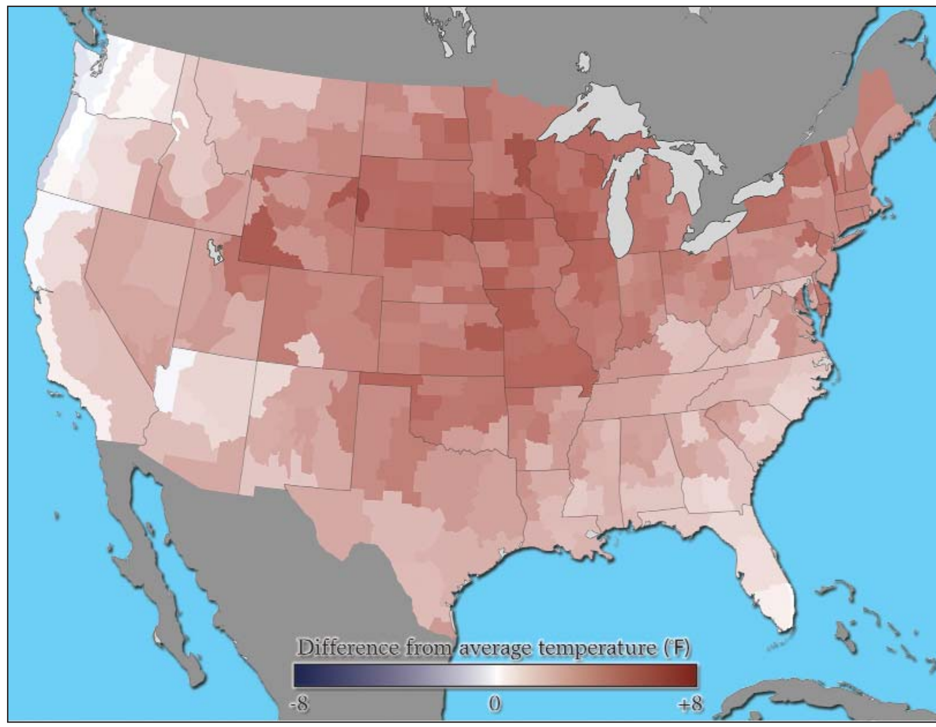
HOT TIMES in the URBAN FOREST: Climate Change and What It Means for Insect Pests

By Michael J. Raupp, Ph.D.

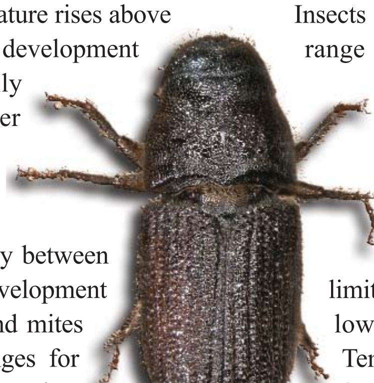


According to the latest statistics from NOAA's National Climatic Data Center, the average temperature for the contiguous United States for 2012 was 55.3 F, which was 3.2 F above the 20th-century average and 1 F above the previous record from 1998. The year consisted of the fourth-warmest winter, a record-warm spring, the second-warmest summer, and a warmer-than-average autumn.

For many regions of the United States, 2012 was remarkable weather wise because it was the warmest year in recorded history. While the causes for global warming and man's contribution to these changes remain the topic for debate, there is general agreement in the scientific community that the temperature of the world is increasing, particularly so in land regions of the Northern Hemisphere (Hansen et al. 2006). This warming trend will have profound effects on animals and plants around the globe.

Temperature regimes drive patterns of rainfall, humidity and soil moisture. Insects and mites that attack trees and shrubs are dependent on many environmental conditions, but temperature is one of the prime movers of their development and activity. Insects and mites are ectotherms; that is, they depend mostly on ambient temperatures to warm their bodies and power the processes of growth, development, reproduction and movement. For insects and mites there exists a lower developmental temperature, a lower threshold, below which growth and development cease. As temperature rises above this threshold growth, development and activity generally increase until an upper threshold is reached above which continued exposure results in death.

This strong dependency between temperature and the development and activity of insects and mites portends important changes for plants and insects in a warming world. While no one can predict the exact outcome of climate change on pests and their damage, this article explores some of the patterns and processes associated with climate change that are already underway.



Mountain pine beetle. Photo by Javier Mercado, Colorado state University, Bugwood.org

Range expansions of pests

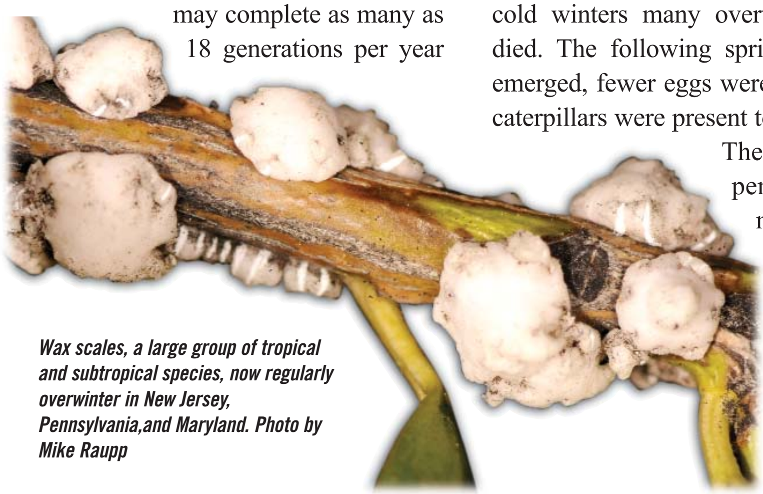
Insects are adapted to exist within a range of ambient temperatures. Some can withstand the heat of desert environments while others thrive in the chill of frigid glaciers. However, the geographic range of many insects is limited by their ability to endure low hibernal temperatures. Temperatures below a critical lower threshold kill overwintering stages of insects and prevent them from inhabiting regions at higher latitudes and altitudes even if their host plants are present. As temperatures have risen, range expansions and outbreaks of insects have been observed in forest pests such as winter moth in Europe, and spruce budworm in North America (Klapwijk et al. 2012).

The unprecedented outbreaks of mountain pine beetle in Canada and the western United States are thought to be related to warmer winters that lack cold snaps lethal to overwintering pine beetles. As a result, mountain pine beetles are marching into coniferous forests further north and those higher in elevation on mountainsides that were once uninhabitable due to lethal cold temperatures (Klapwijk et al. 2012). There is a growing concern that the mountain pine beetle will escape the confines of western North America and become an important pest in central and eastern forests as it shifts from western lodgepole pines to forests dominated by jack pine (Klapwijk et al. 2012).

In recent years, sightings of southern insect pests have occurred with alarming regularity in northern states. Several species of wax scales, *Ceroplastes spp.*, regular denizens of the Deep South (Johnson and Lyon 1988), now overwinter successfully in northern states including Maryland, New Jersey and Pennsylvania where they infest and damage a wide variety of landscape plants (Stimmel 1998, Raupp 2009).

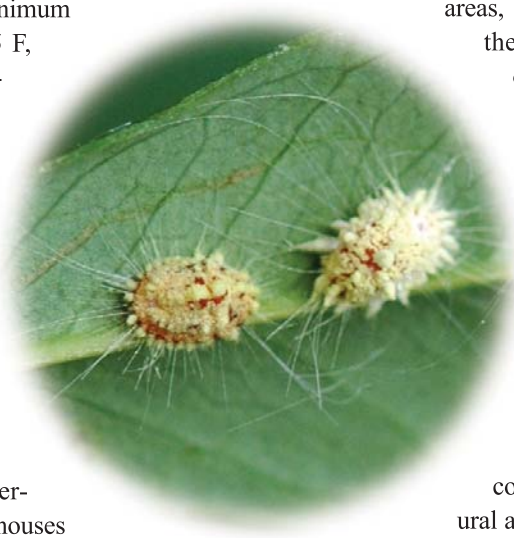
Cottony cushion scale, a serious pest of fruit crops and landscape plants in warm regions of Australia and New Zealand, was accidentally introduced into the United States in the 1860s where it became a major pest of citrus. This pernicious scale insect typically resides in southern states including California and Florida, but in 2008 it was observed in Washington, D.C., and Maryland on elm, holly and nandina in landscape plantings. Its appearance early in the growing season suggests that winters are now mild enough in parts of the mid-Atlantic region to permit survival of cottony cushion scale at least in some years (Gill et al. 2008).

Chili thrips, a tropical and subtropical pest, was first detected in the continental United States damaging roses in Florida in 2005, but it has now spread across states bordering the Gulf of Mexico. Chili thrips is known to feed on more than 100 species of herbaceous and woody plants including camellia, cherry, holly, oak, pear, photinia, pieris, pittosporum, pyracantha, rhododendron, rose and viburnum (Osborne 2011). A recent study suggested that Chili thrips may complete as many as 18 generations per year in warm states including Florida and California. In cooler states to the north, fewer generations are predicted and in regions that experience five or more days with a minimum temperature of ~ 25 F, chili thrips is unlikely to survive (Nietschke et al. 2008). However, in spring of 2012, chili thrips was detected damaging hydrangea on Long Island, New York. Although the hydrangea had overwintered in hoop houses prior to discovery of the thrips, there is concern that this pest might have survived the mild winter of 2011-2012 outdoors (Gilrein 2012).



Wax scales, a large group of tropical and subtropical species, now regularly overwinter in New Jersey, Pennsylvania,and Maryland. Photo by Mike Raupp

Street trees in northern cities may be disproportionately affected by elevated populations of cold-sensitive pests. Cities can be as much as ~18 degrees F warmer than surrounding suburban and natural areas (Raupp et al. 2010, 2012 and references therein). Mimosa webworm is a key pest of honeylocust, a tree native to North America widely planted along streets and as specimens in landscapes. In studying honeylocust and webworms in cities in Iowa, Hart et al. (1986) discovered that damage to honeylocust was significantly less following cold winters and much greater following warm winters. During cold winters many overwintering pupae died. The following spring fewer adults emerged, fewer eggs were laid, and fewer caterpillars were present to damage trees. The converse happened following mild winters. In mild winters, more pupae survived and more adults were produced. This translated into more caterpillars that caused significantly more defoliation. Hart et al. (1986) suggested that because cities are warmer than the surrounding suburbs and natural areas, they may provide a thermal refuge for overwintering mimosa webworm in the northern part of its range. Hence, honeylocust in cities are likely to suffer more damage from mimosa webworm than those in cooler suburbs or natural areas. To what extent other cold sensitive insect and mite pests find winter refuge in the warmth of cities remains unknown.



Cottony cushion scale, a resident of Florida and California, has been detected in landscapes in Maryland and Washington, D.C., in recent years.

Changes in plant and insect phenology

An additional outcome of a warming environment is the seasonal advancement of phenological events in plants in temperate zones. In recent years many plants have broken bud, flowered, and produced fruit surprisingly early. Advancement of phenological events in plants can work to the favor or disfavor of pests. Many early season defoliators such as gypsy moth and cankerworms depend on nutritious young foliage to survive. If larvae hatch too early in spring, foliage may not be present and caterpillars may starve. If larvae hatch too late, leaves may be tough and lower in nutritional value. Insects consuming older foliage may be smaller, less vigorous and unfit.

If plants respond to warming temperatures by producing leaves earlier, pests that might have starved due to emergence at a time of food scarcity may gain an advantage and survive. Conversely, if warming temperatures allow leaves and other plant parts to grow and develop rapidly, then associated pests may find these physiologically older plant tissues less nutritious and less suitable as food. The effects of climate change on the phenological asynchrony between plants and their pests are another rich area of largely underexplored research (Raupp et al. 2012 and references therein).

Warming means more generations for multivoltine pests

Many key insect pests of trees and shrubs have but a single generation each year. This life history pattern is termed univoltine, or one generation. Examples include some of our most damaging caterpillars including gypsy moth, eastern tent caterpillar, cankerworms and winter moth; beetles like Japanese beetle, emerald ash borer, and Asian longhorned beetle; and sucking insects including calico scale, tuliptree scale, oak lecanium, obscure scale, juniper scale, honeylocust plant bug and many others. However, more than a hundred species of insects and mites that attack trees and shrubs have more than one generation each growing season and are called multivoltine pests (Davidson and Raupp 2010).

For univoltine insect pests, development is sometimes linked to a critical environmental cue such as day length or a period of chilling. For example, eggs of the gypsy moth must undergo a period of cool temperatures before they will begin to develop and hatch into caterpillars. This period of arrested development is called an obligate diapause. For insects with this type of life cycle, it is unlikely that climate change will affect the number of generations realized in a given year (Klapwijk et al. 2012). By contrast, many species of small sucking arthropods including spider mites, armored scales, aphids, lace bugs, thrips, and many bark beetles are multivoltine. The number of generations realized in a growing season in a location will be strongly influenced by ambient temperatures, with warmer temperatures producing many more generations of pests.

A prime example of this phenomenon is the cosmopolitan two-spotted spider mite, a ubiquitous and damaging plant pest worldwide. In managed landscapes it is a common pest of many shrubs and trees including cotoneaster, burning bush, buddleia, redbud, ash and tulip poplar. Research has shown that at a temperature of 59 F it takes two-spotted spider mite 36 days to develop from egg to adult. At a temperature of 86 F, this transformation takes place in a mere seven days (Sabilis 1981). For two-spotted spider mite an increase of 27 degrees translates into a fivefold increase in generations in the same period of time. For other species of spider mites, including those found on linden, higher temperatures also translated into greater survival and elevated reproduction (more eggs laid per female) (see Raupp et al. 2012 and references therein).

As regions warm, pests with multiple generations such as (l. to r.) aphids, spider mites and lacebugs will complete more generations each year. Left and right photos by Mike Raupp; center photo by John Davidson.

Effects of a warming climate on predator and prey interactions

There is little doubt that natural enemies, predators and parasites, play an important role in reducing pest populations on trees and shrubs (Davidson and Raupp, 2010; Raupp et al. 2010, 2012). As mentioned previously, elevated temperatures enable insects and mites to complete their growth and development more rapidly. Many insect pests have specific windows of vulnerability, times in which they are more susceptible to attack by natural enemies.

Frank and Shrewsbury (2004) discovered that predators including ground beetles, rove beetles and spiders were able to subdue and kill small caterpillars but not larger ones. They demonstrated that once prey obtained a certain size they were no longer vulnerable to some predators. In a similar way, early stages of lace bugs were more vulnerable to predation by lacewing larvae than were older more active nymphs and adults that could defend themselves from these formidable predators.

If climate change enables insect and mite pests to race through windows of vulnerability and escape death from natural enemies, then we might expect greater levels of pests and associated damage as a consequence of global warming (Raupp et al. 2012). Conversely, if predators and parasitoids are more sensitive to increasing temperatures than their herbivorous prey, then the balance may tip in favor of the beneficial insects and less plant damage and fewer pest outbreaks may occur as the world warms (Berggren et al. 2009).

The world has undergone several periods of warming and cooling over its 4 billion year history. Historically, as the world warmed and cooled distributions of plants and animals changed. Although there is much concern that the current increase in global temperatures will lead to greater amounts of damage to trees and shrubs associated with greater numbers or activity of insects and mites, empirical evidence to support these concerns is limited. We are in the midst of a great experiment and only time will tell how a warming world affects woody plants and their associated arthropods.

References

Berggren, A., C. Björkman, H. Bylund, M. P. Ayres. 2009. The distribution and abundance of animal populations in a climate of uncertainty. Oikos 118: 1121-1126.

Davidson, J. A. and M. J. Raupp. 2010. Second edition. *Managing insects and mites on woody plants: An IPM approach*. Tree Care Industry Association. Londonderry, NH. 177 pp.

Gill, S. 2008. TPM/IPM Weekly Report for Arborists, Landscape Managers & Nursery Managers, University of Maryland Cooperative Extension. http://ipmnet.umd.edu/landscape/LndscpAlerts/2012/12Apr20L.pdf. Accessed January 5, 2013.

Frank, S. D., and P. M. Shrewsbury. 2004. Effect of conservation strips on the abundance and distribution of natural enemies and predation of Agrotis ipsilon (Lepidoptera: Noctuidae) on golf course fairways. *Environmental Entomology* 33: 1662-1672.

Gilrein, D. 2012. Cornell Cooperative Extension. Personal communication. June 6, 2012.

Hansen, J., M. Sato, R. Ruedy, K. Lo, D. W. Lea, and M. Medina-Elizade. 2006. Global temperature change. Proceedings of the National Academy of Sciences. 103 (39): 14288-14293.

Hart, J. H., F. D. Miller Jr., and R. A. Bastian. 1986. Tree location and winter temperature influence on mimosa webworm populations in a northern urban environment. *Journal of Arboriculture* 12: 237-240.

Johnson, W. T. and H. H. Lyon. 1988. *Insects That Feed on Trees and Shrubs*, 2nd ed. Cornell Univ. Press, Ithaca, NY. 556 p.

Klapwijk, J., M. P. Ayers, A. Battisti, and S. Larsson. 2012. Assessing the impact of climate change on outbreak potential. In: Insect outbreaks revisited. P. Barbosa, D. Letourneau, and A. Agrawal eds. Wiley-Blackwell, Oxford, UK. pp. 429-450.

Nietschke, B.S., D.M. Borchert, R.D. Mabery and M.A. Ciomperlik. 2008. Climatological Potential for Scirtothrips dorsalis (Thysanoptera: Thripidae) Establishment in the United States. Florida Entomologist. 91: 79-86.

Osborne, L. 2011. Chilli Thrips, Scirtothrips dorsalis Hood. www.mrec.ifas.ufl.edu/lso/thripslinks.htm. Accessed January 5, 2013.

Raupp, M.J. 2009. The holly and the wax scale – *Ceroplastes sp.* Bug of the Week. http://www.bugoftheweek.com/BugOfWeek_50D.html. Accessed January 5, 2013.

Predators including rove beetles (seen above), ground beetles and spiders were able to subdue and kill small caterpillars but not larger ones. Photo by Susan Ellis, Bugwood.org

Raupp, M.J., P.M. Shrewsbury, and D.H. Herms. 2010. Ecology of herbivorous arthropods in urban landscapes. Annual Review of Entomology. 55:19-38.

Raupp, M.J., Shrewsbury, P.M. and D. H. Herms. 2012. Disasters by design: Outbreaks along urban gradients. In: Insect outbreaks revisited. P. Barbosa, D. Letourneau, and A. Agrawal eds. Wiley-Blackwell, Oxford, UK. pp. 313-340.

Sabelis, M. W. 1981. Biological control of twospotted spider mites using phytoseiid predators. Agriculture Research Reports 910. Pudoc, Wageningen, The Netherlands.

Stimmel, J. 2009. Wax scales, Ceroplastes spp. (Homoptera: Coccidae). Regulatory Horticulture (Pennsylvania Department of Agriculture). 24(2): 17-19.

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This article was based on his presentation on the same subject at TCI EXPO 2012 in Baltimore last November. To listen to the audio recording of that presentation, go to the digital version of this issue of TCI online at www.tcia.org and click here.