Wisconsin Cranberry School proceedings. Volume 15 2007

Madison, Wisconsin: Wisconsin State Cranberry Growers Association, 2007

https://digital.library.wisc.edu/1711.dl/4CDTJQ2IN3R3Z8Z

HOW FUNGI INFECT AND HOW FUNGICIDES WORK

P.S. McManus
Department of Plant Pathology
University of Wisconsin-Madison

In Wisconsin, approximately 25 diseases have been reported on cranberry, and the majority of these are caused by fungi. The most important fungal diseases in Wisconsin are: cottonball (*Monilinia oxycocci*); the fruit rot complex (several fungi, but most notable in recent years, *Colletotrichum* and *Phomopsis*); and upright dieback (*Phomopsis vaccinii*). *Phytophthora* spp. that infect roots and runners, are superficially similar to fungi, but genetically very different. Cranberry stem gall, which is a serious problem in some locations in some years, is most likely caused by bacteria that produce a plant growth hormone.

Fungi (singular form: fungus) are a unique kingdom of life. Despite attempts to lump them with plants, fungi are actually more closely related to animals than plants. Fungi lack chlorophyll, and therefore cannot make their own food. They also lack vascular tissue, and therefore cannot effectively move water throughout their "bodies." Therefore, fungi need to live in close contact with a source of nutrients and water. Since plants don't have true immune systems to thwart off such freeloaders, it's not surprising that some fungi are parasites (=pathogens) of plants.

The fungal infection process consists of a series of steps. Taken together these steps make up the disease cycle for a pathogen. Fungicides act by disrupting one or more of these steps.

- *Inoculation*—the fungal spore lands on a plant surface.
- *Adhesion*—the fungal spore exudes a glue so that it sticks to the plant even if there is rain.
- *Germination*—the fungal spore takes up water and a germ tube emerges.
- *Penetration*—the germ tube enters the plant, either by poking directly through the epidermis or by going through stomata or wounds.
- *Plant-pathogen recognition*—chemical or molecular signals are exchanged between the fungus and the plant so that the fungus knows it is on a suitable host.
- *Infection*—the fungus invades the plant by growing into or between cells, and the fungus produces spores that are released at the plant surface.

The fungicides registered on cranberry vary in the steps of the infection process that they disrupt. To some extent, this is determined by where the fungicide ends up after it is sprayed onto the plant. **Contact fungicides** remain on the surface of the plant, and move only when rain or irrigation water redistributes them. For this reason, a little rain after a fungicide application is not a bad thing. Fungicides are formulated to adhere to the plant, and they are rainfast except under extreme circumstances. Contact fungicides inhibit spore germination but do not work if a plant is already infected. This type of activity is referred to as **protectant**. Examples of contact fungicides with protectant activity are chlorothalonil, mancozeb, and copper. **Systemic fungicides** move through a plant's vascular tissue. Examples of systemic fungicides are Aliette and phosphorous acid products, which are taken up by leaves and transported to runners and roots to inhibit *Phytophthora*. **Locally systemic fungicides** are taken up by leaves or flowers and move a short distance within the leaf or flower. For example, they can move from one surface of a leaf to the other or from the base of a flower to the stigma (where the cottonball pathogen infects). Uptake is better through soft tissues, such as growing shoot tips and young fruit rather than hard tissues such as mature leaves and fruit. Examples of locally systemic fungicides are propiconazole and azoxystrobin. Locally systemic fungicides do their best work by inhibiting growth of fungi after infection, and are said to have **post-infection activity.**

Brand name	**Active ingredient**	**Protectant**	**Post-infection**
Bravo	chlorothalonil	X	
Dithane, Pennozeb	mancozeb	X	
Champ, Kocide, etc.	copper	X	
Orbit	propiconazole	X	X
Abound	azoxystrobin	X	X
Ridomil	mefanoxim	X	X
Aliette	fosetyl aluminum		X
Phostrol, Prophyt, etc.	phosphorous acid		X

For a fungicide to work, it must reach its target. That is, it either has to contact the fungus at the surface of the plant or inside the plant. Contact fungicides must be present at the infection court, the site on the plant where the fungus penetrates. This means that coverage with a contact fungicide has to be nearly perfect for the fungicide to work. Coverage can be improved by using higher spray volumes and by applying under calm conditions. Systemic and locally systemic fungicides are a little more forgiving of incomplete coverage, but obviously, they won't reach their intended targets if applied when there is a breeze. Some infection courts are easier to protect than others. *Phomopsis vaccinii* (upright dieback pathogen) and *Monilinia oxycocci* (cottonball pathogen) infect through elongating shoots. These "roughneck" shoots are a relatively large infection court and have a lot of nooks and crannies for spores to hide in and escape contact fungicides. Consequently, controlling primary cottonball infections and upright dieback is not always successful, even when the most effective fungicides are used. On the other hand, the infection court for secondary cottonball infections is the floral stigma, a relatively small, soft target that probably takes up the systemic fungicide propiconazole very well. In this way, control of secondary cottonball infections is usually successful if an effective fungicide is used during bloom.

Sometimes fungicides are used, but disease still develops. What goes wrong? The issue of getting the infection court covered is discussed above. This can be improved by increasing spray volume and spraying during calm conditions. Increasing spray volume will also reduce the risk of phytotoxicity from chlorothalonil, because the concentration of the product is reduced. Fungicide timing must be right for the fungicide to reach the susceptible infection court on the plant. For primary cottonball and upright dieback, this means spraying during shoot elongation. Research has shown that the best time for cottonball sprays are when more than half of the shoots show about ½ inch of new growth. To prevent secondary cottonball infections, sprays must go on during bloom. Fruit rot sprays are most effective if applied at late bloom and early fruit set. Plant growth stages vary among varieties and across a cranberry marsh. Although it's not always practical, disease control will be better if problem beds are sprayed according to their own growth stage. More details on spray timing and disease cycles are available in other extension publications. Lastly, it's important to use a fungicide that is effective against the disease you are trying to control. A fungicide that is cheap to buy is expensive to use if it doesn't work! Research done here in Wisconsin and in other states has provided us the following information about which fungicides are best for which purpose.

	chloro-thalonil	**mancozeb**	**copper**	**propi-conazole**	**azoxy-strobin**	**mefanoxim**	**fosetyl-Al**
Cottonball	F	P-F	P	E	F-G	?	?
Upright dieback	G-E	NA	?	?	NA	?	?
Fruit rot	E	F-G	P-F	P-F	F-G	?	?
Phytophthora	?	?	?	?	?	G	F-G

E=excellent; G=good; F=fair; P=poor; NA=not allowed based on timing of permitted sprays; ?=unknown. Phosphorous acid has not been tested on the strains of *Phytophthora* present in Wisconsin, but in other disease systems its performance has been similar to that of fosetyl aluminum.

HOW HERBICIDES WORK IN TERMS THAT WE CAN ALL UNDERSTAND

Jed Colquhoun, Extension Weed Specialist,
Dept. of Horticulture, University of Wisconsin-Madison

Herbicide mode of action can be a daunting and complex subject. However, a general understanding of how herbicides work and knowledge about weed biology can greatly increase herbicide performance. Several factors affect herbicide performance, such as climatic conditions (Table 1) and herbicide uptake, translocation, metabolism, and mechanism of action (Table 2). These factors are discussed in more detail below, with examples using common herbicides in Table 2.

Herbicide uptake

Herbicide uptake is generally through the roots or through the leaves and stems. While seeds can absorb some herbicide in the water they imbibe, this is fairly uncommon and rarely leads to weed control. Soil-applied herbicides are generally taken up by the roots of broadleaf weeds and the roots and shoots of grass weeds. A couple of plant barriers can reduce herbicide root uptake, such as the casparian strip. The casparian strip is a waxy layer in the root that is somewhat analogous to the waxy cuticle on a leaf surface. Post-emergent herbicides (applied to leaves) must also cross several barriers to be absorbed in the plant, such as the waxy leaf cuticle and cell walls and membranes. Surfactants increase absorption of some post-emergent herbicides by decreasing the surface tension of the spray droplet, thus spreading the droplet over a larger portion of the leaf surface.

Herbicide translocation

Some herbicides are translocated or "piped" in the plant to the target site, while others are considered "contact" herbicides that do not move much from the site of absorption. Contact herbicides tend to act fairly quickly. Translocated herbicides move through the xylem or phloem. In general, the xylem transports water (along with accompanying herbicides) from the roots to new above-ground growth. The majority of soil-applied herbicides are transported in the xylem. The phloem is a transport system made up of living plant tissue. The phloem generally transports sugar and other materials (including herbicides) to areas of new growth in the spring and storage organs in the late summer and fall.

Herbicide metabolism within the plant

Metabolism refers to the ability of a plant to breakdown or degrade herbicides. Selectivity – the ability to control target weeds without significantly injuring the crop – is most often based on metabolism. The crop plant and uncontrolled weeds metabolize the herbicide into a form that is no longer toxic to the plant (called inactivation). The speed of herbicide metabolism is important. For example, grasses metabolize synthetic auxin herbicides such as 2,4-D much faster than broadleaves and therefore are not usually as injured.

Herbicide mechanism of action

Several plant systems or processes are involved in herbicide toxicity in susceptible species. Herbicides block or inhibit processes that are critical for plant growth and survival, such as photosynthesis, cell wall and membrane production, and pigment production. Other herbicides disrupt or otherwise compromise the integrity of plant structures, such as by destroying cell membranes.

Table 1. General effect of climatic conditions on herbicide uptake, translocation, metabolism, and mechanism of action. A "+" indicates an increase in the variable, while a "-" indicates a decrease in the variable.

	Drought	High Moisture	Low Temperature	High Temperature
Root uptake	-	++	-	+
Leaf uptake	--	+	-	+
Translocation	--	+	-	+
Metabolism	-	?	--	++
Mechanism of action	-	?	-	+

Table 2. Summary of herbicide characteristics.

Herbicide group	Examples*	Uptake site	Translocation	Mechanism of action	Selectivity	Symptomology
Cellulose inhibitors	Casoron	Soil	Xylem	Inhibits new root/shoot growth and seed germination	Selected grasses and broadleaves controlled	Affected weeds often don't emerge from soil or re-grow in spring
Inhibition of VLCFAs	Devrinol	Soil	Xylem	Inhibits synthesis of fatty acids and cell division	Selected grasses and broadleaves controlled	Affected weeds often don't emerge from soil or re-grow in spring
Carotenoid biosynthesis inhibitors	Evital	Soil	Xylem	Carotenoid pigment synthesis blocked; cell membranes leak	Selected grasses and broadleaves controlled	Bleaching (whitening) of above-ground vegetation
Synthetic auxins	2,4-D, Stinger, Weedar 64	Primarily post	Phloem (with sugars)	Excess synthetic hormones disrupt cell division and growth	Broadleaves controlled	Twisting of stems and leaves, leaf cupping
Lipid synthesis inhibitors (ACCase inhibitors)	Poast, Select Max, Fusilade	Post	Phloem (with sugars)	Blocked enzyme inhibits lipid production	Grasses controlled	Growing point turns brown, new leaves pull easily
Amino acid synthesis inhibitors (EPSPS inhibitors)	Glyphosate (Roundup and others)	Post	Phloem (with sugars)	Blocked enzyme inhibits amino acid and protein production	Non-selective	Relatively uniform yellowing, followed by necrosis (dead tissue)

* Pesticide labels change frequently. Always read and follow the label prior to any pesticide use.

PHYSIOLGY OF CRANBERRY YIELD

Teryl R. Roper
Dept. of Horticulture, University of Wisconsin-Madison

Yield is the holy grail of cranberry producers. Pursuing higher yields requires knowing what is currently limiting yield. This article will outline our current understanding of yield limiting factors in cranberry production.

> *Practically everything we see about us involved photosynthesis at some stage or other. The gardener often talks about 'feeding' plants when he applies fertilizers and the notion that plants derive their nourishment from the soil is one that is commonly held. They do not. Plants take up minerals from the soil, they derive their nourishment from the air."*
>
> *Edwards and Walker, 1983*

All yield and productivity in agriculture is based on photosynthesis. Photosynthesis is the process plants use to convert light energy from the sun and store it as chemical energy as lipids, proteins, and carbohydrates. Common external limitations to photosynthesis that may subsequently affect yield include light, CO_2 concentration, and temperature. Internal factors such as stomatal opening and the nutrient and water status of the vines may also affect photosynthesis.

Light. Cranberry growers really don't farm the soil, they farm sunlight. Fortunately, light is rarely limiting to cranberry photosynthesis. The maximum rate of photosynthesis occurs at about 1/3 of the light intensity of full sunlight. Light may be limiting on very heavily cloudy days and during the morning (sunrise) and evening (sunset). When vine canopies become too dense light may be limiting in lower portions of the canopy.

CO_2 Concentration. As a result of burning fossil fuels the CO_2 concentration in the atmosphere is increasing slowly over time. In theory as more carbon dioxide is available in the atmosphere the rate of photosynthesis should also increase. We tested on a small scale what happens to cranberry vines grown under elevated CO_2 levels. We found that growth and yield were not affected, but that starch accumulated in the leaves. In the real world CO_2 concentration is unlikely to limit crop yield.

Temperature. The optimum temperature for cranberry photosynthesis is about 70 to 75°F. When temperatures are lower or higher than the optimum the rate of photosynthesis declines. When correlations are made between yield and weather a frequent finding is that highest yields occur during years with moderate temperatures. Growers can affect temperature through timely irrigation during very hot weather.

Yield component analysis is a statistical procedure that assigns relative importance to various factors that determine yield of a given crop. Cranberry was subjected to yield component analysis and two factors were found to be the most important determinants of yield: the proportion of fruiting uprights and fruit set. It seems prudent to focus our energy on the two factors that are most important in determining yield.

Fruiting uprights. Individual uprights tend to bear biennially. That is an upright that flowers and fruits one year is unlikely to flower and fruit the following year. Cultivars and location affect the extent to which biennial bearing occurs. Vigorous uprights are less likely to be biennial bearing than less vigorous uprights. Some newer cultivars show improvement in the inclination to rebud during the fruiting year. This should result in higher yields. This is an area where potential yield increases through breeding are possible.

Fruit Set. Fruit set is the culmination of several previous steps. Prior to fruit set we must have flowers, the flowers must be pollinated with compatible pollen, the pollen grain must germinate and the egg cell in the ovary must be fertilized by one of the sperm nuclei from the pollen. Once that happens, if there are sufficient resources, the fruit will begin to swell and grow. We know that fruit set can be improved slightly through better pollination. When insect pollination was supplemented with hand pollination fruit set increased by 8%. When vines are sprayed with the growth regulator Gibberellic acid fruit set increased to about 50%, but fruit size was about half the control group. Thus, fruit set increased, but yield did not.

Fruit development also requires resources, primarily carbohydrates. The time of fruit set is the most critical and anything that reduces availability of resources to fruit at the time of fruit set also reduced fruit set. Carbohydrates to support fruit growth can come from the new leaves above the fruit, from one-year-old leaves below the fruit, or from leaves on an adjacent upright along the same runner. Using leaf removal and radioactive labeling we determined that the primary source of carbohydrates for supporting fruit growth are the new leaves above the fruit. Thus getting sufficient vegetative growth before the time of fruit set and maintaining these leaves in good conditions appears prudent to maximize yields.

During the course of two seasons we measured the rate of photosynthesis and we followed the pattern of change in carbohydrate pools in cranberry vines. We found that carbohydrate pools were large in the spring, then dropped precipitously at the time of fruit set, suggesting that the developing fruit were a large draw on the carbohydrate resources of the vines. Thus anything that reduced the ability of vines to supply carbohydrates to developing fruit would be a potential cause of yield reduction. At the same time we measured photosynthesis in the field. We found that current season leaves had a rate of photosynthesis roughly double that of one-year-old leaves. When we totaled up the carbon cost of fruit and compared that to the carbon available via photosynthesis we calculated that, in general, an individual upright was capable of supporting the growth of two fruit per season. If you go out into a good bed of cranberries on your marsh I would be willing to bet that the average number of fruit per upright will be two.

Fertilizer. Having sufficient mineral nutrients in cranberry vines is essential to the process of photosynthesis. However, adding more fertilizer won't necessarily result in greater yields. Cranberry fruit are 85 to 90% water. About 94% of the remaining dry weight is composed of carbon, hydrogen and oxygen: the products of photosynthesis. Thus, about 6% of the remaining dry weight is nitrogen, phosphorus, potassium, calcium, etc. Increasing the percentage of dry weight of these mineral nutrients won't necessarily result in higher cranberry yields.

In Oregon research was conducted on a nitrogen deficient cranberry bed. When nitrogen fertilizer was added upright density increased along with the number of flowering uprights. Fruit set increased as nitrogen fertilization rate went from 0 to 40 pounds per acre, but did not increase beyond 40 pounds of N per acre. The greatest increase in yield from providing sufficient nitrogen was from an increase in berry number. Only a marginal increase in yield was related to berry size.

Weather. Climate and weather have substantial effects on cranberry yield, yet we can do very little about the weather. Researchers in the 1940's correlated yield with weather patterns during bud development. Cranberry yield is not well correlated with growing degree days or light received by the canopy. It is, however, well correlated with the number of moderate temperature days (highs between 61 and 86°F). These results are interpretable because we know the optimum temperature for cranberry photosynthesis.

Climate and weather are important determinants of cranberry yield that we are unable to manage. While we should do our best to manage what we can, a substantial portion of what determines yield is outside of our control.

Summary. What is the 'take home message' from this article? Fertilizer is not the only determinant of yield. In fact, it is not a very important contributor to yield. Other factors such as weather and genetics are far more important contributors to yield than fertilizer is. With an understanding of the physiology of yield growers will be better able to make management decisions, including fertility. They'll be less prone to sales pitches that lack sufficient research base to support them.

Our goal with tissue testing and writing nutrient management plans is to apply sufficient fertilizer so that fertility is never the limiting factor for plant growth and yield. To say it another way, we want to obtain and then maintain tissue sufficiency. Adding fertilizer beyond that is wasteful and will not lead to higher yields.

Note: A longer version of this article was distributed at the 2007 Wisconsin Cranberry School. Rather than reprinting this publication in the proceedings the above summary was provided. The full text of the larger publication is available on the Internet at the following URL:

http://www.hort.wisc.edu/cran/mgt_articles/YieldPhysiology.pdf

SELECTED TOPICS IN CRANBERRY ENTOMOLOGY

Dan Mahr
Dept. of Entomology, University of Wisconsin – Madison

This year, the Education Committee asked that I cover the following three topics.

1. What Integrated Pest Management Isn't

I think it is more understandable to first cover what Integrated Pest Management (IPM) is, so I'll do that first, and then return to the question at hand.

IPM is nothing new; the concept was developed in the 1950s in response to serious problems that were arising from overuse of broad spectrum pesticides. IPM is a knowledge-based approach to pest control; IPM practitioners must have a good working knowledge of the biology of the pest insects, their natural enemies, pest scouting practices, economic thresholds (action levels), and the crop environment, as well as an understanding of the strengths and drawbacks of the various types of control practices. As new techniques and tools are developed, education must be an on-going process. A couple other characteristics of IPM are (1) that it is a preventative rather than curative approach for reducing pest problems, and (2) that it aims to reduce the harmful effects of pesticides.

Historically, and continuing to the present time, most insecticides have a broad spectrum of activity, meaning that they are not very selective as to the types of insects that are killed. Under certain situations, some of the unanticipated things that insecticides can do include

- change plant chemistry to be more nutritious to certain pests,
- actually directly increase pest reproduction,
- kill the natural enemies of pests, and
- have a loss in effectiveness through the development of resistance.

All of these things can result in an increase in pest populations rather than pest control. IPM uses techniques to reduce these problems.

When IPM was first developed, it was the integration of pesticides and beneficial "natural enemies" to manage pest populations so that they do not cause economic injury. The concept has expanded over the past 50 years and now includes the usage of all appropriate techniques, not just chemical and biological controls. It also integrates insect, plant disease, and weed management, recognizing that in many cases these can interact. And it also integrates pest management with crop production and marketing practices into what is known as Integrated Crop Management (ICM).

The Knowledge Base. The greater knowledge about pests and their control, the better position you will be in to make effective and economical management decisions. This will be increasingly true as broad spectrum insecticides are gradually replaced by more selective ones. An understanding of the following areas will be useful in structuring your IPM program.

Pests. Knowledge of individual pests should include 1) familiarity with their seasonal life cycles, 2) an ability to recognize damage, identify the likely cause, and understand the potential economic loss, 3) an understanding of the existence of natural enemies and their potential impact, and 4) appropriate monitoring methods.

Natural enemies. Dearness scale has highly effective natural enemies that can be disrupted by broad spectrum insecticides. Tipworm has modestly effective natural enemies. Blackheaded fireworm and cranberry fruitworm do not have highly effective natural enemies, but the use of broad spectrum insecticides against these can impact the natural enemies of other pests.

Insecticides. When possible, use more selective insecticides, such as insect growth regulators and spinosads to protect beneficial insects. However, use of these may require more specific application timing than traditional broad spectrum materials.

Other controls. Flooding, sanding, mating disruption, and biological controls have all been proven effective for controlling certain pests and fit harmoniously into IPM programs.

Pest scouting. Pheromone traps are available for blackheaded fireworm, cranberry fruitworm, sparganothis, and cranberry girdler. Sweep sampling is important for various "worms" (Lepidoptera larvae) and cranberry flea beetle. Visual observation is important for identifying dearness scale, and soil feeders such as girdler, flea beetle larvae, and June beetle grubs. Degree day information is available for forecasting pest activity periods. Remember that monitoring must be done routinely or else problems can be missed.

Action levels. It is not economically practical to attempt to kill every insect pest on the marsh; if pest populations are very low, the cost of applying a pesticide will likely be more than the savings from the added protection. Action levels, also known as economic thresholds, have been developed for several pests. The economic threshold (ET) is simply the pest population level where it is economically justifiable to spend money on controls. The factors that determine the ET include the crop market value, the cost of applying controls, and the amount of yield reduction caused by an individual pest. Action levels are highly important for successful IPM because they help us decide when pesticides are not necessary, and therefore help preserve natural enemies.

Cranberry IPM Today. Universities began working with the cranberry industry and private consultants well over 20 years ago to develop IPM programs. Many tools have been developed and refined during this period, such as pheromone traps, degree day models, action thresholds, selective pesticides, and cultural controls. IPM has become widely adopted by the industry, but IPM will continue to evolve as new information is learned and new tools are developed.

What IPM Is:

- Pest management decisions based on economics.
- Routine use of pest scouting and monitoring to determine pest population levels.
- Knowledge of pest biology and damage.
- Awareness of the benefits of natural enemies.
- Thoughtful integration of multiple control methods.
- A process that will continue to be constantly evolving.

What IPM Is Not:

- Avoidance of sound economic principles in pest management decision making.
- Unwillingness to do pest scouting and monitoring.
- Failure to incorporate knowledge of pest biology into management decisions.
- Disregard of natural enemies.
- Unthinking reliance on a single pest management tactic.
- A rigid, unchanging practice.

2. ECONOMIC ENTOMOLOGY 101: Insects as Plant Pests

> "The struggle between man and insects began long before the dawn of civilization and has continued without cessation to the present time, and will continue no doubt, as long as the human race endures. It is due to the fact that both men and certain insect species constantly want the same things at the same time."
>
> -- From *The Insect, the Farmer, the Teacher, the Citizen, and the State*, Bulletin of the Illinois State Laboratory of Natural History, 1915.

A "pest" is an organism that interferes with human activities; it is purely a human concept – without us there would be no pests, only competitors for Earth's finite resources.

Sometimes it is hard to pigeon-hole a particular species as to whether or not it is a pest. That pretty white butterfly brightens up the day; but did you notice it laying eggs on the cabbage plants in the garden? Bumble bees are wonderful pollinators, but have you ever gotten too close to the entrance of their colony? Cranberry tipworm reduces yield in the northern part of the state, but may actually increase the number of blooming uprights further south.

And "pest" status is often a numbers game: a couple of mosquitoes are tolerable, a swarm becomes outright pestiferous.

How insects become pests. The following is a general discussion of how insects become plant pests. Where appropriate, reference is made to the cranberry crop.

New introductions. Many of the most serious agricultural pests in the United States were accidentally introduced through the movement of humans and their possessions, and through commerce. A study commissioned by the U.S. Congress reported in 1993 that over 2000 non-native species of insects and arachnids have become permanently established in the United States. A few common examples important to Wisconsin crops include alfalfa weevil, European corn borer, Japanese beetle, Hessian fly, German yellowjacket, and codling moth. Invasive species introductions are not a thing of the past; they continue today, with recent introductions into the U.S. such as Asian longhorned beetle, emerald ash borer, and soybean aphid, the first North American report of which was from Wisconsin in 2000. New introductions have not yet been a pest to Wisconsin cranberries, but that may change. The permanently-colonized area of gypsy moth is still spreading from east to west in the state, and we are uncertain of its ultimate pest potential in this part of the country. Although generally considered a tree pest, during outbreak periods larvae will feed on most types of plants, and it has caused economic losses to cranberry production in Massachusetts.

Native insects attack new hosts. Cranberry, along with blueberry, sunflower, and pecan, is one of North America's few native crops. Therefore, the insects that feed on it here evolved with it here. Most of our crop plants are introduced and in some cases, native insects have willingly developed a fondness for them. Examples include the Colorado potato beetle, the alfalfa butterfly, and apple maggot, all of which fed on wild native plants prior to the introduction of their now-favored crops.

An abundance of food. In natural landscapes, many plant species are scattered here and there and are not particularly abundant. The insects that feed on them spend considerable time and energy finding their food, time that could otherwise be used in reproducing. Along comes modern agriculture and monocultures – vast expanses of nothing but the cultivated crop. This allows insects to eat lots, grow quickly, and reproduce abundantly. Although cranberry cultivation does not compare with corn in the Corn Belt, Wheat in the Wheat Belt, or cotton in the southern Cotton Belt, our fields do provide a much greater abundance of plants than the normal native habitat along the edges of wetlands. We grow cranberries, but we also grow cranberry pests.

Upset pests. In some cases, farming activities actually stimulate pest outbreaks; these pests are called upset pests because we have upset the balance of nature in favor of the pest species. The most common cause of pest upsets is when the use of broad spectrum pesticides for control of major pests kills the natural enemies of minor pests. Without natural predation, these minor pests can explode to damaging levels. The practices of Integrated Pest Management (IPM – outlined above) are specifically intended to reduce the likelihood of creating upsets pests. Many cranberry insects have natural enemies that provide some benefit in pest management. Dearness scale is probably the best example of an upset pest in Wisconsin cranberry production. It has an abundance of highly effective natural enemies, but these can occasionally be eliminated by the use of broad spectrum insecticides, allowing for a scale outbreak.

Native crop, native pests. There are relatively few native North American crops, but each of these crops has several insects that have evolved to feed on it. Examples include sunflower moth, pecan weevil, and blueberry maggot. Virtually all of our cranberry pests are native to North America, though there is some evidence that they have been spread from region to region with vines.

Insect Biology – A Quick Refresher. Understanding the basics of insect biology is important for making pest management decisions. The following is a brief summary of insect growth and development and the types of plant damaged based upon mouthpart types.

Insect growth. Most insects start life in the egg stage. The egg hatches into an immature form. As the immature insect feeds, it must periodically shed its hard, inflexible skin (exoskeleton) in a process known as **molting** or **ecdysis**. The stage of the immature insect between molts is called an **instar**. Most insects have between 3 and 8 immature instars, meaning that they must shed their skins 3 to 8 times before reaching adulthood. Some of our modern Insect Growth Regulator (IGR) insecticides specifically interfere with this molting process. All growth is in the immature instars; once reaching adulthood, which is characterized by reproductive maturity and, in most insects, by the presence of fully developed functional wings, the insect no longer grows and no longer sheds its exoskeleton.

In the maturation process from immature to adult, the insect changes in form; this change is called **metamorphosis**. In more primitive insects, the change in form is relatively minor and the immatures look like small, wingless versions of the adult. The main changes between the last immature instar and the adult include the growth of full-size functional wings and the addition of reproductive structures. The term used for these types of immature insects is **nymph**. This rather direct type of growth is called **simple metamorphosis**. Insects with simple metamorphosis include such things as grasshoppers, katydids, cockroaches, plant bugs, leafhoppers, aphids, earwigs, and lice. Cranberry insects with simple metamorphosis include dearness scale and blunt-nosed leafhopper.

In all higher forms of insects the immatures look drastically different than the adults. In these insects, the immature stages are things like caterpillars, grubs, and maggots, with the corresponding adult stages being moths, beetles, and flies. Collectively, these immature forms are known as **larvae** (singular – **larva**). Because larvae and adults are so different from each other, these insects have a transitional stage called the **pupa**. This type of growth, from egg to larva (multiple instars) to pupa to adult is much more complicated than simple metamorphosis and is called **complete metamorphosis**. Common insects with complete metamorphosis include beetles and weevils, butterflies and moths, bees, wasps, and ants, flies, gnats, and midges, and fleas. Cranberry insects with complete metamorphosis include the following moths: blackheaded fireworm, sparganothis fruitworm, cranberry fruitworm, spanworms, cranberry girdler, cutworms and armyworms, and blossomworm. Also with complete metamorphosis include the beetles cranberry weevil, cranberry flea beetle, and June beetles (white grubs), and the flies cranberry tipworm, mosquitoes, and deer flies. Metamorphosis is under hormonal control in the insect, and certain modern IGR insecticides cause death by interfering with normal hormonal activity.

Type of plant damage relates to feeding method. Although there are some rather peculiar exceptions, the mouthparts of plant feeding insects are basically of two forms: the more primitive **chewing mouthparts** and the more specialized **piercing-sucking mouthparts**. Insects with chewing mouthparts have two pairs of opposing jaws (mandibles) which grip the food, tear it, and chew it into small pieces before swallowing. Examples include grasshoppers, crickets, katydids, caterpillars, grubs, adult beetles, bees, and ants. Cranberry insects include flea beetle and its larval stage, June beetle and its grub, and the various types of caterpillars such as fireworms, fruitworms, spanworms, and girdler.

Chewing insects cause many types of plant damage. Leaf feeding (defoliation) results in loss of chlorophyll and nutrients resulting in overall plant stress and a loss in productivity and fruit quality. Cranberry insects that cause this type of foliar damage include fireworms, sparganothis, spanworms, armyworms, and flea beetle adults. Chewing insects can also cause damage to fruit, either by feeding on the surface or tunneling within. Examples are fruitworms and fireworms. Chewing insects can kill or damage stems and roots, restricting the movement of moisture and nutrients within the plant, resulting in plant stress and even death. Examples are the larvae of cranberry girdler and cranberry flea beetle.

Piercing-sucking mouthparts have developed numerous times in the evolutionary history of insects. Probably the most notorious group of insects with this type of feeding are the mosquitoes. Amongst plant pests, all members of the order Hemiptera have this type of mouthpart. The mandibles have evolved into very thin stylets that are hypodermic needle-like. The stylets are inserted into the plant and the insect then injects salivary fluids which help "pre-digest" the plant cell contents, allowing the insects to suck up nutrients along with plant sap. This typically results in loss of chlorophyll, plant moisture, and nutrients, which stresses the plant, resulting in poor growth and reduced yields. Certain insects with piercing-sucking mouthparts, notoriously leafhoppers and aphids, are known for transmitting certain plant pathogens, especially viruses and phytoplasmas. Examples of this group of insects include the plant bugs, aphids, leafhoppers, cicadas, and spittlebugs. The only significant Wisconsin cranberry pests that have piercing-sucking mouthparts are dearness scale and blunt-nosed leafhopper.

3. Overview of Cranberry Insecticides

The following is a brief summary of the more commonly used cranberry insecticides. The table lists the various materials by insecticide class. When rotating insecticides to avoid insecticide resistance, it is best to rotate between classes. Note that this information does not imply an endorsement by the University of Wisconsin of these products over other products.

Chemical Group	Product common name	Example brand name	IPM fit	Mammalian toxicity (oral)
Organophosphates	acephate	Orthene	poor	slight
	chlorpyrifos	Lorsban	poor	moderate
	diazinon	diazinon	poor	slight
	phosmet	Imidan	poor	moderate
Carbamates	carbaryl	Sevin	poor	slight
Neonicotinoids	thiamethoxam	Actara	ok ?	low
Insect Growth Regulators	tebufenozide	Confirm	good	low
Bacillus thuringiensis	Bt	DiPel	good	essentially non-toxic
Spinosyns (Naturalytes)	spinosad	SpinTor, Entrust	good	low

The following products are listed by common name; commonly-used or original brand names are also listed.

acephate (Orthene™)

Target insects: fireworm, fruitworm, spanworms, sparganothis.
Restricted Entry Interval (REI): 24 hr.
Preharvest Interval (PHI): 75 days.
Comments. Water soluble. Maximum of 1 application per year. Broad spectrum.

chlorpyrifos (Lorsban™)

Target insects: fireworm, fruitworm, spanworms, sparganothis, cranberry weevil, dearness scale (effective but not listed on label).
Restricted Entry Interval (REI): 24 hr.
Preharvest Interval (PHI): 60 days.
Comments. Maximum of 2 applications per year. Broad spectrum.

diazinon

Target insects: fireworm, fruitworm, tipworm, cranberry girdler (14G formulation)
Restricted Entry Interval (REI): 12-24 hr.
Preharvest Interval (PHI): 7 days.
Comments. Maximum of 6 applications per year of foliar formulations. Broad spectrum.

phosmet (Imidan™)

Target insects: fireworm, fruitworm, spanworms, sparganothis, cranberry weevil, blossomworm, tipworm, armyworm, cutworm.

Restricted Entry Interval (REI): 24 hr.

Preharvest Interval (PHI): 14 days.

Comments. Maximum of 15.6 lbs per year. Broad spectrum. Spray waters must be buffered.

carbaryl (Sevin™)

Target insects: fireworm, fruitworm, sparganothis, cranberry weevil.

Restricted Entry Interval (REI): 12 hr.

Preharvest Interval (PHI): 7 days.

Comments. Maximum of 5 applications per year. Broad spectrum.

thiamethoxam (Actara™)

Target insects: flea beetle, cranberry weevil

Restricted Entry Interval (REI): 12 hr.

Preharvest Interval (PHI): 30 days.

Comments. Maximum of 8 oz/acre per year. Narrow spectrum.

tebufenozide (Confirm™)

Target insects: fireworm, fruitworm, spanworms, sparganothis, blossomworm, false armyworm, gypsy moth

Restricted Entry Interval (REI): 4 hr.

Preharvest Interval (PHI): 30 days.

Comments. Maximum of 4 applications per year. Very narrow spectrum – just Lepidoptera. Does not kill instantly. Timing of application is critical – refer to label.

Bacillus thuringiensis (DiPel™, etc.)

Target insects: spanworms.

Restricted Entry Interval (REI): none listed.

Preharvest Interval (PHI): 0 days.

Comments. Use with spreader-sticker. Does not kill instantly. Works best on small larvae. Very narrow spectrum.

spinosad (SpinTor™, Entrust™)

Target insects: fireworm, fruitworm, spanworms (loopers), sparganothis, blossomworm, armyworm.

Restricted Entry Interval (REI): 4 hr.

Preharvest Interval (PHI): 21 days.

Comments. Entrust™ for certified organic. Very narrow spectrum.

What is Brix?

Teryl R. Roper
Dept. of Horticulture, University of Wisconsin-Madison

In the food industry the term Brix is used to describe the approximate amount of sugars in fruit juices, wine, soft drinks and in the sugar manufacturing industry. For fruit juices, one degree Brix is about 1-2% sugar by weight. This usually correlates well with perceived sweetness. As the Brix reading increases so does the perceived sweetness of fruit, fruit juices, etc.

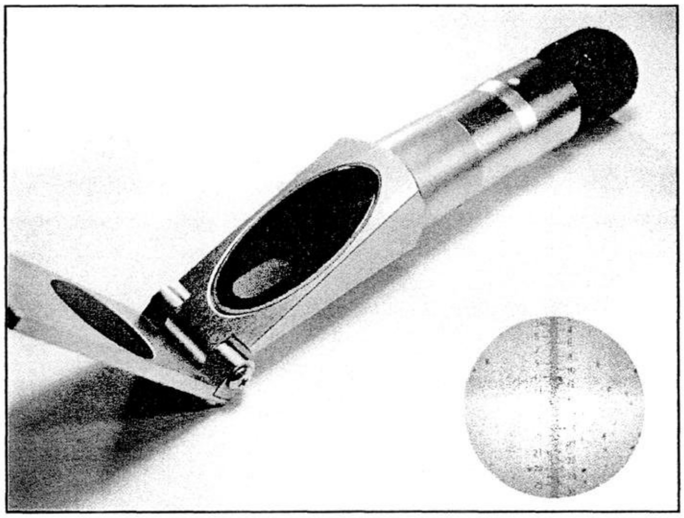
In reality, degrees Brix (°Bx) is a measurement of the amount (by weight) of dissolved sucrose to water in a liquid. For example, if 100 grams of a solution had a reading of 25 °Brix that would mean that the solution consisted of 25 grams of sucrose and 75 grams of water.

Since cranberry juice requires additional sweetness to make it palatable, handlers and juice manufacturers need to know the amount of sugar or sweetness in the raw fruit. In most fruit the °Brix increases as the fruit become ripe and are ready to harvest. Often °Brix and TAcy rise together as fruit ripen. If cranberries naturally have more sugar that means less external sweetener is needed to make a product palatable or to meet manufacturing standards. Handlers desire fruit with higher Brix readings.

Measuring °Brix

Brix can be determined in several ways and each method has its level of accuracy. The most common way to measure °Brix is with a refractometer. A photo of a hand-held refractometer is shown below. Refractometers work on the principle that compounds refract light and the amount of light that is refracted is related to the concentration of the compound in solution. So as the sugar concentration in a solution, such as fruit juice, increases light refraction also increases.

When determining the average Brix reading for a crop the reading should be taken from a composite sample rather than from individual berries. Berry to berry variation makes conclusions drawn from individual readings dubious at best. A composite sample is made by taking at least 100 grams of fruit randomly, chopping coarsely and then filtering the juice through several layers of cheesecloth to remove fruit chunks and then reading the °Brix on a refractometer. Hand held refractometers such as pictured here are acceptable for approximations and for field work. In a laboratory setting a temperature compensated model should be used. Digital models offer even greater accuracy.



Adapted from information at Wikipedia.org

What is Total Anthocyanin (TAcy)?

Teryl R. Roper
Dept. of Horticulture, University of Wisconsin-Madison

The word anthocyanin is derived from two Greek words: anthos = flower and kyanos = blue. Anthocyanins are water soluble pigments in plants that will appear red to blue depending on pH. At low pH anthocyanins appear red and high pH they appear blue. Anthocyanins are the pigments that give cranberry fruit their characteristic dark red color. Typically anthocyanins are found only in the outer two to three cell layers of cranberries.

Anthocyanins can be found in flowers, fruit, leaves, stems, and roots of plants. In flowers they act to attract insects to aid in pollination. In fruit they attract animals that will disperse the fruit and seeds. In leaves anthocyanins may act to protect the photosynthetic apparatus—acting like sunscreen to chlorophyll. In leaves the red color may also serve to repel animals because the red color is frequently associated with high levels of unpalatable phenolic compounds.

In cranberries anthocyanins or their precursors, proanthocyanidins, are likely responsible for their heart healthy attributes. Similar compounds are found in red and purple grapes and blueberries.

Cranberry juice manufacturers are interested in the anthocyanin content of fruit and some pay a premium for anthocyanin content that exceeds a base level. In the manufacturing process juice must have a consistent color from batch to batch so that when juice is displayed in the grocery store all bottles are exactly the same color. Consumers expect consistent color and quality as well.

When shipments of harvested fruit are received by handlers they take samples from each load and determine the anthocyanin content of those samples. This is typically expressed as total anthocyanin and is abbreviated as TAcy. The Cranberry Institute recently introduced a uniform method that will be used by all handlers to extract and quantify total anthocyanin.

The extraction process involves grinding up a known amount of fruit in a blender with an aqueous solvent, filtering out the solids, diluting to a lower concentration then reading the amount of light absorbed by the sample in a spectrophotometer. Absorbance of light at specific wavelengths is proportional to the concentration of anthocyanin.

Anthocyanin production is encouraged in the fall before harvest by bright sunny days (light) and cool nighttime temperatures. Clearly cultivars produce different amounts of anthocyanin. Ben Lear, for example, colors well and early, while Stevens are prone to color late and poorly. Some growing regions (Oregon) tend to produce higher anthocyanin than others (Wisconsin). This is likely related to climatic conditions.

While having high anthocyanin levels in fruit is desirable, there is little scientific data that specific management practices will necessarily lead to better color. Such research is difficult as climatic conditions may mask treatment differences from year to year. Ethylene is known to improve fruit color in most fruit crops, but its use has produced inconsistent results in cranberry.