Wisconsin Cranberry School proceedings. Volume 10 1999

Madison, Wisconsin: Wisconsin State Cranberry Growers Association, 1999

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

PHYTOPHTHORA ROOT ROT OF CRANBERRIES

Peter V. Oudemans
Rutgers University, Blueberry and Cranberry Research and Extension Center, Chatsworth, NJ 08019

Many crop species are affected by Phytophthora root rot (3). Most of the more than 50 species in the genus *Phytophthora* are soil-borne and cause symptoms ranging from root rots, butt rots, trunk cankers and tuber rots. Phytophthora root rot was described from cranberry relatively recently (1). The disease is caused principally by *P. cinnamomi* although other species such as *P. megasperma, P. dreschleri* and others have been implicated (2, 4). These pathogens are members of the class Oomycetes and are very dependent on water for dispersal of the self-motile, flagellated zoospores. As such, many *Phytophthora* species are spread through irrigation water (7, 9) and under sufficiently wet conditions will disseminate, infect and ultimately kill the plant. A typical Phytophthora life cycle is shown in Fig. 1.

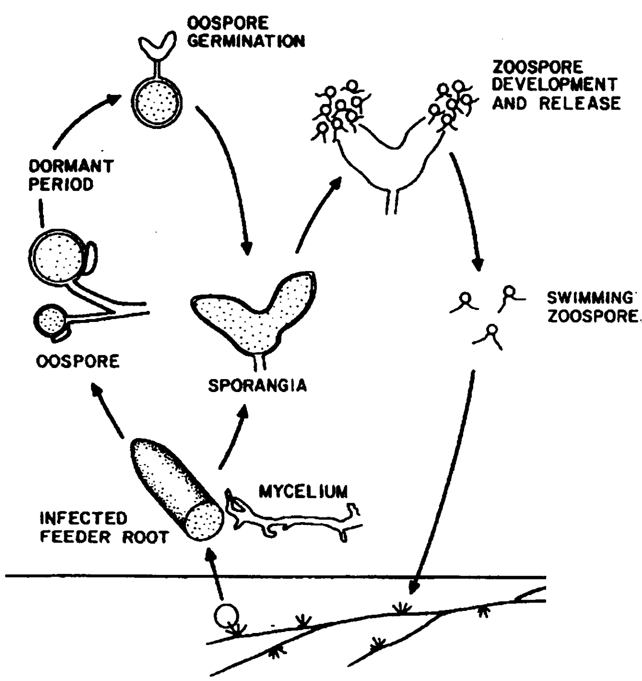


Fig. 1. A typical *Phytophthora* life cycle. Sporangia are formed under nearly saturated conditions and zoospores are released. The zoospores swim in saturated soil and infect cranberry roots and runners. Other spore types include oospores and chlamydospores (not shown). These spores form in rotted tissues and over winter in soil and initiate infections the following season.

Cranberry root rot causes a reduction of root mass, stunting and eventual death of the vine. Since cranberry plants colonize areas by runner growth, inhibition of runner root development also slows the colonization of a cranberry bed with vines. The symptoms of root rot appear as weakened vines and as a general decline (i.e. unlike upright dieback). Closer inspection generally reveals a weakened root system and discolored lesions in the runners. Lesions often form near a rooting point. Since *Phytophthora* species reduce root volumes several additional symptoms coincide with root rot. The most severe symptoms (plant death) are the result of infections by *Phytophthora cinnamomi,* a species that does not occur in Wisconsin. Under less severe conditions plants can be stunted, display symptoms of nutrient deficiency, and be less tolerant of drought (5, 6). These chromic infections can significantly reduce yield. Sandler et al. (8) showed that loss of feeder root densities through *Phytophthora parasitica* infection of citrus plants could reduce yield and fruit quality significantly without having major impacts on tree health. In that study, tree decline ratings differing by as much as 0.6 (scale of 0-3, i.e. treated trees 0.2 versus untreated trees 0.8) resulted in significantly different yields. This type of situation is probably very common although methods for detection and mapping of affected plants can be problematic.

Optimum conditions for spore germination and plant infection

- Sporangia form on infected plant tissues
- The optimum condition for formation and germination is wet - saturated soil
- Zoospores are released under saturated conditions and swim in water
- Plant infection occurs when zoospores are present

The zoospores of *Phytophthora* are carried in surface irrigation water (not in well water) and therefore are introduced regularly into the cranberry beds (7). However, symptoms develop in only a small percentage of the total acreage exposed. This low level of symptom expression is due to the generally excellent drainage of cranberry soils as well as the low pH values (3.0-4.5). These factors are known to reduce development of root rot (3, 10). Research has repeatedly demonstrated that under saturated soil conditions *Phytophthora* species produce sporangia, release zoospores and infect plant roots (10). As soil conditions become less saturated and flooding episodes less frequent, the probability of infection is reduced and the number of infection cycles declines.

Control practices.

Controlling cranberry root rot requires integration of several components. The most critical control practice relates to water management methods. Drainage is the most important soil property determining the degree of damage to be caused by Phytophthora infection. Uniform drainage allows soil water content to be managed to a level where infections are minimized. Problems arise where soil drainage is highly variable. In those cases it is not possible to irrigate sufficiently in well-drained areas and not over irrigate in poorly drained ones. Thus in establishing new beds uniform drainage should be attempted. The formation of a puddle or standing water is first place Phytophthora infections occur. Thus drainage methods that remove standing water such as ditches or underdrains are very useful in controlling root rot. Irrigation uniformity is also an important factor since over watering in some areas can increase the chances of

Management practices important for Phytophthora control

- Soil drainage
- Soil drainage uniformity
- Irrigation uniformity
- Irrigation timing
- Soil pH
- Sanitation practices
- Diagnosis of the pathogen
- Resistance level of cultivars
- Timing of fungicide applications

infection. Repeated cycles of wetting and drying, especially extreme cycles are conducive for root rot development. Irrigation timing should focus on consistently maintaining soil moisture near the optimum level determined for the crop as opposed to long intervals between irrigation events. Soil pH is a questionable factor used for *Phytophthora* control. Since cranberry is an acid loving plant it can tolerate relatively low pH levels. However, use of sulfur to reduce pH in areas with symptoms of root rot can lead to additional damage if the soils are not dry or well drained. Thus this practice should be used with caution. Sanitation practices are generally recommended however, do not strictly apply to cranberry culture. Growers should be aware of the levels of *Phytophthora* in irrigation reservoirs and if possible the species that are present. This information is useful in determining the critical timing for control measures (see below) as well as potential fungicides that may be effective (see below).

Several *Phytophthora* species have been described from cranberry. These species are different in terms of pathogenicity, temperature optima, fungicide sensitivity and geographic distribution. For this reason, diagnosis can be important component in developing a Phytophthora management program. A summary of the *Phytophthora* species found on cranberry is given below.

Species	Distribution	Ridomil Sensitivity	Temperature optimum	Pathogenicity
P. cinnamomi	NJ, MA, OR, WA, (BC)	Sensitive	20 – 30 C	Very pathogenic
P. megasperma	above, WI	Resistant	15 C	Pathogenic below 15 C
P. dreschleri	above, WI, BC, Que	Sensitive	Not determined	Not determined
P. spp. (3-5)	All	Mostly sensitive	Not determined	Not determined

Fungicides are used to treat infected areas. The use of fungicides for root rot control should be delayed until drainage has been improved. The greatest effects of Ridomil will be seen when the infected areas are properly drained and beginning to recover. In fact the major effect of the fungicide will be to increase the rate of recovery. Fungicide applications should be made to coincide with the timing of fungal activity and also to protect vulnerable tissues. Generally, a root flush in cranberry occurs during early bud break and again in late summer to early fall. The young roots are particularly susceptible and therefore applications timed to root flushes are most effective.

Conclusions

Phytophthora root rot is a widespread disease in cranberry production in North America. In the worst case scenarios plants are killed leaving bare spots in the beds. However, chronic infections, where plants are stunted, are probably much more common. These chronic infections cause crop losses of varying levels depending on the Phytophthora species present and the extent and duration of flooding. Treatment of these chronic infections is complicated by the difficulty in detection. One approach being developed for this use is remote sensing. Color infrared aerial photographs have been used to visualize and begin modeling cranberry yields. These photographs are now being used to detect Phytophthora injury along with other yield limiting factors.

Useful sources of information:

RCE FAX INFO LINE has newsletters and fact sheets available in a FAX-back format. (732) 932-6767

Rutgers University Blueberry and Cranberry Research Centers Website has various documents and sources for information.
http://aesop.rutgers.edu:80/~bluecran/

Literature Cited

1. Caruso, F. L., and W. F. Wilcox. 1990. *Phytophthora cinnamomi* as a cause of root rot and dieback of cranberry in Massachusetts. Plant Disease. 74:664-667.
2. Drilias, M. J., and S. N. Jeffers. 1990. Detection of *Phytophthora* species in cranberry field soils. Phytopathology. 80:1025.
3. Erwin, D. C., and O. K. Ribero. 1996. Phytophthora diseases worldwide. APS Press, St. Paul.
4. Jeffers, S. N. 1988. *Phytophthora* Species Associated with a Cranberry Decline Syndrome in Wisconsin. Phytopathology. 78:1572.
5. Johnson, K. B. 1987. Defoliation, disease and growth: A reply. Phytopathology. 77:1495-1497.
6. Kocon, L. 1996. Drought increases *Phytophthora* root rot. Cranberries:7&27.
7. Oudemans, P. V. 1999. *Phytophthora* species associated with cranberry root rot and surface irrigation water in New Jersey. Plant Disease. 83:251-258.
8. Sandler, H. A., L. W. Timmer, J. H. Graham, and Z. S.E. 1989. Effect of fungicide applications on populations of *Phytophthora parasitica* on feeder root densities and fruit yields of citrus trees. Plant Disease. 73:902-906.
9. Von Broembsen, S. 1984. Distribution of *Phytophthora cinnamomi* in rivers of the south-western cape province. Phytophylactica. 16:227-229.
10. Zentmyer, G. A. 1980. *Phytophthora cinnamomi* and the diseases it causes. Monograph NO. 10. The American Phytopathological Society.

Integrated Management of Cottonball

Patricia McManus, Violet Best, and Rick Voland
Department of Plant Pathology
University of Wisconsin-Madison

Cottonball, caused by the fungus *Monilinia oxycocci*, is an economically important disease on many cranberry marshes in Wisconsin. Cottonball has also been described in the Pacific Northwest and southeastern Canada, but losses in these areas have generally been minor. For reasons that are not known, cottonball has increased in importance in Wisconsin over the past 30 years. In recent years, about 20% of bearing acreage has been treated with fungicides specifically for cottonball control. Where cottonball occurs, the incidence of infected fruit is typically 2-10%, but it can exceed 40% if left unchecked. Control of cottonball has depended largely on fungicides. As we gather more information on the interaction of *M. oxycocci* and cranberry in the marsh environment, we are developing safer and more sustainable means of controlling this disease.

Cottonball disease cycle (Fig. 1)

The cottonball fungus, *M. oxycocci*, overwinters in mummified remains of previous seasons' infected fruit, technically known as sclerotia. In the spring, small mushroom-like structures called apothecia grow from some of the sclerotia (mummies). Ascospores are ejected from the apothecia, starting at about budbreak and continuing until just before bloom. Maximal ascospore release occurs over a 10- to 14-day period when the majority of shoots are ½ to 1 ¼ inches long and very susceptible to infection. Infection probably requires water and moderate temperatures, although this has not been determined experimentally. The exact sites on the elongating uprights where the fungus penetrates are not known. Infection results in "tip blight" symptoms: crooked over shoot tips, tan discoloration of leaves, and blasted blossom buds starting about a week before bloom.

Just before bloom, the fungus produces spores (conidia) on infected floral and vegetative uprights. Conidia are carried to flowers by wind, insects, or both. There they germinate on the stigma and grow down the style to the developing ovary, similar to the pattern of pollen germination and growth. As the fruit matures, the fungus fills the seed cavity and eventually grows into the fleshy tissue. By harvest time, sclerotia develop in 25-50% of the infected fruit; berries that do not have sclerotia by harvest time decompose by the following spring.

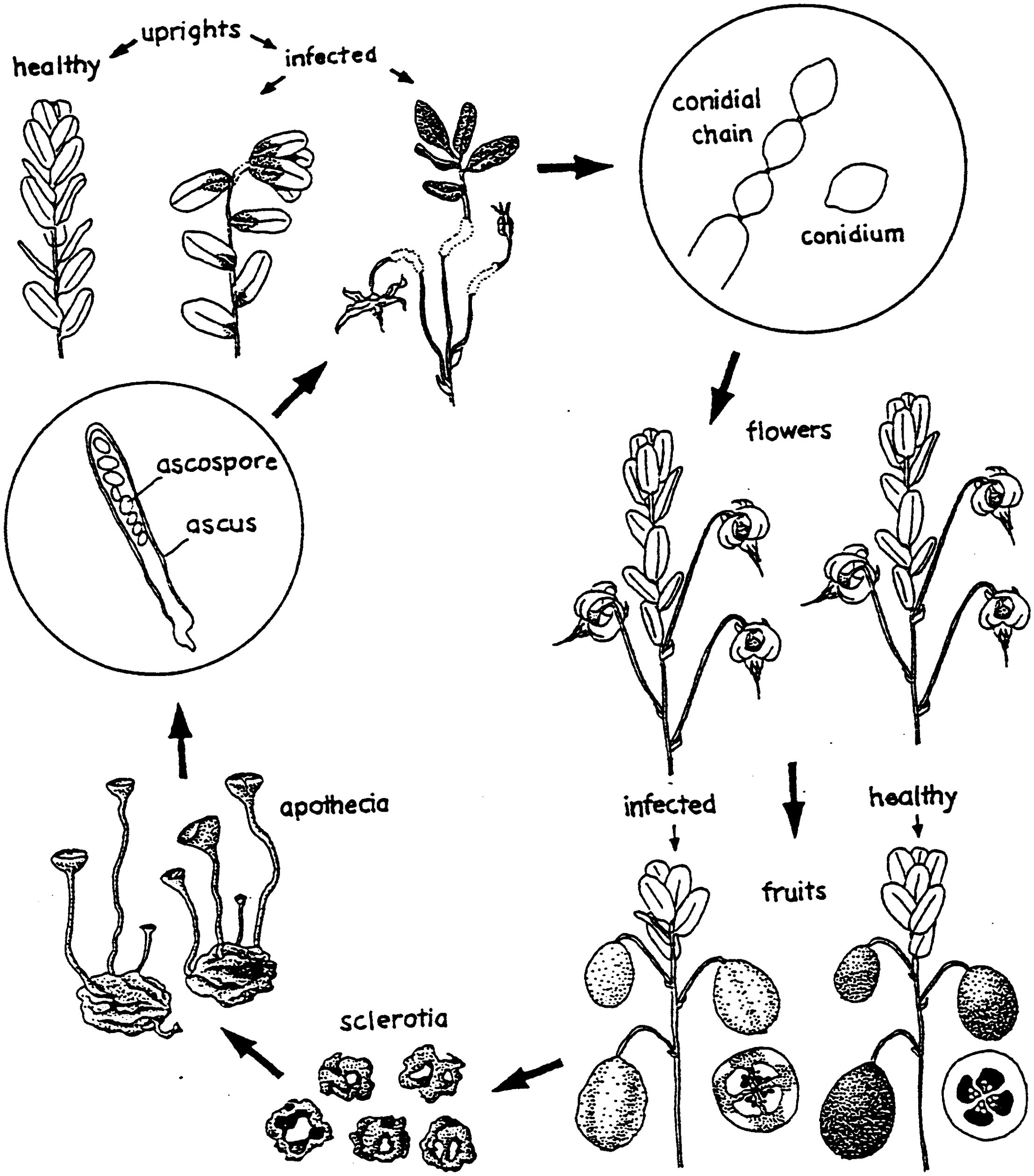


Figure 1. Cottonball disease cycle.

Integrated Management

Sanitation and cultural practices. Most recent research on cottonball has focused on chemical control and efficient use of fungicides. However, there are limited data and circumstantial evidence on the influence of sanitation and cultural practices that guide us in developing an integrated approach to control. For example, cottonball fruit and mummies float, and many are removed during harvest. Some growers have found that re-flooding beds after harvest cleans out not just cottonball mummies but other pests as well. We have noticed that primary infection (shoot infection) is often most severe along ditches, especially where there is dense moss. Perhaps these areas remain wet for prolonged periods and this promotes germination of mummies. Alternatively, vines in these areas may be prone to frost injury. On lowbush blueberry, frost-injured plants are more susceptible to mummy berry, a disease similar to cottonball. Finally, we have observed severe cottonball in areas of beds where newly applied sand remained saturated for several days. Thus, good drainage appears to be important not only for the general health of the cranberry plant but also to prevent cottonball mummies from coming to life.

Chemical control. In the early 1980s, Funginex (triforine), a sterol inhibitor (SI) fungicide, was registered on cranberry for control of cottonball. By the mid-1990s, Funginex was no longer being produced, but another SI fungicide, Orbit (propiconazole) became available by Section 18 emergency registration. With both Funginex and Orbit, two sprays during shoot elongation (budbreak) and two sprays during bloom have been permitted. However, most growers who treat for cottonball spray fewer than four times per season. So *which sprays are more important—shoot elongation or bloom?* Answering that question was the *first objective* of our research. A *second objective was to test new fungicides*, especially those that have been deemed "reduced-risk" by the EPA. To delay the development of Orbit-resistant populations of *M. oxycocci*, we need new fungicides with modes of action different from the SIs. A *third research objective was to determine whether fungicide-resistant populations of M. oxycocci had already started to evolve* at sites where SI fungicides (Funginex and Orbit) had been used. The fact that the SI fungicides, which have a single mode of action, have been used frequently, and often exclusively, to control cottonball for the past 16 years is reason enough to be concerned about fungicide resistance in *M. oxycocci*.

Field tests conducted in 1996 and 1997 showed that under low to moderate disease pressure (<15% cottonball berries at harvest), making two sprays during bloom was just as good at reducing cottonball at harvest as making two sprays during shoot elongation *plus* two sprays at bloom (Figs. 2 and 3). In other words, the shoot elongation sprays were a waste of time and fungicide. We also found that some experimental fungicides were as effective as Orbit at controlling cottonball. These will be pursued for future registration. It's encouraging that none of the fungicides tested reduced yield, fruit size, fruit retention, or fruit color.

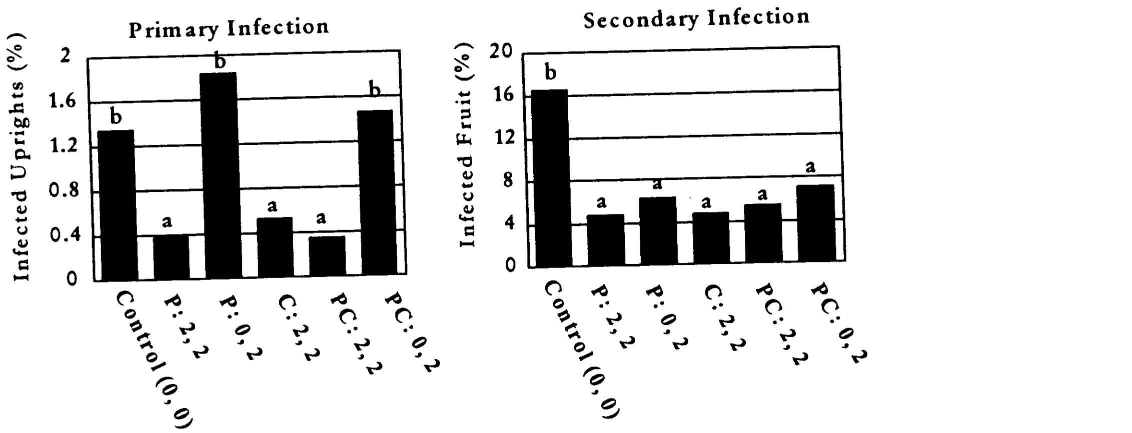


Figure 2. Incidence of primary (shoot) and secondary (fruit) cottonball infection in 1996. Data from two sites were combined. P=propiconazole (Orbit); C=experimental fungicide; PC=mixture of P and C. Numbers after P: or C: are number of shoot elongation (budbreak) sprays, number of bloom sprays. Within a graph, the same letter above bars indicates no statistically significant difference between the treatments.

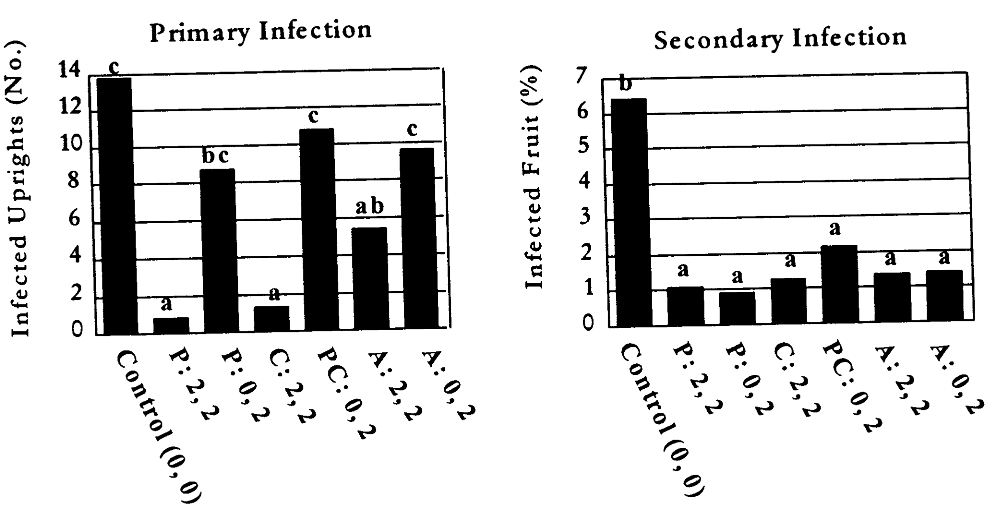


Figure 3. Incidence of primary (shoot) and secondary (fruit) cottonball infection in 1997. P=propiconazole (Orbit); C and A=experimental fungicides PC=mixture of P and C. Numbers after P:, C:, or A are number of shoot elongation (budbreak) sprays, number of bloom sprays. Within a graph, the same letter above bars indicates no statistically significant difference between the treatments.

Fungicide resistance concerns. Despite using fungicides with a single mode of action for several years, there have been no reported suspicions of resistance to Orbit. But if Orbit "failure" is reported in the future, how will we know whether it's because of resistance or some other factor (*e.g.*, too low a rate used or poor spray coverage)? To answer this question in the future, we need to know just how susceptible *M. oxycocci* is to Orbit now, *before* it's been used for several years.

To get a "baseline" fungicide sensitivity standard, and to see whether resistance to Orbit might already be developing, we collected populations of *M. oxycocci* from three sites that differed in fungicide use history. At site 1, fungicides had never been used; at site 2, two to four SI sprays had been applied each year since 1989; and at site 3, two to four SI sprays had been applied each year since the early 1980s along with other fungicides (*e.g.*, copper, mancozeb, captafol, and chlorothalonil). Then, in the laboratory we determined the ED_{50} (*i.e.*, fungicide concentration that reduced fungal growth by 50%) for each member of each population. The frequency distributions for ED_{50}s show that isolates of *M. oxycocci* from a given site vary in sensitivity to Orbit, but the average ED_{50} did not differ significantly among sites (Fig. 4). These data suggest that field populations exposed to the SI fungicides Funginex and Orbit have not become resistant to Orbit. The data also provide a "baseline" sensitivity standard to which we can compare suspected Orbit-resistant populations of *M. oxycocci* in the future.

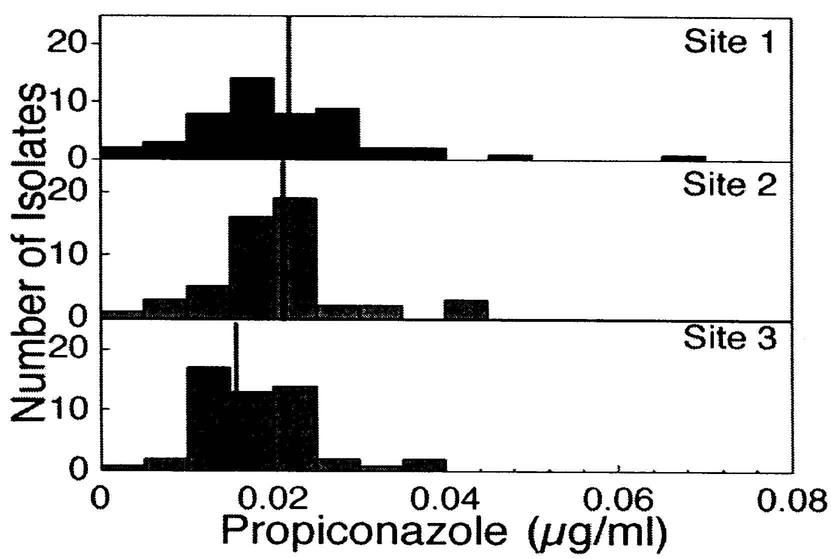


Figure 4. Frequency distributions of ED_{50} values to propiconazole (Orbit) for populations of *Monilinia oxycocci* from sites with different fungicide use histories (see text for details). Values on the x-axis are ED_{50} fungicide concentrations; values on the y-axis are number of isolates of *M. oxycocci* in each ED_{50} class. Vertical bars represent the mean ED_{50} for each site.

Susceptibility of popular varieties

Cottonball has been observed on all the popular varieties (*e.g.*, Stevens, Ben Lear, Searles, Pilgrim, McFarlin) in the field, but reports on the relative resistance of these varieties to cottonball have been inconsistent. In the field, susceptibility to cottonball depends on genetic interactions between *M. oxycocci* and the cranberry plant during primary infection of shoots, secondary infection of flowers, the overlap of bloom and spore production on shoots, and environmental factors such as temperature and moisture. But because infection of flowers is the economically important phase of the disease, and we know how to infect flowers under controlled conditions (*e.g.*, the greenhouse), our experiments focused on the susceptibility of the most popular cranberry varieties in Wisconsin—Ben Lear, Pilgrim, Searles, and Stevens—to floral infection. We found that following artificial inoculation in the greenhouse, these varieties did not differ in susceptibility to fruit infection (Fig. 5). In particular, Stevens, which some claim is relatively resistant, was at least as susceptible as the others. We speculate that it enjoys a reputation for resistance in the field only because many Stevens plantings are relatively young and disease pressure has not yet accumulated.

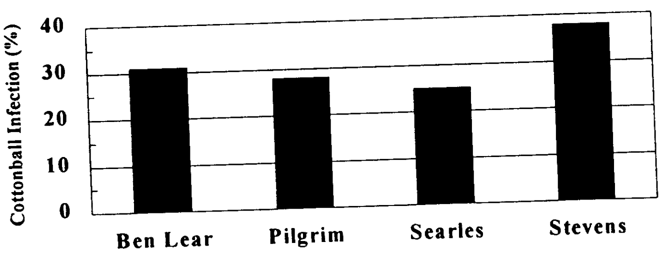


Figure 5. Incidence of cottonball secondary (fruit) infection of popular cranberry cultivars in Wisconsin. Approximately 500 flowers of each variety were hand-inoculated in a greenhouse. The differences in percent infection are not statistically significant.

Summary and Recommendations

Experimental data and the observations of growers, crop consultants, and researchers are leading to a better understanding of cottonball. With this information, we are developing sustainable cottonball management programs that integrate sanitation, cultural practices, and fungicide use. The following recommendations should result in disease control that will be safe for humans and the environment and also delay the onset of fungicide resistance in populations of *M. oxycocci*.

- Re-flood beds after harvest to remove cottonball berries and mummies. This will reduce cottonball inoculum and other pests as well.
- Consider all the most popular varieties susceptible to cottonball. Don't expect a bed of Stevens to remain disease-free if planted next to a bed with cottonball.

- Control moss and avoid having areas of saturated sand in the spring when mummies germinate. Mummies germinate through sand, so you can "bury" last year's problem.
- Under "low disease pressure", skip shoot elongation sprays and spray only during bloom. "Low disease pressure" is a subjective term that will vary among growers. If coming into the season, you know you want to treat for cottonball but don't think it's bad enough to justify all four sprays, then consider it "low disease pressure".
- Just before bloom, scout for primary (shoot) infections so you can decide whether or not to spray during bloom. Look especially closely along ditches, wet areas, and where frost may have occurred.
- Two sprays are permitted during bloom. Be certain that the first one goes on at 10-20% bloom. These early flowers are the ones most likely to set fruit and therefore are the most important ones to protect.
- To the extent possible, spray a variety according to *its* developmental stage, rather than treating early and late varieties at the same time.
- When using Orbit, do not go below 4 oz per acre. Sterol inhibitor fungicides generally do not perform well if rates are skimmed. Also, for other plant pathogens it's been shown that using lower rates of SIs actually promotes the development of fungicide resistance.

THE FOOD QUALITY PROTECTION ACT: AN UPDATE, AND WHAT IT MAY MEAN TO THE FUTURE OF CRANBERRY INSECT CONTROL

Daniel L. Mahr
Department of Entomology
University of Wisconsin - Madison
and
University of Wisconsin - Extension

FQPA Update. The impacts of the federal Food Quality Protection Act of 1996 (FQPA) are still being sorted out. New decisions are being made, and new procedures are being implemented regularly. The following were developments during 1998.

- The review of all high-priority products (including organophosphate and carbamate insecticides) is to be completed by 2002.
- Decisions will likely be made product by product as the various reviews progress.
- Crops that pose the biggest risk, based upon issues such as total quantity consumed, pesticide usage patterns, and childhood exposure, will be dealt with first.
- Decisions on "negligible-risk" crops, which are those that do not fit into the above categories, are likely to be delayed. Cranberry is in this category.
- Decisions for continued registration of products on negligible-risk crops will likely be made by the product registrants (pesticide companies), based upon risk-cup issues; ultimately, this relates back to product profitability.
- Registrants continue to meet with EPA and with commodity groups.
- Representatives of the cranberry industry have been very active in arguing the industry's case with both EPA and the registrants.
- There is still a large amount of uncertainty about the ultimate outcome; but there may be more cause for optimism than a year ago.

Life after FQPA. It's a bit hard to predict what insect management will be like once FQPA becomes fully enacted, because we don't have a clear picture as to the final decisions that will be made. However, even in the worst-case scenario of the elimination of all organophosphate and carbamate insecticides (which, in my opinion, is unlikely to happen), there will still be tools in the pest management tool box.

- Pest scouting will become increasingly important. As we lose broad-spectrum pesticides, we will likely be using more selective materials. This will mean that growers will need to know precisely what pests are causing economic injury so that the best management methods can be used. The cranberry industry has adopted IPM-based pest monitoring programs better than most other agricultural commodities, and is in a good position to use this experience as scouting becomes even more important.

- The cranberry industry has long used "cultural controls" such as sanding and flooding for pest control. These methods may even increase in importance in the future. I think more research needs to be done on the use of short-term, strategically-targeted floods for controlling problems such as girdler and tipworm. However, in conjunction with this, we need to conduct research on how to use such floods so that they do not harm the crop or the vines.

- Biological controls may play an increasingly important role. Research continues in perfecting commercially-available beneficial organisms such as insect-parasitic nematodes for cranberry girdler. A new species of *Trichogramma* wasp, an egg parasite of blackheaded fireworm, is being evaluated in the Pacific Northwest and the results are promising. New strains of *Bacillus thuringiensis* are being developed that may be more effective against our hard-to-control pests such as fireworm.

- Pheromone-mediated mating disruption appears very possible with both blackheaded fireworm and sparganothis fruitworm. Field trials will be expanding in 1999, and commercial products will be on the market. Further research is needed to know exactly how to use these materials in combination with other control practices.

- Some currently-available insecticides will continue to be useful. We may lose some registrations of organophosphates and carbamates, but I believe there will continue to be opportunities for use of at least some of our currently-registered materials. In addition, pyrenone and Bts will continue to be available.

- Finally, new insecticides with totally "new chemistry" are becoming available for use in cranberry, some likely as early as 1999. These products tend to be more selective in there activity and have less impact on non-target organisms; that is, they tend to be safer to pesticide handlers and applicators, and more benign to the general environment. Also, they are less harmful to our beneficial organisms; some may even be available for use during bloom when bees are pollinating. Beneficial natural enemies of our pests will more likely be conserved, therefore providing even better natural control. For their target pests, these new products are equally as effective as our traditional materials.

In conclusion, because the cranberry industry has been proactive in the acceptance of IPM practices, and in the support of research on new pest management methods, we should be able to survive FQPA quite well. We may all have to learn some new techniques, but that shouldn't be difficult with the pest management infrastructure already in place. Finally, because many of the newer practices will be more selective and easier on beneficials, in some ways we may actually end up better off than before. 015

CHEMICAL CHARACTERISTICS OF CRANBERRY WATER SOURCES

Eric Hanson
Department of Horticulture
Michigan State University

Introduction

Irrigation water quality is particularly important in cranberry production since up to up to 8 feet of water may be applied annually for irrigation and flooding. Several characteristics of water can be of concern. High total salts (electrical conductivity) can stress plants by impeding water uptake and inducing nutrient deficiencies. High sodium concentrations relative to other ions can result in sodic soils where drainage is impeded. High alkalinity levels can increase soil pH above desired levels. Lastly, some specific ions can be toxic to plants (eg. boron). There is often some confusion regarding the definitions of several of these terms.

Alkalinity is the total concentration of bases, expressed in ppm calcium carbonate ($CaCO_3$) equivalent. Alkalinity levels tell how easily water can be neutralize by acids. Water high in alkalinity resists pH changes when acid is added. Total alkalinity includes carbonate, bicarbonate, and hydroxide alkalinity. Labs may analyze for these components separately, or report total alkalinity.

Carbonates: Inorganic carbon may be present in water in the form of free carbon dioxide (CO_2), bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}). Free CO_2 is the dominant form when pH is below 6.4, and HCO_3^- dominates at pH 6.5 to 10. Water contains little CO_3^{-2} unless the pH is greater than 10. The carbonate system (CO_2 - HCO_3^- - CO_3^{-2}) contributes most of the alkalinity and buffering capacity to natural water.

Hardness is the concentration of multi-valent cations, primary calcium (Ca^{+2}) and magnesium (Mg^{+2}). Hardness is not the same as alkalinity, though they are often similar because the carbonates in water usually are derived from calcium and magnesium carbonates.

pH is a measure of acidity expressed as the negative log of the H^+ ion concentration. pH values below 7.0 are acidic, 7.0 is neutral, and values above 7.0 are alkaline. A change of one unit (5.0 to 6.0) represents a 10-fold difference in H^+ concentration.

In cranberries, alkalinity was a recognized concern several decades ago. The diversion of alkaline water for use on cranberry beds appeared to have increased soil pH and rendered a successful cranberry production area in Wisconsin nonprofitable (Stevens, 1946a; Stevens et al., 1940). Very low carbonate (alkalinity) levels may increase the risk of oxygen deficiencies when plants are flooded (Stevens and Thompson, 1942). Cranberry injury from saline water (high soluble salts) was observed when hurricanes contaminated Massachusetts cranberry beds with sea water (Chandler and DeMoranville, 1959).

Until recently, commercial cranberry culture had been confined to acidic, hydric soils in Massachusetts, New Jersey, Oregon, Washington, Wisconsin, and the Canadian province of British Columbia. Surveys in the 1940's indicated that water used on Massachusetts cranberry plantings was very low in alkalinity (1 to 6 ppm bound CO_2) and acidic to neutral in pH, whereas water from Wisconsin operations was usually higher in alkalinity (5 to 80 mg/l bound CO_2) and pH (Stevens, 1946b). Water from New Jersey cranberry farms was very low in alkalinity (Stevens et al., 1940).

The recent strong demand for cranberries has resulted in the construction of cranberry plantings in new regions such as Maine, Michigan, Minnesota and New York in the United State, the Canadian Provinces of Quebec, Nova Scotia, and New Brunswick, and in Chile. Some recent plantings are situated on the traditional acidic, hydric soils, but where these soils are limited or protected from development by regulations, plantings have been built on upland sites (Roper and Planer, 1993). As a whole, new plantings may represent more diverse soil and water characteristics than were associated with the traditional production regions. In 1998, we surveyed the chemical properties of water sources being used for cranberry production in order to aid individuals evaluating the potential of sites and water sources for cranberry production.

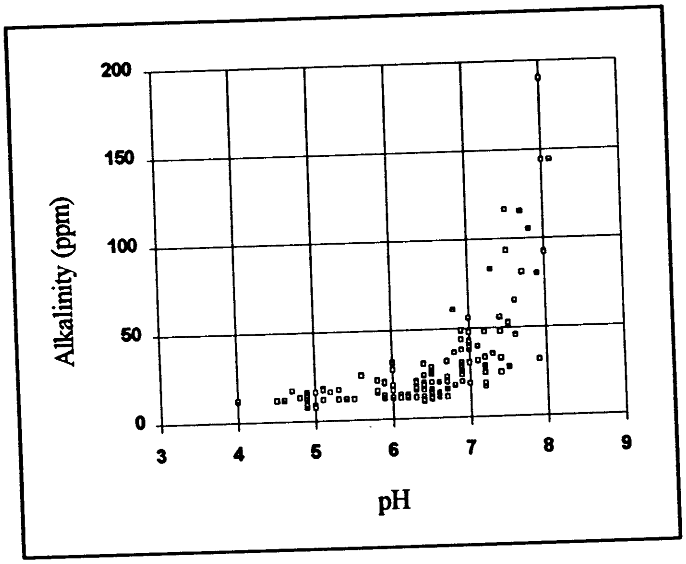
Methods

Samples were collected between March and November from streams and rivers above or below cranberry operations, and ponds, lakes and reservoirs that served as water sources for cranberry operations (Table 1). Samples from Chile, British Columbia, Quebec, Washington, and Wisconsin were provided by Benjamin Little (Cran Chile), David McArthur (University of British Columbia), Jacques Painchaud (Conseiller Regional en Horticulture), Kim Patten (Washington State University), and Teryl Roper (University of Wisconsin), respectively. Carolyn DeMoranville (University of Massachusetts), David Yarborough (University of Maine), and Nicholi Vorsa (Rutgers University) assisted with collections from their respective states. Water was placed in polyethylene or glass bottles, and sent to Michigan for analyses. Some samples were sent fresh and processed immediately, whereas others were frozen until processed.

Results

The mean and range of various chemical characteristics of water from the different regions are illustrated in Table 2. Mean pH was relatively low in New Jersey (5.2) and Massachusetts (6.1), and high in Michigan (7.7), Chile (7.4) and Washington (7.4). The range and mean pH levels for Massachusetts and Wisconsin samples (Table 2) are similar to those reported previously (Stevens, 1946b). Mean alkalinity levels were lowest in New Jersey (14 ppm) and Massachusetts (18), and highest in Michigan (105). Alkalinity data reported here are consistent with a previous survey (Stevens, 1946b), where water from Wisconsin cranberries exhibited higher mean alkalinity, and a wider range, than samples from Massachusetts.

The hazard from alkaline water is that soil pH may increase above desired levels. It is important to recognize that soil pH is affected by the alkalinity, not pH, of water. The impact on soil pH depends on the use rate and alkalinity levels of the water, and the buffering capacity of the soil. A useful rule of thumb is that an acre-foot of water with an alkalinity levels of 100 ppm $CaCO_3$ contains about 270 lb of lime. This quantity may not affect the pH of a highly buffered organic soil, but could increase the pH of a clean sand. About 86 lb sulfur would be needed to neutralize 270 lb of lime, so the annual S requirement to counteract the lime added by 100 ppm alkalinity water could represent a significant long term cost.



Based on samples from this survey, alkalinity levels can be assumed to be low (<50 ppm) when pH is <6.8 (see figure). However, when pH is above 6.8, alkalinity levels varied enormously. In other words, water sources with a pH <6.8 likely contain safe alkalinity levels, whereas water with pH >6.8 may or may not contain problematic alkalinity levels.

The tolerance of cranberries to salinity (soluble salts), sodium (Na) and chloride (Cl) has not been clearly defined. In general agriculture, water containing <0.75 mmho salinity (USDA, 1954), and less than 40 ppm Na and 60 ppm Cl (Biernbaum and Versluys, 1998), is suitable for irrigation uses. In our survey, salinity levels rarely approached 0.75 mmho. The highest salinity was found in the most alkaline samples. Samples seldom contained more than 40 ppm Na or 60 ppm Cl. The exceptions to this were several samples from British Columbia. These samples were collected at the end of a very dry summer, and suggest that some intrusion of sea water into ditches has occurred.

Some caution is advised in comparing water characteristics between regions or states. Samples from each region were taken at different times of the year. Chemical characteristics would likely differ somewhat if samples were collected during different years or months. Samples were also handled somewhat differently. Some were refrigerated and analyzed within a few days of collection, whereas others were frozen until analysis. To test the stability of samples over time, a set of 15 samples were analyzed immediately after collection and again after 4-6 weeks storage at room temperature. The only measurement that changed significantly over the storage period was soluble salts (tended to increase with time. This suggests that differences in sample handing did not alter analytical results to a large extend.

Literature Cited

Biernbaum, J.A., and N.B. Versluys. 1998. Water management. HortTechnology 8:504-509.

Davenport, J.R., and C.J. DeMoranville. 1993. A survey of several soil physical characteristics of cultivated cranberry bog soils in North America. Commun. Soil Sci. Plant Anal. 24:1768-1773.

Roper, T.R., and T.D. Planer. 1993. Upland cranberry plantings in Wisconsin, thoughts on creating the appropriate agronomic conditions. Cranberries Magazine. August pp. 4, 18.

Stevens, N.E. 1946a. Further observations on alkaline flooding water in cranberry growing. Trans. Wisc. Acad. Sci. 36:395-398.

Stevens, N.E. 1946b. Observations on flooding water used in cranberry culture. Mass. Expt. Sta. Bull. 433. P. 37-48.

Stevens, N.E., N.F. Thompson. 1942. Factors influencing injury to cranberrry plants during flooding. Trans. Wisc. Acad. Sci. 34:73-81.

Stevens, N.E., L.M. Rogers, and H.F. Bain. 1940. Alkaline flooding water in cranberry growing. Trans. Wisc. Acad. Sci. 32:351-360.

United States Department of Agriculture. 1954. Quality of irrigation water. In: Diagnosis and Improvement of Saline and Alkali Soils. U.S.D.A Handbook 60. pp 69-82.

Table 1. Water source locations and sampling times.

Location	Time	Sources
British Columbia	Sept	Reservoirs in Delta, East and West Richmond, Fort Langley, Langley, and Pitt Meadows.
Chile	Sept	Properties of Cran Chile near Valdevia.
Maine	Aug	Adroscoggin County stream. Reservoirs in Kennebec, Lincoln, and Washington Counties.
Massachusetts	March to Aug	Plymouth and Barnstable County streams, rivers, ponds and reservoirs.
Michigan	Aug to Oct	Reservoirs in Allegan, Cheboygan, Chipewa, Ottawa, and VanBuren Counties.
New Jersey	July	Atlantic County stream. Burlington County streams, rivers, drain, and lake. Camden County river. Ocean County streams and rivers.
Quebec	Aug	Irrigation canal, reservoirs, and rivers near St-Louis-de-Blandford and Notre-Dame-de-Lourdes.
Washington	Oct to Nov	Reservoirs and ponds in Grayland, Long Beach, and North Beach.
Wisconsin	May to Aug	Various sources in Adams, Jackson, Juneau, Monroe, Oneida, Portage, Vilas, and Wood counties.

Sample number (n), and mean and range (parentheses) of selected chemical properties of cranberry water samples.

	n	pH	Soluble salts (mmho)	ppm Ca	Mg	Na	Cl	Alkalinity
British Columbia	11	6.9 (6.5-7.3)	0.28 (.11-1.05)	36 (0-160)	7 (3-21)	42 (5-162)	83 (17-354)	40 (16-61)
Chile	5	7.4 (7.2-7.9)	0.05 (.02-.07)	27 (21-32)	2 (0-2)	5 (5-7)	13 (5-19)	26 (17-32)
ME	14	7.0 (5.3-7.4)	0.13 (.03-.34)	11 (0-40)	1 (0-9)	10 (5-24)	14 (3-48)	31 (17-56)
MA	50	6.1 (4.0-6.9)	0.12 (.05-.34)	16 (9-67)	2 (0-3)	12 (0-46)	21 (0-80)	18 (9-44)
MI	8	7.7 (7.0-8.1)	0.32 (.11-.58)	66 (20-133)	11 (1-20)	4 (0-8)	16 (0-38)	105 (32-190)
NJ	19	5.2 (4.5-7.1)	0.05 (.03-.12)	2 (0-18)	0 (0-1)	6 (4-13)	6 (2-22)	14 (8-40)
Quebec	11	7.0 (4.9-7.6)	0.15 (.02-.31)	34 (10-57)	1 (0-3)	0 (0-0)	0 (0-0)	46 (16-116)
WA	12	7.4 (6.8-7.9)	0.20 (.07-.33)	10 (0-50)	5 (0-14)	18 (4-49)	36 (14-80)	53 (18-116)
WI	28	7.0 (6.2-8.0)	0.14 (.02-.46)	15 (0-0-80)	3 (1-20)	10 (2-69)	22 (3-126)	40 (16-128)

Figuring Out Stem Gall (Canker)

Patricia McManus
Department of Plant Pathology
University of Wisconsin-Madison

The malady commonly called "canker" was found on several different cranberry varieties throughout Wisconsin in 1998. Canker is certainly not new—growers and researchers have reported its sporadic occurrence for many years in Wisconsin and other cranberry growing regions. But in 1998 it was especially widespread and severe in Wisconsin. Only time will tell whether stem canker is an emerging problem that will pose a significant threat to the industry in Wisconsin. In the meantime, however, it is wise to become educated on the cause of canker so that management strategies can be implemented.

"Canker" is really "stem gall"

Canker symptoms from the dike appear as patches of unthrifty or dead uprights. Upon closer examination, runners and/or uprights are swollen with bumps and galls erupting through the bark. Thus, canker might more appropriately be called "stem gall." The current year's growth is stunted or dead. Symptoms have been noticed in early July, but extensive damage is usually not detected until late July through September. When galls first emerge they are soft, green, and moist. Later they shrink, and become hard and brown to black. The galls appear to originate from outside the vascular cambium, the cell layer from which new food- and water-conducting tissues are born. However, if the galls become large and encircle the stem, they apparently crush the vascular cambium thereby killing tissues above the galled area. Within a few weeks an upright can go from looking healthy with large fruit starting to color, to completely withered with brown leaves and dried-up fruit. Stem tissue below the galled area is green and often sends out new shoots. Thus, even where stem gall has been severe, it has not killed cranberry plantings outright. However, growers suffer significant yield losses as it takes a few years for the new growth to regain full productivity.

What causes stem gall?

The cause of stem gall has been debated by growers and researchers for several years, but evidence is mounting that a species of the soil-borne bacterium *Agrobacterium* may be the culprit:

- *Agrobacterium* causes "crown gall" or "cane gall" on over 200 different plants, including relatives of cranberry (*e.g.*, blueberry and rhododendron).
- Stem gall symptoms on cranberry resemble symptoms caused by *Agrobacterium* on other woody plants such as grape, raspberry, and blueberry.

- Bacteria (but not pathogenic fungi) are commonly found in association with the galls, and some of these bacteria have been identified by biochemical, physiological, and molecular (DNA) tests as *Agrobacterium*.
- *Agrobacterium* enters plants through wounds. The pattern of stem gall symptoms in the field often follows tire tracks or appears to have resulted from beater injury.
- Some of the putative *Agrobacterium* strains isolated from cranberry, and a known strain of *Agrobacterium*, cause galls when re-inoculated onto cranberry.

We are continuing to inoculate cranberry plants under controlled conditions in the greenhouse so that we can re-isolate *Agrobacterium* and complete the necessary steps to prove that *Agrobacterium* is the cause of stem gall. Also, we will identify our strains of *Agrobacterium* to species to see if the cranberry strains are unique or are common inhabitants of agricultural soils. Knowing this is critical to developing control strategies.

Cranberry culture and potential for infection by *Agrobacterium*

The life cycle of *Agrobacterium* in a cranberry planting is unknown. However, cranberry culture has some unique features that might influence infection by *Agrobacterium*, the development of galls, and spread of the pathogen. For example, *Agrobacterium* appears to be systemic in cranberry stems. If so, then the pathogen would be readily spread in cuttings used to establish a new planting. Cranberry in Wisconsin is highly susceptible to winter injury which creates wounds through which the pathogen could infect. If the weather is mild following harvest and plants don't harden off well before the first cold snap, injury could occur in November or December. On beds where it's hard to hold a winter flood, exposed vines could be injured. Ironically, the mild winter of 1997-1998 might have resulted in significant winter injury: many beds did not hold a flood and vines were exposed to fluctuating temperatures for several weeks. The harvest process itself can damage vines, and sometimes stem gall is worse near the ends of beds where tractors and beaters turn. *Agrobacterium* is readily dispersed in water. Beater damage, winter injury, and water are all part of cranberry culture. Thus, it's not hard to envision infection of cranberry by *Agrobacterium*.

Control of crown gall on other plants

Until we know more about the *Agrobacterium*-cranberry interaction, it makes sense to consider how the crown gall is managed in other systems and apply these strategies to cranberry where appropriate. In other woody plants, integrated control of *Agrobacterium* includes:

- *Sanitation*—nurseries inspect and reject suspicious plants.
- *Biocontrol*—nurseries treat roots or seedlings with biocontrol bacteria.
- *Chemical*—soil is kept free of root-chewing insects.
- *Cultural*—root and crown injury is avoided; hardening off encouraged by not applying nitrogen late in season; plants protected during winter.

In general, these measures are preventative. There is no cure for *Agrobacterium* infections once established, and experiments with bactericides such as copper and antibiotics have not been promising.

Control of cranberry stem gall

To a limited extent, cranberry growers can adopt the management strategies outlined above:

- *Sanitation*—do not use cuttings from a planting with any history of stem gall.
- *Chemical*—keep soil free of chewing insects.
- *Cultural*—do not overfertilize with nitrogen; minimize beater damage; avoid winter injury with timely winter flooding.

As for other crops, there is probably no cure for *Agrobacterium* infection of cranberry. That's the bad news. The (sort of) good news is that even severely affected plantings have recovered fully after 2-3 years.

In summary, the cause of cranberry stem gall is not fully understood, but appears to be caused by the soil-borne bacterium, *Agrobacterium*. Developing management strategies requires that growers share their observations and experiences with one another, with crop consultants, and with university researchers. Each group sees this problem from a different angle and will make essential contributions to solving the problem.

Cranberry Production in Michigan

Eric Hanson
Department of Horticulture, Michigan State University

Michigan has a long history of cranberry production. Early records show over a dozen commercial cranberry operations in the state at the beginning of this century (Corbett, 1903). These operations eventually disappeared, though the reasons are not clear. The demand for cranberries during the last decade stimulated renewed interest, and today there are about 165 acres of cranberries managed by ten individuals. All but one of these plantings is less than 6 years old. Most plantings are situated in the "blueberry belt", near the Lake Michigan shore in southwest Michigan. These plantings were established on the acidic, sandy soils typical of blueberry plantings. The sites have natural water tables within a foot or two of the surface. Two plantings are located in norther Michigan on sites that may be more typical of many in Wisconsin. Stevens accounts for about two thirds of the acreage, followed by Pilgrim, Searles, and Ben Lear. Michigan growers have used both plug plants and vines to establish plantings.

Michigan Strengths

Michigan offers a number of potential advantages over some other states pursuing a cranberry industry. With over 140,000 acres of fruit crops, Michigan has an extensive fruit handling, storage, and processing infrastructure that could facilitate the development of a cranberry industry. There appear to be adequate suitable sites for cranberries. State agencies are working to facilitate the development of cranberry acreage. The Michigan Department of Agriculture (MDA) developed Generally Accepted Agricultural and Management Practices to help potential growers understand regulatory aspects of site selection and protect current growers from nuisance complaints. The state legislature and Michigan State University have provided support for cranberry research. MDA, Michigan Department of Environmental Quality (MDEQ), and MSU developed a Cranberry Expert Team, which, on request by landowners, visits sites and makes initial assessments of the potential for cranberry production. MSU and MDA funded a detailed market analysis for cranberries in 1998, which has helped individuals make planting decisions.

Some Challenges

The primary challenge at this time is growing a new crop in new areas. Michigan has several distinct climatic zones. The southwest part of the state that contains most of the plantings experiences winter conditions that are most similar to Massachusetts, whereas winters in northern Michigan are more analogous to central Wisconsin. With no recent production history, growers are not sure whether the disease and insect complexes will develop to be similar to those in Wisconsin, Massachusetts, or a combination of the two. Current sites vary greatly in soil and water characteristics, so the same rules regarding fertilization and water management will not apply to everyone. Growers are learning how to manage water alkalinity levels, which are often higher than those observed in traditional production states. Although the current growers are very astute individuals, few have cranberry experience, so growers and extension workers alike are on steep learning curves.

As more fruit is harvested during the next couple years, growers will be challenged to find suitable markets. Until the Michigan industry grows and demonstrates a production capacity, most growers will be looking to local processors and possibly fresh markets.

Regulatory Structure

One of the first difficulties confronted by potential growers were the confusing wetland regulations and administering agencies. Michigan differs from many states in that the state Department of Environmental Quality (MDEQ) administers Section 404 of the Federal Clean Water Act. Potential growers apply for wetland permits through the MDEQ, although the Army Corps of Engineers, Detroit District is responsible for navigable waters and adjacent wetland, and also reviews permit applications for larger operations.

The Future

Current growers are optimistic about cranberries, and it appears that planting will continue at least at a modest rate. This last December, growers indicated they were committed to planting at least 65 additional acres in 1999. The industry may grow more quickly than this. Muskegon County in southern Michigan owns about 1,900 acres of land that could accommodate up to 1,000 acres of cranberries. A study in 1998 concluded by recommending that cranberry production be pursued, but that a processing facility originally considered was not justified based on the processing capacity already in the state. The county funded a detailed engineering study that is underway, and will decide how to proceed when the study is completed in 1999. Another substantial planting of over 100 acres is planned by one individual in the Upper Peninsula of Michigan.

Literature Cited

Corbett, L.C. 1903. Cranberry Culture. U.S. D.A. Farmer's Bulletin No. 176.

Cranberry Fruit Rot

Peter V. Oudemans
Rutgers University, Blueberry and Cranberry Research and Extension Center, Chatsworth, NJ 08019

Cranberry fruit rot is a disease complex caused by over fifteen different fungal species. The disease is generally divided into two distinct categories: field rot and storage rot. The field rot phase is expressed pre-harvest and constitutes a major component of direct crop loss. Storage rots cause a reduction in the quality and shelf life of fresh, refrigerated fruit. There is overlap among the fungi causing field and storage fruit rots however, there are also fungal species unique to each type. In fungicide efficacy trials, the incidence of field rot is not always correlated with the incidence of storage rot. The management practices for the two phases of the disease differ, and fruit destined for the fresh market is typically harvested and handled in a manner that minimizes storage rot.

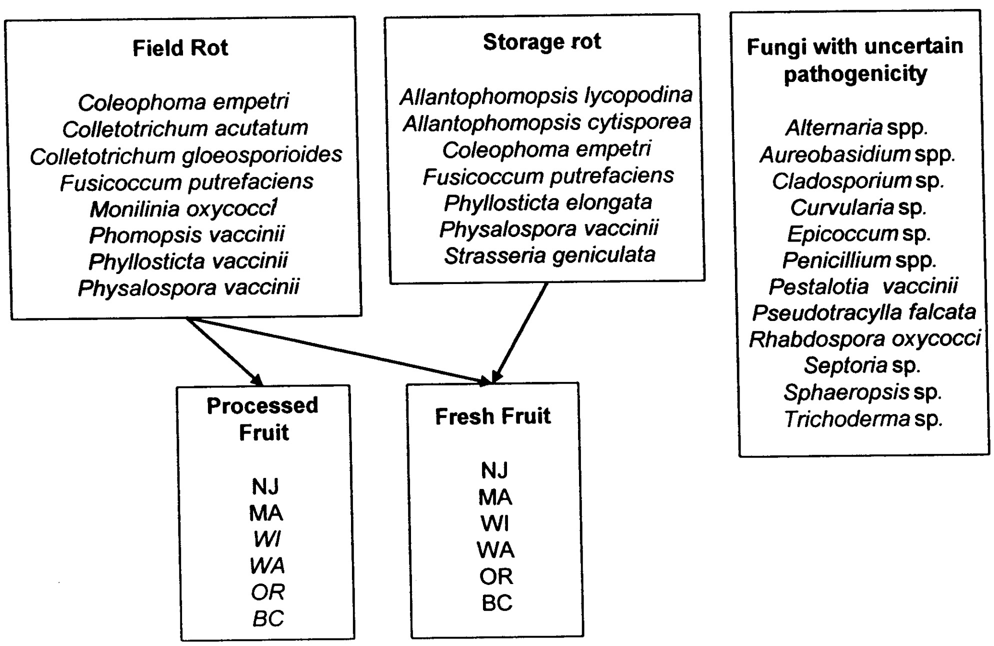


Fig. 1. Cranberry fruit rot is a disease complex that occurs in two phases and has numerous causal agents.

Field rot is a major threat to cranberry production, especially New Jersey and Massachusetts where, if left uncontrolled, may cause crop losses in excess of 50%. The most effective control measures rely on nonselective, protectant fungicides including ferbam, mancozeb, and chlorothalonil. In a typical commercial setting, four to five fungicide applications are made during the growing season and resultant field rot levels range from <1 – 15%. Currently, fungicide applications begin during early bloom (June 1 – 15 in New Jersey) and are repeated on a ten to fourteen-day schedule. Field-rotting fungi are believed to infect early in the growing season and remain latent until the fruit begin to ripen. One exception is the fungus *Phyllosticta vaccinii,* which causes an early fruit rot as well as a variety of other symptoms including leaf drop and blossom blight.

The timing of fruit infections that lead to fruit rot show considerable variation depending on the fungal species in question. I will focus on field rot for the remainder of this discussion. In field experiments conducted over three years the timing of fungal

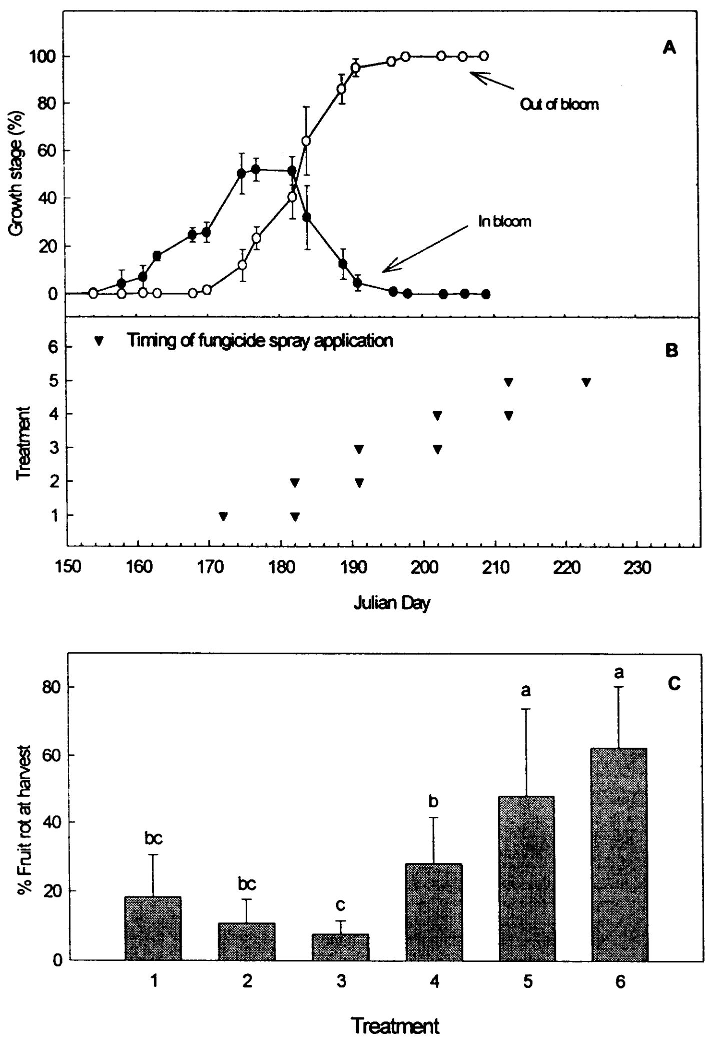


Fig. 2. Results of an experiment demonstrating the effect of fungicide timing on fruit rot control. A) Represents the phenology of the cranberry crop. In bloom and out of bloom represent the stages of flower development. B) Shows the timing of fungicide applications. Treatments (Y-axis) each included two applications of chlorothalonil and were staggered at 10-12 day intervals. C) Levels of fruit rot observed at harvest. Treatments (X-axis) correspond with treatments (y-axis) in panel B. Treatment 6 is the control and no fungicides were applied.

infections leading to fruit rot (in New Jersey) was found to be concentrated around the period immediately following bloom (Fig. 2). Fungicide applications initiated during early fruit set, which corresponds to late bloom showed the greatest efficacy. Treatments initiated after this time showed progressively less effect on disease control. These results suggest that infection must occur within a short window of time in order for fruit rot to occur. Infections occurring later have less chance of developing into field rot, however, those infections may result in storage rot. Based on these results the effect of delaying fungicide applications will, after a certain point, result in a loss of control. Fig. 3 shows the relationship between the delay of fungicide applications and level of fruit rot control. This emphasizes the importance of timely applications for maximum benefit.

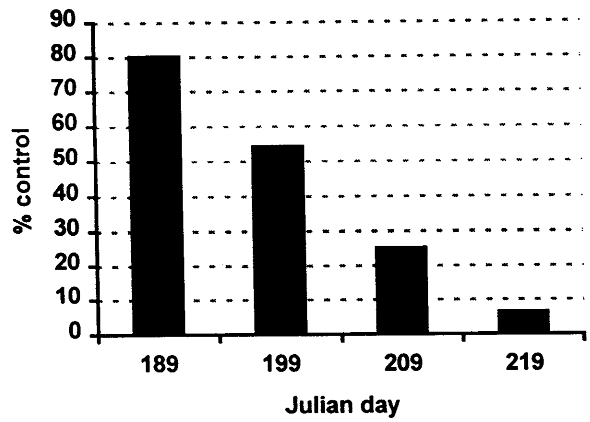


Fig. 3. Effect of delaying fungicide applications on the level of fruit rot control. Applications initiaited on day 189 provided nearly 80% control whereas applications intiated on day 219 gave less than 10% control.

- Infection leading to fruit rot occurs during a 20 to 30-day period beginning at fruit set.
- Infections may occur following this period, however, do not lead to field rot.
- Fungicide applications should begin during fruit set.
- Delay of initial applications will permit greater levels of fruit rot to develop

Fungicides. Fungicides useful for controlling fruit rot are listed in Table 1. These fungicides are registered, however, in planning a fruit rot management program one should always observe the preharvest intervals as well as recommendations made by a particular handler. The fungicides chlorothalonil and mancozeb have the greatest effect on cranberry fruit rot control. Ferbam, and copper containing compounds tend to be less effective. There is little difference among the different formulations of chlorothalonil and formulation should reflect an individual preference with regards to ease of handling, and cost.

Table 1. Fungicides effective for cranberry fruit rot control

Fungicide	Formulations	Effectiveness	Phytotoxicity
Chlorothalonil	Bravo, Terranil, and several others	Very effective under high disease pressure	At high temperatures (>90 F) blossom damage can occur. Fruit scarring has een noted
Ferbam	Ferbam	Effective	None reported. Can leave a black residue
Mancozeb	Dithane, Manzate	Very effective	Reduces color development
Copper	Champ, Kocide	Effective under low disease pressure	None reported from cranberry. Can cause scarring on fruit at high rates

Phytotoxicity. Fungicides useful for cranberry fruit rot control are broad-spectrum materials. These fungicides will damage plants if they can enter the plant cell. However, these materials are formulated such that they do not cross the cuticle and enter the cell. Therefore, mixing pesticides and use of additives should be done with caution because this can alter the characteristics of the formulation and result in phytotoxicity. In particular some of the newer insecticides being registered have additives to enhance uptake. Mixtures with those insecticides and current fungicides will result in phytotoxicity.

Two fungicides, chlorothalonil and mancozeb can cause phytotoxic effects however when used properly these effects can be minimized and fruit rot can be held in check.

Rules for avoiding phytotoxicity

Rule 1. Chlorothalonil should be used after the majority of cranberry fruit are set.

Rule 2. Chlorothalonil should not be used if the projected bed temperatures for that day are expected to rise above 90 F.

Rule 3. Do not mix chlorothalonil with compounds designed to enhance uptake.

Rule 4. Do not use mancozeb after fruit are over a ¼ inch in diameter.

Upright Dieback *vs.* Uprights Dying Back

Patricia McManus
Department of Plant Pathology
University of Wisconsin-Madison

Nearly every cranberry grower in Wisconsin has experienced problems with scattered unthrifty vines and even large areas of dead uprights in otherwise healthy plantings. Sometimes the problem can be traced back to a clearly defined trauma such as herbicide misapplication or frost injury. But often these cases of vine and upright death are of unknown origin. When growers, crop consultants, and researchers try to diagnose the cause of the problem, the term "upright dieback" frequently is mentioned. In fact, some use "upright dieback" as a catch-all term for any problem that causes uprights to die back. This causes confusion because there is a specific malady known as **upright dieback** that is distinct from other causes for **uprights dying back**. What is the difference between upright dieback and uprights dying back? The short answer is: Upright dieback is *probably* a disease, whereas uprights dying back is a symptom brought on by a number of biotic (living) and abiotic (non-living) factors. The longer explanation follows.

Upright Dieback—the "Disease"

Upright dieback has been called a disease because several fungi, most notably *Phomopsis vaccinii* (also called *Diaporthe vaccinii*), can be isolated from vines with symptoms. Also, we know that various species of *Phomopsis* are pathogens on other woody plants such as blueberry, grape, and peach. However, all of the criteria required for a fungus to qualify as a pathogen have not been met for *Phomopsis* on cranberry. The criteria are that the fungus must be:

1. found in association with the affected plant.
2. isolated from the affected plant and grown in pure culture.
3. re-inoculated onto a healthy plant and symptoms reproduced.
4. re-isolated and grown again in pure culture.

With *Phomopsis* on cranberry, we get hung up at step number three. Despite this technical difficulty, we will assume that the pathogen *Phomopsis vaccinii* causes the disease known as upright dieback.

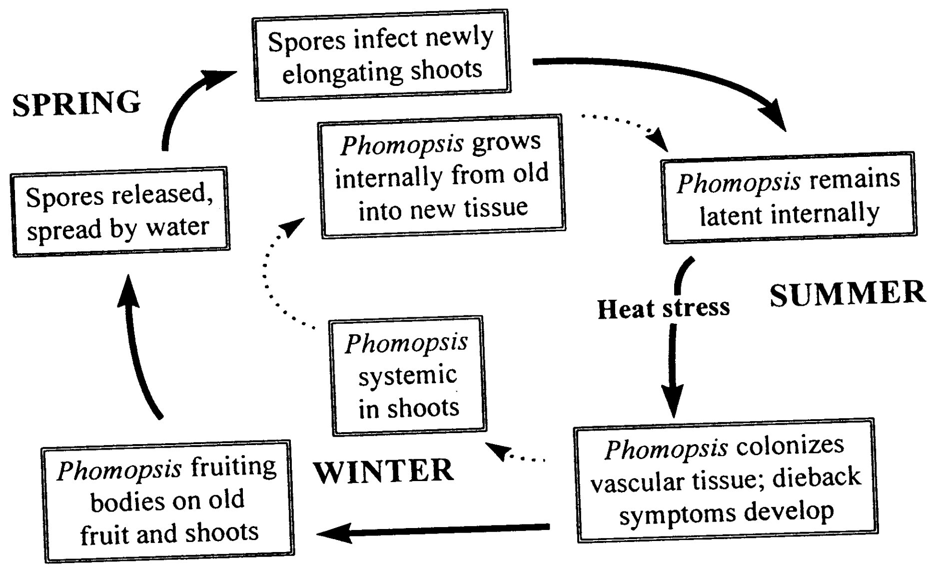
Symptoms of Upright Dieback:

- Yellow-orange-bronze-brown (*not* bright red) uprights
- Superficially resembles early stages of cottonball tip blight
- Dead uprights often scattered among healthy uprights (salt and pepper pattern)
- Can occur in patches in young beds
- Roots not affected
- Runners and uprights do not appeared chewed

Disease Cycle

The disease cycle for upright dieback is poorly understood. However, based on when and where *Phomopsis* is detected on vines, when symptoms appear, and when chemical control seems to work best, a disease cycle is proposed below.

Upright Dieback--Proposed Disease Cycle



Phomopsis overwinters in the form of fungal fruiting bodies on old fruit (viscid rot) and dead shoots. It may also overwinter internally in dormant vines. In the spring, spores ooze out of the fruiting bodies and are spread by rain and irrigation (frost protection) to newly elongating, succulent shoots. Exactly where on the new tissue infection occurs is not known, but chemical control has been most effective when shoots show about ½ inch of new growth. *Phomopsis* that overwintered in vines may grow internally into new tissue. After new growth is invaded, infections remain latent (dormant) for several weeks. During this period, *Phomopsis* can be isolated from healthy-looking vines. Later in the summer, as vines become stressed from heat and perhaps the burden of bearing fruit, *Phomopsis* comes out of latency and colonizes vascular tissue. As the food- and water-conducting tissues are invaded, uprights turn yellow and eventually die back. During fall, the fungus forms fruiting bodies on dead tissues where it overwinters.

Control of the Disease Upright Dieback

Because we know so little about the disease cycle of upright dieback, control has been difficult. Cultural practices that minimize stress, especially during the hot summer months as fruit begin to size, will give the plant the upper hand and probably help keep *Phomopsis* in a latent phase. This would include adequate (but not too much) irrigation, weed control, and adequate but not excessive nitrogen fertilization. Bravo Weather Stik (formerly Bravo 720; EPA Reg. No. 50534-188) is available for upright dieback control by special registration until December 31, 1999 unless revoked by EPA. Limited research and grower experience has shown that the most effective time to spray is when most shoots show about ½ inch of new growth. Bravo does not control upright dieback if applied later than early bloom—by this time the fungus has apparently invaded shoots and is out of reach of protectant fungicides. Fungicides will not cure upright dieback.

Uprights Dying Back—Common Symptom with Numerous Causes

The disease upright dieback is only one of numerous reasons for uprights dying back. Other potential causes are:

- herbicide or other pesticide injury
- drought
- heat
- too much water (wet feet)
- winter injury
- nutrient deficiencies
- biotic factors such as insects or other fungi (*e.g.*, girdler, *Phytophthora*)
- combination of factors

Diagnosing the Problem

So how do you know whether you have upright dieback, the disease caused by *Phomopsis vaccinii*, or uprights dying back from who knows what? This is one of the most difficult questions in cranberry pathology. First, be completely honest with yourself and with your crop consultant or university contact about what has or has not happened in the way of irrigation, herbicide application, etc. Observe the pattern of vine death. Does it have the classic salt and pepper scattering characteristic of upright dieback? Large dead patches are usually not attributed to *Phomopsis* upright dieback. What time of year are you seeing uprights starting to die back? Symptoms from *Phomopsis* infection usually show up in mid to late summer. Dead uprights and defoliation during May and June are probably because of something else (winter injury?). For a small fee you can submit declining (not dead) vines to the University of Wisconsin Plant Pathogen Detection Clinic. However, even this might not provide a conclusive answer—there are a lot of fungi other than *Phomopsis* that grow out of declining vines. But if *Phomopsis* is abundant, then chemical control the following year might be justified.

CRANBERRIES 101:

Highlights of
Crop Growth and Development,
Fertility and Fertilizers,
Plant Nutrition,
Water Quality,
and Soil Characteristics

By:
Jonathan D. Smith Ph.D.
Northland Cranberries, Inc.

For:
1999 Wisconsin Cranberry School

CROP GROWTH & DEVELOPMENT

ANATOMY OF A CRANBERRY PLANT

Runners

- Juvenile part of the plant
- Typically occurs due to excessive fertilization
- Runners are for nutrient storage
- New plantings up to 6' lengths

CROP GROWTH & DEVELOPMENT

ANATOMY OF A CRANBERRY PLANT

Uprights

- Short vertical stems on runners
- Vegetative or reproductive
- 450 uprights /sq. ft. optimum density

CROP GROWTH & DEVELOPMENT

CRANBERRY ROOT SYSTEM

- Fine and fibrous, weblike
- No root hairs.
- Inefficient nutrient and water uptake.
- Rootlets grow from larger roots
- Adventitious roots form on stems covered with soil
- Sanding is very important for continued root development

CROP GROWTH & DEVELOPMENT

Cranberry plant propagation

A cranberry plants' sole purpose is to propagate itself as much as feasibly possible.

- 2 choices
  - Produce Runner Growth
    - » (Increase plant vine mass)
  - Produce Seeds
    - » (90 million seed per acre of fruit)

CROP GROWTH & DEVELOPMENT

Cranberry plant propagation

What determines the plants choice for max. propagation...

- N is the most limiting element
- N is critical for survival
- Plants accumulate as much N as possible, and put into storage
- Plants store excess N in runners
- When less N, plant produces seeds for max. propagation

CROP GROWTH & DEVELOPMENT

ANATOMY OF A CRANBERRY BUD

- Terminal Buds form in August and September
  - Contains all flowers, leaves, and young shoot primordia for the next season.
- Any damage from harvest to early Spring will affect buds

CRANBERRY FERTILIZERS

LIQUID FERTLIZERS

- FOLIAR FERTILIZATION
  - fertilizer applied with little water
  - most stays on the leaves for very quick uptake
  - Up to 90% absorption of N by cranberry leaves
- FERTIGATION
  - Injected through chemigation system
  - Uses large amounts of water
  - Most fertilizer percolates into the soil

CRANBERRY FERTILIZERS
FOLIAR FERTLIZATION

- Why use Foliar Fertilizers?
  - Correct nutrient deficiencies quickly
  - Supplement nutrients to the plant at critical times of development
  - Overcome soil-induced nutrient deficiencies
- Examples:
  - For micronutrient applications
  - N appl. for a quick response

CRANBERRY FERTILIZERS
FOLIAR FERTLIZATION

- Potential Problems with Foliar Fertilization
  - Phytotoxicity
    - » Ammonium nitrogen fertilizers
    - » Impure fertilizers
  - Plants absorb all nutrients that come into contact with leaves
    - » Overgrowth due to force-feeding
    - » Precision applications necessary

CRANBERRY FERTILIZERS
READING A BAG OF FERTILIZER

Nutrients found in a bag of fertilizer

- **N -Nitrogen**
- **P - Phosphorus**
- **K - Potassium**
- **Ca - Calcium**
- **Mg - Magnesium**
- **Mo - Molybdenum**
- **Fe- Iron**
- **S - Sulfur**
- **Mn - Manganese**
- **Al - Aluminum**
- **B - Boron**
- **Zn - Zinc**
- **Cu - Copper**

BY LAW, THE BAG MUST BE LABELED WITH THE AMOUNT OF N, P, K

THE LABEL WILL CONTAIN CONC'N OF ALL NUTRIENTS IN THE BAG

CRANBERRY FERTILIZERS
READING A BAG OF FERTILIZER

SAMPLE LABEL

6-24-24

Nitrogen (as ammonium)...6%

Phosphorus as P_2O_5.........24 %

Potassium as K_20............24%

CRANBERRY FERTILIZERS
READING A BAG OF FERTILIZER

- NITROGEN
- Three Forms of Nitrogen
  - Urea (two ammonium attached)
  - Ammonium (NH_4)
  - Nitrate (NO_3)
- Cranberries Utilize Ammonium and Urea nitrogen
- Nitrogen transformations

  Urea -- NH_4 --NO_3

CRANBERRY FERTILIZERS
READING A BAG OF FERTILIZER

- Phosphorus
  - On the label P_2O_5
  - Taken up by the plant as PO_4
  - Utlized as P
- The label says 24 % P_2O_5
- Actually only 10.5 % P
-
- Calculation:
  - bag % / 100 x 0.44 = Actual P

CRANBERRY FERTILIZERS
READING A BAG OF FERTILIZER

- Potassium
  - On the label K_2O
  - Taken up by the plant as K
  - Utlized as K
- The label says 24 % K_2O
- Actually only 19.9 % K
- Calculation:
  - bag % / 100 x 0.83 = Actual K

CRANBERRY FERTILIZERS
READING A BAG OF FERTILIZER

- All other nutrients, including Nitrogen, show exact percentages on the label.
- Example:
  - K-Mag
    - 0-0-20-9

CRANBERRY NUTRITION

BASIC PRINCIPLES OF NUTRITION USE

- Perennial plants contain substantial nutrient reserves
- More fertilizer does not necessarily mean more fruit
- Plant's don't use vitamins or stimulants
- There are 13 mineral elements + CO_2, sunlight, and water

CRANBERRY NUTRITION

NUTRIENT INTERACTIONS IN SOIL

Cranberry Roots actively take up nutrients
- Energy is needed
- If no energy, no nutrient uptake

Nutrients in the soil solution can either help or hinder uptake of other nutrients

- Synergistic
  - N --- P
  - N --- Mg
- Antagonistic
  - N --- Ca
  - K --- Mg
  - Fe --- Mn
  - P --- Zn

Climatic Conditions affect nutrient uptake

Soil Temperature - Cold, slow uptake
Too Wet - No oxygen, slow uptake
Too Dry - No nutrient flow to rootlets

CRANBERRY NUTRITION

UNDERSTANDING PH

- pH measures acidity of a soil
  - Hydrogen (H+)
  - Hydroxyl (OH-)

  - pH range is 0 - 14
  - Neutral is 7.0
- When a solution is neutral, there are equal amounts of H+ and OH-
- A 1 pH unit change is a 10 fold difference in concentration!

CRANBERRY NUTRITION

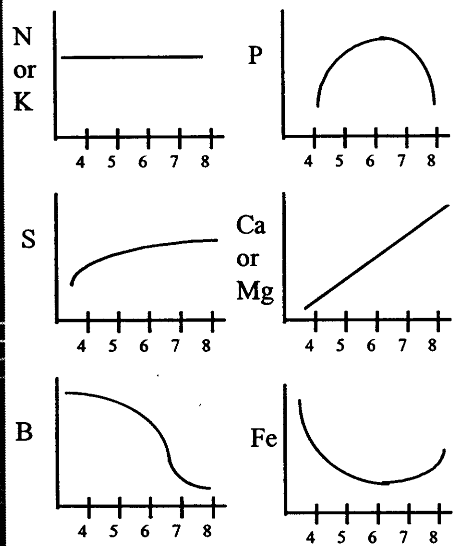
OPTIMUM PH LEVELS

- Best pH range: 4.5 to 5.5
  - The soil pH determines which nutrients hold tightly to the soil, and which are released.
- Why do Cranberries live in low pH?
  - Cranberry Roots tolerate high levels of Al and Mn
- When pH is too high...
  - Nutrient imbalances can affect plant functions

PH IS THE BASIS OF ALL PLANT NUTRITION

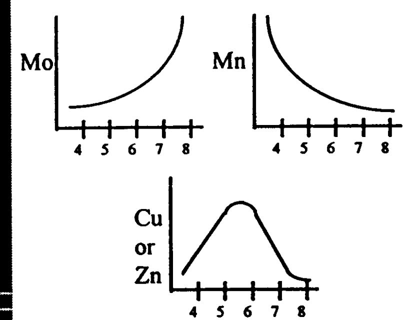
CRANBERRY NUTRITION

NUTRIENT AVAILABILITY BY PH



CRANBERRY NUTRITION

NUTRIENT AVAILABILITY BY PH



WATER QUALITY

BICARBONATES IN THE WATER

- Irrigation Water Analysis
  - pH
  - Various nutrients
  - Bicarbonates
- Bicarbonates can be toxic to plants, especially those which are "acid-loving".
- HCO_3-
- When combined with other elements
  - $MgCO_3$ $CaCO_3$ $NaHCO_3$

WATER QUALITY

BICARBONATES IN THE WATER

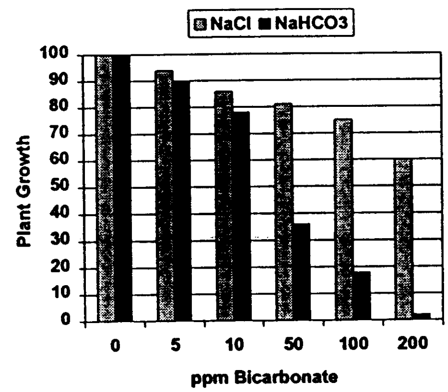
- Bicarbonates are not found in soils below pH 5.5
- If bicarbonates in the water, they will affect soil pH.
- Not been researched in cranberries at all.
- With respect to plant nutrition...
  - Fe Chlorosis (Iron)
  - Oversupply of P
  - Zn deficiency
- Levels found in water (WI)
  - 0 to 250 ppm

WATER QUALITY
BICARBONATES IN THE WATER

- Bicarbonates contribute to the increase in soil pH.
- Example:
  - If your water contains 72 ppm
  - If you apply 3 acre-feet per year
  - You apply 583 lb. / acre of lime equivalents per year
- This can greatly influence your pH control decisions.

WATER QUALITY
BICARBONATES IN THE WATER

Example of Growth differences comparing chloride to bicarbonate (radish)



WATER QUALITY
SOIL AMMENDMENTS

- What are Ammendments?
  - Build soil body, tilth, strength
- Two Basic reasons for their use
  - Adjust pH levels
  - Improve Water Penetration
- Examples:
  - Lime, Sulfur
  - Organic Matter
  - Epsom Salts

WATER QUALITY
SOIL AMMENDMENTS

- To adjust soil pH
- Increase Acidity
  - Elemental Sulfur
  - Sulfuric Acid
  - Lime Sulfur
- Decrease Acidity
  - Lime

WATER QUALITY
SOIL AMMENDMENTS

- Increase Water Penetration
  - Irrigated Ag. farmland
  - Prevents puddling on soil surface
  - Use Gypsum
- Why and How?
  - Surface puddling is due to high sodium levels which form a crust and prevent water penetration.
  - Gypsum (Mg and Ca) displaces the sodium, allowing water to percolate

WATER QUALITY
SOIL AMMENDMENTS

- Will soil ammendments help percolation in cranberry soils?
  - Only if sodium levels are v. high
  - SAR on water analysis > 6.0
  - So far, only 1 instance of an SAR>6.0. Using a water softener.
- Other reasons for poor water penetration..
  - Compacted soils from wheel pressure
  - Clay or hard pans
  - Too close to the groundwater

Cranberry Self -Test

Crop Growth and Development

1. True or False. Prior to bud break in the Spring, the bud of a flowering upright already contains all the flower buds for the upcoming season.

2. On an upright, in what order do flowers open?
   a) From Bottom to Top
   b) From Top to Bottom
   c) Random

3. True or False. Runners are formed by cranberry plants to store excess nutrients absorbed by the roots.

4. True or False. Cranberry roots use root hairs to absorb water and nutrients.

Fertility and Fertilizers

5. True or False. If we spread 6-24-24 fertilizer at 100 lb. per acre, we would be increasing the amount of phosphorus in our soil by 24 pounds per acre.

6. True or False. Foliar fertilizers can be effectively used to correct nutrient deficiencies.

7. True or False. Up to 90% of the foliar fertilizer which lands on the leaves is absorbed into the plant.

Plant Nutrition

8. Which is not a required nutrient for cranberry production.
   a) Manganese
   b) Boron
   c) Silicon
   d) Calcium

9. Which of these forms of nitrogen is not efficiently utilized by cranberry?
   a) Urea
   b) Nitrate
   c) Ammonium

Water Quality and Management

10. True or False. When a soil pH is above 6.0, bicarbonates in the water can impact plant productivity.

Soil Characteristics and Management

11. True or False. Sodium levels in our water should be considered as a serious threat to our soil structure.

12. Which of the following is a soil amendment?
    a) Lime
    b) Organic matter
    c) Potassium and magnesium sulfate (K-Mag)
    d) Elemental sulfur
    e) Trick question. They are all soil amendments.

Winter Management and Hardiness
Using Finite Element Analysis to model Heat Transfer During and After the Winter Flood

James Altwies[1], Beth Ann Workmaster, Joy Altwies, Jiwan Palta, Teryl Roper
Dept. of Horticulture, University of Wisconsin-Madison

Introduction

Winter flooding of cranberry beds is a traditional protection technique from dangerously low winter air temperatures. Cold hardiness data gathered in previous years via laboratory research has determined that even dormant uprights possess a critical temperature at which the cells become damaged, thus effecting the next year's growth and yield. Temperature under the ice within the airspace has been measured and determined to be at or just below freezing. But the temperatures within the ice, where the uprights and buds are encased are not well documented. Various weather conditions and ice cover also play an important role in determining the temperature in this critical zone. By developing a model using a process called *Finite Element Analysis*, we produced a rudimentary model that can determine the effects of various environmental conditions on the uprights encased in ice.

Finite Element Analysis

Finite Element Analysis is a tool that may be used to model complex systems or systems in which a large variety of small factors play a role in determining the outcome of that system. By dividing the system into small or finite pieces, the tool may calculate each tiny piece and its related stimuli, obtain a result, and recombine the pieces into the whole. The researcher may then visualize this complex system and make alterations of the stimuli to witness the variable outcome. The tool used in this experiment is called *FEHT*, or **F**inite **E**lement **H**eat **T**ransfer. Developed at the University of Wisconsin Solar Energy Lab, FEHT allows the user to enter specific physical properties of the materials being studied, the conditions under which the materials are observed, and the time frame in which the materials should be constrained.

Materials, Conditions, and Time

This study used a cranberry bed, viewed in cross section with varying soil types under saturation or field capacity as well as differing temperature regimes. Daily air temperature was obtained from a field weather station on or near the typical date of flooding with low air temperatures reaching –13° F. Two sets of models, one containing a bed as the flood goes on and the other after ice has formed and water has been drained away. Two basic soil types (sand and peat) were generated as the primary bed material. Loam was used for dike material in both models. The base temperature data were altered by +10 and +20° F to obtain medium and warm day simulations. Incident solar radiation and wind speed remained constant throughout the three temperature regimes.

Soil Properties

Three physical properties govern the activity of soil under the pre-determined environmental conditions. Density determines how much of a mass of a given substance is packed into a given volume. Specific heat is a measure of the energy required to raise 1 gram of a material 1°celcius, and thermal conductivity is a measure of the amount of energy transmittable through a material via molecular bonds. However, the situations we wished to model required calculation and or slight alterations to the materials utilized. Different coefficients were required for saturated versus field capacity conditions.

Environmental Factors

In order to construct accurate models the interaction of the environment upon the model must be taken into account. It also must be understood that no environment may be modeled *exactly*, resulting in minor adjustments and assumptions. For our situation, we simulated full winter sun at a low angle of incidence. Wind data was retrieved from weather stations in the vicinity of cranberry marshes and extrapolated to the appropriate height. As stated earlier, air temperature data was collected from the same weather station and all components were linked together via a computer program that allowed the conditions to be looped in 24 hour segments, simulating daily fluctuations in temperature, wind and light levels.

With all models, some assumptions must be made, for a fragment of the data needed to construct a complete model may not be easily accessible or have not been collected. We made assumptions, based on material properties of cellulose wood fiber, percent water in the uprights during dormancy and relative proportion of the upright encased in ice and determined that the plant mass would contribute little if any to the heat flow from the ice to the soil. In fact, the plant mass may offer insulating value, but this remains to be tested.

Results

Two ice scenarios and two soil scenarios as well as the initial flooding event were computed by FEHT. The data from these models appear below. The initial flood model described the freezing activity of the flood when applied to a frozen bed, and air temperature at –4 F (–20° C). The first Ice scenario models the effects of diurnal environmental fluctuations on the temperature of the air space under the ice, soil temperature, and temperature within the ice in a range approximating the location of encased uprights with a thin protection (8 inches) of ice. The second model observes the same conditions except with thick ice (16 inches). Both ice models were calculated under cold (-13 F), medium (5 F), and high (23 F) temperatures.

Temperature thin ice and high temperature regime

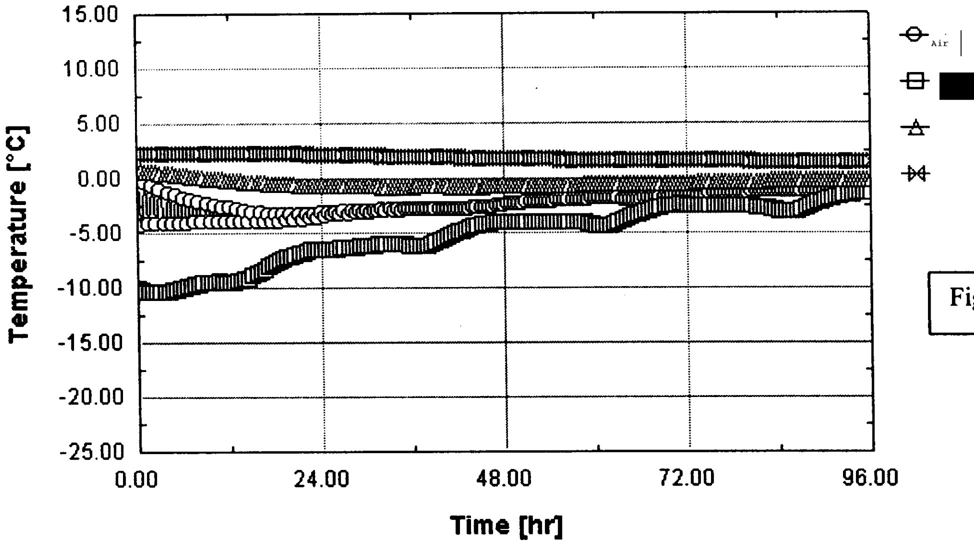


Figure 1

Figure one shows temperature fluctuations of the inter-nodal ice, air gap, soil surface and 15 cm beneath soil surface under thin ice and high temperature regime. Outside air temperature of 23 F (–5 C) is relatively warm a winter scenario but not unheard of. The chart shows fluctuation over a 96-hour (four-day) period. The fluctuation of air gap temperature is contributed to by equilibration of the air and heat flux emanating from the soil and the heat sink of the ice layer. However, after 96 hours the soil temperature only drops to 27 F (–3 C), which is consistent with data gathered in the field under an ice sheet as seen in figure 3.

Thick Ice and Low Temperature Regime

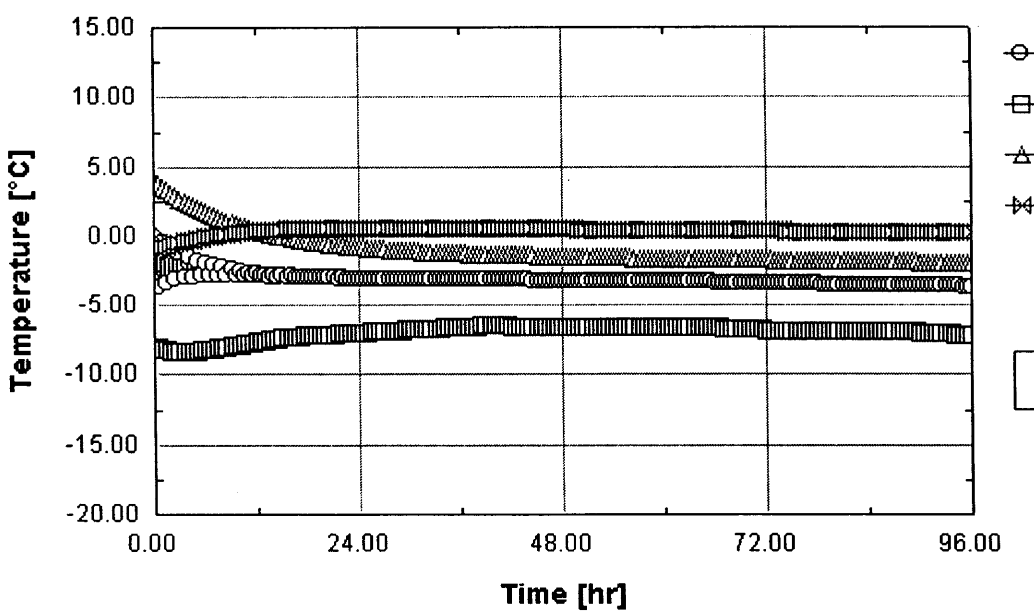


Figure 2

Figure 2 depicts the activity of a thick ice scenario (16 inches) under low temperature {-13 F or -25 C) condition. Once again, the gap air temperature shows a large fluctuation until it equilibrates with the soil and ice temperatures. But the gap air temperature, even with the coldest regime and largest ice insulation, remains within the tolerance of field data in figure 3.

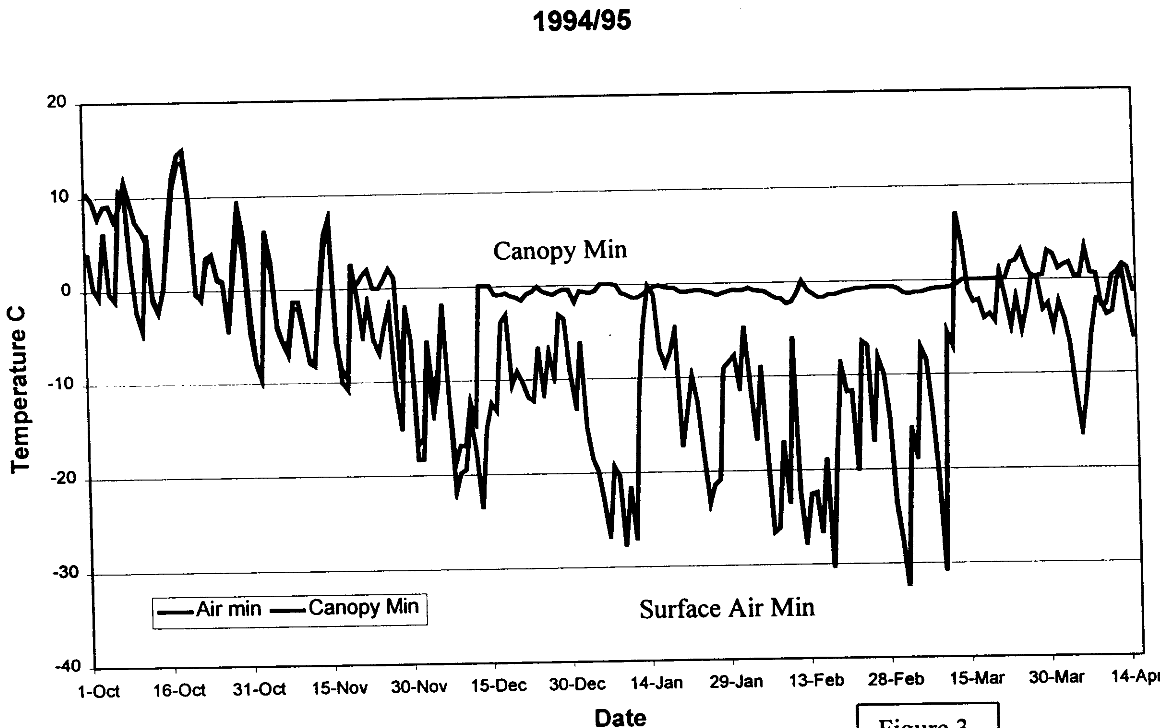


Figure 3

The following chart describes the temperature expected under the ice in the air gap as modeled by FEHT.

	Low	Medium	High
Thin Ice	23 F	25 F	30 F
Thick Ice	25 F	27 F	28 F

Chart 1

Chart 2 describes the temperature regime experience by cranberry uprights as they are encased in ice during winter freeze determined by FEHT.

	Low	Medium	High
Thin	**10 F**	**19 F**	**30 F**
Thick	**19 F**	**21 F**	**23 F**

Chart 2

Chart 3 describes the mid-winter survival temperature of leaves and buds as determined by laboratory experiments.

	3/97	2/98
Leaves	**14**	**-4**
Buds	**-4**	**-8**

Chart 3

It is evident that the ice offers more insulation as it becomes thicker. Also, the temperature within the bud-ice zone is well above the lowest survival temperature as determined in the laboratory, even under the thin ice scenario.

Conclusion

Finite Element Heat Transfer has proven that is may be a useful tool in modeling the activity of a freezing cranberry bed during and after the winter flood. By entering parameters specific to each material to be modeled, and including interactive effects of environmental conditions a researcher is able to accurately predict temperatures in the air gap, at and below the soil surface and within the critical zone where the uprights and buds are encased in ice. This information with data gathered concerning bud hardiness, we have shown that varying thickness of ice sheets in conjunction with cold and warm winter air temperatures is a distinct modeling possibility, offering insight to various management practices. Future models include the addition of snow cover, sand cover, possible inclusion of plant material, and field data pertaining to soil temperatures at specific depths.

3M Sprayable Pheromone for Mating Disruption of Blackheaded Fireworm: Use in IPM Programs and Examples from Reseach Trials

by Sheila Fitzpatrick
Agriculture and Agri-Food Canada, Pacific Agri-Food Research Centre,
PO Box 1000, Agassiz, British Columbia, Canada V0M 1A0

How 3M Sprayable Pheromone Works

3M Sprayable Pheromone releases tiny amounts of synthetic Z 11-tetradecenyl acetate -- the main component of fireworm pheromone -- into the air around cranberry plants. Male fireworm moths follow airborne trails of natural pheromone to locate receptive females. In areas treated with 3M Sprayable Pheromone, most male fireworm moths are unable to find females and the number of fireworm matings is reduced. The numbers of fertilized eggs and hatching larvae are also reduced, and there is less damage to the crop.

Sprayable pheromone works by interfering with moth communication and behaviour. This mechanism is very different from the rapid killing action of insecticides. When using Sprayable Pheromone, it is helpful to understand the following points.

1. ***Sprayable Pheromone best disrupts mating where there are few fireworm moths.***

   Where there are few moths, they are likely well-separated and males are relying mostly on trails of natural pheromone to lead them to females. Under these circumstances, Sprayable Pheromone interferes with the major method of female-to-male communication.

   Where there are many moths, the moth-to-moth distance is short. One moth taking flight disturbs others which, in turn, fly and disturb more moths. Moths may see and hear each other easily. They may be able to detect ("smell") odors from other moths' scales. Under these circumstances, males may see, hear, and smell females. Males may be close enough that the female's natural pheromone signal is too strong to be blocked or overpowered by Sprayable Pheromone.

2. ***Mated fireworm females can fly into an area treated with Sprayable Pheromone and lay fertile eggs from which larvae emerge. Crop damage can result.***

   Imagine two adjoining farms. One has been treated with Sprayable Pheromone and the other has not. Fireworm mating and egg-laying is greatly reduced on the treated farm. However, the untreated farm has many fireworm moths along the adjoining edge, and much mating and flight is occurring. Some mated female moths fly into the treated area and lay eggs. Three weeks later, the manager of the treated farm finds spots of unexpected fireworm damage.

We don't know how far fireworm females fly. They are seen flying in short hops, and moving with the prevailing wind rather than against it.

3. ***Sprayable Pheromone promotes a gradual, season-by-season reduction in fireworm populations. This is slower than the quick reduction caused by insecticide application.***

In spring, fireworms hatch from overwintering eggs. Sprayable Pheromone has no effect until the moth stage. If most mating is prevented during the first flight, the number of larvae and moths in the second flight will be reduced. If most mating is prevented during the second flight, the number of overwintering eggs should be reduced, and the number of larvae that hatch the following spring should be reduced.

If Sprayable Pheromone is used to disrupt mating only in the first half of a flight, it is likely that mating will occur in the second half and there will be little reduction in eggs, larvae or the next flight of moths.

4. ***In a field treated with 3M Sprayable Pheromone, male moths can find IPM pheromone traps even though they can't find females.***

It's a question of signal strength. The pheromone lures used as bait in IPM pheromone traps emit a powerful signal -- perhaps as powerful as 1000 fireworm females.

In research trials, I found that males have trouble finding less-powerful lures. A lure loaded with 0.01 mg of the fireworm pheromone blend (100 times less powerful than the IPM lures) is a good approximator of males' ability to find a female. I suggest that several such "decoy-female" traps be used to assess mating disruption in areas treated with Sprayable Pheromone.

Using 3M Sprayable Pheromone in IPM Programs

Sprayable Pheromone will be most effective on farms with low to moderate fireworm populations, especially if the farm is isolated or surrounded by others that are also using IPM programs and Sprayable Pheromone.

It will be helpful to use several "decoy-female" pheromone traps in addition to IPM traps. "Decoy-female" lures can be purchased from PheroTech (British Columbia), Scentry (Montana) and probably from other suppliers of fireworm pheromone lures; request lures loaded with 0.01 mg instead of 1 mg of fireworm pheromone on gray septa. IPM and "decoy-female" traps should be at least 50 feet from each other.

In the first year of use, scout for fireworms as usual and apply pesticide as needed. Pay particular attention to reducing the number and size of "hot spots" -- areas with many fireworm larvae. Apply 3M Sprayable Pheromone when the first fireworm moth is caught in IPM pheromone traps or, preferably, several days before first catch. Continue applications at intervals of 2.5-3 weeks during each flight of fireworms.

In the second year of use, scout for fireworms in spring and, if necessary, apply pesticide to kill hatching larvae. Apply 3M Sprayable Pheromone when the first fireworm moth is caught in IPM pheromone traps or, preferably, several days before first catch. Continue applications at intervals of 2.5-3 weeks during each flight of fireworms.

Scout for larvae in late June and early July to determine if the number of fireworm larvae warrants a pesticide application. If fireworm populations were low to moderate at the beginning of the first year, if there were few hot spots and if mating disruption has been effective, summer pesticide application against fireworm larvae should not be required.

In the third year of use, follow the protocol for the second year. The summer pesticide application against fireworm larvae should not be required. It may be possible to reduce the spring pesticide application to partial or spot treatments.

In subsequent years, follow the protocol for the third year. A small number of fireworm moths will continue to exist in areas treated with 3M Sprayable Pheromone. If Sprayable Pheromone use is discontinued, the population will likely increase.

What about other pests?

3M Sprayable Pheromone for Mating Disruption of Blackheaded Fireworm will not control other pests.

3M Sprayable Pheromone for Mating Disruption of Sparganothis Fruitworm should soon be registered for use in the United States. The two Sprayable Pheromone products will be tested together by other researchers in 1999 trials.

Research on biologically based management of other cranberry pests such as tipworm will be initiated by other researchers in 1999. Biorational insecticides that will be alternatives to organophosphates and carbamates are being investigated, and registrations are being pursued. Sprayable Pheromone products are compatible with biologically based management and biorational insecticides.

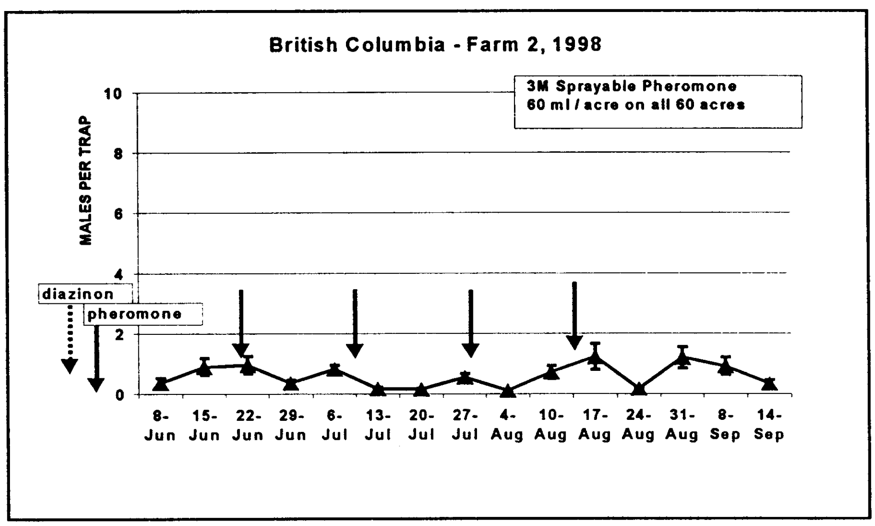
Examples from Research Trials of 3M Sprayable Pheromone

The four graphs on the following pages show the numbers of males caught in "decoy-female" pheromone traps in areas treated with 3M Sprayable Pheromone and in Control areas not treated with Sprayable Pheromone. Pesticides were applied to all or parts of these areas according to the recommendations of IPM scouts. Some pesticide applications targetted other pests, like flea beetle.

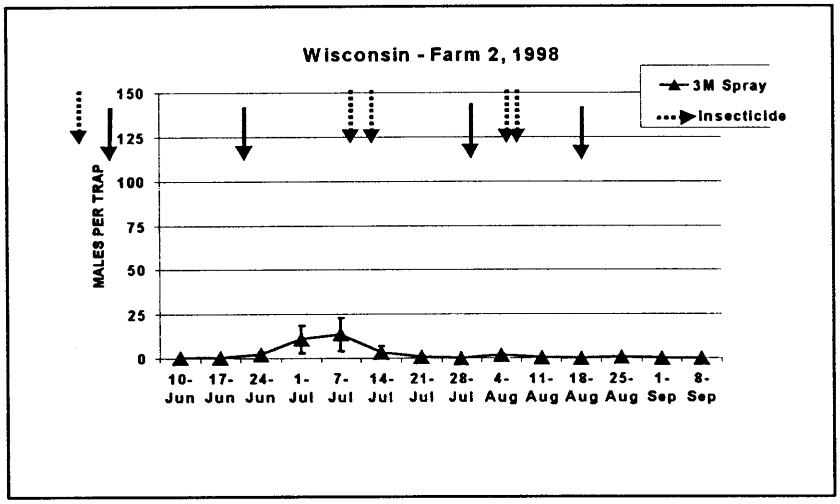
The "MSTRS®" mentioned in the following examples 2-4 are "Metered

Semiochemical Timed Release Systems" developed by Dr. Tom Baker of Iowa State University. These systems are plastic boxes containing battery-powered aerosol containers that spray small amounts of pheromone into the field at timed intervals. MSTRS are placed around field edges. In research trials, MSTRS have been shown to disrupt mating as effectively as 3M Sprayable Pheromone. Full details of research on MSTRS, 3M Sprayable Pheromone and the two systems used together may be found in Research Reports by Fitzpatrick and by Baker to Ocean Spray Cranberries and to the Wisconsin Cranberry Board.

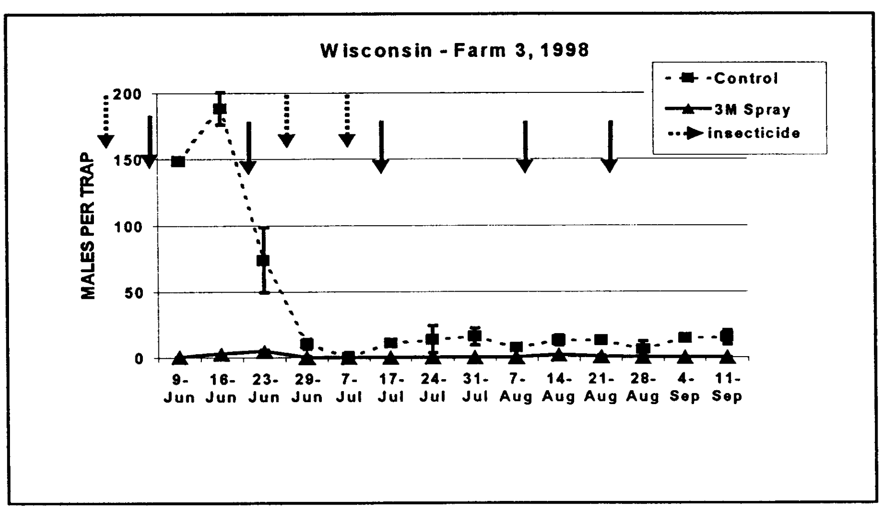
Example 1. This isolated farm has a history of low fireworm populations, and has never applied pesticide for the second flight. In 1997, two-thirds of the farm was treated with 3M Sprayable Pheromone; in 1998, the entire farm was treated (on dates shown by solid arrows). On May 15, 1998, 470 two-foot-square areas were sampled for fireworm; 77 contained fireworm larvae. On July 15, 1998, only 9 of 486 samples contained larvae.



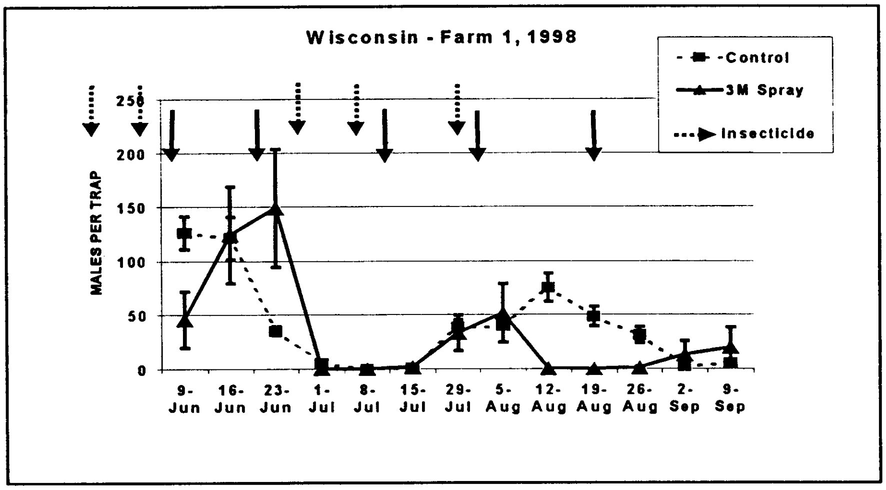
Example 2. This relatively isolated farm has a history of moderate fireworm populations. Two-thirds of the farm was treated with pheromone (3M Sprayable or MSTRS) in 1996 and 1997. In 1998, the entire farm was treated with pheromone (3M Sprayable, MSTRS, or Sprayable + MSTRS). Only the 3M Sprayable treatment (90 ml/acre; solid arrows) is shown here. Complete results can be obtained from Research Reports by Fitzpatrick and by Baker to Ocean Spray Cranberries and the Wisconsin Cranberry Board.



Example 3. This large farm is bordered by others, and has a history of low to moderate fireworm populations. A small amount of the farm was treated with 3M Sprayable Pheromone or MSTRS in 1997. In 1998, approximately 60 acres was treated with pheromone ((3M Sprayable, MSTRS, or Sprayable + MSTRS). Only the 3M Sprayable treatment (90 ml/acre; solid arrows) and the Control (which had some "hot spots" of fireworm infestation early in the season) are shown here. Complete results can be obtained from Research Reports by Fitzpatrick and by Baker to Ocean Spray Cranberries and the Wisconsin Cranberry Board.



Example 4. Parts of this farm were used in research trials of 3M Sprayable Pheromone and MSTRS in 1996 and 1997. In 1998, trials were expanded to include areas not previously treated with Sprayable Pheromone or MSTRS. The area treated with Sprayable Pheromone had an infestation of fireworm larvae. Trap counts show that Sprayable Pheromone (90 ml/acre; solid arrows) was not effective until pesticide applications reduced the population. Complete results can be obtained from Research Reports by Fitzpatrick and by Baker to Ocean Spray Cranberries and the Wisconsin Cranberry Board.



Acknowledgements

I would like to thank all grower-cooperators in Wisconsin, British Columbia and Washington for hosting research trials in 1996, 1997 and 1998. Thanks to all research assistants in the three areas, particularly to Amy Blodgett and Merrilee Busch for their excellent handling of the work in Wisconsin in 1998. I appreciate the cooperation and ideas of Tom Baker, Agenor Mafra-Neto and Henry Fadamiro, who have since 1996 tested MSTRS alongside 3M Sprayable Pheromone. Funding from Ocean Spray Cranberries, the Cranberry Institute, the Wisconsin Cranberry Board, 3M Canada Company, the Pacific Coast Cranberry Research Foundation, the British Columbia Cranberry Growers Association, and Agriculture and Agri-Food Canada is much appreciated. Finally, a special thank-you to Tim Dittl and Leroy Kummer of Ocean Spray Cranberries for so ably organizing and facilitating this project in Wisconsin.

LATE BLOOM

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

In late August 1998 I heard from several growers who had beds in the Cranmoor and Warrens areas that were producing flowers again. I heard estimates as high as 10% of the uprights were flowering late. That sounded pretty significant to me so I made some time to investigate.

I visited three different growers in Central Wisconsin and looked carefully at their beds. I was able to find an occasional flower here and there on all the cultivars we examined, but it certainly wasn't 10% in bloom, perhaps 0.01% in bloom.

For the most part the uprights that I saw in flower weren't "umbrella bloom". The terminal bud had produced additional growth of leaves and stems so the flowers weren't terminal on the uprights. In some cases pinhead and larger fruit were developing. It was still green and very small and was almost certainly sorted out by size in the harvest and cleaning process. Some of these new uprights were beginning to show development of a new terminal bud.

Late bloom doesn't occur too frequently in Wisconsin. It is fairly common in New Jersey where it frequently appears as "umbrella bloom". In this article I will speculate on what caused the late bloom, what effect it will have on the 1999 crop and whether it will happen again.

Bud development in cranberry begins about the same time as fruit set. Bud development can be subdivided into several steps. The first is bud induction. How bud induction occurs and the signal that leads to induction is not well understood. Factors that are thought to play a role include daylength, light quality (red *vs*. far red), temperature, carbon resources and plant hormones. Once the signal is given the result is the genetic material produces code for new proteins that alter the way cells grow and divide.

Once bud induction has occurred then we can physically see the development of the buds. Usually we can't really see the buds clearly until mid to late July. Buds continue to develop throughout the summer and into the fall. The rate of growth is dependent on the vigor of the vines and the weather they experience. Moderate weather and ample sunshine lead to the fastest growth rates. Bud development slows, but does not stop during the winter (Fig. 1).

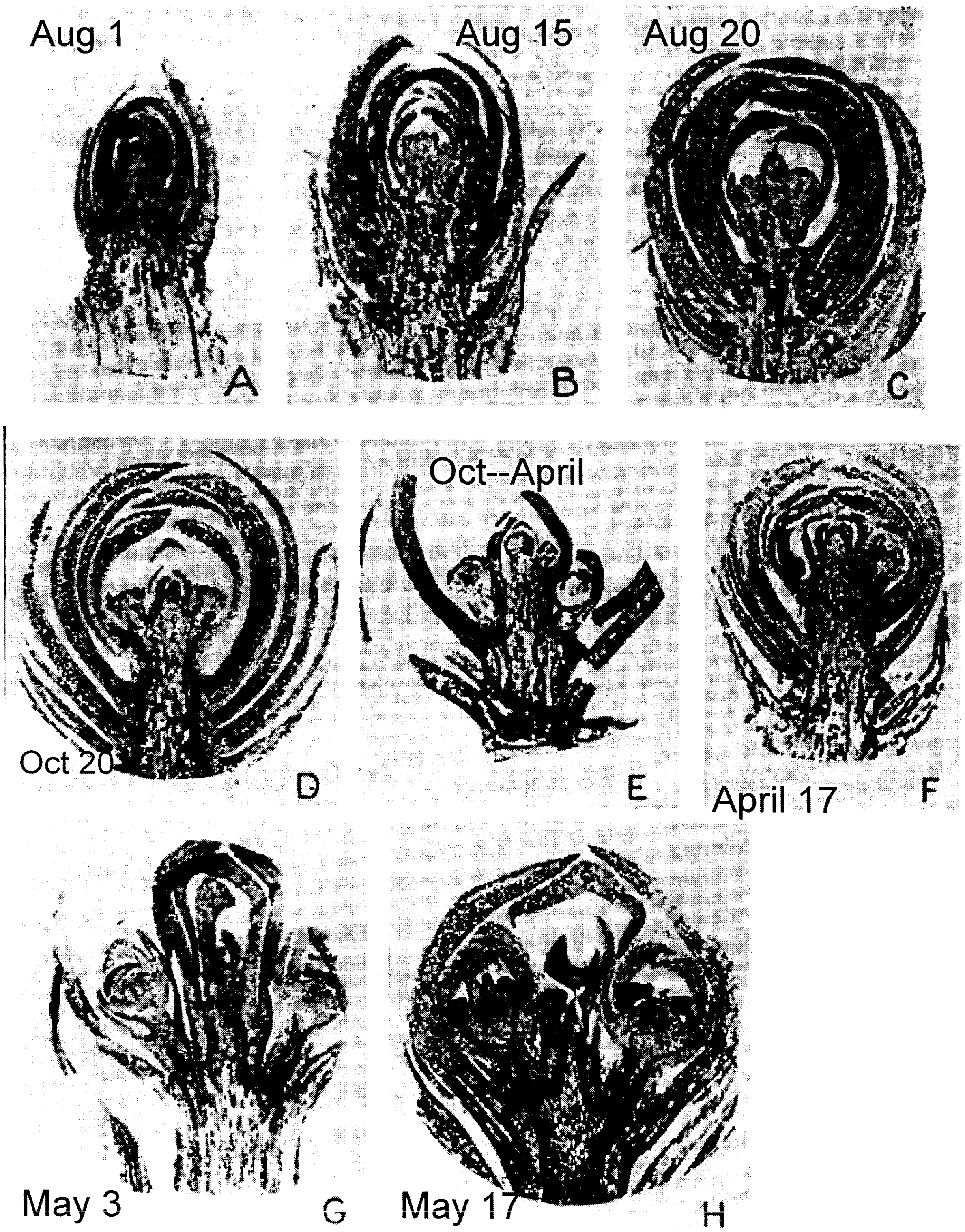
At some point in this process a second "decision" occurs. Buds either become reproductive or remain vegetative. This is a differentiation process. The signal to change from a vegetative to a flower bud is not well understood.

Cranberries, like most temperate fruit crops usually require a period of chilling before buds will open and grow again. However, if favorable conditions have led to rapid bud development and maturity or if the vines are stressed flowers can appear in the fall. It is not uncommon for ornamental crabapples to be completely defoliated from apple scab. Some years when this occurs there is a second light flush of flowers in the early fall. This is a stress response in apple.

What effect will this late bloom have on next year's crop? Given the small amount of late bloom that I saw I don't think it will have any effect. In most cases I think the new terminal, if one is produced, will be vegetative. However, given the spotty nature of this late bloom it still shouldn't be significant next year.

Is there anything that can be done to avoid this from happening in the future? Short of regulating the weather I don't think so. This isn't a very "researchable" topic either because it is impossible to predict when it will occur (unless you can predict these temperate *el Nino* summers). In my opinion, this is one of those odd occurrences that happen occasionally, but not something to worry about.

Figure 1. Cranberry bud development in Massachusetts in 1926 From LaCroix.



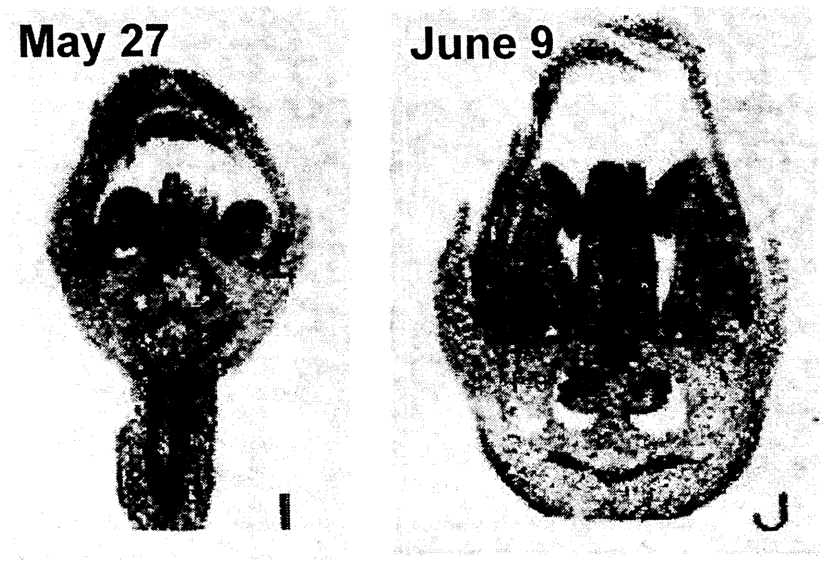
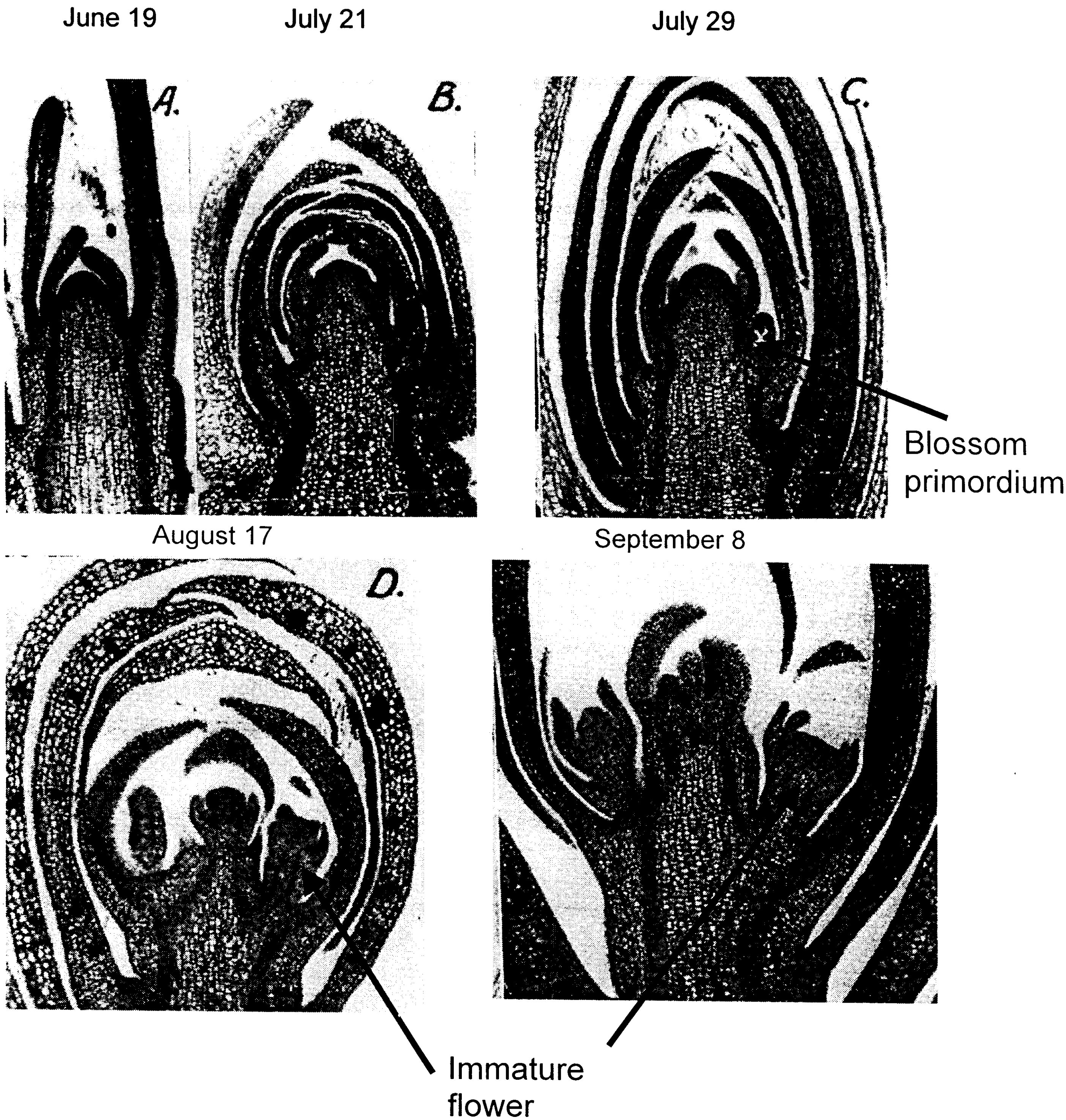

May 27
I
June 9
J

Figure 2. Bud development in Cranberries in Wisconsin. Goff 1901.



Principles of Weed Management

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

When the concepts of Integrated Pest Management (IPM) are discussed the discussion usually relates to insect and disease management. However, of the pests that infest cranberry beds, weeds have the potential to be the most yield limiting. When new herbicides were registered yield per acre increased, in some cases dramatically. Recent estimates suggest yield reductions of up to 60% if current weed management materials were lost. Left uncontrolled, weeds will compete for light, water and nutrients.

Weed management approaches have changed dramatically over time. A generation or two ago growers could only hand weed, clip the weeds to reduce shading or spot treat with salts or petroleum distillates to control weed competition. Today growers still use hand weeding and clipping, but the use of chemical herbicides and biological agents to control weeds offer exciting possibilities. This article will discuss cultural, mechanical chemical and biological aspects of weed management.

Cultural management techniques

Managing weeds really begins before beds are planted. Using excavated sand rather than surface sand for the bed surface will minimize the amount of weed seed present. Make sure that the planting stock came from a bed that had minimal weed populations. It is always prudent to visit the source of the vines before they are mowed.

Having good drainage throughout a bed will reduce some weed pressure. Some weeds prefer wet areas and won't be a problem if drainage is adequate. Good drainage also promotes good vine growth and a healthy canopy will compete well with weeds.

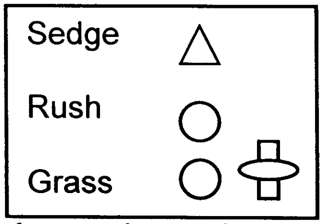
Along with good drainage, maintaining a proper soil pH will discourage the growth of some weeds. The weed profiles of older beds in traditional settings have a different weed spectrum than newer beds with sandy soils in upland settings.

Being clean and tidy can also minimize weed encroachment. When beds are established if the dikes are seeded to a grass and then mowed as needed will reduce the weed pressure onto the beds. Grasses will keep broadleaf weeds from becoming established and broadleaf weeds are the most likely to have seeds that will blow onto a bed. A post-harvest trash flood can serve to float off trash including weed seeds. This is particularly important for dodder. This will also remove diseased leaves and may reduce disease pressure. Place tarps under harvest equipment on dikes and then collect and remove the debris.

For some weeds there is no substitute for handweeding. New beds will require one or two hand weedings until the vines cover the soil and can compete with the weeds. In some cases clipping or mowing the weeds above the canopy will reduce the competition and allow cranberries to flourish.

Weed Identification

Optimal weed management required that growers know what weeds are in their beds and where they are. Management of perennial woody weeds is different than perennial herbaceous weeds. Managing grass weeds is different than broadleaves, sedges or rushes. Weed identification guides have been produced with color photographs of the weeds as well as a description of their botanical characteristics. These are also available on the Internet at the WSCGA web site. Other good sources of weed identification materials are wildflower books for the Midwest.

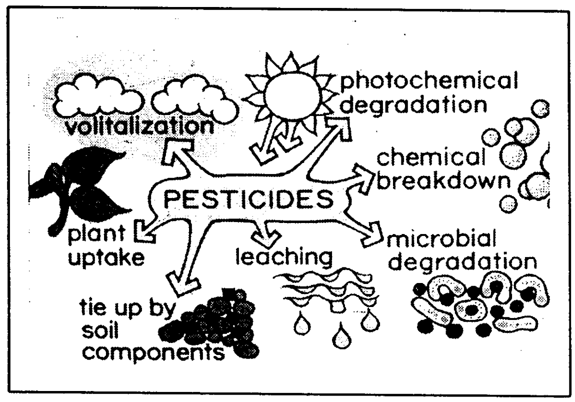


Differentiating between grass and broadleaf weeds should be simple. Telling grasses from sedges from rushes is more difficult. Fortunately these weeds do have distinguishing characteristics. If you pick the stem of these types of weeds and rub the stem between your fingers you'll be able to tell that the stem is round or triangular. Rushes and grasses are round while sedges have a triangular stem. If the stem is round you can look at the stem to see if nodes are present, i.e. that leaves arise at various heights along the stem and that there are slightly raised rings where the grass leaves attach. Rush leaves all arise from the plant base.

Chemical weed management

Since the late 1950's a number of herbicides have been evaluated and several have been registered for use on cranberries. Successful use of herbicides requires information about how particular herbicides work, how they are absorbed and where they are active and for how long. In order to be effective, herbicides must be present at the site of action in sufficient quantity to be active and when the target plant is most susceptible.

Herbicides act by disrupting some critical plant function. Some herbicides interfere with photosynthesis energy transport so plants can't transform light energy to chemical energy. Others disrupt photosynthetic pigments. Others prevent the formation of critical amino acids, proteins, or nucleic acids. Some interfere with root growth while others disrupt the plant cuticle causing plants to dry and wither. Some act only where applied and others are translocated within the plant.



Since herbicides are placed into the environment they are also subject to degradation. Degradation is necessary so herbicide active ingredients don't persist in the environment indefinitely, but they must be present long enough to be effective. Many herbicides break down when exposed to light, particularly UV light. These herbicides (Devrinol) must be covered or washed into the soil shortly after application. Soil microbes can break down some herbicides and either uses them as an energy source or at least cleave the active ingredients into innocuous compounds (Devrinol). Chemical reactions in the soil such as reacting with water or soil ions can deactivate some herbicides (Roundup). Some herbicides will leach through the upper soil layers so that they are below the effective rooting zone (Stinger). When herbicides are absorbed into non-susceptible plants they can be metabolized and deactivated inside those plants. Some herbicides have a high vapor pressure and will volatilize into the atmosphere (Casoron). The various herbicides must be managed differently to obtain the desired results.

Because different herbicides have different modes of action (disrupt different aspects of plant metabolism) they also control different groups of weeds. The weeds that will be controlled by a product are listed on the package label. While these lists are not exhaustive, they usually represent the range of weeds that are prominent for the crops on which it is labeled. Some products are better on grass or broadleaf weeds. Others work only on grasses. Because of these differences in effectiveness it is critical to know what weeds are present before choosing a product to use.

Chemical herbicides can further be classified as pre-emergent or post-emergent. Pre-emergent herbicides either prevent germination or, more typically, interfere with rooting or growth of the seedling. Post-emergent herbicides will kill grasses that are actively growing. Most post-emergent herbicides are selective only through selective application.

Table 1. Characteristics of herbicides registered for cranberry as of 1999.

Herbicide	Weed spectrum	Fate	Half life	Mode of action	Transport
Casoron	Broadleaf, grass, sedge	Microbial degradation, volatilization	2-12 months	Rooting and germination inhibitor	Xylem
Evital	Grass, sedge, rush	Microbial degradation, light, volatile	45-180 days	Inhibits pigment synthesis	
Devrinol	Annual grass, some broadleaf	Microbial degradation	8-12 weeks	Inhibits root growth	
Princep	Annual grass, broadleaf		> 1 year	Inhibits photosynthesis	Xylem
2,4-D	Broadleaf	Microbial degradation	1-2 weeks	Unknown, multiple sites	
Roundup	Emerged weeds	Degrades quickly	0 days	Inhibits amino acid synthesis	Phloem
Poast **Select** **Fusilade**	Emerged grass		2-5 days 2-5 days < 20 days	Inhibits lipid synthesis	
Scythe	Green tissue		No residual activity	Disrupts membranes	

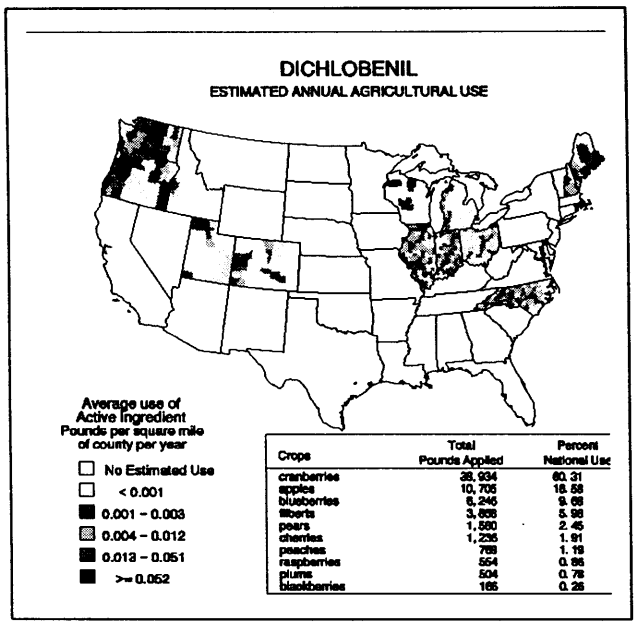
In addition to traditional chemical herbicides there are also possibilities for "bio-herbicides". These would be disease or perhaps viruses that would attack the weeds but not cranberries. With today's technology the fungal spores or virus particles do not persist well in the environment. With more careful application and proper formulation perhaps their longevity and activity can be improved.

Weed mapping allows optimal application of herbicides. Using a map of your beds indicate on the maps where particular weeds or groups of weeds are a particular problem. Rank the weeds as very invasive (high priority), moderately invasive and moderately competitive (medium priority), or not competitive or invasive (low priority). As you plan your herbicide applications you can pay particular attention to areas that are a high priority.

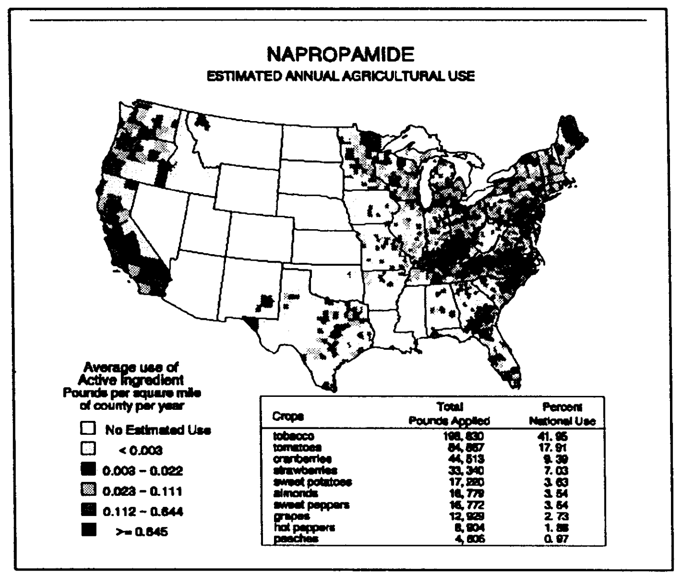
Conclusion

What does the future hold for weed management? There are lots of possibilities, but also lots of uncertainty. Molecular biology/genetic engineering holds some opportunities. A resistance gene could be inserted into cranberry allowing broadcast application of an herbicide over the cranberries to control weeds. This would be very beneficial during the early establishment years when competition is critical and the canopy is incomplete. There are opportunities to use existing chemistry for cranberry once efficacy, crop safety and residue analysis are completed. Funding from the industry to continue this research will be critical.

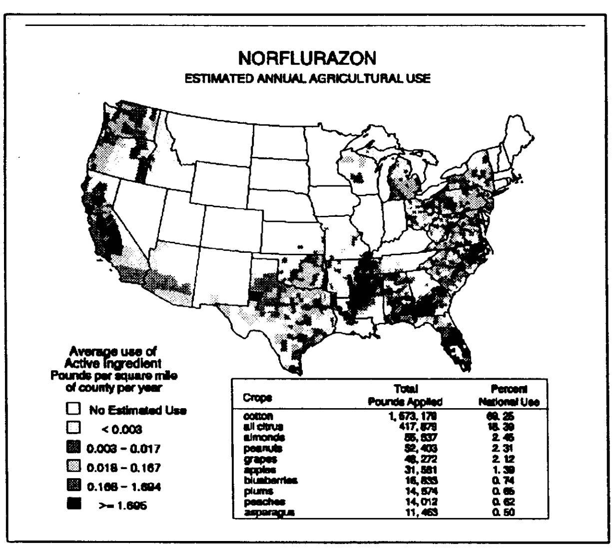
No single method of weed management is sufficient in today's environment. Good cultural practices like managing pH and selecting appropriate sites are equally important to using the correct herbicide. Timing herbicide application for the target weed species can be improved. Maintaining the current arsenal of products and practices is important while we seek new products and practices to manage weed pests.



Crops	Total Pounds Applied	Percent National Use
cranberries	38,934	60.31
apples	10,705	16.58
blueberries	6,246	9.68
filberts	3,858	5.98
pears	1,580	2.45
cherries	1,236	1.91
peaches	769	1.19
raspberries	554	0.86
plums	504	0.78
blackberries	166	0.26



Crops	Total Pounds Applied	Percent National Use
tobacco	198,830	41.95
tomatoes	84,867	17.91
cranberries	44,513	9.39
strawberries	33,340	7.03
sweet potatoes	17,220	3.63
almonds	16,779	3.54
sweet peppers	16,772	3.54
grapes	12,929	2.73
hot peppers	8,804	1.86
peaches	4,606	0.97



Crops	Total Pounds Applied	Percent National Use
cotton	1,673,179	69.25
all citrus	417,879	18.39
almonds	55,537	2.46
peanuts	52,403	2.31
grapes	48,272	2.12
apples	31,581	1.39
blueberries	16,835	0.74
plums	14,574	0.65
peaches	14,012	0.62
asparagus	11,463	0.50