4-4.4

Evaluating cauliflower varieties for Connecticut growers

By David E. Hill

It has been said that cauliflower is the "aristocrat of the cabbage family" because its requirements for growth are more demanding. Like other cole crops of the genus Brassica, it requires cool temperatures. However, if temperatures are too cold, small heads form prematurely, and if temperatures are too hot, heads don't form at all.

Its popularity is burgeoning. A survey by Michigan State University reported that in the United States, the per capita consumption of cauliflower has more than doubled in the last 10 years, a record surpassed only by broccoli. Production of fresh cauliflower increased three-fold from 77,650 tons in 1974 to 235,600 tons in 1984. At the same time, production for processing increased 26%.

Although cauliflower can be grown in spring or fall, Connecticut's cauliflower crop has been limited to a few tens of acres grown for roadside markets. Because increased sales of cauliflower in Connecticut have evoked discussion of a "Cauliflower Project" similar to the 1986 "Broccoli Project" of 10 growers producing broccoli for direct sales to local supermarkets, the time had come to determine which cauliflower cultivars are suitable for spring and fall in Connecticut. Accordingly, in 1986 I tested 10 cultivars in the spring and added six more, including three experimentals, in the fall. The cultivars included early, middle, and late maturing varieties, as well as self-blanching ones whose leaves naturally enfold the head, called the curd, to ensure whiteness without requiring the leaves to be tied to enclose the curd.

Trials were conducted at the Valley Laboratory, Windsor on a sandy loam terrace soil with somewhat limited moisture holding capacity, and at Lockwood Farm, Mt. Carmel on a fine sandy loam upland soil with a moderate moisture holding capacity. The cultivars, which included hybrids and open-pollinated types, were grown both spring and fall in each location. The spring crop was started in a greenhouse on March 10, transferred to a cold frame for hardening on April 7, and transplanted in the field between April 25 and 28. The fall crop was started outdoors on June 19 and transplanted in the field on July 23.

The soil was fertilized with 10-10-10 at 1300 lb/A or 4.5 lb/50 ft of row. Lime was added to raise the pH to 6.5. The transplants were set 18 inches apart in rows 3 feet apart. Each cultivar had 30 plants randomly set in five replications of six plants each. Root maggots were controlled by Lorsban in the water at transplanting. Lorsban is available only for commercial use; Diazinon is available for home gardeners. Cabbage worms were controlled with malathion as needed. Seedlings were irrigated four times in the spring and twice in the fall. Weeds were controlled by cultivation with a hoe.

When the curd was 1-2 inches wide, leaves of the entire spring crop were tied to assure blanching, although some cultivars were of the self-blanching type. As daily temperatures increased late in the spring, the inner leaves of self-blanching cultivars did not always tightly enfold the curd as it developed rapidly. In the fall, the curds of self-blanching cultivars developed more slowly as temperatures decreased and the inner wrapper leaves enveloped the growing curd and eliminated the need for tying.

As cultivars were harvested, the yield was weighed and the color and compactness of the curd judged. Defects of the curd such as browning (boron deficiency), ricing (premature elongation of flower parts creating a velvety appearance), and leaves protruding from the curd were noted.

Harvest of the spring crop began in mid-June and concluded in mid-July. The fall crop was harvested from mid-September to mid-November. About 5% of the fall crop was damaged by mid-November temperatures in the low 20s.

The average yield in spring of all cultivars at Windsor was 13,589 lb/A, 17% more than the 11,535 lb/A at Mt. Carmel. In fall, the average yield of all cultivars at Windsor was 15,225 lb/A, 20% more than the 12,630 lb/A at Mt. Carmel. In spring, seven of 10 cultivars yielded above the national average of 10,800 lb/A at both sites. In fall, 13 of 16 yielded above the national average.

In spring, five of seven cultivars that had high yields were judged to have consistently good quality, (Table 1). Andes and Polar Express produced large, smooth curds, weighing nearly 2 lbs. Although the curds of Snow Crown, White Empress, and White Knight were somewhat variable in size, their quality was consistently good. The curds of Early Abundance were smooth and consistent, but about 50% of the plants developed premature button-sized curds; this early maturing cultivar might have produced larger heads if it had been planted about May 10 instead of April 25. Alert had low yields and inconsistent size, while Dominant and Snowball T3 had brownish curds, and Snowball had rough, leafy curds.

In fall, four of 16 cultivars had high yields and consistently good quality. Andes, Polar Express, White Knight, and experimental PSR 100184 produced large, smooth curds weighing about 1.5 lbs. The curds of the other 12 cultivars were of inconsistent size or they displayed brown discoloration or ricing.

A notable characteristic of experimental PSR 100184 was its resistance to hollow stem. This defect, common to all other cultivars that I grew, is caused by a boron deficiency.

In fall, all of the cultivars that produced high quality heads except Polar Express were of the self-blanching type and were not tied. Other untied self-blanching types such as Snowball Improved, Snow King, Snow Pak, White Empress, experimentals PSR 277854 and PSX 27885 had rough inconsistent curds, or displayed ricing or brown discoloration. Tied heads of Alert, Dominant, Early Abundance, Snowball, Snowball T3, and Snow Crown had similar defects.

The time of maturity is important to schedule planting for a specific harvest period. In Table 1, the days to maturity were calculated from the day of transplanting to the day when half the curds were harvested. In spring, maturity among the 10 cultivars ranged from 39 to 67 days and was consistent at both sites. In fall, the same 10 cultivars took an average of 17 days longer to mature at Windsor and 24 days longer at Mt. Carmel.

The span of harvest is another important facet of maturity. Long spans of harvest benefit commercial

Table 1. Yield and maturity of cauliflower cultivars that produced high quality heads in spring and fall. Averages of trials at Mt. Carmel and Windsor.

Cultivar	Wt/ Head lb	Yield lb/A	Maturity days	Harvest Span days
		Spring Crop		
Andes*	2.1	20155	67	16
Polar Express	1.8	17640	60	13
Snow Crown	1.2	12040	55	20
White Empress*	1.3	12310	61	21
White Knight*	1.5	14375	56	20
		Fall Crop		
Andes*	1.5	14210	80	15
Polar Express	1.5	14630	75	11
White Knight*	1.6	15215	74	6
PSR 100184*	1.4	14225	95	19

Other cultivars tested: Alert, Dominant, Early Abundance, Snowball, Snowball T3, Snowball Improved*, Snow King*, Snow Pak*, PSR 277854*, PSX 27885*.

*Self-blanching types.

growers with small acreages and home gardeners who harvest in several pickings. Short spans of harvest increase the efficiency of harvest of growers with large acreages who prefer to harvest all at once.

In spring, the average span of harvest of all cultivars was 23 days at Mt. Carmel and 18 days at Windsor. In fall, the span of harvest decreased to 16 days at Mt. Carmel and 13 days at Windsor. As the days to maturity increased in the fall, the harvest span decreased.

Among the cultivars that produced high quality curds in spring, Polar Express had the shortest span of harvest of 2 weeks. Snow Crown, White Empress and White Knight had a span of harvest of 3 weeks. In fall, White Knight's span of harvest shortened to 1 week while PSR 100184 had a span of almost 3 weeks. The 2-week span of harvest of Andes was consistent spring and fall.

The 1986 cultivar trials demonstrated that large yields of cauliflower can be grown in Connecticut for harvests from mid-June through mid-July and from late September through early November. In spring, a single planting in late April of early-maturing Polar Express or White Knight and late-maturing Andes provided continuous harvest from June 11 to July 16 at Mt. Carmel. At Windsor, the span of harvest of these cultivars was June 13 to July 3. Since the span of harvest of most cultivars was shorter at Windsor than at Mt. Carmel, the harvest could likely be extended into mid-July in the Connecticut Valley by planting a second crop about May 10.

In fall, a single planting late in June of early-maturing Polar Express or White Knight and late-maturing Andes again provided the broadest span of harvest. Harvest in Windsor was from September 25 to October 20; at Mt. Carmel, October 5 to October 30. Although untested, I speculate that a second planting of early maturing White Knight and Polar Express about August 5 to August 10 would provide harvest late-October or early-November in the Connecticut Valley. In colder areas of Litchfield and Windham counties, a second planting seems too risky because of killing frosts.

Despite the fact that cauliflower is more temperature sensitive than other members of the genus Brassica, I have shown that plantings for spring and fall harvest can produce abundantly for both the commercial grower and home gardener. Therefore, it seems that the aristocratic nature of cauliflower lies not in its demand for attention but in its tasty and nutritious qualities.

Bacterial pesticide sprayed by helicopter controls gypsy moth in Ledyard

By John F. Anderson

When control of the gypsy moth is desired on a small lot, infested trees are often sprayed during mid-May to mid-June. Usually, a chemical insecticide, such as carbaryl (Sevin), is applied from the ground. *Bacillus thuringiensis (B.t.)*, a bacterial insecticide which kills small gypsy moth caterpillars but does not harm humans, domestic animals, birds, or bees, may also be used.

If 10 or more acres are to be sprayed, aerial application is the most efficient and economical method. In Connecticut, *B.t.* is the only insecticide approved for application to forested land from the air.

In the early 1980s, Station scientists in collaboration with the U.S. Forest Service demonstrated that either one or two applications of *B.t.* applied by helicopter to small plots could control gypsy moths. These experiments indicated proper timing and dosage to achieve satisfactory results, and they revealed the lack of serious effects of the spraying on natural enemies.

Although large areas of the state are no longer sprayed by air, the Experiment Station has participated several times in recent years in a practical trial of aerial spraying in the Town of Ledyard in southeastern Connecticut.

In 1986, the Station's participation began with a request in July 1985 from the Mayor of Ledyard for a survey of woodlands for egg masses of the gypsy moth in accordance with Connecticut General Statutes 22-91b. This survey, which was completed December 3, 1985, revealed that about 11,200 acres were infested with gypsy moth eggs. At a meeting on January 9, 1986, the Station reported to the Mayor, other town officials, and interested citizens that gypsy moths would be numerous enough throughout Ledyard to cause severe defoliation in the spring of 1986. The town then decided to assist citizens with an aerial spray program and hired a person to obtain the necessary permits and to coordinate the program. Citizens of the town signed a contract with a helicopter spray company from Gettysburg, PA.

Permits for aerial spraying with *B.t.* were issued by the Commissioner of Environmental Protection for 44 different neighborhoods and one state park in Ledyard. The Station helped calibrate application by the helicopters, suggested dates of application based on the growth of the caterpillars, supervised the mixing and loading of the *B.t.*, marked critical boundaries of spray areas with helium-filled balloons, assessed effectiveness of the treatment, and served as a liason between the spray company and the town.

The selected neighborhoods were sprayed twice with *B.t.* (Dipel 8L, Abbott Laboratories). Spraying commenced on May 21 when all caterpillars were in the second stage of growth (about 1/4 inch long), and was completed on May 24 when third stage caterpillars (almost 1/2 inch long) were appearing. Three helicopters sprayed a total of 2200 acres. The second application began on May 29 when most caterpillars were in the third stage and was completed May 31. *B.t.* was applied at the rate of 12 BIU (1 1/2 pints) per acre mixed with water containing 1.3% Bond Sticker Extender (Loveland Industries, Inc.) to give a final volume of 1 gallon.

Although specific counts were not taken, areas treated with *B.t.* had fewer caterpillars than adjacent untreated areas, and the foliage on trees was protected from being severely defoliated. Later, the State Entomologist, conforming with Connecticut General Statutes 22-91e, certified to the Connecticut Finance Advisory Committee that an emergency had existed in Ledyard because of the prevalence of the gypsy moth, and the citizens of Ledyard thus became eligible to receive a modest sum of money from the State to defray some of the cost of spraying.

Although this was a relatively modest program, it shows that spraying with a biological insecticide was a practical option for those who wanted to reduce the nuisance caused by the caterpillars and protect foliage on their trees.

Suggested Reading

Andreadis, T.G., N.R. DuBois, R.M. Weseloh, R.E.B. Moore, J.F. Anderson, and F.B. Lewis. 1982. Aerial spray tests with *Bacillus thuringiensis* for control of the gypsy moth in Connecticut. Conn. Agric. Exp. Stn. Bull. 807. 5p.

Andreadis, T.G., N.R., DuBois, R.E.B. Moore, J.F. Anderson, and F.B. Lewis. 1983. Single applications of high concentrations of *Bacillus thuringiensis* for control of gypsy moth (Lepidoptera:Lymantriidae) populations and their impact on parasitism and disease. J. Econ. Entomol. 76:1417-1422.

Hemlock woolly adelgid may also attack spruce

By Mark McClure

Two scale insects from Japan have been slowly killing Eastern hemlock, (*Tsuga canadensis* Carriere), in southwestern Connecticut for 70 years, but a new insect recently joined them and is threatening to greatly hasten the decline of this tree species.

The insect is the hemlock woolly adelgid, *Adelges tsugae* Annand, (Fig. 1), so named because it covers itself and its eggs with a white, woolly substance. It was not found in Connecticut until 1985, but it now inhabits the southern half of the state and is spreading rapidly. The adelgid is a small insect that damages trees by sucking sap from the branches. Like the two scale insects, it is believed to be a native of Asia.

Until now, the adelgid was thought to occur only on hemlocks and to have a simple wingless, parthenogenetic (composed only of females) life cycle with only one generation per year. My studies, however, have shown that the adelgid has a complex life cycle, which involves several generations per year and previously unknown life stages including a winged migratory form and both males and females (See cover).

I found the crawlers that hatch from eggs laid by overwintering females are not inactive in the spring as previously reported. Instead, they develop into two distinct forms. About half develop into wingless parthenogenetic females nearly identical to their mothers. The other half develop into a previously unknown winged migratory stage (Fig. 2).

Discovery of this winged stage has created new questions to answer. In all known adelgids that produce winged forms, part of their life cycle must be completed on spruce; an example is the Cooley spruce gall aphid, which migrates between spruce and Douglas fir. If the adelgid could survive and reproduce on spruce in Connecticut, its ability to attack hemlock could be magnified because some of the adelgids that develop on spruce could migrate back to hemlock. Therefore, I began looking for spruces upon which this winged form could survive.

I conducted my studies at two sites where both winged and wingless forms of the adelgid were being produced during 1986.

One site in Essex was in a mature forest composed mostly of hemlock. Although the infestation had begun only 2 years before, I found the hemlocks heavily infested with the adelgid. I began monitoring development of the adelgid each week starting in March 1986. In May, before the winged migratory adults developed, I planted eight

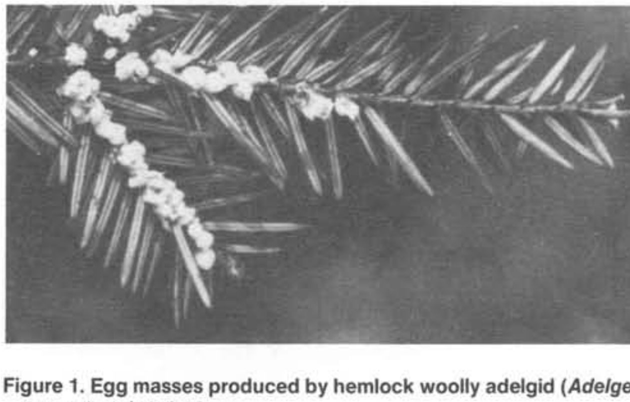

Figure 1. Egg masses produced by hemlock woolly adelgid (*Adelges tsugae*) on hemlock.

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The annual Plant Science Day open house will be held at Lockwood Farm in Mt. Carmel on Wednesday, August 12 from 10 a.m. to 4 p.m.

species of spruce (Picea) in the forest. On June 11, I placed infested hemlock branches at the base of each tree to ensure that the winged adults had the opportunity to colonize them. The species were: *P. abies* Karsten (Norway); *P. engelmannii* Parry (Engelmann); *P. glauca* Voss (White); *P. jezoensis* Carriere (Yezo); *P. mariana* Britton (Black); *P. pungens* Engelmann (Colorado); *P. rubens* Sargent (Red); and *P. sitchensis* Carriere (Sitka).

The other site was at the Montgomery Pinetum in Greenwich, which is a 125-acre park where more than 80 species and varieties of conifers from around the world are growing. The Eastern hemlocks, which abound in the surrounding forest and grow throughout the park, were heavily invested with the adelgid. The species of spruce were: *P. abies* Karsten (Norway); *P. asperata* Masters (Dragon); *P. glauca* Voss (White); *P. heterolepis* Rheder and Wilson (Red twig dragon); *P. orientalis* Carriere (Oriental); and *P. pungens* Engelmann (Colorado). The foilage of some spruce trees actually touched infested hemlocks.

On July 15 and August 12, I sampled branches from the eight species of spruce I had planted in Essex and on July 16 from the six species in Greenwich that were growing within 20 meters of infested hemlocks.

I found winged adelgids had laid eggs on each of the 11 spruce species, but no crawlers that hatched survived for more than a few days. I also observed a few winged adelgids on hemlocks after the migration period, but all died without producing eggs. Although the winged form of the adelgid does not appear important in damaging hemlocks, the wingless adelgids of the second generation produced about 10 offspring each and therefore had more than compensated for the loss of the winged adelgids that failed to survive.

Although the winged form of the adelgid is not likely to become a pest of the 11 native and exotic spruces I tested, the fact that it exists is significant because the winged form may eventually encounter susceptible spruces on which it can survive.

Regardless of whether I actually found a new form of the adelgid or whether its existence was a well-kept secret for 65 years, my discovery may drastically alter our approach to controlling this pest. The pesticides used to control the adelgid and schedules for their application, which have mainly targeted crawlers hatching in the spring or adults maturing in the fall, will need to be changed to include the second wingless generation, and perhaps their descendants on spruce as well.

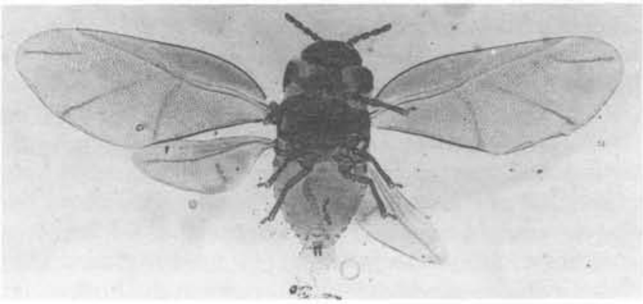

Figure 2. Winged migratory adult of hemlock woolly adelgid.

The Connecticut Agricultural Experiment Station, founded in 1875, is the first experiment station in America. It is chartered by the General Assembly to make scientific inquiries and experiments regarding plants and their pests, insects, soil and water, and to perform analyses for State agencies. Subscriptions are available free upon request to Publications; Box 1106; New Haven, Connecticut 06504

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