SMALL GRAINS

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SMALL GRAINS

CROP OVERVIEW, GROWTH & DEVELOPMENT

The high-quality soils in the Basin, particularly on the leased lands, provide grain yields somewhat higher than the national average. The relatively cool climate is especially suited for crops of malting barley; the predominant grain grown on Refuge lands. Small grains are grown in rotation with row crops on Tulelake NWR leased lands as opposed to the leased lands of Lower Klamath NWR where small grains are grown without rotation. Grain crops are important from a wildlife perspective because the crops provide both food and habitat for waterfowl, pheasants, and song birds.

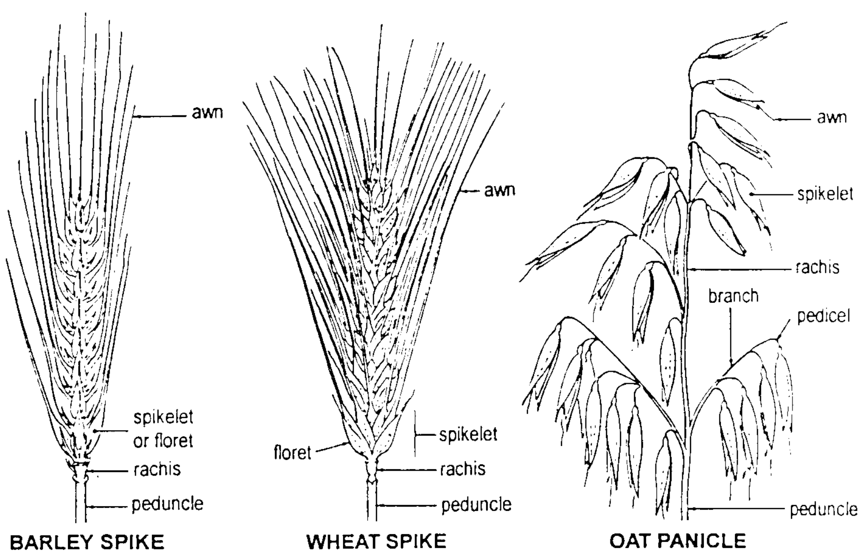

Figure 1.
Structures of small grain inflorescences
(University of California Statewide IPM Project, Publication No. 3333)

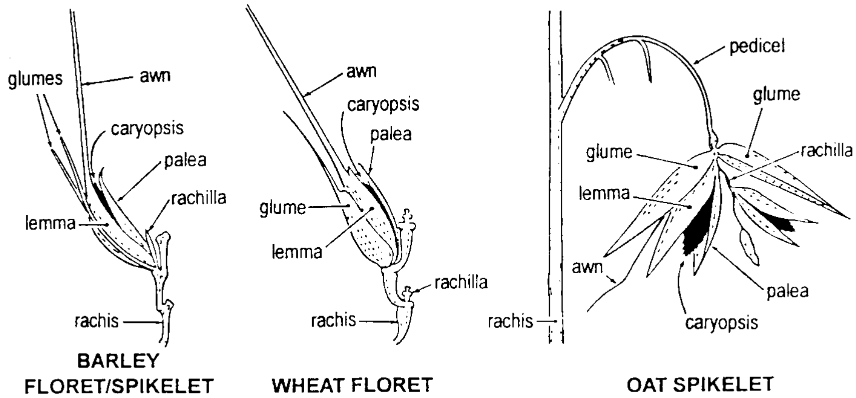

Figure 2.
Structural details of small grain inflorescences
(University of California Statewide IPM Project, Publication No. 3333)

However, the lack of crop rotation on the Lower Klamath Refuge has exacerbated some pest problems, notably barley root-knot nematode, wheat stem maggot, and common root rot. Other major pests for *both* refuges include the Russian wheat aphid, other aphids (greenbug, bird-cherry oat aphid , and English grain aphids), grasshoppers, and mites. Race 24 of yellow barley stripe rust (*Puccinia striiformis*) is the major disease of concern. Races that can cause significant damage to barley were confined to Europe until 1975, when they were introduced into South America. Barley strip rust was first detected in the U.S. in Texas in 1991, and only recently (1993/94) was detected in California. A major epidemic on barley occurred in 1996. However, certified seed has been used to effectively control many of the seed transmitted disease of small grains.

Table 1.
Status of small grain pests on Refuge lands

Major Pests (as noted by ♦)	**Minor Pests** (as noted by ◊)
Invertebrate	**Invertebrate**
Russian wheat aphid	wheat stem maggots
oat bird cherry aphid	armyworms
English grain aphid	greenbug
grasshoppers (*Melanoplus* spp.)	
mites (various species)	
barley root-knot nematode	
Disease	**Disease**
yellow barley stripe rust	loose, covered, and stinking smuts
(also called stripe rust)	common root rot
	Columbia root-knot nematode
	lesion nematode

MONITORING

Weekly scouting of fields is advisable throughout the season. In addition to pest management, scouting is useful for observing crop growth stages to schedule critical management practices. Weekly scouting requires access to weather data, scouting sheets for recording data, and a 10X hand lens or binocular visor. A programmable computer or calculator also are handy.

If a grain crop (especially barley) is going to be planted in the spring, growers may wish to sample for barley root-knot nematode the preceding fall.[3] This is particularly true if the previous crop was barley. (There are some crop rotations suggested under Field Trial Recommendations that may provide some nematode control.) As soon as the crop is up, monitoring for the Russian wheat aphid should begin. Weeds should be monitored as well at this time. Around late spring and continuing through the season, scouts should be on the look-out for other aphids. Monitor pasture/range-lands and uncultivated areas during early summer if grasshoppers are a concern. Begin looking for mite damage when the weather warms and becomes drier. If the previous winter has been mild, begin looking for armyworm damage around early June.

For aphids, large and non-uniform fields may need to be split for sampling purposes. Fields larger than 80 acres should be split into uniform parcels of less than 80 acres. Fields made up of different grain varieties, planted at different dates, or tilled differently (within a field) should be divided into uniform areas and sampled separately.

Tillers must be randomly sampled, and chosen blindly to avoid sampling bias. When a sample is needed, pick a number between 10 and 20, count your paces, and stop at that predetermined pace number. Without looking down, pick a single tiller to inspect for aphids.[1]

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

Pest	When/how to scout	Interim action threshold*	Remarks
Russian wheat aphid (Pacific Northwest Extension guidelines)[(1)]	emergence to heading heading to soft dough soft dough to harvest Tillers must be randomly sampled, and chosen blindly to avoid sampling bias. When a sample is needed, pick a number between 10 and 20, count your paces, and stop at that predetermined pace number. Without looking down, pick a single tiller to inspect for aphids.	5-10% of tillers infested 15-20 % tillers infested Treatment after soft dough produces no benefits	Fields larger than 80 acres should be split into uniform parcels of less than 80 acres. Fields made up of different grain varieties, planted at different dates, or tilled differently (within a field) should be divided into uniform areas and sampled separately. Pay special attention to field borders, corners, and areas with poor plant stands. A tiller is considered infested if one or more Russian wheat aphid is found.
Russian wheat aphid (U.C. Davis provisional guidelines for Central Valley grains)[(2)]	2-leaf stage early tillering late tillering	1 aphid per plant 3 aphids per tiller 8 aphids per tiller	The thresholds listed here are provisional, resulting from research at U.C. Davis.
Russian wheat aphid	Sequential sampling plan outlined in *Appendix G-1* can be used to scout.[(4)]		For each 1% increase in the number of infected stems during stem extension stage, a 0.4-0.5% decrease in yield may be expected.[(6)] These thresholds were developed for wheat, but also may be applicable for barley.[1] (See footnote below.)

[1]**Assumption 1:** The grower knows the cost of control ($9/acre, for example). **Assumption 2**: The expected market value of the crop will be $100/acre (for ease of calculation). **Assumption 3:** For each 1% increase in the number of infected stems during stem extension stage, a 0.4 to 0.5% decrease in yield may be expected.

Then: The action threshold will be roughly 18% infested tillers. This level of infestation will cause losses of roughly $9/acre, equal to the cost of control. *However*, this is only true at the stem extension stage, relatively late in the development of the crop. It may be wise to use the 5 to 10% infested tillers threshold listed in **Table 3** (Pacific Northwest Extension guidelines) in the early season.

Pest	When/how to scout	Interim action threshold*	Remarks
Greenbug	3-5 leaf stage on wheat 3 tiller (6 leaf stage) stem extension stage	50 greenbugs per linear foot-row 100 greenbugs per linear foot-row 3-500 greenbugs per linear foot-row	Aphids should be counted or estimated at a minimum of 5 locations in a field: a 1-foot length of row should be sampled. Fields should be sampled from seedling emergence to tillering.
English grain aphid Oat bird-cherry aphid	Early season, whole plants should be sampled. As plants get larger, tillers are sampled at 40-50 sites randomly selected from the field. Field edges should be sampled separately.	50-60 per tiller	If predators and parasites are abundant, treatment may not be needed. High populations on heads do not reduce grain yields unless they interfere with harvest.
Barley root-knot nematode Columbia root-knot nematode[3]	Root zone soil samples should be taken immediately after harvest or just prior to harvest if crop shows signs of damage. Fields should be divided into blocks of 20 acres which have similar damage, soil texture or cropping history. Several subsamples from each block should be well-mixed to create a single, one-quart sample.	If sampling reveals populations of barley root-knot nematode, rotation to non-cereals or resistant oat cultivars is recommended.	Soil samples should be kept cool, but not frozen. Local experiment station can provide details needed for labeling samples and names of laboratories that can analyze them.

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

INVERTEBRATE PESTS

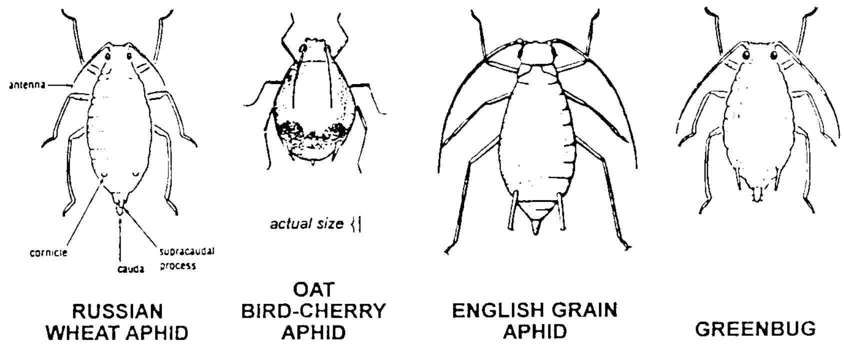

Figure 3.
Russian wheat, oat bird-cherry, English grain aphids and greenbug
(Russian wheat aphid and greenbug: University of California Statewide IPM Project, Publication No. 3333. Oat bird-cherry and English grain aphids: after Texas A&M Agric. Exp. Stn.)

♦ RUSSIAN WHEAT APHID *S Diuraphis noxia*

Life Cycle, Host Crops, Seasonal Development

The Russian wheat aphid is an important pest of small grains. Barley and wheat are the most susceptible hosts for the Russian wheat aphid. Oats do not appear to sustain much damage, while the damage sustained by rye is intermediate. Other hosts include the following cool-season grasses: jointed goatgrass, various bromegrasses, wheatgrass, canarygrass, wild rye and various native grasses. Warm-season host grasses include green sprangletop, buffalograss, and several species of gammagrass.

The degree of infestation is probably related to two factors: 1) snow cover and severity of cold temperatures the preceding winter, and 2) the populations to the south that may be brought in on spring winds. This aphid is exceptionally cold-hardy; it may overwinter in the egg stage or as adults on winter grains/grasses under snow cover. Lack of snow cover and very cold temperatures will kill overwintering populations. Heavy populations in the south accompanied with high spring winds may promote early spring outbreaks in Klamath Basin. Aphids generally first appear in the early spring and form small colonies.

Damage and Symptoms

The first sign of this aphid usually is the loss of pigment in the leaves that results when toxic saliva is injected into the plant during feeding. It requires relatively few Russian wheat aphids, compared to other species, to cause injury because of this toxicity. The resulting damage is often a tell-tale white streak on the leaf of the plant. Russian wheat aphid is not a vector of the barley yellow dwarf virus.

Short- and Long-term Management Recommendations

▶ *Monitoring*

- As soon as the crop is up, monitoring for Russian wheat aphid should begin. Scouting for Russian wheat aphid is difficult because this insect usually is found in the leaf sheath or within a curled leaf. There are several options provided for scouting and action thresholds.

- Russian wheat aphid monitoring using information developed by Pacific Northwest Extension is outlined in *Appendix G-1*.[4] The sequential sampling plan provided has potential to save scouts time in the field depending on the aphid populations observed. For a given number of samples taken, the model will indicate whether treatment is necessary and/or to continue sampling. For example, instead of sampling 50 sites in a field, it may be necessary to sample only 10 or 15 sites before the sequential sampling model provides a “treat” or “no-treat” decision.

- This model also allows growers the flexibility to determine action thresholds by considering likely yields, market prices, and the cost of control. The action thresholds listed do not take into account variability in market prices for the grain, or the price of pest control. Instead, a range of action thresholds are provided (e.g., 5 to 10 percent infested tillers) as general guidelines for management decisions. For emergence to heading, the action threshold is 5 to 10 percent of tillers infested. For heading to soft dough, the action threshold is 15 to 20 percent tillers infested. From soft dough to harvest, treatment produces no benefits.

- It should be noted that for each 1 percent increase in the number of infected stems during stem extension stage, a 0.4-0.5 percent decrease in yield may be expected.[5] These thresholds were developed for wheat, but may be applicable for barley, also. (See footnote in *Table 2*.)

- Russian wheat aphid ***action thresholds listed here are provisional***, resulting from research at U.C. Davis.[2] These infestation levels each resulted in 15 percent yield reductions and treatment is advised if populations reach the following thresholds. For the two-leaf stage, the action threshold is one aphid per plant; for the early tillering phase, three aphids per tiller; and for late tillering, 8 aphids per tiller. If crop is water-stressed, thresholds should be lowered.

- Fields larger than 80 acres should be split into uniform parcels of less than 80 acres. Fields made up of different grain varieties, planted at different dates, or tilled differently (within a field) should be divided into uniform areas and sampled separately. Tillers are sampled at 40 to 50 sites randomly selected from the field. When a random sample is needed, pick a number between 10 and 20. Count your paces and stop at that predetermined pace number. Without looking down, reach down and pick a single tiller to inspect for aphids. Individual tillers must be chosen blindly to avoid sampling bias. Field edges should be sampled separately. Decisions to treat an entire field should not be made in the borders only. If heavily infested areas are found within a field, it may be necessary to spot treat based on the severity of the infestation, the size of the area infested, and the practicality of treating only the infested area.[(4)]

▶ Cultural

- Plant barley as early as possible to reduce spring infestation potential.[(1)]

- Growing a healthy crop free of water and nutrient stress is probably the best protection against Russian wheat aphid damage.

- Removal of host weeds will help prevent high populations from developing. There is some anecdotal evidence that rains will decrease Russian wheat aphid populations, but the actual effect of rain on the Russian wheat aphid is not understood.

- Russian wheat aphid-resistant barley germplasm line STARS-9577B has been officially released to the barley industry and results of field experiments conducted in Wyoming using this germplasm are being followed up in several locations.[(6)]

▶ Biological

- Over 20 species of parasites and predators of the Russian wheat aphid have been identified in the Pacific Northwest. There have been several species of Russian wheat aphid predators and parasites released at Lower Klamath NWR by U.C. researchers

working to lessen this wheat aphid's impact on small grains.[2] However, it is not known if permanent populations of beneficial species developed as a result of these releases.

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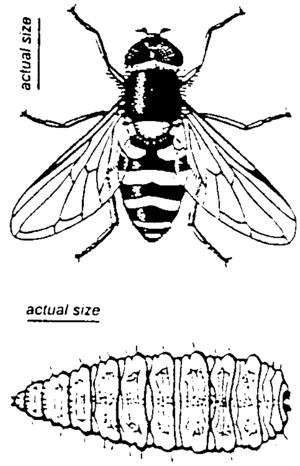
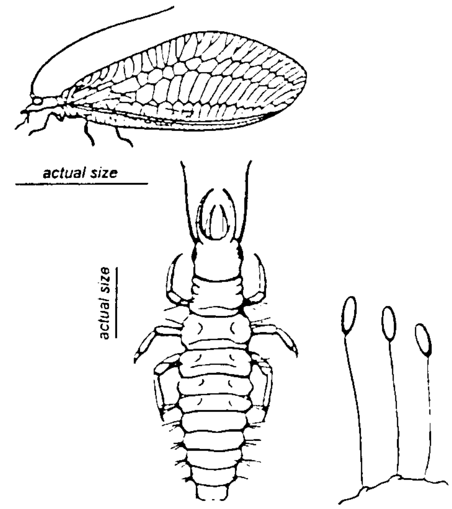
[2]*Russian wheat aphid biological controls released at Lower Klamath NWR in 1993.*

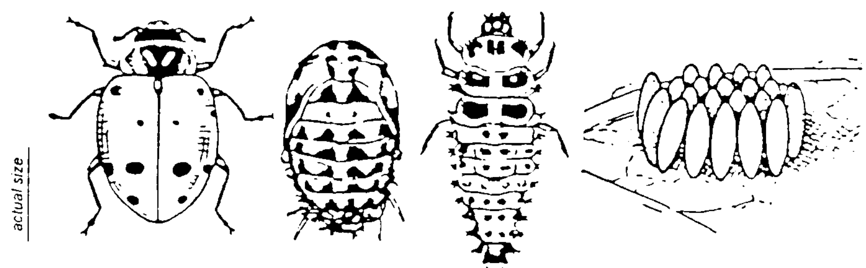
Scientific Name	**Family**	**Source Country**	**Identifier** (agency making identification of parasite and code number for that parasite cohort)
Aphidius matricariae	Aphidiidae	Kazakhstan	T-91080A (Texas)
Diaeretiella rapae	Aphidiidae	Iran	T-91068 (Texas)
Aphelinus varipes	Encyrtidae	Altai, China	EPL-92-55 (European Parasite Lab)
Aphelinus asychis	Encyrtidae	Kazakhstan	EPL-92-60 (European Parasite Lab)



SYRPHID FLY
Top: adult. *Bottom*: larvae.



GREEN LACEWING
Top: adult. *Bottom*: larvae. *Right*: eggs.



LADY BEETLE
Left to right: adult, pupa, larvae, eggs

Figure 4.
Beneficial insects effective against invertebrate pests found in small grains
(Syrphid fly: after USDA Bull., 1930. Green lacewing: after Ext. Serv. 4-H Handbook.. Lady beetle: *Handbook of the Insect World*, Hercules Powder Co.)

- Most Russian wheat aphid biological controls work best once temperatures are greater than 60 degrees F. Aphid populations can usually be kept under control by conserving natural enemies, creating habitat for natural enemies by providing pollen and nectar sources (by using pest break strips, for example), and by releasing biological control agents. However, these measures will not always control aphid infestations and pesticides may occasionally be needed. The combination of new biological control agents and Russian wheat aphid-resistant grains (that should be available within the next few years) may preclude the need for any chemical treatments for aphids in the near future. Use of pest break strips and enhancing biological control are further discussed under Field Trial Recommendations.

Table 3.
Aphid predators and parasites

Natural enemy	Type of organism	Commercially available*	Host plant (pollen/nectar source for beneficial insect)
Syrphid larvae	fly larva	no	Carrot family (Queen Anne's lace, dill, sunflower family (sunflowers, dandelion, goldenrod), buckwheat, sweet alyssum, coyote brush, knotweed protect from wind
Green lacewing (*Chrysoperla carnea*)	adult and larval insect are both aphid predators	yes	Carrot family (Queen Anne's lace, dill, sunflower family (sunflowers, dandelion, goldenrod), buckwheat
Beauveria bassiana	fungus	yes	Avoid fungicide sprays
Diaeretiella rapae	parasitic wasp	yes	Nectar-rich plants with small flowers such as mustard, white clover, dill, parsley, sunflower, hairy vetch, buckwheat, cowpea, common knotweed, and Queen Anne's lace
Aphidius spp.	parasitic wasp	yes	Mustards, white clover, carrot family plants such as Queen Anne's lace, dill,
Coccinella septempunctata	lady beetle, both adult and larvae are aphid predators	yes	Carrot family (Queen Anne's lace, dill, sunflower family (sunflowers, dandelion, goldenrod), buckwheat, crimson clover, hairy vetch, grains and native grasses, buckthorn, saltbush and black locust

* most of these beneficial organisms are probably already present to some extent in Klamath Basin.
Source: [7]

▶ *Chemical*

- DiSyston, a systemic insecticide, has been approved (for Russian wheat aphid) for use on the refuges through the pesticide use proposal (PUP) process.

- Alternative chemical treatments for aphids on grains would include the use of Gaucho as a seed treatment.

- Seed treatments with Gaucho would be especially effective against early season infestations, although the cost of Gaucho might preclude its use.

♦ OAT BIRD-CHERRY APHID S *Rhopalosiphum padi*
♦ ENGLISH GRAIN APHID S *Macrosiphum avenae*
◊ GREENBUG S *Schizaphis graminum*

Life Cycle, Host Crops, Seasonal Development

Information about the following aphid species has been combined because similar management considerations are applicable.

The ***oat bird-cherry aphid*** is generally only damaging to small grains if high populations develop. This aphid usually appears at boot or head emergence in Klamath Basin and may be the first aphid species in the crop. These aphids colonize the underside of lower leaves initially, moving up the stem to upper leaves and wheat spikes as the plant develops. Host crops include wheat, barley, oats, rye, and triticale. This aphid may overwinter as eggs on some *Prunus* species (e.g., wild plum and cherries) locally.

The ***English grain aphid*** is generally only damaging to small grains if high populations develop. This is probably the largest aphid commonly found on cereals in the Klamath Basin. It is light green to reddish-brown, with black antennae, cornicles, and leg joints. It appears later in the season than the Oat bird-cherry aphid. During the summer, it survives on various wild and cultivated grasses. It will move to grains in the fall and overwinter there as nymphs and adults.

The ***greenbug*** can be damaging in small grains. However, it generally develops too late in the season to be a significant pest in the Klamath Basin. Barley is the best host for rapid population build-up.

Damage and Symptoms

***Oat bird-cherry aphid*:** Low populations cause no significant economic damage. High populations (over 30 aphids per tiller) may cause a yellowish streak on the leaves. Other symptoms of high populations include a cork-screw curling of the leaves that may cause the head to have a hooked appearance. Very high populations of this and other aphids may create problems from honeydew production. If large amounts of honeydew are produced and the crop does not dry out prior to harvest, the honeydew may combine with grain dust and chaff to clog combines and slow harvest. If this occurs and endangers the harvest, steam cleaning may be an option.

The ***oat bird-cherry aphid, English grain aphid,*** and ***greenbug*** are vectors of barley yellow dwarf virus.

The ***English grain aphid*** tends to colonize the heads of wheat, but prefers the stem and foliage of barley and oats.

The ***greenbug*** is similar to the Russian wheat aphid in that it injects a toxin when it is feeding. Because of this, relatively low populations of the greenbug may cause economic damage. Feeding injury appears as yellow patches or spots on the leaves, or occasionally, as reddish or brown patches. The entire leaf may turn yellow if high populations develop.

Short- and Long-term Management Recommendations

▶ Monitoring

For ***oat bird cherry aphid***, whole plants should be sampled in the early season. As plants get larger, tillers are sampled at 40 to 50 sites randomly selected from the field. When a random sample is needed, pick a number between 10 and 20. Count your paces and stop at that predetermined pace number. Without looking down, reach down and pick a single tiller to inspect for aphids. Individual tillers must be chosen blindly to avoid sampling bias. Field edges should be sampled separately. The action threshold is 50 to 60 aphids per tiller. Treat only if there are no parasites or predators present or if the plants are several weeks from flowering. High populations on heads do not reduce grain yields unless they interfere with harvest.

Whole plants should be sampled in the early season for ***English grain aphid*** as well. As plants get larger, tillers are sampled at 40 to 50 sites randomly selected from the field. When a random sample is needed, pick a number between 10 and 20. Count your paces and stop at that predetermined pace number. Without looking down, reach down and pick a single tiller (or plant, when sampling early in the season prior to tillering) to inspect for aphids. Individual tillers must be chosen blindly to avoid sampling bias. Field edges should be sampled separately. Field edges should be sampled separately. The action threshold is 50 to 60 aphids per head. High populations on heads do not reduce grain yields unless they interfere with harvest.

For ***greenbug***, fields should be sampled from seedling emergence to tillering. Aphid numbers should be counted or estimated at a minimum of five locations in a field: a 1-foot length of row should be sampled. When a random sample location is needed, pick a number between 10 and 20. Count your paces and stop at that predetermined pace number. Without looking down, place a 1-foot measuring stick along the row, and then inspect all the plants/tillers along that length for greenbugs. For the three-to-five- leaf stage on wheat, the action threshold is 50 greenbugs per linear foot-row. For the three-tiller (six-leaf stage), the action threshold is 100 greenbugs per linear foot-row. For the stem extension stage, the action threshold is 300 to 500 greenbugs per linear foot-row. For large populations, counting individuals is too time-consuming, so populations should be estimated counting by 10s. It is suggested that these estimates be double-checked for accuracy by occasionally performing actual aphid counts.

▶ *Cultural*

- Destroy volunteer cereals prior to crop emergence.

- To better tolerate aphid populations, plants should be managed to promote health, and the effects of both environmental and human-induced stress minimized. Soil compaction is a good example of a stress that reduces soil drainage and aeration, causes puddling, and thereby creates conditions favoring plant disease. A stressed or diseased plant is much more susceptible to damage by aphids.

- Plant at the date most appropriate for the cultivar to help reduce the stress due to environmental factors such as frost.

▶ *Biological*

- Biological controls work best once temperatures are greater than 60 degrees F.
- Predators and parasites generally keep this aphid under control, although the greenbug should be closely monitored.[(26)]
- Many of these beneficial organisms are commercially available.
- Beneficial insects work best when good beneficial insect habitat, such as sources of nectar and pollen, is located adjacent to crop fields.[3]

▶ *Chemical*

- No chemical treatments should be made unless action thresholds are reached. Growers should consider populations of beneficials when making treatment decisions.
- Malathion is currently the PUP-approved chemical treatment for aphids other than the Russian wheat aphid in small grains. However, local growers express doubts as to the effectiveness of this chemical. The repeated treatments with Malathion necessary to obtain control of aphid populations have negative impacts on beneficial organisms and promotes pest resistance.[4] Malathion has been shown to inhibit seedling growth in wheat and cause chromosome damage in barley.[(24)]
- An alternative chemical treatment for aphids on grains would include the use of Gaucho as a seed treatment.
- Gaucho would be especially effective against early season infestations, although the cost of seed treatments might preclude their use, particularly against a relatively minor pest such as the oat-bird cherry aphid, or against relatively late-season pests such as the English grain aphid and the greenbug.

♦ GRASSHOPPERS *S Melanoplus* spp.

Life Cycle, Host Crops, Seasonal Development

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[3]**PEST BREAK STRIPS HAVE BEEN EFFECTIVE ENHANCING BIOLOGICAL CONTROL. [(8)] A FARM IN CENTRAL CALIFORNIA MADE 40-FOOT-WIDE PEST BREAK STRIPS AT INTERVALS OF 350 FEET ACROSS THE FARMS. THE MOST EFFECTIVE MIX WAS FOUND TO BE PREDOMINANTLY ALFALFA (60%) MIXED WITH DUTCH WHITE CLOVER, STRAWBERRY CLOVER, BERSEEM CLOVER AND CRIMSON CLOVER (10% EACH).**

[4]Cornell University has developed a formula, known as the Environmental Impact Quotient (EIQ), for comparing the environmental impact of some chemical insecticides. According to this system, one treatment of DiSyston (PUP-approved for use against the Russian wheat aphid) has a lower EIQ than four treatments of Malathion. It should be noted that multiple treatments of a single chemical such as Malathion will likely increase the rate that aphids develop resistance to it and related compounds. If action thresholds are exceeded for this pest, a single treatment with DiSyston may be more effective and have less impact on beneficials.

Grasshoppers may migrate from rangeland (especially overgrazed rangeland) to grain crops on adjacent land. They are an infrequent pest of grains. The grain-attacking grasshoppers pass the winter in the egg stage. The eggs are laid in a 1-inch-long bunch, usually no deeper than 2 inches below the soil surface. The eggs generally are deposited in uncultivated ground, such as pasture lands. Two other locations in the Klamath Basin where eggs might be found are the areas adjacent to canals, and in alfalfa fields.

Damage and Symptoms

Both adults and nymphs feed on the foliage of grains and other grasses. High populations can be extremely damaging and consume the entire plant, although this is relatively rare.

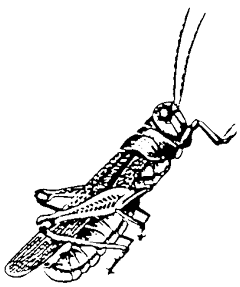

Figure 5. *Grasshopper* (*Handbook of the Insect World*, Hercules Powder Co.)

Short- and Long-term Management Recommendations

▶ *Monitoring*

- There are no action thresholds developed for grasshoppers on small grains.
- Egg-laying sites for the grasshoppers on both Refuge lands and adjacent rangelands should be identified and monitored.
- Birds of many types often form feeding swarms around hatching beds and these swarms may be used to locate the beds.
- Once identified, the egg-laying sites should be inspected on a weekly basis during egg hatch, roughly mid- to late spring for most species.
- Monitoring and treatment of off-Refuge areas will require the permission of private landowners.

▶ *Cultural*

- Most grasshopper problems begin in adjacent rangelands or in upland areas of the Refuge that are grazed, not in the crop fields.
- The most damaging pest species of grasshopper prefer bare, dry areas in which to bask or lay their eggs,[9] so land management practices which allow such situations to develop should be reviewed in areas with frequent grasshopper outbreaks.

▶ *Biological*

- Birds are an important biological control of grasshoppers.
- Mycotrol (by Mycotech Corp.) is a formulation of *Beauveria bassiana* (a fungus) registered for use against grasshoppers on rangeland. Depending on species of grasshoppers identified, Mycotrol should be considered for

PUP approval to test its effectiveness against grasshoppers during outbreaks on the refuges.

▶ *Chemical*

- There are currently no PUP-approved insecticides available for grasshopper control on the refuges.

- Spot treatments of a 2 percent carbaryl/bran mix applied at 2 lbs. per acre on "hatching beds" is very effective in controlling grasshopper populations (Dr. Mark Quinn, grasshopper researcher, personal communication, October 24, 1996). Since the rate of active ingredient (carbaryl) applied is roughly half an ounce per acre, it has minimal effects on wildlife. This treatment should be considered for PUP approval.

♦ BROWN WHEAT MITE *S Petrobia latens*
♦ WINTER GRAIN MITE *S Penthaleus major*
♦ BANKS GRASS MITE *S Oligonychus pratensis*

Life Cycle, Host Crops, Seasonal Development

Mites are occasional pests on grains in Klamath Basin although in 1996 a serious outbreak of mites occurred on small grains. The ***brown wheat mite***, also known as the petrobia mite, favors grass hosts and other monocots, such as onions. However, during high infestations these mites may go to broadleaved crops, including alfalfa. Brown wheat mite is strictly a dry weather pest.

The ***winter grain mite*** has a similar host range to the brown mite, but may also infest legumes, such as alfalfa. It is larger and darker, often a dark blue or green, compared to the smaller brown wheat mite. Both mites will deposit two types of eggs, diapausing (resting) and non-diapausing, on soil particles near the plant. The winter grain mite also lays eggs on the lower leaves and stems of hosts. The summer, or non-diapausing eggs hatch in roughly 10 days. The diapausing eggs require moisture to initiate hatching, otherwise they'll remain dormant for an indefinite period. Activity of the winter grain mite drops off and eggs fail to hatch at temperatures greater than 75 degrees F. Adults of the winter grain mite are most active between 40 and 75 degrees F and generally will be found feeding after sunset, at night, or on cloudy days. These mites seek shelter in the soil during hot weather.

The ***Banks grass mite*** also is known as the timothy mite. The early stages are white-to-light salmon colored and become progressively darker green during their life cycle. The first pair of legs will remain salmon-colored, however. Adults are a deep green with an iridescent hue in some light. Overwintering forms are bright orange and may be found at the base of the host plant.[10]

Damage and Symptoms

Plants heavily infested with mites have a stippled appearance, giving a gray or silvery cast to the plants in the case of the winter grain mite, or a more bronzed, yellowish appearance from brown wheat mite damage. Damage from the brown wheat mite is always associated with drought stress. Water-stressed plants are more susceptible to mite damage.

Banks grass mite infestations will cause the foliage to turn yellow initially, then as the infestation increases, the leaves become dead and turn yellowish-brown. Heavy webbing on infested plants is typical of this species. The webbing will form a loosely-woven mat generally on the underside of leaves and on new growth. The webbing protects the mites from predators and often becomes a dusty gray.

Short- and Long-term Management Recommendations

▶ *Monitoring*

- Weekly monitoring should concentrate on field edges and corners where infestations are likely to begin.

- During hot, dry periods, field edges and locations exposed to dust should be scouted especially closely.

- Although there are no action thresholds developed for mites, monitoring will provide information about mite populations before mites cause significant damage.

▶ *Cultural*

- Ensure plants have sufficient water, as this will help them to tolerate mite damage.

- Sprinkler irrigation at the outset of population increase of the Banks grass mite or the brown wheat mite is recommended for control of these pests. Heavy rains are damaging to mite populations, so sprinkler irrigation might be useful in preventing population build-up to economically damaging levels, in addition to alleviating possible water stress of the plant. Duration of irrigation will depend on the water needs of the plant relative to the effectiveness of the irrigation in slowing mite population increases. The field should be scouted after the irrigation to determine mite populations. At present, this option may not be practical because many small grain growers are flood-irrigating, and conversion to sprinkler irrigation may be costly.

- Crop rotation away from grains to non-host crops will help maintain low populations. In fact, injury by the winter grain mite can be prevented by rotating crops every 2 years.[10]

- Late sowing and deep plowing also help to avoid economically injurious populations.

- Keeping dust to a minimum will also help prevent mite populations from exploding. The number and speed of vehicles traveling along roads adjacent to grain fields should be kept to a minimum to prevent dust. Heavily traveled roads can be mulched with hay or other material, or sprayed with water to keep down dust.

▶ *Biological*

- Heat, dust, and drought may create conditions that hinder natural controls, and favor explosive build-up of mite populations.
- Conserving natural enemies by minimizing use of insecticides is the most efficient form of control. Releasing commercially available biocontrols, such as predacious mites, is not economically practical at this time.
- Mites have a wide range of natural enemies, including various fungi, predacious insects, and predacious mites. These beneficial organisms are the reason that mites are only occasional pests in grains.

▶ *Chemical*

- There are no action thresholds for these mites in Klamath Basin.
- Weekly scouting is needed to monitor mite populations.
- If populations are increasing, particularly during extended periods of hot, dry weather, some control measures are needed.
- Sulfur sprays during warm weather can provide some control for brown wheat mite populations and should be considered for PUP approval.
- Chemical treatment of edges, or hot spots where monitoring has revealed localized but growing mite populations, may be more effective and less expensive than treating the whole field.
- Prior to mites reaching economically damaging levels, irrigation of the crop should be attempted. If this fails, then sulfur dusts are recommended. However, good coverage is needed, particularly if the damage is due to the Banks grass mite, as the webbing this mite produces will provide some protection from the sulfur. In the event that damaging levels occur during cool weather, DiSyston (used during the 1996 mite outbreak) is recommended.

◊ WHEAT STEM MAGGOTS *S Meromyza* spp.

Life Cycle, Host Crops, Seasonal Development

The wheat stem maggot is an occasional pest in Klamath Basin. It is the larval stage of a small light-yellow fly with bright green eyes. Larvae overwinter inside the lower stem of grasses or small grains. In early spring, the maggot pupates. The adult will emerge in late spring and, after mating, will lay eggs on the stem or leaves of host plants. The larva bores into the stem, feeds for 3 to 4 weeks, then pupates. The cycle repeats after the adults emerge and another generation of eggs are laid in the early summer.

Most problems with the wheat stem maggot on Refuge lands (and problems with common root rot and barley root-knot nematode) are a result of grain cropping without rotations on Lower Klamath Refuge.

Damage and Symptoms

Damage is easily seen—a white head of the damaged plant that contrasts strongly with the green background of healthy plants. The head can be easily pulled from the leaf sheath where the larva has fed. This will distinguish wheat stem maggot damage from frost injury or root rot symptoms. Because the damage is so obvious, growers may over-estimate the actual damage and decide too hastily to treat.

The problem with this pest is that by the time economic damage is obvious, there is probably little that can be done. Mild winter and warm spring conditions occurred in the Klamath Basin in 1992 and 1993, during which higher than usual numbers of larvae apparently survived the winter, causing wheat stem maggot populations in the spring crop to explode. Significant damage to cereal crops was experienced, with up to 50 percent of the tillers affected at Klamath Experiment Station and with serious crop losses in several commercial fields in the Lower Klamath Lake area.[11]

Short- and Long-term Management Recommendations

▶ Monitoring

- There are no action thresholds for this pest because it is a minor pest in most places in the U.S.

▶ Cultural

- Rotating to a non-host crop is an essential strategy to manage this pest. See Field Trial Recommendations for wheat stem maggot.

▶ Biological

- Although there are parasites and predators of the wheat stem maggot, these beneficial organisms are apparently insufficient control in the event of a mild winter and spring.

▶ Chemical

- Foliar chemical controls are not recommended for this pest because it is usually not cost-effective to treat (the treatment costs more than the damage prevented by the treatment). An appropriate systemic chemical such as Gaucho, should be considered as a seed treatment.

- Mild winter and warm spring conditions may be an indication that seed treatment with a systemic insecticide may be economically justified to control maggots attacking the spring crop.

◊ ARMYWORM *S Pseudaletia unipuncta*
◊ WESTERN YELLOWSTRIPED ARMYWORM S *Spodoptera paefica*

Life Cycle, Host Crops, Seasonal Development

The armyworm is an occasional pest in Klamath Basin on small grains, particularly following mild winter weather that favors survival of overwintering larvae.[12] Armyworm larvae overwinter in the upper few inches of the soil or under crop stubble. Yellow-striped armyworms appear as a pests less frequently than armyworms.

Armyworm larvae move like loopers, but can be differentiated from loopers by four pair of "legs" in the middle of their body; loopers will only have two pair.

Armyworm eggs are laid in clusters of many dozens that the female covers with either secretions or scales. Economic losses are usually caused by the first generation of eggs laid during the spring, but are infrequent to rare. The larvae may be present from June through September. Larvae develop rapidly over a period of 2 to 3 weeks after hatching.

Damage and Symptoms

Larvae feed at night and leave angular notches in the leaves. Large infestations may consume whole fields or parts of fields, although this is a rare occurrence.

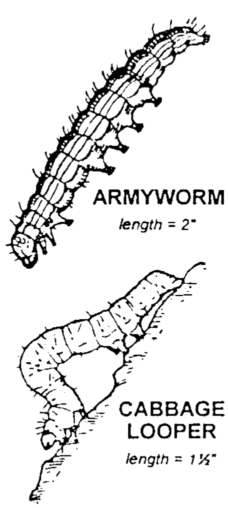

Figure 6. *Armyworm vs. cabbage looper (Handbook of the Insect World,* Hercules Powder Co.)

Short- and Long-term Management Recommendations

▶ *Monitoring*

- There are no action thresholds developed for armyworms on grains.
- During springs that follow mild winters, scouts should be especially vigilant for armyworms during weekly monitoring.
- If notched leaves are encountered, the scout should look in the center of the foliage or dig around in the soil to determine if armyworms are present.
- Because these larvae feed during the night, night scouting may be a useful way of determining numbers and need for treatment, although the decision will rely on the scout's and grower's experience.

▶ *Cultural*

- If armyworms are migrating from another field, a deep, wide ditch filled with water between the "source" field and neighboring fields can prevent infestations.

▶ *Biological*

- *Bacillus thuringiensis* (also known at *B.t.*) var. *kurstaki (k.)* is an effective tool against armyworms, but most effective when the larvae are small, less than 1.5 inches long. If weekly scouting is able to catch a large infestation early on, control should be possible using *B.t.k*.
- *B.t.k.* should be applied in the late afternoon or early evening to avoid

degradation by sunlight.

- *B.t.k*. is not yet PUP-approved for armyworms on grains, but is recommended for PUP approval.

- Growers can enhance and preserve the potential for biological control in their fields by avoiding chemical pesticide applications, if possible.

> *Natural enemies often provide good control of armyworms. Predators include bigeyed bugs, damsel bugs, lacewings, spiders and piratebugs. Many parasites also attack armyworms. The wasp, Hyposter exigua, is known to be especially effective against beet armyworms.*[13] *Viral diseases of armyworms also play an important role in their control.*

▶ *Chemical*

- There have been no requests for PUP-approved insecticides for armyworms on grains.

- Sevin XLR Plus (and several other Sevin formulations) are approved for armyworm control in potatoes. This chemical should be considered for PUP approval in the event *B.t.k*. is used numerous times and proves ineffective against armyworms. Sevin has been shown to reduce parasitoid populations of amryworms. [24]

♦ BARLEY ROOT-KNOT NEMATODE *S Meloidigyne naasi*
◊ COLUMBIA ROOT-KNOT NEMATODE *S Meloidigyne chitwoodi*
◊ LESION NEMATODE *S Pratylenchus* spp.

Life Cycle, Host Crops, Seasonal Development

Only the barley root-knot nematode is known to cause economic losses in small grains in California. However, the Columbia root-knot nematode exists in soils where grains are grown and has potential to reduce yields of not only grains, but crops grown in rotation with grains.

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, perhaps following the ‘smell’ of chemicals emitted by grain plant (or other host) roots. If penetration of the root is successful, the infective stage establishes a feeding site, altering the shape, size and function of the several cells from which it feeds. It is through these cells that plant nutrients, that would normally provide for plant growth and grain development, are 'stolen.' These cells also interfere with water and nutrient uptake from the soil and root function becomes impaired. These 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 one to five, is related to soil temperature. Generations are produced in 20 to 60 days.

Damage and Symptoms

Heavily infested fields will have reduced grain yields. The barley root-knot nematode is the only nematode pest on small grains known to cause above-ground symptoms. Damage is confined to barley. Heavily infested plants will be stunted, yellowish, and may fail to head.[12]

Short- and Long-term Management Recommendations

▶ *Monitoring*

- Root zone soil samples should be taken immediately after harvest or just prior to harvest if the crop showed signs of damage. Fields should be divided into blocks of 20 acres that have similar damage, soil texture, or cropping history. Several subsamples from each block should be well mixed to create a single, 1-quart sample. Soil samples should be kept cool, but not frozen. Local experiment stations can provide details needed for labeling samples and laboratories can analyze them. If sampling reveals populations of barley root-knot nematode, rotation to non-cereals or resistant oat cultivars is recommended.

▶ *Cultural*

- Crop rotation is recommended for control of the barley root-knot nematode.

- Crop rotation is required in sump 2, area 2 and selected lots in sump 3 where barley root-knot nematode populations have been identified.

- Some cultivars of oats (such as Cayuse, Curt, Kanota, and Park) are resistant to this pest and could be planted as part of a rotation to non-hosts. See Field Trial Recommendations.

- Use of washing stations on the Tule Lake Refuge prevents spread of nematodes from one field to another.

▶ *Biological*

- There is a new biological control registered for nematode control. Abbot markets a nematode-killing fungus, *Myrothecium verrucaria*, under the name of DiTera ES (registered for use in California). There also is a promising biological control, the nematode parasite *Bacillus penetrans*, but a cost-effective mass-rearing technique must be developed before commercial production of this organism is possible.

Chemical

- It is generally not economic to treat small grains with chemical nematicides.

DISEASES

♦ YELLOW BARLEY STRIPE RUST (Also Called) STRIPE RUST *S Puccinia striiformis*

Life Cycle, Host Crops, Seasonal Development

Stripe rust attacks both barley and wheat, but the races that attack wheat do not cause economic damage to barley, and vice versa. It is a cool-temperature, early-season disease as rusts go. Ideal temperature for rust disease development is 50 to 60 degrees F along with intermittently damp foliage. The disease cycle is 7 to 10 days.

Damage and Symptoms

Symptoms will appear earlier than those of other rusts and consist of yellowish stripes running lengthwise along the leaf blade or on the glumes of spikes (see *Figures 1* and *2*). Race 24 is new to the Klamath Basin and has apparently overcome resistance in the wheat/barely cultivars that have been planted.

Short- and Long-term Management Recommendations

Cultural

- Control of this disease is through the use of resistant cultivars.
- Wheat cultivars now in use are resistant.
- There is no known alternate host for the specific form of stripe rust that attacks barley, so continued spread of this disease depends on the amount of the pathogen overwintering in fall-sown barley, or the establishment of the pathogen in wild barley (*Hordeum* spp.) populations.
- Barley cultivars are susceptible to stripe rust, although much research is being done to identify barley cultivars with resistance.
- Some barley cultivars (Tambar 500-Pro, Tambar 500-Pro, Tambar 401-Pro, Tambar 401-Uvi, Kold-Pro, Kold-Uvi, and Perkins-Dal) have shown some resistance to yield loss to barley stripe rust in studies in Texas.[14]
- Earlier planting dates are recommended by the Oregon State University Extension Service.

- The Service allows some burning of grain stubble which may help destroy sources of infection. This is only allowed Lower Klamath on a certain percentage of fields and must be immediately followed by flooding.

Biological

- There are some biological controls with potential (such as *Bacillus subtilis*), but no biological controls are commercially available.[15]

Chemical

- Bayleton 50 WP (4 oz / acre) is recommended for use if the disease becomes widespread. This chemical is PUP-approved for emergency use in Oregon.
- Folicure is also effective and was PUP-approved in 1997.
- Though Tilt is PUP-approved for emergency use on barley stripe rust, it is not yet registered in California.
- Baytan seed treatment also provides early-stage control.

♦ BARLEY STRIPE *S Pyrenophora graminea*

Life Cycle, Host Crops, Seasonal Development

Barley stripe is specific to barley and does not affect other grains. It is transmitted by infected seed that appears normal. The fungus is dormant in the outer layers of the infected seed and becomes active during seed germination, infecting the new plant. Cool temperatures (below 54 degrees F) favor infection of the germinating plant; infection is rare above 59 degrees F. Once infected, the pathogen grows systemically throughout the plant, reducing the ability of the plant to produce grain.

Moist conditions (rain, sprinkler irrigation, or heavy dew) will promote spore production about the time the heads of healthy plants are flowering. Spores are carried by the wind to healthy spikes, germinate, and infect the seed. Seed in early developmental stages (up to dough stage) are most susceptible to infection. Once the seed is infected, the fungus becomes dormant until seed germination.

Damage and Symptoms

Grain production from infected plants is drastically reduced. Symptoms first appear in the 2-to-3-leaf stage as yellow stripes, usually on the lower part of the leaf blade or leaf sheath. The stripes become tan and brown as spores develop and eventually the diseased tissue dries and is subject to splitting and tearing. Infected plants are generally stunted. During spiking, the flag leaf of infected plants may appear tan colored and the spike and the kernels may be distorted and discolored to brown.

Short- and Long-term Management Recommendations

▶ *Cultural*

- An effective control is to use certified disease-free seed.

- Crop rotation to a grain other than barley or another crop would also be very effective.

▶ *Biological*

- No biological controls are known.

▶ *Chemical*

- There are no PUP-approved fungicides for control of this disease.

- There are fungicidal seed treatments (Imazalil [Nu-Zone 10 ME, Double R and other similar formulations]) available that will eliminate the pathogen from infected seed, and should be considered should this disease become economically important.

◊ LOOSE SMUT (OF WHEAT, TRITICALE AND RYE) *Ustilago tritici*
◊ LOOSE SMUT OF BARLEY *Ustilago nuda*

Life Cycle, Host Crops, Seasonal Development

The pathogen is transmitted from season to season by infected seed that appears normal. The fungus is dormant in the cotyledon of the infected seed and becomes active during seed germination, infecting the new plant. Once infected, the pathogen grows systemically throughout the plant, ultimately infecting the spikelet and young kernels. Fungal spores then develop in place of the grain.

Damage and Symptoms

Loose smuts generally do not display obvious symptoms until the plant has headed. Infected plants may head out sooner and have their heads elevated above non-infected plants. Usually, all the kernels of an infected spike are replaced by fungus spores. When the thin, gray membrane breaks, the spores blow away to begin another infection cycle.

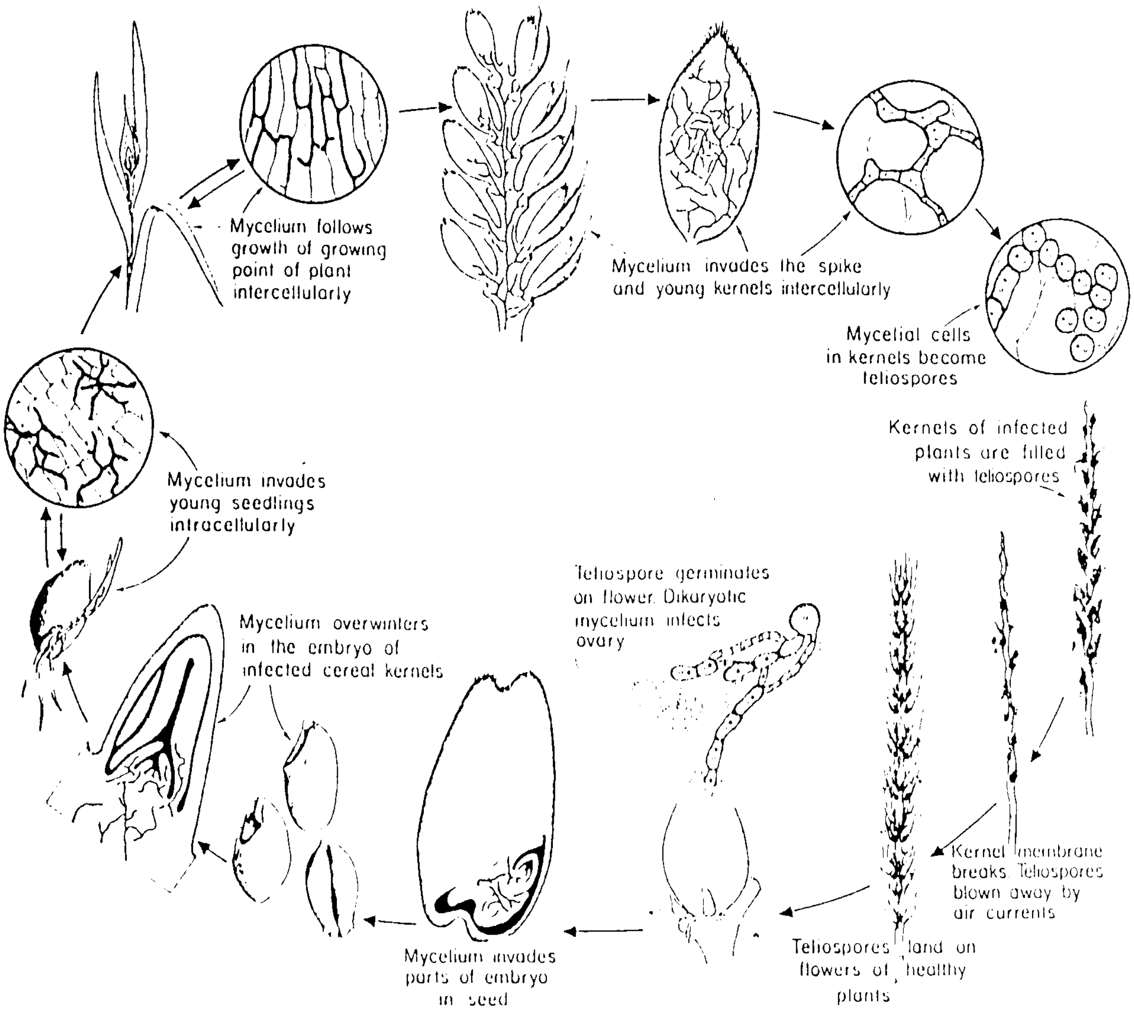

Figure 7.
Disease cycle of loose smuts of barley and wheat caused by Ustilago nuda *and* U. Tritici (copied with permission from Academic Press)

Short- and Long-term Management Recommendations

▶ *Cultural*

- Only certified smut-free seed should be planted. [25]

▶ *Biological*

- No biological controls are known.

▶ *Chemical*

- Seed treatment with systemic insecticide is effective in controlling this disease, but using certified smut-free seed is the best management technique.

◊ **COVERED SMUT OF WHEAT** S *Tilletia caries*
◊ **STINKING SMUT OF WHEAT** S *Tilletia foetida*
◊ **COVERED SMUT OF BARLEY AND OATS** – Different races of *Ustilage hordei*

Life Cycle, Host Crops, Seasonal Development

Unlike loose smuts, covered smuts survive from season to season on the surface of infested seed and in the soil. Grain kernels in infected plants have been replaced by dark spore masses contained in a thin membrane. When the membrane ruptures, often during harvest, these spores may spread to other kernels and to the soil.

Damage and Symptoms

Infected plants generally are smaller and head out later than healthy plants. Grain kernels in infected plants have been replaced by dark spore masses contained in a thin membrane. Crushed spore masses on wheat will have the odor of decaying fish (thus the name, stinking smut).

Short- and Long-term Management Recommendations

▶ *Cultural*

- Only certified smut-free seed should be planted.

▶ *Biological*

- No biological controls are known.

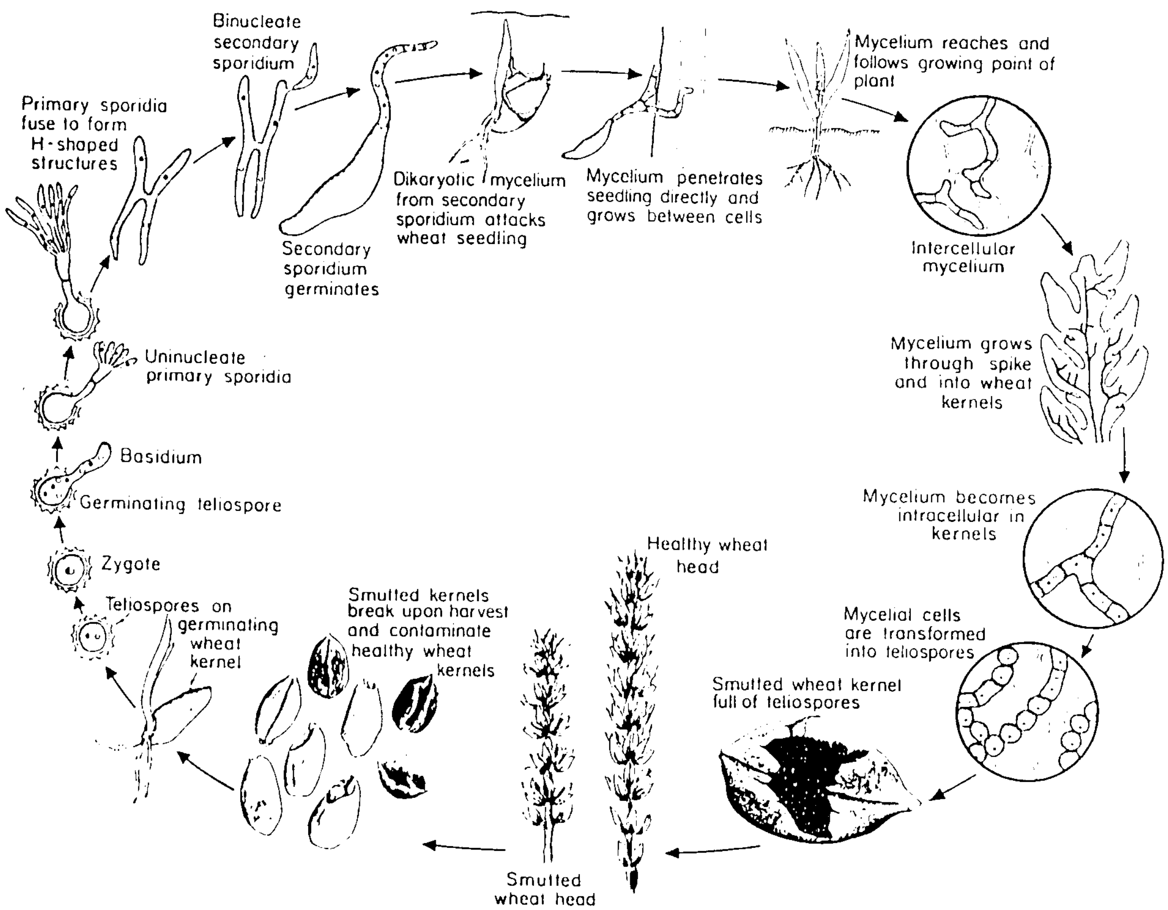

Figure 8.
Disease cycle of covered smut or bunt of wheat caused by Telletia *spp.*
(copied with permission from Academic Press)

▶ *Chemical*

- Seed treatment using contact fungicide (such as carboxin, thiram, chloranil, thiabendazole or benomyl[15]) is effective in controlling this disease.

Table 4.
Disease and treatment summary

Disease	**Symptoms**	**Management**	**Comments**
Common Root Rot (*Fusarium* spp.) (*Bipolaris sorokiniana*)	Darkened and poorly developed roots and crown. Spikes and heads turn white.	Rotate away from grains, or use oats, which is not affected by this disease. Avoid over-fertilization. Avoid moisture stress.	Infection favored by warm weather. Water stress speeds disease development No chemical treatments are recommended for this disease
Leaf Scald (*Rhynchosporium secalis*)	Initial infection shows as dark, pale or bluish gray spots. Lesions enlarge and coalesce, giving leaf scalded appearance.	Rotate away from barley. Destroy volunteer barley and grass hosts. Plant resistant cultivars (UC 337, UC 603, and Madera). Use clean seed.	Net blotch and scald are the most common foliar diseases attacking most varieties of malting barley. [16] Leaf scald is most severe in years when rainfall is higher than average.
Net Blotch (*Pyrenophora teres*)	Initial infection appears as tiny dark green spots. As disease progresses, spots elongate and turn brown, with yellow “halo” of affected tissue surrounding lesions.	Rotate away from barley. Destroy volunteer barley and grass hosts. Plant resistant cultivars (UC 337, UC 476, UC 603, UC 828, Sunbar 458 and Madera) Use clean seed.	*Hordeum murinum* subsp. *leporinum*, a common weed, is the only alternate host found naturally infected in the field. [17]

Table 5.
Calendar of control options

Month	Recommended practice	Remarks
January	Field flooded (Lower Klamath NWR only)	Plan crop management strategies considering field history and spring weather.
February		Revise crop management strategies considering field history and spring weather.
March		Revise crop management strategies (again) considering field history and spring weather and market conditions.
April	Plant certified seed for control of fungal diseases. Weed control with tillage/herbicide combination.	Crop management strategies radically revised due to spring weather conditions. Certified seed will help control smut diseases and barley stripe. Hot water treatments of the seed for disease management is also an option.
May	Plant certified seed for control of fungal diseases. May treat seed with Gaucho for Russian wheat aphid control. Begin monitoring for Russian wheat aphid. Weed control with tillage/herbicide combination. Scout for stripe rust.	New wheat varieties have been released on the high plains that incorporate resistance to Russian Wheat Aphid. Some resistant cultivars that could be tested in Klamath Basin should be available within the next few years. Action thresholds should be used to determine if treatment is necessary for aphids. 2,4 D is generally used for broadleaf weed control, Roundup for grasses (quackgrass). Tilt and Bayleton are used in Oregon (these chemicals are not registered for use in California) and Folicur is effective, PUP-approved and registered for use in California.
June	Weed control with herbicide if needed. Scout for armyworms, other aphids and grasshoppers. Scout for stripe rust.	May need to monitor (and treat) adjacent uncultivated land for grasshopper nymphs. Grasshopper egg-laying sites should be tagged and monitored.
July	Insect/weed/fungus control as needed	
August	Harvest grain.	
September	Harvest grain	
October	Sample for nematodes.	If a grain crop, especially barley, is going to be planted the following spring, the grower may wish to sample for barley root-knot nematode. Begin examining rotation options.

Source: [18,19,20, 12]

FUTURE VISION OF SMALL GRAINS ON THE REFUGES

The following text sets forth a description of how small grains might be grown on the refuges 5 to 10 years from now, using IPM management techniques.

Growers have come to realize additional benefits from using small grains as a crop rotation on Refuge leased lands. More and more growers are using no-till or strip tillage practices when planting after small grains. The stubble protects the soil from wind erosion and protects subsequent crops from "sandblasting" caused by wind-eroded soil. The stubble also conserves soil moisture and in general provides a more benign growing environment for row-crop seedlings. On Lower Klamath leased lands, growers are now rotating grains with lentils, canola, or forage legume mixes. Some growers are intercropping grains with legumes. The nitrogen from the legumes helps both current and next-season crops. Some growers are strip-cropping grains with canola. The canola attracts aphid-eating beneficials which provide pest control for the grain crop. Problems with barley root-knot nematodes have largely been solved with appropriate crop rotations. The Service and environmental groups are pleased because farming practices are now more compatible with wildlife habitat objectives, and Department of Interior policy on pesticides.

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 alternative tillage, new crop rotations and new cropping techniques (such as strip or border cropping). Any grower interested in experimenting and is a good observer can do these trials. Some results of these trials can be quantified by the grower as well (such as changes in yields or quality of the harvest). However, to develop a more detailed picture of what is happening in the field, it is recommended that the grower notify the IPM coordinator and researchers at the local experiment stations to inform them of the upcoming field trials. In this way, useful trial information may be communicated to others and/or refined and investigated further.

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

Aphids

☞ **1. Investigate the plant or plant combinations that, when planted in a strip alongside or in grains (or other crops), will provide some control of aphids (and other pests).**

Just as weeds can provide habitat for pests, certain plants or combinations of plants are favorable to populations of beneficial insects. Pest break strips have been effective in enhancing biological control for potatoes and several other row crops.[8] This report noted that control was ". . . *good to excellent. Insect predators and parasites keep aphid and caterpillars under control; leafhopper and* *leaf miner prefer alfalfa in pest break strips to other hosts."*

Large-scale trials of this nature occurred on a farm in central California where managers made 40-foot-wide pest break strips at intervals of 350 feet across the farm. Several mixes of grasses, legumes, and wildflowers were tested for effectiveness in supporting 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 predators of aphids. Recent research in England[21] indicates that by planting border strips (of plants that provide food and nectar sources for hoverflies) along cereal grains, significant reductions of aphid populations can be obtained. Increased populations of hoverflies extended up to 180 meters (just under 200 yards) from the border strips. Bugg and Ellis[22] observed that flowers of canola attracted adults of the following species of hoverfies (*Syrphidae*): *Allograpta obliqua (Say)*, *Sphaerophiria* spp., *syrphus* spp., and *Toxomerus* spp. Larvae of all of these species are predators on aphids.

W.E. Chaney of the U.C. Cooperative Extension in Salinas, California, has conducted field trials interplanting insectary plants (which provide beneficial insects pollen and nectar) with vegetables for biological control of the green peach aphid. He used sweet alyssum, interplanted every 20 rows in a field of lettuce. Alyssum was chosen because it can be seeded instead of using transplants, and will flower in about 30 days. It does not attract either aphids or tarnished plant bugs, does not spread aggressively, and provides a good food source for parasitic wasps. By adding sweet alyssum and other pollen and nectar plants to monoculture vegetables, natural enemies such as the green peach aphid parasite, *Diaretiella rapae*, will have a chance to play a greater role in vegetable pest control. Under ideal conditions, *Diaretiella rapae* parasitized 90 to 95 percent of available host aphids.[23] Cheney's trial in lettuce provided sufficient reduction of aphids to do without other controls. However, 5 percent of the production area was lost to alyssum. *On Refuge lands, the area planted to insectary habitat will be subtracted from the total lease acreage, reducing annual rent.*

Growers will have to experiment to develop a system that works best for their particular operation. Options for field trials include using border strips of canola, alyssum, alfalfa, or some other plants known as good habitat for beneficial insects (refer to the workbook introduction for more information about insectary plants.) Strip cropping is also an option. For example, some farmers in the Midwest alternate strips (generally one or two planter-widths wide) of soybean with strips of corn to increase the diversity of the farming system.

2. Assess Dr. Gonzolez's release of parasites/predators for Russian wheat aphid management on Lower Klamath NWR. The intention is to build on previous parasite release work so that future releases of parasites have greater chances of successfully establishing populations in the Klamath Basin. In addition, the following should be identified:

- Parasites/predators of Russian wheat aphid that have already been released, or are endemic, locally.

- The ecological requirements of the parasites/predators.

- Cultural practices which may enhance parasite/predator (i.e., strip cropping or planting border strips with insectary plants).

3. Russian wheat aphid-resistant small grain cultivars should be tested in the Klamath Basin as soon as these cultivars are available.

Several states, including Idaho and Colorado, are developing Russian wheat aphid-resistant small grain cultivars. Both growers and researchers could participate in this, although local research stations may be most appropriate for initial trials.

4. **Investigate the difference between tilled and no-till fields in their attractiveness to Russian wheat aphid (and other aphids).**

It has been well documented that high-residue (no-till) fields are much less attractive to greenbugs and aphids compared to "clean" fields with no residue. The high albedo, or reflected light, from the stubble of the no-till field confounds the greenbug search strategy. No-till grain cropping could possibly also confound the Russian wheat aphid search strategy.

Some growers may wish to experiment with no-till to obtain soil and water conservation benefits that this system bestows on users. Local researchers should work in conjunction with growers to quantify the effects no-tillage has on early season aphid populations. Growers have stated that this strategy is unlikely unless one of the Agencies provides a no-till drill for planting trials.

Grasshoppers

1. The species of grasshoppers that attack grain on the Refuge should be positively identified by an entomologist. This task should be performed by experiment station personnel.

Wheat Stem Maggot

☞ **1. A crop rotation system should be trialed, where a non-small grain crop (such as canola, a forage legume, or lentils) would be planted at least 1 out of 3 years.**

The effect of crop rotation on barley root-knot nematode, wheat stem maggot and common root rot and yield and economics should be examined. Local experiment stations collaborating with the IPM coordinator would be the most appropriate group to perform this research in cooperation with local growers.

Yellow Barley Stripe, Stripe Rust

1. Barley cultivars resistant to race 24 and other economically-important races should be trialed in Klamath Basin.

This would be especially important for barley cultivars used in brewing beer, due to the large acreage of this type of barley grown in the Basin. This type of research would be led by the local experiment stations.

Barley root-knot nematode – Meloidigyne naasi

☞ **1. Determine crops or cover crops that may be appropriate to rotate in the Lower Klamath Refuge to reduce the barley root-knot nematode problem (and other pests associated with continuous grain cropping).**

Some possible crop rotations include canola, sorghum-Sudangrass, lentils, alfalfa, oats (only those cultivars that are not hosts to the barley root-knot nematode), and Austrian peas.

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 new crops or rotations contact local researchers so that the results of the field trials can be quantified. Growth of alternative crops would require approval of the IPM coordinator.

2. Examine the effectiveness of some new nematode biological controls.

Abbott Laboratories markets a nematode-killing fungus, *Myrothecium verrucaria*, under the name of DiTera ES. Small research plots in infested fields are perhaps the most appropriate venue for these trials which should be performed by local researchers. This practice would require PUP approval.

FURTHER RESEARCH

Grasshoppers

- The effectiveness of identification, monitoring, and targeting of oviposition sites of grasshoppers should be determined for management of this pest.

- The effectiveness of Mycotech's *Beauveria bassiana* formulation should be tested and evaluated.

Wheat stem maggot

- If the wheat stem maggot is to be treated, then action thresholds for this pest must be developed.

Yellow Barley Stripe, Stripe Rust

- Action thresholds for race 24 on barley should be developed (if resistant cultivars cannot be found).

Barley Stripe

- The effect of crop rotation on prevalence of barely stripe disease needs to be field trialed.

USEFUL CONTACTS AND RESOURCES

Small grains aphid biocontrol

- Dr. Lynell Tanigoshi, Dept. of Entomology, Washington State University, Pullman, WA 99164-6382; (509) 335-3724

- Dr. Dan Gonzalez, Dept. of Entomology, University of California, Riverside, Riverside, CA 92521; (909) 787-5711

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

  Dr. Gonzalez and Dr. Tanigoshi are working with parasites and predators of the Russian wheat aphid and feel that some show potential for biocontrol of the Russian wheat aphid. Steve Orloff is working in collaboration with Dr. Gonzalez to release Russian wheat aphid parasites.

Beneficial organisms

- Hunter, C.D. 1994. *Suppliers of beneficial organisms in North America*. California EPA, Department of Pesticide Regulation.

  One free copy of the above document per request is available from: California EPA, Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1020 N. St., Room 161, Sacramento, California 95814-5604; (916) 324-4100

Grasshoppers

To order the Grasshopper IPM User Handbook:

- USDA-APHIS/PPQ, Stephen A. Knight, Unit 134, 4700 River Rd.,Riverdale, MD 20737; (301) 734-8247

- Cliff Bradley, Mycotech Corporation, 630 Utah Ave., Butte, MT 59702; (406) 782-2386 (Mycotech manufactures Mycotrol.)

- Dr. Mark Quinn, 319 S. Monroe, Moscow, ID 83843; (208) 883-8818

Dr. Quinn is knowledgeable about grasshopper IPM and life cycles. He is doing research in the Klamath Forest National Wildlife Refuge on grasshoppers.

- Gary Brown, USDA/APHIS, 6135 N.E. 80th Ave., Suite A-5, Portland, OR 97215-4033; (503) 326-2814

Small Grains

- Dr. Randy Dovel, Klamath Experiment Station, 6941 Washburn Way, Klamath Falls, OR 97603; (541) 883-4590; fax, (541) 883-4596; e-mail, dovelra@ccmail.orst.edu;
  URL: http://www.orst.edu/dept/kes/dovel.htm

  Dr. Dovel is an agronomist at the Klamath Experiment Station.

- Dr. Charles Summers, U.C. Kearney Field Station, 9240 S. Riverbend, Parlier, CA 93648; (209) 891-2593

- Dr. Calvin Qualset, Dept. of Agronomy and Range Science, University of California, Davis, CA 95616; (530) 752-7323

  Both Dr. Summers and Dr. Qualset are, according to the minutes of Western Region Coordinating Committee meeting of January 1966, working to develop high quality agronomically acceptable cereal varieties with resistance to Russian wheat aphid.

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35. Appendix: *Sampling Russian Wheat Aphid in the Western Great Plains* (No. GPAC-138), by David E. Legg, Gary L. Hein, and Frank B. Peairs. Fort Collins, CO: Colorado State University and Great Plains Agricultural Council, 1991. Used with permission.

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