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A portion of a poster illustrating the damage and life cycle of the pine scale in China. See articles beginning on Page 2.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION   NEW HAVEN

China explored for natural enemies of pest insects

By Paul Gough

Two serious pests of forest trees in Connecticut, the gypsy moth and the red pine scale, were accidentally introduced. The gypsy moth is well-known, having entered this country in 1869 near Boston. It reached Connecticut in 1905. Since 1950, it has periodically defoliated tens of thousands of acres. The red pine scale, which is less well-known, was discovered in Easton, CT in 1946. It is a sap-feeding insect that attacks the branches of red pines, causing them to become cracked and distorted, and kills the tree within 10 years.

Neither insect had many natural enemies in its new land, so control efforts have included a search for natural enemies in areas where the insects are native. The gypsy moth is native to Japan and Europe, and the red pine scale is native to Japan. These areas have been carefully explored for natural enemies of the gypsy moth and promising ones have been imported. China, however, had never been similarly explored.

Two station entomologists, Ronald M. Weseloh and Mark S. McClure, were invited by the Chinese and American governments to be members of two separate scientific teams that visited China in Spring 1982. The Board of Control granted the two scientists sabbatical leaves, and the Connecticut Nurserymen's Association aided Dr. McClure. Each team studied the pests and their natural enemies in China. The map shows the areas each explored (Figure 1).

The red pine scale is restricted to pines that have been planted on watersheds, in forests, and for landscaping in Connecticut and several contiguous states south of the tree's natural range. McClure's studies show that no pines are resistant to the scale and that the native predators that inhabit our forests are ineffective biological control agents.

The gypsy moth is more visible than the red pine scale, but its effects on tree mortality are usually much less. Station studies show that few trees are killed directly by defoliation. Severe defoliation several years in a row, however, will weaken a tree, which can then be attacked and killed by pathogens or other insect pests. Station studies document a shift in the dominant forest species from oak to maple, a trend which has been accelerated by the periodic defoliation caused by the gypsy moth.

Weseloh was in China from May 13 to July 9. Other members of his team were Paul Schaefer of the U.S. Dept. of Agriculture Beneficial Insects Laboratory in Newark, DE and William Wallner of the U.S. Dept. of Agriculture Forest Service Biological Control Laboratory in Hamden.

McClure was in China from May 8 to June 4. Other members of his team were Donald Dahlsten of the University of California (Berkeley), Gary DeBarr of the U.S. Dept. of Agriculture Forest Service in Athens, GA, and Roy Hedden of Clemson University.

The two reports that follow summarize their studies in China.

Figure 1. Map of the portions of the People's Republic of China explored for natural enemies of the gypsy moth (circles) and the pine scale (triangles).

Lady beetle attacks red pine scale

By Mark S. McClure

Matsucoccus matsumurae (Kuwana), believed to be the same insect as the red pine scale, *M. resinosae*, was introduced into mainland China from Japan about 40 years ago. It is a serious pest of Masson pine, *Pinus massoniana*, and Chinese pine, *Pinus tabulaeformis* along an 800-mile stretch of China's eastern coast. Unlike in the United States, there are several predators in China, primarily lady beetles and lacewings, which together cause substantial mortality of the scale. Chinese reports of effective predators of pine scale in an area with climate similar to that of New England, sparked my interest in China as a source of predators for introduction into Connecticut.

I met with 19 scientists who work on pine scale and visited 12 infested forests, parks and botanical gardens throughout eastern China. I sampled three pine stands at the northern edge of the infestation in Liaoning Province, where the climate is similar to that of Connecticut, and three at the southern edge of the infestation in Zhejiang Province, where the climate resembles that of northern Florida, to determine the effects of winter and summer temperatures on the spread of the scale (Figure 1).

In Liaoning Province, where the average length of the frost-free season is 160 days and where the minimum temperature in winter sometimes reaches −23°C (−10°F), 96% of the scales were killed by the cold. In Zhejiang Province, where maximum temperatures exceeding 40°C (105°F) are common in summer, up to 90% of the scales were killed by the heat. Clearly winter and summer temperatures are restricting the northern and southern spread of the pine scale in China.

During the past decade, the Chinese government has launched an intensive control program against pine scale using education and mobilization of the public. Television programs and colorful posters distributed throughout the country illustrate the life cycle of the scale, its injury to pine trees, and beneficial predators (Cover and Figure 2). They warn of the dangers of transporting scale-infested branches and logs and of harvesting practices which render the forest less suitable for predators. Communes are encouraged to integrate various control practices including injecting infested trees with insecticide, rearing and releasing beneficial predators, and replanting devastated areas with scale-resistant pine species.

Laboratory-reared lady beetles have been released in several forests in China

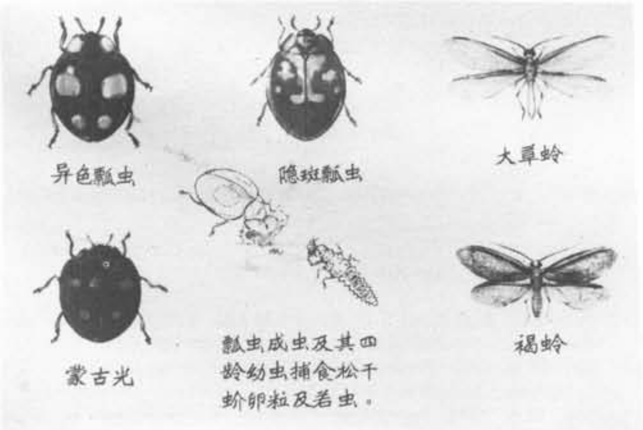

Figure 2. A portion of a Chinese poster illustrating lady beetle and lacewing predators of pine scale. Clockwise from lower left are: *Exochomus mongol* Barovsky; *Harmonia axyridis* (Pallas); *Ballia obscurosignata* Liu; *Chrysopa septempunctata* Wesmael; and *Symphyrobius matsucoccusphagus* sp.n. In the center are adult and larval beetles consuming scales.

Figure 3. Portion of a poster illustrating the technique for injecting insecticide to control pine scale. The bark is punctured at the base of the tree and several holes are filled with an insecticide delivered from a squeeze bottle.

The most widely used method of insecticide application involves poking small holes 10 cm (4 in.) apart around the base of the tree with a hammer-like tool and then filling each hole with 1 to 2 ml of dimethoate (40%) from a squeeze bottle (Figure 3). Injection, which consistently kills 70–90% of the scales is practical, even in large forested areas, because of the massive labor force in China. This method would be impractical in Connecticut because of the expense of injecting large acreages of red pine and the proximity of infested trees to public water supplies.

Although chemical control of pine scale has been somewhat successful in China, the main effort has concentrated on biological control. Of the more than 30 insect predators of pine scale reported in China, two species, *Elatophilus nipponensis* Hiura and *Harmonia axyridis* Pallas, both native to Japan, appear to be most effective. Scale mortality from these predators up to 70% has been reported.

The effectiveness of *E. nipponensis*, an anthocorid bug, has been attributed to its flattened shape which allows it to search efficiently in cracks and crevices in the bark where the pine scale feeds. Difficulty in rearing this predator, however, has severely limited its use in biological control programs. On the other hand, numerous facilities throughout eastern China are successfully rearing the lady beetle, *H. axyridis*. I observed a small rearing facility at the Zhejiang Provincial Forestry Research Institute where 50–100 adult beetles were being produced daily on an artificial diet consisting of pig liver, yeast and honey.

Laboratory-reared lady beetles have been released in several forests in eastern China. In several of these forests I observed large numbers of lady beetles feeding voraciously on all life stages of pine scale. Because of its voracity as a predator of *Matsucoccus*, its three to four generations per year, and its ability to overwinter in northern China where the climate is similar to that of Connecticut, I am now rearing *H. axyridis* at the Experiment Station in New Haven and eventually hope to introduce it into Connecticut (Figure 4). Releasing this lady beetle in the United States is no threat to the environment since it only feeds on aphids and scales, none of which are beneficial.

I am using pea aphids *(Acrythosiphon pisum)* (Harris), living on fava bean plants, to rear larvae and adults of *H. axyridis*. Maintained at 27°C (80°F) in 16 hours of light to simulate summer, seven or more generations are possible each year. With each adult female producing as many as 1000 offspring, beetles can multiply rapidly. Because a single beetle can eat thousands of aphids, maintaining the proper balance between aphid and beetle numbers is crucial to success in laboratory rearing.

Despite considerable effort expended by the Chinese during the past 10 years to rear, release, and observe predators of *Matsucoccus*, there is little documentation of the effectiveness of any one of these predators as biological control agents. I am now conducting experiments to determine the ability of *H. axyridis* to control pine scale populations and to survive Connecticut winters. I have caged young beetles with scale-infested red pines in the laboratory and have determined these beetles can feed on scales, complete their development and reproduce.

In China *Matsucoccus* has invaded and devastated large natural growing areas of pine. Although damage in the United States has been less severe, because the infestation occurs south of the natural range of red pine, the scale continues its relentless spread northward. Control of pine scale and the vitality of red pine in North America may well depend upon the successful establishment of predators such as *H. axyridis*.

Figure 4. Lady beetle predator, *Harmonia axyridis*, reared at Experiment Station.

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Gypsy moth has many natural enemies

By Ronald M. Weseloh

Some gypsy moth natural enemies found in Europe and Japan have been imported into the United States, including Connecticut. Those that have been established include six small, harmless, wasp-like insects and four flies which develop as parasites in gypsy moths, one large beetle that preys on gypsy moth larvae and pupae, and a virus disease that causes caterpillars to "wilt" as they die and often ends outbreaks such as the recent one in Connecticut. China had never been explored for natural enemies although the gypsy moth is native there. Therefore, information on effective natural enemies there could help control the gypsy moth here.

We collected gypsy moth larvae at each location we visited, noting their size, appearance, activity, abundance, food, and habitat. Over 8000 caterpillars were reared on cut tree leaves in paper boxes (Figure 5) and any parasites that emerged were removed. We also observed and collected predators that attacked gypsy moths in the field, and tested sex attractant traps at two locations to see if gypsy moth males in China respond to the same synthetic attractant as in Connecticut.

Foresters in the regions we visited told us that the gypsy moth had been a problem in 1964–65, around 1974, and in 1980–81. The last infestation was the most severe, with thousands of acres defoliated. It is an intriguing coincidence that tens of thousands of acres were also defoliated in Connecticut at the same time.

Gypsy moths in China are similar to those in North America in some ways and very different in others. On both continents, small larvae are found mostly on tree leaves and large ones hide in bark crevices, under loose bark, in cavities under stones, or in leaf litter during the day and feed on leaves at night. In both places leaves of oak and other deciduous trees are favored food. Also, males from both lands respond to the same sex attractant.

Caterpillars varied more in color patterns in China than in North America (Figure 6). About 1 in 100 Chinese gypsy moth larvae have a wide, dark band down the back, which is never present on caterpillars in North America. The colors and the detailed patterns of spots on caterpillar's backs also vary from place to place. For instance, larvae collected in the Northeast Provinces often have, in additional to the usual red and blue spots of North American caterpillars, a line of irregularly-shaped yellow or orange splotches on their backs. Those around Beijing lack these splotches and are generally similar to North American caterpillars in color, except that some large caterpillars have very dark heads. Such variations are expected in the insect's native home, where thousands of generations have increased genetic variability. In North America, where only about 112 generations have occurred, not enough time has elapsed for similar variation to develop.

In North America, female moths cannot fly although they have well-developed wings. After emerging from the pupal case they mate, lay eggs, and die without moving far. Thus, most eggs are deposited on the trunks of trees where caterpillars change to the pupal (resting) stage. The situation in China is different. There, as in Japan and parts of the Soviet Union, females are capable of powerful, sustained flight even when they have a full complement of eggs. They are attracted to outdoor lights at night and lay many eggs on nearby buildings and posts. Away from buildings, most females lay eggs in crevices of rock outcroppings on hillsides rather than on trees as in North America.

Parasites ranged from small, stingless wasps to large parasitic flies.

We found many natural enemies of the gypsy moth in China, and reared twenty-two different parasites from the collected caterpillars. These ranged from small, stingless wasps to large parasitic flies, some of which are already established in Connecticut.

One of these is *Cotesia melanoscelus*, a parasite I have studied extensively. It was much rarer in China than in Connecticut. Another is *Parasetigena silvestris*, a tachinid fly which lays large eggs on caterpillars. *Parasetigena*

Figure 5. Gypsy moths were reared in paper boxes or plastic bags and fed oak leaves until natural enemies emerged.

was abundant in China, and I saw many gypsy moth larvae with eggs on their bodies. A near relative of *Cotesia* called *Glyptapanteles liparidis* was also found. *Glyptapanteles* has been imported from Europe and Japan and released in the United States many times. It has never become established because important alternate hosts, such as the pine caterpillar, which help the parasite survive the winter, are not present in North America. The pine caterpillar is related to the gypsy moth, and we observed many *Glyptapanteles* which had overwintered in it and then attacked gypsy moth larvae in the spring. The pine caterpillar is the most important forest pest insect in China, periodically defoliating larch and pines. Because it is a serious pest, the pine caterpillar cannot be imported as an alternate host for *Glyptapanteles* in the United States. Without the pine caterpillar or a similar host, however, it is unlikely that *Glyptapanteles* can be established in Connecticut.

The most unusual parasite we found was the roundworm called *Hexamermis*. Mature females several inches long emerge from caterpillars and coil up like springs. They enter the soil to complete development. This parasite was rare.

We found 10 predators. These were mostly assassin bugs, stink bugs, and ground beetles; but one spider was also taken. Two of the ground beetles are closely related to the "caterpillar hunter," *Calosoma sycophanta*, which is abundant in Connecticut. Other predators noted were different from those now established.

Diseases found included the same virus which causes the "wilt disease" of caterpillars in Connecticut and a fungus, whose scientific name is *Erynia (Entomophthora)*, which forms a whitish "bloom" over caterpillars when they die. *Erynia* is not abundant on gypsy moths in North America. In China, both diseases were abundant in some areas and may have limited the severity of outbreaks.

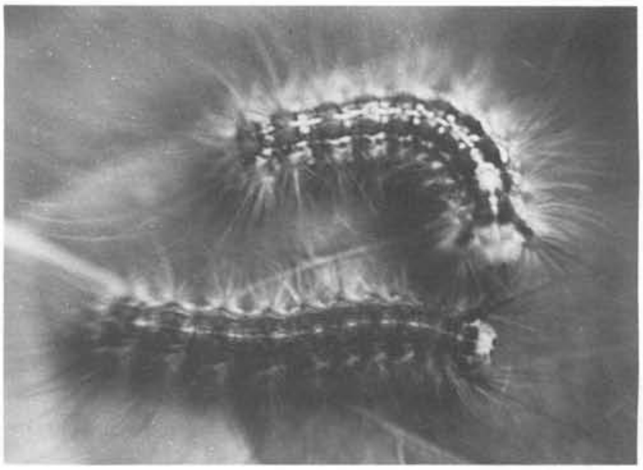

Figure 6. The caterpillar from Heilongjiang Province (top) is much lighter than the one from Beijing (bottom), which is similar to a caterpillar from Connecticut.

The natural enemies we found in China differ little from those previously known in Japan and Europe. Although there were no surprises and no immediate solutions for controlling the gypsy moth from this exploration, our Chinese colleagues seem interested in future cooperative work and our information should be a foundation for further studies in China and Connecticut that may lead to new ways of controlling the gypsy moth.

Tests show variability in potting mixes

By Gregory J. Bugbee and Charles R. Frink

Most people have probably purchased a package of potting soil to start seedlings, grow their favorite house plants, or perhaps even provide some fresh fruits or vegetables. Some have undoubtedly been disappointed when the seeds rotted or the plants died. Although other factors can hinder the growth of plants, the potting soil certainly can. Hence, in cooperation with the Connecticut Department of Agriculture, we surveyed the quality of potting soils sold at retail in Connecticut.

Fifty-one samples were purchased by an agricultural inspector during Summer 1982. Thirty-three were sold as general potting soils, nine as soil for African violets, seven as soils for cacti, and two as soil for orchids or bulbs. For comparison, we also tested two mixes used by commercial growers as well as a fine sandy loam soil typical of backyard gardens.

We measured various physical and chemical properties of the mixes

Plants grown in pots must cope with conditions different from those in the field. There is no reservoir of soil beneath the pot to absorb or release water in response to the vagaries of weather. Similarly, excess water leaches nutrients from the pot while too little water permits salts to accumulate. Finally, the limited volume of the pot often produces a dense root system that requires adequate aeration.

To provide adequate air and water, potting soils are usually mixed with bulky materials such as peat, bark or wood chips, vermiculite, perlite, and even inert plastics such as styrofoam. Many commercial growers have eliminated soil completely from their mixes to reduce soil-borne insects and plant diseases. Still, such mixtures are called potting soils or potting mixes although they contain no soil.

In our tests, we measured various physical and chemical properties of the mixes, and also observed the germination and growth of lettuce seedlings in plastic cubes used for starting seeds. Although little information is available on the requirements of specific house plants, we assumed that the same soils will be favorable or unfavorable for many species. Also, our results may not be identical with the growth of mature plants in pots over long periods of time, but they do indicate the relative quality of the mixes.

The most important physical properties of a mix are the total pore space that can be occupied by air or water and the amounts of air and water in these pores that are available to plants as the mix dries. The total pore space of potting mixes is determined by the bulk density (i.e., the weight per unit volume) of its constituents: mixes light in weight are more porous than those that are heavier. The bulk density of the mixes we sampled varied from about 7 lbs/ft^3 to 56 lbs/ft^3, with a median of 24 lbs/ft^3. For comparison, the mineral soil weighed about 79 lbs/ft^3. The pore space of the mixes ranged from 61% to 95% (percent by volume) with a median of 80%. The mineral soil had less than 50% pore space.

The amount of organic material in a mix is often considered an indicator of pore space: in the mixes we tested, organic matter varied from less than 10% to more than 90%. However, we found that pore space actually decreased in mixes containing more than about 50% organic matter. This was due to an accompanying decrease in materials such as vermiculite, perlite and styrofoam that apparently are more effective in increasing pore space. The extent of decomposition of the organic matter is also important. We separated the mixes with more than 20% organic matter into two categories. "Sapric" organic matter is fine-textured, black, and highly decomposed: swamp muck is a typical example. "Fibric" organic matter is coarse-textured, brown, and not highly decomposed: sphagnum peat moss and bark chips are good examples. We found less pore space in mixes with highly decomposed sapric materials than in mixes with less decomposed fibric materials.

The ability of a mix to provide air and water is controlled by the distribution of pore sizes: large pores drain readily and are usually filled with air, while medium-sized pores hold water available for plants. Small pores hold water so tightly that it is generally not available; hence, plants wilt more readily in mixes with many small pores.

The air in pores after the pots have been saturated with water and allowed to drain is known as air at container capacity. Similarly, the water present is known as water at container capacity or simply total water. As the pots dry, the suction (or negative pressure) required to remove water increases. Since plants generally show signs of moisture stress when the suction required reaches about 4.5 lb/in^2, the water held between container capacity and this suction is called available water.

The air in the mixes at container capacity varied from 5 to 30%, with a median of 7.7%. Since the optimum is thought to be 10 to 20% air, many mixes were likely not well aerated. The water available to plants varied from 22 to 60%, with a median of 43%. More important, the potting soils that held the maximum available water tended to range from 10 to 20% air at container capacity. Thus, the mixes with good aeration also had the most available water.

A practical concern in watering potted plants is the rate in inches per hour that water infiltrates into the pot. In the mixes we tested, the infiltration rate varied from nearly instantaneous (635 in/hr) to nearly impervious (5 in/hr), with a median of 29 in/hr. At the median rate, a typical watering of 1 inch would infiltrate in two minutes.

The chemical properties of the mixtures were nearly as variable as the physical properties. The pH varied from 4.3 to 7.3, and the nutrient status as measured by the Morgan soil test varied from near deficient to near excess. Although the concentration of soluble salts is often thought to be high in potting soils, our survey revealed none contained enough salt to be toxic. Similarly no heavy metals were present in concentrations toxic to plants. We included these analyses in our tests because sewage sludge, which is often high in metals such as zinc, copper, nickel, and cadmium, has been used in commercial potting mixes. The low concentrations of these metals indicates that sewage sludge was not likely a major ingredient in the mixes we examined.

Figure 1. Different growth rates of lettuce in various potting soils. Differences best correlated with soil nitrate nitrogen and available water.

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The ultimate test of a potting soil is its ability to support the germination and growth of plants. In our mixes, the average germination of lettuce was about 70%. In a standard seed germination test, 96% of this particular lot germinated. The seeds germinated best in mixes with the highest total water holding capacity. This does not mean that the mix should be water-logged and poorly aerated, since seeds failed to germinate in the mineral soil with only 4.4% air at container capacity. Two samples had weed seeds that germinated in our tests. The only disease observed was a root-rotting fungus in the wet mineral soil.

Yields of lettuce also varied widely as shown by the range of growth in representative mixes in Figure 1. The best predictors of yield were soil-test nitrate and available water. As nitrate and available water increased, the yield also increased. Indeed, nearly half the variability in yield can be accounted for if these two factors are combined in a statistical analysis of the data.

Despite the acidity of many of the mixes, there was no significant correlation between pH and yield. Acidity affects plant growth in two ways: one is the direct effect of the acid hydrogen ions, and the other is the indirect effect of acidity on the availability of nutrients and toxicity of other elements in the soil. General agronomic experience shows that most plants grow best between pH 5.5 and 7.0. The lack of metal toxicity in these potting soils with pH as low as 4.3 may be due in part to their higher content of organic matter, which reacts with metals and reduces their toxicity.

As a result of this survey we found the quality of potting soils sold in Connecticut is highly variable. Soils ranged from heavy muck-like soils that were low in aeration and available water, to mixes with sphagnum peat, vermiculite, perlite, or bark chips that were well aerated and high in available water. Some soils were not sterilized as indicated by weed seeds, although none appeared to harbor plant pathogens. Many soils were low in fertility, and the pH of many was lower than thought to be optimum. Few differences were evident between general potting soils and those labeled for cacti or African violets. Lettuce germinated best in porous mixes with high moisture holding capacity, and also grew best in those mixes provided adequate nitrogen was present.

A complete report on the analyses of potting soils is available in Bulletin 812, Quality of Potting Soils, available free from Publications, The Connecticut Agricultural Experiment Station, P.O. Box 1106, New Haven, CT. 06504.

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