SUGARBEETS

SUGARBEETS

CROP OVERVIEW, GROWTH & DEVELOPMENT

Good weed control is key to profitability in sugarbeets since yields are significantly reduced by weed competition, especially in the early stages of growth.[1] Weed control in sugarbeets is discussed separately in the weed chapter of this workbook. Flea beetles are the only economically important pest on Refuge lands at this point, but they can cause serious crop damage.[2]

While many diseases affect sugarbeets in other production areas, because of the climate and relative isolation of the Klamath Basin, most of these diseases do not present an economic challenge to the region's beet growers. Seedling damping-off and powdery mildew are the most common disease problems (though neither are severe). Root rot (or crown rot) and root-knot nematodes are minor problems. The yellows viruses (beet western yellows virus, beet yellows virus, beet yellow stunt virus), curly-top virus, Fusarium yellows, downey mildew and beet mosaic either are not present, or rarely cause problems. Rhizomania (beet necrotic yellow vein virus) is a severe pest of sugarbeets grown in other areas, but is not present in the Klamath Basin. If it is accidentally introduced, the cool conditions of the region should prevent it from becoming a problem.

Sugarbeet seed is spring planted in mid-April, and beets are harvested from mid-October to early November. Beets are not grown through the winter, thus a beet-free period occurs that contributes to cultural control of several insect-transmitted diseases, such as curly top and the various yellows diseases.

Crop rotations are mandatory in Reclamation lease agreements, sugar company contracts, and by the California Beet Growers Association. These rotations contribute to the cultural control of several important pests

including weeds, cutworms, wireworms, nematodes, and seedling damping-off diseases.

Table 1.
Status of sugarbeet pests in Klamath Basin

Major Pests (as noted by ♦)	**Minor Pests** (as noted by ◊)
Invertebrate	**Invertebrate**
flea beetles	armyworms
cutworms	green peach and bean aphids
	leafhoppers
	wireworms
Disease	**Disease**
powdery mildew	root rot (Pythium, Rhizopus)
damping off (Pythium Rhizoctonia)	curly top virus
	root-knot nematode

Note: Rare or non-occurring insect and disease pests include the following: beet western yellows, beet yellows virus, beet yellow stunt virus, Fusarium yellows, downey mildew, Rhizomania, beet mozaic, sugarbeet cyst nematode, sugarbeet root maggot, webworms, and white grubs.

MONITORING

Effective sugarbeet monitoring requires: weekly scouting throughout the growing season, scouting sheets for recording data, and a 10X hands lens or binocular visor. Weeds, flea beetles, and cutworms are key early-season pests, so scouting for them should begin early (in mid-April). Scouting for minor pests (aphids and leafhoppers), and signs of nematode damage should also begin then. Armyworm scouting begins somewhat later in the season, about late May. Once the crop reaches 2 months of age, begin looking for signs of powdery mildew and crown or root rot. Record crop growth stage and weed types and locations each week of the growing season.

Table 2.
Summary of monitoring methods and action thresholds for sugarbeet pests

Pest	When/how to scout	Interim action threshold*	Remarks
Flea beetles	Mid-April, begin visual scouting for adult flea beetles and for their feeding damage to first young leaves. Also look for damage caused by larval feeding to germinating seedlings.	No action threshold levels established. University of California guidelines suggest treating when moderate damage levels are reached. Local sugar company field representatives suggest examining a 10-foot row and treating if 25 percent of the plants are damaged (Gordon Fellows, Holly Sugar, personal communication, February 27, 1997).	Flea beetles tend to thrive in weedy areas in fields, so weed control during the season is important. Flea beetles overwinter in weedy areas outside fields so scout field margins especially carefully.
Cutworms	Mid-April, use sweep net to sample for young (small) larvae, look under crop debris on soil surface for older larvae. Watch for cut-off or damaged seedlings, and dig around base of plants to locate larvae in soil.	No action threshold levels established. Decision to take control action is based on size of worms found, amount of damage, and crop stage. Older plants can tolerate more damage. Local sugar company representatives suggest treating for cutworms if the crop is young and any cutworm damage is observed since damage can progress quickly, and once treatments are applied they take several days to control cutworms (Gordon Fellows, pers. comm., February 27, 1997).	Scout for cutworms in evening or early morning using a flashlight, since larvae are most active then.
Armyworms	Check fields regularly during late May, June, and early July for small larvae. Use a sweep net for sampling young larvae; visually search crop debris on soil surface for older larvae.	No action threshold levels established. Armyworm populations rarely warrant control actions.	Armyworms tend to be pests of sugarbeets grown in warm regions and are usually a minor pest in the Klamath Basin. Beneficials often keep armyworms under control. Record numbers of predators, and parasitized or diseased larvae when scouting.
Aphids (bean and green peach)	April and May; visually check fields. Aphids often found in clusters or at field margins. Avoid monitoring only these “hot spots.”	No action threshold levels established. Aphid populations rarely warrant control actions.	Aphid flights are most common during moderate temperatures (60 to 80 degrees F).

Pest	When/how to scout	Interim action threshold*	Remarks
Empoasca leafhopper	Beginning April; count number of adults and nymphs per leaf. Sample 10 leaves from 10 plants in 4 areas of the field.	Consider treatments when leafhoppers (both nymphs and adults) reach 10 to 15 per leaf. Use lower numbers in younger fields. Don't treat fields within 2 to 3 weeks of harvest.	Sugarbeets can tolerate high populations of leafhoppers without experiencing yield reductions.
Beet leafhoppers	Beginning April with visual observations, especially field margins near weedy hosts.	Beet leafhopper populations rarely warrant control actions.	Leafhopper feeding damage is negligible. Curly top virus (which is spread by beet leafhoppers) is prevented by use of virus-resistant varieties.
Powdery mildew	Beginning mid-June; check underside of older leaves for white to light-gray spots.	Action recommended when first small white spots appear.	Focus scouting efforts on areas with nitrogen deficient foliage (light-green) as these plants are most susceptible, and symptoms are likely to appear there first.
Nematodes (Northern root-knot and Columbia root-knot)	1) Pre-season: Sample soil from root zone just before harvest of previous crop; send to diagnostic laboratory. 2) During the season: Scout fields for nematode damage symptoms (i.e., extra long seedlings having either green or yellow leaves, or wilted or stunted plants.)	No action threshold levels established. Nematode populations on sugarbeets rarely warrant control actions. No control actions available mid-season.	Damage symptoms noticed during the season are useful for indicating a problem field, but they are not sufficient for a positive diagnosis.
Root and crown rot	Beginning mid-season; look for "cleft" crowns or crowns that have broken away from their roots.	No control actions available mid-season. Prevention key to control.	Crown rot tends to spread down the row, producing a number of diseased plants in a line.

* Interim Action Thresholds will be used as guidelines on the leased-lands until they are validated.

INVERTEBRATE PESTS

- **WESTERN POTATO FLEA BEETLE** – *Epitrix cucumeris*
- **THREESPOTTED FLEA BEETLE** – *Disonycha triangularis*
- **PALESTRIPED FLEA BEETLE** – *Systena blanda*

Life Cycle, Host Crops, Seasonal Development

Three species of flea beetles are present on Refuge lands; however, the western potato flea beetle causes the most problems on sugarbeets.[1] The other two species are the threespotted flea beetle and the palestriped flea beetle.

Flea beetles are tiny, roughly 0.25 inch long. Potato flea beetles are a shiny black, whereas threespotted flea beetles are slightly larger (two to three times) and have an orange-colored mid-back with three dark spots. Palestriped flea beetles are about the same size as the threespotted, but are dark brown and have a long creamy white strip down each wing cover. All flea beetles have large back legs and jump vigorously when disturbed.[2]

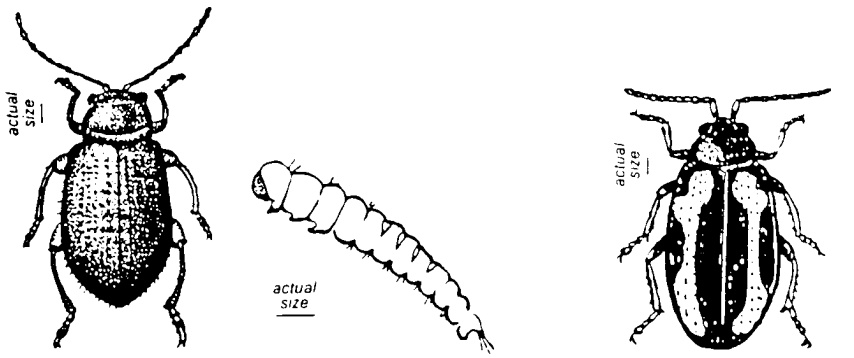


Figure 1.
Western potato flea beetle and striped flea beetle
(Western potato flea beetle: after Wash. Agric. Exp. Stn. Bull, 280. Striped flea beetle: *Handbook of the Insect World*, Hercules Powder Co.)

Adult western potato flea beetles overwinter in debris around field margins.[3] They become active in late March and early April and feed first on weed hosts, then later move to emerging sugarbeet seedlings, and begin damaging the crop.

Eggs are laid in the soil near the base of plants in May, and larvae are present in the soil during June and July when pupation occurs in the soil. Beetles begin emerging in late July and disperse within the same field or to weedy margins. Eggs are laid, and larvae from this generation are present in August and early September. Generally, there are one to two generations

per year.

Damage and Symptoms

Larvae of the palestriped flea beetle feed on roots of young plants and germinating seeds.[2] Damage also is caused by adults feeding on sugarbeet leaves, causing numerous round or irregular holes in the foliage; leaves appear peppered with small shot. Seedlings are especially vulnerable, and sufficient damage can result in their death.

Damage often occurs in localized pockets in a field, especially where adults are entering a field from a weedy border area, or in areas previously infested with weeds. Some sites experience yearly problems with flea beetles, whereas other sites have problems less frequently.[4]

Short- and Long-term Management Recommendations

Monitoring

- Beginning mid-April, scout for adult flea beetles and for their feeding damage to the first young leaves. Also look for damage caused by larval feeding to germinating seedlings. Visual observations are the primary monitoring method, though sweep nets can be useful for sampling adults. Because adults often overwinter at weedy field edges or near structures, early season monitoring of these areas may be helpful for detecting initial infestations.

- There is no established action threshold for flea beetles on sugarbeets.[2] U.C. guidelines suggest treating when a moderate level of damage is reached. Local sugar company representatives suggest examining a 10-foot row of sugarbeet seedlings and treating the field if 25 percent of the plants are damaged by flea beetle adults (Gordon Fellows, Holly Sugar, personal communication, February 27, 1997).

Cultural

- Keep fields free of preferred weed hosts, especially field bindweed and mustard.

- Replant heavily damaged fields.[2]

- Crop rotations are ineffective on flea beetles because of the mobility of the adults, and because of the wide range of wild hosts.

▶ *Biological*

- No economically significant biological controls exist . The main "natural" controls are climatic factors that limit their numbers and distribution.[5]

▶ *Chemical*

- Sevin is PUP-approved on the Refuge for adult flea beetle control.

- Seed treatments with the insecticide Gaucho would be less toxic and potentially more effective than Sevin foliar applications. (See Field Trial Recommendations for further discussion of this insecticide.)

Aboveground Cutworm Species

♦ **VARIEGATED CUTWORM** – *Peridroma saucia*

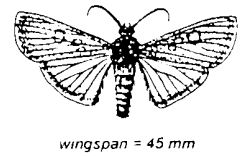
♦ **ARMY CUTWORM** – *Euxoa auxiliaris*

Subterranean Cutworm Species

♦ **PALE WESTERN CUTWORM** – *Agrotis orthogonia*

♦ **BLACK CUTWORM** – *Agrotis ipsilon*

Life Cycle, Host Crops, Seasonal Development



wingspan = 45 mm

length = 40-50 mm

Figure 2.
Variegated cutworm Top: adult. *Bottom:* larvae.
(after Iowa Exp. Stn. Circ. 101)

Several species of cutworms may be present on leased lands. Cutworm larvae are rather large caterpillars, reaching 1.5 to 2 inches long when fully grown. Cutworm larvae attack a wide variety of vegetable and field crops, especially in the seedling stage.

All cutworm adults are moths with dark gray fore-wings, variously marked, and lighter colored hind wings. They feed at dusk on flower nectar and are attracted to lights. They tend to lay their eggs on plants in grass sod or weedy fields. Larvae go though several molts and eventually enter the soil to pupate.

Each species has somewhat different habits. The army cutworm is a surface feeder that does little burrowing. It completes one generation annually, and lays its eggs on the soil. The variegated

cutworm (an above-ground feeder) may complete two generations a year in the Northwest, and commonly overwinters as a pupa.

The pale western cutworm is largely an underground feeder, which lays its eggs on the soil and completes a single generation annually.[6]

Black cutworms are also subterranean species, feeding mostly underground during the night. Young larvae (less than 0.5 inch long) feed above ground. Larger larvae feed at, or just below the soil surface, although in fields with very dry soil conditions, the larvae may be found 2 to 3 inches deep.[5]

Generally, black cutworm moths will not lay eggs in fields that have already been planted. Oviposition (egg-laying) is typically concentrated on low-growing vegetation such as chickweed, curly dock, mustards, or plant residue from the previous year's crop. As a result, heavy spring weed growth, newly broken sod, previous crop, and plant debris all increase the risk of black cutworm infestations.

Most cutworms overwinter as larvae in cells in the soil, in crop residues, or clumps of grass. Feeding begins in spring and continues to early summer when the larvae burrow more deeply into the soil to pupate. Adults emerge from the soil 1 to 8 weeks later, or sometimes overwinter. Most species deposit eggs on stems or behind the leaf sheaths of grasses and on weeds. Eggs hatch from 2 days to 2 weeks later.

The worms are gray to dull-brownish, smooth-skinned, with various markings depending on species. They readily curl into a C-shape when disturbed.[7] They are known to feed on nearly all non-woody plants, and are serious pests on corn, beans, cabbage, cotton, onions, tomatoes, tobacco, and clover, in addition to sugarbeets.[6]

The abundance of cutworms fluctuates considerably from year to year and is affected primarily by rainfall. Rain may prevent the moths from laying their eggs, or force the larvae to the soil surface during the daytime where predators will consume most of them. Conversely, populations will be higher in dry years.

Damage and Symptoms

Age of the sugarbeet crop is the most important factor in determining the severity of cutworm damage. Seedling and young plants are most susceptible to cutworm damage. Damage to older plants is minor.

Most cutworms are either nocturnal or subterranean and are rarely seen, even when their damage becomes obvious. Variegated cutworms feed above ground, cutting the plants off at or above the soil line. Pale western and black cutworms are subterranean species, feeding mostly underground during the night. The larvae cut young plants off below the soil line; this damage is often the first sign of an infestation. The black cutworm is especially active, and will often work its way down a row of sugarbeets, cutting off one plant after the next in a line.[8]

Short- and Long-term Management Recommendations

Monitoring

- Timely detection is critical if insecticidal treatment is to be effective. Look for the presence of cutworm larvae early in the season, and after destruction of adjacent habitats. Later in the season, sample older larvae by looking under crop debris on the soil surface. Cutworms are most active at night, so are best scouted after dark with a flashlight. Look for cut off or damaged seedlings and dig around the base of the plant to locate the larvae.[7]

- There are no established action threshold levels. U.C. IPM guidelines suggest basing the need for treatment on the size of the worms observed, the amount of damage, and the crop stage.[8] Older plants can tolerate more damage. Local sugar company representatives suggest treating for cutworms if the crop is young and any cutworm damage is observed, since damage can progress quickly, and once treatments are applied, they take several days to control cutworms (Gordon Fellows, pers. comm., February 27, 1997).

- Metcalf[6] suggests an interesting technique for estimating spring larval infestations: "Place rather large, compact bunches of freshly cut clover, dock, or chickweed on well-plowed soil. If cutworms are present in the soil, they will collect under such vegetation. Scouts can then look under the bunches in 2 or 3 days and count the number of cutworm larvae as an indication of whether or not treatment is needed."

Cultural

- Clean tillage to remove all weedy vegetation, at least 10 days prior to planting, reduces the number of cutworm larvae.[8]

- Control of weedy vegetation at field borders also reduces the number of invading larvae.

- Crop rotation is an important control tool for cutworms. Avoid planting fields to sugarbeets if monitoring shows high populations of cutworms in previous crops, especially if beets are following alfalfa or cereals in a rotation, since they are especially good hosts for cutworms.[8]

Biological

- Cutworm larvae have a number of natural enemies. Several species of ground beetles prey on them. Several types of flies (tachinids) and wasps (braconids and trichogrammatids) parasitize cutworm eggs and larvae. Cutworms may also be attacked by fungi, bacteria, nematodes and birds.[6]

- Predators and parasites are more effective against the above-ground species of cutworms (e.g., the variegated and army cutworms). Pale

western and black cutworms are not as susceptible to control by these agents due to their subterranean nature. However, they are more susceptible to control by soil-dwelling beneficials such as nematodes, fungi, and bacteria than are the above-ground feeders.

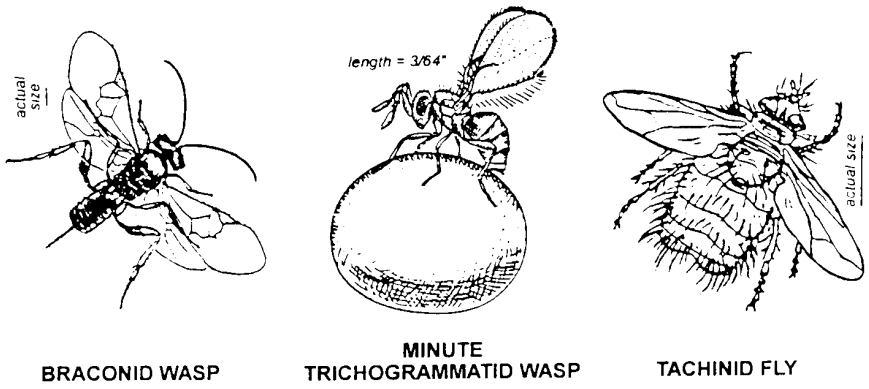


Figure 3.
Beneficial insects effective against cutworms found in sugarbeets (*Handbook of the Insect World*, Hercules Powder Co.)

- Refer to the Extension publication *Beneficial Organisms Associated with Pacific Northwest Crops*, for life cycles and photographs of these important biological control agents.

▶ *Chemical*

- Sevin XLR Plus is PUP-approved for cutworm control on sugarbeets.[9]

- Cutworm larvae are most vulnerable to pesticides when they are small (less than 1.5 inches long). Monitor fields closely.

- Bait formulations (banded over the seed row) are the most effective treatments against cutworms (Cheryl Norton, Abbot Laboratory, personal communication, January 7, 1997). However, baits are generally not allowed on Refuge lands due to potential wildlife hazards. Baits made from the bacteria *Bacillus thuringiensis (B.t.)* var. *kurstaki (k.)* (such as Dipel or Javelin products) would control cutworms and would not pose this hazard. Unfortunately, there are no bait formulations of *B.t.k.* available at this time. If a bait formulation of *B.t.k.* becomes available, it should be considered for PUP approval. Foliar applied formulations of *B.t.k* (which are available) are basically ineffective against cutworms in seedling row crops because the larvae do extensive damage prior to ingesting a lethal dose. They also lose effectiveness within 24 to 48 hours.[7]

◊ **BEET ARMYWORM** – *Spodoptera exigua*
◊ **FALL ARMYWORM** – *Spodoptera frugiperda*
◊ **WESTERN YELLOWSTRIPED ARMYWORM** – *Spodopter praefica*

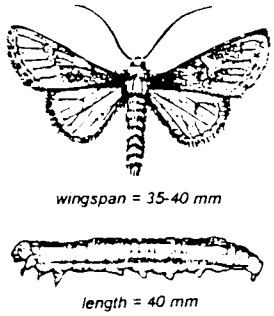


Figure 4.
Western yellowstriped armyworm
Top: adult. *Bottom:* larvae.
(*Insects and Mites of Economic Importance in the Northwest*, OSU, Corvallis, OR)

Life Cycle, Host Crops, Seasonal Development

Armyworms only occur in large numbers every few years. They can be especially bad after mild winters that favor survival of overwintering larvae.

The armyworms overwinter as pupae in the top few inches of soil. Moths emerge in March and April and lay eggs in masses on foliage. Larvae feed on the foliage during May, June and early July, then pupate in the soil. Adults emerge in mid-August through September to form the second generation, and lay eggs. The larvae that hatch feed until they enter the overwintering pupal stage. There are generally two overlapping generations per year in the Northwest.[3]

Damage and Symptoms

Beet armyworms are general feeders and attack the foliage and stems of sugarbeets—their favored host. They skeletonize leaves, leaving the veins largely intact.[10] Whole fields can be defoliated when large numbers of larvae occur. Fortunately, populations on Refuge lands have usually been small enough that they don't warrant treatment.

Short- and Long-term Management Recommendations

▶ Monitoring

- Currently, there are no action thresholds for armyworms in sugarbeets, though the plants can sustain considerable damage, especially late in the season, without incurring yield reductions.[10] Treat only if natural controls fail to keep populations in check.

- Scout fields regularly during late May, June and early July for small larvae. Look especially closely around field edges. Monitor for young larvae with a sweep net, and for older ones by searching through crop debris on the soil surface. Larvae must be at least 0.5-inch long for accurate counting and to evaluate for natural enemies and disease.

- A monitoring program that includes assessment of natural enemy populations is essential for effective armyworm control since a number of natural enemies work to keep populations low. Look for and record numbers of predators such as bigeyed bugs, lacewings, spiders and pirate bugs, larvae parasitized by wasps, and those infected with viral diseases.

- To check a larvae for parasitization, remove the head and carefully pinch the internal contents of the worm out. Look for a pale green parasite larva inside. Caterpillars that are infected with a virus or bacteria first appear yellowish and limp, then hang from the plant after death as shapeless, dark tubes from which the body contents ooze.[10]

▶ Cultural

- Planting pest strip breaks and other methods that improve habitat for beneficials will help promote biological control.

Biological

- Conserve beneficials since they provide significant control of armyworms. The wasp *Hyposter exigua* is known to be an especially effective parasite of beet armyworms.[10]

- Predators known to feed on them include bigeyed bugs, lacewings, spiders and pirate bugs. Many parasites also attack armyworms. Viral diseases of the armyworms also play an important role in their control.

- Spod-x is a new bacculovirus product which may be effective against armyworm infestations. This product is not currently approed in California but could be used in a field trial after obtaining a Research Authorization (see page 13 Workbook Introduction).

- Refer to the Extension publication *Beneficial Organisms Associated with Pacific Northwest Crops*, for life cycles and photographs of important biological control agents.

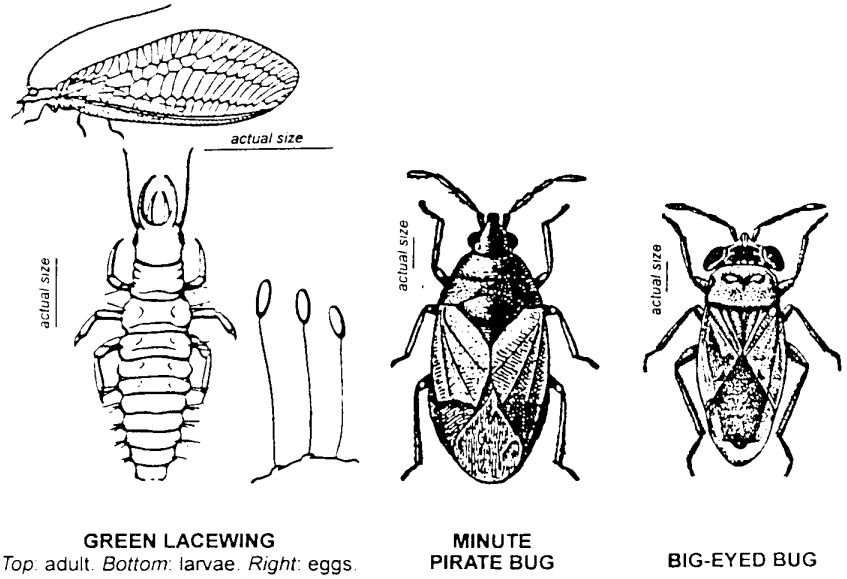


Figure 5.
Beneficial insects effective against armyworms found in sugarbeets
(Green lacewing: *Handbook of the Insect World*, Hercules Powder Co. Minute pirate bug and big-eyed bug: copied with permission from Div. of Agric. and Natural Resources, U.C., Oakland, CA.)

Chemical

- There are currently no PUP-approved insecticides for armyworms on sugarbeets.

- *B.t.* var. *aizawai (a.)* (XenTari WDG, by Abbot Laboratories) provides

good control of armyworms, especially those less than 1.5 inches long. It also conserves beneficials and works well in an IPM program. Ground applications are more effective than foliar, because thorough coverage is critical for successful control. XenTari would probably be most effective when used early in the cropping season, when ground application is still possible. *B.t.a.* should be considered for PUP-approval for armyworms on sugarbeets.

◊ BEAN APHID – *Aphis fabae*
◊ GREEN PEACH APHID – *Myzus persicae*

Life Cycle, Host Crops, Seasonal Development

In the spring, wingless females hatch from eggs and fly to summer hosts, including sugarbeets. In fall, they migrate back to their winter hosts. Males are produced, and sexual reproduction results in the overwintering eggs.

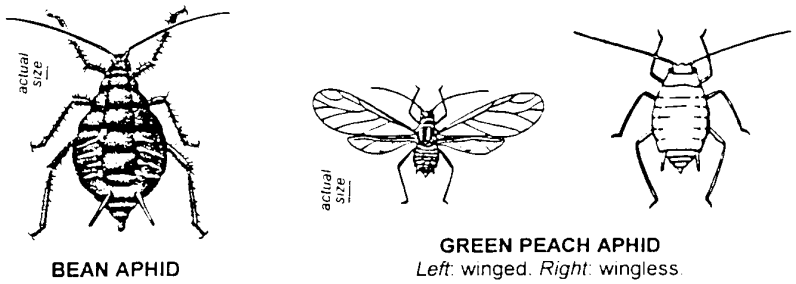


Figure 6.
Bean aphid and green peach aphid
(Bean aphid: after Farbenfabriken Bayer AG Compendium. Green peach aphid: after USDA Bull. 1371.)

Damage and Symptoms

Aphids cause minimal damage to sugarbeets by direct feeding. They do transmit several serious viral diseases, but since these diseases are rare in the region, aphids remain a minor concern. Aphid-transmitted viral diseases of sugarbeets, including beet yellows, beet western yellows, beet yellow stunt virus, and beet mosaic, have yet to cause problems on Refuge-grown sugarbeets, mostly because of the natural beet-free period that occurs during winter.

The bean aphid feeds from the underside of the leaf and colonizes young leaves first before moving on to older leaves as populations grow. Infestations begin in the center of the crown on young leaves. Leaf curling and distortion are typical. Large amounts of honeydew and sooty mold result if populations are high.[11] The green peach aphid occurs annually, but may be present in extremely low numbers and cause no significant damage.

Short- and Long-term Management Recommendations

Monitoring

- Check fields frequently after seedling emergence. Monitor especially carefully during April and May. Flights are most common during moderate temperatures (60 to 80 degrees F). Aphids often concentrate in "hot spots" or near field margins. Avoid monitoring only hot spots.

Cultural

- Eliminate weed species in leased-land fields that may serve as early season hosts for aphids. Host weeds include malva, penny cress, various other mustards and nightshade. Neighboring crops such as potatoes also may harbor aphids.

Biological

- Aphids have many natural enemies, including lady beetles (ladybugs), green lacewings, and several wasp parasites. These natural enemies may provide adequate biological control of aphids many, if not most, years if they are protected from pesticide sprays. Refer to the Extension publication *Beneficial Organisms Associated with Pacific Northwest Crops*, for life cycles and photographs of these important biological control agents.

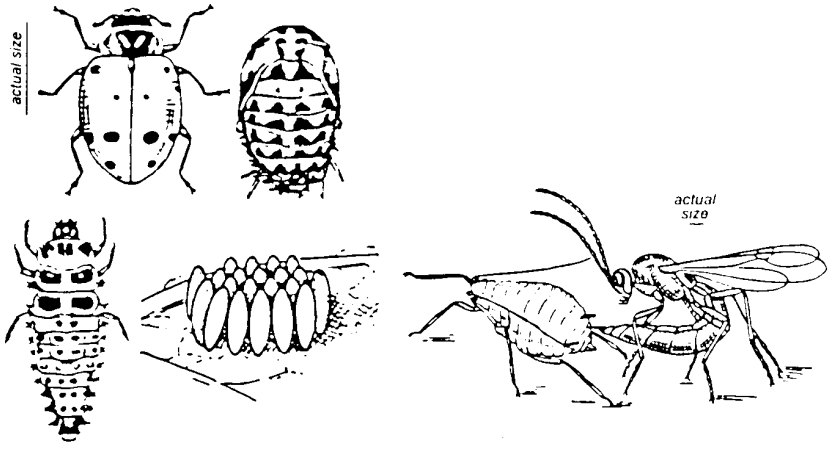


Figure 7.
Beneficial insects effective against aphids found in sugarbeets
(*Handbook of the Insect World*, Hercules Powder Co.)

Chemical

- There are currently no PUP-approved pesticides for aphid control on Refuge-grown sugarbeets.

◊ BEET LEAFHOPPERS – *Circulifer tenellus*
◊ EMPOASCA LEAFHOPPERS – *Empoasca fabae and Empoasca solana*

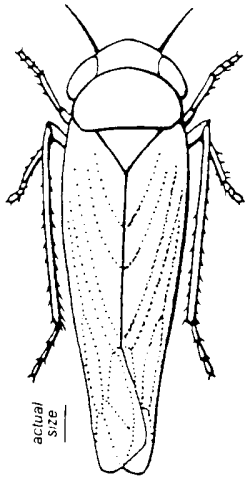


Figure 8.
Beet leafhopper
(after Utah Agric. Exp. Stn. Bull.)

Life Cycle, Host Crops, Seasonal Development

The beet leafhopper has a wedge shape and small size (about 0.125 inch long). Color can vary from pale green to gray to brown, usually—but not always—with dark markings.[12] The similar-looking Empoasca leafhoppers are always a uniform pale green.[13] (The differences are significant since the beet leafhopper is the transmitter of beet curly top virus while the Empoasca leafhoppers apparently do not carry any beet viruses.)

Beet leafhoppers overwinter in uncultivated areas containing wild mustards or other suitable host plants such as Russian thistle, greasewood, and pepperweed. Egg laying starts as plants begin to grow in early spring. Development from egg to adult requires 1 to 2 months, depending on temperature. Three generations typically occur in the Northwest. The first generation is produced on weeds and adults disperse to the summer hosts, mainly Russian thistle. Following generations spread curly top from the desert, rangeland, or waste areas to adjacent cultivated crops.[3]

Damage and Symptoms

Beet leafhoppers cause minimal damage to sugarbeets by direct feeding. They do transmit curly top virus, but since this disease is rare in the region, they remain a minor pest.

Empoasca leafhoppers cause a symptom known as "hopperburn" when populations are high. Leaf margins turn yellow, particularly at the leaf tip, and soon become necrotic (brown and dead). Eventually the entire leaf may turn yellow and resemble a virus-infected plant.

Short- and Long-term Management Recommendations

▶ Monitoring

- U.C. IPM guidelines recommend the following method for monitoring Empoasca leafhoppers:

"Sample by counting the number of adults and nymphs per leaf. Examine a minimum of 10 leaves from 10 plants in at least four areas of the field. Pick fully expanded leaves, avoiding older leaves or leaves in contact with the ground. Also, select leaves that are shaded by other leaves because leafhoppers try to avoid the sun. Leafhoppers are found on the under surface of the leaf, so turn the leaf over and *quickly* count the number of leafhoppers; both adults and immatures can run very fast so you must be quick. Before starting your actual count, look at and count 3 to 4 leaves so that you will know what the leafhoppers look like, particularly the small ones, and how they behave. Then begin your sampling and actual counts.

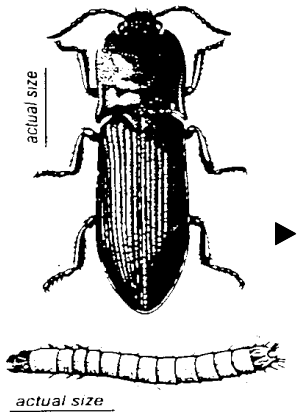


Figure 9. *Wireworm Top*: adult. *Bottom*: larvae. (after USDA Bull. 1657.)

Since sugarbeets can tolerate populations without sustaining substantial yield losses, apply treatments only when Empoasca leafhoppers (both nymphs and adults) reach high levels, about 10 to 15 per leaf. Use the lower number for fields 2 to 3 months up to several months from harvest. Use the higher number for fields within 1 to 2 months of harvest. Do not treat if fields are within 2 to 3 weeks of harvest."[13]

▶ Cultural

- For beet leafhoppers, eliminate weed hosts (e.g., wild mustards and Russian thistle) from leased-land fields and ditch banks, if practical. Consider use of resistant varieties if curly top virus becomes a problem in the Klamath Basin.

▶ Biological

- Beet and Empoasca leafhoppers are attacked by several natural enemies that regulate their populations in some areas, so conserve beneficials.[3]

▶ Chemical

- There are no PUP-approved pesticides for beet leafhopper or Empoasca leafhopper control.

- Insecticide treatments are generally ineffective for controlling beet leafhoppers and reducing the spread of curly top disease, since the virus is readily transmitted after only brief feeding by the leafhoppers.

◊ WIREWORMS

Life Cycle, Host Crops, Seasonal Development

Wireworms (primarily of the genera *Agriotes* and *Limonius*) are the larvae of click beetles. The larvae are thin with a shiny, hard, light brown skin. The full life cycle of wireworms may take 2 to 6 years, with the bulk of that time spent in the soil in the larval stage. Generations overlap, and eggs, larvae and adults may all be found in the soil together at any given time.

Damage and Symptoms

Wireworms may feed on swollen seeds just before emergence, young seedlings, and on the roots and crowns of mature sugarbeet plants. They feed on a wide range of plants including small grains and all wild grasses. Many vegetables, including potatoes and sugarbeets, are also hosts.

Short- and Long-term Management Recommendations

▶ Monitoring

- Damage to young plants by wireworms may be confused with that from cutworms. Since the controls for cutworms and wireworms are largely different, proper identification is important and will probably entail digging in areas where seedlings are being damaged.

- In the Midwest, the presence of wireworms can be determined before

planting by the following method: Three to 4 weeks before planting, establish 4 to 5 bait stations per field by digging a hole 6 inches deep and placing a handful of untreated wheat and/or corn in the hole; cover the hole with soil and mark with a flag; in 2 to 3 weeks dig up the bait, place on a tarp and check for wireworms.[14] This technique should be applicable in the Klamath Basin as well.

▶ *Cultural*

- Although currently not allowed, clean summer fallow (with springtooth or disk), or rest the land every second or third year in fields known to be infested with wireworms.[15] Use shallow tillage in early summer to prevent all weed growth. Avoid deep plowing, which allows the wireworms to penetrate more deeply into the soil.
- Replant fields heavily damaged in the seedling stage.[15]
- Allowing the top 18 inches of soil to dry for a few weeks during the summer once every 6 years reduces populations.
- Flooding can kill all stages of wireworms. A few inches of water must cover the soil for a week when the temperature of the soil at a depth of 6 inches averages 70 degrees F, or higher.[6]
- Rotations with grass-family crops (such as small grains) may exacerbate wireworm host problems.
- Do not plant sugarbeets to a field heavily infested with wireworms without first fallowing or tilling.

▶ *Biological*

- There are no effective biological controls to recommend at this time.

▶ *Chemical*

There are no PUP-approved pesticide controls for wireworms. Pesticide treatments after planting are ineffective.[15]

DISEASES

♦ DAMPING-OFF – *Pythium* and *Rhizoctonia*

Life Cycle, Host Crops, Seasonal Development

The pathogens that cause damping-off of seedlings occur in most soils worldwide. Fungi enter the swollen seeds or young seedlings by direct penetration. Plant host tissues are dissolved by enzymes produced by the fungi. Infected seeds and seedlings may die quickly, while older plants may be infected but damage is usually limited to small lesions. Outbreaks are aggravated by cool temperatures, wet soil, overcast weather, and limited air movement.[17]

Damage and Symptoms

A complex of several fungi cause damping-off disease, which can lead to death of germinating or newly emerging seedlings. Plants surviving fungal attack often remain stunted or eventually die.[17]

Short- and Long-term Management Recommendations

Cultural

- Use cultural practices (e.g., ripping the soil with a shank every 2 to 3 years and planting in raised beds) to promote good drainage. Crops grown in rotation with sugarbeets that have deep roots, such as sorghum-Sudangrass, also help to break up the soil and improve drainage. The grass helps reduce soil-borne disease as well as nematode problems. Flooding would probably reduce damping off pathogens in the soil, too (Mike Davis, plant pathologist at U.C. Davis, personal communication, April 25, 1996).

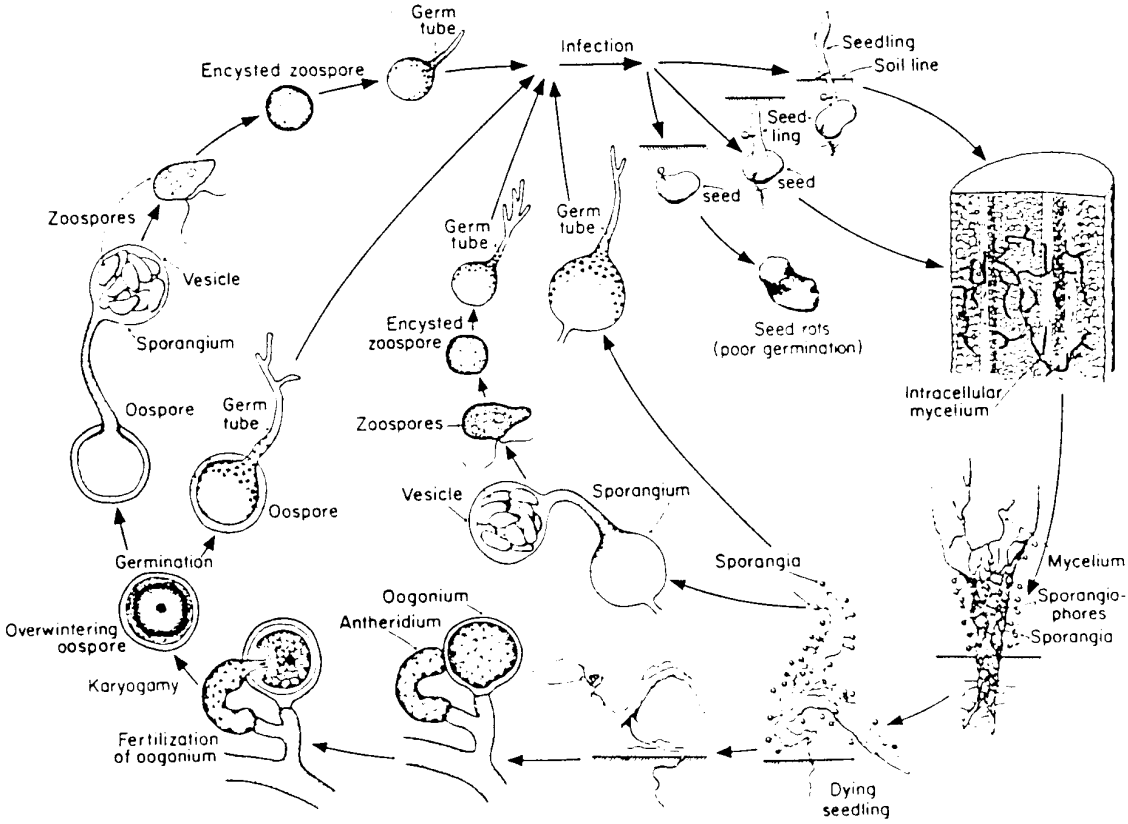


Figure 10.
Disease cycle of damping-off and seed decay caused by Pythium *sp.*
(copied with permission from Academic Press)

Biological

- There are no effective biological controls to recommend at this time. (See Field Trial Recommendations for potential future biological control options.)

▶ *Chemical*

Seed treatments with the fungicides Apron (metalaxyl) and Chlornab or Thiram are typically used for controlling Pythium and Rhizoctonia.

♦ POWDERY MILDEW – *Erysiphe polygoni*

Life Cycle, Host Crops, Seasonal Development

Powdery mildew, caused by a fungus, is favored by long periods of dry, warm days, cool nights, and a wide fluctuation in day-night temperatures. Optimum temperatures for growth are between 60 and 86 degrees F. Fungal growth is arrested when temperatures reach 100 degrees F or higher.

The fungus overwinters on cultivated and wild beet-family plants such as Swiss chard, table beets, or wild beet species that grow throughout the winter. Following initial infection, the fungus grows over the surface of the beet foliage giving the leaves a "powdery" look. Spores are produced and spread by the wind to new plants.

Disease Symptoms

The first symptoms show up as white to light gray spots on the under surface of the older leaves when plants reach 2 to 6 months old.[18] Signs of infection may be most easily seen under full sunlight with the sun to your back.[19] When inspecting a field for powdery mildew, look in areas where plants are showing a little nitrogen deficiency by turning light green or yellow green. These plants are the most susceptible, and if mildew is not found on those plants it is unlikely to be found in other, better-fertilized areas.

Short- and Long-term Management Recommendations

▶ *Cultural*

- Most cultivars grown have some resistance to powdery mildew. However, under conditions highly favorable to the disease, this resistance fails to protect the plant.

▶ *Biological*

- There are no effective biological controls to recommend at this time.

▶ *Chemical*

- If crops are 6 to 8 weeks prior to harvest when symptoms appear, no control of powdery mildew is necessary (Jim Gerick, Holly Sugar plant pathologist, personal communication, January 9, 1997). Occasionally powdery mildew is severe enough on the Refuge to warrant treatments. Sulfur dust or the wettable powder form can be used. Apply sulfur when the first small white spots appear. Applications at 3- to 6-week intervals are necessary if the disease reappears after the first treatment.[18]

Root and Crown Rots

◊ PYTHIUM ROOT ROT – *Pythium aphanidermatum*

◊ RHIZOPUS ROOT ROT – *Rhizopus stolonifer*

Life Cycle, Host Crops, Seasonal Development

These root rots are caused by the same organisms causing seedling damping off. They are most likely to be problems where the soil remains wet over extended periods.

Disease Symptoms

Roots may rot in mid-season. This is often a carry-over from an attack during the seedling stage. Crowns of diseased plants may appear clefted, but sometimes the entire crown breaks away.[17] The fungus tends to spread down the row, producing a number of diseased plants in a line.

Short- and Long-term Management Recommendations

Cultural

- Use crop rotations and production practices that promote good crop vigor and control of seedling diseases.[17]

Biological

- There are no effective biological controls to recommend at this time.

Chemical

- Seed treatments with the fungicides Apron (metalaxyl) and Chlornab or Thiram are typically used for controlling *Pythium* and *Rhizoctonia*.

◊ CURLY TOP VIRUS

Life Cycle, Host Crops, Seasonal Development

Curly top is a severe viral disease of sugarbeets, transmitted by beet leafhoppers. Curly top is currently not a problem in the Klamath Basin, primarily because of the naturally occurring beet-free period that results from freezing winter weather.

Disease Symptoms

Symptoms exhibited in infected plants include dwarfed, crinkled, rolled up leaves. Veins are often irregularly swollen on the undersides of leaves.[20]

Short- and Long-term Management Recommendations

Cultural

- Control overwintering weeds and other plants on adjacent lease lands that host leafhoppers (such as Russian thistle).[20]
- Horseradish is also known to host curly top virus.
- Resistant varieties are available and should be considered if this disease becomes a problem in the future.

Biological

- There are no effective biological controls to recommend at this time.

Chemical

- Insecticide treatments are generally ineffective for controlling beet

leafhoppers and reducing the spread of curly top disease, since the virus is readily transmitted after only brief feeding by the leafhoppers.

Nematode Diseases of Sugarbeets

◊ NORTHERN ROOT-KNOT NEMATODE – *Meloidogyne hapla*

◊ COLUMBIA ROOT-KNOT NEMATODE – *Meloidogyne chitwoodi*

Life Cycle, Host Crops, Seasonal Development

Northern root-knot nematode is widely distributed, but is a minor problem on sugarbeets in California. Columbia root-knot nematode is present in Modoc and Siskiyou counties but no yield reductions have been reported.[21]

Nematodes are microscopic roundworms that feed on plant roots. Root-knot nematodes generally have a wide host range and are well-adapted to surviving harsh environments. Egg masses may be attached to host plant roots, or free in the soil. The infective stage hatches from the egg and migrates through the soil towards host plant roots.

Root-knot nematodes can be found quite deep in the soil; the Columbia root-knot nematode has been found 5 to 6 feet below the surface. The number of generations per year, usually 1 to 5, is related to soil temperature. Generation time is 20 to 60 days.

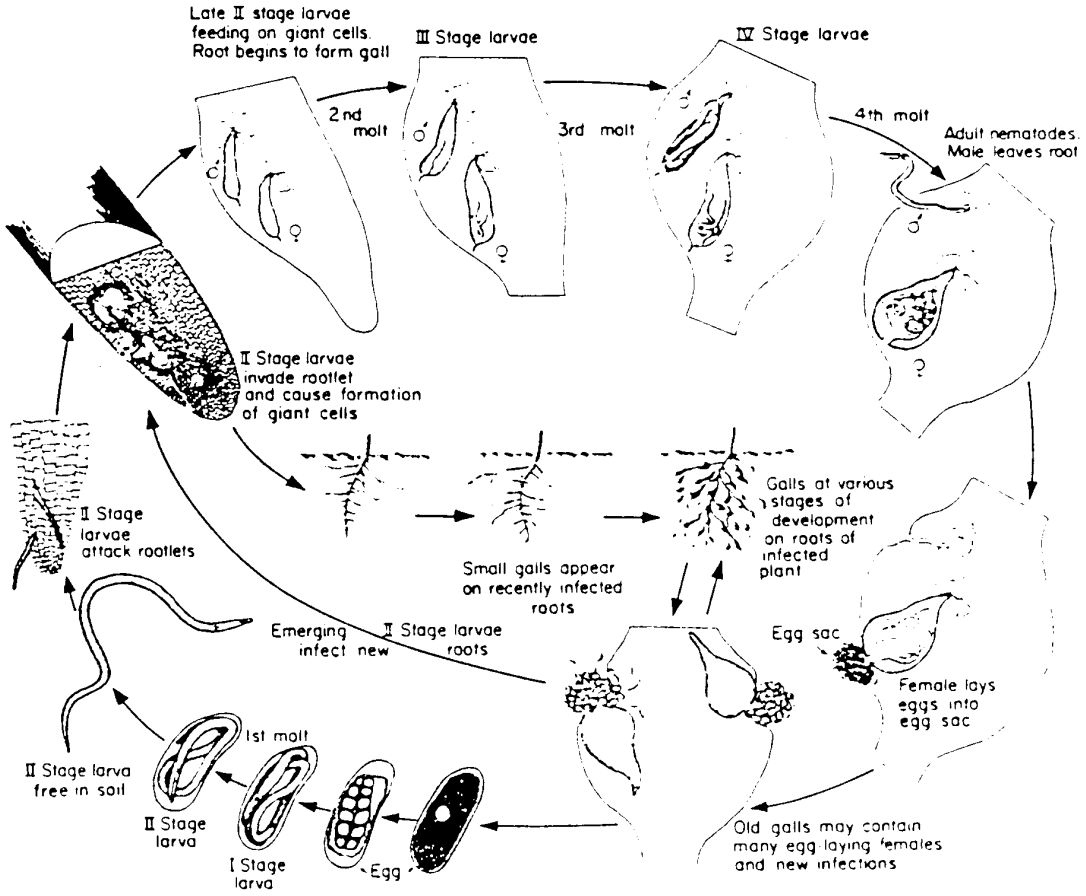


Figure 11.
Disease cycle of the root-knot nematode of the genus Meloidogyne
(copied with permission from Academic Press)

Damage and Symptoms

Nematode infestations can be localized or spread throughout a field. In fields with heavy infestations, seedlings may be killed or their emergence delayed. This damage results in stand reductions. Infested seedlings may also be more vulnerable to soil-borne diseases.[21]

Symptoms of nematode damage are useful for indicating a problem, but they are not sufficient for diagnosis. Similar symptoms may result from other factors such as nutrient deficiencies. Infestations may occur without causing any above-ground symptoms. Longer-than-normal seedlings, with green or yellow leaves, are often symptoms of nematode damage. Wilted and stunted plants are also indications. Storage roots typically do not develop well, and will have excessive fibrous roots.[21]

Short- and Long-term Management

Recommendations

Monitoring

- It is important to identify the type and number of nematodes in a field prior to planting sugarbeets in order to avoid heavily infested sites. To do this, take soil samples from within the root zone just before harvest of the previous crop. Divide the field into 10- to 20-acre sampling blocks, and take several samples from within each block and include some roots in each sample if possible. Mix all samples together to make a composite sample of about 1 quart of soil for each block. Place samples in labeled, sealed, plastic bags, and keep them cool prior to sending them to a diagnostic laboratory as soon as possible.[21]

Cultural

- Crop rotation to nonhost crops can reduce populations below damaging levels, but will not eliminate them. Alfalfa is a nonhost of Columbia root-knot nematode (*M. chitwoodi*) Race 1 and cereals are nonhosts of the northern root-knot nematode (*M. hapla*).[22] It is generally agreed that asparagus, corn, onions, garlic, small grains, cahaba white vetch, and 'nova' vetch are resistant enough that they can be grown as a rotation crop in soils infested with root-knot nematodes. Grasses such as rye also are resistant to root-knot nematodes and are a potential rotation crop. A cover crop of sesame has been reported to decrease root-knot nematodes.[23]

- Corn, cucurbits, potatoes and tomatoes are nonhosts to the cyst nematode (*Heterodera* spp.) and would be potential crop-rotation options for this pest if it becomes a problem in the Klamath Basin.

- Cover crops with winter rapeseed or fall Sudangrass may suppress nematode populations. (See Field Trial Recommendations for discussion of cover crop and trap-crop ideas for nematode control.)

- A weed-free fallow period (which deprives the nematodes of food) reduces nematode populations, though increases soil erosion. Irrigation during the dry period further reduces nematodes if weeds have been adequately controlled.

Biological

- There are no economically-viable biological controls to recommend at this time.

Chemical

- There are no PUP-approved nematicides for use on Refuge-grown sugarbeets. Chemical treatments are probably not economical since yields are rarely affected by nematodes. When sugarbeets follow potatoes in a crop rotation, nematodes usually have been controlled with nematicides prior to planting of the potatoes.

SUMMARY OF PEST MANAGEMENT RECOMMENDATIONS

PREVENTIVE PRACTICES

Pre-Plant and at Planting

- Plant powdery mildew resistant varieties (PM-9 is a variety grown in Idaho which may be suitable on the leased lands). Consider resistant varieties for curly top if this disease becomes a problem in the Klamath Basin.
- Use crop rotations to help reduce seedling damping-off, crown and root rot diseases and cutworms, wireworms, and nematodes.
- Consider field history prior to planting. Avoid sites infested with nematodes, weeds, cutworms, and wireworms.
- Summer fallow or flooding controls wireworms.
- Sample soil for nematodes and wireworms prior to planting.

During the Season

- Exclude pests. Avoid moving soil from contaminated areas to prevent nematode and Rhizomania infestation. Clean contaminated equipment.
- A vigorous crop and good irrigation management reduces seedling damping-off and root and crown rot losses.
- Keep leased-land fields weed free to reduce cutworms, flea beetles, leafhoppers, webworms, and wireworms.
- Monitor for and record pests and beneficials throughout the season. Conserve predators and parasites whenever possible. Ground beetles, lady beetles (ladybugs), bigeyed bugs, lacewings, spiders, pirate bugs, and several parasitic flies and wasps help control cutworms, armyworms, aphids, and beet leafhoppers.

CONTROL OPTIONS

Table 3.
Calendar of control options

Month	Recommended practice	Remarks
March	Clean cultivate 10 days prior to planting. Use wireworm bait stations 3-4 weeks prior to planting.	Clean cultivation prior to planting reduces cutworm populations.
April	Plant resistant varieties. Plant treated seed. Monitor emerging crop for flea beetles, cutworms, beet leafhoppers and aphids. Look for signs of seedling damping-off and nematode damage.	Treated seed reduces damping off and crown and root rots. Resistant or tolerant varieties protect against curly top, damping-off and powdery mildew diseases. Monitor for cutworm damage and larvae at base of plants, using a flashlight at night. Treat with Sevin for flea beetle and cutworm control if damage is severe.
May	Season long: Control weeds in fields and around borders.	Weed control reduces flea beetle, cutworm, leafhopper (and curly top), webworm and wireworm problems.
June-August	Early May, June and July: Monitor fields for armyworms. Mid-June; begin monitoring for powdery mildew and crown rot.	Treat with sulfur for mildew if disease is severe.
September	Take soil samples for nematodes.	
October-early November	Harvest	

FIELD TRIAL RECOMMENDATIONS

Trials are prioritized under each pest, with the most important trial listed first within each pest. Particularly important field trials are noted with the symbol: ☞

The most important ideas presented in the recommendations below investigate the effects of new biocontrol products, crop rotations and cropping techniques (such as strip cropping). Most of these trials can be done by any grower interested in experimenting with the idea. Results of most of these trials can be quantified by the grower, such as changes in yields or quality of the harvest. To develop a more detailed picture of what is happening in the field, it is recommended that the grower notify local researchers and the IPM manager to inform them of upcoming field trials. In this way, useful information developed from the trials may be communicated to other growers and also refined and investigated further by the researchers and IPM coordinator.

The factors that reflected in this prioritization include beneficial impact of results, practicality, and success of the trial elsewhere.

Flea Beetle

☞ **1. Gaucho 480 flowable seed treatments for flea beetle control**. Sugarbeet seed treatment with Gaucho (imidacloprid), a new systemic pesticide, appears to have several advantages for flea beetle control, as well as for aphids:

1) as a systemic seed treatment, it would protect germinating seed and young seedlings when they are the most vulnerable to flea beetle damage;

2) since it is seed applied and systemic, most non-plant feeding beneficial insects and other non-target organisms will not be subjected to spraying;

3) as a seed application, its control is more or less constant rather than being subject to wash-off, photodegradation, and other breakdown.

Field research is still being conducted to determine optimum rates, and a final label should be available soon (Steve Kaffka, Agronomist at U.C. Davis, personal communication, April 24, 1996). This seed treatment should be considered for PUP approval, since it would be a less-toxic alternative to aerial Sevin applications.

Cutworms

1. Beneficial nematodes. Beneficial nematodes may prove to be an alternative to Sevin applications for subterranean cutworm control.

Research on the parasitic nematode species, *Steinernematidae carpocapsae*, has shown it to be a very successful control agent for subterranean cutworms, such as black cutworms.[24][25] Beneficial nematodes enter the bodies of

cutworm larvae and release an intestinal bacteria (*Xenorhabdus* spp.), paralyzing and killing the worm within 24 to 48 hours. The nematode then completes several generations within the carcass. During the winter, predatory nematodes burrow deep into the soil for hibernation and return near the surface too late to control early-season larvae, so re-application must be made annually.[26] Beneficial nematodes do not work well against above-ground feeders such as the variegated or army cutworm.

The nematode product, BioVector: Biological Insecticide for Fruits and Vegetables, is typically used at rates of 1 billion nematodes per acre. Rates of 0.5 billion per acre (roughly $35 to $40 /acre) have worked well at times, depending on moisture conditions (Rick Miller, Product manager for Biosystems, personal communication, January 8, 1997). Since nematodes perform best with ample soil moisture, they might provide good control of cutworms in sugarbeets because moist conditions are typical of newly emerging beet fields. Applications may control cutworms for 4 to 6 weeks, an advantage over Sevin applications, which lose effectiveness more quickly.

According to the manufacturer, the ideal application strategy for using beneficial nematodes would be to apply 0.1 to 0.2 inches of water via overhead irrigation to the crop when the cutworms are still small. Then treat with Biovector at the 0.5 billion nematodes per acre rate, wait 5 to 7 days and monitor for damage. Re-treat only if necessary.

There are no regulations in California restricting the use of beneficial nematodes but their use would require PUP approval. Trials with these organisms could be done by growers in coordination with the IPM manager and/or by local Extension and experiment station researchers.

2. Enhance habitat to increase predation of cutworms by bats and birds.

Significant or properly sited bat populations may be especially helpful in managing cutworm adults. A bat can eat its body weight in insects in one night.[27] Bats feed during the same time that cutworm and armyworm adults are active and if numbers are sufficient, can significantly decrease pest populations. Bats may also have a repellant effect, as cutworm and armyworm adults are sensitive to bat echo location and may tend to avoid areas where this exists.

Bat habitat can be dramatically increased by simple modifications of existing farm structures (i.e., adding a board to a beam). Increasing bat habitat would be low cost and has the potential of dramatically decreasing cutworm and armyworm populations.

Growers could enhance bat habitat in coordination with the IPM coordinator and/or with local Extension and experiment station researchers.

3. Preirrigation. Preirrigation or heavy spring rainfall forces cutworms from protective burrows where they are more readily exposed to predators

and parasites.[6][28] This vulnerability could be exploited by applying extra water in years when cutworm damage is predicted to be high.

Aphids

Aphids are minor pests of sugarbeets in the Klamath Basin, but the following trials might be useful for enhancing the potential for biological control, and thus reducing the chances of aphids reaching the action threshold. Insecticidal soaps, horticultural oils, and neem products are generally "soft" on beneficials, and would thus work well in an integrated pest management approach:

1. Strip planting. Field trials should be set up to investigate plants or plant combinations that when grown in strips within a sugarbeet field will enhance habitat for beneficials. By adding sweet alyssum and other pollen and nectar plants to field crops, natural enemies such as the green peach aphid parasite, *Diaretiella rapae*, will have a greater chance to control aphids and other sugarbeet pests such as armyworms, beet leafhoppers, and cutworm larvae.

Bill Chaney of the U.C. Cooperative Extension Service in Salinas, CA, has done field trials where he interplanted "insectary" plants (those that provide beneficial insects with pollen and nectar) in with vegetable crops to enhance biological control of green peach aphids. In his trials, he planted sweet alyssum every twenty rows in a field of lettuce. Alyssum was chosen because it is easily direct sown, and doesn't require transplanting. It flowers about 30 days after planting, which provides a quick source of nectar and pollen for parasitic wasps early in the cropping season. It also does not attract pests and is non-aggressive. Under ideal conditions, the small wasp *Diaretiella rapae* parasitized 90 to 95 percent of the aphids in the trials and no other controls were needed.[29] However, 5 percent of the production area was taken up by the alyssum plantings. ***Note:*** *On Refuge lands, the area planted to insectary habitat will be subtracted from the total lease acreage, reducing the annual rent. Row-crop acreage will not be reduced.*

A variation of strip cropping, trialed successfully in California, is the use of ***pest break strips.*** Pest strips are created by sowing a select mix of habitat plants such as clovers, alfalfa, and non-invasive wildflower species in 40-foot-wide strips. These strips are planted at 350-foot intervals across the field. They have proven effective for enhancing biological control in potatoes and several other row crops. Good-to-excellent control of aphids, caterpillars, leafhoppers, and leafminers is reported with this method.

Several mixes of grasses, legumes and wildflowers were tested for effectiveness in creating pest strips that support beneficial insects. The most effective mix was found to be predominantly alfalfa (60 percent) mixed with Dutch white clover, strawberry clover, berseem clover and crimson clover (10 percent each).

Hoverfly larvae are aphid predators. Recent research in England[30] indicates that by planting border strips of habitat plants significant reductions of

aphid populations can be obtained. Increased populations of hoverflies extended to about 200 yards away from the border strips. Bugg and Ellis[31] observed that flowers of canola attract adults of the following species of hoverflies (*Syrphidae*): *Allograpta obliqua (Say), Sphaerophiria* spp.*, syrphus* spp.*,* and *Toxomerus* spp. Larvae of all of these species are aphid predators.

Growers will have to experiment to develop a system that works best for their particular operation. It is recommended that growers interested in experimenting with some form of strip cropping contact local researchers so that the results of the field trials can be quantified. Options for field trials include using border strips of canola, alyssum, alfalfa, or some other plants known as good habitat for beneficial insects.

2. Insecticidal soaps, horticultural oils or neem extracts (e.g., azadirachtin). These materials have been used with some success against aphid species in other crops. The success of insecticidal soap (M-Pede is one tradename) and horticultural oil applications is highly dependent on good coverage since they are only effective by direct application to the pest—residues on leaves exhibit no insecticidal qualities, whether by contact or ingestion. When using soaps or oils for aphid control, it is important to assure that the leaves are blown around enough to allow spray penetration to the undersides of leaves where the aphids are located.

Recent research[32] indicates that neem seed oil or azadirachtin (the most active component of neem) reduces green peach aphid reproduction and survival. This decrease in fertility, and also the fact that aphids exposed to neem seed oil or azadirachtin produce large numbers of dead offspring, would integrate well with control by natural enemies. The neem-based product, Align, is registered for use on sugarbeets in California. However, its use would require PUP approval.

Trials with these materials could be done by growers in coordination with the IPM coordinator and/or by local Extension and experiment station researchers.

Disease Control Trials

Seedling Damping-off Diseases

1. Biofungicides. W.R. Grace has developed a new biofungicide based on the beneficial fungus, *Gliocladium virens*, that is effective for control of common damping off and root rot diseases, caused by *Pythium* and *Rhizoctonia* spp. The granular formulation is called SoilGard 12G. This product is not currently registered for use in California. If it does become registered, it should be tested for its effectiveness on the Refuge. Research on a range of biofungicides will begin at UC Davis and other California locations in 1998 (Dr. Steven Kaffka, Extension agronomist, personal communication, August 11, 1997)

Nematode Control Trials

Nematodes are minor pests of sugarbeets in the Klamath Basin to date, but the following trials might be useful for fields known to be infested.

1. Trap crops for nematode control. In Wyoming, a cover crop of the nematode-resistant European fodder radish is proving to be an effective alternative to pesticides for controlling cyst nematodes in sugarbeets.[33] When planted after barley in an on-farm trial, the radish reduced infestations by 57 percent compared with no-cover control plots. The cover also boosted yields in the following sugarbeet crop by 5 tons per acre—a 30 percent increase over plots using pesticides. Researchers estimate that a 1.5 ton-per-acre yield increase will pay for the cost of the radish cover crop, which also serves to reduce soil erosion. Trap crop trials could be adapted to the Klamath Basin and tried in fields with known nematode infestations.

Trials with trap crops could be done by growers in coordination with the IPM coordinator and/or by local Extension and experiment station researchers.

2. Nematode-suppressive crop rotations and cover crops. Research at Oregon State and Washington State universities has documented that fall-planted Brassica green manure crops (such as rapeseed), grown over the winter and disced in before spring planting, suppress nematodes and weeds and provide winter cover to prevent wind erosion.[34]

The best rotation for Columbia root-knot nematode involves planting a summer nonhost crop, and a fall or winter cover crop (such as Sudangrass or rapeseed) incorporated as a green manure. A grower could use any of the following nonhosts: Supersweet corn ('Crisp' or 'Sweet 710/711' cultivars), pepper, lima bean, turnip, squash, rapeseed ('Humus' cultivar), canola, mustard, and Sudangrass ('Trudan 8', or 'Sordan 79' cultivars). The diversity of choices increases each year as more varieties are tested.[34]

Sudangrass, rapeseed, some canola cultivars and mustard release nematode-killing compounds after soil incorporation. In the Columbia Basin, the most benefit is gained from this effect when fall Sudangrass is plowed down after it is stressed (i.e., after the first frost or irrigation is stopped). Mid-March incorporation of winter rapeseed and canola is the best timing for that region too. Local trials could be done to determine the best timing for the Klamath Basin.

Table 4.
Possible 3-year rotation with sugarbeets using nonhost crops and cover crops

Year 1	Fall	Harvest sugarbeets and plant winter wheat as cover crop*
Year 2	Spring	Plant cash crop that is a poor nematode host, such as canola
Year 2	Winter	Canola stubble fallow**
Year 3	Spring	Plant nonhost cash crop
Year 3	Fall	After cash crop harvest, plant winter rapeseed as a green manure crop
Year 4	Spring	Disc under winter rapeseed and plant sugarbeets in the spring***

Adapted from Cardwell, Ingham and William, 1996

Notes:
* Wheat captures excess soil nitrogen and prevents nitrate leaching into the groundwater.
** During fallow, nematode densities will not change or will decrease.
*** Best timing of rape incorporation needs testing.

FURTHER RESEARCH

The following trials are expected to require significant research investments prior to implementation or adoption by growers.

Cutworms

1. Determine the effectiveness of monitoring cutworm populations using pheromone traps. This should be combined with positively identifying the species of cutworms causing economic damage to sugarbeets.

Montana has had a statewide monitoring program since 1992 for pale western and army cutworms. Adults are monitored using pheromone traps during late summer through fall when they move from oversummering sites and begin mating and egg laying. Continuous, long-term monitoring provides information about population increases, and may indicate potentially damaging outbreaks.

However, this technique is effective only if the correct pheromone trap for a particular species of cutworm is used. This is why it is necessary to determine which species of cutworms are most important in sugarbeets.

2. Determine appropriate action thresholds for cutworms on sugarbeets.

In potato crops, the following method is suggested for determining the number of cutworm larvae per foot row. This might prove a useful technique for sugarbeet monitoring as well.

Shake 5-foot sections of two adjacent rows into the furrow and count the larvae on the soil surface. Divide the number of larvae counted by five. The resulting number is the number of worms per foot row. Repeat in several locations throughout the field since infestations may be restricted to certain areas.[35]

There are no action thresholds now used for cutworms on sugarbeets. If appropriate action thresholds were determined for the Klamath Basin, it would provide growers with better guidelines for control.

3. *B. t.* var. *k.* trials with bait formulations. Soilserve Company in Salinas, California, has a label for a bait formulation of *B.t.* but has not received California EPA approval for its use. If a bait formulation of *B.t.k.* becomes available, trials should be done with it to determine the best timing and application strategy.

Researchers might consider doing limited trials to make a bait using another formulation of *B.t.k.* (such as a wettable powder) and applying it to a suitable substrate. Such trials probably would require a research authorization permit from California EPA, but these can usually be granted within a few weeks.

Adding caffeine to the bait might be another option for increasing the effectiveness of *B.t.* against cutworms. A note in *New Farm* magazine[36] mentioned that laboratory and greenhouse tests showed caffeine boosted *B.t.* effectiveness by up to 900 percent against armyworms. Much like *B.t.,* caffeine interferes with pests' digestive and nervous systems. It is most promising for pests that are weakly susceptible to *B.t.* itself. Recipe; dissolve 13 oz. pure caffeine in water. Add the solution to 100 gallons of standard *B.t.* spray and apply as usual. This practice would require PUP approval.

Seedling damping-off diseases

1. Non-alkaline forms of calcium could be used as a soil amendment. There is considerable research supporting the notion that calcium, added to the soil as gypsum or similar forms, can suppress *Pythium* spp. and increase host resistance.[37] Where infestation is severe, trials using a calcium-rich soil amendment might be warranted.

CONTACTS AND RESOURCES

Sugarbeets

- Bill Chaney, U.C. Cooperative Extension Service, 1432 Abbot St., Salinas, CA 93901; (408)759-7350

Bill Chaney has researched ways to enhance biological control of aphids by sowing plants that support beneficial insects in vegetable fields.

- Gordon Fellows, Assistant Manager, Holly Sugar; 4016 Jana Dr., Klamath Falls, OR 97601; (541) 891-1764(mobile phone)

- Jim Gerik, Plant Pathologist, Holly Sugar, P.O. Box 60, Tracy, CA 95378; (209) 835-3210

- Steve Kaffka, Agronomy and Range Science, University of California, Davis, CA 95616; (530) 752-8108

  Steve Kaffka is a Sugarbeet Specialist for California.

- Kerry Locke, Klamath County Extension Agent, Klamath County Cooperative Extension Service; (541) 883-7131

- Bob Lewellen, U.S. Agricultural Research Station, 1636 E. Alisal St., Salinas, CA 93905; (408) 755-2825

  Bob Lewellen is a sugarbeet seed breeder, contact for resistant varieties.

- Larry Peach, Holly Sugar Field Rep., 2056 Lawrence St., Klamath Falls, OR 97601; (541)885-9184 (mobile phone)

- Ken Rykbost, Klamath Experiment Station, 6941 Washburn Way, Klamath Falls, OR 97603; (541) 883-4590

  Ken Rykbost has expertise in sugarbeet cultural management and runs sugarbeet varietal trials.

- Charles Summers, University of California, 9240 S. Riverbend Ave., Parlier, CA; (209) 646-6564

  Charles Summers authored U.C. IPM guidelines for sugarbeet insect pests.

- Steven Temple, Agronomy and Range Science, 183 Hunt Hall, University of California, Davis, CA 95616; (530) 752-8216

For further information on flea beetles contact:

- Allen Moczygemba, Gustafson Sugarbeet Product Manager, Gustafson, Inc., 1400 Preston Road, Suite 400, Plano, TX 75093; (972) 985-8877 Extn. 3326

  Allen Moczygemba authored U.C. IPM guidelines for sugarbeet diseases.

- Michael Davis, Dept. of Plant Pathology, University of California, Davis, CA 95616; (530) 752-0303, or 752-3831

Beneficial organisms and biological controls

The publication, *Suppliers of Beneficial Organisms in North America*, lists 132 commercial suppliers of beneficial organisms including parasites, predators, nematodes, bacteria, fungi, protozoans and viruses useful for biological pest control.

One free copy of the document is available from:

- California EPA, Dept. of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1020 N. Street, Room 161, Sacramento, CA 95814-5604; (916) 324-4100

The Directory of Least-Toxic Pest Control Products is updated and published yearly by the Bio-Integral Resource Center (BIRC). It lists over a thousand pest control items including products, services and beneficial organisms. Descriptions and contact information for manufactures and suppliers are given for each product. Contact BIRC at the following address to request a copy:

- BIRC, P.O. Box 7414, Berkeley, CA 94707; (510) 524-2567

Local suppliers of BioVector Biological Insecticide for Fruits and Vegetables:

- United Horticulture Society, 1000 S. Central, Medford, OR 97501; (541) 772-4597

For further information about *B.t.k.* for cutworm control and for registration status of *B.t.k.* bait formulations contact:

- Cheryl Norton, Abbot Laboratories, Northern California Sales Rep., 8125 Bailey Rd., Yuba City, CA 95993; (530) 673-7537

Supplier of cutworm lures:

- Scenturion, 4809 E. St. Hwy 525, Clinton, WA 98236; (360) 341-3989. Contact: Joan Fisher, owner

For further information about the use of beneficial nematodes for cutworm control contact:

- Rick Miller, product manager, Biosys, 10150 Old Columbia Rd., Columbia, MD 21046; (410) 381-3800

For further information about bat predation enhancement contact:

- Dr. Steve Cross, Southern Oregon State College, 1250 Siskiyou Blvd., Ashland, OR 97520-5071; (541) 552-6749

  Dr. Cross has done extensive work increasing bat habitat.

- Jim Kennedy, Bat Conservation International; (512) 327-9721

  BCI has a wealth of information concerning bats and bat habitat.

- Rachael Long, Farm Advisor, U.C. Cooperative Extension, 70 Cottonwood St., Woodland, CA 95695; (530) 666-8143

  Rachael Long is working with growers in Yolo County to increase bat populations and study the positive effects in increased bat populations.

Suppliers of insecticidal soap (e.g., M-Pede), horticultural oil and neem-based (e.g., Align) products are listed below. Also see Directory of Least-Toxic Pest Control Products cited in the following resources section for other suppliers:

- Harmony Farm Supply, 3244 Hwy. 116 No. B, Sebastopol, CA 95472; (707) 823-9125

- Peaceful Valley Farm Supply, P.O. Box 2209, 125 Springhill Blvd., Grass Valley, CA 95945; (530) 272-4769

- Biosys (Align manufacturer), 10150 Old Columbia Rd., Columbia, MD 21046; (410) 381-3800

Cultural controls

For more information on trap crops for nematode control in sugarbeets contact:

- David Koch, Dept. of Plant, Soil and Insect Sciences, P.O. Box 3354, University Station, Laramie, WY 82071-3354; (307) 766-3242

For further information about nematode-suppressive crop rotations and cover crops contact:

- Russ Ingham, Dept. of Botany and Plant Pathology, Oregon State University, 2082 Cordley Hall, Corvallis, OR 97331-2902; (541) 737-5255

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