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MATING DISRUPTION: WHAT IS IT AND HOW DOES IT WORK?

Sheila Fitzpatrick
Pacific Agri-Food Research Centre
Agriculture & Agri-Food Canada
6947 # 7 Hwy, P.O. Box 1000, Agassiz
British Columbia, Canada VOM 1AO

Introduction

Mating disruption is an insect management technique that prevents male insects from finding females. The technique is constructed from the following "building blocks": an understanding of communication and attraction between male and female insects; identification and synthesis of the sex attractant odor, called a pheromone, normally produced by female insects; and a way of releasing synthetic pheromone into the environment in quantities sufficient to prevent male insects from locating sexually receptive females.

I will first explain the pheromone-based mate-location behavior that is interrupted by mating disruption. I will then go on to explain how synthetic pheromone is released into an area, and how the pheromone interferes with mate location. From there, I'll describe the implementation of mating disruption for control of the blackheaded fireworm in cranberries, and show some of the data from field tests. I hope to leave you with an understanding of this technique, and also to emphasize that this is "knowledge-based" technology.

Finding a Mate: How Pheromones are Used by Moth Pests

When a female moth emerges from her pupal case, she has two or three predetermined missions. The first is to crawl away from the pupal case, climb onto something vertical, expand her wings and allow her soft body parts to harden. During this period of several hours, she is unable to fly and therefore quite vulnerable to predators. Once her wings are in working order, she may fly about in search of water and, in some cases, nectar for food. Her next task is to attract a mate, which she does by sending out a chemical signal.

The female's chemical sex attractant signal is called a pheromone. It is produced in a gland at the end of her abdomen. To send the pheromone signal, the female extrudes her gland, allowing the volatile pheromone to evaporate from the gland surface. The pheromone signal drifts downwind away from the female, much the same way that smoke drifts away from a cigarette. The female may repeatedly extrude and withdraw her gland, so that the pheromone signal is puffed out in pulses. The pheromone is emitted in very tiny amounts, on the order of less than a billionth of a gram per hour.

The pheromone signal typically contains several chemicals in a ratio particular to the moth species. Thus the pheromone signal is a blend that carries the message, "There is a female of species 'X' seeking a mate of the same species". Pheromones are kind of like personal ads.

A male moth detects the pheromone signal through sensory cells on the sensillae (tiny hairlike projections) of his antennae. The cells are so sensitive that they can detect tiny quantities -- molecules -- of pheromone chemicals. There is a different type of sensory cell for each chemical in the pheromone blend. Parts of the male's brain are genetically programmed to decide if the chemical blend is coming from a female of his species.

Male moths spend much of their time "sniffing" for a pheromone signal. They sit on plants or other vertical structures with their antennae upraised, and fly around searching the air for pheromone. They frequently clean their antennae with their front legs, so that the delicate sensory cells are kept clean of dust and other odor molecules.

When a male moth detects a pheromone signal, he begins to fly upwind along the invisible, smoke-like "plume" of pheromone. He attempts to keep at least one antenna in the pheromone plume during upwind flight. If his right antenna loses the pheromone signal, he turns left across the wind, then continues upwind flight. If his left antenna loses the signal, he turns right. Thus his upwind track along the pheromone plume is full of zigzags. If he loses the plume altogether, he zigzags left and right in the air where he last sensed the pheromone. If he still can't find it, he may land, clean his antennae, then take off and try again. Or he may fly downwind, then turn around and fly upwind in wide zigzags.

Like a smoke plume, the invisible pheromone plume gets narrower and less dispersed close to its source. As the male nears the female, his flight path gets straighter. He lands next to her, and does a series of courtship behaviors so rapid that the individual behaviors can't be seen unless they are videotaped and played back slowly. Male courtship behaviors may include wing fanning, sound, touching and release of a male pheromone. All of these behaviors tell the female that the male is from the right species and the right side of the tracks. Females may reject males that don't display all the elements of good courtship. When a male is accepted, he clasps the female's genital armature with his own, and mating occurs. If the mating is successful, the female will begin to lay fertilized eggs, usually within 24 hours.

The mating disruption technique attempts to prevent males from finding and following a female's pheromone signal. If mating disruption is successful, there will be many females "calling" (releasing pheromone), but no males answering.

How Mating Disruption Works

The mating disruption technique takes a synthetic copy of the pheromone blend produced by female moths and broadcasts it over the area where male and female moths are found. To get synthetic pheromone for a given moth species, biologists rely on their friendly chemist colleagues to first identify the chemicals in the natural pheromone blend, then reproduce the blend. It was first thought that, to be an effective disruptant of mating, the synthetic pheromone blend had to be virtually indistinguishable from the natural phermone blend. However, we now know that it is also possible to disrupt mating by using only the main chemical component(s) in a pheromone blend.

The synthetic pheromone is injected into or enclosed in controlled-release devices, which are distributed in the field. These devices may be small plastic or polyvinyl chloride (PVC) tubes or spirals, flakes, "twist-tie ropes" (small plastic tubes with a twist-tie wire inside), clips similar to bread ties, microscopic polyurea capsules, or timed-release spray canisters. The tubes and flakes are designed to be scattered by hand or from an airplane. Spirals, twist-tie ropes and clips are attached by hand to branches. Microscopic capsules can be sprayed from a helicopter or conventional sprayer, and timed-release spray canisters are attached to stakes and placed in the field by hand. All of these controlled-release devices allow small amounts of pheromone to escape gradually into the air around the crop.

For mating disruption of the blackheaded fireworm of cranberries, we began with PVC spiral dispensers, and are now testing microscopic capsules (Fitzpatrick) and timed-release spray canisters (Baker and Mafra-Neto).

Before going into more detail about the cranberry system, I would like to explain how synthetic pheromone, emanating from controlled-release devices, may disrupt mate location in moths. In the following discussion, you will notice that the words "may", "might", and "possibly" are often used. There are still many unsolved mysteries in our understanding of how mating disruption works.

Reduced Responsiveness due to Sensory Adaptation or Habituation. Male moths exposed to high, uniform concentrations of pheromone in the lab stop responding to females emitting pheromone. This may be because the sensory cells on their antennal sensillae become adapted and stop responding to the small amounts of pheromone emitted by females, or because the decision-making part of the brain gets habituated (overloaded) and no longer recognizes female pheromone. Adapted or habituated males are likely to stop searching. Sensory adaptation or habituation is similar to what happens to us when we walk into a kitchen filled with the aroma of baked goodies. At first the aroma is very strong but, after some time in the room, we cease to notice it.

Camouflage of the Female's Pheromone Plume. Synthetic pheromone in the air may camouflage the filamentous structure or the concentration of odor molecules in the female's natural pheromone plume. Camouflage renders the natural pheromone plume indistinguishable from the background of synthetic pheromone. Males continue to search, but cannot find the females.

False Trail Following. When there are many controlled-release devices in the field, each one emitting pheromone, there may be many false pheromone trails for males to follow. Males are able to locate the pheromone plumes, but their zigzagging flight takes them to controlled-release devices instead of females. Close to the device, the high concentration of pheromone may cause sensory adaptation or habituation, and the male may stop, clean his antennae and sit quietly for a while.

Imbalance of Sensory Input. When an incomplete pheromone blend is used to disrupt mating, some of the males' sensory cells may become adapted while the others continue to function. Thus the males may not be able to accurately perceive the natural pheromone blend released by a female. For example, the blackheaded fireworm pheromone contains at least three components, but we use only the main one as a mating disruptant. The sensory cells that are designed to perceive the main component may receive so many odor molecules that those cells become adapted and stop responding. A male downwind from a calling female would then perceive only part of her chemical signal, that is, the part containing the second and third pheromone components. He would not recognize this as a pheromone, and would not fly upwind toward the female. Another possiblity is that all his sensory cells might continue to receive information, but he wouldn't recognize female pheromone because the ratio of odor molecules from the three components would be skewed.

Species and Systems for which Mating Disruption is Likely to Work

Mating disruption is most likely to be a successful management technique for insects that have one kind of host plant. For such insects, if mating can be disrupted in fields containing their host plant, there is no chance that mated females will fly in from nearby fields containing other host plants. For example, if mating of blackheaded fireworm moths on a cranberry farm can be prevented, we can be sure that there will be no mated fireworm females in the pasture next door. However, if we were to attempt mating disruption of cranberry girdler on the same cranberry farm, mated girdler females from the pasture would probably fly onto the farm and lay eggs. Thus, even though mating of cranberry girdlers was disrupted on the farm, there would still be damage from cranberry girdler larvae.

Following the same reasoning, mating disruption of blackheaded fireworms on a farm is more likely to succeed if the neighbouring farms also use mating disruption or have very low fireworm populations. "Area-wide" mating disruption reduces the likelihood that mated females will fly into disrupted areas and lay eggs.

Mating disruption is most likely to work where populations of the target insect are low to moderate. Where populations are high, males and females are in close proximity and males may not have to follow pheromone plumes to find females. If they are very close, males may simply see or hear the females, approach and perform their courtship behaviors. Or, there may be so many females emitting pheromone that males have a good chance of following a pheromone plume to a female rather than to a controlled-release device.

Systems where crops are grown on even terrain and have little three-dimensional structure should allow pheromone from controlled-release devices to permeate most of the air above and around the plants. Crops on slopes are often subject to upslope winds in the morning and downslope winds late in the day. Winds can move the pheromone around and leave sections of the field or orchard unprotected. Similarly, the tops of trees may be left unprotected if controlled-release devices are placed in the lower part of the canopy.

The nature of the cranberry system and the monophagous (single host) lifestyle of the blackheaded fireworm lend themselves well to the mating disruption technique, so long as fireworm populations are low to moderate.

Species for which Mating Disruption is Successful

Mating disruption is being used to control pink bollworm on cotton in California, Arizona and Egypt; the oriental fruit moth in the United States, Europe, Australia and Brazil; tomato pinworm in the United States and Mexico; the lightbrown apple moth in Australia and New Zealand; the currant clearwing moth in New Zealand; the European grape moth and grape vine moth in Europe; the grape berry moth in North America; codling moth in Europe and North America; and some leafrollers in orchards in Europe and North America. Mating disruption of other agricultural and forest pests is being tested in North America, Europe, South America and other parts of the world.

Mating Disruption of Blackheaded Fireworm in Cranberries

In 1992, my research team and I did the first, small-scale experiments on mating disruption of blackheaded fireworm in cranberries. We began by using PVC spirals releasing either the three-component blend of synthetic pheromone chemicals or the single, main component. Over the next three years we continued our tests in British Columbia, and came to three main conclusions. First, the spirals were great for small research plots but too labor-intensive for farms over five acres. Second, the single, main component disrupted mating as effectively as the three-component blend, which was good because formulating one component should be cheaper than formulating three. Finally, we concluded that mating disruption was a very promising technique for blackheaded fireworm in cranberries.

In 1996, a sprayable formulation of blackheaded fireworm pheromone became available, and we did tested it on a large scale in Wisconsin and Washington. This sprayable, microencapsulated formulation contains the single, main component of fireworm pheromone enclosed in microscopic, polyurea-based capsules. The formulation, called "MEC" for MicroEnCapsulated, can be applied by helicopter, fixed wing aircraft, mist blower or through the sprinklers. Alongside our tests of MEC, Drs. Baker and Mafra-Neto tested Metered Semiochemical Timed Release Systems (MSTRS): canisters of pheromone released at timed intervals. Both the MEC and the MSTRS gave very good results.

Before I discuss results of the MEC tests, I will explain how tests of mating disruption are evaluated. Earlier, I said that mating disruption is "knowledge-based technology". I've explained that we need to know the host range and population density of the target insect. We especially need to know how to tell if mating disruption is working.

Evaluating Tests of Mating Disruption.

1. Caged Females. After controlled-release devices have been applied to the field and synthetic pheromone is being released into the field, it would be great if we could capture wild females and see if they were mated. (Males transfer a spermatophore full of sperm during mating; this can be found in mated females.) However, to capture a representative number of wild females, we'd have to spend days walking all over the field during bloom and early fruit set. So the next best technique is to place virgin, lab-reared female moths in tiny cages that allow males to enter, and put the cages in the field for three or four days. The females are then brought back to the lab, killed quickly by freezing, and dissected to see if they contain spermatophores. We do this once or twice a week for the duration of the fireworm flight period, and compare the percentage of mated females in the pheromone-treated fields with the percentage in control fields (not treated with pheromone). If the pheromone treatment is effectively disrupting mating, the percentage of mated females in the treated field will be zero, or very low compared to the percentage in the control field.

The only loophole in this evaluation technique is that the females are mostly surrounded by a plastic cage. Much of the pheromone they release may stick to the plastic of the cage and their pheromone signal may be much weaker than that of wild females. Thus, this technique may be evaluating whether males can locate hard-to-find females in a pheromone-treated field. It may not be telling us much about whether males can find nearby females releasing normal amounts of pheromone.

2. Pheromone Traps. Another technique for evaluating mating disruption is to compare the number of males caught in sticky-bottomed pheromone traps in pheromone-treated field with the number caught in control field. If mating disruption is working, the number of males caught in the treated field will be zero, or very low (1-5%) compared to the number in the control field. The pheromone traps contain a rubber septum impregnated with a high concentration of the blend of three components of fireworm pheromone. In a sense, these traps are super-females. The assumption in this evaluation technique is that, if males can't find the pheromone lure in the trap, they can't find females either. However, if the pheromone lure is very concentrated, the trap's signal may be detectable over the background of synthetic pheromone even when a female's signal is not. Therefore, we take care to use pheromone lures that are about as readily located as caged females. We are also aware that, although the pheromone blend in the lure is our best copy of the natural blend, a female may be more attractive.

3. Number of Larvae. Another way of evaluating mating disruption is to compare the number of fireworm larvae in the pheromone-treated field with the number in a control field. This is a difficult thing to do on cranberry farms. A thorough evaluation of the number of larvae, or population density, in a field requires that samples be taken (visually or by sweep net) from all parts of the field. This involves much walking at the bloom and early fruit development stages. Also, insecticides are usually applied to kill larvae before they get very big. This is a good management practice, but makes it difficult to estimate the number of larvae in a field. One of Dan Mahr's students has shown that there is no correlation between the number of very young larvae picked up in a sweep-net sample and the actual number in a field. There is a correlation between the swept and actual numbers of older larvae (third, fourth and fifth instars).

4. Combination of Methods. The best evaluation method is to use techniques 1-3, and use the same fields for about three years. If the synthetic pheromone treatment is effectively disrupting mating we should see a progressive decrease in, or continual low numbers of, mated caged females, males caught in pheromone traps, and larvae relative to the control field. Several fields should be treated with pheromone, and several should be left as controls. Management practices should be similar in each pair of treated and control fields.

Results from Tests of Mating Disruption using "MEC" in Wisconsin, 1996.

We tested MEC on three farms in Wisconsin in 1996. All were somewhat isolated, and had what we believed to be low to moderate populations of blackheaded fireworm. We had really excellent cooperation from all three growers. Drs. Baker and Mafra-Neto tested their MSTRS on the same farms, and will be discussing their results separately.

On one of the farms, it turned out that fireworm populations were a little too high for control by mating disruption. On another, we applied the MEC a little too early to give good control all the way through the first flight. On the third farm, populations were moderate and the timing of MEC applications was better. I will be discussing results from this third farm, which I will call Farm 1, because I think they illustrate many of the considerations important to the successful implementation of mating disruption.

On Farm 1, we chose four fields totalling 11.8 acres to receive MEC, and one 3.4-acre field as a control. The control field was upwind and across a road from the fields to be treated with MEC, to minimize the chance that pheromone would drift from the treated fields to the control. Our objective was to put on one application of MEC in the spring to disrupt males in the first flight of moths, and a second application to disrupt males in the second flight.

MEC was applied by helicopter on June 12, at a rate of 180 milliliters of product containing 36 grams of active ingredient (pheromone) per acre. We were a little early with the MEC application. Ideally, it should go on when the first males are caught in pheromone traps. The spring of 1996 was unseasonably cool, and moth flight began two to three weeks later than normal. We were hedging our bets by applying the material when we did, but we wanted to be early rather than late. As it was, larvae were still in the field at the time of pheromone application. An insecticide to control fireworm larvae was applied to all fields on the same day that pheromone was applied to the four chosen fields.

From June until September, we evaluated mating disruption by using pheromone traps and, in July and August, by sweeping for larvae. Now I've just finished telling you that it's best to combine three evaluation methods: caged females, pheromone traps and sweeps for larvae. What I didn't tell you is that to have enough female moths at the right time, a full-time technician is required to maintain the fireworm colony and provide a large number of females every week. So we compromised, and used pheromone traps and sweeps. I am confident that the data we obtained from pheromone traps was similar to data we would have obtained from caged females. And we needed a full-time technician anyway! Tony Bonanno was kept extremely busy checking and changing pheromone traps on all three farms, as well as doing sweeps on all three farms for four weeks.

The first moths were caught in traps on June 20 (Figure 1). This marked the beginning of the first flight. Trap catches in the control field increased to a peak on July 3. From June 27 until July 11, the numbers of moths caught in pheromone traps in the MEC-treated fields were about 85-93% lower than in the control field. On July 14, as bloom was just finishing, an insecticide was applied to all fields.

MEC was reapplied on July 15, four weeks after the first application. We were finding out from our field tests in British Columbia and Washington that MEC lasted

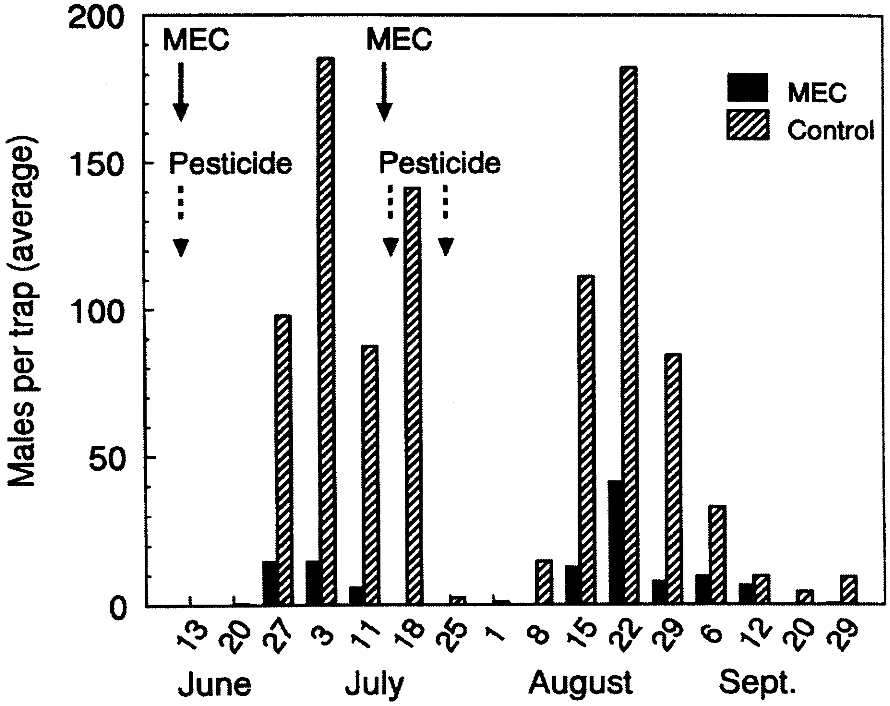

Figure 1. Pheromone trap catches on Farm 1. Solid arrows show MEC applications; dotted arrows show insecticides.

about four weeks in the field. Because there were still many moths coming to the pheromone traps in the control field, we knew that the first flight had not ended, and wanted to be sure that we had synthetic pheromone in the field for the entire duration of the first flight. On July 18, following the second application of MEC, trap catches in the MEC-treated fields plummeted to less than 1% of catches in the control field. This result is a very encouraging indication that the fresh MEC prevented males from finding pheromone traps and, we hope, from finding wild females in the field.

On July 25, larval populations in all fields were such that another application of insecticide was warranted. The insecticide brought the first flight of moths to an end. For the next three weeks, very few males were caught in any of the pheromone traps.

The second moth flight began on August 8 and continued until September 12. The second application of MEC probably lasted only until August 8 or 15, just as the second flight was climbing to a peak. Despite the MEC wearing off, pheromone-trap catches in the MEC-treated fields from August 22 until September 5 were 78-91% lower than catches in the control field. This reduction, while not enough to prevent subsequent fireworm populations from increasing, is still substantial. It suggests that MEC may have some residual activity beyond four weeks, and also suggests that there were fewer moths in the MEC-treated fields due to the disruption of mating during the first application of MEC in June and July.

It is interesting to note that the insecticide applications did not reduce the size of the second flight of moths in the control field relative to the first flight. I have no explanation for this, except to say that the insecticide does not seem to have done its job.

I would now like to discuss the pattern of moth captures in relation to the location of individual traps (Figure 2). In the control field, there were three traps: one at each end and one in the middle. The average number of moths caught per week was the same for each trap: 60. In the northernmost MEC-treated field, the average catch per week was 23 for the trap at the west end, 6 and 5 for the two traps in the middle, and 10 for the trap at the east end. In the MEC-treated field to the south of it, the average catch per week was 20 at the west end, 4 and 3 for the two traps in the middle, and 2 at the east end. In the other two MEC-treated fields, which were further east and south, the three traps caught an average of 1, 3 and 4 moths per week.

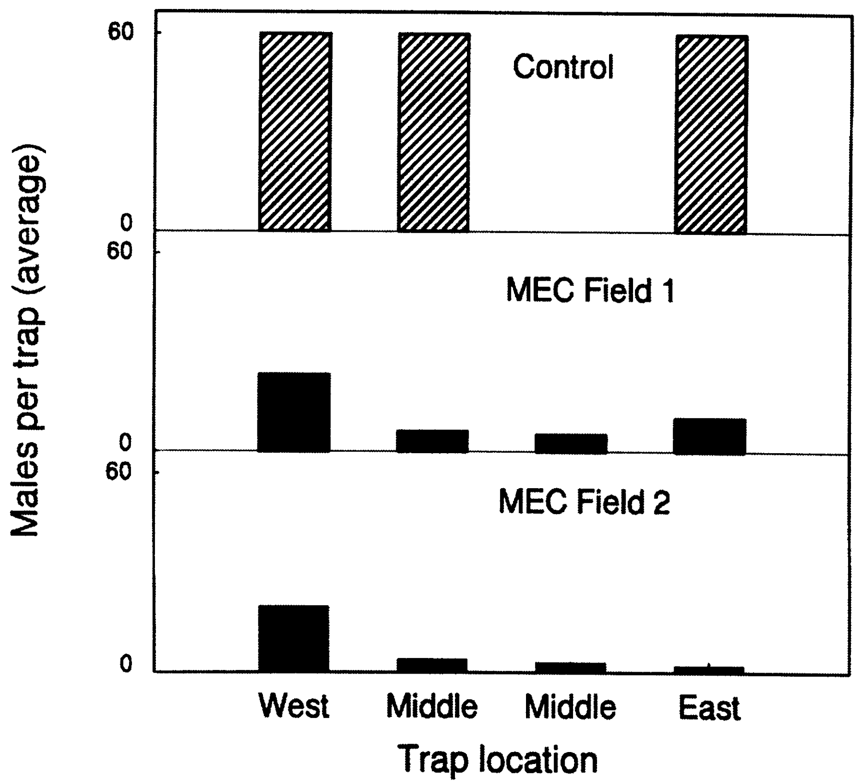

Figure 2. Pheromone trap catches according to trap location. Values are average totals for the season.

Of all the traps in the MEC-treated fields, those at the west end of the two northern- and westernmost MEC-treated fields caught the most moths. Why might that be?

The western ends of the MEC-treated bogs were next to a marsh. Therefore, it is probable that the helicopter pilot came in quite steeply to the west end of the cranberry fields in a effort to avoid spray drift to the marsh. If he did this with the MEC, he probably did it with insecticide as well, in 1996 and previous years. Thus there may have been a "hot spot" of fireworms at the west end of those two fields. Also, the prevailing wind in the area was usually westerly. Westerly winds would blow the MEC east, away from the west end of the field. Thus males at the west end may have been more able than those in other parts of the field to find the pheromone traps and the wild females.

Larvae showed up earlier in the control field than in the MEC-treated fields (Figure 3). The insecticide application on July 14 reduced the number of larvae in the control, but the number of larvae in the northernmost MEC-treated fields was relatively high, probably because the insecticide did not kill eggs that were ready to hatch. After the insecticide on July 25, almost no larvae were picked up in sweep nets in any of the fields. In the MEC-treated fields, larvae were swept from inner and edge sweeps. Visual inspection of the fields showed that there were "hot spots" of larvae under and around the pheromone traps. The most probable explanation for this is that the pheromone traps, which were covered with plastic bags during the insecticide and MEC application on June 12, acted as umbrellas over the cranberries and created small insecticide-free and MEC-free zones where larvae and moths could develop. In future, we will avoid having covered pheromone traps in the field during insecticide and MEC applications.

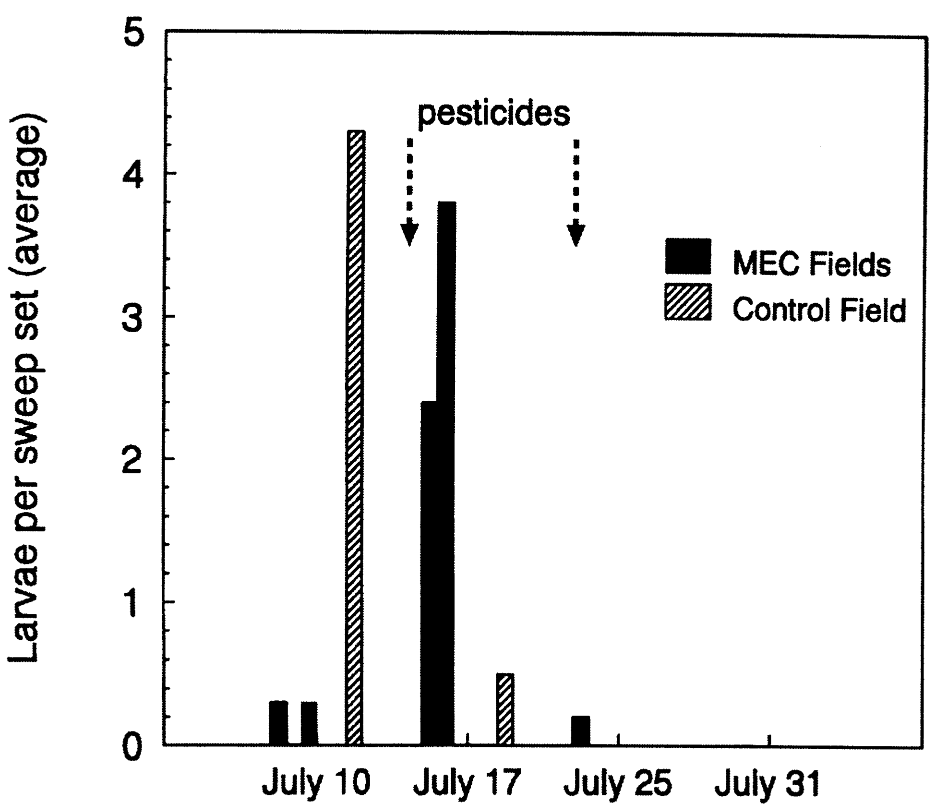

Figure 3. Average number of larvae per sweep set in MEC-treated fields versus the control field.

Conclusions from MEC tests in Wisconsin. In spring, MEC should be applied when pheromone traps catch the first fireworm moths. The second application of MEC should go on when pheromone traps catch the first moths of the second flight. I will be talking to the companies that make and sell the pheromone, to encourage them to extend MEC's "lifetime" beyond 4 weeks or to reduce the price of MEC so that it will be economical to use three applications if required. At upwind edges of fields, it may be most effective to use a combination of MEC and MSTRS (the timed-release canisters of pheromone tested by Drs. Baker and Mafra-Neto). Insecticides should be applied as usual in addition to MEC during the first year of mating disruption.

Mating of other moth pests, such as Sparganothis fruitworm, will not be disrupted by the MEC applied for blackheaded fireworm. Dr. Polaravarpu from Rutgers University, New Jersey, is working on mating disruption of Sparganothis and spotted fireworm. He and I will be coordinating our work so that management of the complex of moth pests in Wisconsin is achieved.

Concluding Remarks

Mating disruption is a very promising non-insecticidal technique for management of blackheaded fireworm in cranberries, and is being used successfully on other species of moth pests in cotton, tomatoes, grapes and orchards. By attempting to prevent males from finding females, the technique disrupts behaviors that have evolved over millions of years and are vital to moth reproduction. For this reason, we know that implementation of mating disruption is not simply a matter of applying synthetic pheromone to a field and hoping it will work. We can expect that the moths will do everything they can to find each other through the miasma of synthetic pheromone.

We can improve the odds that mating disruption will work by eliminating "hot spots" of larvae and preventing high density patches of moths from occurring. We can ensure that MEC is applied to all areas of a field, and perhaps improve protection of upwind edges by using MSTRS (the timed-release canisters of pheromone tested by Drs. Baker and Mafra-Neto). Successful adoption and use of the mating disruption technique will ultimately depend on cooperation and sharing of knowledge between researchers, integrated pest management consultants, growers, pheromone companies and regulatory agencies.

Acknowledgements

I thank Randy Bennett, David Searles and Charles Strozewski for their willing participation and excellent cooperation in on-farm tests of mating disruption in Wisconsin in 1996. I am indebted to Tim Dittl and Tony Bonanno (Ocean Spray Cranberries) for thorough and diligent management of the on-farm tests. Drs. Tom Baker (University of Iowa), Agenor Mafra-Neto (University of Riverside) and Don Weber (Ocean Spray Cranberries) have all provided helpful discussion and feedback. Financial support for the mating disruption project (1992-1996) has been provided by Ocean Spray Cranberries, the British Columbia Cranberry Growers Association, the Pest Management Alternatives Office of Canada, and Agriculture & Agri-Food Canada.

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Cranberry Integrated Pest Management in Wisconsin: Past, Present, and Future. A Panel Discussion.

Daniel L. Mahr, Moderator
Department of Entomology
University of Wisconsin - Madison

Introduction of the Topic

Integrated Pest Management (IPM) is an approach to managing pests that relies on the usage of multiple control tactics, with specific tactics being chosen based upon the pest complex that is actually present in a field at any given time. IPM users recognize the importance of all major pest control approaches: chemical control (such as pesticides and pheromonal mating disruption), biological control (manipulation of beneficial "natural enemies"), mechanical controls (such as hand weeding and mowing), physical controls (such as sanding and flooding), cultural controls (such as cleanup of infested crop residues), and host plant resistance. IPM users also understand that pest numbers are often below economically damaging levels, and during these periods no control actions are required. Further, successful IPM relies on the knowledge that some pest management practices can interfere with others (such as broad spectrum pesticides that eliminate beneficial natural enemies) and that management practices should be designed to truly integrate the most compatible practices available.

Because IPM programs rely on a multitude of specific pest control tactics that need to be integrated together based upon the specific pest complex at any given time, frequent and routine pest monitoring (scouting) is an important key to the success of IPM. In short, the best management decisions can only be made with a good understanding of what the pests are actually doing. For this reason, the University of Wisconsin initiated the UW-Extension Cranberry IPM Program in 1986, with leadership from the UW-Madison Departments of Entomology, Plant Pathology, and Horticulture, the UW-Extension IPM Program, and the cranberry industry. During the 4-year pilot IPM program, we developed pest monitoring practices and demonstrated how these practices could be used to both improve pest control and reduce the use of pesticides. The success of the program can be measured by the degree of interest that the cranberry industry had in continuing IPM at the time of termination of the university's pilot program.

Today, the Wisconsin cranberry industry is recognized nationally as a leader in IPM implementation. With a reported 70-80% of the state's acreage under some form of IPM program, I can state that this is one of the highest rates of adoption for any crop in the nation. I compliment Wisconsin cranberry growers for their continuing interest in integrated pest management.

Introduction of the Panel

IPM is not a static practice; it continues to evolve as new practices are developed through research and old practices are modified through experience. The purpose of today's panel discussion is to take a critical look at cranberry IPM in Wisconsin. As we have passed the 10-year anniversary of the inception of the UW pilot program, we want to look at where we have been, where we currently are, and what our future needs may be relative to cranberry IPM.

Our panelists today well understand the history and current status of Wisconsin cranberry IPM. They have also been asked to look into the future and suggest areas where improvement may be made, or where new techologies may be helpful. Our panelists are

- Lou Ann Bever, Cattail Marsh Consulting
- Jayne Sojka, Lady Bug IPM
- Jonathan Smith, Northland Cranberries, Inc.
- Leroy Kummer, Ocean Spray Cranberries, Inc.

Cranberry Integrated Pest Management in Wisconsin: Past, Present, and Future. A Panel Discussion.

A Few Thoughts on IPM Past, Present, and Future

Lou Ann Bever
Cattail Marsh Consulting

A consultant's role in agriculture is to serve as a liaison between the grower and the researcher. By spending time with both groups, consultants have firsthand knowledge of the needs of both parties. After doing IPM for 6 years in potatoes, alfalfa, corn, etc. it was immediately apparent to me that there was a lack of basic research in cranberries. This lack of knowledge created some major challenges for me as a consultant. Some of this changed, 12 years ago, thanks to Rose Kachadorian. Rose was the first person to set up IPM for cranberries. She did basic research on our major pest at the time, the blackheaded fireworm. She also established the first threshold levels for this pest.

Prior to this basic research it was not uncommon to observe large "hot spots" or areas of damage on marshes. Managing the insect pests was a matter of playing defense in an attempt to minimize the damage to the crop. Our defenses at the time were mostly chemical with parathion being the major player. Parathion was inexpensive and under certain conditions very effective.

At the present time we feel the pressure of big business, which is reluctant to meet the needs of minor crops. We have lost many of our chemical defenses. However, the defense which remains is a good one and it is no longer just chemically based. With continued research to understand the activities of our major insect, disease and cultural pests we have increased our level of knowledge which we need to plan our strategies. We are working with new varieties. We have access to new and improved equipment. We have an active research program.

The future is always uncertain. The only certainty seems to be that we will always be dealing with pests. They will not be eradicated. We have laid the foundation for improvements; however, not all of our dreams will come true. We must always be alert for new problems. We need to encourage new people to join in the game. As pests present themselves we will have to work with what we have!

Cranberry Integrated Pest Management in Wisconsin: Past, Present, and Future. A Panel Discussion.

INSECTS, WEEDS, AND DISEASES IN THE CRANBERRY INDUSTRY

Jayne I Sojka
Lady Bug IPM

Pests are not new to our industry. The challenges of weeds, insects and diseases plagued us for longer than one realizes.

In searching the archives I was pleasantly surprised to see what was written about the pests that the early growers faced. Here are some recollections of Dr. George L. Peltier concerning the Wisconsin Cranberry Station, 1903-1917. He states that 5 acres were rented from the Cranberry Growers Association, and responsibility for research at the station was assigned to the Department of Ag Physics, Department of Horticulture. He shares that in 1893 to 1902 only $250 a year was made available for research. On May 10, 1903 by a Legislative Act an appropriation of $2500.00 per year for 2 years was allocated for the enlargement and improvement of the cranberry industry in our state. These monies were used to investigate shortages and sources of water, suitability of marshes, the best methods of planting, flooding, draining, and combating diseases.

Understand that the first variety plots were planted by Andrew Searles in 1893.

From Annual Reports of the Experiment Station I found that as early as 1906 and 1906 there were summaries of cranberry insects by USDA Bureau of Entomology by Hardenberg and Malde.

Dr. Peltier continues to share that in 1909 false blossom was widespread tending toward epidemic proportions. Yet it wasn't until 1929 that Dr. Kunkel found that "False Blossom" was due to a virus transmitted from plant to plant by the bluntnosed leafhopper.

In the early 1920's the only method of weed control was hand pulling. Most grasses were mowed with a scythe. There wasn't any herbicide.

Even though the Experiment Station was in existence 14 short years very informative data were gathered.

In an article dated February 1929, Department of Agriculture bulletin, Henry Bain shared that it was customary to classify cranberry insects into what they fed upon; for example: foliage, bud, fruit, stem and root attacking forms. Now, tell me if any of these insects are familiar to you: cranberry tipworm, chain-spotted geometer or spanworm, blackheaded fireworm, and cranberry fruitworm. In 1929 the state's most difficult insect pest was the cranberry fruitworm. Henry Bain stated, there was no known control with the exception of a belief that water-handling methods gave partial control.

Henry J. Franklin wrote articles in the Agricultural Experiment Station bulletin concerning cranberry insects dated in 1948. Treatment for pests were flooding, dusting with clear pyrethrum dust or 5% DDT dust to the acre. Some sprays that were recommended were 2 pounds of soap to 100 gallons of water to the acre. (Pyrethrum soap makes an excellent spray for the first brood, but it tends to stunt the small cranberries that are present when the second brood of pests appear. Franklin shared.)

In the early 50's documentation was made of the life cycles of known insect pests. Types of injuries were noted. Treatment was with water. Some notes went as far as stating that when water was held into May, it was a sure control measure. Sand-weeds were pulled by hand or cut off before harvest. Nicotine sulfate sprays, fish-oil soaps, pyrethrum dusts, and other control measures were available in the 1940's and 1950's. The key words here are available and then affordable.

Finally by the mid-1950's applications of petroleum products such as paint thinner, kerosene, and solvents were used on weeds. Spot treatments were made during the growing season but a majority of the applications were made after dormancy. Nothing was noted in my readings on early emergence or timing for a specific weed.

In the 1960's and 70's our control measures changed. New chemicals were being developed and were more available to us. Herbicides, fungicides and insecticides were becoming more popular. Crop dusters could cut down the hand labor of applications. More mechanized technology was on the horizon.

By 1986 a pilot IPM program was introduced to our industry by the University of Wisconsin-Madison (coordinated by Dan Mahr and Rose Kachadorian). This three year project served 7 Wisconsin growers. It was found that the economic benefits ranged from $73.00 to $246.00 savings per acre, in a given year. Plus by practicing IPM the 7 growers averaged one to two less insecticide applications per year and they maintained or increased yield.

The President of the U.S. has set a goal for all the nation's ag businesses to be practicing IPM to a 100% capacity by the year 2000. The cranberry industry can be proud, for by our calculations we feel that better than 85% of you are already on a formal scouting program or many of you assume IPM tasks of your own. We implement biological methods of control, cultural practices and chemical applications as well; intertwined if you will. Our philosophy is to time the control so that we can reduce the use of chemicals out there and yet get good control without economic loss. Phermone trapping, sweeping, making observations, searching for answers, and raising questions are all integral parts of IPM.

We know that economically it is vital to practice IPM. If we relied solely on chemicals where would we be? Over the past few years we have lost registrations for chemicals that we depended upon (parathion) and I might add had positive results with. Current studies indicated that without insecticides, yields could be reduced 15 to 50% in the first year, and in subsequent years pest pressure would be higher and losses even more severe. (Imagine a bed in the middle of your marsh that has become HOT with BHFW and you had nothing to combat them with. Imagine this small breeding ground spreading its challenge throughout your entire property. What would happen to your crop? What about next year?) Same scenario holds true for disease. Picture cotton ball left unattended. What about upright die-back disease? For our fresh fruit growers, fungicides are needed. What would the keeping quality of our fruit look like in December if one had trouble with black rot, end rot, or yellow rot and did nothing to combat it?

I reiterate it is not wise to lean solely upon one means of control. We must be willing to try biological measures, along with cultural practices and chemicals.

Today we live in a society that puts stringent demands upon us. First they want the BEST quality ever, yet they do not want any artificial interference with that request. The consumer is a conscientious label reader crying, "Give me pure and natural products." As an industry we are proud to be a state that we have nothing to hide. IPM is a strong advocate for timing all pesticide applications closely so we do indeed reduce the applications in any given year. With CCM, growing degree days, models that predict insect hatch or early weed emergence we feel that we are on top of a potential problem before it appears.

For the past 14 years the Wisconsin Cranberry Board has funded over $1,000,000 in research projects. Many of these projects have enlightened us on the timing of herbicides, fungicides and insecticides. Your research moneys have been centered on the betterment of our industry. We are presently placing emphasis on biological controls, mating disruptions, plant breeding for disease and insect resistance. We are trying to improve application methods, understand bud sensitivity and dormancy. I feel that many of these projects are complimentary to Integrated Pest Management. Proving once again our philosophy that integrated means many parts of a whole. It means using cultural practices like flooding, sanding, hand weeding, along with biological control measures, nematodes, Bt products, mating disruptions, and using chemicals. Our goal has been and still is to provide the consumer with a healthy product that we are indeed proud of in this Crimson Cranberry Country.

We have come a long way since the early 1900's, and yet the journey has just begun.

Cranberry Integrated Pest Management in Wisconsin: Past, Present, and Future. A Panel Discussion.

BEYOND 2000: WHAT WILL PEST CONTROL AND IPM BE LIKE IN THE NEXT CENTURY?

Dr. Jonathan D. Smith
Northland Cranberries, Inc.

Since the major pesticide re-registration in 1988, the cranberry industry has lost a significant number of valuable pesticides due to health and environmental concerns or the cost of re-registration. Pesticides are still a necessity for effective pest control and will continue to play a vital role in our future. However, given the current trends in chemical production, minor use crops such as cranberry should expect to have fewer chemicals available for pest control in the future. In response to this sobering expectation, it is necessary that we as an industry attempt to embrace all available technology for controlling cranberry pests. When we speak of pests in cranberry, it encompasses every weed, disease, and insect which impacts cranberry production. My talk will focus on new technology and products we may employ in the future for pest control.

Pest Control for the 21st Century

Development of safer pesticides

Synthetic pesticides will continue to be an integral part of our pest control arsenal. In today's market, manufacturers will not register a new pesticide unless it is registered on at least one major crop like cotton, corn, wheat, or soybeans. For additional registration on a minor crop like cranberry, the pesticide will also have to be extremely safe to the aquatic and wetland environments. The safer pesticides will need to be effective in very small quantities and control specific insect pests, minimizing the impact on beneficial insects. The search for new pesticides will need to continue as our current pesticides are lost from registration.

Biological Control Measures

In conjunction with the development of safer synthetic pesticides, the evolution of sophisticated biological control measures will need to be developed in the next century. Little is known about the biological control of pests, and significant work will be necessary to implement effective biological control measures into cranberry production.

Insect Mating Disruption with Pheromones

Pheromones are used extensively to monitor pest populations. These pheromones mimic sex pheromones which naturally attract males to the female. The use of pheromones for mating disruption is the next potential big step in insect control. In theory, flooding the crop with pheromones reduces the ability for males to find the theory, flooding the crop with pheromones reduces the ability for males to find the female moths. This avenue of pest population management will be the quickest for implementation after prices and delivery systems are optimized for production use. It is probably the other pheromones controlled system will be developed as more is learned about the cranberry insects.

Introduction of Natural Enemies. Every insect pest which has evolved for long periods of time in one area has a host of natural enemies. The use of nematodes for cranberry girder control is one example of this successful implementation.

Introduction of natural enemies provides a significant area for development in all the crop markets, and especially those highly managed farms like cranberry properties. In North America there are 132 supplies which sell 129 different beneficial organisms, mostly for controlling pests in high value crops and orchids (John Brewer USDA-ARS). It is important to note that the research and development of natural enemies for a particular insect will be costly and require time to understand the basic biology of both predator and the pest. However, this is one area of great opportunity for the cranberry industry throughout the next century.

Development of Botanical Insecticides. Botanical insecticides have been around for many years but are only experimented with by a small niche of organic growers. These include basic garlic repellents, chrysanthemum extracts, etc. It is possible that we could see a resurgence of research in this area to develop more reliable botanical insecticides which are safe and natural.

Inserting Genes into Cranberries for Herbicide and Insecticide Tolerance. Gene insertion will lead the research efforts of all crops through the 21st century. As an industry, we are fortunate that Dr. McCown has already initiated this research work on cranberries at the University of Wisconsin. His research in this area will lay the groundwork for future gene in section research into cranberries. The benefits of gene insertion for herbicide tolerance is now evident on a number of crops, and we should expect to pursue this research effort through the next century.

Development of Bio-control Agents for weed control. The first bio-control agent for cranberry weed control is currently in development at the UW-Madison by Dr. Hopen. Within a few years, we could see dodder successfully controlled with a fungal organism. There is also plenty of opportunity for other bio-control agents in weed control of cranberries. Beneficial insects which selectively feed on the weeds and not cranberries could be developed in this next century.

Classical Breeding for Disease Resistance. The ground work for this future development is being initiated by Dr. Vorsa at Rutgers University. His current breeding efforts have generated thousands of new cultivars with varying degrees of disease resistance. These new cutlivars will probably be available in the next century for areas with high disease pressure.

Systematic Activated Resistance. A novel new idea for disease control called systematic activated resistance has been proposed for development in the future. The procedure uses the plant's own natural defense mechanism against the pathogens. For example, when a disease organism attacks leaf tissue, the plant's defense mechanisms are activated to isolate the disease and slow or eliminate its spread throughout the plant. New chemicals may soon be available which can be applied to the plant prior to a known disease pressure. This chemical would boost the plant's natural defenses which could ward off the disease as soon as the plant is attacked. In a typical system, the plant's defenses are not activated until after the disease attacks the plant. This has been investigated and developed in cucumbers and tobacco, and research in cranberries should be addressed in the future.

Advancement For the IPM Program

Integration of Total Quality Management into the IPM Program

The next advancement in IPM is to combine our cultural management practices with pest management to ultimately minimize pest problems. The name for this program is called Total Quality Management (TQM). The basic premise of TQM is that our cultural management practices have a direct effect on pest populations. This includes cultural practices such as proper nutrition, water management and drainage, cultivar and site selection, frost protection and winter protection, as well as many others. We know that stressed plants are more susceptible to pest infestation and that healthy plants can tolerate or resist pest pressures. For example, a cultural practice which greatly affects pest populations is drainage. An area with poor drainage will have poorer yields, less vine coverage, more weed pressure, as well as a higher incidence of disease and insect outbreaks. Improving the drainage problem will minimize vine stress and create a healthier plant with greater yields and less pest problems.

Advancements in Application Equipment

The widespread utilization of the spray boom system in the mid 1980's has significantly increased pest control and minimized the number of applications. However, one setback with respect to pest management is that the entire beds or property is usually sprayed when an isolated outbreak occurs, even though the pest population on most of the bed is below threshold. I feel that our next advancement will be equipment which can selectively apply chemicals or bio-control agents only where needed. Several prototypes of spraying equipment have already been developed which can selectively apply herbicides only to the weeds. A camera system linked to a computer detects the differences between weeds and crops. Depending on the type of weed the computer sees, a specific chemical can be applied only to the affected area. Camera systems are also being developed to detect pest activity, or even plant stress. In all these cases, the new technology will allow us to micro-manage our crop, applying only what is necessary to achieve optimum productivity.

What needs to be accomplished?

A significant amount of basic research will be necessary to bring this technology to the cranberry growers in the next century. Some of this research may be developed in private laboratories, but most will be initiated at the university level. A significant amount of money and time will need to be invested into understanding the basic biology and ecology of both natural predators and pest populations. In the cranberry industry, we have just begun to understand the current pests which attack our crop. Once the basic research is established, the development and implementation of successful bio-control programs will be realized. All moneys invested today in this basic research will pay off with great rewards as our requirements for growing cranberries changes in the 21st century.

Cranberry Integrated Pest Management in Wisconsin: Past, Present, and Future. A Panel Discussion.

IPM – Where has it been, and where is it headed?

Leroy Kummer
Ocean Spray Cranberries Inc.

Integrated Pest Management (IPM) can best be described as the incorporation of a variety of biological, chemical and cultural control methods to minimize insect, disease and weed pest roles on crop production. It is an effort to maximize the grower's profits by minimizing their monetary inputs. This is also the raising of an agricultural crop in an environmentally safe manner.

Cranberry IPM has progressed dramatically during the past decade. Grower knowledge of cranberry pests and management strategies has continuously evolved. Growers no longer prescribe to calendar sprays; they now spray when they can get the most economic benefit. The days of old broad spectrum had hitting pesticides have been replaced by more pest specific control options; bacteria (Bt), nematodes, fungi and insect growth regulators. Plant varietal improvements and producing pest resistant plants and better producing plants. New IPM practices into the year 2000 will also include: disruptive mating techniques, biological and cultural control, more target pest specific controls and crop modeling. IPM will soon be replaced by TCM (Total Crop Management Practices), understanding the whole system and how one management practice may influence another or the system as a whole. Nutrient inputs and crop outputs will be evaluated all in an effort to maximize grower's profit.

TECHNICAL APPROACHES TO MATING DISRUPTION OF BLACKHEADED FIREWORM

Sheila Fitzpatrick
Pacific Agri-Food Research Centre
Agriculture & Agri-Food Canada
6947 # 7 Hwy, P.O. Box 1000, Agassiz
British Columbia, Canada VOM 1AO

Introduction

In my previous discussion, "Mating Disruption: What is it and How does it Work?", I told you about pheromone-based mate location behavior in moths, and how mating disruption interferes with this behavior. I briefly described the formulations of synthetic pheromone used for mating disruption of blackheaded fireworm and explained how tests of mating disruption are evaluated. Finally, I showed results of mating disruption tests done in Wisconsin in 1996.

Here I will explain in more detail the technical aspects of taking mating disruption technology from the research trial to the farm. I will first discuss the properties of the MEC (MicroEnCapsulated) formulation of pheromone, then describe the steps involved in registering MEC. I will go step-by-step through the process of using MEC to disrupt mating of blackheaded fireworm moths in cranberries. Finally, I will discuss ways in which mating disruption might be enhanced with other pheromone-release technologies (e.g., MSTRS) or augmented with biological control agents.

The MEC (MicroEnCapsulated) Formulation of Fireworm Pheromone

The MEC formulation of fireworm pheromone is a water-based suspension of the main pheromone component, Z 11-14:Ac, encapsulated in microscopic, polyurea-based shells. The formulation contains 8-20% water and 20% Z 11-14:Ac by weight. The polyurea-based shells, which are 25-35 microns in diameter, are somewhat adhesive and protect their contents to some degree from the sun's ultraviolet radiation. There is no sticker or ultraviolet protectant in the formulation. In the field, the polyurea-based shells degrade slowly by hydrolization, oxidation and biological degradation.

The process of formulating MEC by encapsulating Z 11-14:Ac into polyurea-based shells is done by chemists at 3M Canada. The chemists are willing to try to improve the field performance of MEC if necessary by changing the shell size and thickness of the wall to slow the release of pheromone, or by adding stickers (latex-based adhesives) to the formulation. The polyurea-based shells are also being used to encapsulate pheromones of other moth pests of forests, grapes and cranberries (Sparganothis), and 3M is working closely with various scientists on field tests of these materials.

The MEC formulation can be applied by helicopter, fixed-wing aircraft, sprayer or through the sprinkler system.

<u>MEC: From Research Material to Registered Product</u>

The MEC formulation of pheromone belongs to the category of "straight-chain lepidopteran pheromones" established by the Environmental Protection Agency (EPA). As such, MEC can be used in research trials on up to 250 acres per year, so long as the total amount of active pheromone ingredient does not exceed 150 grams per acre per year. Cranberries produced in MEC-treated research plots can be marketed normally and need not be destroyed.

Registration of straight-chain lepidopteran pheromones such as MEC is supposed to be a more streamlined process than registration of other materials. Toxicity data in EPA files and in the public domain demonstrate that alcohols, acetates and aldehydes with a chain length of 11-18 carbon atoms have very low acute oral, acute dermal and acute inhalation toxicities, as well as ecotoxicites. The toxicities of these straight-chain lepidopteran pheromones are lower than the testing limits of the EPA. Therefore, minimal or no toxicology data are required for registration, making the registration process is less much costly than it would otherwise be to the registrant. Efficacy data are not required, although the registrant is required to have such data on file. Some research scientists believe that the lack of requirement for efficacy data creates a "buyer-beware" situation. However, if buyers are aware of the history of research and development of the pheromone product, there should be no surprises when the product is used in the field. Cranberry growers are a shining example of well-informed buyers.

At least two registrations must be obtained for MEC in the United States: one for the technical active ingredient (Z 11-14:Ac), and one for the end-use product (MEC). Three companies are involved: Bedoukian, which produces Z 11-14:Ac; 3M Canada, which formulates the pheromone; and Ecogen, which markets the end product.

The cost of MEC to the grower has not yet been established. In my discussions with the companies involved, I have frequently heard that the pheromone is expensive but the microencapsulation technology is not. The companies realize that MEC needs to be cost-effective compared with other management options, or they won't sell any. MEC will be marketed by Ecogen under the registered tradename "NoMate BHF MEC".

<u>Technical Aspects and Management Protocol for Using MEC as a Mating Disruptant</u>

At the time of this writing, MEC is still a research material. It may be registered for commercial use by the summer of 1997. Here I will describe the technical aspects and management protocol involved in using MEC in research trials, with a view to commercial use.

<u>Considerations Prior to MEC Treatment.</u> For research trials, and for commercial use in future, the farm to be treated with MEC should be isolated. If there are adjoining farms, they should also be treated with a mating disruptant, so that area-wide management is achieved. The farm(s) to be treated should have low to moderate populations of fireworms. To determine whether populations are low to moderate, a monitoring program should be used. Pheromone trap data from the previous year, along with larval data from the current year, are used in determining if populations are low to moderate. For these reasons, it is important to keep good records from year to year. At present, we have "gut-feeling" or relative thresholds for deciding about population size. The farms with the highest trap counts and sweep samples are "high". Those that with no history of fireworm populations are "zero". Those in between, tending more toward the "zero" farms than the "high" farms, are low to moderate. If mating disruption is used on a farm with moderately high populations, insecticide applications will be needed along with MEC for two or three years, until populations are reduced.

The relative thresholds may seem unnecessarily fuzzy and imprecise. One reason that better thresholds have not yet been established is that different cranberry growing regions use different kinds of pheromone traps and larval monitoring methods. In British Columbia, where we use wing traps that can hold 300-400 males, our experience suggests that fields with 150 or fewer males per trap at peak catch have low to moderate fireworm populations. In Wisconsin and Washington, smaller delta-type traps are used and these hold at most about 200 males. Where the delta-type traps are used, low to moderate fireworm populations would probably be indicated by 100 or fewer males per trap at peak catch, but more experience is needed to support this threshold. In British Columbia, where we sample visually for fireworm larvae, experience suggests that an average of 1 larvae per 2 square feet of vines is a moderate population. In Wisconsin and Washington, where larvae are sampled with sweep nets, the threshold for a moderate population has yet to be determined. It is probably as important to know the location and number of "hot spots" (patches with many larvae) as to know whether populations are low to moderate.

Monitoring Program for Areas to be Treated with MEC. The monitoring program begins with sweep-samples or visual searches for larvae in April and May. The objective of sampling for larvae is to find out when they have hatched from eggs and where the hot spots are. The size and number of larvae found will guide the IPM manager or grower in deciding when and where to apply insecticide. The location of hot spots will indicate where extra attention is needed. (A computer mapping program called a Geographic Information System can help to map hot spots. We are developing such a program in British Columbia.) Where there are many larvae, there are likely to be many moths and, in these areas, synthetic pheromone likely will not prevent males from finding females. The hot spots are usually around field edges.

After the spring insecticide has been applied and any hot spots have been identified and treated, pheromone traps should be placed in fields. IPM managers already use pheromone traps for routine monitoring, and these should be placed as they normally would be. The lures in the delta-type pheromone traps contain 1 milligram of the three-component blend of fireworm pheromone. These "high" lures will accurately detect the beginning, peak and decline of both the first and second flights of fireworms, even after MEC treatment. The "high" lures are like super-females that males can detect even in an atmosphere of synthetic pheromone.

When the first males are caught in "high" pheromone traps, marking the beginning of the first flight, MEC should be applied. In research trials, the rate we use is 180 milliliters of MEC containing 36 grams of Z 11-14:Ac per acre. Following MEC application, "low" pheromone traps should be placed in the fields. The "low" lures contain 0.01 milligrams of the three-component blend of fireworm pheromone. The "low" lures are like regular females that males should not be able to detect in an atmosphere of synthetic pheromone. For this reason, the "low" traps are sentinel traps. In future large-scale research trials, or when MEC is used commercially, I will probably recommend that some "low" traps be placed near known hot spots, and others away from hot spots. They should be at least 50 feet from "high" traps. I believe it is better to have the "low" and "high" traps in separate, but adjoining, fields. The specific guidelines for the number and placement of "low" and "high" traps have yet to be determined, but will be worked out in next year's trials.

The "low" traps tell us if mating disruption is working. In research trials, we compare catches in "low" traps placed in MEC-treated fields with catches in "low" traps placed in control fields. If mating disruption is working, the catches in MEC-treated fields will be zero or very low compared to catches in control fields. In future commercial use of MEC, where there will be no control fields, the numbers of males caught in "low" traps will be considered in relation to the numbers caught in "high" traps. When few or no males are caught in "low" traps and many males are caught in "high" traps, it is likely that males are flying but unable to find females. About four weeks after MEC application, the number of males in "low" traps may increase and there may still be males coming to the "high" traps. This will be an indication that males are still flying but the MEC is wearing off. At this point, the IPM manager or grower will need to decide whether to reapply MEC and cover the remaining part of the first flight, or wait and reapply at the beginning of the second flight. Based on knowledge and experience gained so far, I lean towards recommending that the first flight should be entirely covered, even if it means leaving the latter part of the second flight unprotected. As I stated in the previous paper, it may be necessary for the pheromone companies to lengthen the active life of MEC or to lower the price so that three applications can be made when necessary.

After peak catch in the "high" pheromone traps, sweep-samples or visual samples should be taken to assess the numbers of summer (second-generation) larvae present. If the IPM manager or grower decides that a post-bloom application of insecticide is warranted, it should be applied (in research trials or in future commercial use). Monitoring for larvae later in the summer, after the second peak catch in "high" pheromone traps, is not necessary unless larval populations earlier in the year have been extremely high. Females of the second flight lay mostly diapause eggs, which overwinter and hatch the following spring. If larval populations earlier in the year have been very high, there may be enough second-flight females laying enough non-diapause eggs to result in hot spots of larvae late in the season. However, if an insecticide application is being considered in late summer, one must pay close attention to the pre-harvest interval on insecticide labels.

In research trials or in future commercial use of MEC, the following three-year program should be adhered to, if possible. In the first year, monitoring and insecticide application should continue as normal, and MEC applied as suggested above. In the second year, monitoring should be done in spring and, if necessary, insecticide should be applied to control spring (first-generation) larvae. MEC should be applied, and monitoring continued as usual. Careful monitoring of summer (second-generation) larvae will determine if populations have been sufficiently reduced by mating disruption. By the second year of the mating disruption program, if populations of fireworms were low in the first year, it should not be necessary to apply insecticide to control summer (second-generation) larvae. In the third year of the program, monitoring will determine if a spring insecticide is necessary. MEC should be applied as suggested above and, by the third year, fireworm populations should be low and a summer application should not be required.

Mating disruption using MEC will reduce the need for insecticides, especially summer applications, to control blackheaded fireworm larvae. We don't yet know if the need for insecticides will be totally eliminated.

Enhancing Mating Disruption and Future Use of Biological Control Agents. In my previous paper, I said that upwind edges of fields may require extra treatment, because the wind tends to blow MEC into the centre of the field and leave pheromone-free air at the upwind edge. Similarly, helicopter-applied insecticide or MEC may not reach edges or portions of fields near marshes, houses or powerlines. In these situations, it may be helpful to use MSTRS, the Metered Semiochemical Timed Release Systems, to apply disruptant pheromone to the missed or upwind edges. For further consideration, I refer you to the discussion of MSTRS by Baker and Mafra-Neto. Other agricultural systems have similar problems. In cotton, before the plants are fully leafed out, the air circulation through the crop is good and twist-tie ropes are applied to promote mating disruption of pink bollworm. Later in the season, when plants have all their leaves and air circulation is minimal, a MEC formulation is used. For mating disruption of codling moth in Europe, orchard borders are protected by applying a double rate of controlled-release devices.

In British Columbia, Dr. Henderson of E.S. Cropconsult is studying the use of a native strain of the tiny egg parasitoid, *Trichogramma*, against fireworm eggs in late summer. This tiny wasp diapauses inside overwintering eggs. It emerges the following summer to reproduce and deposit its tiny eggs inside diapause eggs laid by fireworm females of the second flight. *Trichogramma* will likely be a valuable complement to mating disruption, and should reduce the need for insecticides even further.

Concluding Remarks

We are making steady, straightforward progress toward the use of mating disruption and fewer applications of insecticide to control the blackheaded fireworm of cranberries. The microencapsulated, sprayable formulation of fireworm pheromone is easy to apply, and may be improved if necessary by modifying the size of the microcapsules or the thickness of their polyurea-based walls. Registration of the MEC formulation of pheromone is not far off. MEC will be best introduced to on-farm use through a three-year program, in which MEC is used in addition to insecticides the first year, then in place of the summer insecticide treatments in the following two years. A thorough management protocol, involving monitoring of larvae and pheromone trapping of moths, is the cornerstone of this program. Accurate, up-to-date information about the numbers and locations of fireworms will show where mating disruption is effective and when insecticides need to be applied.

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Much of the information in this discussion was drawn from the following sources.

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FIRST ATTEMPTS AT DISRUPTING SEX PHEROMONE COMMUNICATION IN THE BLACKHEADED FIREWORM IN WISCONSIN USING A NOVEL CONTROLLED-RELEASE DEVICE

Thomas C. Baker, Agenor Mafra-Neto[1], Timothy Dittl[2]
Department of Entomology, Iowa State University, Ames, Iowa
[1]Current Address: Dept. of Entomology, University of California, Riverside, CA
[2]Ocean Spray Cranberries, Inc., P.O. Box 155, Babcock, Wisconsin

Abstract

The results of experiments using a novel, controlled release system, called the Metered Semiochemical Timed Release System, or MSTRS™, for disrupting mating or pheromone source location by males of the blackheaded fireworm are described. In this system, pheromone is emitted at rates ca. 20 times higher than existing dispensers. Fewer dispensers are therefore needed for effective disruption and they can easily be deployed in and around cranberry beds and retrieved at the end of the season for re-use in subsequent seasons. Unlike existing systems, MSTRS allows the user not only to choose how frequently pheromone is discharged but also to regulate the diel periodicity of this emission to correspond to the time of activity of the adults of the targeted pest insect. In addition, the pheromone is protected from oxidation and UV degradation since it is housed in pressurized canisters.

Introduction

There has been much progress over the past ten years or so in improving the release-rate characteristics of some of the most commercially successful pheromone mating disruption formulations. However, none of the existing controlled-release technologies allow the user to actively alter the release rate. The existing systems are all passive systems that emit pheromone continuously according to ambient wind and temperature conditions.

We recently described a new system, called Metered Semiochemical Timed Release Systems, or MSTRS™ (Mafra-Neto and Baker, 1996a), in which an aerosol canister containing pheromone is placed in a machine and an aerosol spray-burst is emitted onto a large pad on a timed basis (e.g., every 15 minutes). Pheromone is then emitted from the pad at extremely high rates, ca. 20 times higher than most existing dispensers. Fewer dispensers are therefore needed for effective disruption. Unlike existing systems, ours allows the user not only to choose how frequently pheromone is discharged but also to regulate the diel periodicity of this emission to correspond to the time of activity of the adults of the targeted pest insect. Pheromone is not wasted by being passively emitted from the reservoir during periods of the day when the insects are inactive. In addition, the pheromone is protected from oxidation and UV degradation since it is housed in pressurized canisters.

Significant work on disrupting mating of this serious pest of cranberries has been undertaken by Fitzpatrick et al. (1995), and has shown much promise for this technique, using Shin-Etsu ropes or Ecogen Spirals (Scentry/Ecogen, Billings, Montana) with a total application rate of ca. 70 gm pheromone/acre. One problem with these dispensers, however, is that they must be retrieved at the end of the season due to the potential for the buildup of environmentally unacceptable levels of plastic in the cranberry marshes.

The placement and retrieval of a high number of point sources on the cranberry beds would also result in unacceptably high foot traffic, which would damage the delicate, slow-growing plants. The use of MSTRS devices would be advantageous because only a few dispensers would be necessary per acre, mostly deployed around the perimeter of the beds where they could be fairly easily retrieved without incurring crop damage. Furthermore, the MSTRS can be stored for re-use in subsequent years.

Materials and Methods

We used MSTRS devices and affixed them to wooden stakes at a height of 20cm above the cranberry plant canopy. The canisters contained either 8 or 20 gm of *R. naevana* pheromone, which is a blend of (*Z*)-11-tetradecenyl acetate, (*Z*)-11-tetradecenyl alcohol, and (*Z*)-9-dodecenyl acetate in a ratio of 9:3:1 (McDonough et al., 1987; Slessor et al., 1987). These components were purchased from Bedoukian Research, Inc., diluted in reagent alcohol to a weight of 40 gms solution, and formulated with propellant in the cans for a total weight of 160gms inside each can.

Devices containing the 8gm of pheromone in the cans were deployed at a density of 5/acre along and within cranberry beds or series of beds that averaged ca. 3 acres in total area. Two configurations were used for this density of devices, one being a perimeter-only treatment with MSTRS spaced ca. every 100 ft. at the edges of the beds. The second consisted of the same density of devices and amount of pheromone per acre overall, but three devices were removed from the perimeter (remaining devices being more widely, but evenly spaced) and instead were deployed across the centers of the beds, bisecting them longitudinally. The cans containing 20 gms of pheromone were deployed at a density of 2/acre along the same sized beds, such that there were only 9 machines around the perimeter of the 3-acre beds.

Treatments as well as 3-acre control plots several hundred meters from the treated beds were replicated 3 times in different grower locations within ca. 30 miles of each other in the cranberry growing region near Babcock, Wisconsin. During the first flight of moths, the machines were programmed to discharge every 15 minutes, 24 hours per day. During the second flight, they were programmed to discharge in the night-only mode, in which a light-sensor triggers them to begin discharging every 15 minutes only around sunset, and they continue to do so until triggered to stop by the meter around sunrise.

Disruption was assessed by counting the number of males captured in wing traps baited with 10 μg of the above pheromone blend on a rubber septum, a lure that has been shown to be comparable in attractancy to females (Fitzpatrick et al., 1995). The wing traps were placed, 3 per 3-acre plot, at locations in the interior of the marsh, and not closer than 100 ft. from the nearest machine. The number of males captured was assessed weekly, the males removed, and trap bottoms replaced as needed.

Results and Discussion

During the first flight, disruption averaged 99% in the first grower location, and 95% in the second grower location (Figs. 1A,B) regardless of the MSTRS deployment pattern. However, disruption averaged only 82%, 80%, and 57% for the 5/acre cross pattern, the 2/acre perimeter pattern, and the 5/acre perimeter pattern, respectively, in the third grower site (Fig. 1C), which had a history of very high populations of fireworm and low yields compared to the industry average in the region. During the first flight, captures in the control plots at the three sites averaged 52.3, 73.4, and 63.3 males per trap per week over the six-week flight period. Unlike the treated beds in the first two grower locations, the 3 acres comprising the treated areas for each of the three MSTRS deployment arrays in the poor-disruption location (Fig. 1C) were comprised of six, 0.5-acre beds each separated grass-covered dikes. Thus, it is possible that the aerial transport of pheromone plumes from the MSTRS over the disruption areas could have been disturbed in these plots, resulting in lower efficacy of disruption. In all three locations, the MSTRS devices were deployed at the same time as a sprayable formulation of pheromone (microencapsulated, called MEC; Scentry/Ecogen) was applied directly to the cranberry beds; the MSTRS were as effective in disrupting pheromone source location as the sprayable formulation in all plots (Sheila Fitzpatrick, personal communication).

During the first flight, sweep samples were taken in most plots to assess larval infestation levels. These samples included our check plots used for trap counts in the beds not treated with disruptant shown in Fig. 1, and in some cases in addition included other beds in the same location that were not used for any pheromone trapping whatsoever. These we have called "normal practice" plots. As can be seen in Table 1, for the first, second, and third grower locations the larval infestation rates were not significantly lower in the MSTRS-treated plots than in the check plots. The check plot sweep samples were at or near zero in most cases, and so it would be difficult to reveal an effect of the disruptant on larval density in this experimental setup.

However, it is clear that our data reveal no reduction in the population density of the next generation of larvae, and therefore no reduction in mating or egg-laying significant enough to control this insect in these plots. This may be because the moths appear to be highly aggregated in the beds, and the appropriate measure of disruption would be to assess the ability of the disruptant to prevent mate-finding within these aggregations, which is the distance that males must naturally move while following a female's pheromone plume. If the adult moths are in fact highly aggregated like this, then it is highly unlikely that we would fortuitously place our three monitoring traps in each bed in the centers of such aggregations. Therefore, even in the check plots we are measuring the traps' ability to lure males out of their aggregations, and hence in the MSTRS disruption plots (and MEC plots or any other disruptant formulation) we are only measuring the ability of the pheromone disruptant to reduce the attraction of males out of the aggregations, not the ability of males to locate pheromone sources (such as females) within an aggregation. This situation would need to be addressed in future experiments by attempting to place monitoring traps appropriately, and of course, by using the most stringent measure of successful disruption, reduction of mating, by freely flying females as assessed by examining captured females for the presence of spermatophores injected into females by males.

During the second flight, in which the night-only emission of pheromone was tried, disruption was not as good as during the first flight in most plots, but still averaged 86.7% in the first location overall for all MSTRS configurations (Fig. 1A), 85.4% in the second location (Fig. 1B), and 53.8% in the third, poorest disruption location (Fig. 1C). Our measurements of the emission rates from the pads during the daytime when they are not being recharged shows that after 14 days of night-only emission, the pads from the MSTRS containing cans with 8 gms of pheromone release Z11-14:Ac at 8 μg/minute during the first three hours of daylight, and then by nightfall this rate diminishes to 2.5 μg/minute. It is not clear exactly when during the day (or night) that *R. naevana* mate, but it is possible that the night-only discharge and slow diminution of emission rate from the pads during the day may be sub-optimal compared to 24-hr discharge as during the first flight. On the other hand, population levels may have been somewhat higher during the second flight and caused a poorer percentage disruption of male attraction to traps. The higher adult population levels might not be reflected in the check plot capture levels if the traps themselves are at or near saturation when accumulation of scales from 100-150 males would prevent efficient capture of further males entering the traps.

On the other hand our results are encouraging in this first attempt at using MSTRS on this species, in that they show that a relatively few MSTRS per acre can effectively disrupt pheromone source location by *R. naevana* at levels of 98% disruption for an entire flight period on 3-acre cranberry beds. The machines proved to be highly durable, and examinations of the batteries and the ability of the machines to produce sprays during the entire season showed that greater than 98% of the machines and batteries were unimpaired and functioning perfectly all season long. This was encouraging since many of the beds were spray-irrigated and regularly drenched the machines and pads, and in addition, the usual summer thunderstorms with high winds occurred in the area.

It is likely that the geometry of deployment of such a low number of release devices is important, and it must be considered that the smaller the plot, the greater the edge area there is to protect relative to the interior area of crop. In principle, the MSTRS technology should work better over a very large, regularly shaped area where there will be fewer pheromone-plume-free holes along the edges. Also, dispersion of the pheromone plumes will probably be aided by deploying the devices on the grassy banks of the dikes rather than on the beds themselves, as was done this time.

Finally, it must be considered that the efficacy of widely-spaced dispensers such as these, whose plumes need to sweep for tens, and perhaps hundreds of meters horizontally over the crop canopy to both attract and habituate males sufficiently that they are prevented from mating, will likely be more dependent upon ambient meteorological conditions than will be numerous lower-emission-rate point sources spaced only meters apart throughout the crop. This vulnerability may be accentuated for species that mate during the daytime, when adiabatic lapse rates are highest, and unstable, rising air can carry plumes from disruptant dispensers up and away from the canopy.

Acknowledgments

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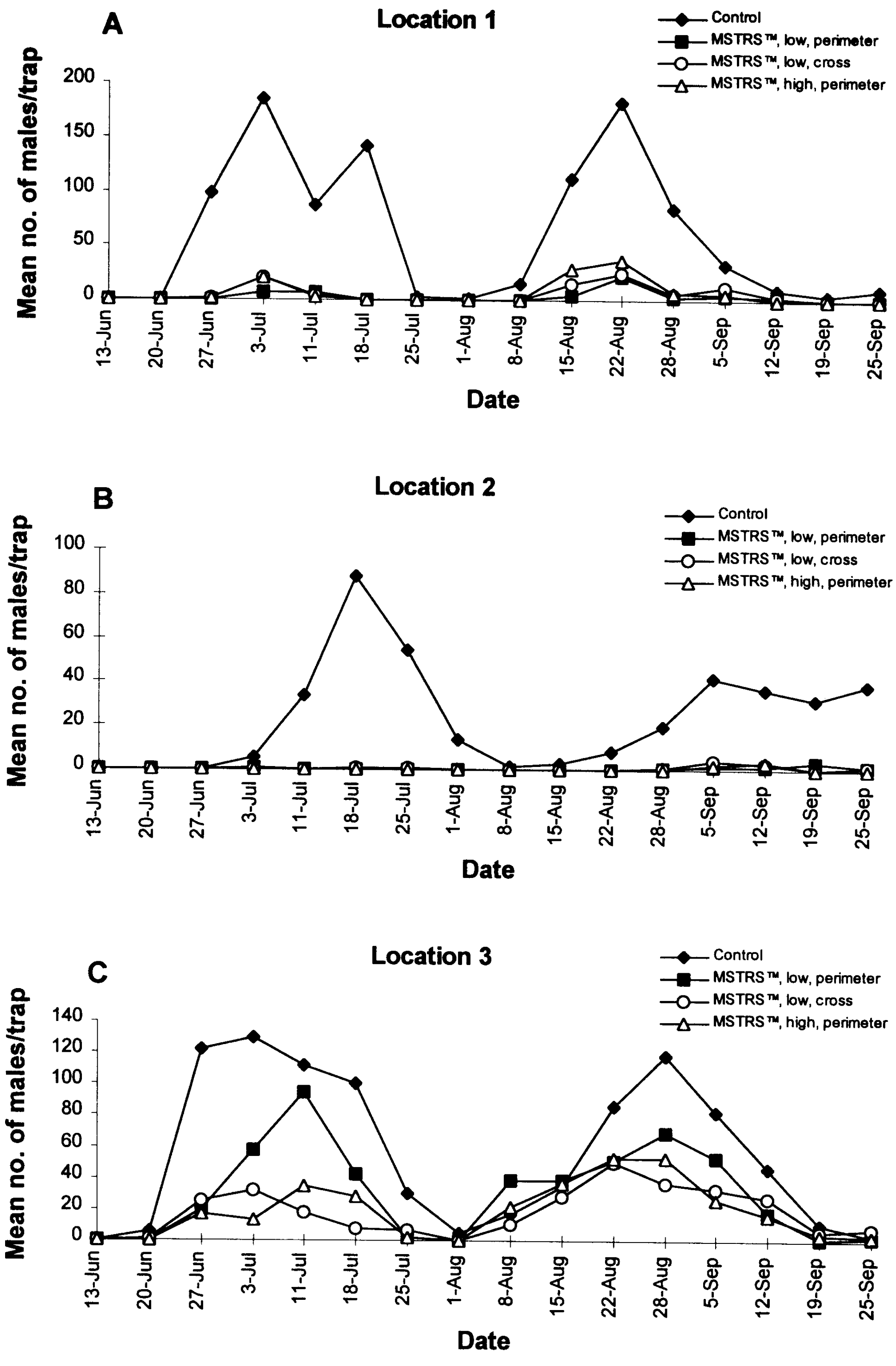

Figure 1. Mean capture of male blackhead fireworm in wing traps (n = 3) containing 10 μg of synthetic pheromone in 3-acre cranberry marshes at one of the three locations in Wisconsin in which either 2 or 5 MSTRS^{TM} devices per acre were deployed. The devices were activated before the first flight began and continued to release pheromone throughout the flight (ending August 1-8) from either 20-gm cans (2/acre) or 8-gm cans (5/acre). During the second flight the MSTRS were programmed to release pheromone onto the pads only at night.

Table 1. Infestation rates of blackheaded fireworm as assessed by sweep samples taken from the same plots (locations 1, 2, and 3) as illustrated in Figure 1.

Location 1

Treatment	Date: 7/15-7/18	7/22-7/25	7/29-7/31	8/5
Control	0.9 ± 0.6	0.1 ± 0.4	0.0 ± 0.0	0.0 ± 0.0
MEC	3.0 ± 1.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
MSTRS™, Low, Perimeter	2.0 ± 0.8	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
MSTRS™, High, Perimeter	0.8 ± 0.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
MSTRS™, Low, Cross	1.0 ± 0.8	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Normal Practice	0.3 ± 0.6	1.7 ± 1.5	0.0 ± 0.0	0.0 ± 0.0

Location 2

Treatment	Date: 7/15-7/18	7/22-7/25	7/29-7/31	8/5
Control	0.0 ± 0.0	0.6 ± 0.7	0.0 ± 0.0	—
MEC	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	—
MSTRS™, Low, Perimeter	0.0 ± 0.0	0.3 ± 0.8	0.0 ± 0.0	—
MSTRS™, High, Perimeter	1.0 ± 1.7	4.0 ± 4.0	0.0 ± 0.0	—
MSTRS™, Low, Cross	0.0 ± 0.0	4.7 ± 3.8	0.0 ± 0.0	—
Normal Practice	0.0 ± 0.0	2.0 ± 1.4	0.0 ± 0.0	—

Location 3

Treatment	Date: 7/15-7/18	7/22-7/25	7/29-7/31	8/5
Control	5.3 ± 6.7	7.3 ± 6.8	0.0 ± 0.0	0.0 ± 0.0
MEC	1.5 ± 2.8	3.6 ± 5.2	0.5 ± 1.0	0.7 ± 0.8
MSTRS™, Low, Perimeter	5.5 ± 4.4	9.0 ± 8.4	2.0 ± 2.7	1.7 ± 1.7
MSTRS™, High, Perimeter	5.0 ± 4.2	7.5 ± 0.7	0.0 ± 0.0	0.0 ± 0.0
MSTRS™, Low, Cross	0.8 ± 1.0	2.5 ± 1.7	2.0 ± 2.7	2.5 ± 2.1
Normal Practice	—	—	—	—

Strategic Use of Fungicides for Cottonball Control

Patricia McManus
Department of Plant Pathology
University of Wisconsin-Madison

Cottonball disease, caused by the fungus *Monilinia oxycocci*, is an economically important disease in many Wisconsin cranberry marshes. Many aspects of the biology and ecology of cottonball are not understood, and consequently, reliable cultural and non-chemical means of control (e.g., resistant cultivars, biocontrols) have not been developed. Thus, control of cottonball has been, and continues to be, dependent on fungicides, particularly those in the sterol demethylation inhibitor (DMI) group. Fungicides are not the final word for cottonball control, however. More sustainable control methods are needed and are being investigated, but their implementation is many years away.

The availability and registration status of fungicides for cottonball control are currently in a state of flux. Federal registration and marketing of Funginex® (triforine) have been voluntarily canceled by Ciba-Geigy Corporation. However, growers may continue to use existing stocks of Funginex® under a 24(c) Special Local Needs label that expires July 25, 1999. Orbit® (propiconazole) had an emergency label (Section 18) during the 1996 growing season. A request for a Section 18 label for Orbit® in 1997 has been submitted to the EPA. The registration status for Orbit® will be reported in the WSCGA News and the CCM Newsletter as information becomes available.

For the moment, let's assume that we will have Orbit® and remaining stocks of Funginex® in 1997 for cottonball control. By combining what we know about cottonball and how the DMI fungicides (such as Funginex® and Orbit®) work, a rational control strategy can be developed. Understanding the disease cycle of cottonball (Figure 1) is critical in making decisions regarding when to spray. The idea is to identify "weak links" in the disease cycle where the pathogen is vulnerable to DMIs and points where the plant is receptive to uptake of DMIs.

Cottonball disease cycle

The cottonball fungus, *M. oxycocci*, overwinters in sclerotia which are the hard, mummified remains of previous seasons' infected fruit. In the spring, small mushroom-like structures called apothecia grow from some of the sclerotia. 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.

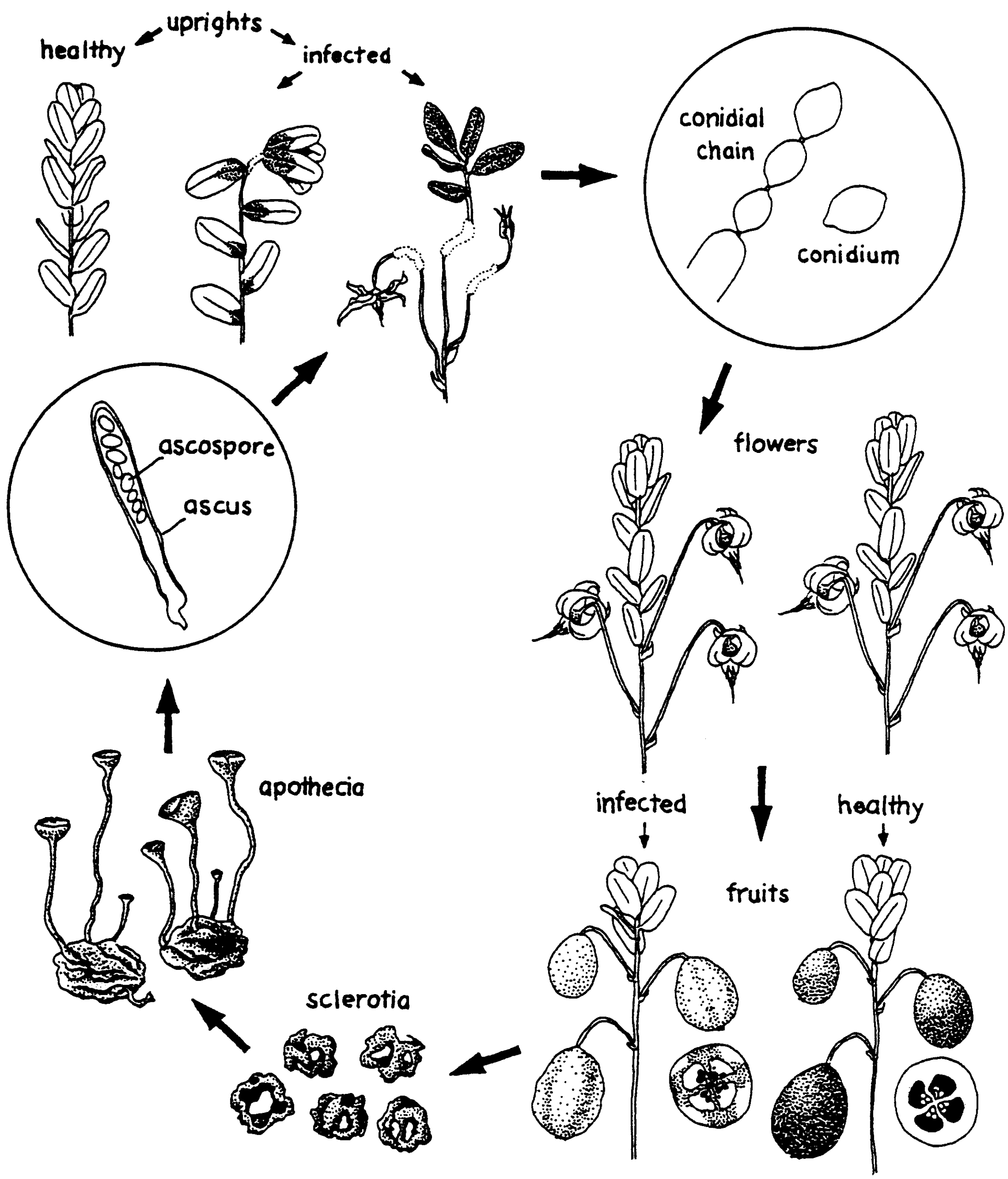

Figure 1. Cottonball disease cycle.

Just before bloom, the fungus produces spores (conidia) on infected floral and vegetative uprights. Conidia are carried to flowers by wind (the role of insects is unknown) and presumably infect by germinating on the stigma and growing down the style to the developing ovary, analogous 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, sclerotia develop in 25-50% of the infected fruit; berries that do not have sclerotia by harvest time decompose by the following spring.

How sterol demethylation inhibitor fungicides work

The DMI fungicides Funginex® and Orbit®, though chemically distinct, inhibit fungi in the same way. Both inhibit the formation of a sterol molecule that is an important component of the fungal cell membrane but is not present in plant cell membranes. Both fungicides are locally systemic; that is, they are taken up through the plant surface and are transported upwardly (acropetally) in the transpiration stream and to a limited extent in the downward direction (basipetally). While on the surface of the plant, the DMIs provide protection against fungal infection; that is, the fungus is not allowed to penetrate the plant. Because they are taken up by the plant and are locally systemic, the DMIs also have after-infection (post-infection, eradicant, kick-back) activity; that is, they stop the fungus *after* it has penetrated.

The degree of protection and after-infection activity conferred by the fungicide varies among the DMIs and has not been tested for cottonball or any disease on cranberry. Based on other plant-pathogen systems, however, Funginex® provides 1 day of protection and 3 days of after-infection activity; Orbit® provides 4 to 5 days of protection and 2 days of after-infection activity (Figure 2). The Funginex® label and the proposed Section 18 label for Orbit® suggest making applications at 10- to 14-day intervals. Based on our knowledge from other diseases controlled by DMIs, 10 days is probably better than 14 days—the gap in which plant tissue is unprotected should be minimized. Uptake and activity is enhanced if the product is allowed to dry thoroughly and is not washed off by rain or irrigation water. Uptake is also better through tissues with a thin or no cuticle (protective waxy coating). On cranberry, elongating shoots have relatively thin cuticles and the stigma of the flower has no cuticle, so uptake should be very good in the tissues where infection occurs.

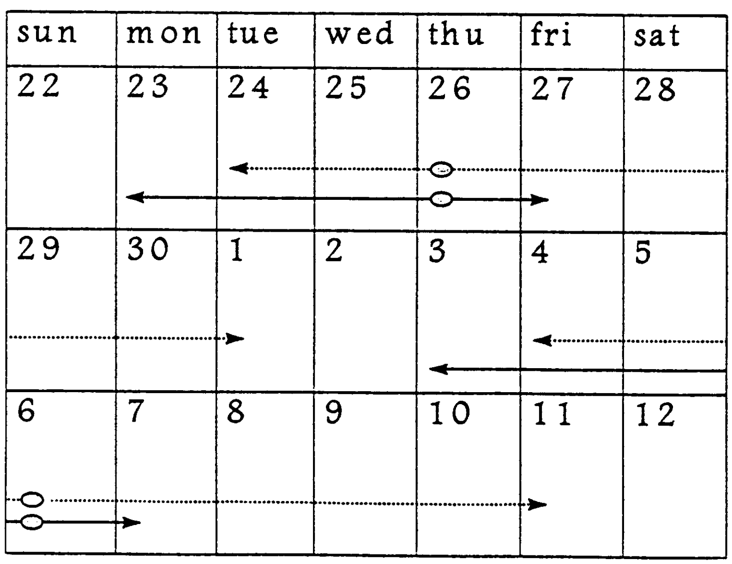

Figure 2. Comparison of protection and after-infection activities of Orbit® (-----) and Funginex® (_____).

Getting the fungicide to its target

Another critical factor affecting fungicide performance is coverage. Is the fungicide reaching its target? Considering how small spores are relative to elongating shoots, it's not hard to imagine infection occurring in a tiny island of unprotected tissue (Figure 3A). We don't know exactly where on the elongating shoot the cottonball fungus penetrates, so the safe bet is to make sure that coverage of elongating shoots is thorough to prevent primary infection by ascospores. On the flower, infection probably occurs through the stigma and growth of the fungus through the style, so fungicide application will be most effective when stigmas and styles are exposed (Figure 3B). The stigmas and styles are small targets that are oriented downward and sometimes beneath a canopy of leaves. Fungicides must penetrate the canopy to ensure good coverage of susceptible flower parts. Coverage is generally better when greater spray volumes are used. The time and money invested in calibrating and upgrading spray equipment will be repaid in better pest control.

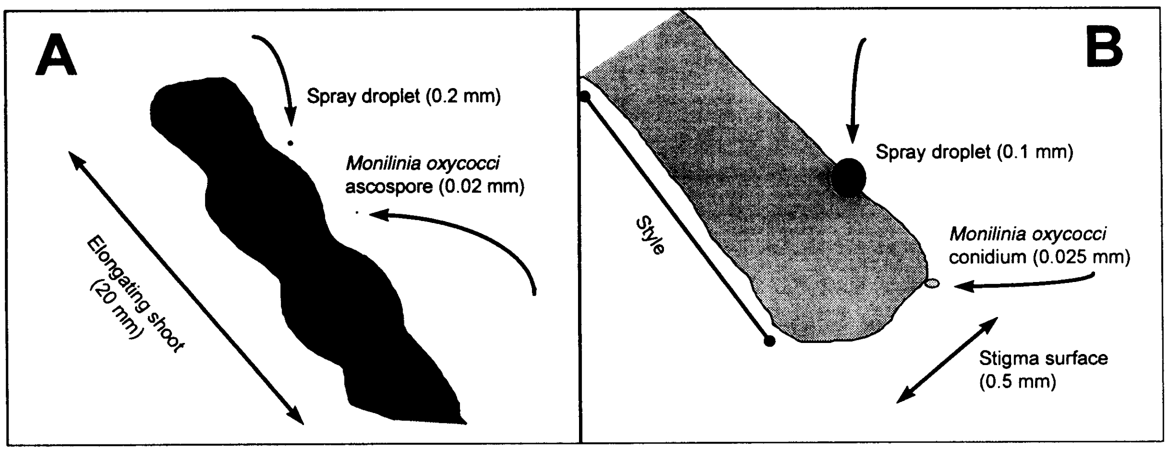

Figure 3. Relative sizes of *Monilinia oxycocci* spores, spray droplets, and plant parts. **A,** primary infection of an elongating shoot by an ascospore. **B**, secondary infection of a stigma by a conidium. Drawings are approximately to scale, but scales are different for **A** and **B**. For simplicity, one spray droplet and one spore are shown in **A** and **B**; in reality, numerous spray droplets and spores would be landing on plant parts.

Practical questions on cottonball and fungicides

This section will attempt to address questions that growers have posed about cottonball and the fungicides used to control it. Answers are based on research conducted in Wisconsin unless otherwise indicated.

Budbreak and bloom each occur over a period of several weeks, but protection and after-infection activity of fungicides are optimal for only a few days. When is the best time to spray?

Budbreak applications should be: 1) when greater than 50% of shoots are starting to elongate; and 2) about 10 days later. Bloom applications should be: 1) when 10-20% of flowers are open; and 2) about 10 days later. Measure these percentages objectively rather than "eyeballing" it. Toss a ring (about 6-8 inches in diameter) into a representative spot in the bed, and determine the number of elongating uprights per total uprights, or the number of open flowers per total flowers. Multiply the fractions by 100 to get percentages. Do this at least five times and in different parts of the bed and calculate the average reading. On any given date at one location, different cultivars will be at different stages of development. Spray schedules should be adjusted accordingly.

Does spraying Funginex® or Orbit® during bloom reduce yield?

No, based on a total of eight field trials conducted by three researchers at four locations in Wisconsin. Follow directions on the label, and minimize the risk of spray injury by spraying in the early morning or evening.

Which works better—Funginex® or Orbit®?

Orbit® has outperformed Funginex® in reducing fruit infection when all four applications were made. It is not known whether one fungicide is better than the other in preventing tip blight.

If disease pressure is low, can the rate of Funginex or Orbit be reduced?

Do not go below rates recommended on the 24(c) and Section 18 labels (24 oz per acre for Funginex®; 4-6 oz per acre for Orbit®). With DMIs used to control diseases on other crops, failure has often been attributed to skimping on fungicide rates. Also, using low rates of DMI fungicides over several years could increase the rate at which fungal populations develop resistance to the DMIs.

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Understanding Cranberry Frost Hardiness

Beth Ann A. Workmaster and Jiwan P. Palta
Department of Horticulture
University of Wisconsin, Madison, WI 53706
phone: (608) 262-5782 or 262-5350
email: palta@calshp.cals.wisc.edu

The threat of frost is an important limiting factor in the production of cranberries in Wisconsin. Although there is no month free from the possiblity of frost, we know that spring and fall are the most critical times of the year. In spring the plants are vulnerable after the pulling of the winter flood and as they begin to grow under favorable conditions. In the fall the threat of frost limits the length of time the berries can be left on the vines to develop maximum color. Irrigation pipes are removed prior to harvest, thus, prior to making ice cover for the winter, reflooding is the only frost protection method available. Reflooding is expensive and is not always feasible.

Despite the reality of the importance of frost protection, there is a sense among growers and managers that the crop is typically "overprotected" by the initiation of overhead sprinklers at relatively warm temperatures. This is understandable due to the high value of cranberries and the current lack of understanding about the hardiness levels of the plant throughout the year. Our goal is to provide recommendations for more efficient frost protection strategies; to help growers save money, energy, and water.

Bud stage terminology

When we started our work in 1995, we focused on sampling weekly and performing hardiness tests in our laboratory. We observed dramatic changes in the hardiness of buds and leaves; from surviving temperatures less than 0°F when the flood was first removed in the early spring, to only being able to handle temperatures around 32°F when the new growth emerged. At this time we saw that we needed to be able to refer to the various stages of growth that occurred between these extremes in hardiness. This had important implications for the sampling for our freezing tests as several stages would be present in a bed at a given time. With input from growers and other researchers we, with Teryl Roper's help, defined eight stages of bud development. **An illustrated article containing details on bud development and bud terminology will appear in the February 1997 issue of *Cranberries* magazine.** Aside from use in our own work, we hope this terminology will be useful to growers and others studying other aspects of cranberry growth and development. The eight stages are: 1) tight bud; 2) bud swell; 3) cabbagehead; 4) bud break; 5) bud elongation; 6) rough neck; 7) hook; and 8) bloom. Table 1 gives a brief description of each stage.

The 1996 growing season

Development of protocols for assessing frost hardiness of various parts of the cranberry plant:

This past season we sampled 'Stevens' uprights from the Nekoosa area from mid-April to mid-October, with the last sample date being just prior to harvest. Random samples were collected from six areas of the bed using a 10"x10" square frame. After transport to Madison on ice, the samples were sorted by bud stage. The most numerous advanced bud stage was used for hardiness testing in order to characterize the most vulnerable yet also the most meaningful stage at each date. The uprights from the selected stage were then cut to approximately 4 inches and put in large test tubes., which in turn were placed in a large circulating glycol bath. The bath was lowered through a series of freezing tempertures at intervals of 1 to 3.5°F every half hour. A small piece of ice was added to each tube at about 30°F to assure uniform ice formation across all of the tubes. Samples were removed from the bath as particular temperatures were reached.

After the samples thawed overnight, they were held for five days at 39°F for any recovery to occur. **Damage from the freezing stress was evaluated in three ways: visual scoring of browning and water-soaking, ion leakage measurements, and observation of the uprights' abilities to root and regrow.** A water-soaked appearance in leaves, buds, and flower parts are visual signs of damage. Damage to the interiors of buds and flowers are observed by dissecting these to look for further signs of water-soaking and browning. When cells in plant tissue are injured by stresses, such as chilling and freezing temperatures, parts of the cells' membranes are weakened. This affects their ability to retain the cells' contents, such as ions like potassium. The amount of leakage, and hence injury, can be assessed by soaking pieces of the tissue in distilled water and then measuring the electrical conductivity of that water. Regrowth studies entail monitoring the ability of terminal and axillary buds and adventitious roots to grow after exposure to different freezing temperatures.

Results to date:

Since there are no economic thresholds defined for frost damage, the results from these freezing experiments are summarized as the **lowest survival temperatures (LST)** for the different plant parts. This is the **lowest temperature at which all of the tissue of a particular plant part survived**. These **results are preliminary, and should not be considered as a recommendation regarding frost protection practices.**

Leaves developed during the previous growing season (old leaves) were initially very hardy in the early spring after the pulling of the winter flood (Figure 1). At this time of the year, old leaves were able to survive temperatures of about 0°F to about 10°F. With the beginning of new growth in early June, the hardiness of old leaves had decreased to about 32°F. A significant loss of hardiness occurred between the May 13 and May 20 sample dates. This is likely due to the plants' response to the warming springtime tempertures (Figure 3). New leaves were initially very sensitive to freezing temperatures, only being able to survive temperatures around 30°F. This sensitivity is due the lack of a thick waxy cuticle and possibly the lack of certain substances, such as suberin and lignin, in the cells of those new leaves. By late summer the new leaves were able to survive temperatures about 20°F and by the beginning of October they had hardened to about 10°F.

The lowest survival temperatures of buds, flowers, and fruits are shown in Figure 2. Buds showed significant changes in hardiness from early spring, at the tight bud stage, to bud break. At the tight bud stage, buds survived temperatures as low as -10 °F. Buds from the first two samples were rated as being significantly less hardy (around 10 °F). **This is likely due to a high incidence of pre-existing bud damage in the bed. These damaged buds had green healthy-looking bud scales, but were brown and dead on the inside.** By the time of bud break, the new growth was only able to withstand temperatures around 32 °F. Between these two extremes of both development and hardiness several significant changes were observed. As seen in the old leaves, a dramatic loss in hardiness also occurred in the buds between the May 13 (about -5 °F) and May 20 (about 13 °F) samples. However, between these two sampling dates the most numerous bud stage remained the bud swell stage. This further supports the idea that the plants were deacclimating from their hardier state in response to the warmer field temperatures (Figure 3). Another notable change in hardiness was also seen the following week (May 27) as the next bud stage, cabbagehead, had an LST of only around 26 °F.

As expected, flowers were extremely sensitive, only being able to survive temperatures around 30 °F. Green fruits of all sizes were sampled in late July and mid-August and were very sensitive, with no damage only occurring at temperatures between 32 and 30 °F. By early October, **when the fruits were greater than 75% blush, they were able to experience temperatures about 23 °F with no damage.**

These preliminary data are a baseline upon which our further work will be based. Just as some questions about the hardiness of different plant parts are beginning to be answered, many new questions also arise. **Some of these additional areas of inquiry include issues such as the impact of pre-existing bud damage levels on hardiness determination, the effect of the duration of freezing temperatures on hardiness, and the possible importance of hardiness of different flower parts (pollen, ovary, style) to fruit set.** Pre-existing bud damage may be responsible for the lower initial hardiness ratings of the buds from our first samples. Potential sources of damage include harvest, flooding, and winter stresses. Systematic information about the duration effects of freezing temperatures is greatly needed. It would be very useful to study durations that are typically experienced in nature. We know that flowers are generally very sensitive, but it is not known how cold and freezing temperatures affect the functioning of specific parts of the flower.

Infrared Video Thermography

This past fall we performed some experiments using infrared video thermography at the controlled environment facility at UW-Madison, called the Biotron**, to investigate and "see" how ice forms and spreads in fruiting cranberry uprights.** This work was done with the help of Dr. Michael Wisniewski from the USDA Appalachian Fruit Research Station in Kearneysville, West Virginia.

Thermography is a technique for detecting and measuring the heat emitted by objects. Heat waves are detected by a sensor where they are transformed into visible signals that can be recorded photographically, in this case by video. "Infrared" simply describes the type of heat waves, or radiation, that are sensed by the equipment. This technique, then, can visually depict a freezing event since heat is released when water changes from a liquid to a solid.

Uprights with fruits at the blush to red stages of ripening, as well as some detached fruits, were used. Samples were nucleated at 30 or 28 °F with a solution containing a protein-producing bacteria to ensure the uniform ice formation on the samples. Following nucleation, samples were cooled to 21 °F in approximately one hour. The following observations were made: 1) When nucleated at a cut end, ice propagated rapidly throughout the stem and into the leaves at a tissue temperature of about 25°F. However, ice did not propagate from the stem through the pedicel to reach the fruit. During the one hour after ice propagation in the stem, the fruit remained supercooled. 2) Within the duration of the experiment, leaves could not be nucleated from the upper surface. Ice from the lower leaf surface did nucleate the leaf, and ice propagated from the leaf to the stem and other leaves readily. 3) Both red and blush berries could only be nucleated at the calyx end of the fruit. 4) Red berries supercooled to colder temperatures and for longer durations than the blush berries.

These observations suggest that: 1) The **upper leaf surface and the fruit surface** (other than the calyx end) **are barriers to ice propagation in the cranberry plant**; and 2) At later stages of fruit ripening the pedicel becomes an ice nucleation barrier from the stem to the fruit. This may contribute to the ability of the cranberry fruit to supercool.

Table 1. Cranberry bud development stage terminology and description.

Developmental Stage	Description
1. Tight bud	Resting bud that has fulfilled dormancy requirements. Bud scales are tightly wrapped and the bud has a compact appearance.
2. White bud	Bud is no longer at rest. Bud has begun to swell. Bud scales are pushed outwards and have a slightly loosened appearance.
3. Cabbagehead	Substantial growth of bud has occurred. Bud scales are opening, but new growth is still enclosed.
4. Bud break	Bud growth has taken place. Tips of uppermost new leaves are visible.
5. Bud elongation	Leaves and some flower bracts are visible. All new growth is held tightly and parallel to the stem.
6. Roughneck	Stem has elongated enough to make visible all flower buds and bracts, which are held tight to the stem.
7. Hook	Flower pedicels have elongated such that flower bud droops.
8. Bloom	Flowers open.

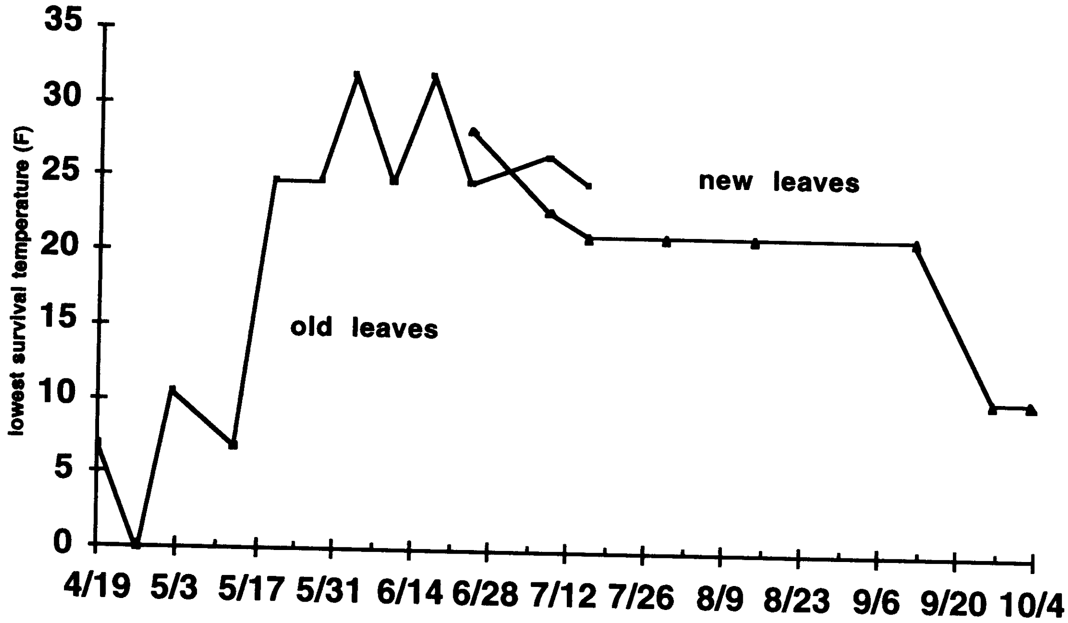


Figure 1. Lowest survival temperatures of old and new leaves from samples collected throughout the 1996 growing season.

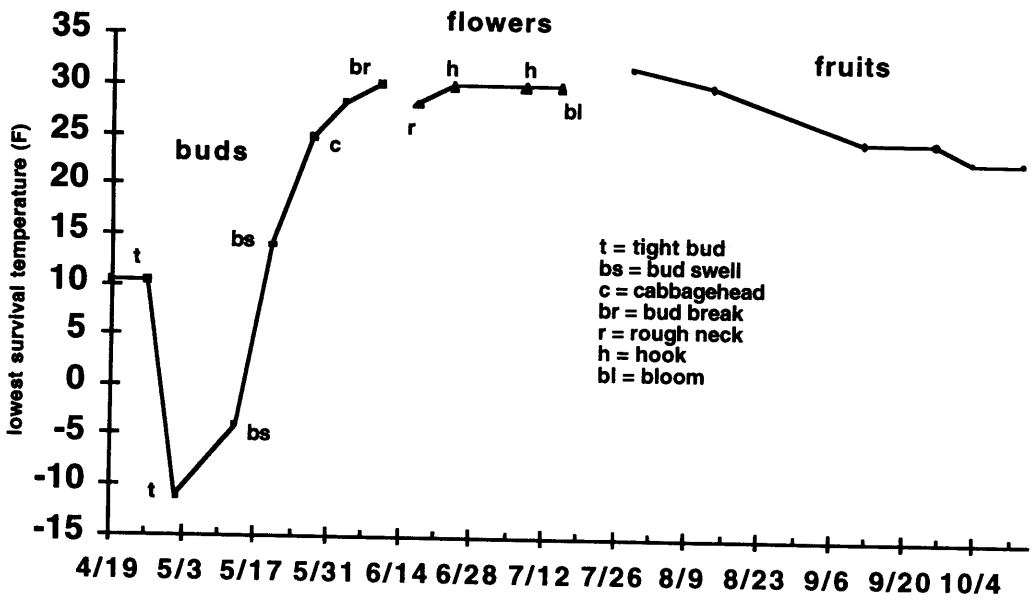


Figure 2. Lowest survival temperatures of terminal buds, flowers, and fruits from samples collected throughout the 1996 growing season.

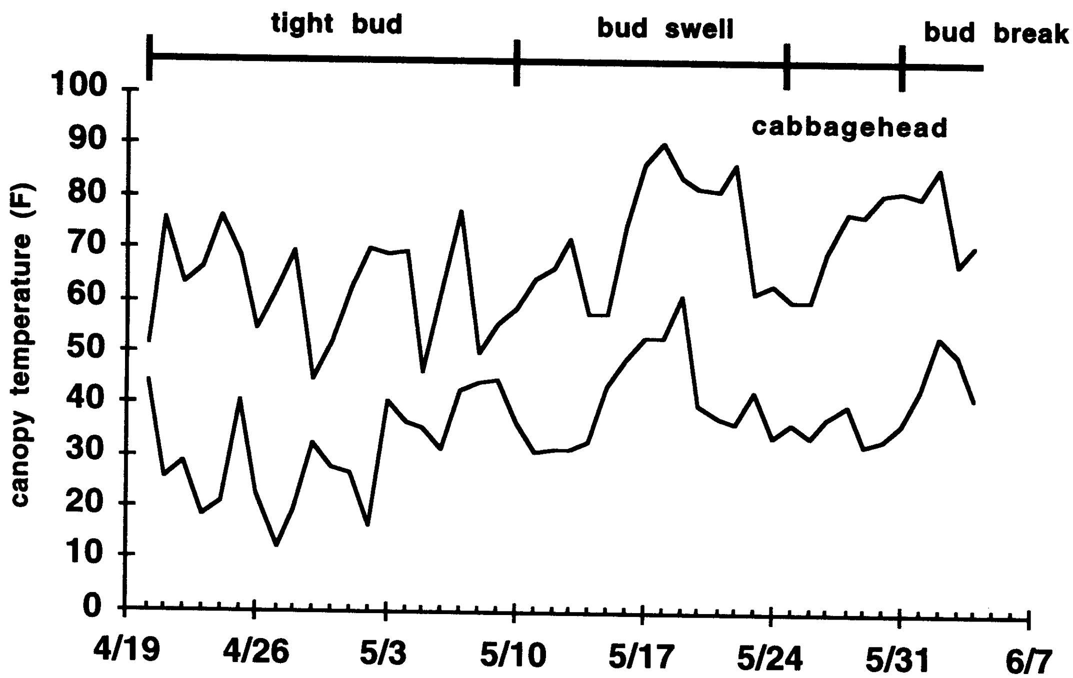


Figure 3. Daily maximum and minimum canopy temperatures recorded at sampling site (near Nekoosa) in Spring 1996.

AT LAST, A USE FOR COMPUTERS: WEATHER FORECASTS AT THE BED LEVEL

Bill Bland
Extension Agricultural Climatologist
Department of Soil Science, Univ. Wisconsin-Madison

Computer-based communications are a powerful way of getting the latest weather information, and we are making good progress on building computer models of the cranberry bed environment. We believe that communications and environmental modeling will be major roles of computers in cranberry management. In this paper I will describe our efforts at predicting low temperatures in cranberry beds, and how we are experimenting with disseminating these forecasts using the World Wide Web.

The work that I am going to share is part of a larger project, named TiSDat --Timely Satellite Data for Agricultural Management. I introduced TiSDat in an article in the program for the 1996 Annual Summer Meeting and Field Day. TiSDat was initially funded by the National Aeronautics and Space Administration (NASA) in 1994, and will continue through 1997. NASA is always interested in fostering new applications of satellite data, so that the benefits of space technology can be shared among the citizenry. Additionally, the US government is interested in encouraging growth of the Internet and faster computer communications, because such capability improves the economic competitiveness of country. TiSDat thus has two goals: develop new ways to use satellites in agriculture and encourage use of the Internet (or World Wide Web) as a business tool. The TiSDat project involves three major products: estimates of evapotranspiration from well-watered crops for use in irrigation scheduling, frost predictions in cranberry beds, and estimating the relative humidity around the leaves of potato, for use in disease predictions.

The Basic Weather Forecast

All modern day weather forecasting begins with "soundings" of the atmosphere, that is measurements of T, rh, wind, and pressure, made with weather balloons. There is a worldwide system of balloon launches that gives meteorologists a snapshot of the atmosphere twice each day. In Wisconsin, weather balloons are launched routinely only at Green Bay.

Data from all of these soundings are entered into computers and transmitted via networks to various users, including the National Weather Service headquarters near Washington. Here the data are fed into some of the world's biggest computers, which are loaded with some of the world's biggest programs -- computer models of Earth's atmosphere. Meteorologists are always among the first in line for the latest computers, because trying to describe and predict the behavior of the entire atmosphere is a big job. These computer models take in the recent soundings and begin making millions of calculations to predict what the atmosphere will look like in the coming hours, typically out to two days. Once the model predictions are made they are put on the computer networks for dissemination to local forecasters. Local forecasters use the model predictions in a variety of ways: to help fuel the forecaster's intuition, as input to rules of thumb developed for a particular forecasting task, or as input for yet another computer model.

Cranberry Forecasts

Back when I was youngster and Len Purvis was raising mink instead of cranberries, a U.S. Weather Bureau (as it was called then) fellow named Jim Georg, who apparently loved frost and/or hated winter, would to come to Wisconsin to do cranberry forecasts in summer, then move to Florida to do citrus frost forecasts. Georg and some UW-Madison folks, perhaps Champ Tanner and Vern Soumi, also did some field research to help refine methods for cranberry weather forecasts. I know that a few growers recall some of this, and I would like to visit with you so that I can write a record of the work.

The forecasting method Georg and company developed was used during the following decades by the Weather Bureau and successor National Weather Service (NWS). At the heart of the method were two tables of likely bog temperatures, one as predicted by dewpoint temperature and expected cloudiness, and the other as predicted by the amount of water in the atmosphere (called precipitable water) and the air temperature at 850 mb pressure (about 3/4 of a mile above ground level). Use of these tables required forecasting dewpoint, clouds, precipitable water, and temperatures in the atmosphere. This step originally was largely based on forecaster judgment, but decades of advances in meteorology, such as large computer models, offer great help nowadays.

New Tools

The opportunity that we saw for improving cranberry weather forecasts was based on two tools that had not been fully applied to the problem: GOES and ASOS. GOES is the satellite that provides your TV weather forecaster with the pictures of clouds that he or she shows each night. As an aside, the late UW-Madison Professor Vern Soumi is generally considered the father of the GOES system. Perhaps you have seen advertisements for UW-Madison during televised sports events in which we claim to have invented weather satellites. This is largely true, and refers to Soumi's pioneering work.

The Automated Surface Observation System (ASOS) and its cousin the Automated Weather Observation System (AWOS) are just now coming into operation. The first priority of these stations is landing airplanes, which seems right if you're flying in an airplane, but can be frustrating if you are interested in other uses of weather data, like growing food. Figure 1 is a map of ASOS and AWOS locations in Wisconsin. There appears to be reasonable coverage of the state by these automated weather stations, and there is a crew of federal employees driving around doing maintenance on them. We should work darn hard to be sure that we fully exploit the potential usefulness of these stations before we resort to routinely operating our own observation network. The continuing support of the cranberry industry for our research weather stations is critical to our efforts to learn more about the applicability of this new federally-operated network.

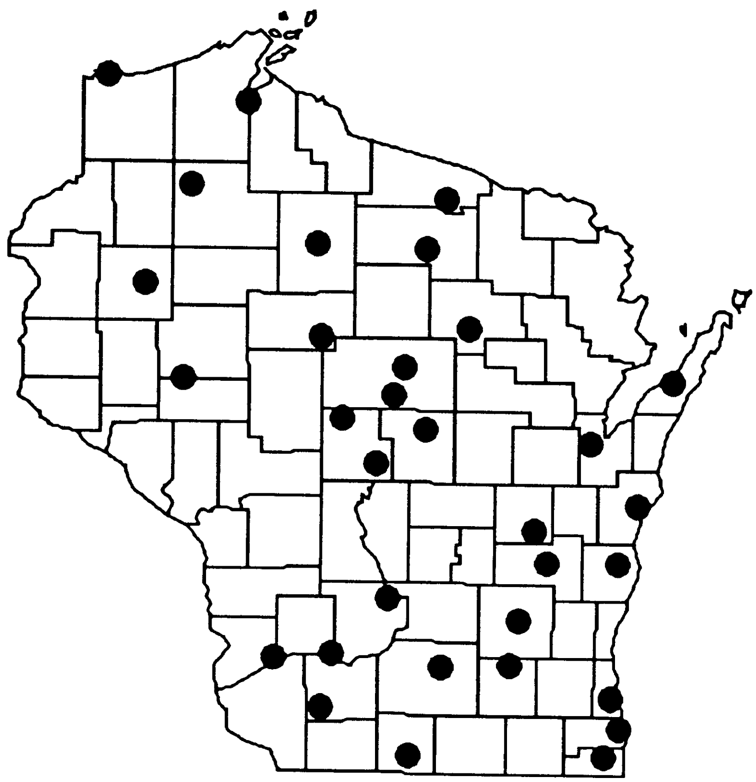


Figure 1. Locations of ASOS and AWOS stations in Wisconsin.

The TiSDat Forecast

Like everyone else, we start with a sounding, specifically the "12Z", which is made at noon in Greenwich England, which is about 7 am here in the summer. It takes several hours to get the data gathered and the NWS computer model results out to us in Madison.

At this point the other folks working on this project at the Space Science and Engineering Center of UW-Madison take the NWS model results and feed them into what is called a mesoscale model (named CRAS), which attempts to simulate conditions over North America in greater detail than did the NWS models. Forecasts from CRAS then move by computer network to the Soil Science Building and to one of our computers, which runs another model, CranEB. Now CranEB operates at the cranberry bog scale--we run it for a handful of locations in WI, including the two sites (Cranmoor and Manitowish Waters) where we have 30 foot-tall towers to take measurements just as they are made at ASOS stations. Our first forecast comes out about lunch time.

Instead of just forecasting the minimum temperature, we draw a graph of what the temperature will be through the night (Fig. 2). We create graphs for what the model thinks will be the cloud conditions, and for the case if the model is wrong about clouds and skies will be clear. Often, the model predicts clear skies so the two lines are the same. In the figure, clear skies were forecast until just after midnight, when the clear and cloudy forecasts become different.

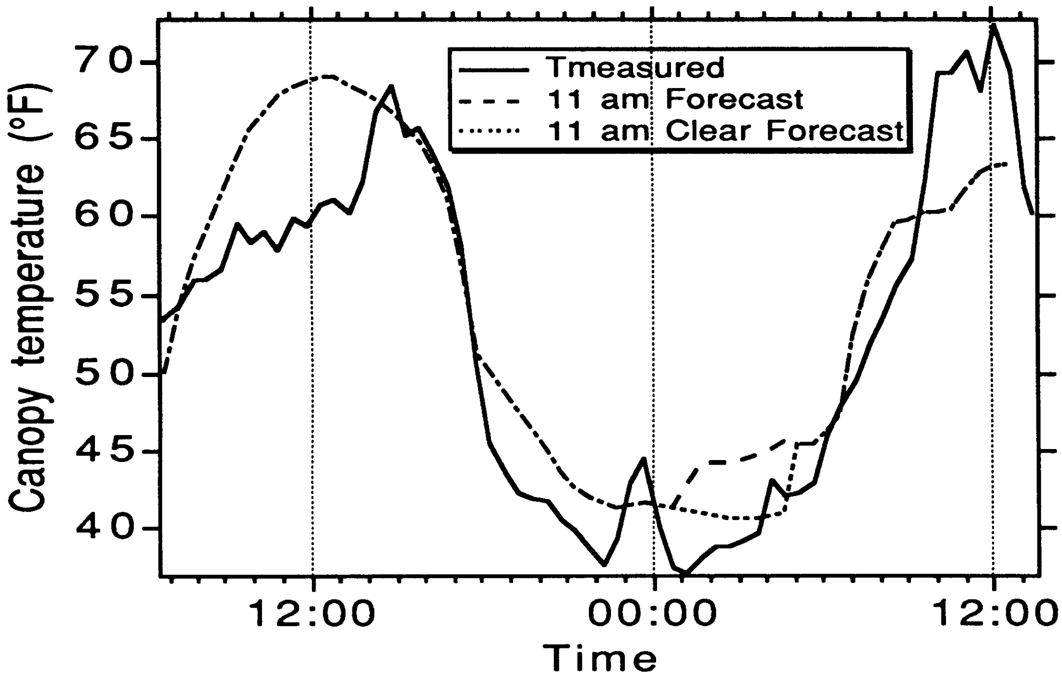


Figure 2. Example forecast made by the TiSDat system during Fall 1996.

In addition to temperature, we also predict wind--you really can't do temperature without wind, and you know from experience how closely the two are connected. The marsh environment is an unusual situation, with large expanses of very smooth areas and bumps with roads where we are allowed to put our instruments to measure the wind. We are confident that our wind forecasts can be improved.

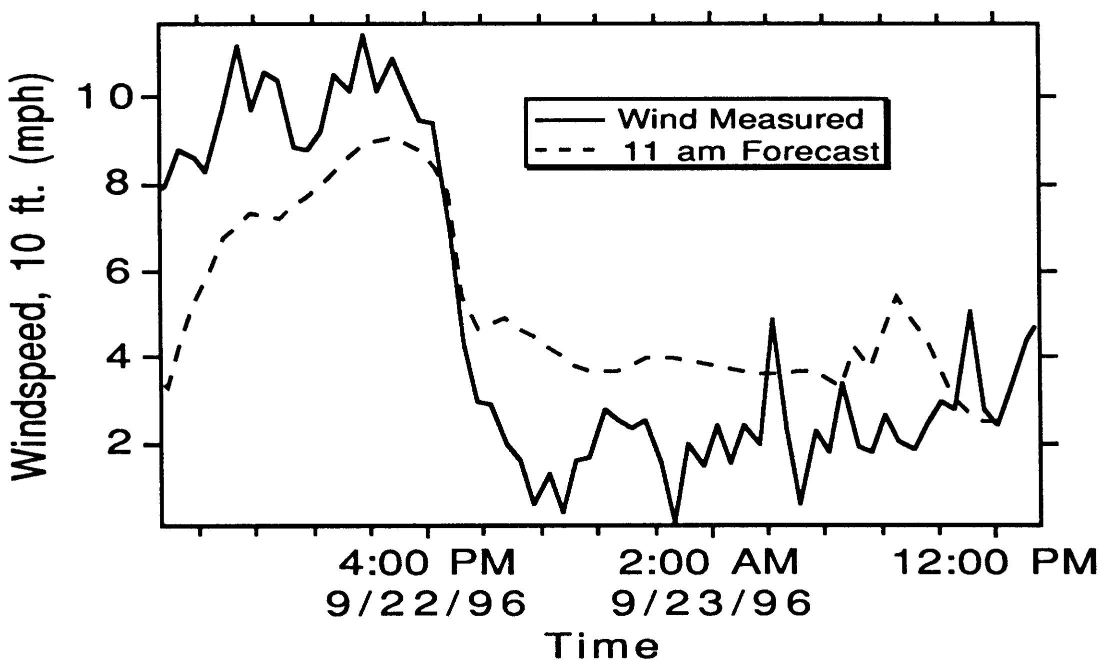


Figure 3. TiSDat automated forecast of the wind at 10 feet above the crop surface.

Through last summer and fall we steadily improved our models by changes and additions in the basics--not by tweaking to match a particular measurement. Ultimately, will need to do some plain-old fudging, but we are still making the model as sound in principle as we can.

Comparison With Conventional Forecasts

The Wisconsin Cranberry Growers Association contracted with a private forecasting firm, American Weather Concepts, for forecasts during last summer. Figure 4 compares our results to theirs for August and September, for days when either a forecast or an observation was below 40°F.

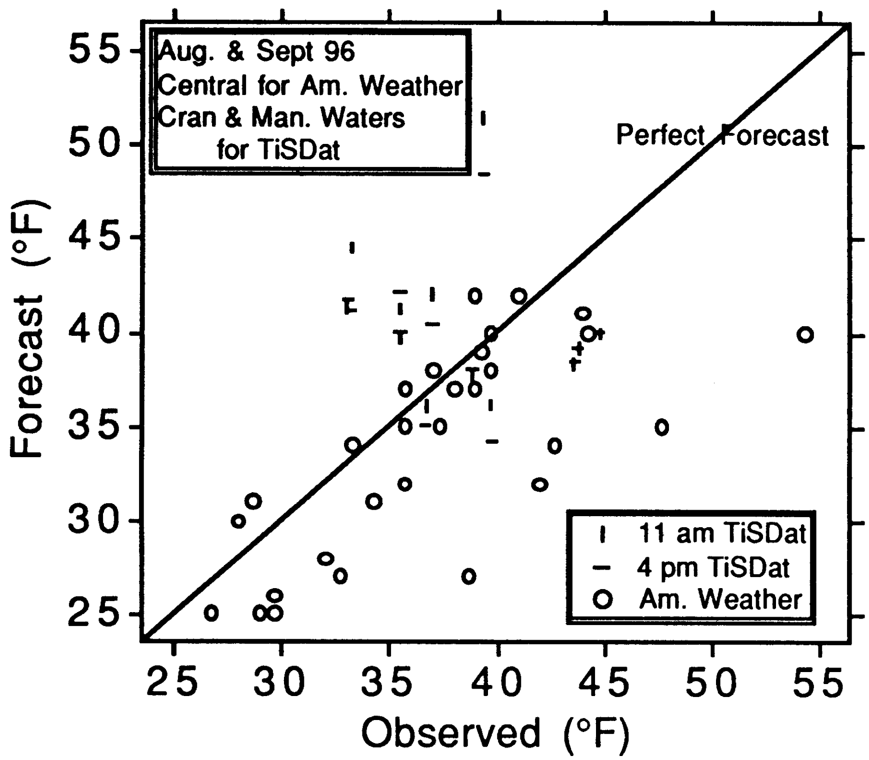


Figure 4. Comparison of TiSDat automated forecasts with convention forecasts made by American Weather Concepts (AWC). The diagonal line is where a point representing a perfect forecast would fall.

Figure 4 shows that AWC did a good job on many days, and tended to be conservative on other days--that is they sometimes predicted colder temperatures than were observed. In contrast, TiSDat tended to make the opposite and more dangerous mistake often--not predicting cold enough. On some occasions the updated forecasts made later in the day were closer to the observed than the first forecasts. The updating system in use during this period was only a portion of the final system that we envision.

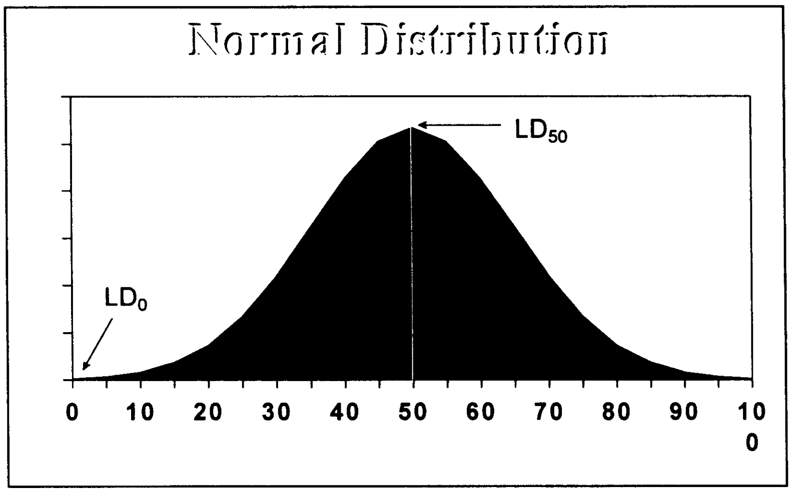
In summary, the current TiSDat system cannot do any better than conventional forecasts, which AWC does well. We believe that the great virtues of our experimental system are in correcting the situations in which conditions changed substantially after the conventional forecast was made. Updates will be possible through use of automated observations, both on Earth and from space, and the speed and convenience of the World Wide Web.

What's an LD_{50}?

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

Pesticides are commonly used pest management tools on Wisconsin cranberry marshes. For the most part pesticides are reliable and economic tools when used according to the label instructions. However, since pesticides are designed to kill pests they do pose health risks to humans. This article will describe methods of comparing the toxicity of various products and offer suggestions to limit exposure to pesticides.

Not all pesticides are equally toxic or dangerous to mammals. In order to compare the relative toxicity of various products the concept of LD_{50} was developed. In a typical population of test animals or humans there is a range of susceptibility to toxic agents. That is to say, a given acute dose of a pesticide may not kill all members of a population. On the other hand, some particularly susceptible individuals may be injured or killed when given a very small dose of a toxicant (Fig. 1). When deciding whether to expose yourself to various toxicants, it is helpful to know where in the normal distribution you fall. Of course, there is no way to know that except through exposing yourself to a lethal dose!



An LD_{50}, then is the amount of toxin that will kill 50% of the exposed population. It is usually expressed as the mg of toxin per kg of body weight. By expressing the ratio this way the data can be extrapolated from mammals such as rats and rabbits to humans. The trick is to transfer an LD_{50} of say 100 mg/kg to the amount that would kill 50% of 180 pound men who were exposed to that level. Table 1 is an attempt to express the values for an LD_{50} to a recognizable form for growers. By examining this table you can gauge the relative toxicity of common cranberry pesticides.

However, I think the number that is really of most value and interest to applicators is the LD_0. That is the amount of toxicant that will kill none of the population. That figure appears at the far left tail of the normal distribution. Again this is largely a theoretical number. You can make sure that you don't approach this number by handling pesticides carefully and in compliance with the label instructions. The most important part of the pesticide label for applicators is the section that deals with wearing personal protective equipment. You must always wear gloves when working with pesticides and you must wear the personal protective equipment listed on the product label.

Table 1. LD_{50} information for common cranberry pesticides. The far right column lists the amount of chemical formulation required to kill 50% of people who would ingest that amount of formulation. The LD_0 is much lower.

Product	LD50 (mg/kg)	g ai/180 lbs	% active	g of formulation	amount of formulation
2,4-D 20G	300	24.6	0.2	123	0.27 lbs
Orthene	900	73.8	0.75	98.4	0.22 lbs
Guthion 50W	13	1.066	0.5	2.132	2.132 grams
Sevin XLR	307	25.174	0.04	629.35	1.3 liters
Bravo 720	10000	820	0.54	1518.519	2.1 liters
Lorsban	380	31.16	0.04	779	1.6 liters
Diazinon 50W	66	5.412	0.5	10.824	10.8 grams
Casoron 4G	3160	259.12	0.04	6478	14.27 lbs
Roundup	3000	246	0.41	600	1.25 liters
Devrinol 10G	5000	410	0.1	4100	9 lbs
Poast EC	3000	246	0.18	1366.667	7.6 liters
Mancozeb 80WP	11200	918.4	0.8	1148	2.53 lbs

You should also realize that the LD_{50} concept is based on acute oral exposures to pesticides. Data for dermal exposure are also available and are expressed as a dermal LD50. It is unusual for pesticides to be ingested orally unless through a purposeful act (suicide). The most common avenue for pesticides into the body is through dermal exposure through the hands and groin area. Dusts may also be breathed into the lungs or liquids or dusts may enter the body through the eyes.

LD_{50} does not take into account chronic exposure over a period of months or years. Further, it does not consider the indirect effects of pesticides as they may be carcinogenic (cancer inducing), mutagenic (induce mutations in the genetic material) or they may be teratogenic (inducing developmental changes, particularly in fetal development). While these issues are not immediately fatal, they almost always reduce the length or quality of life.

Pesticides are not necessarily the most toxic substances you may encounter during the course of a day. Many common substances are toxic if we are exposed at elevated levels. A listing of the LD50 for common materials and pesticides is given in Table 2. Notice that caffeine and nicotine are more toxic than Malathion or Poast. Even table salt has about the same toxicity as Casoron (but I don't know how you could eat a half pound of salt at one sitting). In small quantities materials such as Tylenol, Aspirin and Ibuprofen offer relief from pain. In large quantities at one time they may be fatal. The truth of the statement "The dose makes the poison" is evident here.

Used prudently synthetic chemicals can enhance the quality of life. Misused or used carelessly they may be very dangerous. Applicators should use caution when mixing, loading or applying pesticides to minimize exposure through the use of appropriate personal protective equipment, as specified on the product label and through minimizing the opportunity for exposure to either concentrate or dilute solutions.

Table 2. LD50 values for common materials and pesticides

Material	**LD_{50}, g ai to kill 150 lb person**
Parathion	<1 gram
Guthion	<1 gram
Thiodan	3
Mesurol	9
Lorsban	9
Gasoline	11
Paraquat (Gramoxone)	11
Nicotine	16
Caffeine	16
Diazinon	20
Tylenol	23
Sevin	34
2,4-D	34
Ridomil	46
Valium	48
Aspirin	51
Enide	65
Funginex	68
Ibuprofen	72
Malathion	94
Poast	182
Dacthal	205
Table Salt (NaCl)	226
Casoron	290
Roundup	334
Chloropropham	341
Princep	341
Sinbar	341
Captan	614
Ronilan	682
Alcohol	699
Benlate (Benomyl)	>700

Plans and Specifications for Mixing/Loading Pad and Pesticide Storage Building

David W. Kammel
Agricultural Engineering Department
University of Wisconsin-Madison

Ronald T. Noyes, Professor
Biosystems and Agricultural Engineering Department
Oklahoma State University

The following plan and specifications is developed from the material contained in the MWPS-37, Designing Facilities for Fertilizer and Pesticide Containment. It is a conceptual plan showing the integration of the functional areas such as storage and mixing/loading into a facility. The dimensions can be modified to accommodate various sizes of equipment or storage needs for a particular operation. More detailed information of construction can be found in the MWPS-37 Handbook.

Variations of this plan have been used in several demonstrations around Wisconsin including a cash grain farm, an orchard, a dairy farm and a golf course. The plan is fairly flexible in allowing different users to design and manage the space in the facility for their particular needs. The information in this paper attempts to describe the different areas in order to get a better understanding of the function of the area and how it relates to the rest of the building design. There are also appropriate specifications suggested that are based on the MWPS-37 which should help contractors determine the construction required in the facility.

Functional System Design

Each of the functional areas is provided with separate secondary containment. This prevents an accidental spill in one area from contaminating an adjacent area or the entire facility. Ramping between areas allows easy access by hand truck or forklift for moving packages into the areas during the mixing process, or loading and unloading of product.

Sump Design

A shallow sump is also designed into each area to provide a low point in the area for recovering spilled material easily. The sumps are not designed to hold material for an extended time, but only allow recovery of as much of the material as possible. Accumulated solids in sumps should be cleaned out weekly or immediately after an accumulation of solids is evident. Fluid should be pumped directly into application equipment if possible or into labeled rinsate storage tanks. An 80 mesh screen is commonly used to screen the fluid from the pump to prevent clogging of nozzles or solids from deposits in the rinsate tanks.

The sumps are usually precast concrete surrounded by placed concrete or are poured as an integral part of the concrete slab. An alternative is to use a stainless steel sump surrounded by placed concrete described in MWPS-37.

Rinsate Management

Rinsate tanks should be cone bottom design or depressed outlet type tanks to allow complete draining of the tank and any accumulated solids.

The load pad should be washed down daily after use. Although it is good practice to minimize the amount of rinsate generated, it is also important to clean any spilled fertilizer or pesticide solutions off the pad to prevent degradation of the concrete.

Management

Maintain a list of all stored product kept in the facility in the emergency response plan for the facility. Keep this inventory up to date especially in spring when product moves in and out of the facility quickly. Over winter as little product as possible.

General Notes

This facility should be placed a minimum of 50 feet away from other buildings for fire protection reasons. Construction should comply with all applicable local and state building/construction codes. There may also be applicable Federal Environmental Protection Agency, State Environmental Protection Agency or State Department of Agriculture regulations.

Construction materials are suggested in the specifications and plans, but substitutions can be offered if performance is equivalent to suggested materials.

Pesticide Storage Areas

The pesticide storage areas include a heated and ventilated pesticide storage for year round storage and a seasonal storage area used to store liquid and dry formulations of agricultural pesticides and or fertilizer. Secondary containment is provided for all areas to contain potential spills and allow for reclamation of spilled materials and decontamination of the surfaces and liners of the facility. The secondary containment capacity of the pesticide storage area is approximately 95 gallons. The seasonal storage area has a secondary containment capacity of approximately 135 gallons.

The seasonal storage area is used to store the large quantity of product that is common in the spring rush. Depending on needs, this area may not require environmental control which can keep the cost down, but if necessary the entire area can be heated if over wintering is required for a large quantity of product. It is not designed as a long term storage area.

Mixing/Loading Pad

Mixing/loading pads are used to collect and contain spills from the handling and transfer of pesticides from storage to spray equipment. Unloading and transfer of pesticides into the storage building will also take place over the pad. Equipment will be parked on the pad during filling or maintenance. The pad should be cleaned after any leak or spill. Wash water or rinsate from the cleaning of the pad shall be collected and transferred to rinsate storage tanks located on the pad. These rinsates can be used as makeup water for subsequent sprayer loads or disposed of under label directions. The secondary containment capacity of the mixing loading pad is approximately 250 gallons.

Additional capacity can be achieved by increasing the slopes on the ramps into the areas, adding additional height on the curbing of the areas or increasing the slopes on the floor areas of the facility. Also increasing the dimensions of the building will tend to increase the capacity of the building.

Personnel Safety Area

A personnel safety area should be developed in the facility. At a minimum, this area should include an emergency shower/eyewash, spill recovery kit and first aid kit. A clean clothes locker and storage for personnel protection equipment should also be available.

Waste Disposal Area

Disposal of empty containers should be according to label directions. These containers should be stored in the facility or in a separate roofed area until they are disposed of.

Building

The entire facility is roofed for several reasons. The roof prevents the entry of clean rainwater that potentially would have to be handled as a rinsate. A 100 year, 24 hour storm in Wisconsin is a 6 inch rainfall. This rainstorm would generate approximately 1000 gallons of rinsate on the mixing/loading pad area. Annually Wisconsin's precipitation would generate 5400 gallons of rinsate if it were allowed to accumulate on the pad. This would amount to eighteen 300 gallon sprayer loads. The entire building provides a secondary containment capacity of 480 gallons, but it is designed to allow isolated secondary containment of each of the functional areas.

Site Investigation

A site investigation should be performed to determine any pre-existing contamination on the site and/or well. Soil samples should be taken on the site and tested for pesticides used previously at the site. Water samples should be taken at the well and tested for pesticides used previously at the site.

Excavation and Sitework

All top soil, organic matter and debris should be removed from the site. Excavate to remove soil to a sufficient depth to allow the subbase and concrete slab to be situated on firm undisturbed soil at elevations shown on drawings. The compacted granular subbase should be placed in maximum 6 inch lifts.

Concrete Design

The concrete slab is designed as a floating slab. Depending on the complexity of the final design, the slab can be poured integral or may require separate pours. If separate pours are necessary, waterstops should be used at the cold joints.

Each of the functional areas is or can be poured separately from the others to allow simple construction. Control joints are at the high point of the ramp so that the joint can be maintained and most likely will not be exposed to water for extended periods of time.

At the entrance to the overhead doors, there is a ramped portion of concrete that extends into the building approximately 6 inches. This prevents rain and snow melt water from entering the building as it is shed from the door or as accumulated snow next to the door melts. There have been several buildings designed without this, and the common problem to them all is accumulation of rain and snow melt water into the sump of the loading pad.

Concrete Specifications

Concrete should be ready mix delivered to the site. The concrete mix and the pad construction should be designed to the following construction specifications:

Type I or Type II cement.
Minimum 28 day strength: 4,000 psi.
Air entrainment: 6 percent +/- 1 percent.
Water-cement ratio: 0.40-0.45.
Slump: 2-4 inch.
For improved workability a water reducing agent (plasticizer) should be added the plant or site and mixed according to manufacturer's recommendations.
Additional water should not be added.
Moist cured for not less than 14 days (28 days preferred).
No cold joints if possible.
Water stops at all cold joints.
Minimum vibration during placement.
Maximum aggregate size: 1 inch.

Control joints are cut into the green concrete at the specified locations at a depth of 2" or 1/3 the slab thickness.

Reinforcing bars should have at least 2 inch concrete cover on formed concrete surfaces and 3 inch minimum for concrete placed against soil or subbase.

Finish concrete with a steel power trowel, then wood float in direction of slope for a nonskid surface.

Use a polyurethane base joint sealer or equivalent.

The floor coating should be an epoxy base providing a chemical impervious and nonskid surface. Incorporate grit in final coat to provide for nonskid surface.

Steel Specifications

Reinforcing steel should be Grade 60 #4 reinforcing bar (epoxy coated is preferred).

Lap all splices 12 inches minimum.

Provide adequate support for all reinforcing bar during concrete placement to maintain position in the slab.

Post Frame Building Specifications

Typically the building shell is constructed separate from the concrete slab. This provides for the opportunity to use a post frame building and would not require footings integral to the slab.

A post frame building shell is suitable construction for the building shell. Stud frame and concrete block have also been used in other situations. Consult with local building codes to determine required construction for site.

For the post frame shell use 6" x 6" treated wood post foundation at 8' on center (OC). A minimum of 4' post depth should be adequate. Posts should rest on 6" thick x 18" diameter precast concrete footing. Building roof construction to be pre-engineered truss at 8' OC designed for appropriate snow load at the site. 2" x 6" girts at 2'-6" OC for the sidewall and 2" x 6" purlins at 24" OC dropped between the truss and supported by joist hangers should be used for the roof. Full length painted ribbed 29 Ga steel siding and roofing should be used.

An option in some areas may be to insulate the entire area and use fences for security of adjacent storage areas if needed.

The exterior walk doors should open to outside. A self closing door with exit lock and panic hardware is recommended. The door should be metal construction, solid core, with metal jamb and weather seal, and a 3/4 hour fire rating.

The splash skirt or interior liner should be plywood with epoxy paint or painted steel. The liner should allow water to shed onto the loading pad or inside the building.

Pesticide Storage Room Specifications

Wall construction should be 2" x 6" treated wood sill anchored to slab or curb 4' OC. The wall is 2" x 6" wood stud at 16" OC insulated with 6 inch Kraft faced fiberglass batt. The ceiling is 2" x 10" joist at 16" OC insulated with 12 inch Kraft faced fiberglass batt. Use a 6 mil vapor barrier with taped joints to produce continuous vapor barrier on the warm side of the wall or interior of room before the interior liner is installed.

The interior liner should be 1 layer of 5/8" Type X gypsum wallboard covered with 1/2" exterior grade plywood laminated with High Density Polyethylene (HDPE) or equivalent to provide a surface impervious to chemicals and easily cleaned and decontaminated. An alternative liner is 29 Ga ribbed steel.

The exterior liner on storage room should be 1 layer 5/8" Type X gypsum wallboard covered with full length 29 Ga white painted steel.

Electrical Specifications

The electrical service should comply with Class 1 Division 2 of National Electric Code. The service should be sized to provide all electrical requirements for installed lighting, heating, outlets and ventilating equipment rated at 110/220 V and approximately 100-200 amp, depending on load. Provide exterior disconnect of electrical service in locked weather proof cabinet and separate meter for building.

All duplex electric outlets located as per plan equipped with Ground Fault Circuit Interrupters (GFCI) circuit.

Lighting

Lights may require some offset from the centerline of the building, especially if overhead doors are used. Since it is common during the use of the building that the overhead doors are up during the day they may cover up the lights if they are not positioned correctly, effectively limiting lighting. This may not be a problem during midday with the sun shining, but there could be low light levels during cloudy days and also at dusk and dawn when the building is just getting setup or just getting cleaned up. An option may be to use roll up doors, bi fold doors or sliding doors. Another option may be to position the lights on the sidewall up high but not obscured by the overhead door in the open position.

Fluorescent or incandescent lighting fixture with vapor protection on same switch with ventilation fan to be placed on the exterior of the pesticide storage room.

Fluorescent, incandescent or high pressure sodium lighting fixtures with vapor protection in remainder of building.

Exterior weather resistant fluorescent or high pressure sodium light on photocell and/or motion sensor.

Fire Safety

Optional dry chemical fire suppression system.

Smoke and heat alarms with remote warning system tied to residence or fire official.

Plumbing Specifications

Frost hydrant to be located as per plan. Water system beyond frost hydrant should be designed to allow draining during winter to prevent freezing. Water source to building to be provided with a reduced pressure principle backflow (RPPB) prevention device or a water storage tank and air gap to prevent backflow. All water and drain plumbing should be above ground. No open drains to outside of building or to underground storage should be allowed.

HDPE, or stainless steel (type 304, 306, 316) rinsate tanks.

Counter top and sink as per plan. Drain to rinsate collection tanks in secondary containment.

Equipment

Equipment is available from safety supply houses including Lab Safety Supply (P.O. Box 1368, Janesville, Wisconsin 53547-1368. Phone (800) 356-0783) or Gempler, Inc. (P.O. Box 270, 211 Blue Mound Road, Mt. Horeb, Wisconsin 53572. Phone (800) 382-8473). Alternative suppliers can be used if equivalent.

15-18 inch wide movable shelving as per plan to be anchored to wall for support. Steel construction capable of supporting loads from stored materials.

Exhaust fan ducted to within 12 inches from the floor. 150 cfm capacity at 1/8" static pressure during occupancy and operated by exterior switch located near door of storage room. Exhaust fan and lights on same switch. Indicator light on exterior of pesticide storage room to indicate lights and fan are on.

Louvered openings for passive inlet of air during exhaust ventilation, providing approximately 36 square inches and located opposite of exhaust fan, as per plan, approximately 12 inches off floor.

10,000 Btu electric heater capable of maintaining winter interior temperature of 50°F.

Three 10# ABC Halon fire extinguisher located near doors.

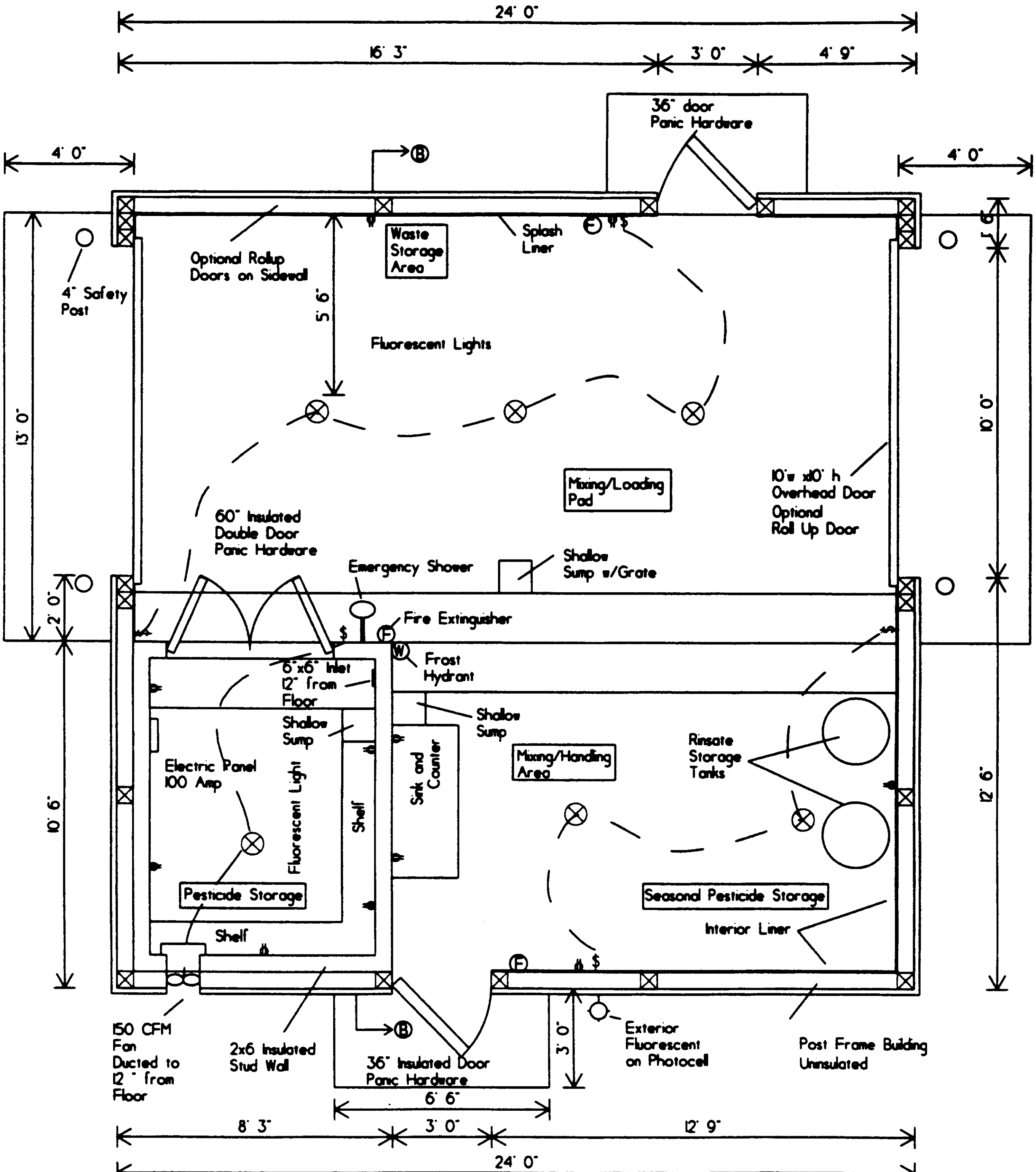
Exterior visible signs to indicate "Pesticide Storage", "No Smoking", and NFPA sign at entry doors. "EXIT" signs located on all exits.

Emergency eyewash/shower located as per plan.

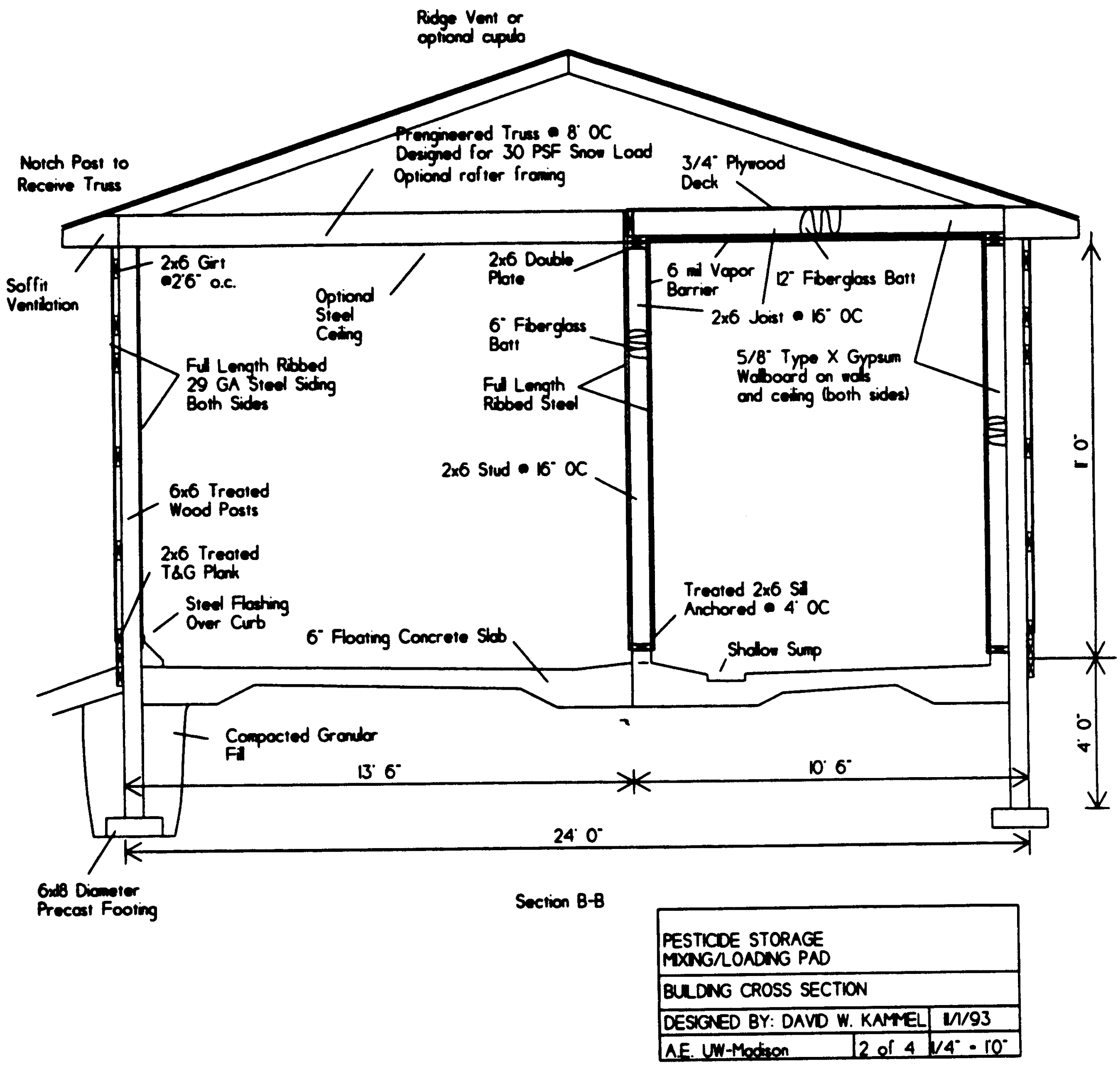
Ion type fire smoke alarm located as per plan, option to signal remote site such as main office.

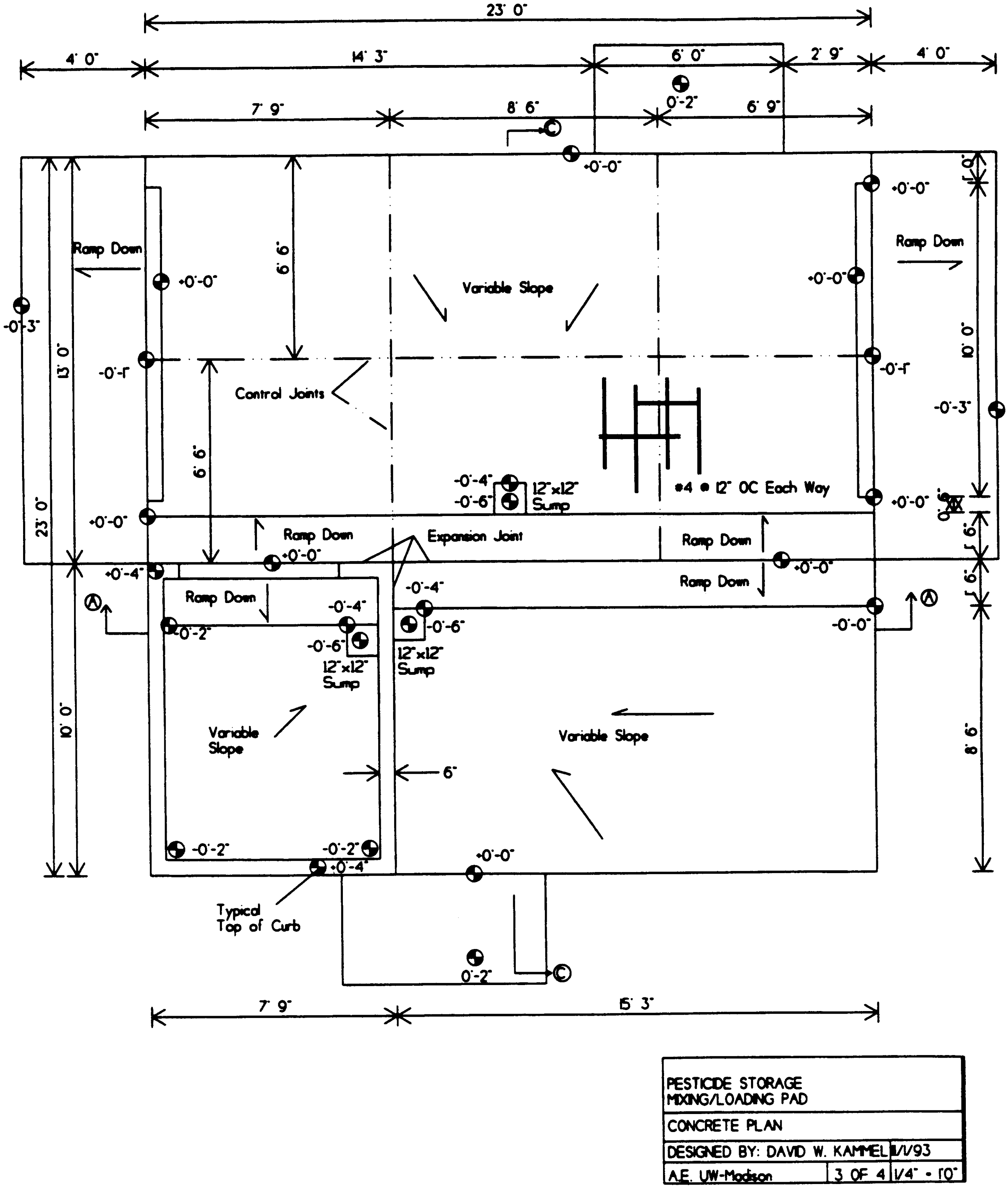
Clothes locker.

Personal safety kit and spill kit.

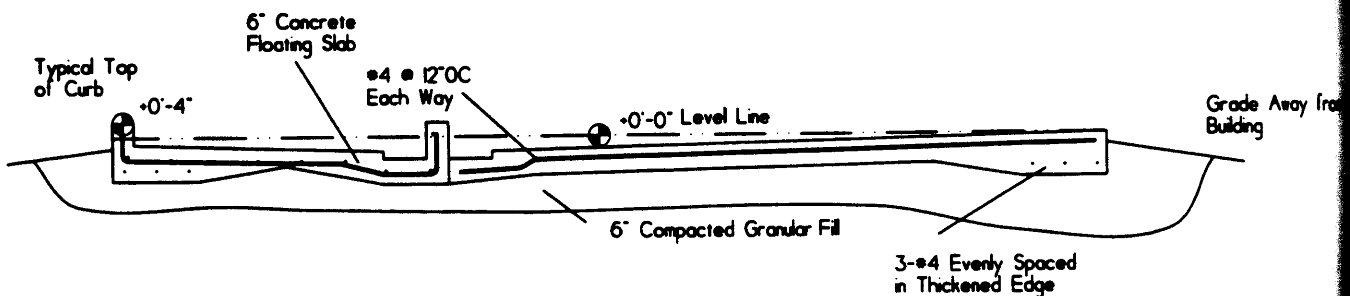


PESTICIDE STORAGE MIXING/LOADING PAD		
BUILDING PLAN		
DESIGNED BY: DAVID W. KAMMEL		1/1/93
A.E. UW-Madison	1 OF 4	1/4" = 1'0"

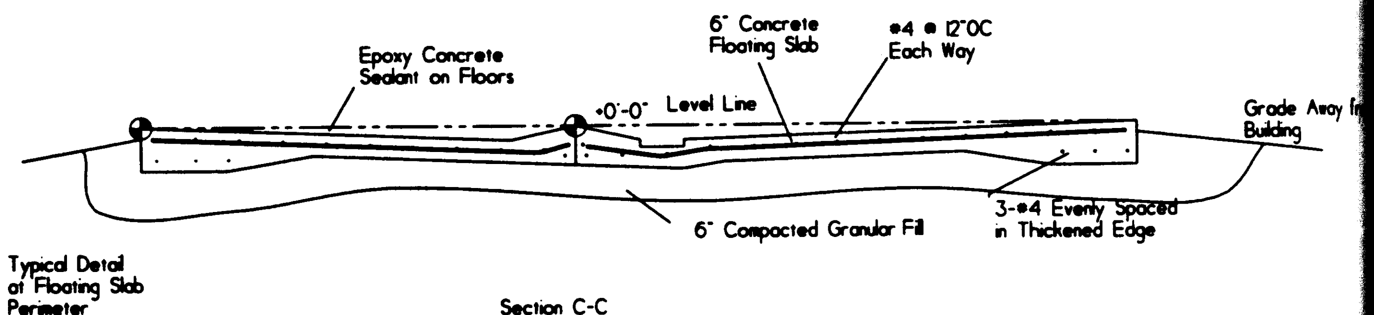

Ridge Vent or optional cupula
Notch Post to Receive Truss
Prengineered Truss @ 8' OC Designed for 30 PSF Snow Load Optional rafter framing
3/4" Plywood Deck
Soffit Ventilation
2x6 Girt @2'6" o.c.
Optional Steel Ceiling
2x6 Double Plate
6 mil Vapor Barrier
12" Fiberglass Batt
2x6 Joist @ 16" OC
6" Fiberglass Batt
5/8" Type X Gypsum Wallboard on walls and ceiling (both sides)
Full Length Ribbed 29 GA Steel Siding Both Sides
Full Length Ribbed Steel
2x6 Stud @ 16" OC
8' 0"
6x6 Treated Wood Posts
2x6 Treated T&G Plank
Steel Flashing Over Curb
6" Floating Concrete Slab
Treated 2x6 Sill Anchored @ 4' OC
Shallow Sump
Compacted Granular Fill
4' 0"
13' 6"
10' 6"
24' 0"
6x18 Diameter Precast Footing
Section B-B
PESTICIDE STORAGE MIXING/LOADING PAD
BUILDING CROSS SECTION
DESIGNED BY: DAVID W. KAMMEL
1/1/93
A.E. UW-Madison
2 of 4
1/4" = 1'0"



23' 0"
4' 0"
14' 3"
6' 0"
2' 9"
4' 0"
7' 9"
8' 6"
6' 9"
0'-2"
+0'-0"
Ramp Down
Ramp Down
Variable Slope
6' 6"
-0'-3"
13' 0"
-0'-1"
Control Joints
10' 0"
-0'-3"
6' 6"
-0'-4"
-0'-6"
12"x12" Sump
#4 @ 12" OC Each Way
23' 0"
Ramp Down
Expansion Joint
Ramp Down
Ramp Down
Ramp Down
-0'-4"
-0'-2"
-0'-6"
12"x12" Sump
Variable Slope
Variable Slope
6"
10' 0"
8' 6"
+0'-0"
-0'-2"
+0'-4"
Typical Top of Curb
0'-2"
7' 9"
15' 3"
PESTICIDE STORAGE
MIXING/LOADING PAD
CONCRETE PLAN
DESIGNED BY: DAVID W. KAMMEL 1/1/93
A.E. UW-Madison 3 OF 4 1/4" = 1'0"

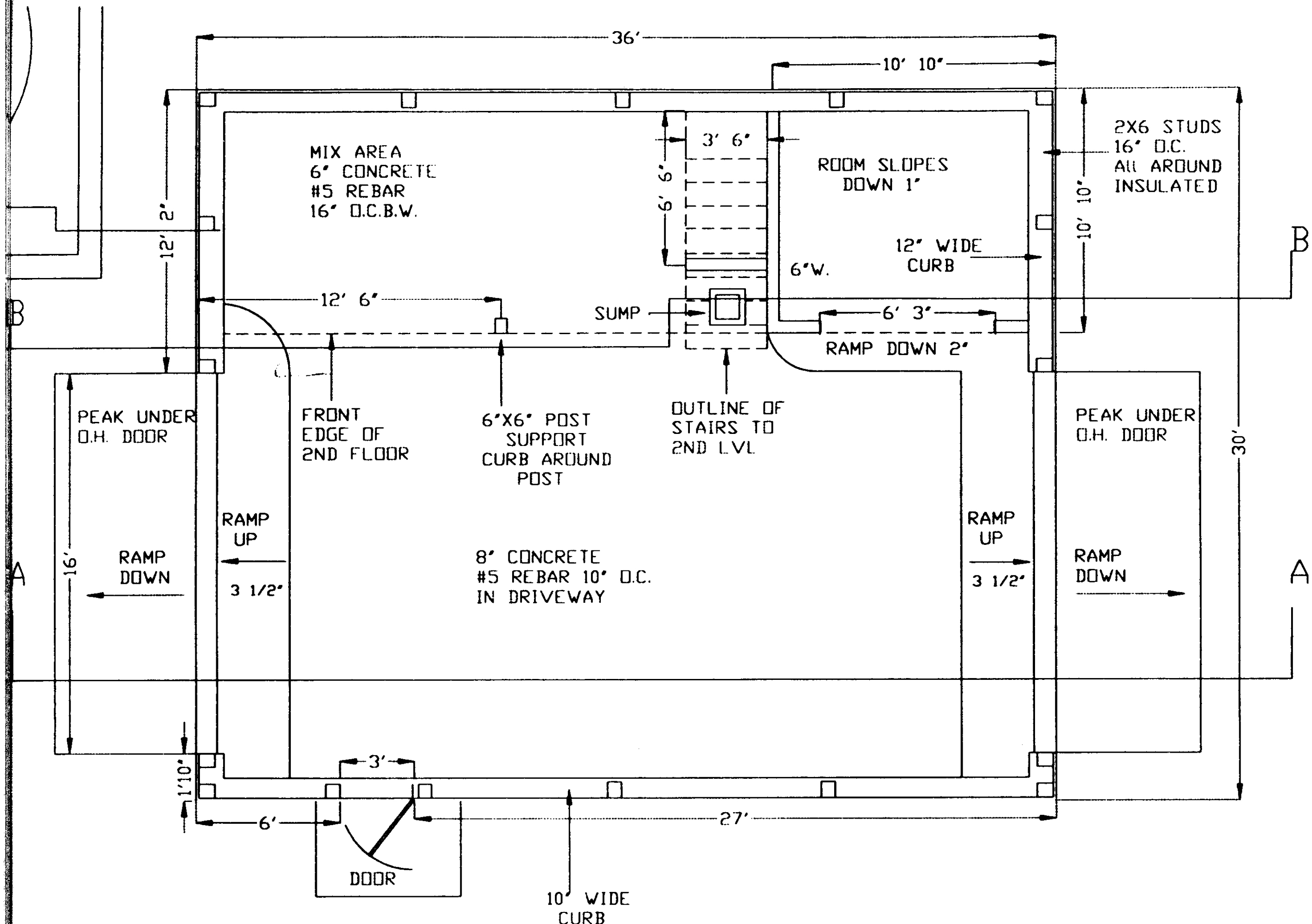


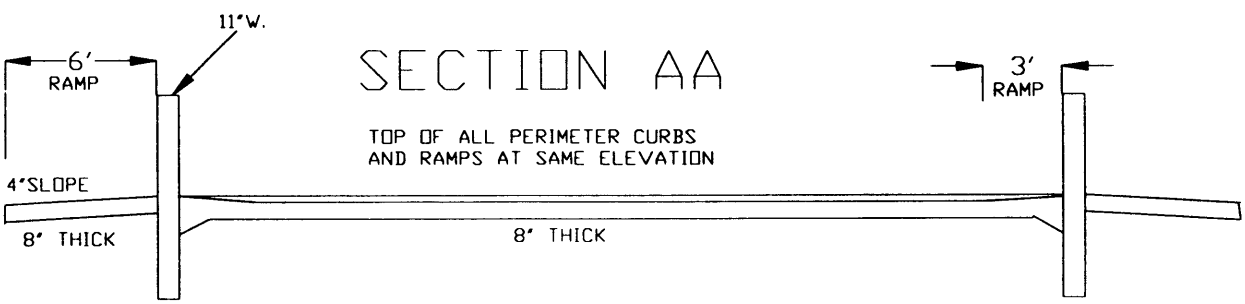
Section A-A

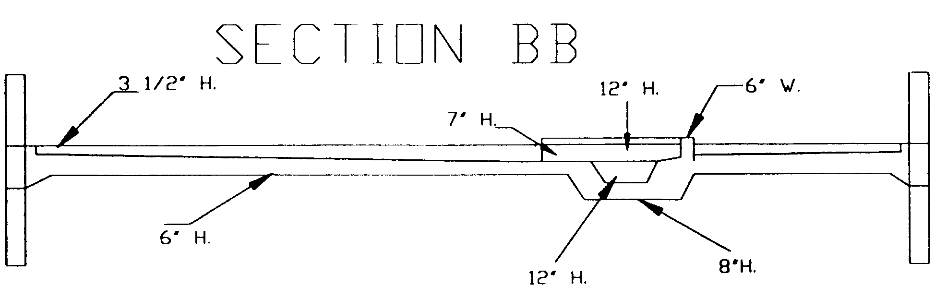


Section C-C

PESTICIDE STORAGE MIXING/LOADING PAD		
CONCRETE CROSS SECTIONS		
DESIGNED BY: DAVID W. KAMMEL		1/1/93
A.E. UW-Madison	4 OF 4	1/4" - 1'0"


36'
10' 10"
MIX AREA
6" CONCRETE
#5 REBAR
16" O.C.B.W.
3' 6"
6' 6"
ROOM SLOPES
DOWN 1"
2X6 STUDS
16" O.C.
All AROUND
INSULATED
12' 2"
10' 10"
12" WIDE
CURB
6"W.
B
12' 6"
SUMP
6' 3"
RAMP DOWN 2"
PEAK UNDER
O.H. DOOR
FRONT
EDGE OF
2ND FLOOR
6"X6" POST
SUPPORT
CURB AROUND
POST
OUTLINE OF
STAIRS TO
2ND LVL
PEAK UNDER
O.H. DOOR
30'
RAMP
UP
RAMP
DOWN
16'
A
3 1/2"
8" CONCRETE
#5 REBAR 10" O.C.
IN DRIVEWAY
RAMP
UP
3 1/2"
RAMP
DOWN
A
1'10"
3'
6'
27'
DOOR
10" WIDE
CURB


11"W.
6'
RAMP
SECTION AA
3'
RAMP
TOP OF ALL PERIMETER CURBS
AND RAMPS AT SAME ELEVATION
4"SLOPE
8" THICK
8" THICK


SECTION BB
3 1/2" H.
12" H.
6" W.
7" H.
6" H.
12" H.
8"H.