Temperature alters population dynamics of common plant pests

August 1 2013

This is a tea tortrix larva on tea leaf. Credit: Hiroshi Suenaga, a Kagoshima entomologist

Temperature-driven changes alter outbreak patterns of tea tortrix—an insect pest—and may shed light on how temperature influences whether insects emerge as cohesive cohorts or continuously, according to an international team of researchers. These findings have implications for both pest control and how climate change may alter infestations.

"While the influence of temperature on individual-level life-history traits is well understood, the impact on population-level dynamics, such as population cycles or outbreak frequency is less clear," the researchers report in today's issue of *Science Express*. Researchers currently use temperature to predict the number of generations that appear each year and the timing of the various insect life stages, which is critical for scheduling pest control.

"While we had a really good record of temperature and the number of cohorts that appeared each season, we had no clear understanding of the difference between distinct and continuous reproduction," said Ottar N. Bjørnstad, professor of entomology, biology and statistics, Penn State. "Understanding the timing of generations is important because typically insecticides work only during one or two of the life stages of these pests."

The researchers looked at more than 50 years of data on the tea tortrix and also developed an independent mathematical population model that can predict population dynamics under both constant and seasonally driven temperature regimes.

While the tea tortrix is native to Japan, many similar moths exist in North American including the spruce bud moth, grape berry moth, light brown apple moth and summer fruit tortrix.

The researchers, who also include William A. Nelson, associate professor of biology, Queens University, Canada, currently on sabbatical at Penn State, and Takehiko Yamanaka, senior researcher, National Institute for Agro-Environmental Sciences, Tsukuba, Japan, used long-term data on the population dynamics of the tea tortrix that span 51 years and more than 200 outbreaks. The data were collected every five days at the Kagoshima tea plantation in Japan.

These are tea leaves showing curling and predation by the tea tortrix. Credit: Hiroshi Suenaga, a Kagoshima entomologist

This type of insect remains dormant during the winter and emerges once the temperature reaches a certain level in the spring. Because the first generation is triggered by this temperature increase, the insects emerge all at once.

"We found the tea tortrix data very interesting," said Bjørnstad. "Often in North America we have one or two discrete early cohorts because winter synchronizes them and later, we find a background of multiple generations at all times."

The tea tortrix starts out in this way, but the researchers found that desynchronization does not occur. Through the warm season, outbreaks become more and more synchronous and distinct from each other.

"When the temperatures are high, the reproduction rate is high and the developmental rate of the tea tortrix is high," said Bjørnstad. "The population grows very fast and becomes unstable. Above a certain temperature, the population numbers overshoot the carrying capacity and the population crashes. After a bit, another generation comes in."

To better understand how temperature influences tea tortrix and other insect populations, the researchers developed a mathematical population model that is based on the insect life cycle and the effects of temperature on individual stages, and used this to predict population dynamics.

"The model is developed to represent the biology of the insect," said Nelson. "It is realistic, fully developed and parameterized independently of the field data."

This is a tea tortrix moth on leaf. Credit: Hiroshi Suenaga, a Kagoshima entomologist

The model is based on laboratory data and is fully independent of the Japanese data set.

"We speculated that temperature might do something to population dynamics," said Bjørnstad. "We documented that temperature itself is destabilizing to the dynamics of this pest. This is the first clear demonstration that temperature has the ability to alter those dynamics, causing large cycles in the insect."

The researchers believe that these mechanisms have implications for what might happen faced with global warming. The cycles of infestations may become more violent and more frequent.

Provided by Pennsylvania State University