A CROP EVALUATION
CALIFORNIA SUGARBEET INDUSTRY

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DISCLAIMER

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This Crop Evaluation is submitted to the State of California Department of Pesticide Regulation as a review of the current diseases and pests of sugarbeets in California. This is a background to develop a sugarbeet pest management work plan. The report was submitted on March 9, 2000.

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ABSTRACT

The sugarbeet industry has a history of innovative solutions to pest problems. Many of these solutions have involved cooperative efforts among sugarbeet growers and between the sugarbeet industry and other commodity groups. The beet free system for control of sugarbeet yellows virus and the cross-commodity approach to curly top control have been models for other industries to follow.

The FQPA provides for the review of many pesticides considered essential for profitable sugarbeet production and may lead to their loss. Previous pest management research in sugarbeets often has emphasized the use of these materials and is reviewed in the Pest Management Evaluation with some discussion on alternative low risk concepts of pest control.

The Pest Management Evaluation includes chapters on the important pests and diseases in sugarbeets and a summary of current control practices. It discusses the various disease complexes as they relate to California's four sugar beet production areas. Where possible, the Evaluation identifies opportunities for reducing risks and tries to measure the potential for adoption

This evaluation proposes a systems approach to stand establishment and post establishment pest control consistent with the goals of the FQPA. Alternatives to the use of listed pesticides for the control of aphid and leafhopper transmitted viral disease and reduced risk methods for armyworm and associated foliar pests will be demonstrated, substituting seed treatments for foliar and soil applied pesticides. The use of new weed control strategies and better assessment of economic thresholds for the control of foliar feeding insects during the stand establishment and main production phases are discussed.

CROP EVALUATION
CALIFORNIA SUGARBEET INDUSTRY

A. PRODUCTION

The following information is for sugarbeets grown in the areas served by Spreckels Sugar Company in California and the Klamath Basin area of Oregon and represents the 1998 Crop consisting of approximately 108,260 harvested acres.

- The above area ranks fourth in the U.S. in the production of sugarbeets.
- It accounts for nine percent of the total U.S. sugarbeet production.
- There were 3,243,778 tons of sugarbeets valued in excess of $133 million produced during the 1997 Crop Year.
- Production costs averaged about $900 per acre, with a range of $700 to $1200 per acre.
- A five-year history of sugarbeets in California:

Year	Planted Acres	Harvested Acres	Tons Per Harvested Acre	Average % Sugar	Tons of Sugar Per Acre
1998	108,260	105,616	26.95	16.09	4.336
1997	111,504	107,588	30.15	15.51	4.676
1996	90,760	88,022	29.20	15.81	4.617
1995	103,457	99,964	27.63	16.20	4.476
1994	141,216	137,313	28.49	15.42	4.393

B. PRODUCTION REGION

Sugarbeets are grown in such diverse climates as the high intermountain area of the Klamath Basin about 4,000 feet m.s.l. to the low desert areas of the Imperial Valley, much of which is below sea level. They are also grown in the alluvial plains of the great Sacramento and San Joaquin Valleys, from Glenn County in the north end to Kern County in the south. There are also about 100 acres of sugarbeets grown in the coastal area of Hollister/Gilroy (San Benito County).

Sugarbeets are planted in nearly every month somewhere in the state and are generally harvested from late March to November when rains and wet soils stop harvest.

Area	Plant	Harvest	Est. 1999 Acreage
Imperial Valley (Imperial)	September-October	April-July	34,000
Klamath Basin (Modoc/Siskiyou)	April-June	October	8,000
Sacramento Valley (Sacramento to Glenn)			
Spring Harvest	May-June	April-June	12,000
Fall Harvest	January-April	September-October	5,000
San Joaquin Valley (San Joaquin to Kern)			
Spring Harvest	May-June	April-June	17,000
Summer Harvest	October-January	July-August	18,000
Fall Harvest	January-April	September-October	14,000

C. CULTURAL PRACTICES

Sugarbeets are grown in rotation with other crops in a grower's farm system. Crops grown in rotation with sugarbeets include, but are not limited to: cotton, alfalfa, beans, tomatoes, grain crops (corn, wheat, etc.), vegetable crops to a small degree, and other field crops. Industry policy dictates that sugarbeets only be produced one year in four on a given acreage. This rotation reduces the spread of soil-borne diseases or other problems such as nematodes.

California sugarbeets can be grown on a variety of soils; however, acreage is concentrated in heavy clay and clay loam soils. The entire crop in the state is irrigated either by furrow or sprinkler and requires from 18 to 54 inches of irrigation water, depending on weather and planting date. A deep rooted crop, sugarbeets have been shown to recover 2.5 to 3.5 times the amount of nitrogen applied as fertilizer and require 25 to 50 percent less fertilizer than corn. As such, they are useful in rotations to utilize excess nitrates that otherwise might contribute to ground water contamination.

Tillage practices during seedbed preparation control many early germinating weeds. Postemergent herbicides are applied only as germinating weeds are identified, and then are applied on a band over the row, which reduces the area treated to as little as one-third of the total acreage while at the same time minimizing grower costs. Between the rows, weed control is achieved through cultivation prior to the crop reaching full canopy cover. Insects are monitored throughout the growing season, and insecticides are applied only as economic threshold levels are reached.

Integrated Pest Management

The industry has always been a leader in developing effective and environmentally benign pest management practices. The "beet free" program of isolating old sugarbeet fields from new plantings has been a notable example of effective integrated pest management (IPM) to control virus yellows disease. This program demonstrates the ability of the state's sugarbeet industry to act in a coordinated way to control pests.

The approach to sugarbeet pest management in California has been to develop varieties tolerant to the major pests. This has worked fairly well for curly top, *Erwinia* root rot, and most recently, rhizomania, but has not been successful for other diseases such as yellowing viruses. No resistance has been found for nematodes, armyworms, or other insect pests. However, breeding work is continuing to find resistance traits for the crop problems. It appears there will be transgenic varieties with resistance to Roundup® and Liberty® herbicides available to growers in the near future.

D. INSECT/MITE CONTROL

APHIDS/YELLOWS VIRUS

Green Peach Aphid, *Myzus persicae*
Black Bean Aphid, *Aphis fabae*

Summary

Two species of aphids commonly infest sugarbeets in California. The green peach aphid (GPA), *Myzus persicae*, has been a recognized pest of sugarbeets for 50 plus years. The black bean aphid (BBA), *Aphis fabae*, (also called the bean aphid) is a relatively new pest of sugarbeets in California. These two aphids are similar in their damage, importance, life history, etc., and will be considered together in this analysis. The differences will be pointed out when applicable.

The bean aphid is dark olive green to black with a dull, matte-like appearance. It can be easily confused with the cowpea aphid and the dark morph of the cotton aphid, which do not commonly occur in sugarbeets. The green peach aphid is pale green and medium-sized. Both aphid species have been present in California at least since the 1940's. However, yellow water pan trap samples collected near sugarbeet fields in Yolo and Solano Counties in the late 1960's by Dr. Harry Lange showed that less than one percent of the collected alate aphids were bean aphids; whereas, 80 percent of the aphids were green peach aphids. Samples collected from 1992 to 1997 by Dr. Larry Godfrey, in cooperation with sugar company and California Beet Growers Association personnel, showed a dramatic reversal. Today about 70 percent of the alate aphids collected in the spring in traps adjacent to sugarbeet fields are bean aphids, and green peach aphids comprise the other 30 percent. The reason for this shift in species composition is unknown.

Populations of GPA and BBA typically build up in the spring (March) and persist through about May. The exact dates are dependent on the environmental conditions. GPA cannot tolerate heat; therefore, populations crash as temperatures exceed 851F; BBA are more tolerant of heat, and populations persist longer, in some cases through the summer. BBA populations appear again in the fall; whereas, GPA are at very low numbers in the fall and the rest of the year. The most severe aphid problems in sugarbeets are in the Central Valley, particularly in the lower Sacramento Valley and upper San Joaquin Valley (Glenn County to the north and San Joaquin County to the south).

The primary damage done by these aphids in sugarbeets is their propensity to vector virus diseases including western beet yellows luteovirus and beet yellows closterovirus (BYV). These diseases, along with others, are commonly called the yellows complex. Beet yellows closterovirus has been shown to be the most damaging of these virus diseases and is of the greatest concern to the industry. Some of the key life history traits of GPA and BBA are summarized below.

Summary of Aphid Traits

	Black Bean Aphid	**Green Peach Aphid**
Heat Tolerance	tolerates heat well	populations decline at temp. >85°F
Other Host Plants	wide host range	wide host range
Overwintering	weeds, overwintered sugarbeets, eggs on *Euonymous* in Europe	weeds, overwintered sugarbeets, as eggs on peach trees in cold areas
Ability to Transmit BYV	30% efficient	60% efficient
Generation Time	7-10 days	7-10 days

The primary damage and concern from aphids in sugarbeets is the transmission of virus diseases. Infection with the yellows virus complex early in the growth of the beet can result in a 50 to 75 percent reduction in yield. This susceptible period is up to six weeks after seedling emergence. More mature plants are not so severely affected by the yellows complex; however, a ten percent yield reduction can still result from infections of sugarbeet plants that are nine weeks old, for example. The yellows virus complex reduces plant leaf area, photosynthesis of the remaining leaves, and can kill plants with early infections.

BBA infestations, besides introducing BYV into the crop, can also reduce sugarbeet yield. This species, as it feeds, injects a toxin which "stunts" plant growth. The infested leaves curl and do not develop properly. Threshold values have been developed for BBA on sugarbeets (Summers, et al, 1996). GPA feeding alone does minimal obvious damage to the plant. Both species exude honeydew which coats the leaves and stimulates the growth of sooty mold fungus. The effects of this coating on sugarbeet growth have not been fully evaluated, but in other systems it is known to be detrimental to plant growth. Aphid management in sugarbeets involves an integrated program of cultural, biological, and chemical controls.

Current Pest Management Practices

Chemical Controls: Foliar insecticides are occasionally used to control BBA that have reached levels high enough to cause plant damage; these infestations are often spotty, so spot treatments can be used. Chlorpyrifos (Lorsban®), diazinon, oxydemeton-methyl (Metasystox-R®), and endosulfan (Thiodan®) are used. (See Appendix A, page 51, for rates and areas treated.)

However, the primary concern with aphid pests in sugarbeets is the transmission of virus diseases. The primary use of insecticides for aphid control is to minimize this injury. Two approaches are used: 1) planting time applications in areas and months when the threat of aphid infestation and virus introduction is severe, and 2) applications of foliar insecticides following seedling emergence and aphid infestation. The challenge with all these insecticide treatments is that aphids can transmit BYV in as few as 15 minutes. Few insecticides can kill pests that fast or protect the plant that thoroughly. Insecticides can, however, reduce aphid densities and subsequent secondary spread of virus diseases within the field. Planting time treatments include aldicarb (Temik®), phorate (Thimet®), and imidacloprid (Gaucho®) seed treatment. Aldicarb and phorate can also be applied postemergence. These two products do not seem to appreciably reduce the percentage of plants with BYV; but especially with aldicarb, there is a measurable positive yield response.

Imidacloprid is a reduced-risk insecticide that was available starting in 1997 for aphid-BYV management. This product is used at 45 grams active ingredient per 100,000 seeds, or 45 to 60 grams per acre at common seeding rates. This rate protects the seedling for three to five weeks and has no effect on beneficial insects. Imidacloprid also controls other seedling pests such as flea beetles, wireworms, etc.

Foliar insecticides are used during periods of high aphid density to reduce populations and virus spread. Chlorpyrifos, diazinon, oxydemeton-methyl, and endosulfan are used. Methamidophos (Monitor®) was also used before its loss in 1998. The drawback of the foliar treatments is that they also kill beneficial insects. These natural enemies assist with aphid control, but more importantly, they impede the buildup of armyworm, leafhopper, and spider mite pests.

Alternatives: No host plant resistance to GPA or BBA is available. In addition, resistance to the most detrimental component of the beet yellows complex (beet yellows closterovirus) has been researched for 40 years with no break-throughs to date. Resistance through transgenic techniques is being examined in Europe. The exact details of this research are unavailable to us at this time. The importance of sugarbeets to the economy of many European countries clearly warrants this research. However, in the U.S., California is the only production area with serious problems with aphids and yellows diseases. The size of our industry has not yet warranted transgenic efforts in this area. The direct applicability of the European transgenic sugarbeets to BYV management in California is doubtful. First, the sugarbeet varieties grown in Europe and California are greatly different. Secondly, the viruses and/or virus strains involved in the yellows complexes in California and Europe are probably different and may limit direct applicability of the European transgenic efforts to California.

Cultural Controls: The timing of sugarbeet planting and harvest is highly regulated by the industry. The characteristics of the plant allow sugarbeets in the Central Valley to, in theory, be planted and harvested during any month. In addition, it has an indeterminate growth characteristic, especially in the nonbolting varieties. The industry is organized into a series of districts with specific windows for planting and harvesting. The primary goal of this program is to assist in management of the yellows complex by separating older (overwintered, possibly infected) sugarbeets from new plantings in space and time. This reduces the introduction of BYV into the newly emerging sugarbeets, which is the most critical time for the crop. This program has been highly successful and is one of the pre-eminent examples of area-wide pest management.

This area-wide strategy is very successful, but BYV is not completely controlled by it. Why? The original research in the 1960's suggested that at least a ten-mile buffer (and possibly more) was needed to prevent aphid movement from overwintered beets to newly planted beets. This is not feasible in many areas, and a five-mile buffer is used. This still allows for some aphid movement from infected to new beets. Environmental conditions and winds also contribute to aphid movement between old and new beets. More importantly, the emergence of the bean aphid as a common aphid pest has greatly threatened this system. The ability of the bean aphid to withstand hot temperatures has compromised the utility of delaying planting past the timing of the aphid flight peak in March-April. BBA was uncommon when the planting/harvest system was implemented in the late 1960's. It is also possible that BBA is able to fly farther than GPA.

Other cultural control measures for sugarbeet aphids include diligence in removing weedy (keeper) beets, minimizing weeds around fields, etc.

Biological Controls: Several generalist predators and parasites kill aphid pests of sugarbeets. Lacewings and lady beetles are important predators. Parasites, such as *Lysiphlebus testaceipes*, are important. In spite of these naturally-occurring biological control agents, outbreaks commonly occur. In addition, both aphid species can transmit BYV in as few as 15 minutes and predators/parasites may not act quickly enough. Methods to increase and manipulate levels of predators such as releases of lacewings and food sprays to attract native lacewings have been tried with minimal success. These techniques may offer help in the future following more research.

Other Issues: The Food Quality Protection Act could have significant impact on management of aphids and yellows virus diseases. The strengths of the present system are the variety of strategies used, including cultural, biological, and chemical. Within the chemical control strategy is the availability of products possessing a range of modes of action and with several use patterns. The range of modes of action inhibits the build-up of insecticide resistance in the aphids. Aphids, especially green peach aphids, have the propensity to quickly attain resistance. The ability of materials used as seed treatments, as granular soil-applied treatments, and as foliar applications provides growers with considerable flexibility and options for aphid management.

The implementation of FQPA could result in the loss of registrations of organophosphates, carbamates, and organochlorines; this would leave only imidacloprid for aphid management. The availability and use of only one material would be the worst-case situation for IPM. The use of imidacloprid would likely increase as growers would be left with no foliar treatment options. (Foliar treatments are not the best method to manage yellows diseases but do provide options for growers in emergency situations.) Therefore, the implementation of the FQPA would greatly hinder aphid/disease management and IPM in sugarbeets.

Several other challenges are present to threaten the current system of managing aphids and virus diseases in sugarbeets:

- GPA and BBA have a history of the development of insecticide resistance. This has been shown in several systems and countries.
- Aldicarb, a key product used for aphid control, is under constant regulatory scrutiny because of its environmental and human health concerns.
- The availability of imidacloprid, a reduced-risk material, is an asset for the sugarbeet industry. However, aphids, especially BYV, tend to cycle in importance; and during years with outbreaks, insecticidal control has not been sufficient to prevent substantial crop losses.
- The planting date restrictions are useful for minimizing aphid and BYV incidence, but these restrictions compromise the crop potential and increase the damage from other "pests." Delaying the planting until May/June (after the aphid flight) increases the stress from rhizomania and decreases seedling establishment due to hot weather. Managing aphids and virus diseases through host-plant resistance, biological control, etc. would greatly benefit sugarbeet production.

ARMYWORMS

Beet Armyworm, *Spodoptera exigua*
Yellow-striped Armyworm, *Spodoptera praefica*

Summary

A major problem for California sugarbeet producers is the beet armyworm, *Spodoptera exigua*, and the western yellow-striped armyworm, *Spodoptera praefica*. Both pests can occur at the same time in sugarbeet fields and can be hard to distinguish. Damage and control measures are similar for both.

Armyworms are a problem in sugarbeets in the summer months. Seedling loss can be significant in the interior valley when planting occurs in June. Damage from armyworms at emergence is loss of seedlings and lower yield. In the Imperial Valley and other fall plant regions, seedlings are sprayed routinely. Seedling loss is more critical as growers continue to eliminate labor for thinning by space planting and planting to a final stand.

Much of the discussion of armyworm and cutworm damage revolves around establishing and maintaining high populations of sugarbeet plants. It has been shown repeatedly, in California and elsewhere, that plant population and yield are highly correlated. Growers have been made aware of this and attempt to manage pests that can cause seedling loss accordingly.

Growers and pest control advisors in the Imperial Valley have noticed greater damage from the postemergence herbicides phenmidipham plus desmidipham (Betamix®) and Betamix® plus ethofumesate (Progress®) following minor armyworm feeding on emerged sugarbeets. It has been suggested that minor feeding damage stresses the young beets enough to cause increased susceptibility to herbicides. This minor feeding damage may also physically compromise the plants' ability to tolerate the herbicide. In order to maintain herbicide control without sugarbeet injury, growers spray insecticide on armyworm populations that, by themselves, would not cause economic injury. The detrimental effect of these herbicides is increased by high temperatures, which typically occur at time of sugarbeet emergence.

Sugarbeet armyworm becomes a more geographically distributed pest later in the season. Older sugarbeets can suffer yield loss from reduction in leaf area by armyworm feeding. This damage occurs in July and August and can continue into September and October. In general, yield loss from armyworm feeding is in direct proportion to the amount of leaf area lost, but this has not been established quantitatively. Increased losses from root rot disease are associated with armyworm defoliation late in the summer. Armyworm feeding provides an entry for fungal pathogens, such as *Rhizopus.* The loss of leaf area increases plant stress and susceptibility to soil pathogens, such as *Phytopthora* and *Pythium*.

The worst armyworm problems develop in the San Joaquin Valley in July and August but can continue through October. Sugarbeets have a dense canopy at this time that is very difficult to penetrate with contact insecticides. Growers have treated five or more times, trying to stop complete defoliation of the crop and subsequent loss of sugar and yield. In many years, spider mites and *Empoasca* leafhoppers reach damaging populations, possibly the result of armyworm control efforts that eliminate all beneficial insects.

Field evaluations over several years indicate that the behavior of the armyworm may be changing. Armyworms are found nearer the crown of the plants as opposed to the outside leaves. More often, crown feeding is occurring with associated complications with root rotting organisms. This may be a result of insecticide selection pressure producing armyworms that are hiding in the dense foliage nearer the base of sugarbeet plants. Older studies on damage thresholds reported by Suh (1980) may no longer apply.

<u>Current Pest Management Practices</u>

<u>*Chemical Controls*</u>: The use of insecticides currently under review by FQPA figures prominently in chemical control of sugarbeet armyworm. Chlorpyrifos (Lorsban®) and methomyl (Lannate®) are interchangeably applied by growers up to five times per year. If a leafhopper problem is increasing, growers will mix methomyl and naled (Dibrom®) to control both pests. Some three- and four-way mixes were used in 1998 to attempt to achieve armyworm control.

Chlorpyrifos and methomyl are the most frequently used insecticides in sugarbeet production. Nearly 35 percent of the base acres were treated with chlorpyrifos and 22 percent with methomyl in 1995, more than any other pesticide. Growers report wide variability in the use of armyworm insecticide from year to year, so the information from a single year is only marginally useful. Growers with a large infestation, any year, have a critical need for insecticides.

While some chlorpyrifos may have been used for black bean aphid control, the majority of use has been targeted toward armyworm control. Control has been variable most years and is perceived by most growers to be declining. Whether this is due to loss of efficacy, a change in the habits of the larvae, or built-up resistance is unknown. Resistance in beet armyworm to these materials has been documented in the southern San Joaquin Valley. Cost of armyworm control can be as high as ten percent of the overall sugarbeet production costs. Production costs vary by growing area but, in general, range between $700 and $1,200 per acre.

The use of biological insecticides has not become established in sugarbeet production. *Bacillus thuringiensis* (Bt) has not been effective late in the season, when armyworm pressure is at its worst. As sugarbeets develop a large canopy, microbials are less effective. Microbial insecticides are only moderately effective early in the season when worms are small. Many growers have tried the many brands of Bt and have decided they are not effective. The biggest advantage is that Bt's do not destroy beneficial insects, a minor consideration for growers when sugarbeets are being defoliated. (See Appendix A, page 51, for rates and areas treated.)

Alternatives: Pest management options are presently limited to insecticide applications. Growers cannot allow the crop to be defoliated by armyworms, nor can they afford to spray needlessly. Information is not available on effective biological controls that are reliable from a grower's perspective. Late season armyworm control is hampered by the dense sugarbeet canopy. Control measures targeted at the moths to prevent egg laying (mating disruption) have more potential in this situation.

Cultural Controls: Researchers at the University of California have done work to establish a damage threshold based on age of plants, percent defoliation, and number of defoliations (Suh, 1980). A four-year study in the late 1970's tested the yield effect of natural and artificial defoliation of sugarbeets. The clover cutworm was used in these studies to do the defoliation. This species does not do any crown feeding but feeds only on the leaves. Sugarbeets six weeks after emergence could tolerate three larvae per plant, at 12 weeks five to ten larvae, and after 12 weeks as many as 15 larvae per plant, as long as damage only occurred once. Significant yield reductions were reported with increasing number of defoliation events. Results from the study were not always consistent and have never been field tested. Field experience has demonstrated that root rot increases with uncontrolled armyworm damage at any level. This threshold has never been used by growers, and the UC Integrated Pest Management guideline for sugarbeets does not mention it.

Biological Controls: Rachael Long, a farm advisor with the University of California, has cooperated with Spreckels Sugar Company research over the past several years to find better ways to manage sugarbeet armyworm. Long has evaluated the use of an armyworm phenology model to predict the need for sprays and to better time sprays. Fourteen sugarbeet fields in three counties were monitored with beet armyworm pheromone traps. Eight of these fields were also monitored weekly for larvae in the fields.

In all cases, the number of moths caught in traps seemed to have little connection with the number of larvae found in fields. This may have been due to biocontrol early in the year by *Hyposoter* wasps, which can be effective parasites of beet armyworms. There may be other predators and parasites that decimate larvae before they become a problem. It may also be explained by moths flying into sugarbeet fields from other hosts. Information is needed about how many moths enter sugarbeet fields from other crops in relation to how many are generated from within fields. A whole farm and regionalized approach to armyworm management will rely on this type of information. Long reported that when moth activity was low (less than three moths per trap per day throughout the season), growers did not need to control worms. If confirmed, this could be useful information for growers.

New information was gathered on the dynamics of beneficial insects in sugarbeet fields. *Hyposoter* wasps also were abundant early in the season and in some cases were 100 percent effective in parasitizing sugarbeet armyworm. Long reported that early treatment with insecticides often removed these beneficial parasites from fields, and armyworms would cause damage and growers would have to spray. Growers who sprayed early had to spray often, sometimes as much as five times.

It was also found that a hyperparasite became abundant in August and decimated populations of *Hyposoter*. As *Hyposoter* declined, sugarbeet armyworm populations increased and growers were forced to spray. Conservation of *Hyposoter* early in the season may be critical to sugarbeet armyworm management.

An inherent problem with biological control is lag time. Rapid defoliation by large populations of armyworms preclude any reliance on biological controls. Growers base treatment decisions primarily on damage. Some of the growers in Long's study treated "damage," even as the armyworm population was declining from parasitism.

Other Issues: Pest management challenges are many. The greatest challenge appears to be regulatory. The loss of chlorpyrifos and methomyl will cause severe hardship on the industry until alternatives are researched and subsequently proven effective to growers.

No proven, low impact control strategy is currently available. We have little information about how biological insecticides might reduce FQPA chemical use or how they may reduce pesticide applications by maintaining beneficial predators and parasites. Armyworm control with insecticides is implicated in secondary outbreaks of spider mites in the San Joaquin Valley and leafhoppers in the Sacramento area. There are several new (some reduced risk) insecticides that are being developed for amyworm control. These are being studied for their applicability to sugarbeets. Registration of any of these products in sugarbeets is uncertain given the relatively small acreage and risk cup calculation.

A big challenge, certainly with current pest management practices, is controlling armyworm populations late in the season within dense sugarbeet canopies.

Growers in California have many cropping options. The industry must find new and better ways of managing pests in order to compete for acreage with other commodities. If pest control options become too costly or complicated, growers will likely move to crops that are "easier" or less costly.

In 1999, the industry began a pest management work plan for the DPR. Preliminary results from this PMA funded project in the Imperial Valley are encouraging. The work group demonstrated the value of a reduced risk approach to seedling armyworm damage that was cost effective and used significantly fewer pesticides applications. Growers in the area were surprised with the results and would like to see further demonstration.

Portions of the current work plan will demonstrate the benefits of delaying pesticide applications to take advantage of the potential control by natural enemies and the effect this delayed and reduced pesticide use will have on secondary pests (mites, leafhoppers, seedling disease). The work plan will also demonstrate for growers and pest control advisors a better way to monitor for armyworms and reduce pesticide use by better application timing.

EMPOASCA LEAFHOPPER

Empoasca fabae
Empoasca solana

Summary

The *Empoasca* leafhoppers, *fabae* and *solana*, are small, wedge-shaped insects that can cause sugarbeet yield loss at large populations. They occur in higher numbers than the sugarbeet leafhopper, *Circulifer tenellus*, and are not known to transmit any disease. Most of the damage is done by high populations of *Empoasca* that feed on the plant sap and inject a toxin that causes yellowing. Feeding causes a symptom called "hopperburn" that can progress from mild stippling and yellowing to complete loss of chlorophyll and leaf death. Damage has been reported in areas of California, and growers are usually quick to apply insecticides to control this leafhopper.

There are many generations per year on sugarbeets. The insect can also be found in alfalfa and beans. The current damage threshold, developed in Tulare County, is 10 to 15 leafhopper nymphs and adults per leaf. Growers are encouraged to use the lower threshold number two to three months from harvest and the higher number for fields within one to two months of harvest. Most growers will not treat within one to two weeks of harvest. Early harvest may even be used in problem fields to avoid treating.

A two-year study was funded by Spreckels Sugar Company in 1995 and 1996 to determine the economic threshold for Northern California. The results were inconsistent, but it appears that the Southern San Joaquin Valley threshold is reasonable for Northern California. High populations of leafhoppers did not develop, so definite conclusions were not made. It was interesting that there was found to be an interaction between beet yellows virus infection and leafhopper damage. Sugarbeets infected with yellows virus suffered greater yield loss to leafhoppers than virus-free plants. An attempt was made to develop more "grower friendly" sampling methods, such as sweep nets and presence/absence monitoring.

The threshold is difficult to apply in the real world because of the quick movement of the nymphs. They prefer the underside of leaves and quickly move to the opposite side when being counted. A tongue-in-cheek threshold: when the grower walks into the field and inhales a cloud of leafhoppers, it's time to treat.

Empoasca leafhoppers cause the most damage in the summer months. Typically, populations increase to damaging levels at the same time sugarbeet armyworm is being treated, July and August. Treatments are usually the same as those used for armyworms. Growers periodically treat for leafhoppers alone. Methomyl (Lannate®) and naled (Dibrom®) have been a good combination for growers attempting to control both leafhoppers and armyworms. Chlorpyrifos (Lorsban®) has been used, and methamidophos (Monitor®) was used when it was still available. Some small scale plots in the Davis area showed that mites can become a problem after leafhoppers are treated with

methamidophos. Whether this is true of some of the other insecticides is unknown. (See Appendix A, page 51, for rates and areas treated.)

As with armyworm control, the dense canopy limits the effectiveness of chemical applications, as does the tendency for the insects to remain on the underside of leaves. Multiple sprays may be needed, particularly if sugarbeets are near crops such as alfalfa or beans.

Growers throughout the state have experienced damaging populations of *Empoasca* leafhoppers. Loss of sugar content rather than tonnage is reported by spring harvest growers. Fall harvest growers can suffer both sugar content and tonnage reduction.

Current Pest Management Practices

Chemical Controls: Control of the damaging effects of *Empoasca* leafhoppers relies on chemical tools, many of which are targets of FQPA. Growers rely on many of the same insecticides used for armyworm control, but on occasion will treat solely for leafhoppers. The choice of armyworm insecticides and even the decision to treat for armyworm is influenced by leafhopper populations. Growers monitor both pests and spray for the combination, even if neither pest by itself would be damaging.

Alternatives: None known.

Cultural Controls: Early harvest is the only practiced form of cultural control. No host plant resistance is known and none is currently being investigated. Host plant resistance has been considered, but other priorities have commanded the attention of plant breeders. The loss of chemical tools may shift emphasis toward host plant resistance.

Biological Controls: None known.

Other Issues: None known.

FLEA BEETLES

Epitrix spp.

Summary

Flea beetles, primarily *Epitrix* spp., can be important pests of sugarbeets. These pests feed on seedling beets at the time of emergence or even slightly before the emergence of the seedling through the soil. Flea beetles are recognized sugarbeet pests in the Klamath Basin and in many cases must be controlled in order to establish a stand. The production of potatoes in this area many contribute to the populations of flea beetles since the tuber flea beetle feeds on potatoes and can occasionally be a pest of sugarbeets. Flea beetles are not a known pest in the other production regions but may be a component of the complex causing poor seedling establishment. This is presently being researched, and no conclusions have been obtained yet.

Flea beetles overwinter as adults in crop residue and in soil cracks. As the temperatures warm in the spring, they emerge and are voracious feeders. This corresponds with the planting and emergence of beets in the Klamath Basin. The flea beetles clip the seedlings as they emerge. The adults deposit eggs in the soil and the resulting larvae feed in roots. The larval damage is not known to cause any problems in sugarbeets. There are two flea beetle generations per year.

Current Pest Management Practices

Chemical Controls: Insecticidal controls are used for flea beetles management in the Klamath Basin. Imidacloprid (Gaucho®) seed treatment, aldicarb (Temik® granular) at planting, and carbaryl (Sevin XLR Plus®) are the most effective treatments. Several other foliar treatments as well as phorate (Thimet® granular) have been evaluated with poor to moderate results. (See Appendix A, page 51, for rates and areas treated.)

Alternatives: Seed treatments with low dosage of insecticides. The use of low dosage seed treatments (imidacloprid) could result in reduced foliar and soil treatments.

Cultural Controls: No cultural controls are available for flea beetles. Minimizing crop residue, fencerow vegetation, etc. would, in theory, remove the overwintering sites, but this really is not practical to the extent needed. The beetles are quite mobile and can disperse over a wide area. Maximizing sugar beet seedling growth so the seedlings will move through the susceptible stage is important. Once the seedlings have two true leaves, the flea beetles do no significant damage. Unfortunately, in the Klamath Basin early-season sugarbeet growth is frequently limited by environmental conditions and is beyond control.

Biological Controls: None known.

Other Issues: If fully enacted, the outcome of FQPA would result in only imidacloprid being available. Since imidacloprid is a seed treatment, this would be a totally preventative program. The present system utilizes both preventative and as-needed, foliar treatments. This range of treatment strategies is a positive force in terms of IPM.

There is a lack of understanding of flea beetle population dynamics, factors influencing flea beetle density, possible biological control, etc.

Prediction of fields with damaging flea beetle populations has been difficult.

SPIDER MITES

Two-Spotted Spider Mite, *Tetranychus* spp.

Summary

Spider mites, especially two-spotted spider mite (*Tetranychus* spp.), have on occasion (the latest being Crop Years 1995 and 1996) been a severe problem in sugar beets, especially in the Fall

Plant/Summer Harvest Areas of the San Joaquin Valley. Mites feed on leaf surfaces and reduce the photosynthetic capacities of the plant. Mite colonies can reduce sugar and tonnage.
It is not fully understood why the problem occasionally occurs; however, shifts in planting dates relative to cotton, milder weather, the use of broad spectrum pesticides, and mite resistance to miticide are probable causes for the outbreaks.

Current Pest Management Practices

Chemical Controls: Various populations of two-spotted spider mite have been shown to be resistant to propargite (Comite®), fenbutatin-oxide (Vendex®), and dicofol (Kelthane®). These are the primary acaricides that have been used for 20 to 40 years to control spider mites in crops throughout the San Joaquin Valley. Newer acaricides such as abamectin (Zephyr®) have been registered in cotton, ornamentals, and strawberries, but are not registered in sugarbeets. Currently, sugarbeet growers have available sulfur and the organophosphate naled (Dibrom®) for spider mite control, and both products are relatively ineffective in controlling two-spotted spider mite. Efforts are underway to obtain registration of additional acaricides for sugarbeets. Information is needed to determine if sugarbeet spider mites are resistant to older acaricides such as propargite. For newer acaricides such as abamectin, even if a registration is obtained for sugarbeets, there is the potential for resistance to develop because abamectin is already being used heavily in neighboring crops such as cotton. Thus, sugarbeet growers need a long-term solution to the management of spider mites that reduces their dependence on acaricides.

Alternatives: Resistance management for spider mites is a key element in sugarbeet IPM. Successful programs with spider mites have been demonstrated worldwide, and resistance management has been developed in California cotton. The key is applying materials only when needed as determined by scouting, using sound treatment triggers, rotations of materials and rotating between materials with varying modes of action. For example, in cotton, even though resistance to propargite and fenbutatin-oxide exists in spider mites, susceptibility is being maintained by limiting applications to once per year per compound and using abamectin. Key to spider mite resistance management in sugarbeets will be the availability of products with different modes of action. The lack of these compounds only hastens the resistance problem.

Spider mite outbreaks are related to seasonal factors, regional cropping patterns, and insecticide use in the surrounding area. Knowledge of these factors is very limited but could provide the keys in developing areawide, multiple crop management programs. Current understanding is very limited, and more thorough studies will be required.

Cultural Controls: None known.

Biological Control: Biological control of spider mites using predatory mites such as *Galendromus occidentalis*, *Neoseiulus californicus*, and *Phytoseiulus persimilis* has been very successful in various tree crops, greenhouse vegetables, strawberries, and vines. Research is needed to see what species of predatory mites are currently found in San Joaquin Valley sugarbeets and to determine if springtime augmentative releases could be used to manage spider mites problems.

Other Issues: None known.

E. WEED MANAGEMENT

Summary

Sugarbeets are a relatively long-duration crop in comparison with many other row crops. In some regions of the Central Valley and in the intermountain production region, the crop may be harvested in five to six months after seeding; but in other regions, such as the Imperial Valley, the crop is grown through the winter and harvested in the spring after about eight to ten months' growth. In certain regions of the Central Valley, sugarbeets are planted in the late spring and then harvested the following spring (the beets are said to be overwintered) and are in the ground for about 12 months. This means that weeds must be controlled for relatively long periods, which may span two or three climatic seasons.

Weed populations in sugarbeet fields differ by season and location in the state. From October to February, during stand establishment until layby, winter annual weeds such as mustard, chickweed, shepherdspurse, sowthistles, volunteer cereals, annual ryegrass, and annual bluegrass can be troublesome. Winter annual weeds die out in summer, but summer annuals begin germinating in March and continue throughout the summer growing season. Summer annual weeds that are often problems include barnyardgrass, johnsongrass, nutsedges, pigweeds, lambsquarters, common purslane, nightshade, velvetleaf, and knotweed. Again in fall, overwintered beets can become infested with winter annuals such as mustard species and wild oat.

The sugarbeet plant is a poor competitor against weeds. Uncontrolled weeds that emerge with the crop typically cause from 50 to 90 percent yield loss. Increasing weed density causes increasing magnitude of yield loss. As few as one or two weeds, such as barnyardgrass every five to ten yards of row, still cause economic loss. Little is known about the losses caused by other weed species under California conditions. Weeds present late in the season can hinder harvesting operations. High levels of weed control are essential for profitable sugarbeet production.

Many weeds and volunteer sugarbeets from previous crops may host diseases (e.g., beet yellows virus, curly top virus), insects (e.g., black bean and green peach aphid), and nematodes (e.g., sugarbeet cyst nematode) and thus act as sources of infestation for the sugarbeet crop. To reduce the risk of infestation, weeds and escaped volunteer beets in or around sugarbeet fields must be controlled as part of an IPM program. Weeds known to be hosts of sugarbeet cyst nematode should be controlled in rotation crops.

Current weed management programs rely heavily on herbicides in the general class of carbamates. The herbicides EPTC (Eptam/Genep®), used at layby for late season control of many grass and broadleaf weeds, pebulate and cycloate (used preplant incorporated [PPI] for control of grass weeds and many broadleaf species) are all thiocarbamates. Economics have shown that the use of one of the latter two herbicides is essential to profitable production of the spring-sown crop. The herbicides phenmedipham and desmedipham, which are bis-carbamates, are used postemergence alone or in mixture for control of annual broadleaf weeds in all sugarbeet production regions of the state. There is no alternative postemergence herbicide that could replace these chemicals. With the currently

available alternative herbicides, it is thus likely that profitable sugarbeet production would not be possible in California due to increased losses to weeds and increased costs of weed control if the use of carbamate herbicides were canceled or suspended.

Current Pest Management Practices

The extended planting period, the long duration of the crop, the various growing regions in the state, differing weed spectra, and the lack of competitive ability mandate that an integrated program approach be taken for weed management. The current program integrates use of cultural, mechanical, and chemical controls. Cultural controls include varieties that are resistant to pathogens, and correct fertilizer and water use to ensure a vigorous crop can suppress late emerging weeds. Rotations are used to control perennial and other weeds that currently cannot be controlled in sugarbeets. Mechanical control includes use of between-row cultivation, mechanical thinners, and hand hoeing.

Selection of the best weed management program is governed by the following factors:

- Geographic location: determines planting date, weed spectrum, irrigation/rainfall pattern.
- Date of planting: determines weed spectrum, irrigation/rainfall. The latter then determines the feasibility of cultivation on a timely basis.
- Weed species present (or anticipated to be present): determines choice of weed control method and choice of herbicides.
- Availability/cost of hand labor for weeding: determines if hand weeding can be considered as part of the program.
- Availability of equipment: determines how well cultivation can be conducted and if required herbicides can be applied accurately and, if needed, properly incorporated into soil.
- Method of irrigation: determines choice of herbicide and influences cultivation.

Chemical Controls: A typical weed management program may include a preplant incorporated herbicide or a pre-emergence herbicide at planting, an early postemergence herbicide, and possibly a layby herbicide application. Omitting any one of these applications often results in less than optimum weed control. Economic analyses of various combinations of herbicides have demonstrated that inclusion of a PPI herbicide (cycloate) in the program for spring planted sugarbeets is essential to avoid decreased net return or even net loss.

Several herbicides are registered for selective weed control in sugarbeets, but no single chemical controls all weeds that infest sugarbeet fields. Frequently, two or more herbicides must be combined sequentially or as tank mixes to achieve adequate broad spectrum weed control.

Herbicides used for sugarbeets are typically applied as bands centered on the crop row. Width of the band applied depends to a considerable degree on the capability to conduct close cultivation. Narrower herbicide bands can be utilized if close cultivation can be achieved. This has advantages in cost reduction and also places less herbicide into the environment.

Herbicides available for weed management in sugarbeets have been grouped according to time of application. (See Appendix B, page 52, for rates.)

(A) Preplant and pre-emergence herbicides: Preplant foliar: Postemergence herbicides such as paraquat (Gramoxone®) and glyphosate (Roundup®) are used to kill emerged weeds on preformed beds before planting sugarbeets. This has no direct bearing on the in-crop weed management. Paraquat has contact action only and is thus most effective on young seedlings. Glyphosate has systemic action and is thus effective on established weeds. A few species, such as mallows *(Malva* spp.), are tolerant to this herbicide and are not well controlled by it. Care should be taken to ensure that either chemical does not drift off the target field.

(B) Preplant incorporated: Preplant incorporated herbicides must be physically mixed (incorporated) into the soil soon after application to prevent volatilization of the chemical and to move the herbicide into the root zone. These herbicides perform best when incorporated with a power driven rotary tiller.

(C) Pre-emergence: Pre-emergence pyrazon (Pyramin®) or ethofumesate (Nortron®) treatments are not effective unless incorporated by light rainfall or sprinkler irrigation (less than 0.5 inch). Apply less than 0.75 inch of sprinkler irrigation per set following pre-emergence application of pyrazon until the beets have four true leaves as the herbicide may be leached into the seedling root zone and cause injury to the crop. Under furrow irrigation, physical incorporation of the herbicides is required.

Endothall (Herbicide 273®) is water soluble and not bound to soil particles. It thus moves readily with water and performs erratically when applied preplant or pre-emergence unless irrigation is absolutely uniform.

(D) Postemergence herbicides: Phenmedipham plus desmedipham (Betamix®) is the current standard treatment for postemergence control of most annual broadleaf weeds. It is mixed with other herbicides to obtain broader spectrum control.

Endothall provides postemergence control of several weeds, such as fiddleneck, knotweed, smartweed, and volunteer cereals, that are difficult to control with other herbicides. Thorough coverage is essential. Endothall will usually have to be applied in combination with another herbicide, such as phenmedipham plus desmedipham, if broad spectrum weed control is required. Endothall responds to temperature; best results have occurred when volunteer cereals were treated during periods of occasional frost. Control has been erratic, and the risk of phytotoxicity to sugarbeets increases in warm weather.

Inadequate control following postemergence use of pyrazon occurs when weeds at application were beyond the two- to four-leaf stage or when applied in warm weather (over 701 to 761F) and not irrigated within two or three days. Irrigation following application is essential for best results because the herbicide must be moved into the weed root zone. The likelihood of crop injury increases in warm weather.

If pigweed is the predominant broadleaf weed present, application of desmedipham (Betanex®) will provide slightly greater control than phenmedipham plus desmedipham. The combination of phenmedipham, desmedipham, and ethofumesate (either as a tank mix of Betamix® plus Nortron® or as Progress® premix) improves control of difficult to control weeds such as common knotweed.

Sethoxydim (Poast®) can be used for postemergence control of grass weeds. It must be applied with an oil concentrate adjuvant to obtain satisfactory activity. This herbicide should not be mixed with any other herbicide; mixtures with phenmedipham plus desmedipham have resulted in decreased grass control. Control is often erratic because of lack of soil activity.

(E) Application timing: Young weeds are more readily controlled than older weeds. It is estimated that for every day in delay of application of phenmedipham plus desmedipham passed the optimum, a one to two percent reduction in control resulted. Phenmedipham plus desmedipham or phenmedipham plus desmedipham plus ethofumesate (Progress®) give erratic control when applied to weeds larger than cotyledon to early two-leaf stage of growth.

(F) Multiple applications: Split applications of phenmedipham plus desmedipham or phenmedipham plus desmedipham plus ethofumesate about seven to 12 days apart with the first application to cotyledon stage beets and weeds. Multiple application increases weed control and reduces injury to sugarbeets; the first application must not exceed 0.5 pounds per acre. Multiple applications of triflusulfuron methyl (UpBeet®) are essential in order to control weeds like velvetleaf. Application must start at the cotyledon to one-leaf growth stage of the weed. Three applications may be required for satisfactory control.

(G) Layby herbicides: Trifluralin (Treflan®) or EPTC can be applied to the furrows and bed shoulders just prior to canopy closure (layby) to provide seasonlong control until harvest. Neither herbicide has any activity against established weeds; it is thus essential that the field be weed-free at the time of application of these herbicides. Both herbicides must be physically mixed into the soil (incorporated) immediately after application, or they must be applied in the irrigation water. (See Appendix B, page 52, for rates.)

Alternatives: The use of transgenic sugarbeets resistant to glyphosate or glufosinate (Liberty®). Both of these herbicides are environmentally and toxicologically benign and thus appear to offer alternatives to current herbicides when they are registered for use in California. Extensive reliance on either of these herbicides has the drawback that a weed flora will develop that is resistant to them if also used on rotational crops.

Cultural Controls: (A) Field selection/seedbed preparation: Most perennial weeds are difficult to control in sugarbeets. Avoid fields heavily infested with johnsongrass, nutsedges, and field bindweed. Some annual weeds, such as sunflower, cocklebur, velvetleaf, and wild beets, are difficult to control economically in the sugarbeet crop, and heavily infested fields should also be avoided.

Uniform beds with accurate row spacing are essential for precision cultivation and to permit application of narrower bands of postemergence herbicides. The degree to which precision cultivation can be performed is established at the time of initial bed preparation.

Clean all field equipment before entering a new field if the previous field in which the equipment operated was weedy. Sugarbeet diggers, for example, have great potential to carry weed seeds, tubers, etc., from field to field.

A well prepared seedbed that is free of large clods permits precision planting with more rapid and uniform emergence of beet seedlings. Uniform seeding depth is critical when using preplant incorporated herbicides as increased depth of seeding can result in increased phytotoxicity to the seedlings. Well prepared seedbeds also permit proper and accurate incorporation of preplant incorporated herbicides, leading to improved weed control.

(B) Planting date: Date of planting determines the weed spectrum that can be anticipated. Weed management programs must be adjusted to reflect the weed species that can be expected to grow. Climatic limitations are also important for certain planting dates. It may, for instance, be difficult to cultivate a fall-sown crop during the winter in the Sacramento Valley.

(C) Preirrigation: Unless winter rains occurred, beds should be preirrigated before seedbed preparation. Preirrigation followed by cultivation improves the tilth of the seedbed and permits better mechanical incorporation of preplant herbicides. Preirrigation is particularly useful following barley, wheat, oats, sorghum, or safflower crops to germinate the volunteer crop prior to seeding the sugarbeets. The beds should be shallow cultivated after the weeds and volunteer crop seedlings emerge. Paraquat or glyphosate may be used in place of cultivation on preshaped beds. In sprinkler-irrigated fields where pre-emergence herbicides are used, preirrigation reduces the amount of water needed to germinate the crop. This can improve the activity and selectivity of herbicides because less water is required to germinate the crop.

(D) Crop rotation: Weeds are less troublesome if beets are planted following tilled row crops and are more troublesome following pasture, alfalfa, broadcast-planted safflower, sorghum, or any other crop in which weeds were allowed to mature and set seed. Rotation allows reduction of populations of weeds that are difficult to control in sugarbeets, such as velvetleaf. Rotation also permits control of perennial weeds that can be troublesome in sugarbeets, such as field bindweed.

(E) Mechanical: Cultivation is an effective method for between-row weed control. It is essential that bed shaping and planting be accurate in order to permit close, or precision, cultivation. Repeated shallow cultivation will dislodge small weed seedlings that emerge after each irrigation. Timeliness in cultivation is essential; seedling weeds are much easier to kill than older established weeds. Cultivation can be performed until the beet leaf canopy closes over the furrow.

Weed control by cultivation must be coordinated with irrigation scheduling. Wet soil can prevent the use of cultivation equipment at the optimum stages of weed growth. Timing of irrigation following cultivation can also be critical. Irrigation too soon after cultivation can lead to rerooting of weeds, such as purslane. Wet soil in winter may delay, or even preclude, cultivation for weed control. This possibility must be considered when designing a weed management program for fall-planted beets.

None of the above cultural techniques provides complete weed control, but all are part of an integrated weed management program.

Hand weeding (pulling or hoeing) is still necessary in many situations and should be included as part of a long-term weed management program. However, attempting to rely on hand labor without herbicides is not economically feasible. Studies between 1994 and 1998 at UC Davis for the spring plant/fall harvest crop have shown hand hoeing times without herbicides varied between 40 and 100 hours per acre. At $6.50 an hour, this translates to between $260 to over $650 per acre. Thus, it is not possible to produce an economically viable crop in the absence of herbicides for in-row weed control.

Biological Controls: Biological control of weeds that infest sugarbeets is inadequate to provide economic weed suppression. Purslane, for example, is attacked by two leaf miners. Attack by these two insects can lead to complete defoliation of the weed, but this defoliation only resulted in reduction in competitive ability of the weed in one of four years. Although insects or pathogens attack other weed species to a limited extent, there is no evidence that such attack provides economic control of the weeds.

Other Issues: None known.

F. NEMATODE CONTROL

Sugarbeet-Cyst Nematode, *Heterodera schachtii*
Root-Knot Nematode, *Meloidogyne spp.*

Summary

The sugarbeet-cyst nematode (SBCN) *Heterodera schachtii* and/or root-knot nematode (RKN) *Meloidogyne* spp. occur in many sugarbeet fields in California and cause significant yield losses. Historically, the use of l,3-dichloropropene (Telone II®), a B2 carcinogen, has been the nematicide of choice. Following the suspension of l,3-dichloropropene in California (April 1990), a study was conducted by SRI International to assess the influence of the suspension on agricultural production in California. Accordingly, SRI International estimated that because l,3-dichloropropene was not available, increased yield losses in sugarbeets due to nematodes in 1991 vs. historic average losses were $6.1 million, and that increases in other nematicide treatment costs in sugarbeets were $16 million (Landels, 1992). Renewed use of l,3-dichloropropene in California has only recently been approved, and on a very limited scale.

The first recorded nematode pathogen of sugarbeets was SBCN, and it remains a primary pathogen throughout California (Altman & Thomason, 1971; Cooke, 1993; Roberts and Thomason, 1981). SBCN is common and is a significant problem in most areas of the world where sugarbeets are grown (Potter and Olthof, 1993). The SBCN has hosts in a range of plant families, approximately 200 hosts in 98 genera from 23 of 49 families investigated by Steele (1965). Of the agronomic crops that are known hosts, most occur within the Chenopodiaceae (sugarbeet, fodder beet, red beet, mangolds, and spinach) and the Cruciferae (cabbage, kale, Brussels sprouts, broccoli, cauliflower, turnip, kohlrabi, mustard, and radish).

In 1978, more than 200,000 acres in California were reported infested with the SBCN (Roberts and Thomason, 1981). SBCN is thought to have been brought into California many years ago and to have been accidentally distributed throughout much of the older sugarbeet growing areas. It is not prevalent north of Yolo and Sacramento Counties or in the Tulare, Kings, and Kern growing areas. Elsewhere, it is considered the major nematode problem on sugarbeets. Several species of RKN are widely distributed throughout all sugarbeet growing areas, and the nematode is known to cause damage in most. In all regions other than the Tulelake Basin, populations consist primarily of four species, with some species containing several races: *M. incognita, M. hapla, M. javanica* and *M. arenaria* (Siddiqui et al., 1973). Approximately 80 percent of the time that identifications are made, *M. incognita* is present. The remainder of identified RKN are divided among the other three species. It is possible for mixed populations of RKN species to occur in a single field. In the Tulelake Basin, populations of RKN are predominately *M. chitwoodi* but also include *M. naasi* and *M. hapla*. Sugarbeets are a new crop for the Tulelake Basin. They are known hosts for the RKN species present, but major losses have not yet been attributed to those nematodes.

The RKN and SBCN are considered, respectively, to be the first and third most important plant-parasitic nematode in the world (Eisenback and Triantaphyllou, 1991; Sasser and Freckman, 1987). Because of its importance on sugarbeets, considerable research on SBCN has been conducted in California (Baldwin and Mundo-Ocampo, 1991; Caswell and Thomason, 1991; Gardner and Caswell-Chen, 1993, 1995; Lear et al., 1966; Roberts, 1985; Roberts and Thomason, 1981; Roberts et al., 1980; Steele, 1984).

Historically, both crop rotation and nematicides have been used to control SBCN (Altman and Thomason, 1971; Cooke, 1993) while RKN control has been mainly via chemical nematicides. Typically for SBCN, rotations of three years or longer are required to reduce SBCN populations to levels below the damage threshold. Rotations in Northern California appear to be less successful than in southern growing areas, with rotations of eight to ten years being necessary in many instances. It is suspected that this is, at least partially, due to poor weed management during rotations. This extended rotation period results in relatively few acres being available each year for sugarbeet production. Consequences for the industry have been severe in recent years because each processing plant needs to draw from a minimum number of acres to operate efficiently.

Nematodes are microscopic roundworms with a life cycle consisting of an egg, four juvenile (J) stages, and the sexually mature adult stage. In SBCN, the second-stage infective juvenile (J2) hatches from the egg, is attracted to host roots by exudates, penetrates a host root, and establishes a permanent feeding site. The nematode feeds and grows to the adult stage, with the adult female retaining most of the eggs (up to 600) internally. The female body hardens after death, protecting the eggs from adverse environmental conditions (Roberts and Thomason, 1981). Activity, reproduction, and development occur between 8-35°C, and reproduction is most rapid between 21-27°C (Thomason and Fife, 1962; Caswell and Thomason, 1991). The developmental periods from J2 to J3, J4, adult, and the next generation J2 have been found to be 100, 140, 225 and 399 degree-days (base 8°C), respectively (Griffin, 1988, Caswell and Thomason, 1991). Cysts containing eggs persist in soil for many years in the absence of a host. Although the presence of host roots stimulates egg hatch, a certain number of eggs hatch each year, even in the absence of a host, resulting in a slow decrease in viable eggs.

For RKN, the invasive J2 hatches from the egg and seeks a feeding site within a root (Roberts and Thomason, 1981). The juvenile molts to the J3 and begins enlarging as the reproductive system develops. Nematodes that become females are no longer mobile, and are unable to leave the root. They continue to enlarge as they go through the J3 and J4 stages. During this time, cells around the head of the nematode enlarge to form nurse cells or giant cells. For RKN, galls will typically develop on the root. Upon becoming adults, RKN will begin to lay eggs (up to several hundred) which are contained in a gelatinous matrix at the posterior end of the body. The egg mass may be within the root or partly or wholly exposed on the root surface while the swollen body of the female remains within the root. Adult males are rare in RKN and not required for reproduction. In SBCN, males are more common and are required for reproduction. It has been shown that males become more plentiful when food sources are limited.

Temperature is also an important factor in the development of species of RKN. In those RKN species studied, approximately 600 degree days are required per generation. However, the minimum temperature for infection and reproduction vary considerably between species, which affects the overall length of time per generation and number of generations per growing season in different areas of the state. For example, the minimum temperatures for infection by *M. chitwoodi*, *M. hapla*, and *M. incognita* are 6, 12, and 18°C, respectively. The minimum levels for reproduction are 6, 12, and 10EC, respectively.

Current Pest Management Practices

Nematode management options include: nematicides, growing nematode resistant cultivars, growing nonhost primary crops (rotations), growing nonhost cover crops, using fallow periods, enhancing natural biological control, and implementing cultural practices (Thomason and Caswell, 1987).

Chemical Controls: The following chemicals are registered for nematode management in sugarbeets: 1,3-dichloropropene, aldicarb (Temik®), chloropicrin, metam-sodium (e.g. Vapam®) and DiTera® (a toxin produced by a fungus). (See Appendix A, page 51, for rates and areas treated.)

Alternatives: Effective nematode management requires combinations of tactics, and the tactics are selected relative to the nematode species, crop possibilities, environmental conditions at a given location, and potential economic impact. For example, if a nematicide is registered for a given crop, the grower may decide to use it if it is effective against the nematode in question and an (often intuitive) economic cost-benefit analysis is positive. Alternatively, the use of cultivars resistant to the main nematode species in a field is often effective. Frequently, however, there are several damaging species present, and cultivars with resistance to multiple nematode species are not available. In addition, nematode species differ in their host ranges, and plants differ in their host status to various nematodes. These differences are the basis for crop rotation sequences. After defining what nematodes are present in their fields, growers may consult nematological "experts" to reach a management decision. Even the "experts" have a difficult time constructing a decision given the volume of information that should be considered. Because of this, at the present time, there is little integration among the various control methodologies. Development of a knowledge-based system is needed to make integration a reality.

Cultural Controls: Relatively unsophisticated rotation to nonhost crops is the major cultural practice in use for SBCN management. For SBCN, this includes crops other than cole crops and mustard. The species of RKN found throughout the major sugarbeet growing areas have very broad host ranges. Nematode-resistant processing tomatoes containing the *Mi* gene would be a typical nonhost rotation crop for several species. At the present time, biological control and mechanical methods are not utilized in nematode management on sugarbeets.

Biological Controls: None known.

Other Issues: Because of the stringent nature of the Food Quality Protection Act (FQPA), replacement pest management systems are badly needed for the sugarbeet industry. Historically, a B2 carcinogen, 1,3-dichloropropene, has been the most widely used nematicide in sugarbeet production. The second most widely used nematicide has been the carbamate aldicarb. The use of 1,3-dichloropropene in California was suspended for several years because of human exposure to nematicides due to off-site movement in the air. Although its use has been reinstated, it is under constant evaluation, has increased significantly in cost, and could be suspended again at anytime if detected in the air above California--even at parts per trillion levels. If for any reason (such as FQPA evaluation) 1,3-dichloropropene and aldicarb become unavailable, growers are left with only three registered products: metam-sodium, chloropicrin, and DiTera®. None of these products has been tested extensively enough on sugarbeets to allow prediction of efficacious methods of application. In addition, both metam-sodium and chloropicrin pose significant hazards for human exposure due to off-site movement.

G. DISEASE CONTROL

CURLY TOP

Sugarbeet Leafhopper, *Circulifer tennellus*

Summary

Curly top disease has caused losses to sugarbeet, tomato, bean, cucurbits, and several other plants since its discovery in the U.S. in 1888. Curly top is widespread throughout the arid and semiarid western U.S. In California, curly top epidemics have occurred periodically on the west side of the San Joaquin Valley between Stockton and Bakersfield and in the Sacramento Valley. A new production area between Tulelake, California, and Klamath Falls, Oregon, has been found to be an area with high potential for curly top.

The beet leafhopper is the only important vector of curly top. Beet leafhoppers have an extensive host range, produce many generations under favorable conditions, and can move great distances to locate new host plants. Leafhoppers acquire the virus in as little as one to two minutes of feeding time on an infected plant and retain the virus for months. Transmission can occur in less than four hours after acquiring the virus.

Spring harvest growers are particularly susceptible to curly top disease. The specter of virus yellows disease dictates that these growers plant after the weather warms. Unfortunately, with warming temperatures, the foothill weeds that harbor the disease-carrying leafhoppers die. The leafhoppers then migrate to the valley floor and infect seedling sugarbeets, resulting in yield reductions corresponding to level of infection.

Many weeds are reservoirs for the disease. There are 44 plant families and more than 300 species of plants that are hosts of curly top. Filaree, Russian thistle, mustard, plantain, and several others are important in California. The predominant method of control relies on these foothill weeds. As the foothill hosts begin to die, the leafhoppers congregate on the remaining weeds. These concentrated leafhopper pockets can then be efficiently sprayed and eliminated before moving to crops in the valley.

Current Pest Management Practices

Chemical Controls: Curly top management in California relies on an integrated approach that includes a unique, cooperative spray control program supported by several commodities. Populations of leafhoppers are sprayed with malathion as they congregate on "green" plants remaining in the drying foothills. It is common for this spray program to reduce populations by 95 percent.

This program has been in existence since 1943 and has been effective most years. Notable exceptions were severe outbreaks of curly top in 1950 and 1966. This was the result of extremely high leafhopper populations in those years.

The Curly Top Virus Control Program (CTVCP) is supported by an assessment on sugarbeet, bean, melon, tomato and several other crops. The CTVCP monitors leafhopper populations and issues bulletins to growers describing the yearly curly top potential. Growers are advised on cultural practices that will aid in controlling the spread of curly top and damage to crops. Weed control on ditchbanks and abandoned areas is stressed to keep preferred host weeds off the valley floor. High populations of leafhoppers are noted, and growers are advised of the need and benefits of systemic insecticides on crop plants.

The use of phorate (Thimet®) as a treatment for prevention of curly top began in the 1960's. The insecticide is placed several inches below the seed at planting. A threefold reduction in curly top infection was common with this treatment. Spreckels' research over several years has confirmed this as a cost effective means of curly top control. It is still recommended today, particularly if the CTVCP issues warnings that leafhoppers are likely to invade cropland. The cost of the chemical and application is cheap, and most growers in curly top prone areas consider the application good insurance against the disease. (See Appendix A, page 51, for rates and areas treated).

Alternatives: There have been conflicting reports of the effect of imidacloprid (Gaucho®) on curly top control. The low use rate, 45 grams per acre, would make this an exceptionally good alternative to both malathion and phorate. Imidicloprid also has low mammalian toxicity and is applied to the seed, which is then coated with a polymer. Contact with the chemical (worker exposure) would be minimal. Positive results with imidicloprid could be applied to other commodities plagued by curly top.

Cultural Controls: Since the 1940's, resistance has been incorporated into sugarbeet varieties. This has been very successful. The introduction of rhizomania into California in 1983 resulted in many new varieties to combat this new threat. In the rush to get rhizomania resistance, curly top resistance was secondary. Many of the first rhizomania resistant cultivars were susceptible to curly top.

Rhizosen, one of the first rhizomania resistant varieties, was quickly abandoned by growers because of susceptibility to curly top. Currently, growers have available varieties tolerant to both diseases.

Curly top virus exists in many strains. Strains have differential reactions on different host plants. Most produce symptoms on susceptible sugarbeets, and some produce symptoms on "resistant" sugarbeets. The existence of curly top strains is of concern to the industry. Seed variety evaluation committees composed of growers and processor representatives regularly assess the curly top resistance of varieties to be planted in the state. Even a highly resistant variety will suffer yield loss if infected in the seedling stage.

Changing land use patterns can have a major effect on the current control program. The drought years of 1986 through 1992 led to the abandonment of cropland on the west side of the valley floor. Weed hosts, particularly Russian thistle, invaded this area and proliferated. In effect, this brought prime overwintering habitat of the leafhopper close to the agricultural areas. It also spread out the areas where leafhoppers could breed and congregate, thwarting the spray program. Growers reacted by protecting new sugarbeet plantings with systemic insecticides.

Growers attempt to plant at a time when leafhoppers are absent. Factories rely on sugarbeets throughout the year. Plantings in May are needed to supply factory operations the following April and May. Therefore, many growers are forced to plant in May, a time when the potential for curly top is high. Other growers can plant in the winter and avoid curly top infection without any other control means. Many years ago, that was the only control practice growers had available.

Growers' attempts to plant to stand are integrated with curly top and plant populations. High plant populations must be maintained at the same time seed is space planted. Because sugarbeet leafhopper is a desert insect, it prefers gappy stands and low plant populations. Growers planting to stand run the risk of low plant populations (if seedling problems occur), resulting in gappy stands that are attractive to sugarbeet leafhoppers.

Biological Controls: The CTVCP is investigating the introduction of predators and parasites for control of sugarbeet leafhopper.

Other Issues: One of the obvious threats to the curly top program is the loss of phorate and malathion. Both insecticides are pivotal for continued field and regional scale management. The immediate challenge, in light of the FQPA, is to demonstrate to growers that imidicloprid is an acceptable replacement for phorate in the field.

The challenge for regional control of leafhopper will shift to biological controls. Predators and parasites must be found that are effective in reducing leafhopper populations below levels that will cause economic loss. Part of this challenge will be to find the funds to search for new biological controls wherever they may be.

Land use issues are a concern to the industry. Intermittent use of cropland on the west side of the San Joaquin Valley increases summer hosts (Russian thistle) of sugarbeet leafhopper. Overgrazing of land in this area increases winter hosts, such as plantain and peppergrass, of sugarbeet leafhopper.

An increase in either will lead to greater and more widely dispersed populations of sugarbeet leafhopper.

Regulatory issues, beyond FQPA, are impacting the CTVCP. Environmental Assessment (EA) must be made every five years before the BLM and DOT will allow spraying of leafhopper hotspots on land owned by either agency. This process becomes more difficult each year. The presence of the California red-legged frog and elderberry longhorn beetle (speculated) has imposed severe restrictions on spraying many areas. The U.S. Fish and Wildlife Service has proposed that money used for spraying and for research into parasites for leafhopper control be used for water monitoring and pesticide drift assessment. If this erosion of a program that has worked for 50 years continues, several commodities will be searching for curly top management options.

POWDERY MILDEW

Erysiphe polygoni

Summary

Sugarbeet powdery mildew was unknown in the United States until the pathogen was reported in a single field in California in 1934. The disease was not again reported in this country until it became epidemic in 1974. In April of that year, the disease became widespread in the Imperial Valley of California. By September, the malady had spread all the way to Sidney, Montana; and by the following year, the disease occurred in all sugarbeet production areas of the United States.

Powdery mildew is a fungal disease. The causal fungus is called *Erysiphe polygoni*. It is related to the fungi that cause powdery mildews on grain and other crops. The fungus produces spores called conidia. The conidia blow in the wind, and some will land on sugarbeet foliage. The conidia then germinate and start growing. The fungus grows vegetatively by producing strands called hyphae. The hyphae first appear in small circular areas of the leaf, growing superficially on the surface. As the hyphae grow, these areas will coalesce, and they eventually cover the surface of the leaf. Usually, the upper surface is more affected than the lower surface. The fungus derives its nutrition by adsorption through specialized hyphae called haustoria. The hyphae will grow through the cell wall of the plant and form haustoria. The haustoria invaginate the cell membrane; nutrients defuse through the membrane and are absorbed by the haustoria.

Soon after infection, the fungus will begin to produce conidia. The conidia are formed on other specialized hyphae called conidiophores. The conidia form on the ends of the conidiophores in short chains. The conidia are each composed of a single cell, measure approximately 2/1000 inch long by 1/1000 inch wide, and are transparent.

When the hyphae and conidia form, the leaf will take on a white, powdery appearance. As the infection progresses, the leaf tissue becomes chlorotic, then brown. These symptoms usually form first on the older leaves. Eventually, all leaves may become infected.

Like most powdery mildew fungi, the sugarbeet pathogen has a relatively narrow host range. Other forms of *Beta vulgaris*, such as table beet and Swiss chard, are susceptible. Six additional *Beta* spp.

are susceptible, but only *Beta macrocarpa* might be important in the epidemiology of the disease in the United States.

The conidia of powdery mildew fungi are unique in their response to humidity. Most fungal spores require 100 percent relative humidity or free water to germinate. Powdery mildew conidia are capable of germination at any humidity. This enables the pathogen to spread during the entire season, and not just during periods of rainy weather. Disease spread does increase at higher humidity.

The fungal structures are very sensitive to low temperatures and will not overwinter in the sugarbeet production areas of the Great Plains and Rocky Mountain areas. The fungus probably overwinters in California on winter-grown sugarbeet crops and on weed species such as *Beta macrocarpa*. The beet seed fields of Oregon could also be a source of inoculum and may provide inoculum for beets grown in Modoc and Siskiyou Counties. It is thought that wind currents during the summer months move the conidia long distances. These spores infect sugarbeets and produce secondary inoculum, and the disease spreads throughout the crop. Some of these secondary conidia will also be blown long distances, and the cycle repeats. In this way the disease progressively moves from the southwestern part of the country throughout all of the sugarbeet production areas of the United States.

The age of the sugarbeet crop is an important factor in susceptibility to disease. The disease is rarely seen in the field until eight to 12 weeks after emergence. The disease occurs first on the older leaves. If allowed to go unchecked, the disease progresses and within a month will cover all the leaves in a field.

Yield loss due to powdery mildew will occur if the disease is allowed to go unchecked. The earlier the disease occurs during the season, the greater the loss. Loss will occur due to decreased root yield as well as decreased sucrose concentrations. Gross sugar yields may be decreased by as much as 40 percent under severe infection. In addition, powdery mildew will cause a reduction in purity. Infected plants have higher concentrations of sodium and amino-nitrogen in the roots. The decreased purity will reduce the amount of extractable sugar.

Little is known about variability of the pathogen. Major gene resistance has not been deployed, so selection of races has not occurred. In the early 1980's, strains resistant to benzimidazole fungicides quickly developed. Some reports of triazole fungicide resistance have remained unsubstantiated.

Current Pest Management Practices

Chemical Controls: A very effective control procedure is the application of sulfur. This material is used throughout California to control powdery mildew on sugarbeets. Not only are sulfur applications very effective for control, they are also inexpensive. Sulfur is not a hazardous pesticide. Sulfur dust applied at 20 to 40 pounds per acre will provide excellent control of the disease. Wettable sulfur applied at three to ten pounds per acre in at least ten gallons of water per acre also will protect the crop from serious loss. It is very important that the sulfur application be made with an adequate volume of water or its effectiveness will be reduced. Often, if the sulfur application is to be made by an aerial applicator, less water is applied. If disease onset occurs early in the season, more than one application of sulfur may be required. Usually the second sulfur application is made three to four weeks after the first.

Sulfur controls the disease by dramatically lowering the rate of disease spread. The sulfur will decrease the production of secondary conidia and will protect noninfected leaf surfaces from becoming infected. The noninfected tissues will remain healthy.

Foliar sprays of triadimefon are also used for powdery mildew control. Triadimefon is a triazole fungicide and is classed as a steroid demethylation inhibitor. The fungicide provides systematic control of powdery mildew. It is particularly useful under lower ambient air temperatures when sulfur is not effective. Triadimefon is on the U.S. EPA FQPA list as a unquantitative carcinogen. (See Appendix C, page 53, for rates.)

Alternatives: None known.

Cultural Controls: Most sugarbeet cultivars grown in California have some resistance to powdery mildew. This resistance is quantitative or minor gene resistance and is not in itself adequate for control of the disease under the extreme infection pressure inherent in California. Major gene or qualitative resistance does exist but has not been deployed. In most powdery mildew host systems where this type of resistance has been used, the population of the pathogen quickly shifts to a virulent form that will overcome the resistance genes.

Cultural practices have not played a big part in powdery mildew control. There is some speculation that overhead irrigation may increase severity of the disease. This is due to the irrigation water washing the sulfur from the leaves of the plant.

Biological Controls: Currently, there are no biological control options being implemented for powdery mildew control in sugarbeets.

Other Issues: A new generation of fungicides may become available that could increase the options for powdery mildew control. The new class of fungicides called B-methoxyacrylates have been shown to be very effective against the powdery mildew fungi as well as other fungal pathogens. A new experimental fungicide, CGA-279202, from Novartis has been reported by the company to be very effective for controlling powdery mildew on sugarbeets.

If the onset of powdery mildew occurs a month or more before the crop is to be harvested, control is usually warranted. Because of the rapid rate with which the disease increases, control measures must be initiated at the first observation of symptoms. A delay will cause control measures to be less effective.

Before control measures are commenced, consideration must be given to the time of harvest. If the field is to be harvested within three to four weeks after disease onset, control is probably not necessary. If a field is being harvested on a daily quota, perhaps the disease in only a portion of the field should be controlled. These are some of the variables that must be considered.

Several challenges are presented to threaten the current system of managing powdery mildew in sugarbeets. Sulfur has been under review. Existing regulations have limited its use near inhabited areas. Restrictions exist on the use of some sulfur formulations by aerial applicator. Triadimefon is under review by the EPA.

The new family of fungicides may prove to be very effective in control of powdery mildew on sugarbeets. The first of these new products, azoxystrobin (Heritage®), was registered on February 7, 1997, and is a new fungicide for use on golf courses and commercial turf. It is the first of a new class of pesticide compounds called B-methoxyacrylates which are derived from the naturally occurring strobilurins. Strobilurins are organic compounds produced by some naturally occurring fungi. They function by inhibiting the electron transport of other potentially competitive fungi. It has low application rates and longer intervals between applications than most alternatives. The broad control spectrum and new mode of action should make it a likely candidate for use in resistance management. It is labeled for use in integrated pest management programs. According to EPA risk assessment, this product has no acute risk levels of concern for birds, mammals, and bees.

CERCOSPORA LEAF SPOT

Cercospora beticola

Summary

Cercospora leaf spot is a foliar disease caused by the fungus *Cercospora beticola.* Disease development is favored by temperatures in the range of 68 to 95° F and must be accompanied by high humidity or moisture on the leaves. In most years, it occurs in a very limited geographic area: the east side of the San Joaquin Valley, where still nights result in heavy dew starting in August. In the Fall Harvest Area of Glenn County, *Cercospora* leaf spot can also be a problem. Sprinkler irrigation can increase disease levels or result in disease development in locations where *Cercospora* leaf spot usually is not a problem. Symptoms will usually become evident in August and continue through the fall. In most cases, the areas affected are harvested in September through November. Very little research has been conducted on this disease in the last two decades.

Cercospora causes severe reduction in sugar content, reducing grower profits. Infected leaves die, causing the plant to produce more leaves at the expense of sugar production and growth. The plants develop a large crown, which disrupts efficient harvest operations.

Current Pest Management Practices

Chemical Controls: Current management of this disease is to spray at the first sign of symptoms and continue as necessary. If spraying for insect problems, such as armyworms or *Empoasca* leafhoppers, a fungicide will be included. The list of active ingredients registered for control include copper sulfate, cupric hydroxide, copper oxychloride, mancozeb, maneb, manzate, and thiophanate-methyl. With the except of thiophanate-methyl, recommendations are to repeat every seven to ten or seven to 14 days. Thiophanate-methyl recommends treatment every 14 to 21 days. Also, the USDA in Colorado has confirmed low levels of resistance to benzimidazoles in the Tulare County area. (See Appendix C, page 53, for rates.)

Alternatives: The most likely management options that could reduce pesticide use for this disease are reduction of crop canopy by reducing nitrogen and water (likely to have an impact on yield) and use of tolerant/resistant varieties. California has some major requirements for disease resistance, such as curly top and beet yellows virus, in the varieties used here that make it unwise to use varieties that have *Cercospora* tolerance but no tolerance to other more serious and geographically widespread diseases. Because the geographic area of California sugarbeet production that is affected is relatively small, the development of *Cercospora* tolerance is not a top priority in breeding programs for California.

Cultural Controls: Standard recommendations for this disease are to incorporate crop residues and avoid planting back in the same field. Growers already incorporate residues and control volunteers for controlling virus problems. Also, they do not plant back into a field with sugarbeets for three to five years to control/avoid other disease and pest problems.

Biological Controls: None known.

Other Issues: Pest management challenges include the need for tolerant varieties and the need for effective fungicides that do not require frequent reapplication until tolerant varieties are available. As discussed in the paragraph above, the development of tolerant varieties is not likely in the near future. Where this disease is a problem in other states, another fungicide, Duter®, that is more effective than the ones available in California can be used. Duter® is a tin compound and not likely to be registered in California, but other states are looking at replacements for Duter® due to fungal resistance and review by EPA. If an effective alternative fungicide is identified, it would be desirable but probably a regulatory challenge to have it registered in California.

RHIZOMANIA

Summary

Rhizomania is considered the most serious disease of sugarbeets worldwide, and continues to spread throughout the California sugarbeet growing area since its first diagnosis in 1984. The disease is caused by beet necrotic yellow vein virus (BNYVV) and is vectored by the primitive soil fungus, *Polymyxa betae*. Both the primary pathogen and the vector are obligate parasites.

Current Pest Management Practices

Chemical Controls: The only chemical registered for control is the fumigant 1,3-dichloropropene (Telone II®), but none is used commercially because: 1) it is cost prohibitive; and 2) adequate disease management is achieved using IPM practices.

Alternatives: None known.

Cultural Controls: The disease is manage through a strict program of utilizing resistant varieties, long rotations with nonhost crops, critical irrigation management, and cultural practices that reduce soil compaction and improve soil tilth and drainage.

Biological Controls: None known.

Other Issues: None known.

H. SEEDLING DISEASES

Summary

Sugarbeet seedling diseases are caused by a variety of soil-borne and seed-borne fungi. These fungi infect the succulent young seedlings shortly after germination. The infected seedlings usually decay at the soil level. They will fall over because of lack of supporting tissue during this early stage of growth. This process is known as damping-off. The name is derived from the moist decay of the seedling and the moist conditions under which the diseases occur.

Two distinct forms of damping-off are recognized. Pre-emergence damping-off occurs before the seedlings ever arise from the soil. In this phase no direct symptoms of the disease are visible above the soil surface. Postemergence damping-off occurs after the seedlings have appeared above the soil surface.

Seedling disease control is a very important aspect of sugarbeet production. Loss of stand due to disease is time consuming. Replanting sugarbeet fields is expensive due to direct costs, such as seed and operational expenses, as well as to indirect cost. The most significant indirect cost is reduced yield due to a shorter production season. Also, it is difficult to re-establish sugarbeet stands after loss due to seedling disease. Fields to be replanted usually have increased inoculum concentrations and increased pathogen activity due to higher soil temperature. Adequate control of seedling disease will help assure the necessary plant population needed for a healthy sugarbeet crop.

APHANOMYCES

Aphanomyces cochlioides

Summary

Aphanomyces seedling disease is caused by the same pathogen that causes black root rot, *Aphanomyces cochlioides*. This soil-borne pathogen causes postemergence damping-off of sugarbeets in the seedling stage. The fungus survives in the soil and infects the host by swimming spores called zoospores. The zoospores must have free water to swim to the host tissue and infect. Symptoms of *Aphanomyces* seedling disease are unique. Infection occurs on the root or hypocotyl at or just below the soil level. As the infection spreads up the hypocotyl, it begins to darken and turns jet black. The cortex of the hypocotyl dries and shrinks to a dark slender thread, and the seedlings weaken and fall over. Characteristically, the cotyledons remain green and turgid during the initial phase of the disease, but eventually the seedlings die.

Aphanomyces seedling disease is most prevalent when soil temperatures are greater than 70°F and may be very severe. In conditions of warm, moist soil, seedlings stands can be devastated. Replanting of fields after stand loss is not likely to be effective due to an increase in inoculum concentration and warmer soil temperatures.

Current Pest Management Practices

Chemical Controls: The seed treatment Tachigaren® will effectively control the disease when used at a rate of 90 grams per 100,000 pelleted seeds. This treatment has not been widely used in California.

Alternatives: None known.

Cultural Controls: Control of this disease is through an integration of cultural practices. Fields to be planted should have conditions of friable, well-drained soils and be free of weeds such as lambsquarter and pigweed, which can harbor the pathogen. The fields should be planted before soil temperatures warm above 60°F. High soil phosphate promotes vigorous growth that will reduce the time seedlings are susceptible to infection. Rotations with nonsusceptible crops will reduce the inoculum in the soil and the probability of severe disease occurrence.

Biological Controls: None known

Other Issues: None known.

DAMPING OFF

Rhizoctonia solani

Summary

Rhizoctonia solani is a soil-borne fungus that causes both pre-emergence as well as postemergence damping-off of sugarbeet seedlings. In contrast to *Rhizoctonia* root rot, caused by a single strain of the pathogen, several different strains of this fungus causes seedling disease on sugarbeets.

The pre-emergence phase of the disease occurs when the fungus infects the seedling as it is growing from the seed. The seedling is killed and never emerges from the soil. Symptoms of the postemergence phase of the disease can be very distinct and include stunting and chlorosis. Dark brown and black lesions appear on the root and hypocotyl. The lesions may spread the entire length of the hypocotyl, but it does not shrink and become thread-like as with *Aphanomyces* seedling disease.

Rhizoctonia seedling disease usually is most severe with warm soil temperatures, 70-85°F. Moist soil conditions will contribute to the severity of this disease,; but the pathogen is not as dependent on soil moisture as *Aphanomyces* seedling disease.

Current Pest Management Practices

Chemical Controls: Control of this disease is by fungicide seed treatment. Chloroneb® (6 oz./cwt.) and Thiram® (8 oz./cwt.) are both effective. Planting seed shallow will control the disease by minimizing the area of the hypocotyl exposed to the pathogen.

Alternatives: None known.

Cultural Controls: Crop rotation can dramatically affect the severity of this disease. Previous crops that contribute a lot of residue to the soil, such as grains or alfalfa, make the disease more severe in a following sugarbeet crop.

Biological Controls: When possible plant in lower soil temperatures. This many times is impossible since the spring plant or fall plant beets are sown at higher ambient temperatures.

Other Issues: None known.

PYTHIUM

Pythium ultimum
Pythium aphanidermatum

Summary

Pythium spp. are very common seedling disease pathogens. These soil-borne pathogens infect a wide variety of crops in many different soils and areas. On sugarbeets, these pathogens cause both pre-emergence as well as postemergence damping-off. The pre-emergence phase is more common. These pathogens can infect the seed very quickly after planting, inhibiting their germination and resulting in poor stands. Postemergence symptoms include wilting and total tissue collapse. The root, hypocotyl, and cotyledons become water soaked, turn dark in color, and collapse very quickly. These symptoms are followed immediately by seedling death.

Two species of *Pythium* are responsible for these diseases. In wet, cool soils (<65°F) *Pythium ultimum* frequently occurs. This is the most common of the two species, occurring in most of the sugarbeet growing areas of the United States. In the warmer parts of the country, such as California, where sugarbeets are planted into warm soils (>80°F), *Pythium aphanidermatum* can be an important seedling pathogen. Both pathogens are more severe under wet conditions.

Current Pest Management Practices

Chemical Controls: Seed treatment fungicides are very effective for control. Apron® seed treatment (1 oz/cwt.) is used to control these pathogens.

Alternatives: None known.

Cultural Controls: Good irrigation practices such as preirrigating before planting may help to reduce the amount of infection and stand loss.

Biological Controls: None known.

Other Issues: None known.

SEED-BORNE PATHOGEN

Phoma batae

Summary

Phoma betae is the only seed-borne pathogen that is capable of causing seedling disease. Seed infection occurs in the seed production fields where, during cool wet periods, the fungus infects developing floral parts. The fungus colonizes the developing seed. It can cause pre-emergence damping-off when the seed is planted. The disease usually only occurs under very wet and cool soil conditions (<50°F), and only then if the seed is infested with the pathogen.

Current Pest Management Practices

Chemical Controls: Thiram® seed treatment is effective.

Alternatives: None known.

Cultural Controls: Control of this pathogen is provided mainly by seed production techniques. Cultivation and harvesting of sugarbeet seed include methods that minimize the exposure of the seed to periods of cool and wet conditions. Processing of the seed removes the outer layers of the cortical tissues that are most likely to harbor *Phoma batae*.

Biological Controls: None known.

Other Issues: None known.

I. ROOT ROTS

Pythium Root Rot, *Pythium aphanidermatum*
Phytophthora Root Rot, *Phytophthora drechsleri*

Summary

In California, sugarbeet root rot is caused mainly by a few soil-borne fungi. These pathogens share very similar life cycles, and their control is based on similar principles. This treatise will consider the two most common pathogens, although the principles are the same for other related pathogens.

Pythium root rot is a serious disease of sugarbeet growing in warm soils. The disease is caused by the fungus *Pythium aphanidermatum*. The disease occurs in California as well as in other sugarbeet growing areas. Symptoms of the disease include wilting of the foliage and premature death of the lower leaves. Root symptoms are characterized by black necrosis, proceeding inward through the tap root from lateral roots where the infection had begun. A large portion of the surface of the tap root may be discolored. The disease usually progresses downward through the tap root, and secondary organisms may invade the tissue, causing a soft rot. The diseased tissue is usually sharply delimited from the lower, healthy tissue of the tap root.

Phytophthora root rot is caused by the fungus *Phytophthera drechsleri*. The disease occurs in California when beets are grown during the summer months. The lesions that develop on the surface of the tap root are usually brown. The interior tissue is an amber to reddish brown. Symptoms of the disease usually occur at the tip of the tap root and progress upward toward the crown. A sharp delimitation occurs between the diseased lower tissue and the healthy upper tissue of the tap root.

Both pathogens are zoospore producing oomycetes. Zoospores are motile spores that swim in soil water. Zoospores are attracted to the root surface by exudates produced by the host. If the spore encounters a root surface, it will encyst and infect the tissue. The pathogen grows in the tissues vegetatively and at some point produces more spores. These spores are released in response to water saturation of the surrounding soil, such as would occur during an irrigation event. These secondary spores will infect more tissue and other nearby roots. The disease progresses with each subsequent irrigation.

Both pathogens require warm soil temperatures for infection. Temperatures above 30°C are conducive for rapid spread of the disease. For this reason, these diseases are rarely seen during the cooler months of the year.

Both pathogens produce resting spores called oospores. These spores are resistant to desiccation and will survive many years in the soil.

Populations of the pathogens are delimited by the soil environment. It is assumed that variability in populations exist both regionally and geographically. This variability has not been studied in relation to sugarbeet root disease, and it is not known how this variability affects disease pressure.

Yield loss due to root rot is usually directly related to the amount of disease in a field. Infected beets usually decompose relatively quickly and directly reduce tonnage to be harvested. Loss can also result from more recently infected beets. These have not decomposed and are harvested, but most of the sucrose has been metabolized by the pathogen and secondary organisms. This process results in a very low quality raw product with little if any extractable sugar.

Current Pest Management Practices

Chemical Controls: Currently, no pesticides are used for control of root disease caused by these fungi. This is due to lack of fungicides available and to difficulty in reaching the infection sites because of the soil matrix. Pesticides used to control leaf-feeding armyworms and other insect pests may aid in control of root rot by preventing defoliation. This practice will keep the soil cooler and may lower infection pressure. Irrigated sugarbeets that are defoliated transpire less; soils remain wetter longer; and conditions conducive to root rot pathogens are maintained.

Alternatives: No qualitative resistance to the rot pathogens has been found. Continual selection under severe disease pressure has resulted in the selection of some cultivars better able to withstand infection pressure than others. These cultivars have been generally deployed throughout California. Rhizomania resistant cultivars will have a healthier root system under rhizomania conditions. These cultivars are generally more tolerant to the rot pathogens than rhizomania susceptible lines.

Cultural Controls: Control of *Pythium* and *Phytophthora* root rot is difficult at best. Root rot infection occurs by zoospores, and long-term exposure to saturated soil during periods of high temperature must be avoided. Fields should have adequate drainage, and beets should be planted on raised beds. If a grower has a history of root rot, it would be best to grow the beets under sprinkler irrigation rather than irrigating by furrow.

During periods of high soil temperature, furrow irrigation must be practiced with the utmost precision. Fields must not be allowed to get too dry. Under this situation, all the feeder roots will die; and when the field is watered, these roots must first re-grow before the beets are able to extract water from the soil. This results in a soil profile that remains saturated for a longer period than necessary. The optimum irrigation strategy is to water when the soil reaches a critical water potential, usually between -0.5 and -0.8 bars, then water with as fast a set as possible. This strategy will keep the beets in good condition to remove the added water as quickly as possible.

Biological Controls: Currently, there are no biological options being implemented for rot control.

Other Issues: A new generation of fungicides may become available that could increase the options for rot control. The new class of fungicides called B-methoxyacrylates have been shown to be very effective against the oomycetes as well as other fungal pathogens.

J. BIRD CONTROL

Summary

Horned larks can cause significant damage to seedling sugarbeet fields throughout the Sacramento and San Joaquin Valleys when planted in the fall or early winter. These birds work down the row uprooting seedlings, the damage being roughly proportional to the area on which they feed. Replanting is often needed where they have been feeding. The problem shows up in variable locations and times but is usually a problem in at least some fields every year. Fall planting is common in Kern County, Tulare County, and western Fresno and Merced Counties. Overall the percentage of fields affected may be small; but for those fields that do become a target, the damage can be substantial. Sugarbeets are also planted in late summer/early fall in the Imperial Valley, and although there have been occasions where horned larks have caused damage, it has been very rare, and damage has been relatively insignificant.

Chemical Controls: Currently, no pesticides are registered for controlling these birds.

Alternatives: Current methods used to control horned larks include the use of aluminum ribbon strips, Zon® guns, whistles, or employees who haze and scare the birds. Apparently no research has been conducted to evaluate the effectiveness of these methods, but they have been described as marginally successful.

Cultural Controls: None known.

Biological Controls: None known.

Other Issues: None known.

K. RODENT CONTROL

Summary

Large populations of rodents, mostly meadow vole (*Microtus* spp.) and to a lesser degree ground squirrels (*Spermophilus* spp.), cause severe damage to emerging beets. This causes loss of stands and occasionally leads to replanting. The greatest damage occurs later in the year to the developing sugarbeet root.

Evidences of vole infestations are hollowed out portions of roots, a nearby burrow, or a mound of soil with near dead or dying plants. Overwintered sugarbeets are an attractive habitat for meadow voles, providing cover, source of food, and protection from predators. Vole damage is most severe in overwintered beets where the populations have reached numbers between 1,000 and 3,000 animals per acre. Damage is usually concentrated at the edge of fields. Later, when populations increase, the area of damage expands, as does yield losses. Root feeding will also allow secondary root rot pathogens to enter and deteriorate the entire root, causing an additional loss in production.

Ground squirrels have been less of a problem in sugarbeets. However, existing populations next to a newly planted field can reduce stands by feeding on emerging plants. Effective control options exist for squirrels, including fumigants, traps, and poison baits. The use of PVC pipe with baits inside, placed near the area of activity, has been a successful management tool.

Current Pest Management Practices

Chemical Controls: Control of meadow voles is only effective with zinc phosphide bait (five to ten pounds of bait per acre) applied to the populated areas of the field. If applied by air, the agricultural commissioner must make an inspection to verify vole population and must be present during the application of zinc phosphide. Regulatory personnel need not supervise ground applications. Little impact on populations have been made by natural predators or other nonchemical strategies.

Alternatives: None known.

Cultural Controls: None known.

Biological Controls: None known.

Other Issues: None known.

L. CHALLENGES

Sugarbeets are a crop with a relatively high cost of production and a low margin of return. Sugarbeet growers continually strive to reduce production costs and improve yields. This has been an ongoing challenge, and it is imperative for the survival of the industry in California.

The potential loss of many of the current pest management tools, Lorsban®, Betamix ®, and Temik®, to name a few, could impact the productive capabilities of growers. How the EPA and other governmental agencies implement the FQPA could have a direct impact on sugarbeet production. If the availability of the current chemicals is limited, yields will drop, and resistance to the remaining materials could increase.

Assuming the number of ag chemicals is reduced, finding "environmentally friendly" alternatives will be a challenge, since the industry may not have sufficient time to develop, test, and achieve producer confidence with the new materials under projected FQPA timetables.

M. INNOVATION

The sugarbeet industry has been quite innovative in controlling diseases and pests. The Beet Free Programs to manage planting and harvest schedules to escape aphid flights is an IPM scheme that has worked for a number of years in protecting from virus yellows. The joining together of a number of commodity groups under the Curly Top Virus Control Program to spray the breeding grounds of the beet leafhopper before the insect moves to cropland is another example.

The industry is implementing new criteria of plant populations and reduced nitrogen fertilizer application, which improves the crop and benefits the environment. Low dosage seed treatments of systemic insecticides and fungicides are now available to control some disease and pest problems. The development of cultivars with resistance to the herbicides Liberty and Roundup will be completed just after the turn of the century.

Mating confusion techniques of sugarbeet armyworm has been investigated; however, more research is needed before practical application. Adaptation of population thresholds as a determinant for the necessity of insecticide application is a priority.

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APPENDIX A

INSECTICIDES REGISTERED FOR USE IN CALIFORNIA SUGARBEETS

Insecticide	Trade Name	Spectrum	Typical Use Rate (A.I. Lbs/Acre)	Est. Acres Treated (%)
Chlorpyrifos	Lorsban	Armyworm Aphid	1/2 - 1	40%
Methomyl	Lannate	Armyworm	1/4 - 1	30%
Naled	Dibrom	Leafhopper	1/2 - 1	10%
Endosulfan	Thiodan	Aphid	3/4 - 1	<5%
Diazinon	D-Z-N	Aphid Leafhopper	1 - 2	<5%
Bacillus thuringiensis	Dipel Javelin	Armyworm	1/4 - 1-1/2	<5%
Malathion	Cythion	Aphid	1 - 1-1/2	<10%
Phorate	Thimet	Leafhopper Aphid	7	10 - 20%
Aldicarb	Temik	Aphid	7 + 7	10 - 30%
Oxydemeton-methyl	Metasystox-R	Aphid Leafhopper	1/2 - 3/4	10%
Methamidophos	Monitor	Aphid Leafhopper	1/2 - 1	10%
Carbaryl	Sevin XLR	Flea beetles Cutworm	1 - 1-1/2	10%
Esfenvalerate	Asana	Armyworm	0.03 - 0.05	<5%

APPENDIX B

HERBICIDES REGISTERED FOR USE IN CALIFORNIA SUGARBEETS

(Includes Type of Weeds Controlled and Typical Rate Range)

Herbicide	Trade Name	Type of Use	Weeds [1/]	Typical Use Rate (Lbs/Acre)
Paraquat	Gramoxone	Preplanting	BL	0.6-0.9
Glyphosate	Roundup, Rattler	Preplanting	GR & BL	0.5-1.25
Cycloate	RoNeet	PPI	S A	3.0-4.0
Pebulate	Tillam	PPI	S A	4.0-6.0
Ethofumesate	Nortron	PPI/pre/post	W & S BL	1.5-3.75
Pyrazone	Pyramin	PPI/pre/post	W BL	3.5
Endothall	Herbicide 273	Pre/post	W A	3.0-6.0
Phenmedipham + desmedipham	Betamix	Post	BL	0.75-1.25
Desmedipham	Betanex	Post	BL	0.75-12.5
Phenmedipham + desmedipham + ethofumesate	Progress	Post	BL	0.75-1.25
Triflusulfuron methyl	UpBeet	Post	S BL	0.5-1.5 oz/acre
Sethoxydim	Poast	Post	GR	0.3-0.5
Clethodium	Prism	Post	GR	0.125
EPTC	Eptam/Genep	Layby	S A	2.0-3.0
Trifluralin	Treflan	Layby	S A	0.5-0.75
Metam-sodium	Vapam	Preplanting	All	10-12 gal. band

[1/] Overall predominant type of weeds controlled: A = annual; BL = broadleaved; GR = grasses; S = summer; W = winter.

APPENDIX C

FUNGICIDES REGISTERED FOR USE IN CALIFORNIA SUGARBEETS

Fungicides	Trade Name	Spectrum	Typical Use Rate (A.I. Lbs/Acre)	Est. Acres Treated (%)
Sulfur		Powdery mildew	5 - 10 wettable 40 dusting	90%
Triadimefon	Bayleton	Powdery mildew	4 - 8 oz	<5%
Copper zinc sulfate	Copper-Z	Cercospora leaf spot	1/4	<1%
Cupric hydroxide	Nu-Cop	Cercospora leaf spot	2 - 5	<1%
Manganese	Maneb	Cercospora leaf spot	3/4 - 1-1/2	<1%
Manganese zinc	Manzate	Cercospora leaf spot	3/4 - 1-1/2	<1%
Manganese zinc	Diathane DF	Cercospora leaf spot	1-1/2 - 2	<10%
Thiophanate-methyl	Topsin	Cercospora leaf spot	1/2	<10%