ALFALFA

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CROP OVERVIEW, GROWTH & DEVELOPMENT

Alfalfa crop development can be divided into three stages: plant establishment, vegetative growth, and flowering and fruiting.[1] The plant establishment and vegetative growth phases are particularly critical to management of weeds and other pests. Several insects and diseases can cause problems during the establishment phase that are rarely problematic in older stands.

Management practices that prevent pest problems are the cheapest and most reliable defense against alfalfa pests. Field history and characteristics should be carefully considered prior to making the decision to plant alfalfa. A history of weed or disease infestations, unmanageable drainage problems, compacted soil, the presence of vertebrates that cannot be managed economically, or the existence of a previous crop that cannot be harvested soon enough to enable timely alfalfa establishment are conditions that may make a field unsuitable to alfalfa production.[1]

Hay management practices such as proper land preparation (e.g., primary and secondary tillage and land leveling), fertility, irrigation, and harvesting strategies that maintain healthy, vigorous vegetative growth will help prevent or reduce pest problems in established stands.

Biological control also plays an important role in alfalfa pest management. Many natural enemies attack alfalfa weevils, aphids, armyworms, cutworms and other pests. Border harvesting and the use of selective pesticides can increase biological control benefits. The publication, *Beneficial Organisms Associated with Pacific Northwest Crops,*[2] provides life cycle information and color photographs of many beneficials that occur naturally in alfalfa fields.

The recently published *Intermountain Alfalfa Management*[3] manual details regionally appropriate production practices for alfalfa on Refuge lands. This important guide covers a spectrum of topics including alfalfa site selection,

stand establishment, variety selection, irrigation, fertilization, pest management (weeds, insects, nematodes, diseases and vertebrate pests), harvesting (including timing, curing, baling and storage), quality testing, grazing management, and depleted stand management.

VARIETY SELECTION

Alfalfa is a long-term crop, and variety selection is key to preventing disease and other pest problems. The need for disease or insect-resistant varieties will vary depending on the history and characteristics of the field. For instance, due to the well-drained soil of Tule Lake NWR, Phytophthora root rot is rarely a problem and planting a resistant variety is not as important as it is for other diseases. In general, varieties that are resistant to bacterial wilt, Verticillium wilt, Fusarium wilt, southern anthracnose, pea aphids, blue aphids, stem nematodes, and root-knot nematodes should be grown on the Refuge.[3]

Winter hardiness is another very important characteristic for variety selection in the Intermountain Region. Varieties without winter hardiness may suffer winterkill, and the stand may be reduced to below economic levels within a couple of years.[3] Poor stands are also more susceptible to insect, disease, and weed pests.

Varieties are rated for their degree of fall dormancy. Dormancy is the ability of the variety to stop growing in the fall and thus become tolerant of freezing temperatures. Studies conducted in Tulelake show that varieties in fall dormancy class 3 tend to produce the highest yields with adequate winter survival.[3]

Cultivars differ in their tolerance or resistance to insect pests and diseases. *Table 1* lists fall dormancy class 3 alfalfa cultivars that are also disease and pest tolerant or resistant. Another source of pest resistant varieties is *Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties*, produced by the Certified Seed Council in Davis, California. Each variety has a diverse genetic background, so some plants of a resistant or tolerant variety may still be susceptible to the pest.

Table *1.*

Note: this table is not available. See the Executive Summary for further information.

Table 2.
Status of alfalfa pests on Refuge lands

Major Pests (as noted by ♦)	**Minor Pests** (as noted by ♢)
Invertebrate alfalfa weevil aphids (blue and pea)	**Invertebrate** variegated cutworm armyworms **Disease** stem nematode root-knot nematodes spring blackstem phytophthora root rot

Note: Rare or non-occurring insect and disease pests include the following: alfalfa caterpillar, thrips, clover root curculio, stagonospora crown and root rot, bacterial wilt, verticillium wilt, downey mildew, and southern anthracnose.

MONITORING

Sampling techniques and action threshold guidelines are available for the major alfalfa pests. Check each field weekly when pests are likely to occur. More frequent monitoring (two to three times per week) is necessary when counts show that populations are approaching damaging levels. Pest levels may vary greatly within a single field. Therefore, it is important to take at least four random samples—one in each quadrant of the field—on each visit to assure a representative reading. Avoid taking samples from field edges (but keep them under observation). Pests in high and low spots, wet areas, borders, and in weedy spots may not represent the average population in the field. Watch these "trouble spots" for unusual insect activity, and consider localized spot treatments if action thresholds are reached.

Alfalfa weevil larvae, alfalfa caterpillars and armyworms usually are sampled with a sweep net. Stem counts are taken for aphid sampling. Visual counts—used to tally the number of organisms in a given area—are often done for cutworms, small caterpillars and for diseases. Predators, parasites and diseased pests can also be monitored by using sweep nets and visual counts.

Table 3.
Summary of monitoring methods and action thresholds for alfalfa pests

Pest	When/how to scout	Interim action threshold*	Remarks
Alfalfa weevil	Early April through mid-June, use sweep nets to monitor weevil larval populations. Sample every 2 to 4 days once larvae appear. Divide each field into at least five sample sites across the field. At each sampling, take at least 10 sweeps while walking at a steady pace. Empty the net contents on a clean surface and count the number of weevil larvae. Base the population estimate on an average of all sweeps taken per field. Also record types and numbers of beneficials. When walking the field, search for wasp parasite cocoons around base of plants—small, brown, football-shaped cocoons that have a white band around the middle.	A general threshold is to consider treatment if 30 to 40 percent of alfalfa tips are damaged by weevil feeding, larvae are present. Sweep net counts are more precise: consider control actions when counts reach an average of 20 larvae per sweep. Use a higher threshold for weed-free fields (>20 larvae per sweep). For fields too short to sweep, consider treatments if 30 percent of the young shoots show obvious signs of larval feeding.	Severity of damage is influenced by alfalfa variety, stand health, weather, growing conditions, and degree of weevil parasitization.

Pest	When/how to scout	Interim action threshold*	Remarks
Aphids (blue and pea)	Early to mid-April through mid-July, monitor fields at least weekly. Monitor fields where aphids are approaching action thresholds every 2 to 3 days. Divide each field into five sampling sites. Cut 5 five to six stem samples at each site. Cut stems close to the ground with a sharp knife, pulling the stem up, and rapping it sharply against a stiff piece of paper or into a white pan. This will dislodge the aphids and they can be easily counted. Repeat, cutting a number of stems at several locations in the field. Use a hand lens to distinguish between the two aphid species: blue aphid antennae are uniformly brown, and those of pea aphids are green with a narrow dark band at the tip of each segment. Distribution of aphid species differs; pea aphids tend to be located over most of the plant, whereas blue aphids are primarily found on new, tender shoots and developing leaves.	Do not use insecticides to control aphids unless monitoring shows aphid populations are too high and natural enemy populations are too low to provide good biological control. Action thresholds vary with plant height and species of aphid. *Pea aphid*: plants <10" high, 40-50/stem; plants >10" high, 70-80/stem; plants >20" high, 100/stem. *Blue aphid*: plants >10" high, 40-50/stem. Do not treat if the ratio of lady beetles to aphids is equal to or exceeds the following per sweep. *Standing hay:* >1 lady beetle adults to 5-10 aphids; >3 lady beetle larvae to 40 aphids. *Stubble:* >1 lady beetle barvae to 50 aphids.	Pea aphids usually appear earlier than blue aphids. Blue aphids are more damaging. Aphids tend to occur slightly later than do alfalfa weevils, though their presence may overlap. Aphids cause more damage to short alfalfa than they do when the hay is taller. Insecticide treatments for weevils kill aphid natural enemies and increase the likelihood of having aphid problems later in the season.
Variegated cutworm	Early March through early June, look under crop debris on the soil surface for larvae and for signs of their damage. Estimate and record size and location of any areas damaged by cutworms. Use a flashlight to scout at dusk or at night, when larvae are most active.	Though action thresholds are not established, one to two larvae per foot of row may warrant treatment. The need for treatment is based on the size of the worms observed, the amount of damage, and the crop stage. Older plants can tolerate more damage.	Cutworm populations fluctuate considerably from year to year and are primarily affected by rainfall. Populations will be higher in dry years.

Pest	When/how to scout	Interim action threshold*	Remarks
Armyworm	Weekly from mid-July through mid-September, check two or three times a week if heavy populations begin to develop. Monitor armyworm larvae with a sweep net. Take five sweeps at each of five sampling sites throughout the field. Note numbers and types of beneficials and of diseased larvae. Larvae must be at least 0.5 inch long for accurate counting and to evaluate for parasitism and disease.	Treatments usually are required when nets yield 15 nonparasitized worms of more than 0.5 inches length per sweep.	High armyworm populations occur only every few years. They can be especially bad after mild winters that favor survival of overwintering larvae. Conditions that favor the pest include slow crop growth, hot dry weather, and low populations of natural enemies. The presence of a number of diseased larvae in the field may indicate that a natural epidemic may soon occur.

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

INVERTEBRATE PESTS

♦ ALFALFA WEEVIL *S Hypera postica*

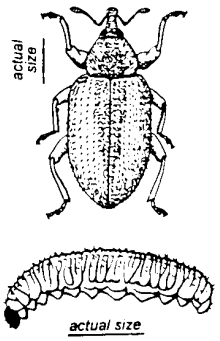


Figure 1.
Alfalfa weevil
Top: adult. *Bottom:* larvae
(after USDA Bull. 368)

Life Cycle, Host Crops, Seasonal Development

The alfalfa weevil is the primary insect pest of alfalfa on leased lands. The western strain of the weevil is predominant.[4]

Each year the timing and pattern of weevil development differs due to weather and temperature changes. In general, overwintering adult weevils normally become active in late winter or early spring, when they begin to mate[3] and lay eggs in the alfalfa stems. The yellow-to-brown eggs are laid in masses of 2 to 25, which the female inserts into the stems. Each female is capable of laying 500 to 2,000 eggs.[5]

Depending on temperatures the eggs may hatch as early as late March, but mid-April is more typical. The larvae move up the stem to the shoot terminals, where they feed. Larval development takes 3 to 4 weeks and is normally completed about the time of the first cutting (i.e., mid-June). Mature larvae drop to the ground to pupate, emerging as adults in about 1 to 2 weeks.[3] Adults feed on crown buds briefly before dispersing to weedy areas near the field and entering a summer resting state.[3] There is generally one generation completed each year.

Damage and Symptoms

Weevils cause two main types of damage: defoliation, which reduces yields, and damage to regrowth buds, which stunts growth. The first signs of weevil damage are small holes eaten in the leaves at the growing tip during the early spring (April and May). Initially the larvae are well hidden in the leaves of the growing tips. As they grow, the injury becomes more apparent and attacked plants show skeletonizing or shredding of the leaves. Growing tips are eaten off, plant growth is stunted, and the field may appear to suffer from severe frost injury in heavily infested sites.[6]

Damage is most severe to the first cutting, and to a lesser extent, to the regrowth of the second cutting. Injury typically increases from early spring until shortly before the first cutting. In general, it is the larvae that damage the first crop, while adults feed on the developing crown buds and slow regrowth of the second crop. Severity of damage is influenced by alfalfa variety, stand health, weather, growing conditions, and degree of weevil parasitization.[5]

Short- and Long-term Management Recommendations

Monitoring

- Spring egg-hatching dates will vary depending on climatic conditions. Begin larval sampling by early April. Larvae may appear as early as late March, but are most prevalent from mid-April to mid-June.[3] Although there is a chance that alfalfa weevil egg-hatch will be missed when any date is used, there is usually time for control actions (if needed) because economic damage typically does not occur until at least 1 week after egg-hatch.[7]

- Use sweep nets to monitor weevil larval populations. Sample every 2 to 4 days once larvae appear. Divide the field into at least five sample sites from across the entire field. At each sampling site, take at least 10 sweeps while walking at a steady pace. Empty the sweep net on a clean surface and count the number of weevil larvae. Base the population estimate on an average of all sweeps taken per field.[1]

- A general threshold is to consider treatment if 30 to 40 percent of alfalfa tips are damaged by weevil feeding, larvae are present, and early harvest is more than 1 week away.[5] Sweep net counts provide more precise information. U.C. IPM guidelines[8] suggest control actions when counts reach an average of 20 larvae per sweep. When monitoring weed-free fields, adjust the action threshold upward because sweep counts are often higher in weed-free fields even though weevil damage is not increased.[1]

- Sometimes fields will have very high populations of weevil larvae before the alfalfa growth is tall enough to sweep. If this happens, use controls if 30 percent of the ends of the young shoots (terminals) show obvious signs of larval feeding.[3]

- When scouting, also look carefully for and record the number of weevil parasites. The tiny wasp, *Bathyplectes cucurlionis*, is the most common

parasite and is easily recognizable. The most obvious sign of this beneficial is the presence of small, brown, football-shaped cocoons that have a white band around the middle. The parasite cocoon is usually found beside the cocoon of the dead weevil, typically located on the ground near the base of alfalfa plants. ***Monitor fields with high levels of beneficials more frequently. Consider holding off on spraying fields with high populations of beneficials since they may prevent the weevil population from reaching the action threshold and make a pesticide treatment unnecessary. Avoid spraying beneficial insect habitat.***

▶ *Cultural*

Proper stand management. **Stand management** is critical to alfalfa weevil control. Vigorous, dense, uniform alfalfa stands that have well-developed root systems can withstand more weevil feeding than can poor stands. Proper cutting intervals, fertility management and crop rotations are sound cultural practices that can help maintain a healthy alfalfa field and reduce weevil and other pest problems. Refer to the *Intermountain Alfalfa Management* manual for details on best management practices for alfalfa.

Strip or border harvesting. **Strip or border harvesting conserves beneficials that can keep alfalfa weevils and other pests below economically damaging levels.**[9] Research conducted in California during the 1950s showed that strip-harvested fields contained four times the number of natural enemies, required no pesticide applications for aphids or caterpillars, and produced 15 percent more hay per acre than did conventionally harvested fields.[10]

Strip cutting is accomplished by harvesting alfalfa in alternate strips so that two different aged hay stands occur in a field at the same time. When one set of strips is cut, the alternate strips are about half grown. Thus, the field is never completely bare of hay. This technique produces a fairly stable environment in the field, with beneficials moving to (and surviving in) uncut areas instead of dying after harvest. During irrigation and harvesting, the two sets of strips in each field are farmed as though they are two separate fields.

How to strip cut: Begin strip cutting with the first cutting of the season. Observe length of new buds at the base of the plant to determine correct cutting time. Cut the first set of strips when 25 percent of new shoots are 0.5 to 0.75 inches long. Cut the second (or alternate) set of strips about 10 days later. This sets up a harvesting differential for the second cutting.[10]

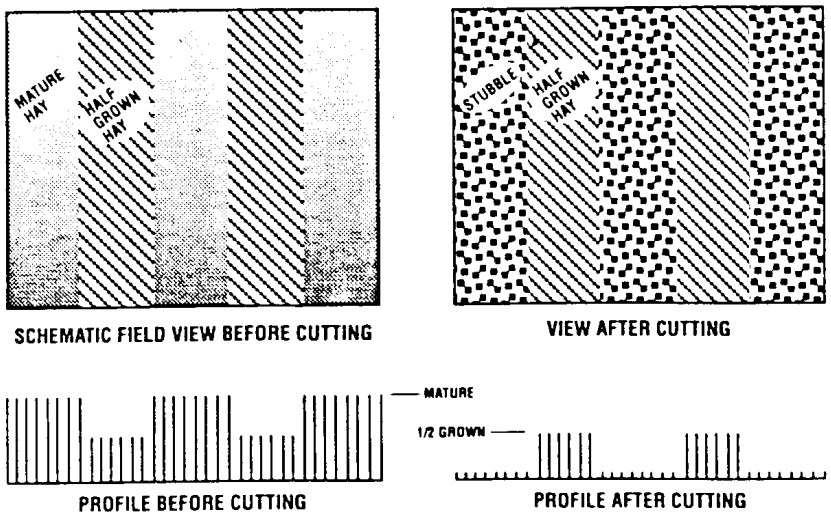


Figure 2.
Schematic diagram of a strip-cut alfalfa field
(*IPM Practitioner*, XV (4), April 1993)

Border harvesting. If strip cutting is impractical, border harvesting is an alternative, though slightly less-effective, method for conserving beneficials. With this method, a 10-foot, uncut strip of hay is left on alternate field borders. Strips left uncut at one harvest are cut at the next, and strips are then left on the previously clean-cut levees.[(1)]

Oil added to dormant weed control: The addition of crop oil to winter-applied herbicides often delays peak weevil populations during the first cutting by one to two weeks, or it lowers peak weevil levels.[(8)] If a winter herbicide application is warranted (see Weeds for a discussion about the economics of herbicide use in alfalfa), then adding oil to the mix may increase pest control benefits by reducing weevil damage. Use of oil would require PUP approval.

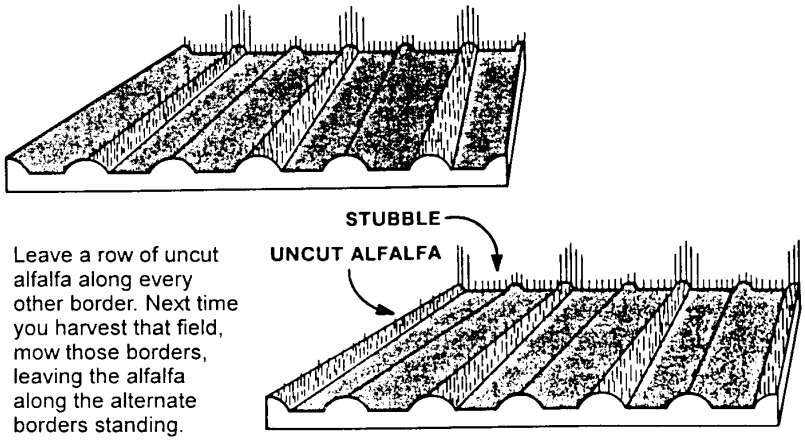


Figure 3.
Border harvest
(Summers, C.G., D. Gilchrist and R. Norris. 1985. *Integrated Pest Management for Alfalfa Hay*. U.C. Statewide IPM Project, Div. of Agric. And Natural Resources, Oakland, CA)

▶ *Biological*

- The USDA's Animal and Plant Health Inspection Service (APHIS) has released a number of parasite species in an effort to control the weevils. A complex of natural enemies is now keeping weevils in check in many locations across the country.

- The species that seems to have the greatest potential in the Klamath Basin is the tiny parasitic wasp, *Bathyplectes cucurlionis*. Samples collected in Modoc County, California, from 1987 to 1989 showed that 66 percent of weevil larvae were parasitized.[4]

- The life cycle of the beneficial is well timed with the weevil in the Klamath Basin, enabling it to be a good parasite of the pest. Adult wasp activity matches the spring activity of the weevil larvae. The parasite flight lasts several weeks, with peak parasitism levels occurring 1 to 2 weeks prior to peak weevil larval numbers. By late spring to early summer they enter a state of "diapause," a condition of arrested activity and development. In the fall, they feed on nectar and pollen then hibernate during the winter. In the spring, they come out of hibernation and begin laying eggs in the hatched weevil larvae. During diapause and hibernation they are fairly resistant to pesticides. *Bathyplectes cucurlionis* has one, and possibly a partial second generation each year.

- The adult wasps lay their eggs inside young weevil larvae. When the parasite egg hatches, the young wasp feeds inside the weevil eventually killing it after the weevil has finished spinning its cocoon. Although the weevil larvae may continue to survive for a period of time, feeding damage is greatly reduced.

- After the weevil dies the wasp larva spins a cocoon of its own. The parasite cocoon is the most obvious sign of its presence and is useful to

scouts trying to determine the degree of parasitization occurring in a field. *Bathyplectes cucurlionis* cocoons are elongated, brown, and football-shaped with a white band around the middle.

- ***What growers can do to encourage biocontrol in their fields***. *Bathyplectes* parasites are not commercially available, but they are likely to exist in Refuge alfalfa fields. The most important consideration for enhancing biological control is the conservation of these parasites, particularly by avoiding insecticide use when the adult wasps are active (i.e., early in the spring). Harvesting the field in strips, or leaving 10-foot wide uncut borders around the edge of a field enables the beneficials to survive in parasitized weevil larvae. The parasites will then be available to control the weevils the next year.

▶ *Chemical*

- The presence of weevils in an alfalfa field does not necessarily justify a pesticide application. **Chemical control should not be used unless weevil damage approaches about 20 larvae per sweep**. Any decision to spray should be based on scouting data.

- Sevin XLR Plus and Pounce currently are the only PUP-approved insecticides for alfalfa weevil control.[11] In 1996, weevils reached unprecedented levels on the Refuge, and Sevin applications did not sufficiently control the population.

♦ PEA APHIDS *S Acyrthosiphon pisum*
♦ BLUE APHIDS *S Acyrthosiphon kondoi*

Life Cycle, Host Crops, Seasonal Development

Both pea and blue aphids may attack alfalfa in the Intermountain Region. They may both be present in the field at the same time and will typically occur from early April through mid-to-late July. Pea aphids are usually found in the field later in the season than are blue aphids because they can tolerate higher temperatures. Both aphid species tend to occur slightly later in the season than do alfalfa weevils, though their presence may overlap.[3]

Because blue aphids are more damaging to alfalfa and thus have a lower action threshold, it is important to know how to distinguish

between the two species. The easiest way to tell them apart is to examine their antennae with a hand lens. The antennae of blue aphids are uniformly brown, and those of pea aphids are green with a narrow dark band at the tip of each segment. Distribution of the species on the alfalfa plant differs too. Pea aphids tend to be located over most of the plant, whereas blue aphids are primarily found on new, tender shoots and developing leaves.[3]

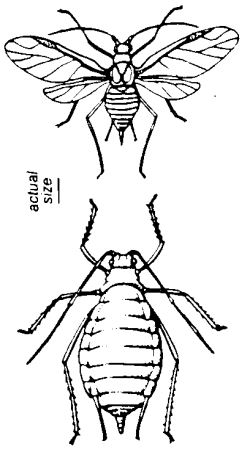


Figure 4.
Blue alfalfa aphid and pea aphid
Top: nymph. *Bottom:* adult. *Blue alfalfa aphids and pea aphids closely resemble one another. The* ***blue alfalfa aphid*** *is bluish green and its antennae are uniformly brown. The* ***pea aphid*** *is yellow-green or light green and the third antennae segment has a narrow dark band at the tip.* (after USDA Bull. 1945)

Damage and Symptoms

Both aphid species feed on plant juices, reducing yields and stunting plants if infestations are severe. They secrete "honeydew," a sticky substance that can hinder harvest. Blue aphids also inject a growth-reducing toxin into the plants when feeding. Both types of aphids cause more damage to short alfalfa than they do when the hay is taller.

Short- and Long-term Management Recommendations

Aphid populations seldom reach economically damaging levels in the Intermountain Region.[3] A complex of natural enemies often keep them under control, although sometimes populations can explode. **Early season insecticide treatments for weevils kill aphid natural enemies and increase the likelihood of having aphid problems later in the season.**

Monitoring

- Sweep nets used to sample other insects may indicate the need for more detailed aphid sampling described below.

- Monitor fields at least weekly. Monitor fields where aphids are approaching action thresholds every 2 to 3 days. Divide each field into five sampling sites. Cut five to six stem samples at each site.[1] U.C. guidelines suggest the following method for sampling pea or blue aphids:

  > "Cut alfalfa stems close to the ground with a sharp knife, pulling the stem up, and rapping it sharply against a stiff piece of paper or into a white pan. This will dislodge the aphids and they can be easily counted. This procedure should be repeated, cutting a number of stems at several locations in the field.
  >
  > While counting aphids, note the presence or absence of lady beetle larvae, parasitized aphid mummies, or aphids killed by fungus. When inspecting individual stems on new regrowth alfalfa, it is important to pry open small, new leaves and search the spaces between them; many first and second instar nymphs can often be found there."[12]
  >
  > If both species of aphids are present, use blue aphid treatment levels.

Table 4.
Treatment thresholds for pea aphid and blue alfalfa aphid[1]

Plant height	Pea aphids	Blue aphids
Under 10 inches	40-50 per stem	
Over 10 inches	70-80 per stem	40-50 per stem
Over 20 inches	100 per stem	

- Do not treat if the ratio of lady beetle to pea or spotted alfalfa aphids is equal to or exceeds the following:

On standing hay: 1 or more lady beetle adults to 5-10 aphids
3 or more lady bettle larvae to 40 aphids

On stubble: 1 or more lady beetle larvae to 50 aphids

▶ *Cultural*

- Strip and border harvesting (as described under cultural controls for alfalfa weevils) are effective methods of conserving beneficials that control aphids.

- Resistant varieties have successfully reduced aphid damage. Alfalfa varieties resistant to pea aphids are readily available for the Intermountain Region. (See *Table 1* for a list of appropriate varieties.) Unfortunately, only nondormant varieties are currently available for blue aphid resistance, though some are tolerant of damage.

▶ *Biological*

- Several good enemies of aphids occur naturally in alfalfa fields. The convergent lady beetle, *Hippodamia convergens,* is an efficient predator. The wasp, *Aphidius smithi,* parasitizes the pea aphid, and *Aphidius ervi* is a good parasite of the blue aphid. Several fungal diseases also play a role in controlling aphids, especially during cool, rainy, foggy weather. Releases of these parasites would require PUP approval.

▶ *Chemical*

- Pesticides should be used as a last resort and only if natural enemies and cultural methods fail to keep the population below action thresholds. No treatment should be initiated if there are one or more convergent lady beetle adults per five to ten aphids,

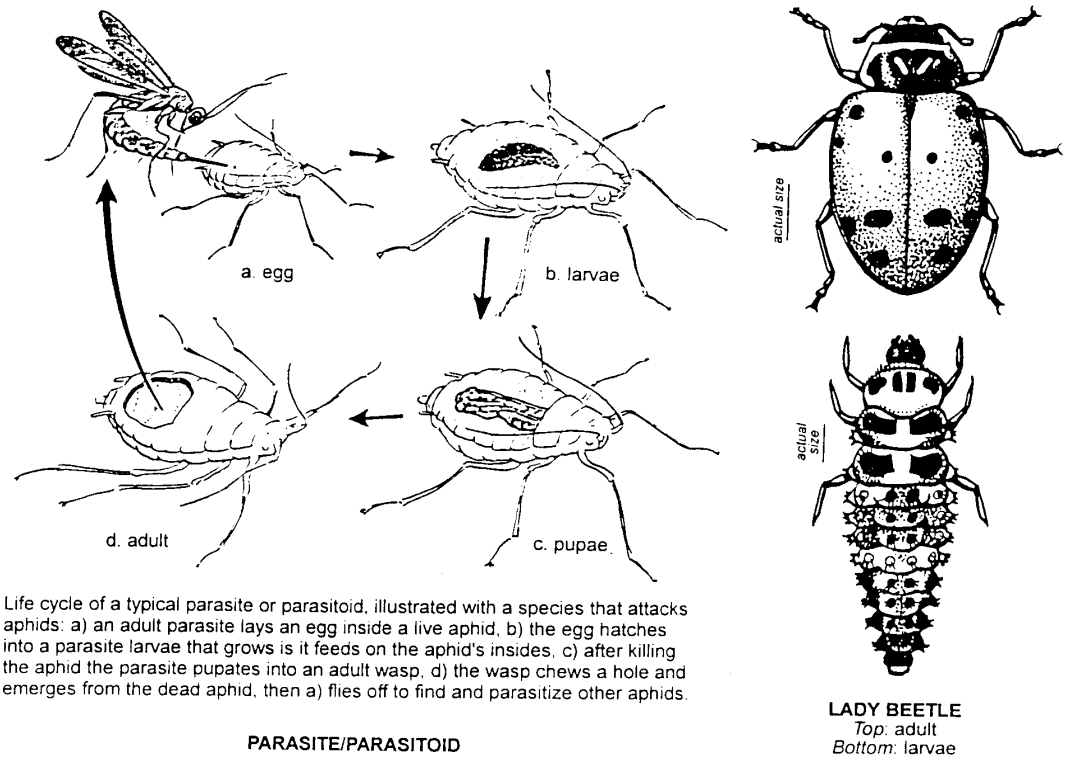


Figure 5.
Beneficial insects effective against aphids found in alfalfa
(Parasite life cycle: Dreistadt, Steve, Jack Clark and Mary Louise Flint. 1994. *Pests of Landscape Trees and Shrubs*. UC Statewide IPM Project. Univ. of CA, Div. of Agric. and Natural Resources, Pub. # 3359. Lady beetle: after USDA Bull. 2148.)

or three or more lady beetle larvae per 40 aphids.[11] Malathion 8 is the only PUP-approved material for aphid control but has limited efficacy for aphids. Malathion is toxic to many species of beneficial insects, including parasitoids and other natural enemies of aphids.[27] Dimethoate and Lorsban were denied approval for Refuge use based on bird toxicity data.[13]

◊ VARIEGATED CUTWORMS *S Peridroma saucia*

Figure 6.
Variegated cutworm
(after Iowa Agric. Exp. Stn. Circ. 101)

Life Cycle, Host Crops, Seasonal Development

Cutworms are sporadic pests of alfalfa, with the variegated cutworm being the species causing the most problems.

Adults begin laying large clusters of eggs on the undersides of leaves in late May and early June. The eggs quickly hatch and the larvae feed on the leaves for 4 to 6 weeks, then pupate in the soil. The second generation of adults emerge in late August, lay eggs, and the larvae that hatch overwinter either in the soil, or under crop debris. There are two generations each year in the Northwest.[14]

The worms are gray to dull-brownish in color, smooth-skinned, with a row of 4 to 6 dull yellow or pink diamond-shaped spots down the back.[15] They readily curl into a C-shape when disturbed.[16] The larvae feed at night and hide in cracks in the soil and under leaf litter during the day. The adults are brownish gray moths that fly at night.

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

Variegated cutworms occasionally damage seedling or established alfalfa fields. They feed above ground and cut seedlings off at or just above the soil line. In established stands they cut off new growth or eat the foliage.

Short- and Long-term Management Recommendations

▶ *Monitoring*

- Beginning early March, look for larvae and signs of feeding damage. The need for treatment is based on the size of the worms observed, the amount of damage, and the crop stage. Though economic thresholds are not established, one to two larvae per foot of row may warrant treatment action.[3] Older plants can tolerate more damage.

- Look under crop debris on the soil surface for cutworm larvae early in the season, and after destruction of adjacent habitats. Since variegated cutworm larvae feed at night and hide during the day, so it is best to scout for them early in the morning or at night with a flashlight.

▶ *Cultural*

- Clean till to remove all vegetation at least 10 days prior to establishing a new field to reduce cutworm larvae. Control weedy vegetation at field borders to reduce the number of invading larvae. Harrowing established fields may provide adequate control when larvae are actively feeding.[3]

- Crop rotation is an important control tool for cutworms, since their populations can build in preceding crops. Cereals are especially good hosts for cutworms, so growers should avoid planting fields to alfalfa if monitoring shows high populations of cutworms in a previous crop.

- After July 15 (to protect nesting waterfowl), flood-irrigating seedling alfalfa stands that have grown at least 3 inches tall suppresses cutworm populations.[3]

Biological

- Cutworm larvae have a number of natural enemies. Predators include several species of ground beetles. Tachinid flies and braconid wasps parasitize the eggs and larvae.[17] Fungi, bacteria, nematodes, birds, and bats also attack cutworms.

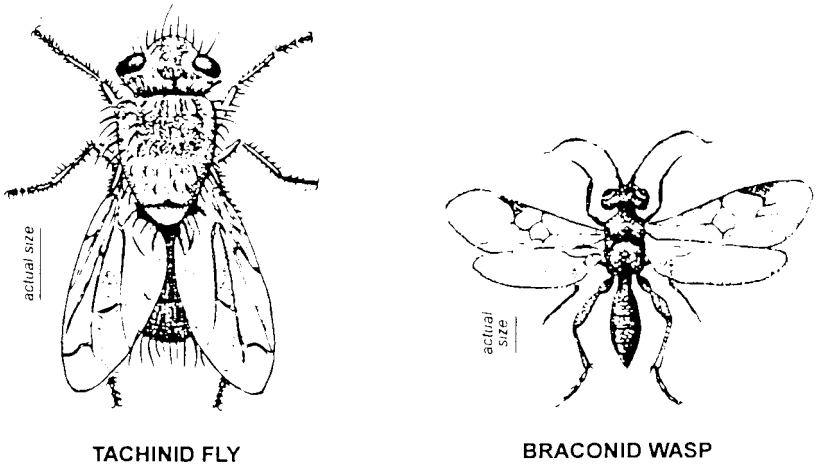


Figure 7.
Cutworm parasites and predators
(*Insects and Mites of Economic Importance in the Northwest*, OSU, Corvallis, OR. Tachinid: original, Mooney. Braconid: after USDA Bull. 233.)

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

Chemical

- This minor pest has not warranted pesticide use on Refuge lands and no pesticides have been requested for approval.

- Bait formulations are generally the most effective against cutworms (Cheryl Norton, Abbott Laboratories Western Regional Sales Representative, personal communication, January 6, 1997). Baits will be considered for use on the refuges, once PUP approved, if they do not pose threats to fish and wildlife. Baits made from the bacteria *Bacillus*

thuringiensis var. *kurstaki (B.t.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.

◊ WESTERN YELLOWSTRIPED ARMYWORM *S Spodoptera praefica*
◊ BEET ARMYWORMS *S Spodoptera exigua*

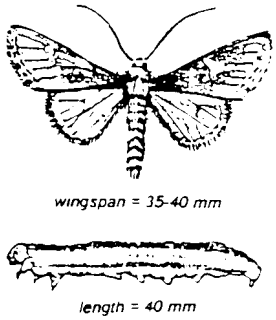


Figure 8.
Western yellowstriped armyworm
(original, Mooney. *Insects and Mites of Economic Importance in the Northwest*, OSU, Corvallis, OR)

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. Conditions that favor the pest include slow crop growth, hot, dry weather, and low populations of natural enemies.

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.[14]

Damage and Symptoms

Armyworm larvae skeletonize foliage leaving the veins largely intact.[18] This feeding is different than that of the alfalfa caterpillar, which eats the entire leaf.

Short- and Long-term Management Recommendations

▶ *Monitoring*

- Monitor weekly from mid-July through mid-September. Increase monitoring frequency to two to three times per week if heavy populations begin to develop. Use a standard-sized sweep net to sample armyworm larvae. Take five sweeps at each of five sampling sites throughout the field.[1] Control actions are usually required when nets yield 15 nonparasitized worms of more than 0.5 inches in length per sweep.[18] The larvae must be at least 0.5 inch long for accurate counting and to evaluate for parasitism 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. The presence of a number of diseased larvae in the field may indicate that a natural epidemic may soon occur.

Cultural

- Early cutting will give satisfactory control if the infestation appears late in the cutting cycle. Armyworms will move out of a cut field, causing damage to neighboring crops, but this migration can be prevented by putting a barrier around the field.[18]

Biological

- Natural enemies often provide good control of armyworms in alfalfa. Predators include bigeyed bugs, damsel bugs, lacewings, spiders and pirate bugs. Many parasites also attack armyworms. The wasp, *Hyposter exigua*, is known to be especially effective against beet armyworms.[1] Refer to the Extension publication, *Beneficial Organisms Associated with Pacific Northwest Crops*, for life cycles and color photographs of important biological control agents.

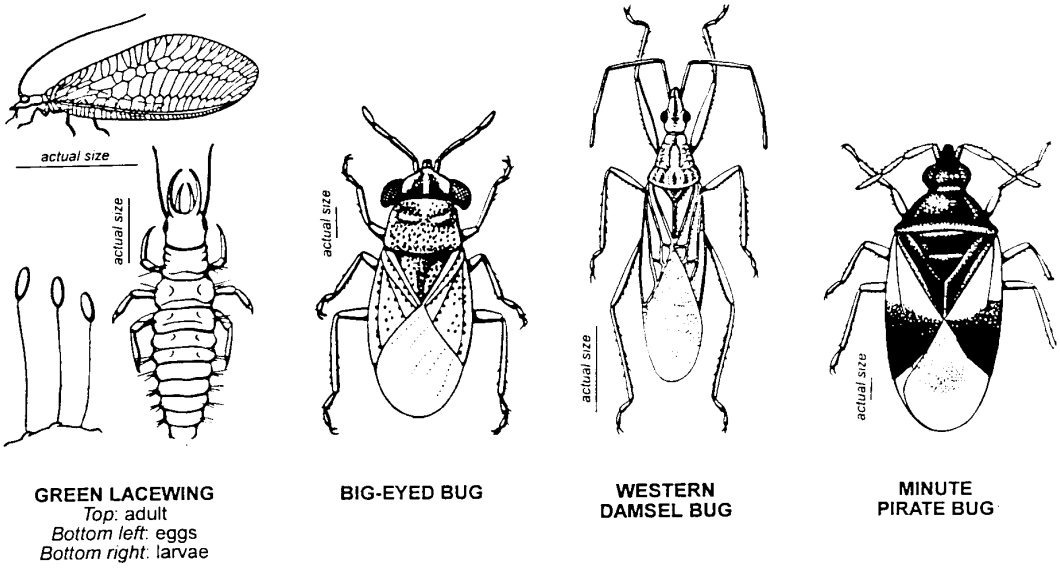


Figure 9.
Common armyworm predators
(*Insects and Mites of Economic Importance in the Northwest*, OSU, Corvallis, OR. Green lacewing, western damsel bug, and minute pirate bug: after Ext. Serv. 4-H Handbook. Big-eyed bug: after Ore. Agric. Exp. Stn. Bull. 749.)

- Viral diseases of armyworms also play an important role in their control. Growers can enhance and preserve the potential for biological control in their fields by avoiding pesticide applications if possible, and by harvesting their crops in a way that provides shelter and protection for beneficials (e.g., by leaving 10-foot wide uncut borders or strip harvesting).

Chemical

- This minor pest has not warranted pesticide use on Refuge lands and no pesticides have been requested for approval.

- *Bacillus thuringiensis* var. *aizawai (B.t.a.)* (XenTari WDG, by Abbot Laboratories) gives good control of armyworms, especially small ones (less than 1.5 inches long). It also conserves beneficials and works well in an IPM program. Ground applications are more effective than aerial, 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 against armyworms on alfalfa if pesticide treatments are warranted.

DISEASES

◊ STEM NEMATODE *S Ditylenchus dipsac*
◊ NORTHERN ROOT-KNOT NEMATODE *S Meloidogyne hapl*
◊ COLUMBIA ROOT-KNOT NEMATODE *S Meloidogyne chitwoodi*

Life Cycle, Host Crops, Seasonal Development:

Stem nematode and root-knot nematodes are the two main nematode species attacking alfalfa in the Intermountain Region. Neither species causes serious losses of alfalfa on Refuge lands.[19]

The stem nematode moves in free water, so infestation and damage are most severe during cool, moist, cloudy weather. Hot, dry summer conditions reduce stem nematode activity. Stem nematodes survive in plant debris or on the soil surface, and are spread between fields on infested plant tissue carried on equipment, wind, and in irrigation water.

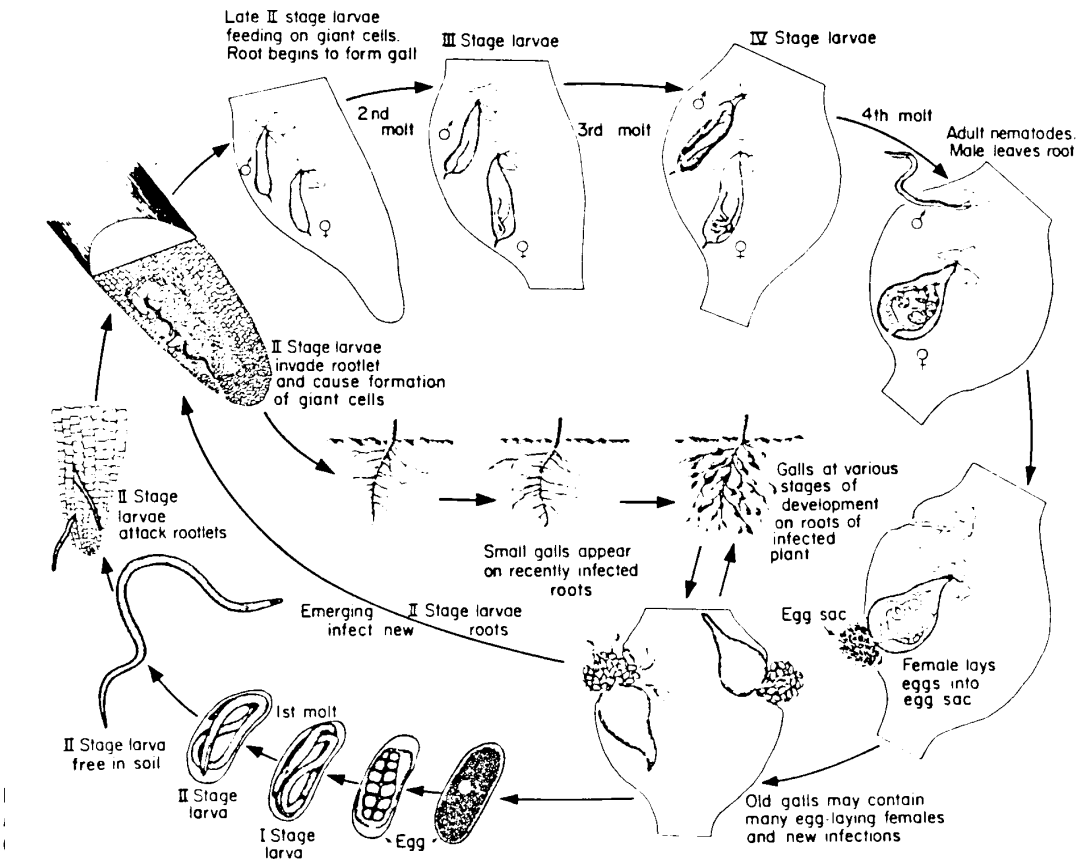


Figure 11.
Disease cycle of root-knot cause by nematodes of the genus Meloidogyne
(copied with permission from Academic Press)

Two species of root-knot nematodes potentially could infest Refuge fields; the northern root-knot nematode, and the Columbia root-knot nematode, which includes two separate races. Race 1 is not a significant problem to alfalfa since it does not reproduce well in the crop, but race 2 successfully reproduces on alfalfa and can cause problems. Often, though, the most serious problem associated with root-knot infested alfalfa fields is from the damage they cause to the following crop in rotation.[3]

Damage and Symptoms

Stem nematode damages stems and crowns of alfalfa plants. Infested stems are stunted and typically turn yellow. Young infested shoots are swollen, spongy, brittle, and have shortened internodes. They also are especially susceptible to frost damage. Symptoms often appear as patches in the field. Buds and leaves are also attacked, and young seedlings may be killed when nematode populations are high.[3]

Root-knot nematodes infest plant roots, causing small galls. Nematode-caused galls can be distinguished from those caused by nitrogen-fixing bacteria by rubbing the roots with a finger. Nitrogen-fixing nodules are easily rubbed off, and those caused by nematode feeding are not.[3]

Above-ground symptoms are more difficult to identify. When infestations are low, yield loss or increased sensitivity to nutrient or water stress may be noticed. With high populations, symptoms may include patches of stunted plants and yield loss.[3] Root-knot nematodes can increase the severity of Fusarium and bacterial wilt diseases.[20]

Short- and Long-term Management Recommendations

Monitoring

- Identify the type and number of nematodes in a field prior to planting alfalfa in order to avoid heavily infested sites. To do this, take soil (from the root zone), roots and plant-tissue samples to a diagnostic laboratory. To collect a sample, divide the field into several blocks that contain different soil types, drainage patterns and cropping history. 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.[3]

Cultural

- Crop rotation with a nonhost crop can effectively reduce nematode populations. For stem nematodes, 2 years of crop rotation to a nonhost (e.g., small grains, sugarbeets or potatoes) should reduce populations below economically damaging levels.[3]

- For root-knot nematodes, proper identification of the species and race present is critical to effective use of crop rotation. Small grains are useful for reducing northern root-knot nematode, since grains are a nonhost for this nematode species. If Columbia root-knot race 1 is present, then alfalfa will not be affected since it is a nonhost (and would make a good crop in a rotation with a susceptible crop like potatoes, sugarbeets or onions). Small grains are a host to Columbia root-knot nematode and would not make a good rotation crop for controlling this species. Onions and pasture grasses are possible hosts for Columbia root-knot nematode. A year of weed-free fallow (with summer cultivation) is an effective alternative to a nonhost crop if a suitable alternative cannot be found.[3]

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

- Many alfalfa varieties are available with resistance to stem nematodes. Plant resistant varieties in fields known to have stem nematodes following two years of rotation to a nonhost. Resistance to the different

species and races of root-knot nematodes is variable. Prior to planting, discuss the root-knot resistance potential of a specific variety with a seed dealer or farm advisor.[3]

▶ *Biological*

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

▶ *Chemical*

- Control with nematicides is not economical in alfalfa. No nematicides are PUP-approved for use on alfalfa leased lands.

◊ ALFALFA FOLIAR AND ROOT DISEASES

There are no severe foliar or root disease problems of alfalfa grown on Refuge lands. Spring blackstem, root rots, and bacterial wilt are occasional problems. Resistant varieties, seed treatments, clean seed, proper irrigation, sanitation and early cutting (prior to defoliation in the case of foliar diseases) are typically used to prevent and treat diseases. Refer to the *Intermountain Alfalfa Management* manual for details on best management practices for alfalfa.

Verticillium wilt, a devastating alfalfa disease, was found in the Intermountain Region in 1993 and may be present on Refuge lands. To prevent its spread, plant resistant varieties and avoid introducing it into fields on contaminated hay or manure. Crop rotation coupled with weed control can reduce (but not eliminate) the amount of *Verticillium* pathogen in the soil. Clean equipment to remove crop debris. Harvest clean fields before harvesting diseased fields.

No fungicides are PUP-approved for use on alfalfa leased lands.

SUMMARY OF PEST MANAGEMENT RECOMMENDATIONS

PREVENTIVE PRACTICES

Pre-plant and at Planting

- Plant resistant varieties for bacterial wilt, Verticillium wilt, Fusarium wilt, southern anthracnose, pea aphid, blue aphid, stem nematode, and root-knot nematode control or suppression.

- Use crop rotations to help reduce root rot diseases and cutworms. Rotation to another crop for 1 year usually allows enough time for alfalfa diseases and pests to dissipate.[3]

- Consider field history prior to planting. Avoid sites infested with weeds or diseases, cutworms, or those having unmanageable drainage problems or compacted soil.

- Proper land preparation (e.g., primary and secondary tillage and land leveling) prior to establishing a new field will promote a vigorous crop and prevent weed, disease, and insect pest problems.

During the Season

- Manage hay production including irrigation, fertilization, and harvest to promote vigorous vegetative growth.

- Keep fields and border areas weed free to reduce cutworms, alfalfa weevil damage, and armyworms.

- Prevent contaminating fields with *Verticillium* from hay or manure. Clean all equipment to remove crop debris, harvest clean fields first.

- Monitor and record pests and beneficials throughout the season. Conserve beneficials whenever possible to reduce alfalfa weevils, aphids, cutworms, armyworms and other insect pests. Leave 10-foot wide uncut borders or use strip harvesting to conserve beneficials.

Table 5.
Calendar of control options

Month	Recommended practice	Remarks
January	If winter herbicide treatment is warranted, add crop oil for weevil control.	
February	End of February through early June, monitor for cutworms.	
March	Clean cultivate 10 days prior to planting new seedling fields.	Clean cultivation prior to planting reduces cutworm larvae.
April	Plant fungicide treated seed. Use resistant varieties. Early-April through mid-June, monitor for weevils. Look for weevil parasite cocoons at base of plants. Mid-April through mid-July, monitor for pea and blue aphids and look for beneficials.	Use sweep nets for counting weevils; 20 weevils per sweep is rough action threshold level. Use stem count technique to monitor for aphids.
May	Season-long, control weeds around field borders.	Weed control reduces armyworms and cutworms and reduces alfalfa weevil damage loss.
June-September	At harvest, use border or strip harvesting to conserve beneficials. Avoid cutting or flooding fields where ground- nesting birds are present. Mid-July through mid-September, monitor for armyworms and their natural enemies.	Control weevils if necessary. Consider early cutting. Count armyworms with a sweep net. Late-fall harvesting benefits ground-nesting birds because the field has less time to grow back, and is therefore less attractive to them.

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 recommendations below are suggested to help develop new information about mechanical, cultural and biological control options. Most of these trials can be done by any grower interested in experimenting with the idea. Results of most of these trials also 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 coordinator to inform them of upcoming field trials. In this way, useful trial information may be communicated to others and/or refined and investigated further.

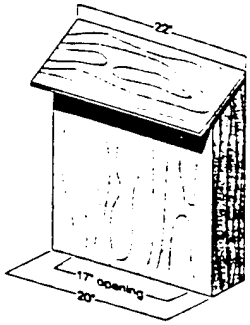
The factors that are reflected in this prioritization include beneficial impact of results, practicality, and success of the trial elsewhere.

☞ *Alfalfa Weevil*

1. Dormant-season flaming. Flaming to kill eggs in dormant alfalfa has produced a 45 to 60 percent reduction in weevil density in some research trials.[21] The main purpose of flaming is to kill the eggs that the adult weevils lay during the winter months. These eggs are primarily laid in the dead alfalfa stems, close to the soil. Flaming to kill these winter eggs is done during the alfalfa's dormant period, or immediately after harvest. Dormant-season flaming can be done any time after the first killing freeze in the fall until the plant starts new growth in the spring (i.e., until about March). Since the weevils lay eggs all winter, delaying flaming until just before growth begins is recommended. The adults also lay eggs in the spring, after alfalfa growth has started, and therefore cannot be killed by flaming without injuring the plants. New seedling stands and fields with new growth are susceptible to heat injury and should not be flamed. Slow ground speeds of less than 4 miles per hour using tractor-mounted propane burners is the most successful method. Approximately 17 gallons of propane per acre are required.

Growers can either make their own flaming equipment or purchase it from a manufacturer or distributor. See Useful Contacts and Resources for a list of manufacturers and suppliers, and for sources of further information on flaming for weevil control.

Flaming trials could be done by growers in coordination with the IPM coordinator, or by local Extension and experiment station researchers.



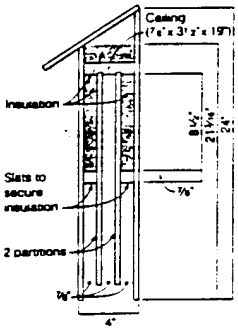


Figure 12.
Bat house
(*Farmer to Farmer*, December 1994)

Cutworm

1. ***Bacillus thuringiensis* var. *kurstaki* efficacy trials**. *B.t.k.* is a bacteria that is effective against lepidoptera (moth and butterfly) larvae. DiPel is a common tradename of one product formulated from this organism. A microbial toxin, it must be ingested by the larvae in sufficient amounts to cause paralysis of the digestive tract. Worms live up to several days after poisoning but do not feed. The toxin breaks down rather rapidly in the environment. Sprays often lose effectiveness within 24 to 48 hours.[16]

A note in *New Farm* magazine[22] 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 the pests' digestive and nervous systems. It is most promising for pests that are mildly 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.

B.t.k. effectiveness trials could be carried out by growers in coordination with the IPM coordinator, or by local Extension and experiment station researchers. Use of *B.t.k.* would require PUP approval. See Useful Contacts and Resources for sources of further information on *B.t.k.*

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 and armyworm adults. A bat can eat its body weight in insects in one night.[24][25] 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. (Rachel Long, U.C. Farm Advisor, personal communication, August 6, 1996)

Bat habitat can be dramatically increased by simple modifications of existing farm structures (i.e., adding a board to a beam with 0.75-inch spacers or hanging thin plywood sheets from the ceiling with plastic netting stapled to one side and 0.75-inch spacers between the sheets). It is best to start small and observe what the bats seem to like. Increasing bat habitat in barns or other structures with existing populations is easiest. To attract bats to new habitat, it helps if some diluted guano "paint" is used on the surface of the wood where the bats are to nest. However, barns with owls will not work, and metal surfaces are not appropriate for bats because they conduct too much heat away from the colony during cold weather.

Placing bat houses around fields is also an option. Bat houses need full sun exposure, and should be painted dark brown to black.

The important idea is to start small and observe what works. Growers would implement this effort. Service personnel could lend support, providing information about the types of bats present in the area of the Refuge and their ecological requirements. See Useful Contacts and Resources for further information about bat predation enhancement.

Nematodes

1. 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 provides winter cover to prevent wind erosion.[27]

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.[27]

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 also is the best timing for that region. Local trials could be done to determine the best timing for the Klamath Basin.

USEFUL CONTACTS AND RESOURCES

Bat predation and enhancement research

- 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

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

Flaming for weevil control

- Flame Engineering, Inc., P.O. Box 577, LaCrosse, KS 67548; (800) 255-2469

- Flame Systems, 3403 Hwy. 93, Eau Claire, WI 54701; (715) 839-7242 or (715) 839-8087. Contact: John Quast

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

Local researchers and other contacts

- Don Kirby, University of California Intermountain Experiment Station, Tulelake, CA 97634; (530) 667-5117

- Steve Orloff, Field Station, 1655 South Main St., Yreka, CA 96097; (530) 842-2711

- Harry Carlson, Ag. Building, University of California Davis, California 95616; (530) 752-3930

Nematode cover crop and crop rotation research

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

Suppliers of beneficial organisms and other pest control products

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 above document is available from:

- California EPA, Dept. of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1020 N St., 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

DiPel (*Bacillus thuringiensis* var. *kurstaki)* and XenTari (*B.t.* var. *aizawai*) (registration status and formulations):

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

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28. Table 1: *Intermountain Alfalfa Management* (Publication 3366), edited by Steve B. Orloff and Harry L. Carlson. Oakland, CA: University of California, Division of Agriculture and Natural Resources. Copyright: 1995, University of California Board of Regents. Used with permission.

29. Figure 2: *The IPM Practitioner* (Vol. XV, No. 4, April 1993). "Strip intercropping for biological control," by Joel Grossman and William Quarles. Berkeley, CA: Bio-Integral Resource Center (BIRC). Used with permission.

30. Figure 3: *Integrated Pest Management for Alfalfa Hay* (Publication 3312), edited by Charles G. Summers, David G. Gilchrist, and Robert F. Norris. Oakland, CA: University of California, Statewide Integrated Pest Management Project, Division of Agriculture and Natural Resources. Copyright: 1985, University of California Board of Regents. Used with permission.

31. Figure 5: (Parasite/Parasitoid) *Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide* (Publication 3359), edited by Steve H. Dreistadt, Jack Kelly Clark, and Mary Louise Flint. Oakland, CA: University of California, Statewide Integrated Pest Management Project, Division of Agriculture and Natural Resources. Copyright: 1994, University of California Board of Regents. Used with permission.

32. Figure 10: *Plant Pathology* (3rd edition), by George N. Agrios. San Diego, CA: Academic Press, Inc. Copyright: 1988, Academic Press, Inc. Used with permission.

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