The New York Berry News

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What's Inside

Currant Events: Grower cooperators are sought to test two new advanced strawberry selections from the Cornell University Small Fruits Breeding Program in Geneva. NY1829 and NYUS304B have been tested for several years at the New York State Agricultural Experiments Station at Geneva and are available in limited numbers for grower testing in 2002.

NY1829 is an early mid-season type with excellent fruit quality. Berries are bright red and firm but not hard, with excellent eating quality and flavor. Fruit is long round-conical with a fancy calyx, which makes them very attractive. Disease and insect resistance is unknown at this stage but no significant problems have been noted to date.

NYUS304B was developed through a joint venture with the USDA breeding program in Beltsville, MD and is resistant to red stele root rot. It is a mid-season selection with good potential. The fruit is a round-conical shaped with darker red color and good flavor. The flesh is firm with good texture and eating quality. Insect and other disease resistance is unknown at this time but no significant problems have been noted to date.

Both selections have been virus indexed and small numbers of dormant or green runner tip plugs are available to growers willing to record and report performance information to the breeder. Interested growers can contact Dr. Courtney Weber directly at (315) 787-2395 or at caw34@nysaes.cornell.edu.

Mark your calendar for the **Small Fruits Twilight Meeting** on Tuesday, June 25, 2002 at Cornell University's New York State Agricultural Experiment Station in Geneva. The focus of the meeting will be the strawberry variety trial established in 2001 which features NY1829, NYUS304B, Darselect, Eros, Sable, Brunswick, and Cabot compared to the industry standards of Earliglow, Jewel, and Honeoye. Also on the docket are presentations on small fruit disease and insect pests by the Geneva and Ithaca researchers including Dr. Bill Turechek, Dr. Greg English-Loeb, and Dr. Marvin Pritts. In addition, early season raspberries may be ready for sampling and evaluation. More details and sign up information will be distributed, as it becomes available.

Fast Facts: SPECIAL SMALL FRUIT DISEASE ISSUE

The biggest problems we routinely face this time of year are losses due to unexpected frosts and diseases. In this issue of the New York Berry News Marvin Pritts will cover the details of frost protection in strawberry. The rest of the issue focuses on disease problems. We provide in depth coverage of three major diseases of small fruit that warrant your attention this time of year: Gray mold, Mummyberry, and Phytophthora Root Rot.

— Strawberry —

1. Irrigation should be in place for frost protection (just in case the warm weather doesn't stick around).
2. Gray mold (blossom blight) management begins with blossom protection. If the warm weather continues we may experience an early bloom period and an increased risk for gray mold (see article below).
3. If the warm weather continues, you may need to think about using Captan or Nova to protect developing berries from black spot (caused by the

leaf spot pathogen) and anthracnose (we will cover these disease in the next issue).

4. Scout for tarnished plant bug. Anytime from just before the blossoms open until harvest, check for tarnished plant bug nymphs by striking the plant over a flat, low-sided, light-colored dish. The suggested action threshold is 0.5 nymphs per cluster, or 4 out of 15 clusters with one or more nymphs. Malathion may be used up to 3 days before harvest.

— Raspberry —

1. Continue to prune out and remove diseased canes before new canes emerge this spring. If you have not yet done so, apply a delayed dormant spray of lime sulfur or copper hydroxide. Note, this spray applied after ½ inch green-tip or under very warm conditions may burn the leaves. This spray is not necessary on fall-bearing raspberries as long as last year's canes mowed and removed from the planting.

2. In plantings diagnosed with *Phytophthora* root rot, a Ridomil Gold application can help to keep it under control. Ridomil Gold should only be used in well-drained plantings. Plantings which are continuously wet will probably not benefit from Ridomil Gold (see article below).

3. Raspberry fruitworm and raspberry sawfly are insect pests targeted this time of year. Sevin can be applied when insects or their damage is noticed in the spring.

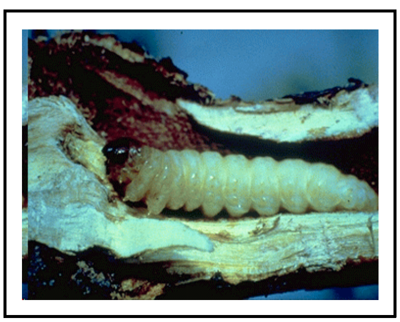

Fig 1. Larva of raspberry crown borer

Last year we encountered some significant damage caused by crown borers. At first glance, the damage resembled what one might expect form Phytophthora Root Rot in that a number of canes were collapsing in the heat of the summer. However, closer inspection of the canes revealed a swelling towards the crown (but sometimes higher). A longitudinal cut into the cane revealed the larvae of a cane borer lying in the pith (Fig 1). The larvae can not be found until later summer, but the adults are clear-winged moths that resemble yellow jackets. No insecticide is labeled for borers in raspberries, except for the red-necked cane borer. If you notice this pest in your planting, be prepared to remove and destroy canes that show symptoms throughout the growing season. Destroying these canes will rid the insect from your planting.

— Blueberry —

1. Continue to prune out and burn Fusicoccum infected canes. A delayed dormant/green tip application of lime sulfur (5 gal/A) should be applied for management of both Fusicoccum and Phomopsis canker. The lime-sulfur application will also be effective against gray mold (aka. Botrytis blight) if this is a problem in your plantings. Remember, do not use lime-sulfur within 14 days of an oil application.

2. This is also the time to begin scouting for mummyberry mummies (see article below).

— Currant and Gooseberry —

1. If you have a problem with scale insects on currants or gooseberries, a dormant oil spray can be applied before bud swell and burst in the spring, to control the overwintering adults. One other potentially important arthropod pest of currants is the currant aphid. The aphids become active around budbreak, causing distorted leaf growth. Timing for control of currant aphids is at budbreak or shortly there after.

2. As the foliage begins to appear, begin to scout for powdery mildew. Applications of Nova 40W or JMS stylet oil should be applied. Care should be taken with oil applications because multiple or excessive applications may delay ripening or reduce the sugars in mature berries. Sulfur is also labeled but should be used carefully because some varieties of gooseberry are "sulfur shy" and applications made to close to an oil application or during warm weather may prove phytotoxic.

Frost Protection in Strawberries

Marvin Pritts, Dept. of Horticulture, Cornell University, Ithaca, NY

Strawberry growers can ensure a full crop of berries only if they exert some influence on temperature during the year. Temperature control is especially important during the winter and early spring when flowers are susceptible to frost. Excessive summer temperatures inhibit growth as well.

Of all the factors that negatively affect strawberry production, frost can be the most serious. Frost can eliminate an entire crop almost instantaneously. Strawberries often bloom before the last frost free date, and if a frost occurs during or just prior to bloom, significant losses can result. The strawberry flower opens toward the sky, and this configuration makes the flower particularly susceptible to frost damage from radiational cooling. A black (rather than yellow) flower center indicates that frost damage has occurred.

Strawberry growers occasionally delay the removal of straw mulch in spring to delay bloom and avoid frost. Research has demonstrated, however, that this practice also results in reduced yields. Also, applying straw between the rows just prior to bloom will insulate the soil from the air. This will increase the incidence of frost injury as solar radiation will not be absorbed by the soil and re-radiated at night. If additional straw is to be applied between the rows in spring, delay its application for as long as possible before fruit set.

Overhead irrigation is frequently used for frost control because flowers must be kept wet during a freeze in order to provide protection. As long as liquid water is present on the flower, the temperature of the ice will remain at 32F because the transition from liquid to ice releases heat. Strawberry flowers are not injured until their temperature falls below 28F. This 4 degree margin allows the strawberry grower to completely cover a field with ice and yet receive no injury from frost. However, if insufficient water is applied to a field during a freeze event, more injury can occur than if no water was applied.

Several principles are responsible for the ability of ice to protect strawberry flowers from injury. First, although pure water freezes at 32F, the liquid in the strawberry plant is really a solution of sugar and salt. This depresses the freezing point to below 32F. Also, ice crystals need nucleators to allow them to form initially. Certain bacteria serve as nucleators. Sometimes, in strawberry flowers, the bacteria that allow ice to form are absent, allowing the freezing point to be lowered.

The temperature of the applied water is usually greater than the temperature of the plants, so this serves to warm the flowers before heat is lost to the air. As long as liquid water is continually applied to the plants, the temperature under the ice will not fall below 32F. When one gallon of water freezes into ice, 1172 BTUs of heat are released.

Several factors affect the amount of water that is required to provide for frost protection, and the timing of application. At a minimum, apply water at 0.1 - 0.15 in/hr with a fast rotating head (1 cycle/min.) Water must be applied continuously to be effective. A water source of 45 - 60 gal/min-acre is required to provide this amount of water. Choose nozzle sizes to deliver the amount of water required to provide protection under typical spring conditions in your location.

Under windy conditions, heat is lost from the water at a faster rate, so more water is required to provide frost protection. For every gallon of water that evaporates, 7760 BTUs are lost. The application rate then depends on both air temperature and wind speed (Table 1). Under windy conditions, there is less chance of flower temperatures falling below that of the air because of the mixing of air that occurs at the boundary of the flower. Winds are beneficial if the temperature stays above the critical freezing point, but detrimental if the temperature approaches the critical point. Less evaporation (and cooling) will occur on a still, humid night.

Under extremely windy conditions, it may be best not to irrigate because the heat lost to evaporation can be greater than the heat released from freezing.

Table 1. Water application rate (in/hr) for a given humidity and wind speed.

	Wind Speed				
Temp (F)	**0-1**	**2-4**	**5-8**	**10-14**	**18-22**
Relative humidity of 50%					
27	0.10	0.20	0.30	0.40	0.45
24	0.10	0.30	0.35	0.45	0.60
20	0.15	0.35	0.45	0.60	0.75
18	0.20	0.40	0.50	0.65	0.80
Relative humidity of 75%					
27	0.05	0.10	0.20	0.25	0.25
24	0.10	0.20	0.30	0.35	0.40
20	0.10	0.25	0.40	0.45	0.60
18	0.15	0.30	0.45	0.55	0.70

FROSTPRO model from North Carolina State Univ.

Stage of development. Strawberry flowers are most sensitive to frost injury immediately before and during opening. At this stage, temperatures lower than 28F likely will injure them. However, when strawberry flowers are in tight clusters as when emerging from the crown, they will tolerate temperatures as low as 22F. Likewise, once the fruit begins to develop, temperatures lower than 26F may be tolerated for short periods.

The length of time that plants are exposed to cold temperatures prior to frost also influences injury. Plants exposed to a period of cold temperatures before a frost are more tolerant than those exposed to warm weather. A freeze event following a period of warm weather is most detrimental.

Flower temperature. The temperature of all flowers in a field is not the same. Flowers under leaves may not be as cold as others, and those near the soil generally will be warmer than those higher on the plant. On a clear night, the temperature of a strawberry flower can be lower than the surrounding air. Radiational cooling allows heat to be lost from leaves and flowers faster than it accumulates through conduction from the surrounding air.

Soil also retains heat during the day and releases heat at night. It is possible that on a calm, cloudy night, the air temperature can be below freezing yet the flowers can be warm. Wet, dark soil has better heat retaining properties than dry, light-colored soil.

Rules of thumb

- Store sufficient water for 2 or 3 consecutive nights of frost protection
- Use small diameter nozzles (1/16 - 3/16 in. diameter)
- A 30 X 30 ft. staggered spacing of nozzles is preferable
- Use metal sprinklers to minimize icing
- Minimum rotation of once per minute

Using row covers. Row covers modify the influence of wind, evaporative cooling, radiational cooling, and convection. Because wind velocity is less under a row cover, less heat will be removed from the soil and less evaporative cooling will occur. Also, relative humidity will be higher under a row cover, reducing heat loss from evaporation. In addition, convective and radiational heat loss is reduced because of the physical barrier provided by the cover. Plant temperature under a cover may eventually equal that of the air, but this equilibration takes longer than with uncovered plants. In other words, row covers do not provide you with additional degrees of protection, but they do buy time on a cold night as flower temperatures will fall less rapidly inside a cover. Often the temperatures fall so slowly under a row cover that irrigation is not needed. If irrigation is required, less water is needed to provide the same degree of frost protection under a row cover. Water can be applied directly over the row covers to protect the flowers inside.

Turning on the water. Since cold air falls to the lowest spot in the field, a thermometer should be located here. Place it in the aisle at the level of the flowers, exposed to the sky, and away from plants. Air temperature measured at this level can be quite different from the temperature recorded on a thermometer at the back of the house. The dewpoint temperature measured in the evening is often a good indication of how low the temperature will drop on a clear night, and is related to the relative humidity. Air temperature will fall less if the humidity is high. If the air is very dry (a low dewpoint), evaporative cooling will occur when water is first applied to the plants, so irrigation must be started at a relatively warm temperature.

Most local weathermen can provide the current dewpoint, or it can be obtained from World Wide Web-based weather information services (see article below).

If the air temperature falls below 34F on a clear, calm night, especially before 3 A.M., it would be wise to start irrigating since flower temperatures could be several degrees colder. On the other hand, if conditions are cloudy, it may not be necessary to start irrigation until the temperature approaches 31F. If conditions are windy or the air is dry, and irrigation is not turned on until the temperature approaches 31F, then damage can occur due to a drop in temperature when the water first contacts the blossom and evaporation occurs. Therefore, the range in air temperatures which indicates the need for irrigation at flowering is normally between 31 and 34F, depending on cloud cover, wind speed and humidity, but can be as high as 40F. Admittedly, these numbers are conservative. Flowers can tolerate colder temperatures for short periods of time, and irrigation may not be needed if the sun is about to rise. Obviously, one does not want to irrigate too soon since pumping is expensive, and excess water in the field can cause disease problems.

Dewpoint	*Suggested starting air temperature (F)*
30	32
29	33
27	34
25	35
24	37
22	38
20	39
17	40

Turning off the water. Once irrigation begins, it should not be shut off until the sun comes out in the morning and the ice begins to slough off the plants, or until the ice begins to melt without the applied water.

Waterless frost protection agents. Future solutions to frost protection could lie in waterless methods, such as genetically engineered bacteria that do not promote the formation of ice. However, to date, these materials have not been consistently effective, so they are not recommended as the sole basis for frost protection.

A Touch of Gray

Bill Turechek, Dept. of Plant Pathology, Cornell University, Geneva, NY

Gray mold is the most serious fruit rotting pathogen of strawberry, raspberry, and blackberry in New York. It is a major problem during bloom and on ripening and harvested fruit. Aside from the direct losses the disease can cause in the field, diseased fruit are unsightly in pick-your-own operations or in pre-picked baskets. Although difficult to obtain exact numbers, this can be a problem in roadside stands and supermarket shelves where the presence of unsightly moldy fruit can adversely influence a customer's perception and affect return and quite possibly new business.

Gray mold is caused by the fungus *Botrytis cinerea*. This fungus is probably the most ubiquitous pathogen worldwide in that it attacks numerous fruits, vegetables, and ornamental plants. The key to managing this disease is to understand when and under what conditions the fungus infects the plant. *B. cinerea* survives the winter in dead or dying leaf tissue and plant debris. In spring, the fungus produces spores that are disseminated to susceptible plant parts by wind and splashing rain (or irrigation water).

Under cool and wet conditions, fungal spores can germinate and infect the blossoms, shoot tips (on blueberry in some cases), and leaves. Symptoms on leaves are uncommon. However, once the leaves begin to die, and for several weeks afterwards, the fungus produces spores on the dead and dying leaves. These spores serve as the major source of inoculum for fruit infection. Infection of the leaves apparently does not accelerate leaf death. Blossom and mature fruit infection is possible when rain, heavy dew, or overhead irrigation occurs in combination with temperatures within the range of 40-85°F. The most conducive temperatures for infection lie within the range of 59-77°F. Infection can occur with as little as 6 hours of wetness, but the rate of infection approaches 90% with 24 hours or greater of wetness.

Blossom infection is the primary means in which fruit become infected. Flowers are susceptible once they have opened, but the susceptibility to infection increases dramatically two to three days after opening. The fungus attacks the petals, stamens, and pistils but not the sepals. One to several blossoms per cluster (inflorescence) may become infected and infected blossoms often turn brown, wilt, and die. This is called blossom blight. The fungus enters immature fruit through these individual flower infections where it remains quiescent (latent) until the fruit begin to ripen. Green fruit are virtually resistant infection.

Upon ripening, the fungus becomes active and begins to colonize the fruit. Symptoms start as a discoloration and typically begin at the calyx end. If the infected berries do not fall to the ground, they shrivel, dry and eventually form a “mummy”. In the process, the fruit will become covered with the grey powdery fungal spores that are easily dispersed by wind and splashing rain. Additional fruit infection from these spores is considered to be of minor importance compared to those initiated through blossom infection. However, healthy fruit can become infected through direct contact with rotten fruit, particularly when wet weather occurs through the harvest period.

Several cultural practices can be used to help minimize disease development. Because prolonged wetting events significantly increases the risk of infection, any practice that promotes good air circulation to facilitate rapid drying can diminish the amount of infection. This includes proper plant spacing within and between rows and weed control. Gray mold is often most severe within the canopy where the air circulation is poorest. Another practice that helps reduce the risk of infection is to remove the dead and rotting tissue from the planting. It is these rotting tissues where the fungus produces the majority of the infective spores. Although, the fungus can attack many plants, it appears that outside sources of inoculum play a small role in the overall development of the epidemic relative to in-field sources of inoculum. Mature fruit are very susceptible to infection, especially if they have been bruised during picking. Therefore, fruits should be handled gently during picking and packing. If wet weather is prevalent during harvest, fruits should be picked promptly to avoid additional infection in the field.

In most seasons, fungicides are needed to manage gray mold. In New York, gray mold can be controlled usually with two well-timed fungicide applications during bloom. The first application should be made at early bloom (5-10%) followed by another 7 to 10 days later or at full bloom. Rovral (iprodione) is labeled for use on raspberries and blackberries. The label permits 4 applications per season and the last application can made up to and including the day of harvest. Benlate and Captan are the only two products labeled for use on blueberry.

Many products are labeled for use on strawberry. Elevate (fenhexamid) is the most effective fungicide for disease management during bloom. However, for resistance management purposes, no more than 2 consecutive sprays of Elevate should be applied. In high pressure years, or when wet weather prevails during harvest, a broad-spectrum fungicide such as captan, Benlate, thiram, or Topsin-M should follow the use of Elevate. These fungicides also have some activity against leaf blight and leaf spot. For all fungicides listed, be sure to check the label for recommended rates and timing.

Recommendations for the Control of Angular Leaf Spot

Dan Legard, Dept. of Plant Pathology, University of Florida, Dover, FL

Angular leaf spot is a bacterial disease caused by *Xanthomonas fragariae*. In Florida, this disease can become severe during cold weather when overhead irrigation is used for freeze protection. Symptoms of angular leaf spot begin as small water-soaked lesions on the lower leaf surface that enlarge and become necrotic forming the angular spots characteristic of the disease. When fresh, the lesions are translucent and produce a windowpane effect held up to a light. Under wet conditions, the lesions may produce slimy bacterial exudates. Infections often follow major veins, producing long water soaked lesions along them. Older lesions become necrotic and turn reddish brown and may coalesce producing symptoms that are difficult to distinguish from other foliar diseases. The pathogen can also cause lesions on the calyx of fruit during severe epidemics. These lesions look identical to the foliar lesions and when severe, can make the fruit unmarketable.

Inoculum for angular leaf spot is introduced into fruit production fields on infected transplants. The pathogen is highly specific to strawberry with no known wild hosts outside of *Fragaria*. The pathogen systemically infects strawberry, and can be spread by harvesting operations when wet and cool conditions favor the production of bacterial exudate. The pathogen is also splash dispersed by rain and overhead sprinkler irrigation. Development of the disease is favored by cool daytime weather (68F, 20C) and freezing nighttime conditions.

The best way to control angular leaf spot is to use pathogen-free transplants. Most bactericides including copper based products are primarily protectants and can only provide limited control of the disease since the pathogen colonizes the plant systemically. Regular applications of cupric hydroxide can reduce the severity of angular leaf spot by limiting the spread of the pathogen. However, copper can be phytotoxic to strawberry and regular applications can reduce yields. Because of the toxicity of copper we recommend it be used only for the control of calyx infections. Growers should avoid harvesting and moving equipment through infected fields when the plants are wet. Minimizing the use of overhead sprinklers during plant establishment and for freeze protection will also reduce the spread of the disease. (Source: Berry Times)

Awakened from the Tomb

Bill Turechek, Dept. of Plant Pathology, Cornell University, Geneva, NY

Mummyberry is caused by the fungus *Monilinia vacinii-corymbosi* and is one of the most serious diseases of blueberry. For some reason, the disease appears to much more problematic in Western and the Finger Lakes Region of New York than towards the Albany and Champlain Valley. Nonetheless, if mummyberry occurs in your planting, control procedures are likely necessary to minimize losses since they can exceed 30 to 40% when no control is practiced.

The fungus causing mummyberry overwinters in infected berries or “mummies” lying under the bushes. In early spring, infected berries produce the primary inoculum (i.e., ascospores) in a mushroom-like structure called an apothecia (Fig. 1). Ascospores are disseminated by wind and rain and infect emerging leaf buds and shoots. Shoots are most vulnerable to infection by ascospores when they are between approximately 5 and 40 mm in length (Fig. 2). Infection requires free water on the plant surface and can occur within 4 hrs under the optimum temperature of 14 C, but takes nearly 10 hrs at 2 C. Infected shoots and leaves wilt, turn brown and die; this is the shoot blight phase of the disease. Its appearance is similar to, and sometimes confused with, frost damage. Symptoms typically develop 2 weeks after infection.

Fig 1. Mummyberry mummies

Fig 2. Susceptible shoots

Infected shoots produce a second spore type, called conidia, that infect the blossoms. The formation of conidia requires high relative humidity. Conidia are disseminated to blossoms by both wind and pollinating bees. The bees are apparently attracted to the masses of conidia at the ends of blighted shoots by the reflection of ultraviolet light off the surrounding necrotic tissue and by the “scent” of sugars secreted by the conidia. Once a conidium has been introduced in to the flower, it will germinate with the pollen and slowly infect the developing fruit. Blossom infections are therefore not evident until the fruit begins to ripen later in the season when the berries begin to shrivel and turn a pinkish color. These are the "mummyberries" and they have been colonized by the fungus. Infected berries eventually fall to the ground, shrivel, and turn dark brown in which they will serve as the primary inoculum source the following spring.

Mummberry can be a difficult disease to control even under the best management practices. Like apple scab, however, the disease can be more easily managed if the primary source of spores is eliminated or disrupted. This can be accomplished through cultural means by raking or discing the soil beneath the blueberry bushes or covering the fallen mummyberries with a 3-4 inch layer of mulch. Growers may also choose to apply 200 lbs/A of 50% Urea prills directly under the bushes to hasten the degradation of the mummyberries. Remember, the formation of apotehecia is greatly enhanced when the mummies make physical contact with the soil. Burying these mummies disrupts their formation.

Fungicides are often necessary under high disease pressure. A key to efficient control with fungicides is to realize that the two spore types are managed differently. Unfortunately, there are no fungicides currently available that have excellent activity against the primary spores. A green tip application of triforine (Funginex) is the most effective chemical treatment for the disease, unfortunately, this fungicide is no longer being produced. Echo 720 and Echo 90DF (manufactured by Sipcam Agro) are chlorothalonil products (like Bravo®) which have just received labeling on blueberry for control of mummyberry (as well as anthracnose). These products have not been tested in New York but, in trials conducted in other states, chlorothalonil has been largely ineffective in controlling mummyberry. Many states in the northeast have obtained a Section 18 Emergency Exemption for the use of Orbit® fungicide against the shoot blight phase of the disease. In New York, we anticipated a federal label for both Orbit® and Indar® fungicides for the 2002 growing season. Unfortunately, with company acquisitions and the implementation of the FQPA, we recently learned it is unlikely that we will see a full registration for this year and likely for several more years to come.

To control the blossom blight/fruit rot phase of the disease, an application of Captan 50WP/Benlate SP (at 5 lb/1 lb per acre, respectively) repeated at a 7 - 10 day interval is recommended. This will also be an important spray for controlling Botrytis fruit rot. As bloom progresses the effectiveness of fungicide applications will decline as these fungicides cannot "cure" infections that have already occurred. For maximum control, fungicide applications should made prior to mid-bloom and should not be applied post bloom.

If you are planting blueberries this year and are concerned about mummyberry, you should avoid planting in areas of the field that are prone to frost (i.e., frost pockets), that are wet, and/or are slow to dry as these areas tend to have more problems with mummyberry. A number of resistant varieties are available. You should check with you local nursery to determine the level infection you could expect in your area.

Phytophthora Root Rot of Raspberries: Cause, symptoms & integrated control

Wayne Wilcox, Dept. of Plant Pathology, Cornell University, Geneva, NY

Phytophthora root rot was first recognized as a cause of declining raspberry stands in 1937 on the variety 'Lloyd George' in Scotland. The next reports of this bramble disease were from the Pacific Northwest, where it was documented on loganberry and 'Canby' red raspberry in 1958 and 1965, respectively. For the next 20 years, Phytophthora root rot was recognized as a common and serious disease of red raspberries in the Pacific Northwest, but was considered to be relatively unimportant in other parts of the world.

In the mid-1980's, however, various research groups in New York, Britain, continental Europe, and Australia began recognizing and documenting the international importance of Phytophthora root rot on red raspberries. In some instances, e.g., most countries of northern Europe, root rot appears to be a relatively new disease, probably introduced recently on infected planting material. In the midwestern and eastern areas of North America, it is likely that the disease has been present for quite some time, but was previously misdiagnosed as "wet feet" or confused with winter injury. The purpose of this article is to provide a brief description of the symptoms and general biology of Phytophthora root rot; outline a general integrated control program; and finally, describe the results of some experiments examining various control procedures.

Symptoms. Infected plants usually occur in patches, with the first symptomatic plants often occurring in the lowest or wettest section of the field. Primocanes and floricanes may both show symptoms. In wet years, affected primocanes may wilt and collapse in the late spring, often after the tissue at the base of the cane dies and develops a dark, "water-soaked" appearance. In other cases, primocanes of infected plants may gradually turn yellow, wilt, and die during the summer, or they may remain symptomless until the following year. Symptomatic floricanes typically produce weak lateral shoots, with leaves that turn yellow or red, wilt, and often "scorch" along the margins or between the veins. Floricanes of severely infected plants wilt and die before harvest.

An important point to note for diagnostic purposes is that the primocanes (suckers) that emerge from diseased areas are often few in number and relatively weak, in contrast with a normal or even excessively vigorous pattern of sucker emergence when floricane collapse is caused by winter injury, boring insects, or other cane diseases. Also, root rot will cause leaves or laterals to show symptoms along the entire length of the affected cane, whereas these other factors may produce wilting or death only above a certain point on the cane.

Because wilt and collapse may have several causes, it is necessary to examine the root system of affected plants to diagnose Phytophthora root rot. Dig up plants that are starting to wilt but have not yet died, and scrape the outer surface (epidermis) from the larger roots and crown. The tissue just beneath the epidermis should be white on healthy plants, but on plants with Phytophthora root rot it will be a characteristic red-brown, eventually turning dark brown or black as the tissue decays. A distinct line often can be seen where infected and healthy tissues meet, especially when infections occur on the crown.

Causal Organisms. Seven different soil-borne species of the fungal genus *Phytophthora* have been documented as causing root rot of raspberries in North America. However, one of them is by far the most important both in the Pacific Northwest and New York (probably in the upper midwest, New England, and eastern Canada as well, although this is not well-documented), and the same species is also the cause of the current root rot epidemic in Europe. Unfortunately, because of the difficulty in identifying individual *Phytophthora* species, this same organism has been called three different names: *P. erythroseptica* (Pacific Northwest, Europe), *P. fragariae* (New York), and *P. megasperma* 'type 2' (Europe). However, the important is to recognize that if one compares reports from different regions, these names do indeed refer to the same pathogen. (Recently, this fungus has been renamed *P. fragariae* var. *rubi*, which may reduce future confusion as different research groups begin to use one common name). It should also be recognized that other *Phytophthora* species may be more important in regions with warmer soil temperatures, such as California, the southeastern U. S., Chile, and Australia.

Disease Biology. Each *Phytophthora* species is somewhat different in pathogenic aggressiveness, temperature requirements, and various other specific properties, but the general disease biology is very similar for all. The fungi primarily persist in the soil as dormant resting spores (oospores) or in an active vegetative state within infected roots. When the soil is moist-to-wet and temperatures are favorable (=39˚F to aprox.70-75˚F for *P. fragariae* var. *rubi*), reproductive structures (sporangia) are formed on the surface of infected roots or as a result of germinating oospores. When the soil becomes completely saturated--i.e., water begins to puddle--infective spores (zoospores) are formed within the sporangia and discharged into the soil. These zoospores then swim through the water-filled soil pores with the aid of specialized "tails" (flagella), attach themselves to the plant's roots, and begin the infection process. Other zoospores may be carried relatively long distances by flowing runoff water, contaminating new fields or irrigation ponds and canals.

Because these fungi are so dependent upon saturated soil for the production and dispersal of their infective spores, episodes of excessive soil moisture effectively serve as infection periods for Phytophthora root rot (the longer the soil remains excessively wet, the more severe the infection period). Once the disease is established, each infected root can serve as a source of new sporangia and zoospores, providing the potential for epidemic disease development in sites that are frequently wet, or after a succession of several wet seasons.

Control. As with all Phytophthora diseases, control is best accomplished through an integrated program that includes site selection and/or modification to maximize water drainage, cultivar selection, chemical control where applicable, and exclusion of the pathogen to whatever extent is possible. (A note on pathogen exclusion: *P. f. rubi* does not appear to be a native inhabitant of soils in the Midwest and Northeast and, furthermore, has a very narrow host range—for all intents and purposes, it attacks only raspberries. Therefore, this is a pathogen which is likely to cause damage only in soils previously planted to raspberries or if it is introduced on infected planting material or in soil and water moving between "clean" and contaminated raspberry fields. It can often be avoided merely through a combination of site and planting stock selection and basic principles of sanitation).

Site modification. As mentioned above, infective zoospores of *Phytophthora* species are produced almost exclusively in saturated or flooded soil. For instance, in a mound of soil rising above a layer of standing water, there are only about 1/3 as many zoospores at a level 2 inches (5 cm) above the water line as there are in the saturated soil below the water line; at 4 inches (10 cm) above the water line, there are only 10% as many zoospores as in the saturated zone; and virtually no zoospores are available for infection 10 inches (25 cm) above the water line.

In 1990, an experiment was conducted which looked at the effects of using raised beds (12 inches) and/or Ridomil treatment on the development of Phytophthora root rot on the highly susceptible cultivar 'Titan'. Although Ridomil frequently provided better control than was obtained in the treated flat beds in this experiment, it has its limitations, particularly when growing highly susceptible varieties in relatively wet sites or years. The "take home" messages from this experiment w: (1) chemical control is no substitute for good soil water management; (2) raised beds are an effective means of limiting root rot severity; and (3) the benefits of chemical and cultural control procedures are additive when these components are integrated into a total management program.

Cultivar selection. Phytophthora root rot has never been reported on blackberries, and all black raspberry varieties grown in eastern North America appear to be quite resistant to *P. f. rubi*, the most important *Phytophthora* species in most regions (black raspberries are susceptible to some other Phytophthora species, but these should only be a problem in very wet sites). All red raspberry cultivars are susceptible to *P. f. rubi* to some extent, although their degree of susceptibility varies greatly. In 1990, a replicated variety trial examining the ability of various red, purple, and black raspberry cultivars to survive in a clay loam soil naturally infested with *P. f. rubi* was conducted. No disease was apparent during the first year, but results for 1991 and '92 are given below. The percentage of dead canes is given for the 1991 data and the number of primocanes per 16 ft row are the data for 1992.

Table 1. Susceptibility ratings for common red and purple raspberry varieties.

Variety	1991	1992
Latham	0	160
Killarney	0	143
Nordic	0	182
Boyne	0	136
Royalty	13	93
Newburgh	13	97
Cherokee	16	77
Taylor	16	130
Brandywine	19	41
Heritage	25	62
Ruby	47	73
Canby	50	35
Titan	59	41

Also included were the black raspberry varieties 'Jewel', 'Haut', and 'Bristol', which developed no apparent root rot.

It is interesting to note that the four varieties with few or no dead plants are all closely related: (1) Latham = Chief x Chief; (2) Killarney = Chief x Indian Summer; (3) Boyne = Chief x Indian Summer; (4) Nordic = Boyne x Fall Red. It is also interesting to note the high initial mortality and poor subsequent growth of 'Titan', a notoriously susceptible variety in commercial settings; 'Ruby', a 'Titan' progeny; and 'Canby', the variety on which *P. f. rubi* was first isolated and described (as *P. erythroseptica*) in the Pacific Northwest in the 1960's. 'Taylor', which has a reputation for poor performance in wet sites in New York, did surprisingly well in this trial. It remains to be seen whether "conventional wisdom" needs to be reevaluated concerning its root rot susceptibility, or if it merely escaped severe infection in this one particular trial.

Groundcover management. Marvin Pritts (Dept. of Fruit & Vegetable Science, Cornell University) and students in his program have shown a profound increase in cane numbers and vigor when weeds are controlled with straw mulch rather than herbicides during the first year of planting a new raspberry bed. However, research in Norway and New York has shown that straw mulch can also aggravate a Phytophthora root rot problem, by maintaining long periods of high soil moisture. It is therefore suggested that the use of straw mulch be limited to the year of establishment (root rot problems are uncommon in New York during this first year), maximizing the benefit of the mulch while minimizing the risk it may involve.

Chemical control. Both Ridomil and Aliette are labeled in the U. S. for control of Phytophthora root rot on raspberries. Both have shown significant effectiveness, although Ridomil often gives somewhat better results in head-to-head comparisons. Nevertheless, as illustrated in the data from the raised bed experiments provided above, chemical control is usually most effective as part of an integrated program which incorporates cultural control along with the fungicide applications. This concept extends to variety selection in which varieties less susceptible to Phytophthora root rot often respond better to chemical treatment.

In summary, Phytophthora root rot is becoming an increasingly serious concern for red raspberry growers throughout the world. However, the disease is controlable by applying several basic principles of any integrated pest managment program, including: (1) horticultural practices that limit pathogen development or infectivity (by limiting excessive soil moisture); (2) the use of partially resistant varieties; (3) sanitation; and (4) chemical control.

Eye on the Sky

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Weather plays a critical role in the daily activities of a grower. Orchard care, fertilization and, perhaps most critically, pest management are all governed by weather. Most growers do not rely on regular calendar applications to manage pests, but try to time important fungicide and insecticide applications based on the weather. In fact, growers who rely on disease forecasting models to time applications know that nearly every model or predictor that forecasts plant disease requires reliable weather information. For example, the MARTBLYT model used to predict blossom blight infection of fire blight of apple and pear requires readings of the daily high and low temperature and measurements of precipitation in the form of rainfall or dew. The *Venturia inaequalis* (apple scab) ascospore maturity model requires daily readings of temperature.

So how does a grower collect reliable weather data? Weather data can be collected in two basic ways: it can be collected from on-farm instrumentation or from offsite instrumentation. The benefit of using onsite weather equipment is that instruments can be placed at locations that historically have higher levels of disease pressure and will enable you to closely monitor conditions. Weather data collected from offsite instrumentation can be very representative of your farm if the instrumentation is located nearby. Offsite data can be delivered via telephone, fax, telemetrically, and via the internet and can be done so at a frequency as little as once per day to being available nearly instantaneously. Nonetheless, depending upon the quality of the instrumentation and the weather variables measured, measurements made on farm are unquestionably the most representative of your farm.

Yet, in the grand scheme of pest management the question arises: How accurate does weather data need to be? Do you need to record temperature to an accuracy of 1 degree? Does it make a difference if 1 inch of rain fell versus 1¼ inches? For plant diseases the answer is: "It depends". It depends upon the disease(s) of concern and the models that you are running. Ultimately, the grower must make the decision how valuable is precise weather data.

Onsite instruments: The basics to weather monitoring begin with measurement of temperature, usually the day's high and low are of greatest importance, atmospheric and free moisture (e.g., relative humidity and rain), and leaf wetness. There are many makes and models of instruments capable of recording these variables and some of these will be discussed in what follows.

Temperature is the environmental variable that is often most correlated with a biological response and is nearly universally included in forecasting models. Several types of thermometers are available to measure temperature. Liquid-in-glass thermometers are the most widely used. Most thermometers now use alcohol (rather than mercury) as a medium and are calibrated to a precision of around 0.5 C. Thermometers should be placed strategically throughout the farm, particularly in low-lying areas where frost is a danger, as those few degrees of variability at lower temperature can be quite critical. Thermometers, particularly high-low thermometers, must be read daily in order to retrieve the data, which can be a cumbersome chore. Otherwise, errors with this type of thermometer are often associated with poor readability, radiation, or through parallax (i.e., not reading the thermometer on a line parallel to the top of the liquid column). Deformation thermometers include the bimetallic strip and Bourdon tube thermometers. The bimetallic strip thermometer measures the linear deflection between the bond of two metals with different thermal coefficients that is caused by a change in temperature. The deflection is recorded mechanically to a strip chart recorder (e.g., hygrothermograph). Similar thermometers are available that measure the deformation of a gas or liquid. These thermometers are similar in accuracy to liquid-in-glass thermometers, but have a slow response time and are also sensitive to solar radiation. These thermometers are most useful in controlled environmental studies where a record of the temperature is needed.

Thermocouples and thermistors are electric thermometers that are well suited to automatic recording and logging data for computer usage. Thermocouples are junctions of dissimilar metals that generate an electromotive force proportional to their temperature at the junction (Campbell and Madden, 1990). Thermistors are semiconductors of ceramic materials made by sintering (i.e., heating until a substance becomes a solid without melting) mixtures of metal oxides (e.g., manganese, nickel, cobalt, iron, copper, and uranium). The electrical resistance of a thermistor is inversely proportional with temperature. Thermistors and thermocouples can record temperature to accuracy of 0.1 C but to assure accurate readings, electric thermometers should be aspirated, shielded from sunlight, and protected from wetness. Different types of shields are available for the different types of thermometers.

Atmospheric and free moisture are key variables in the infection process of many fungi and bacteria. Relative humidity, leaf wetness, rain, and soil moisture are the variables typically measured to quantify the level of moisture in the environment. Relative humidity (RH) is the ratio of the amount of water vapor in the air (i.e., vapor pressure) to the amount of water vapor that the air could contain at that temperature (i.e., saturation vapor pressure). Psychrometers (e.g., the sling psychrometer) measure the difference between the air temperature and the temperature recorded by a wet-bulb thermometer (a measurement of evaporative cooling) to provide a measure of the relative humidity. To obtain accurate measurements of RH with a psychrometer, thermometers capable of recording to an accuracy of 0.1C should be used. Electrical sensors that operate by measuring the change in resistance of water adsorbed to some material are used more commonly to measure RH. Electric sensors take several minutes to accurately respond to a change in RH, but this is typically not a problem in most agricultural settings.

Leaf wetness is a key variable driving foliar plant disease epidemics. Leaves may become wet from dew, fog, guttation water, irrigation water, fungicide, insecticide and fertilizer applications, and, of course, due to rain. Leaf wetness continues to be one of the most difficult parameters to measure because it is itself so variable within the plant canopy. Three general approaches are used to measuring leaf wetness. The deWit leaf wetness sensor mechanically measures leaf wetness by measuring the contraction and expansion of a hemp string or some other element as it responds to wetting and drying. Electric sensors are the most popular. Electric sensors consist of at least two electrodes (e.g., strips of nickel, wire, etc.) that are mounted in parallel on artificial leaves made from circuit board, plastic, cloth, or other type of synthetic material designed (to some degree) to mimic surface characteristics of a leaf. The circuit is completed upon wetting, and the extent of wetting is measured by electrical resistance. However, leaf wetness sensors fall short in capturing the biological and micro-environmental variability found within a canopy, thus careful interpretation of the data reported by leaf wetness sensors must be exercised. Leaf wetness can also be estimated, but this is not widely used. For example, the number of hours above 90% RH has been used to derive an estimate of leaf wetness.

Rain not only contributes directly to leaf wetness, but serves as a major means of disseminating fungal propagules. Indeed, some of our most serious diseases are almost exclusively splash dispersed and the degree of dispersion is directly related to the amount, duration and intensity of the rainfall. Rainfall can be easily and accurately measured with a number of different types of rain gauges. Rain gauges, however, must be visited shortly after the rain event and provide only a measurement of the quantity of rain that has fallen. Tipping-bucket rain gauges are used in electronic setups and provide measurements of rainfall amount, usually to an accuracy of 0.01 inch, as well as the duration of the rain.

Soil moisture is important in studies of root diseases. Soil moisture is probably the most neglected measurement of moisture because it is difficult to quantify accurately. Electric sensors are available for the quantification of soil moisture.

A number of electronic sensors are available that are capable of recording and logging virtually every weather parameter including temperature, relative humidity, rainfall, leaf wetness, light intensity, and soil temperature. These products range in their complexity as well as in their price. In short, recording devices are typically very accurate and can record at intervals as short once per every ½ second to once every few hours. At longer recording intervals, some of these sensors can go on recording for years before running out of space! Most sensors, however, require you to download the information, usually into a portable "shuttle", and then transfer the information from the shuttle to your computer. This is not difficult, however, if you want to collect information daily this can even be even more cumbersome than using simple instruments, especially if temperature is the only parameter that you are interested in. But if you do not need to collect information every day and/or more than one weather parameter is utilized and/or you are using your weather data to run various computer-driven disease or insect models, then using electronic sensors may be your best choice.

Weather equipment can purchased from a number of companies including:

1. A.M. Leonard, Inc. (http://www.amleonard.com/main.html)
2. Forestry Suppliers, Inc. (http://www.forestry-suppliers.com/)
3. Orchard Supply Company (http://www.Orchardsupply.com)
4. Gempler's (http://www.Gemplers.com)
5. Onset Computer Corporation (http://www.onsetcomp.com)
6. Spectrum Technologies (http://www.specmeters.com/)

Although not a realistic option for most growers, portable weather stations are available that can transmit weather data from the field to your computer via modem. These telemetric weather stations usually consist of a combination of the electronic sensors, like those discussed above, but are wired in such a way to deliver the data directly to your computer. Maintenance of the station becomes a chore and setting up the station can be complicated.

Web-based services. Detailed weather information can be obtained via the internet. There are number of commercial and non-commercial sites that are set up to provide free weather information for virtually every town in the United States. Of course, weather stations are not deployed in every town across the United States. Rather, sophisticated algorithms are used to predict weather across a region from base weather stations (usually located at major airports). The algorithms are becoming remarkably more accurate and can provide quite precise information to a number of areas. Some of the most popular and informative weather resources on the web include:

1. The United States Weather Pages (http://www.uswx.com/us/wx/)
2. Intellicast (http://www.intellicast.com)
3. The National Weather Service (http://www.nws.noaa.gov/)
4. The Weather Underground (http://www.wunderground.com/)
5. NewsChannel 9 and Niagara Mohawk "Niagara Mohawk LIVEDoppler 9" (http://www.wixt.com). Radar Images on this website are updated every 10 minutes

Becoming more popular, are sites specifically designed to serve agriculture. Usually for a fee, these sites will provide current weather information, but more useful, they run a number of plant disease and insect forecasting models and provide recommendations based on their output. Some of these sites are setup to deliver personalized data to your email each morning and some provide colorful maps that detail pest pressure that can be viewed over the internet. Two of these companies that serve NY are the Northeast Weather Association (NEWA) and Skybit.

NEWA (http://www.nysipm.cornell.edu/newa/index.html) is a consortium of growers who have installed small weather stations on their land. Each day, information such as the temperature, relative humidity, leaf wetness and precipitation is transmitted from the farm to the Agricultural Experiment Station in Geneva. There, the raw data is processed by several computer programs, each designed to evaluate the data and issue a pest forecast specific to the area where the fruit or vegetable grows. A grower can either choose to find the daily information from a personal computer or opt to have a forecast sent via facsimile.

SKYBIT SkyBit, Inc. (http://www.skybit.com) is a ten-year-old company specializing in development of site-specific weather products for agriculture, energy, and other industries. SkyBit through its E-Weather Service and research programs can provide custom data sets for weather-dependent decisions. E-Weather Service "Ag-Weather" has been supporting the agricultural community weather information needs for more than 6 years. A variety of products have evolved over the years to assist decision making in the field. These products include integrated pest management (IPM) simulation and forecast, irrigation schedule, frost predictions for select crops, as well as custom data for other commodities.

Check out the new NYSAES Tree Fruit and Berry Pathology web site at:

www.nysaes.cornell.edu/pp/extension/tfabp

Questions or Comments about the New York Berry News?

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