Pest Management Strategic Plan
for
Dry Bulb Storage Onions
in
Colorado, Idaho, Oregon, Utah, and Washington

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Executive Summary

EPA is now engaged in the process of registering and re-registering pesticides under the requirements of the Food Quality Protection Act (FQPA). EPA's regulatory focus on the organophosphate (OP), carbamate, and suspected B2 carcinogen pesticides has created uncertainty as to the future availability of these products to growers. At some point, EPA may propose to modify or cancel some or all uses of these chemicals on onions. The regulatory studies that EPA requires registrants to complete may result in some companies voluntarily canceling certain registrations.

The onion industry is at risk of losing a number of essential chemicals critical for pest management. At the same time, a number of newer, unproven, low-risk chemistries are becoming available. The onion industry faces efficacy and economic uncertainties surrounding these shifts in control strategies. In addition, widespread reductions in funding have reduced or weakened the ability of land-grant university personnel to conduct field research and Extension programs.

The Endangered Species Act (ESA) mandates that Federal agencies such as EPA consult with the National Oceanic and Atmospheric Administration (NOAA-Fisheries) if EPA takes an action that may affect threatened or endangered species. Recently, lawsuits have been filed against EPA stating that the agency failed to complete the consultation process. The result of one of these lawsuits is that mandatory no-spray buffer zones have been temporarily imposed for certain pesticides in threatened and endangered salmonid species habitat in Washington, Oregon, and California. Because of the number of consultations that must take place to satisfy the mandates of the ESA and because of the complexity of the process, it is expected that mandatory buffer zones from this lawsuit will remain in effect for several years. These buffer zones, whether planted to crops or abandoned to weeds, have the potential to act as pest reservoirs that will repeatedly infest neighboring crops. The total effect of ESA implementation is yet to be determined; however, it will clearly require new pest management strategies in the onion industry.

A cross-section of onion growers, researchers, Extension service personnel, industry representatives, and crop advisors met for a day-and-a-half workshop in February 2004 to develop a Pest Management Strategic Plan that identifies the critical research, regulatory, and educational needs for their industry. This document is the result of that meeting.

Summary of the Most Critical Needs in Dry Bulb Storage Onion Pest Management in Colorado, Idaho, Oregon, Utah, and Washington

The following priority areas must be addressed to maintain the long-term viability of the dry bulb storage onion industry.

RESEARCH

- Investigate biology, ecology, and management of iris yellow spot virus.
- Investigate biology, ecology, and management of yellow nutsedge specific to onion production.
- Identify effective control measures for onion thrips and western flower thrips.
- Screen new insecticides, fungicides, and herbicides with different modes of action for efficacy and resistance management.
- Identify new control measures for neck rot caused by Botrytis and develop a better understanding of the biology and ecology of the disease.
- Identify new control measures for onion maggot and seed corn maggot.
- Maintain or increase funding for Extension and research programs at land-grant universities; recent budgetary cutbacks and personnel layoffs threaten the viability of IPM research.

REGULATORY

- Encourage EPA to expedite the registration of current pesticide petitions for acibenzolar (Actigard) for iris yellow spot virus and bacterial disease control and the herbicides bentazon (Basagran), dimethenamid (Outlook), ethofumesate (Nortron), flumioxazin (Valor), and fluroxypyr (Starane) for weed control.
- Establish a tracking system for new pesticide registrations indicating stage of the registration process, enabling growers and commodity representatives to provide input where needed.
- Work with EPA to change their definition of harvest. Harvest is when the onions are removed from the field; current EPA definition of harvest is actually what growers define as “lifting.” This is a critical issue because the definition of harvest determines PHI and, thus, which pesticides can be used when the onions are reaching maturity.
- Support the continued registration of EBDC fungicides.
- Develop a viable system for inspecting imported onions for problem pests (e.g., thrips) and for illegal pesticide residues.
- Be consistent in 2ee labels for all Western states growing onions.

EDUCATION

- Communicate to consumers and regulators that onion growers practice IPM; explain which practices are being used.
- Educate regulators about onion crop production operations and pest management practices, which will help them better understand the pest management needs in onions.
- Promote more interstate exchange of information, expertise, and personnel at the industry, university, and state agency levels.
- Educate regulators about the importance of EBDC fungicides to onion production and why it is important to maintain their registration.
- Organize onion field tours for regulators and policy makers to show them the field operations used in onion production and to demonstrate why some current pest management strategies are not working.
- Maintain or increase funding for Extension and research programs at land-grant universities; recent budgetary cutbacks and personnel layoffs threaten the viability of IPM implementation and research. Methods of dispersal of information between publicly funded agencies and the onion industry are slowly disappearing.

Background and Onion Production Overview

Onions, *Allium cepa*, are shallow-rooted, biennial monocots grown as an annual when desired as a vegetable and as a biennial when seed production is desired. Onions grown for seed, bunching (green) onions, and non-storage onions (sold fresh) are produced in the Western states on a limited basis. However, the vast majority of the acreage is planted to dry bulb onions for storage. The bulb is comprised of thickened fleshy leaf bases that grow partially underground. Upon harvest, some of the crop is sold fresh and some is used for processing. Most is stored for at least a short period of time, with marketing of the stored onions occurring over a period of six to seven months.

Cultivated onions are a diverse crop classified into numerous market types. One of the broadest ways to classify onions is based on their response to day length. Onions form bulbs in response to a critical daylength and thus, can be classified as short-, intermediate-, and long-day types. Onions are further categorized by shape (flat, globe, grano, torpedo), skin color (yellow, red, white), pungency (sweet, pungent), and market use (fresh, storage, processing). Most onion cultivars grown in the West are long-day types that respond well to our long daylengths during the growing season. Yellow hybrid cultivars that include some sweet Spanish parentage are the predominate onions grown in Colorado, Idaho, Oregon, Utah, and Washington. They have moderate- to long-term storage capabilities.

In 2003, Colorado, Idaho, Oregon, Utah, and Washington produced about 60% of the dry bulb storage onions in the United States, on approximately 51% of the acreage, which accounts for nearly 73% of the U.S. dry bulb onion crop value.

Dry Bulb Storage Onions, 2003

	Harvested Acres	Total Production (tons)	Value ($ million)
Colorado	9,600	198,800	51.0
Idaho	8,200	246,000	57.7
Oregon	18,500	506,750	108.3
Utah	1,800	41,400	7.9
Washington	16,000	472,000	90.2
Western Region	54,100	1,464,950	351.1

In Colorado, onion production is concentrated in the northern part of the state, with over 50% of the crop produced in Larimer, Boulder, Adams, Morgan, and Weld counties. About 25% of Colorado onions are grown in the southeast, in the Arkansas Valley counties of Baca, Bent, Otero, Prowers, and Pueblo, and the remaining 25% are grown on the Western Slope in Delta, Mesa, and Montrose counties.

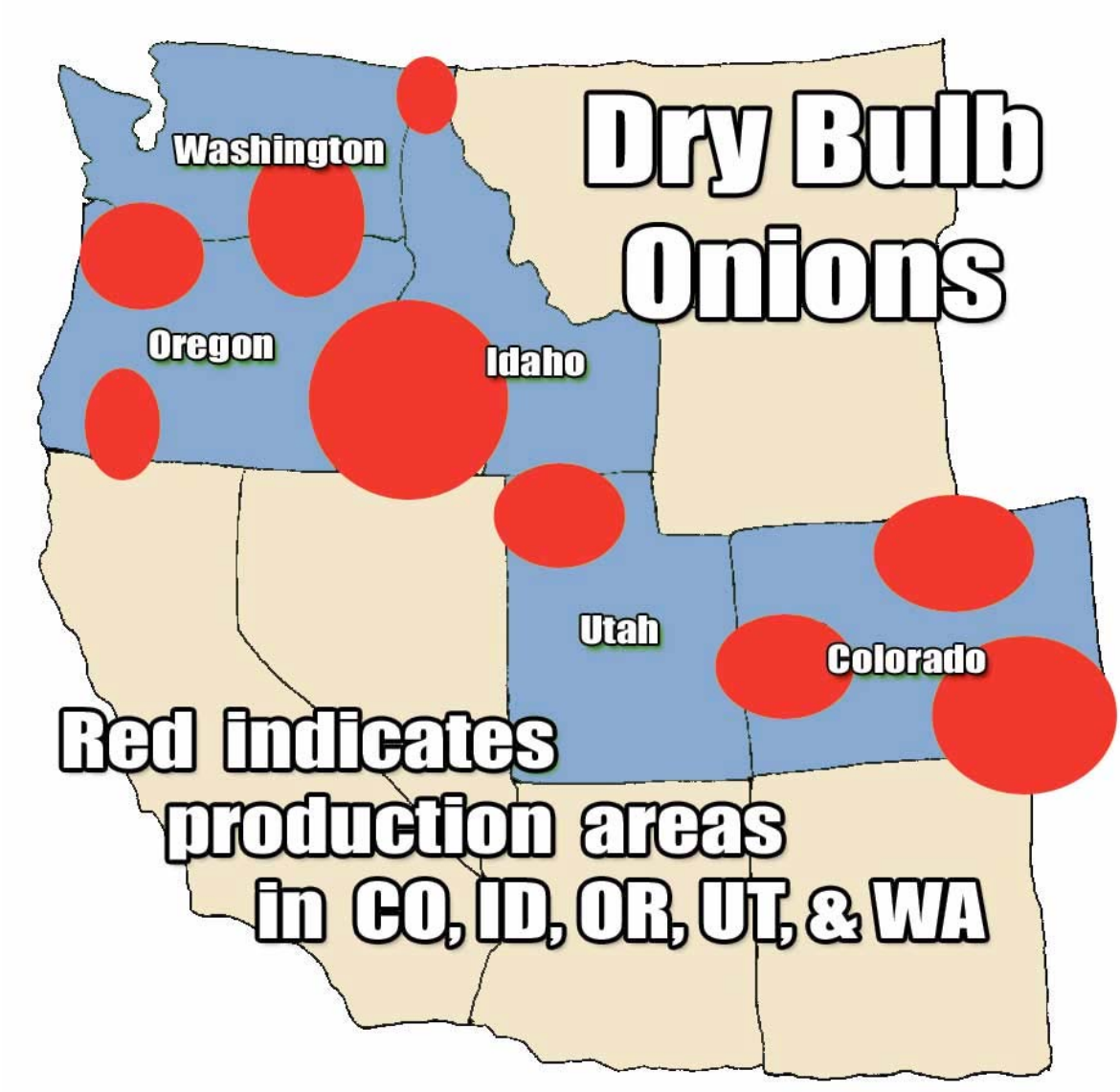
Idaho's onion production occurs primarily in the southwestern part of the state in the Treasure Valley, in Ada, Canyon, Payette, and Washington counties. Other parts of the state that have some onion production include Bonner, Elmore, Gooding, Jerome, and Owyhee counties.

Onion production in Oregon occurs on both the east side and west side of the Cascade Mountains. Westside production accounts for about 8% of the onion acreage and occurs

mostly in Clackamas, Marion, Polk, Washington, and Yamhill counties in the Willamette Valley, with a small amount of production in Jackson County in the southwestern part of the state. The remaining acreage is on the east side of the Cascade Mountains. Approximately 62% of the state's onion acreage is in the Treasure Valley of Malheur County, located in the far eastern part of the state, and 27% of the acreage is in Morrow and Umatilla counties, in the northcentral part of the state.

Onion production in Utah is concentrated in the northern part of the state in Box Elder, Davis, and Weber counties.

In Washington, onions are produced, predominately, east of the Cascade Mountains in the Columbia Basin region, which includes Adams, Benton, Grant, and Franklin counties. Washington also has a substantial non-storage bulb onion production area (approximately 800 acres) located in Walla Walla County in the southeastern part of the state.



The soils and climate in the onion-growing regions of Colorado, Idaho, Oregon, Utah, and Washington are well suited to onion production. Onions grow best in fertile, well-drained

loam soils, but can grow well in a variety of soil types. Compacted soils and soils with poor drainage or high salinity should be avoided. Onions in the Willamette Valley in western Oregon are grown on both mineral soils and muck soils; the muck soils are black in color, with a high level of organic matter formed from ancient lake beds and mineral soils.

Some areas of Colorado, Idaho, Oregon, Utah, and Washington where onions are produced are semi-arid and irrigation is required for optimum production. Irrigation begins after planting and continues as needed throughout the growing season; sandy soils require more frequent irrigation. Irrigation is stopped 3 to 14 days before onions bulbs are removed from the ground (lifted), to allow the crop to cure. The most common method of irrigation for Washington is overhead sprinklers, but furrow irrigation is most common in the other states. Drip irrigation is becoming more popular.

Irrigation Type (percentage)

	Sprinkler	**Furrow**	**Drip**
Colorado	15	80	5
Idaho	1	84	15
Oregon	1	84	15
Utah	0	95	5
Washington	60	20	20

Most dry bulb onions are direct seeded with precision planters. Planting occurs primarily in spring, from early March through April. A small percentage of the crop is seeded in the fall and overwintered to produce bulbs for early harvest. Precision seeding of coated or uncoated seed is used to achieve more precise plant spacing; the coating contains fungicides that help combat soil diseases such as smut and damping-off. Onion transplants are also sometimes planted in early spring for a very early harvest. Once the seed germinates, the onion plant grows vegetatively for 5 to 8 weeks, producing upright leaves during this time. Dependent upon the cultivar, length of daylight triggers the plant to begin bulb formation and temperature determines the subsequent rate of bulb growth. The fleshy leaves at the base of the plant, called scales, enlarge during the latter part of the vegetative growth stage, which lasts for 8 to 10 weeks. The bulbs are mature and ready for lifting (undercutting the bulbs in preparation for harvest) when approximately 50% of the onion tops (leaves) in a field have fallen over. The time needed to produce an onion crop, from planting to harvest, can take up to six months.

A uniform seedbed that allows precise seed placement is very important to achieve a uniform plant stand. Plant spacing affects bulb size, shape, and yield. Increasing the spacing between plants usually results in larger, better-shaped bulbs. Most onions are spaced 3 to 4” or more apart, depending on the cultivar and planting scheme. Plants spaced too widely due to planting skips or other factors produce larger bulbs but are likely to develop thick necks, which are difficult to cure and suffer greater storage losses.

Onions are usually planted in multiple rows on beds. Beds are commonly formed at or just before planting with 2 to 12 rows planted per bed. A typical arrangement is two double rows spaced about 12” apart on beds that range from 30 to 45 inches wide. Multiples of this arrangement are sometimes used, particularly with drip irrigation systems. On some

soils, early season rainfall or irrigation before emergence creates a crust that delays or prevents emergence. When this occurs, either mechanical rollers can be used to break the crust prior to crop emergence or numerous light applications of water, made through sprinkler irrigation, are performed to prevent crusting until the crop emerges. Thinning of onion plants is not practiced in the western states.

Dry bulb storage onions are often grown in 3- to 4-year rotations with other crops. Rotations differ between the growing regions. In general, the main rotational crops include potatoes, carrots, and sweet corn. Other rotation partners may include field corn, wheat, peas, and beans. Alfalfa, sugar beets, and grass seed are also sometimes included in the rotation. Rotational restrictions are very important in making herbicide decisions. Volunteer potatoes from a previous potato crop can become a serious weed in an onion field; therefore, when possible, growers schedule rotations so that potatoes are at least two crop years away from onion production. Onion fields may be fumigated during each rotation cycle. If the rotation includes lower-value crops, the fumigation is done just prior to planting onions. If the rotation partners are carrots or potatoes, fumigation may occur the year before or the year after onions are planted as carrots and potatoes are also high-value crops and successful management of their pests requires fumigation.

Cover crops, usually wheat or other cereals, are usually planted prior to planting onions. They are utilized by some growers largely as a means to reduce soil erosion and to protect young onions from wind and blowing soil damage. The most successful programs employ wheat planted in late summer, which is generally killed by fall herbicide or soil fumigant application. Spring-planted cover crops have proven more problematic due to the difficulty of killing the cover before significant crop competition occurs with the onion crop. This is typically attempted with selective grass herbicides. Cover crops may also have the benefit of providing some weed suppression.

The majority of dry bulb storage onions are mechanically lifted and harvested in the late summer or early fall. The sprout suppressant maleic hydrazide is widely used by Washington growers prior to harvest but is not as common in Colorado, Idaho, Oregon, or Utah. When about 50% of the tops have fallen over, “lifting” occurs. Lifting is a cultural practice that is used to accelerate the maturation of the onion bulb and to help field-cure the onion in preparation for harvest and storage. During lifting, the bulb is undercut with a machine that severs the root system below the onion bulb. Tops may be cut at the same time that lifting occurs. After lifting, the onions remain in the field for about 10 to 20 days until they are cured and ready for harvest, which is the process of removing the onions from the field. Mechanical toppers and loaders are used to pick up and load the field-cured bulbs. On some acreage, where transplanted onions produce thin-skinned bulbs, onions are mechanically lifted but topped by hand.

A properly field-cured bulb, ready for storage, should have a well-dried neck and have at least one, and preferably two, complete, dry scales. Necks that contain moisture or are too short will not seal properly and may favor the growth of pathogens. Overly short necks also allow excessive moisture loss from the bulb in storage. Even with properly field-cured bulbs, additional post-harvest curing in storage is essential. During this time, final drying of the onion neck occurs and wounds caused during harvest will dry and heal. Drying of the external scales occurs most rapidly during this period. Some storage managers heat the

onion bulbs to about 95° F for a short period of time immediately after harvest to further the curing process and reduce incidence of disease.

Once cured, onions store best under dry, cool conditions with positive air circulation. Most storage facilities are not refrigerated but are maintained at temperatures of 35 to 40° F when weather conditions permit. Low relative humidity is essential in storage to inhibit disease and root sprouting. Bulb life is maximized at temperatures of about 32° F, but condensation during grading, packing, and shipping may occur more readily when bulbs are held at this lower temperature.

IPM Strategies in Dry Bulb Storage Onion Production

All dry bulb onion growers use some integrated pest management (IPM) practices in their operation to control diseases, nematodes, insects, and weeds. These practices often include cultural, biological, and chemical techniques. Growing onions is a challenge because the crop is very susceptible to diseases, insects, and especially weeds, all of which can affect the quality of the bulb and/or reduce yield. The ultimate goal of IPM is to ensure the production of an abundant, high-quality crop in an environmentally and economically sound manner.

Commonly used IPM practices for disease control include use of resistant cultivars, crop rotation, field scouting, irrigation and fertilizer scheduling, cull management, and sanitation. For insect control, field scouting, sanitation, preservation of habitat for beneficial arthropods, and cull management are widely used IPM practices. Pest alerts, such as the Treasure Valley Pest Alert in Oregon and Idaho, are utilized by growers and field scouts to assist with field scouting, pest occurrence, and timing of pest management practices. Scouting, cover crops, cultivation, and crop rotation are used in IPM programs for weed control. When using agricultural chemicals, onion growers and commercial applicators regularly calibrate pesticide application equipment to ensure proper and accurate delivery.

IPM and Forecasting: Early detection of pest problems is a key element of an integrated pest management program. The onset and spread of diseases, insects, and weeds are closely linked to weather patterns. By monitoring weather information and forecasts, a pest problem may be predicted and dealt with in a timely and efficient manner. Rather than spraying on a weekly or monthly basis without regard to the pest pressure, growers strive to make control applications only when a problem is present and when it is economically and biologically prudent to do so.

Automated electronic weather stations are located in most major onion production areas of the Western states. These weather stations are equipped with sensors that measure a variety of parameters, including air and soil temperature, humidity, rainfall, and solar radiation. The stations also contain a cellular telephone and modem that enable weather data to be transferred to a main computer on a daily basis for input into pest forecast models.

Forecast models have been developed for several diseases, such as bacterial leaf blight, purple blotch, downy mildew, and Botrytis. These models concentrate on factors such as previous disease pressure, cropping history, current and forecast temperature patterns, current and forecast rainfall patterns, stage of crop growth, cultivar susceptibility, and first

sign of the disease. Disease forecast models integrate these variables to provide growers and crop consultants with a risk potential for disease and appropriate responses, including the timely application of labeled pesticides and biopesticides.

Foundation for the Pest Management Strategic Plan

The remainder of this document is a discussion of the common pests (insects, diseases, weeds, nematodes) that can cause significant damage and economic losses during the various growth stages of dry bulb storage onions and the field and worker activities that are likely to occur during these stages. This document also summarizes current and potential management practices for these pests and lists what the dry bulb storage onion industry believes are the research, regulatory, and educational needs for dealing with pests that occur in onion production. Any differences between production regions in Colorado, Idaho, Oregon, Utah, and Washington are discussed where appropriate.

The use of trade names does not imply endorsement by the workgroup or any of the organizations represented. Trade names are used as an aid in identifying various products.

Pre-Plant

In most of the onion-growing regions of Colorado, Idaho, Oregon, Utah, and Washington, field preparation for establishment of an onion planting begins in the fall prior to planting; in some areas, field preparation begins in early spring of the planting year. For example, in western Oregon, field preparation is more commonly done in the spring because of fall and winter rains. Planting in all regions generally occurs in March and April.

Prior to planting, growers have their soil analyzed to identify available soil nutrients. Based on results of the soil tests, major and minor plant nutrients are usually applied to the soil prior to planting. Nitrogen fertilizer is typically applied as a side dressing or through the sprinkler or drip irrigation system after planting. A soil test to determine occurrence and population of resistant plant parasitic nematodes is taken prior to planting; fields with significant levels of nematodes are avoided or treated pre-plant with a soil fumigant. Cover crops are planted in the fall or early spring by many growers to reduce crop injury, especially those farming sandy soils in windy areas. Growers generally avoid planting a cover crop that is a known host for nematodes; however, cereal grains, which can be a host for nematodes, are often used as a cover crop because of their ability to prevent soil erosion. Careful timing is essential to kill the cover crop with herbicides or tillage to avoid suppressing onion growth. Planting into the residue in the spring provides wind erosion protection. Onions have foliage that is sparse, slow to develop, and competes poorly with weeds or a cover crop.

In preparation for planting, the soil is worked to produce a smooth surface. If the soil is to be fumigated, it is often done at this time (or in the previous fall) for control of nematodes, soil-dwelling insects, soil diseases, and weeds. Beds are then created for planting.

Field activities that may occur during pre-plant:

Plant cover crop
Soil tillage
Cover crop removal (herbicide or tillage)
Soil sampling for nutrients or nematodes
Scouting for weeds and insects
Bed preparation and shaping
Soil fumigation
Fertilization
Pre-plant herbicide application

Insects and Mites

Many different types of insect pests can be found in the soil prior to planting, depending on the previous crop and the history of the field. Armyworms and cutworms are often present at this crop stage but control measures are not initiated at this time.

Farming practices prior to planting can impact the control of maggots and other soil-dwelling insects. Because maggot pupae and other insects overwinter in the soil, operations that disturb their habitat can reduce their populations. Field operations that can be beneficial include crop rotation, plowing, incorporation of previous onion crop residue, and destruction of cull piles. When economically feasible, maintaining a fallow season for

onion fields will also reduce the survival of soil insects that have a limited ability to seek new hosts.

Crop rotation is a practice commonly used to mitigate soil insects such as maggots, symphyla, or wireworms that can damage onions. Continual production of onions in the same field year after year will result in the establishment of resident populations of onion insect pests (and will build up populations of stem and bulb nematodes). Rotating onions with non-susceptible crops such as cereals can reduce some insect populations due both to the rotation crop's lack of susceptibility and to the cultural practices used to produce those crops.

Onion Maggot (*Delia antiqua*) and **Seed Corn Maggot** (*Delia platura*)
The larvae of these insects overwinter in the soil and can be very problematic in fields with high organic content, such as those coming out of pasture or where manure was applied the previous year. The onion maggot larva is creamy-white in color and feeds on the roots or leaves of the developing onion plant. Larval feeding reduces plant vigor and increases rot when bulbs are in storage. Feeding by the onion maggot larvae has been implicated in spreading bacteria that causes bacterial soft rot disease. The seed corn maggot larva is smaller than the onion maggot larva, white to whitish yellow, cylindrical, and tapered with the smaller end in front. It feeds on both the seeds and the emerging seedlings of onions; plant stands can be reduced if populations are high.

Chemical control:
There are no chemical controls used pre-plant to control maggots. Soil fumigation applied prior to planting (with such products as dichloropropene (Telone II), dichloropropene + chloropicrin (Telone C-17 or Telone C-35), or chloropicrin) to control nematodes and other soil-dwelling insects may provide some control of maggots but will not control subsequent re-infestation during the early growing season.

Cultural control:
Crop rotation: Rotating onions with non-susceptible crops such as cereals can reduce maggot populations due both to the rotation crop's lack of susceptibility and to the cultural practices used to produce those crops.

Cultivation: Plowing in the spring prior to the emergence of adult maggot flies turns over and buries the top layers of soil to depths beyond which the adults can emerge, thus reducing their survival.

Cull and crop residue management: Cull onions can also be a source of maggots and should be well removed from production fields. Onion crop residue should be chopped and incorporated into the soil as soon as possible after harvest so as not to attract flies preparing to pupate.

Field site selection: Maggots do not travel far from fields in which the pupae overwinter, so growers consider the distance when selecting fields for planting onions. Rotating to fields farther from previous onion plantings can lessen the likelihood of maggot infestation.

Wireworms (*Limonius* spp.)

Wireworms are the soil-dwelling larvae of click beetles. The adults are slender, tan to nearly black and about three-eighths of an inch long. The larvae are hard, segmented, three-eighths to half an inch long, and dark yellow or brown. They can be found in the soil prior to planting, especially if the field has been rotated out of pasture or non-row crops. Wireworms are found in most onion production areas but Washington has had limited wireworm damage.

Chemical control:
Pre-plant soil fumigation may be practiced to control wireworms and other insects that are found in the soil prior to planting. Soil fumigation is accomplished with such products as dichloropropene (Telone II), dichloropropene + chloropicrin (Telone C-17 or Telone C-35), or chloropicrin.)

Diazinon can be used as a pre-plant broadcast application but has not proven to be effective. None of the registered and labeled biocontrol tools are effective for wireworms.

Cultural control:
Crop rotation: Rotating onions with non-susceptible crops such as cereals can reduce wireworm populations due both to the rotation crop's lack of susceptibility and to the cultural practices used to produce those crops.

Biological control:
None known.

Bulb Mites (*Rhizoglyphus* spp.)
Bulb mites are shiny, creamy white, bulbous shaped, and less than a sixteenth of an inch long. The mites overwinter in decaying vegetation of weeds or a previously planted vegetable crop that remains in the soil. Injury to the onion plant occurs during vegetative growth; feeding injury causes a mottling of the leaves, giving them a bronzed, silvery, or scorched appearance.

Chemical control:
Pre-plant soil fumigation can be used control insect and mite pests that are found in the soil prior to planting. Soil fumigation is accomplished with such products as dichloropropene (Telone II), dichloropropene + chloropicrin (Telone C-17 or Telone C-35), chloropicrin, and sodium methyldithiocarbamate (Metam Sodium).

Cultural control:
Crop rotation: Growers discourage bulb mite build-up by avoiding successive allium crops.

Cull and crop residue management: Bulb mite populations can be reduced by allowing crop residues to fully decompose prior to planting onions. Fallowing to allow complete decomposition of organic matter reduces field populations of the bulb mite but is seldom economically feasible.

Biological control:
None known.

Critical Needs for Management of Insects in Onions: Pre-Plant

Research
- Identify the impacts of IPM and cultural practices on bulb mites.
- Determine the effects of green manure crops on insect pests found in the soil prior to planting.
- Develop a prediction model for potential for maggot damage.

Regulatory
- Registration of alternative products such as fipronil seed treatment for control of maggots, cyfluthrin + tebupirimphos (Aztec) for control of wireworms.

Education
- Invite EPA to visit onion fields in the western states to observe production practices and pest problems.

Diseases

Many different fungal disease organisms reside in the soil or in decaying organic matter in the soil. Control of these diseases prior to planting can eliminate the need for control measures later in the growing season and subsequently help increase plant vigor and improve quality and yield of the onion crop.

Black mold (*Aspergillus niger*)
This fungal organism overwinters in cull piles, crop debris, and soil. It can be transmitted via seed. Damage from black mold affects the bulb; infected bulbs have a black discoloration at the neck, on the outer scales, and between the scales. Advanced stages of the disease will cause the onion bulb to shrivel.

Chemical control:
Pre-plant soil fumigation can help reduce the severity of black mold. Soil fumigation is accomplished with such products as chloropicrin, dichloropropene + chloropicrin (Telone C-17 or Telone C-35), and sodium methyldithiocarbamate (Metam Sodium).

Cultural control:
Eliminate cull piles and onion debris from the field.

Crop rotation: Rotate out of *Allium* crops for at least three years.

Assay seed and select lots with low *Aspergillus* levels.

Biological control:
None known.

Fusarium Basal Rot (*Fusarium oxysporum* f. sp. *cepae*)
The pathogen resides in the soil and affects the onion root and basal plate area of the bulb, causing a pinkish-brown rot that becomes covered with a whitish mycelium. Leaf tips yellow, entire leaves wilt (beginning with the older, outer leaves), scattered plants are stunted and eventually die. Infected bulbs continue to rot during storage.

Chemical control:
Pre-plant soil fumigation can help reduce the severity of Fusarium basal rot; fair to good results have been reported. Soil fumigation is accomplished with such products as chloropicrin, dichloropropene + chloropicrin (Telone C-17 or Telone C-35), and sodium methyldithiocarbamate (Metam Sodium).

Cultural control:
Crop rotation: A crop rotation of three or more years between onion crops helps reduce the severity of Fusarium basal rot.

Biological control:
None known.

White rot (*Sclerotium cepivorum*)
White rot is caused by a fungus that produces hardy sclerotia that can survive in the soil for 20 years or more. Once the disease is established in a field, it is very difficult to grow onions successfully. Affected plants have leaves that decay at the base, turn yellow, wilt, and topple over; older leaves collapse first. Affected bulbs become watery and the outer scales crack, then dry and shrink. White rot can continue to decay infected bulbs in storage if humidity is not kept low.

Chemical control:
Pre-plant soil fumigation can control or help reduce the severity of white rot found in the soil prior to planting onions. Soil fumigation is accomplished with such products as chloropicrin, dichloropropene + chloropicrin (Telone C-17 or Telone C-35), and sodium methyldithiocarbamate (Metam Sodium).

Diallyl disulfide (Alli-up) is applied by some growers to the soil pre-plant to stimulate germination of sclerotia, thus reducing the amount of sclerotia present when onions are planted.

Cultural control:
Sanitation: Most cultural control practices have little effect on white rot once the disease is introduced, so sanitation is critical to reduce the introduction and spread of this disease. White rot is spread by contaminated bulbs or transplants of any member of the onion family, or on contaminated bins, vehicles, and tillage equipment. Soil should be washed off equipment between fields and bins should be cleaned prior to use.

Biological control:
None known.

Damping Off (*Fusarium* spp*., Pythium* spp*., Rhizoctonia* spp*.)*
These soil pathogens reside in the soil. Damping off can occur pre-emergence or after seedlings have emerged. With pre-emergence damping off, the disease attacks the developing shoot and the seedling fails to break the soil surface.

Chemical control:
Pre-plant soil fumigation can control or help reduce the severity of damping off. Soil fumigation is accomplished with such products as chloropicrin, dichloropropene +

chloropicrin (Telone C-17 or Telone C-35), and sodium methyldithiocarbamate (Metam Sodium).

Cultural control:
Planting time and soil preparation: Avoid planting in cold, wet soils.

Biological control:
None known.

Pink Root (*Phoma terrestris*)
Pink root is caused by a soilborne fungal pathogen that can survive many years in the soil, even in the absence of a host plant. It is common in most onion producing regions. The disease causes onion roots to turn pink and die; reduction of the root system reduces plant vigor and decreases bulb size.

Chemical control:
Pre-plant soil fumigation with such products as chloropicrin, dichloropropene + chloropicrin (Telone C-17 or Telone C-35), and sodium methyldithiocarbamate (Metam Sodium), helps reduces severity of the disease; fall fumigation is more effective than spring fumigation.

Cultural control:
Crop rotation: Three or more years between onion crops can reduce the severity of pink root.

Biological control:
None known.

Smut (*Urocystis magica*, formerly *U. cepulae*, and *U. colchici*)
These fungi survive both in the soil and in decaying plant matter. They can cause blisters on the leaves and bulbs of developing onions. Seedlings can die during emergence; those that live produce distorted bulbs with darkish streaks and numerous smutty lesions. Affected bulbs are predisposed to other infections in the field and often break down before bulbs have had a chance to form. This disease is especially prevalent on the muck soils in western Oregon.

Chemical control:
Pre-plant soil fumigation can help reduce the severity of smut. Soil fumigation is accomplished with such products as chloropicrin, dichloropropene + chloropicrin (Telone C-17 or Telone C-35), and sodium methyldithiocarbamate (Metam Sodium).

Cultural control:
Crop rotation: Three or more years between onion crops generally reduces the severity of smut.

Planting time and soil preparation: To reduce intensity of smut, growers avoid planting in cold, wet soils. Working the soil well so organic matter is adequately incorporated also helps manage smut.

Biological control:
None known.

Critical Needs for Management of Diseases in Onions: Pre-Plant

Research
- Develop a protocol to test soils for soilborne organisms.
- Establish economic impact thresholds for soilborne insects to aid in IPM decisions.

Regulatory
- None at this time.

Education
- Educate growers about the use of soil testing and economic thresholds.

Weeds

A wide range of broadleaf and grass weed types are found in the onion-growing regions of the West. Weeds are a major concern, as onions have sparse vegetation, are slow-growing, and do not compete well with weeds. A weedy field can reduce plant vigor, bulb size and, subsequently, yield. Weed control prior to and at planting is critical for the crop. Hard-to-control weeds such as yellow nutsedge, field bindweed, and kochia, are particularly problematic. Fields heavily infested with perennial weeds should not be planted to onions.

An integrated approach to weed control in onion requires the use of effective crop rotations to reduce the amount of weed seed in the soil and to control perennial weeds. During the year onions are produced, the few herbicides registered for use in onions may make it difficult to control certain weed species. Rotation crops can be selected that allow use of effective herbicides for controlling perennial or problematic weeds.

Preparing seed beds in the fall can help reduce weed populations by exposing weeds near the soil surface to extreme environmental conditions during the winter. Weeds that germinate during the winter can be controlled with a non-selective herbicide (e.g., glyphosate) prior to planting onions. In some areas glyphosate (Roundup) may be used to destroy a cover crop, which also kills weeds that have emerged. In areas where onion beds are prepared in the fall, the beds are often “knocked down” prior to planting; the top few inches of soil are scraped off to allow onion seed to be planted in firm, moist soil. Knocking down the beds often controls some of the small weeds that have germinated. Bensulide (Prefar) can be applied in the fall in Idaho and Oregon and must be incorporated into the soil with shallow cultivation or with sprinkler irrigation. Care must be taken to maintain the herbicide in a uniform layer in the soil to ensure good weed control and to prevent onion injury. If the herbicide is too deep it will be out of the area where the weeds geminate and may be in direct contact with the onion seed, which may cause injury. Prefar can also be applied pre-plant and incorporated in the spring; however, use of Prefar is not allowed in the Willamette Valley of Oregon.

Chemical control:

Pre-plant soil fumigation with sodium methyldithiocarbamate (Metam Sodium) provides pre-emergence weed control prior to planting.

Bensulide (Prefar): A pre-emergence herbicide that can be applied pre-plant. Use not allowed in the Willamette Valley of Oregon.

Post-emergence grass herbicides, such as clethodim (Select), fluazifop (Fusilade), and sethoxydim (Poast), can be applied to actively growing grasses prior to planting. These herbicides are also often used for management of a cereal cover crop.

Glyphosate (Roundup): A non-selective, systemic herbicide applied to actively growing grass or broadleaf weeds prior to cultivating the soil for planting. Especially effective in controlling some perennial weeds.

Paraquat (Gramoxone): A contact, non-systemic herbicide that may be applied to actively growing grass or broadleaf weeds prior to soil cultivation.

Cultural control:
Flaming: Directed to actively growing grass or broadleaf weeds prior to cultivating the soil for planting. Not a widely used practice.

Cultivation: Deep tillage buries seed of small-seeded weeds and can prevent germination, but is only effective if the rest of the soil profile is relatively free of weeds. Shallow cultivation can destroy newly germinated annual weeds.

Crop rotation: Rotational crops can be planted that allow use of effective herbicides for controlling perennial or problematic weeds.

Cover crop: A cover crop can help prevent weed germination.

Biological control:
None known.

Critical Needs for Management of Weeds in Onions: Pre-Plant

Research

- Develop a better understanding of the effects of fumigation on weed propagules (esp. nutsedge, quackgrass, Canada thistle, field bindweed).
- Determine efficacy of other pre-plant herbicide applications for nutsedge control, e.g., fall-applied metolachlor (Dual), fallow-applied EPTC (Eptam).
- Develop a better understanding of the effects of green manure crops on weed propagules.
- Determine the effects of crop rotation systems on weed control.

Regulatory

- Maintain registration of fumigants.
- Expand the use of soil fumigants.
- Expedite methyl iodide (iodomethane, Midas) registration.

Education

- None at this time.

Nematodes

Nematodes are categorized as either ectoparasitic (those that feed externally on roots) or endoparasitic (those that penetrate roots and feed internally); both are considered pests of onions in this region. The most common nematodes on onion in Colorado, Idaho, eastern Oregon, Utah, and Washington are stem and bulb nematode (*Ditylenchus dipsaci*), lesion nematode (*Pratylenchus* spp.), northern root-knot nematode (*Meloidogyne hapla*), and stubby-root nematode (*Paratrichodorus* or *Trichodorus* species). Population level of these nematodes in the field prior to planting of onion is one of the factors to be considered while implementing management options. Usually, the number of nematodes will be high in fields following a rotation of alfalfa, corn, potatoes, vegetables, cereals, or grasses. Pre-plant population can seriously limit bulb yield, quality, and vigor; the severity of damage depends on the species of nematode present and population densities in the soil at the time of planting.

Pre-plant soil sampling can determine the occurrence and distribution of the nematodes. Since nematode distribution is seldom uniform and changes may occur rapidly, one of the primary components in determining nematode populations is the collection of representative soil samples.

Stem and Bulb Nematode (*Ditylenchus dipsaci*)
This is an endoparasitic nematode, which enters and feeds on root, stem, and leaf tissues of the onion plant. High populations can contribute to damping-off. Seedlings become deformed and pale green to yellow. Young bulbs become soft, swollen, and misshapen, causing a disease symptom known as “bloat.” Yellow spots, swellings, or open lesions may appear on the leaves of stunted plants. Stems and necks are often softened and there is a high incidence of doubles, cracked bulbs, and culls.

Lesion Nematode (*Pratylenchus* spp.)
Root-lesion nematodes are migratory endoparasites. They are of concern to onion growers because they reduce yield indirectly by reducing plant vigor and increasing stress on the plants, making the plants more susceptible to fungal and bacterial diseases. All life cycle stages of the nematode except the egg stage infect roots immediately behind the growing tips, causing brown lesions around the root cortex. Lesions coalesce, turn black, and are often invaded by soil microorganisms, which can cause weakened root systems, reduced water and nutrient uptake, loss of plant vigor, and yield reduction. Although more than 15 species of root-lesion nematodes are reported, *Pratylenchus penetrans* and *P. neglectus* are the predominant lesion nematode species in Colorado, Idaho, Oregon, Utah, and Washington.

Stubby-Root Nematode (*Paratrichodorus* and *Trichodorus* spp.)
Stubby-root nematodes are migratory ectoparasites; they don’t enter the onion plant but remain in the soil and feed on the roots. Their feeding causes the roots to be short and yellow-brown in color; plants become stunted. With continued feeding, the root tips become darker, stubby, and more branched; bulb size is reduced. Stubby root nematodes have the ability to adapt to unfavorable conditions by migrating downward in the soil.

Damage is profoundly influenced by soil moisture and is greater in wet seasons. Stubby-root nematodes have a wide host range that includes cereal crops and potatoes. Distribution of *P. allius* in the United States is presently limited to Oregon, Washington, and California while *P. minor* and *P. porosus* are common in Idaho and eastern Oregon.

Northern Root-Knot Nematode (*Meloidogyne hapla*)
This endoparasitic nematode is widely distributed in the onion fields of Colorado, Idaho, Oregon, Utah, and Washington. Damage symptoms include plant stunting, chlorosis (yellowing), wilting, and premature death. Below-ground symptoms include small galls on the roots; infected plants also tend to have fewer secondary roots. Damage from the northern root-knot nematode may be most severe following alfalfa hay crops and during years with warm spring temperatures. Cooler temperatures may delay infection and less injury may occur. The number of galls and egg masses on the roots vary with the nematode population densities in the soil, host susceptibility, and environmental factors.

Chemical control:
Pre-plant soil fumigation with such products as dichloropropene (Telone II), dichloropropene + chloropicrin (Telone C-17 or Telone C-35), chloropicrin, or sodium methyldithiocarbamate (Metam Sodium) is often practiced to control diseases but will also control nematodes prior to planting onions.

Cultural control:
Weed management: Weeds act as an alternate host and reservoir for numerous nematode species. Weed control can help reduce nematode populations and thus reduce damage from nematodes.

Crop rotation: Growers avoid rotations that include mint, cereals, alfalfa, garlic, corn, or grasses. Some plant nematode-resistant cultivars of alfalfa or beans in rotation with onions, which considerably reduces the damage caused by nematodes.

Green manure crops (crops that are incorporated into the soil while still green) can be used early during the pre-plant stage. Oil radish or rapeseed crops are planted in the fall before planting the onion crop the following spring. These green manure crops are incorporated into the soil before "freeze-up." When the green plant matter (manure) is incorporated it is macerated, which causes the release of glucosinolates. These glucosinolates may have some nematicidal activity. The green manures also encourage beneficial organisms than can suppress nematode populations.

Biological control:
None known.

Critical Needs for Management of Nematodes in Onions: Pre-Plant

Research

- Determine the effect of a green manure crop on nematode populations and impact on onions.
- Investigate efficacy of rapeseed meal as a soil amendment for nematode control.
- Determine the impact of micro nutrient applications on nematodes.
- Develop nematode-resistant onion cultivars.

- Refine rate and application method of metam sodium soil fumigant.
- Determine efficacy and rate of granular fumigant dazomet (Basamid).
- Determine the interaction of nematodes with soilborne diseases.
- Determine the impact of lesion nematode on onions in the western United States.
- Refine use pattern and rate of methyl iodide (iodomethane, Midas) and fosthiazate.

Regulatory

- Register Inline, the drip irrigation formulation of dichloropropene + chloropicrin.
- Expedite the registration of methyl iodide (iodomethane/Midas).
- Begin the process for registration of fosthiazate; work with IR-4.

Education

- Promote pre-plant soil testing for nematodes.
- Develop an Extension publication about the biology, ecology, and management of nematodes in onion production.

Planting through Emergence (up to and including flag leaf stage)

Most dry bulb onions are direct seeded with precision planters; planting occurs primarily from early March through April. A small percentage of the crop is seeded in the fall. Some onion seed is coated with fungicides that help combat soil diseases such as smut and damping-off.

The soil should be moist at planting and irrigated once the onion shoots have emerged. Some areas irrigate after planting to assist with germination and to help with seedling emergence (irrigation prevents the soil from crusting and thus aids in emergence). Transplanted onions require irrigation immediately after planting.

Emergence is the point at which the flag leaf (thin, curved, cotyledonal leaf) has emerged from the soil. It can take from 10 to 30 days after seeding before a seedling emerges and a flag leaf is present.

Field activities that may occur during Planting through Emergence:

Scouting for weeds and insects
Fertilization
Planting (seeds or transplants)
Irrigation
Pre-emergence herbicide application

Insects and Mites

Bulb mites, wireworms, armyworms, and cutworms can be present at planting through emergence but are not treated at this time. Thrips are not present at this stage, but a systemic insecticide applied at seedling emergence may control thrips later in the growing season.

Onion Maggot (*Delia antiqua*) and **Seed Corn Maggot** (*Delia platura*)

The larvae of these insects overwinter in the soil and can be very problematic in fields with high organic matter. Feeding by onion maggot larvae reduces plant vigor and can increase incidence of rot when bulbs are in storage. The seed corn maggot feeds on both the seeds and the emerging seedlings of onions. Plant stands can be reduced if populations are high.

Chemical control:

Onion seed can be treated with cyromazine, but while this product is registered, it is not used because it is not effective on the seed corn maggot and has questionable performance on the onion maggot.

Diazinon is used at planting (pre-plant incorporate).

Chlorpyrifos (Lorsban 4E) is used as an in-furrow application on the muck soils of western Oregon (Willamette Valley). In other areas, it is banded behind the planter at planting.

In the Columbia Basin, a significant number of growers (about 50%) do not use an insecticide at planting. Utah and Colorado do not use any insecticides at planting.

Cultural control:

Cultivation: Plowing and cultivation in preparation for establishment of onion seedbeds can reduce maggot populations at time of planting.

Cull and crop residue management: Cull onions and onion crop residues can be a source of maggots that can infest the newly planted onion crop. Cull piles should be well removed from production fields and crop residues should be well chopped and incorporated at planting time.

Biological control:
None known.

Critical Needs for Management of Insects in Onions: Planting through Emergence

Research
- Research chemical, cultural, and biological controls for onion and seed corn maggot.
- Identify systemic insecticides (applied at planting) that might be efficacious for onion and western flower thrips.

Regulatory
- Expedite registration of fipronil for onion maggot control.

Education
- Educate regulators on the need for a speedy registration process.
- Invite EPA to visit onion fields in the western states to observe production practices and pest problems.

Diseases

Many different fungal disease organisms reside in the soil or in decaying organic matter in the soil. Control of these diseases prior to planting can eliminate the need for control measures later in the growing season and, subsequently, help increase plant vigor and improve quality and yield of the onion crop.

Black Mold (*Aspergillus niger*)
Described in Pre-Plant section.

Chemical control:
There are no known chemical controls for black mold disease.

Cultural control:
Eliminate cull piles and onion debris from the field.

Plant certified seed.

Biological control:
None known.

Fusarium Basal Rot (*Fusarium oxysporum* f. sp. *cepae*)

Described in Pre-Plant section.

Chemical control:
Fludioxonil (Maxim 4FS) or Thiram can be used as a seed treatment; however, control has been reported as poor.

Cultural control:
Irrigation management: As excessive moisture can increase the incidence of Fusarium basal rot, growers take care not to over-irrigate. Enhancing drainage can help reduce the incidence of the disease.

Biological control:
None known.

White Rot (*Sclerotium cepivorum*)
Described in Pre-Plant section.

Chemical control:
Thiophanate-methyl (Topsin-M) applied in-furrow at planting helps with control.

Cultural control:
Sanitation: As discussed in Pre-Plant section.

Biological control:
None known.

Damping Off (*Fusarium* spp*., Pythium* spp.)
Damping off can occur after seedlings emerge from the soil, causing seedlings to rot at the soil line.

Chemical control:
Onion seed coated with the fungicides thiram, fludioxonil (Maxim 4FS), or carboxin helps control damping off.

Mefenoxam (Ridomil): Helpful but only controls *Pythium* spp.

Biological control:
None known.

Pink Root (*Phoma terrestris*)
Described in Pre-Plant section.

Chemical control:
There are no known chemical controls for pink root disease.

Cultural control:
Resistant cultivars: some cultivars of the “Sweet Spanish” type of onion are partially resistant to pink root.

Biological control:
None known.

Smut (*Urocystis magica*, formerly *U. cepulae*, and *U. colchici*)
Described in Pre-Plant section.

Chemical control:
Onion seed coated with the fungicides thiram or carboxin help control the smut diseases.

Mancozeb (Dithane) or maneb (Maneb) applied in-furrow at seeding can provide some control of smut.

Cultural control:
Resistant cultivars: Some cultivars of the "Sweet Spanish" type of onion are partially resistant to smut.

Planting time and soil preparation: To reduce intensity of smut diseases, growers avoid planting in cold, wet soils.

Biological control:
None known.

Iris Yellow Spot Virus *(IYSV)*
Iris yellow spot is a tospovirus and is related to impatiens necrotic spot (INSV) and tomato spotted wilt (TSWV). Disease symptoms include straw-colored, dry, tan, spindle- or diamond-shaped lesions on the leaves and stalks of onion plants. Some lesions have distinct green centers with yellow or tan borders; other lesions appear as concentric rings of alternating green and yellow/tan tissue. Infected plants may be scattered throughout a field. IYSV is transmitted by onion thrips.

Chemical control:
Control of onion thrips should help reduce incidence of IYSV (see Onion Thrips in the Vegetative Growth stage section of this document).

Cultural control:
Resistant cultivars: Some onion cultivars appear to be less susceptible to thrips and/or the virus.

Sanitation: Do not move soil from one field to the next. Destroy onion debris and culls.

Planting site: New plantings should be located away from overwintering onions.

Biological control:
None known.

Critical Needs for Management of Diseases in Onions: Planting through Emergence

Research

- Evaluate new fungicides as in-furrow and seed treatments for control of damping off complex and white rot diseases.
- Evaluate biopesticides for damping off complex and white rot diseases.
- Research on the biology and ecology of iris yellow spot virus.
- Further investigate the importance and management of seedborne diseases.

Regulatory

- Expedite new pesticide registrations for disease control at planting.
- Continue the white rot control order for Idaho and for Malheur County, Oregon.
- Continue the cull disposal order for Idaho and for Malheur County, Oregon.

Education

- Educate regulators on the specific disease control needs in onion production.

Weeds

Once onions are planted, several weeks elapse before they emerge from the ground. During this period many weeds emerge. Weeds that emerge after planting and prior to onion emergence can be controlled using an application of a non-selective herbicide such as glyphosate (Roundup) or paraquat (Gramoxone). Growers will often time the application of this non-selective herbicide as close to onion emergence as possible to control the greatest amount of emerging weeds and to reduce the time available for additional weeds to emerge before the onions emerge.

After planting, but before crop emergence, soil-active herbicides like DCPA (Dacthal) and bensulide (Prefar) can be applied. Both of these herbicides require incorporation to become active. This is generally done through shallow cultivation except where overhead irrigation is available. However, Prefar and Dacthal are not widely used because it is difficult to mechanically incorporate an herbicide above the onion seed once it has been planted. Also, the additional disturbance of the seedbed can cause critical moisture to be lost.

SLN labels in each state allow pendimethalin (Prowl) to be applied delayed pre-emergence (after about 75% of the onions have germinated but before they emerge from the soil). Prowl applied in this way is often mixed with glyphosate (Roundup). This combination controls emerged weeds and provides soil activity against weeds that will emerge later. The efficacy of Prowl applied this way is dependant on rainfall or irrigation for activation.

Herbicides used during this growth stage can be critical in suppressing weeds until onions reach a growth stage where other herbicides can be safely used.

Chemical control:

Bensulide (Prefar): A pre-emergence herbicide that is applied pre-plant or pre-crop emergence. The spectrum of weed species controlled is limited and there have been instances of reduced onion stand with its use.

DCPA (Dacthal): Not widely used because it is very expensive and has ground water concerns in some production areas. Injury has occurred in western Oregon (Willamette Valley) and is not used there.

Pendimethalin (Prowl): SLN labels are available for CO, ID, OR, UT, and WA. Can be applied after onion seed germination but prior to seedling emergence.

Post-emergence grass herbicides, such as clethodim (Select), fluazifop (Fusilade), and sethoxydim (Poast), can be applied to actively growing grasses.

Glyphosate (Roundup): A systemic, non-selective herbicide that may be applied to actively growing grass or broadleaf weeds after onions are planted but prior to emergence of the onion seedling.

Paraquat (Gramoxone): A contact, non-systemic herbicide that may be applied to actively growing grass or broadleaf weeds after onions are planted but prior to emergence of the onion seedling.

Cultural control:
Flaming: Directed to actively growing grass or broadleaf weeds after onions are planted but prior to crop emergence. Not a widely used practice.

Biological control:
None known.

Critical Needs for Management of Weeds in Onions: Planting through Emergence

Research
- Identify replacements for DCPA (Dacthal).
- Identify more effective pre-emergence herbicides.
- Determine efficacy and crop safety of dimethenamid-P (Outlook) when applied as a pre-emergence herbicide.

Regulatory
- Expedite registration of ethofumesate (Nortron).
- Explore the possibility of registering propachlor (Ramrod) in onions.

Education
- None at this time.

Nematodes

Nematode feeding can affect the quality and vigor of the onion seedlings.

Stem and Bulb Nematode (*Ditylenchus dipsaci*)
Stem and bulb nematodes penetrate the germinating onion seed via the root cap. Damage to the onion seedling has been attributed to direct feeding activity but most of the damage results from the effects of the nematode's salivary secretion on the surrounding plant

tissue. Seedlings become stunted, twisted, and deformed, and frequently die in severely infested areas of the field. Leaves are often short, thickened, and yellow-spotted.

Lesion Nematode (*Pratylenchus* spp.)
The lesion nematode enters the delicate root system of onion at this crop stage and begins to reproduce soon after the onion rootlets are formed. The nematode causes long, narrow, grayish, opaque lesions on the roots. Further detailed research is needed to demonstrate the involvement of lesion nematode on onion damage at this crop stage.

Stubby-Root Nematode (*Paratrichodorus* and *Trichodorus* spp.)
The life cycle of stubby-root nematode is relatively simple. All four juvenile stages resemble the adult stage, except that juveniles are smaller. Since several generations can be produced within a year, large populations of stubby-root nematodes can develop quickly. They may survive cold winters by migrating below the frost line and undergoing dormancy. Damage by stubby-root nematodes is greater in wetter seasons and on sandy soil.

Northern Root-Knot Nematode (*Meloidogyne hapla*)
At this crop stage, the northern root knot nematode can cause serious injury to the onion seedling by feeding upon the root tissues. This nematode causes root galls and plants with fewer roots and root hairs. Plants become stunted and wilted; with severe infestations, plant death can occur. Secondary pathogens may attack the onion tissue after the nematode has penetrated the onion root.

Chemical control:
Oxamyl (Vydate L) can be applied as an in-furrow treatment at planting in Idaho, Oregon, and Washington for suppression of the stubby-root nematode. Results are erratic; more consistent, positive results occur on the muck soils in the Willamette Valley in western Oregon. Efficacy of oxamyl is pH dependent; it doesn't work well in alkaline conditions (the more alkaline, the faster the half-life declines).

Cultural control:
Crop rotation: Growers avoid rotations that include mint, cereals, alfalfa, or grasses.

Biological control:
None known.

Critical Needs for Management of Nematodes in Onions: Planting through Emergence

Research

- Research nematode interaction with other soilborne pathogens.
- Explore efficacy of non-fumigant nematicides.
- Explore efficacy of seed treated with nematicides.
- Investigate impact of green manure crops, mustard and rapeseed meal, and soil fertilizer on nematode populations.
- Develop nematode-resistant onion cultivars.
- Evaluate the impact of sodium methyldithiocarbamate (Metam Sodium) on nematode control.

Regulatory

- Enforce and strengthen the nematode quarantine program.

Education

- Develop Extension publications that highlight the latest nematode research.
- Organize informational meetings for onion growers about nematodes' biology, ecology, and management.
- Increase grower awareness about nematode quarantine in onions.

Vegetative Growth (true leaf to harvest)

After seedling emergence (flag leaf), the first true leaves are formed and the plant grows vegetatively (producing larger plants with long, upright leaves) for about five to eight weeks before bulb formation begins. Timing of bulb formation varies by cultivar and is also dependent upon day length. At this time, the fleshy leaves at the base of the plant, called scales, enlarge and the bulb begins to form. Bulb formation can take up to 10 weeks, until the bulb is large enough and mature enough for lifting and harvest, both of which are discussed in the following crop stage section.

Insect, disease, and weed management continue to be practiced during the vegetative growth period; nematodes are generally not controlled during this time.

Field activities that may occur during Vegetative Growth:

Cultivation between the rows
Hand hoeing
Scouting for weeds, insects, and diseases
Irrigation
Fertilization
Pre-emergence or post-emergence herbicide application
Fungicide application
Insecticide application

Insects

Armyworms and Cutworms

Beet armyworm (*Spodoptera exigua*)
Bertha armyworm (*Mamestra configurata*)
Yellowstriped armyworm (*Spodoptera praefica*)
Black cutworm (*Agrotis ipsilon*)
Variegated cutworm (*Peridroma saucia*)

The larval stage of these lepidopteran insects, in the Noctuidae family, feed on the young leaves of onions as they are growing. They vary in color and range in size from one to two inches long. Cutworms do most of their feeding at the soil line, often cutting off young plants at ground level; however they are only sporadic pests. The variegated cutworm climbs up into the onion plant to feed. Armyworms feed on onion foliage, skeletonizing the leaves or consuming the entire leaf.

Chemical control:

Cypermethrin (Ammo 2.5EC): Effective but, due to resistance management, growers do not rely entirely on the pyrethroids. 12-hour REI, 7-day PHI.

Methomyl (Lannate): Effective only on smaller larvae. 48-hour REI, 7-day PHI.

Permethrin (Permethrin, Pounce): Effective but growers do not rely entirely on the pyrethroids, due to resistance management. 12-hour REI, 1-day PHI.

Bacillus thuringiensis (*Bt*): Effective against early-instar larvae only. Bt is commonly used but, due to the low surface area of onion leaves, it is difficult to get enough coverage on the plant; good coverage is critical for good efficacy. 4-hour REI, 0-day PHI.

Cultural control:
None known.

Biological control:
None known.

Leafminers (*Liriomyza huidobrensis,* others)
Leafminers are a sporadic pest. Adult leafminers are small black to grey flies with yellow markings; the body is covered with long, stiff bristles. Larvae are a nearly translucent white or yellow color and about a quarter of an inch long when mature. Eggs are white, cylindrical, and laid singly or in small groups. Larvae mine between the upper and lower leaf surfaces, creating winding, whitish tunnels that are narrow initially, but widen as the larvae grow. Excessive mining reduces the photosynthetic capacity of the plant and provides easier access for disease organisms.

Chemical control:
Cypermethrin (Ammo 2.5EC) and Lambda-cyhalothrin (Warrior): Both are pyrethroids with similar mode of action. 12-hour REI, 7-day PHI.

Diazinon: The tolerance is established for the crop and onions are on the label, but leafminers are not listed on the label (and, as such, cannot be used in some states). 24-hour REI, 14-day PHI.

Methomyl (Lannate): The tolerance is established for the crop and onions are on the label, but leafminers are not listed on the label (and, as such, cannot be used in some states). 48-hour REI, 7-day PHI.

Cultural control:
None.

Biological control:
None known to be effective.

Onion Maggot (*Delia antiqua*) and **Seed Corn Maggot** (*Delia platura*)
The onion maggot tends to be a problem only during the first few weeks of vegetative growth. It is a small, dark-colored fly (resembling, but smaller than, a housefly), about a quarter of an inch long, with three overlapping generations per year. They tend to fly into onion fields at dusk from field perimeters. Eggs are laid on the soil near the onion seedling or on the leaves and neck of a young onion plant. The legless larvae (maggots) are creamy-white and feed on the roots or leaves of the developing onion plant. Larval feeding reduces plant vigor and can increase incidence of rot when bulbs are in storage. Feeding by the onion maggot larvae has been implicated in spreading bacteria that cause Bacterial Soft Rot disease.

The seed corn maggot is also prevalent in the early stages of vegetative growth. The adult is a slender, light gray fly about a quarter of an inch long that can have up to five generations per year. Eggs are laid in the soil near plant stems. The larvae (maggots) feed on the emerging seedlings. Plant stands can be reduced with high populations of the seed corn maggot.

Both maggots tend to be more problematic in cool, wet years when the onion plant is growing slowly and in fields that contain a high amount of organic matter and decaying vegetation.

Chemical control:
(Chemical treatments applied for thrips at this stage will also control the onion and seed corn maggot adult flies.)

Chlorpyrifos (Lorsban 4E): OR, ID and WA 24c registrations allow for foliar application during vegetative growth. 24-hour REI, 60-day PHI.

Cypermethrin (Ammo 2.5EC): Applied at dusk as flies are entering onion fields. 12-hour REI, 7-day PHI.

Lambda-cyhalothrin (Warrior): 24-hour REI, 14-day PHI.

Malathion: 12-hour REI, 3-day PHI.

Permethrin (Permethrin, Pounce): 12-hour REI, 1-day PHI.

Zeta-cypermethrin (Mustang 1.5EW): Applied at dusk as flies are entering onion fields. 12-hour REI, 7-day PHI.

Cultural control:
Adjacent area management: Control of blooming weeds adjacent to onion fields reduces nectar and pollen sources that attract, hold, and increase fecundity of the egg-laying adults.

Biological control:
None known to be effective.

Onion Thrips (*Thrips tabaci*) and **Western Flower Thrips** (*Frankliniella occidentalis*)
Onion thrips are more prevalent in the early part of the vegetative growth period (although they appear later in the season in the Treasure Valley of Oregon and Idaho) while western flower thrips are more common toward the end of the vegetative growth period (closer to when the onion bulbs are forming). However, both types of thrips can be found anytime during the vegetative growth period and are managed when they appear. Early control is critical to prevent populations from reaching damaging levels. Ground applications of chemical treatments are made during the early part of the vegetative growth period but aerial applications are often made later, as the onion plant is reaching maturity. The exception is western Oregon, where most growers make ground applications only.

Onions' two pest thrips are almost identical in appearance; they are difficult to distinguish without the use of a dissecting microscope. The adults are very small and slender insects

with two pairs of wings that are fringed with long hairs; they are pale yellow to light brown in color. The immature stages have the same body shape as adults but are lighter in color and wingless. Eggs are laid in the tissue of the onion plant. Mature and immature thrips feed under the leaf folds and in the protected inner leaves near the onion bulb. Feeding reduces chlorophyll content of the leaves and the plants take on a silvery appearance. Most damage occurs to the onion bulb, with thrips infesting the bulb beneath the dry scales causing decay losses during storage. Thrips are difficult to control because they have a short reproductive cycle, have a wide host range, and are very mobile.

Onion thrips have been documented as a vector for iris yellow spot virus (IYSV); IYSV can reduce plant and bulb size and can cause plant death.

Chemical control:
Note: In spite of the following lengthy list of chemical controls, no registered product effectively controls thrips. Due to limited modes of action of the available products, resistance has become an issue in controlling thrips. Resistance within both thrips species has been documented. None of the registered products are systemic so good coverage and penetration are important application parameters. Western flower thrips tend to feed on the outside of the leaves, where they are likely to contact pesticides, but onion thrips tend to feed within and between the leaves and bulb scales, where contact with a pesticide is less likely. A tank mix of an organophosphate product with either a carbamate or pyrethroid product tends to work better than using either chemical alone. Even so, control or suppressive effect lasts only about two to three weeks.

Azadirachtin (Neem): May help reduce thrips populations when used in combination with straw mulch. 4-hour REI, 0-day PHI.

Cypermethrin (Ammo 2.5EC): 12-hour REI, 7-day PHI. Not widely used since newer, advanced synthetic pyrethroids have come on the market.

Diazinon: 24 hour REI, 14 day PHI.

Lambda-cyhalothrin (Warrior): In Colorado, is effective only against onion thrips on the eastern side of the Rocky Mountains. In other regions, effectiveness against onion thrips and western flower thrips is equal. 24-hour REI, 14-day PHI.

Malathion: 12-hour REI, 3-day PHI.

Methomyl (Lannate): Effective control in Colorado; works best with the addition of a crop oil or surfactant. 48-hour REI, 7-day PHI.

Methyl parathion (Penncap-M): Micro-encapsulated formulation is safer to use. Use is becoming more popular as newer chemistries show marginal efficacy. 5-day REI, 15-day PHI.

Oxamyl (Vydate L): Works well with center pivot and drip chemigation; does not work with furrow irrigation. Registered for use in Idaho, Oregon, and Washington; 24c registrations in CO and UT allow foliar applications during this stage of plant growth.

Effective control in Colorado; works best with the addition of a crop oil or surfactant. 48-hour REI, 14-day PHI.

Oxydemeton-methyl (Metasystox-R): Supplemental label allows use in Spanish onions west of the Mississippi River; provides suppression only. 10-day REI, 30-day PHI.

Permethrin (Permethrin, Pounce): 12-hour REI, 1-day PHI.

Pyrethrin and rotenone (Pyrellin): 12-hour REI, 12-hour PHI. Not widely used.

Zeta-cypermethrin (Mustang 1.5EW): 12-hour REI, 7-day PHI.

Cultural control:
Adjacent area management: Growers avoid planting onions near grain fields as a way to manage thrips migrating from drying cereal fields.

Cultivar selection: The impact and degree of thrips damage is different with different cultivars but cultivar selection is not very effective in reducing thrips populations or preventing damage.

Irrigation management: Overhead sprinkler irrigation tends to suppress thrips populations.

Straw mulch: Mulch provides protection for beneficial insects and, when used in combination with a biopesticide like azadirachtin, may help reduce thrips populations.

Biological control:
None known.

Critical Needs for Management of Insects in Onions: Vegetative Growth

Research

- Screen new chemistries for thrips (seed, in-furrow, and foliar treatments).
- Evaluate thrips suppression treatments (imidacloprid, thiamethoxam) to reduce iris yellow spot virus potential.
- Develop thrips-resistant cultivars.
- Investigate weed hosts as overwintering sites for thrips.
- Continue investigating the role of beneficials to control thrips when soft insecticides are used.
- Determine which species of thrips is being affected by pesticide application; time of day of the application and of the evaluation may be critical.
- Evaluate rotational strategies of new pesticides and how they might fit IPM and entire cropping system.
- Evaluate effectiveness of aerobic compost tea for thrips control.

Regulatory

- Pursue 2ee for some of the insecticides: need standardized use across the western states to control pests not on labels.
- Ensure that chemical companies develop, and EPA register, new products with resistance management in mind.

- Expedite registration of spinosad for control of thrips.

Education
- Educate growers and crop consultants about checking for thrips populations relative to time of day.
- Educate growers and crop consultants about the difference between 2ee states and the implications.
- Educate growers on importance of resistance management.
- Demonstrate to growers and crop consultants the diagnostic tools for identifying thrips species in the field.
- Invite EPA to visit onion fields in the western states to observe production practices and pest problems.

Diseases

Bacterial Leaf Spot and Blight (*Pseudomonas viridiflava, Xanthomonas axonopodis* pv. *allii*)
These bacteria overwinter on and in seed, crop debris, and other crops that act as an alternate host. The disease is spread in the field by tillage equipment, surface water, animal life in the soil, and wind. Small water-soaked lesions form on the upper leaves and coalesce into larger lesions that may cover the entire leaf. The disease can spread rapidly, especially in cool to warm, wet weather and in areas with sprinkler irrigation.

Chemical control:
Bacillus subtillis (Serenade): This biopesticide is not effective. 4-hour REI, 0-day PHI.

Fixed coppers (Champ, Cuprofix, Kocide, NuCop, etc.): Fixed coppers work well if tank mixed with EBDC fungicides (e.g., maneb, mancozeb). 24-hour REI.

Disinfectants, such as sodium hypochlorite, in irrigation water may suppress the pathogens that cause the disease.

Cultural control:
Plant spacing/row direction: Any practice that increases leaf drying and promotes air circulation (e.g., wide row spacing) will help reduce incidence of the disease.

Use of tolerant or resistant cultivars, prevention of wounds during field operations, and control of weeds all help reduce incidence of leaf spot and blight.

Irrigation management: Growers use well water for irrigation rather than water from ditches. Changing irrigation methods from overhead sprinklers to drip or furrow helps reduce spread of the disease.

Biological control:
None known.

Bacterial Soft Rot (*Pectobacterium carotovora* and others)
Several different bacteria can cause soft rot, with *Pectobacterium carotovora* (formerly *Erwinia carotovora*) being the most common causal agent. The bacteria overwinter in cull piles and in the soil; the disease is spread by irrigation water or on machinery. Leaves, then whole stems, wilt and eventually collapse. The disease progresses in storage and the entire bulb may become soft, watery, and foul-smelling. Feeding by onion maggot larvae earlier in the season has been implicated in spreading this disease. The disease also enters the onion through wounds in the neck or bulb.

Chemical control:
There are no chemical controls for this pest. Control of the onion maggot may reduce incidence of soft rot.

Cultural control:
Reduced mechanical injuries during cultivation and other field operations helps reduce soft rot incidence.

Irrigation management: Growers use well water for irrigation rather than water from ditches. Changing irrigation methods from sprinkler to drip or furrow will help reduce bacterial soft rot. Use of disinfectants in irrigation water may suppress disease incidence.

Fertilizer management: Growers avoid excess nitrogen after bulbs begin to form.

Biological control:
None known.

Black Mold (*Aspergillus niger*)
This fungal organism overwinters in cull piles, crop debris, and soil, and can be found in all stages of onion growth. Damage from black mold affects the bulb; infected bulbs have a black discoloration at the neck, on outer scales, and between scales. Advanced stages of the disease will cause the onion bulb to shrivel.

Chemical control:
There are no known chemical controls for black mold disease. Fumigation, as discussed in the Pre-Plant section, may reduce severity of the disease.

Cultural control:
Eliminate cull piles and onion debris from the field.

Biological control:
None known.

Botrytis Diseases
(*Botrytis allii, B. squamosa, B. cinera*)
Botrytis species can cause numerous diseases of onion including a soil-line rot of bulbs, leaf blast, brown stain of bulb scales, gray mold, and neck rot in storage. The fungi overwinter in cull piles, crop debris, soil, and volunteer onions, and can be transmitted via seed and transplants. Spores are dispersed by wind. Leaf infection initially results in small, oval, white spots with a light green or silver halo surrounding the lesion. Spots eventually

may become tan and coalesce, blighting the leaves, leaf tips (blast), and scales. Neck rot occurs primarily on bulbs in storage. Neck and scale tissues soften as a semi-watery decay moves downward through the bulb. Diseased tissue becomes covered with a grayish mold and thin, black sclerotia form between infected scales. Larger sclerotia may form on the outer surface of diseased bulbs as well.

Chemical control:
Note: Environmental conditions may impact the efficacy of these products throughout this region. Mode of action of the fungicide will affect which diseases are controlled and at what stage.

Bacillus subtillis (Serenade): This biopesticide is not effective. 4-hour REI, 0-day PHI.

Boscalid (Endura): Systemic. 12-hour REI, 7-day PHI.

Boscalid + pyraclostrobin (Pristine): Systemic. 12-hour REI, 7-day PHI.

Chlorothalonil (Bravo Ultrex): Protectant. Will control leaf blast, but not the storage diseases. 12-hour REI, 7-day PHI.

Cyprodinil + Fludioxonil (Switch 62.5 WG): Systemic. 12-hour REI, 7-day PHI.

Dichloran (Botran): Protectant. 12-hour REI, 14-day PHI.

Fixed copper + Zinc + Maneb (ManKocide): Protectant. 24-hour REI, 7-day PHI.

Iprodione (Rovral 4F): Limited systemic activity. 24-hour REI, 7-day PHI.

Mancozeb (Dithane, Manzate): Protectant. 24-hour REI, 7-day PHI.

Maneb: Protectant. 24-hour REI, 7-day PHI.

Cultural control:
Field sanitation: Destroy or bury culls and remove other field crop debris; these are overwintering sites for the disease and proper management can mitigate the effects of the disease.

Crop rotation: Rotate out of an allium crop for at least two years.

Irrigation management: Avoid extended overhead irrigation.

Fertilizer management: Avoid excess nitrogen after bulbs begin to form

Biological control:
None known.

Downy Mildew (*Peronospora destructor*)
This fungus overwinters on infected plants or plant debris. Infections occur on both young and old leaves; slightly pale spots develop at first but turn light brown or purple with time.

As spots enlarge, they girdle the leaf and a grayish-purple furry mold develops on the spot's surface, often on the lower or protected surface of infected leaves. Plants may be dwarfed, distorted, and pale. Plants don't die but bulb quality is poor and spongy. Disease progress can be rapid and severe.

Chemical control:
Azoxystrobin (Quadris): Systemic. 4-hour REI, 0-day PHI.

Boscalid (Endura): Systemic. 12-hour REI, 7-day PHI.

Boscalid + pyraclostrobin (Pristine): Systemic; provides suppression only. 12-hour REI, 7-day PHI.

Bacillus subtillis (Serenade): This biopesticide is not effective. 4-hour REI, 0-day PHI.

Chlorothalonil (Bravo Ultrex): Limited activity as protectant. 12-hour REI, 7-day PHI.

Dimethomorph (Acrobat): Systemic. 12-hour REI, 0-day PHI.

Fosetyl-al (Aliette WDG): Systemic. 12-hour REI, 7-day PHI.

Fixed coppers (Champ, Kocide, others): Protectant. 24-hour REI.

Fixed copper + zinc + maneb (Mancozeb): Protectant. 24-hour REI, 7-day PHI.

Maneb: Protectant. 24-hour REI, 7 day PHI.

Mancozeb (Dithane, Manzate): Protectant. 24-hour REI, 7-day PHI.

Mefenoxam + chlorothalonil (Ridomil Gold Bravo): systemic and protectant. 48-hour REI, 7-day PHI.

Mefenoxam + mancozeb (Ridomil Gold MZ): systemic and protectant. 48-hour REI, 7-day PHI.

Cultural control:
Crop rotation: Crop rotation back to an *Allium* crop should be three years or more.

Soil drainage: Avoid poorly drained soils.

Plant spacing/row direction: Any practice that increases leaf drying and air circulation will help mitigate the effects of downy mildew.

Field sanitation: Destroy or bury culls and remove other crop residues from or near onion fields.

Weed control: Eradicate volunteer or wild *Allium* plants.

Biological control:

None known.

Iris Yellow Spot Virus (IYSV)
This disease is transmitted by onion thrips. Its host range includes onions, leeks, iris, and several ornamental plants. Disease symptoms include straw-colored, dry, spindle- or diamond-shaped lesions on the leaves and scales of onion plants. Plant can be stunted, foliage dies back prematurely, and bulb size can be reduced. Impacts on storage life and quality of bulbs from diseased plants are unknown.

Chemical control:
None. Control of onion thrips helps reduce incidence of IYSV.

Cultural control:
Field sanitation: Eliminate onion debris, culls, and volunteers.

Crop rotation: Rotate out of Allium crops for at lease three years.

Cultivar resistance: Use plant cultivars that are less sensitive to thrips feeding and/or the virus.

Weed control: In and around the onion field.

Fertilizer management: Avoid excessive nitrogen, especially after bulbs have formed.

Reduce plant stress: Avoid moisture extremes, saline/alkaline soils, soilborne diseases, soil compaction, and poor soil drainage.

Biological control:
None known.

Purple Blotch (*Alternaria porri*)
This fungus overwinters on infected bulbs and crop debris; spores are dispersed by the wind. This disease can also be seedborne. Infection often follows injury caused by other fungi or by mechanical injury to the plant (e.g., wind-blown sand, farm machinery, hand hoeing). Lesions form on leaves and are elongated, sunken, and whitish with a purple center. Concentric light and dark zones later appear over part or all of the purple area. These purple blotches may become covered with black fruiting bodies. Leaves wilt and die.

Chemical control:
Note: The following chemicals are utilized in rotation and mixed to prevent resistance. Cost and effectiveness are a factor for several of these products. Treatment is only used when forecasting models predict a disease outbreak.

Azoxystrobin (Quadris): Systemic. 4-hour REI, 0-day PHI.

Bacillus subtillis (Serenade): This biopesticide is not effective. 4-hour REI, 0-day PHI.

Boscalid (Endura): Systemic. 12-hour REI, 7-day PHI.

Boscalid + pyraclostrobin (Pristine): Systemic; provides suppression only. 12-hour REI, 7-day PHI.

Chlorothalonil (Bravo Ultrex): Protectant. 12-hour REI, 7-day PHI.

Cyprodinil + fludioxonil (Switch 62.5 WG): Systemic; label has plant back restriction to onions or strawberries. 12-hour REI, 7-day PHI.

Fixed coppers (Champ, Kocide, etc): Protectant. 24-hour REI.

Fixed copper + Zinc + Maneb (ManKocide): Protectant. 24-hour REI, 7-day PHI.

Iprodione (Rovral 4F): Systemic. 24-hour REI, 7-day PHI.

Mancozeb (Dithane, Manzate): Protectant. 24-hour REI, 7-day PHI.

Maneb: Protectant. 24-hour REI, 7-day PHI.

Potassium phosphide (Prophyt): 4-hour REI.

Pyraclostrobin (Cabrio): Systemic. 12-hour REI, 7-day PHI.

Thiophanate-methyl (Topsin-M): Protectant. 12-hour REI.

Cultural control:
Crop rotation: Crop rotation back to an *Allium* crop should be three years or more.

Plant spacing/row direction: Any practice that will increase leaf drying and air circulation will help mitigate the effects of purple blotch.

Field sanitation: Destroy or bury culls and remove other crop residues and volunteer onions from or near onion fields.

Cultivar resistance: Use tolerant or resistant cultivars (e.g., Fiesta).

Biological control:
None known.

Critical Needs for Management of Diseases in Onion: Vegetative Growth

Research

- Determine efficacy of disinfectants for management of the bacterial diseases.
- Develop new chemistry and alternative chemistry, such as acibenzolar (Actigard), and determine efficacy for the bacterial diseases.
- Identify effective fungicides for control of Botrytis neck rot disease (caused by *Botrytis allii).*
- Develop resistance management strategies for all diseases.

- Research the general biology, transmission vectors, and alternative hosts for iris yellow spot virus.
- Research biopesticides including new alternatives such as bacteriophages.
- Develop disease-resistant cultivars.

Regulatory
- Expedite registration of acibenzolar (Actigard) through the IR-4 program.
- Support the continued registration of EBDC fungicides.

Education
- Provide risk assessment data to EPA for reregistration purposes.
- Promote IPM and pest alerts to growers.
- Organize field tours with EPA to illustrate pest management needs.
- Develop disease modeling/forecasting for Washington and integrate with regional pest reporting networks.

Weeds

Onions have sparse vegetation and are slow growing; as such, they do not compete well with weeds. The early stages of vegetative growth are a critical time for diligent weed management. Generally speaking, the most problematic weeds are yellow nutsedge, nightshade, pigweed, kochia, and volunteer potatoes; however, priority weeds vary from area to area.

During vegetative growth, some soil-active and contact herbicides can be applied to onions. Pendimethalin (Prowl) may be applied up until the 9-leaf stage of the onion plant. Applications of bromoxynil (Buctril) and oxyfluorfen (Goal) cannot be made until onions have at least two true leaves. (Bromoxynil cannot be used in onions grown west of the Cascade Mountains.) Because of the slow growth of onions, weeds can be quite large when onions finally produce two true leaves. Bromoxynil (Buctril) and oxyfluorfen (Goal) are contact herbicides, which become less effective as weed size increases; they are often applied in combination to broaden the spectrum of weeds controlled. Multiple applications, one to two weeks apart, are common. Even when onions are at the proper growth stage, these herbicides can cause injury. Onion growers constantly balance weed control efficacy with crop safety: higher herbicide rates may be required to control the weeds that are present, but may also cause greater onion injury.

S-Metolachlor (Dual Magnum), used in CO, ID, OR, UT, and WA under 24c registration, may be applied to onions with two or more true leaves and is helpful for yellow nutsedge suppression; efficacy is improved with rainfall or sprinkler incorporation. Grass herbicides such as sethoxydim (Poast), clethodim (Select), and fluazifop (Fusilade) can be applied any time the targeted grasses are at the optimum growth stage for control, and within the pre-harvest interval. The soil-active herbicide trifluralin (Treflan) can be applied after the onion crop has emerged but must be applied as a directed spray between the onion rows and requires cultivation immediately after application for activation. Trifluralin (Treflan) applied this way can help suppress weeds germinating late in the season.

Volunteer potatoes are a problem in areas where onions are grown in rotation with potatoes. Application of bromoxynil (Buctril) and oxyfluorfen (Goal) will burn back

volunteer potato foliage but the foliage usually re-grows within a few weeks. Potatoes can also re-sprout following hand removal of foliage because of the energy stored in the potato tuber. In severely infested fields, volunteer potatoes are removed by hand, involving one or more trips through the field. Hand labor may be used for other weeds not controlled with herbicides as well. Hand weeding labor is extremely expensive and can reduce the returns that are realized by the grower. Weeds like yellow nutsedge grow in dense patches with such numerous shoots that hand removal is impractical.

Chemical control:
Bromoxynil (Buctril, Bromox): Broadleaf herbicide that is applied to emerged weeds only after the onion plant has produced at least two true leaves. It cannot be used west of the Cascade Mountains in Oregon and Washington. 12-hour REI.

Clethodim (Select), fluazifop (Fusilade), and sethoxydim (Poast): All provide effective control when applied to actively growing grasses after the onion crop has emerged. All have similar modes of action. Growers rely very heavily on this one mode of action for post-emergence grass control. 24-hour REI, 45-day PHI.

Glyphosate (Roundup): May be applied to actively growing grass or broadleaf weeds after the onion crop has emerged. Since glyphosate is non-selective, it must be used as a directed spray, using shields or a rope wick, to avoid contact with the onion plant. 4-hour REI, 14-day PHI.

Oxyfluorfen (Goal 2XL): Broadleaf herbicide that is applied to emerged weeds only after the onion plant has produced at least two true leaves. 24-hour REI, 45-day PHI.

Pendimethalin (Prowl): Applied pre-emergence to weeds only until the onion plant has reached the 9-leaf stage. 24-hour REI, 45-day PHI.

S-Metolachlor (Dual Magnum): Helps suppress yellow nutsedge. Use allowed under 24c registration in Colorado, Idaho, Oregon, Utah, and Washington. 24-hour REI.

Trifluralin (Treflan): Soil-active herbicide that is applied after the crop has emerged but prior to weed emergence. Applied as a directed spray between the onion rows; requires cultivation immediately after application for activation. When used at this timing, it provides late-season weed control. 12-hour REI, 60-day PHI.

Cultural control:
Cultivation: Cultivation between the onion rows can continue until the tops are too large (9- to 10-leaf stage). Cultivation on top of the onion beds can continue until the onions have about five or six leaves.

Hand hoeing: Hand labor is utilized to control late-season weeds and weeds not controlled by herbicides or cultivation, as discussed in the introduction to this section. Hand weeding is conducted two to five times or more, as needed, per season. It is a particularly frequent practice in western Oregon.

Some growers use weed screens to prevent weed seeds from entering the onion field through the irrigation water.

Biological control:
None known.

Critical Needs for Management of Weeds in Onions: Vegetative Growth

Research
- Research post-emergence yellow nutsedge control.
- Research volunteer potato management.
- Find additional post-emergence herbicides with different modes of action.
- Find herbicides or other techniques for dodder control.
- Investigate effect of early-season, post-emergence weed control on onion quality.
- Research herbicides or other techniques for late-season weed management.

Regulatory
- Register bentazon (Basagran) for yellow nutsedge control.
- Expedite registration of dimethenamid (Outlook), flumioxazin (Valor), ethofumesate (Nortron), and fluroxypyr (Starane).

Education
- Educate growers on the risks/benefits of herbicide applications (i.e., damage from the weeds vs. damage to the onions).

Nematodes

Control of nematodes is generally not practiced during the vegetative growth period of onions. However, stubby-root and lesion nematodes can be controlled with the use of oxamyl (Vydate L) during the early stages of vegetative growth (ID, OR, and WA only). This product is usually applied when the onion plant has two true leaves. Oxamyl efficacy is pH-dependent; it doesn't work in alkaline conditions

Lifting/Harvest/Storage

The multi-step process of lifting, topping, and harvesting dry bulb onions begins in late summer. "Lifting" is a cultural practice that is used to accelerate the maturation process. It helps field-cure the onions in preparation for harvest and storage. During lifting, the bulb is undercut, typically with a machine that severs the root system below the onion bulb. Lifting takes place when about 50% of the tops have fallen over. Tops may be mechanically cut at the same time as lifting.

There are many differences among the western states in the lifting and field-curing process. Western Oregon growers, for example, windrow their onions in the field for drying while other areas don't windrow but leave the onions in place until ready for harvest. After lifting occurs, the onions remain in the field for about 10 to 20 days until they are cured and ready for harvest.

In Washington State, the sprout suppressant maleic hydrazide is widely used. It is applied when about 50% of the onion tops have fallen over, when foliage is still green, approximately seven to ten days after the final irrigation. Use of this product is not common in the other western states.

"Harvest" is the removal of the onions from the field once they have been lifted and field-cured. The vast majority of dry bulb storage onions are mechanically harvested, generally sometime during September. Mechanical loaders pick up and load the field-cured bulbs into trucks that take them to the storage shed. (In some areas, where transplanted onions produce thin-skinned bulbs, onions are mechanically lifted but topped by hand.) Onions store best under dry, cool conditions with positive air circulation. Low relative humidity is essential in storage to inhibit disease and root sprouting.

Field activities that may occur during Lifting/Harvest/Storage:

Lifting (undercutting) onion bulbs
Topping bulbs (mechanical)
Topping bulbs (by hand for transplanted onions)
Windrowing bulbs
Loading bulbs for transport to packing/storage shed

Insects

There are no in-field treatments for insect pest control at this time. Once onions are in storage, thrips excrement and thrips feeding damage may create sugary surfaces and discoloration of the onion bulb, especially in red onions. An ozone-rich storage environment, created with ozone generators, may suppress thrips while the onions are in storage.

Diseases

A properly field-cured bulb, ready for storage, should have a well-dried neck and have at least one, and preferably two, complete, dry scales. Necks that contain moisture or are too short will not seal properly and will favor the growth of pathogens. Overly short necks also allow excessive moisture loss from the bulbs in storage. Even with properly field-cured bulbs, additional post-harvest curing in storage is essential. During this time, final drying of the onion neck occurs and wounds caused during harvest dry and heal. Drying of the

external scales occurs most rapidly during this period. Heating is practiced by some storage managers to reduce Botrytis gray mold. However, heating may enhance bulb rotting caused by Aspergillus black mold if the fungus is present.

Several disease organisms enter the onion plant while in the field but don't show symptoms until in the bulbs are in storage. Grey mold or neck rot (*Botrytis allii*), black mold (*Aspergillus niger*), bacterial soft rot, and purple blotch (*Alternaria porri)* are diseases that appear when onions are in storage. Management options for these diseases are discussed in the previous crop stage section.

Chemical control:
There are no chemical controls used to control fungal pathogens at harvest or during storage. Ozone generators are not effective for disease control.

Cultural control:
Allow bulbs to mature before harvesting begins and properly cure bulb in the field before topping.

Avoid bruising during harvest and handling.

Thoroughly cure onions before storing. Store at 32° F and less than 70% humidity.

Biological control:
None known.

Weeds
Weed control is not practiced at this time.

Nematodes
Nematode control is not practiced at this time.

Critical Needs for Management of Insects and Diseases in Onions:
Lifting/Harvest/Storage

Research

- Research suppression of thrips damage on red onions (sugary scale).
- Further research efficacy of ozone generators for control of thrips and diseases during storage.
- Research control of neck rot.
- Investigate efficacy of treating storage areas for thrips control and plant pathogen management (black mold, *Botrytis*).
- Explore alternative uses for cull onions.
- Investigate translucent scale of onions in storage (an abiotic condition).
- Develop more rapid and effective diagnostic tests to quantify pest incidence in bulb onions.

Regulatory

- Work with EPA to change their definition of harvest. “Harvest” is when the onions are removed from the field; current EPA definition of harvest is actually what growers define as “lifting.” This is a critical issue because the definition of harvest determines PHI and, thus, which pesticides can be used when the onions are reaching maturity.
- Develop uniform protocol for phytosanitary requirements related to various pests.

Education

- Educate growers about definition of lifting and harvest and how each relates to PHI.
- Educate EPA and regulators about harvest and pre-harvest activities (lifting, curing, removal from the field) and the length of time involved.
- Invite EPA to visit onion fields in the western states to observe production practices and pest problems.

Activity Table for Colorado (Excluding Western Colorado)

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed preparation		XX	XXX	XXXX								
Cultivation				XX	XXXX	XXXX	XXXX					
Cover crop establishment									XXXX	XXXX		
Cover crop removal			XXXX	XXXX								
Fertilization			XXXX	XXXX	XXXX	XXXX	XXXX					
Hand hoeing						XXXX	XXXX	XXXX				
Harvest (lifting, topping, loading)								XXXX	XXXX	XX		
Irrigation installation			XX	XXXX	XXXX	XXXX						
Irrigation				XX	XXXX	XXXX	XXXX	XXXX	XXXX			
Planting		XX	XXXX	XXXX								
Soil amendments (lime, etc.)									XXXX	XXXX	XXXX	XX
Soil testing for nutrients									XXXX	XXXX	XXXX	XX

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fumigation (soil)									XXXX	XXXX	XXXX	
Fungicide application			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XX			
Herbicide application			XXXX	XXXX	XXXX	XXXX	XXXX					
Insecticide application					XXXX	XXXX	XXXX	XXXX				
Nematicide application		XX	XXXX	XXXX	XXXX							
Nematode testing	XX	XXXX	XXXX						XXXX	XXXX	XXXX	XX
Scout for diseases				XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			
Scout for insects/mites				XXXX	XXXX	XXXX	XXXX	XXXX				
Scout for weeds				XXXX	XXXX	XXXX	XXXX					

Activity Table for Treasure Valley (Idaho and Eastern Oregon)

Cultural Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bed preparation			XX	XX						XX	XX	
Cultivation				XXXX	XXXX	XXXX						
Fertilization				XXXX	XXXX	XXXX	XXXX			XXXX	XXXX	
Hand hoeing					XXXX	XXXX	XXXX					
Harvest (lifting, topping, loading)								XXXX	XXXX	XXX		
Irrigation installation			XXXX	XX								
Irrigation				XX	XXXX	XXXX	XXXX	XXXX	XX			
Planting			XXXX	XXXX								
Soil amendments (lime, OM, etc.)										XXXX	XXXX	
Soil testing for nutrients			XX	XXXX	XX				XX	XXXX		
Straw mulch						XXXX						
Pest Management Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Fumigation (soil)									XX	XXXX	XXXX	
Fungicide application			XXX	XX	XX	XXXX	XXXX	XXXX				
Herbicide application			XXX	XXXX	XXXX	XXXX						
Insecticide application			XXX	XXXX	XXXX	XXXX	XX					
Nematode testing									XX	XXXX		
Scout for diseases			XXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXX			
Scout for insects/mites			XXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXX			
Scout for weeds			XXX	XXXX	XXXX	XXXX	XXXX	XXXX				

Activity Table for Utah and Western Colorado

Cultural Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bed preparation			XXXX	XXXX	X					XXXX	XXXX	
Cultivation					XXXX	XXXX	XXXX					
Cover crop establishment			XXXX	XXXX								
Cover crop removal				XXXX								
Fertilization			XXXX	XXXX	XXXX	XXXX	XX			XXXX	XXXX	
Hand hoeing					XX	XXXX	XXXX	XX				
Harvest (lifting, topping, loading)								XXXX	XXXX	XX		
Irrigation installation			XXXX	XXXX	XXXX							
Irrigation				XXXX	XXXX	XXXX	XXXX	XXXX				
Planting			XXXX	XXXX								
Rolling beds for soil crust removal			XXXX	XXXX	XX							
Soil amendments (gypsum, etc.)										XXXX	XXXX	
Testing for nutrients (soil & tissue)			XXXX	XXXX	XXXX	XXXX	XXXX					
Straw mulch				XX	XXXX							
Pest Management Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Fumigation (soil)										XXXX	XXXX	
Fungicide application					XXXX	XXXX	XXXX	XXXX	XX			
Herbicide application				XXXX	XXXX	XXXX	XXXX	X				
Insecticide application					XXXX	XXXX	XXXX	XX				
Scout for diseases				XX	XXXX	XXXX	XXXX	XXXX				
Scout for insects/mites				X	XXXX	XXXX	XXXX	XXX				
Scout for mouse/vole damage	XXXX	XXXX								XXXX	XXXX	XXXX
Scout for weeds			XX	XXXX	XXXX	XXXX	XXXX	XXX				

Activity Table for Washington

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed preparation		XX	XXXX									
Cultivation (for weed control)				XXXX	XXXX	XXXX						
Cover crop establishment		XXXX	XXXX						XXXX	XXXX	XXXX	
Cover crop removal		XXXX	XXXX	XXXX						XXXX		
Fertilization		XXXX	XXXX		XXXX	XXXX				XXXX	XXXX	
Hand hoeing					XXXX	XXXX	XXXX	XXXX				
Harvest (lifting, topping, loading)							XXXX	XXXX	XXXX	XXXX		
Irrigation installation			XXXX	XXXX								
Irrigation		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Planting		XX	XXXX	XXXX								
Soil amendments (lime, organic matter, etc.)										XXXX	XXXX	XX
Soil testing for nutrients					XXXX	XXXX	XXXX		XXXX	XXXX	XXXX	XX
Straw mulch												
Tissue testing for nutrients					XXXX	XXXX	XXXX	XXXX				

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fumigation (soil)			XXXX						XXXX	XXXX	XXXX	
Fungicide application					XXXX	XXXX	XXXX	XXXX				
Herbicide application		XX	XXXX	XXXX	XXXX	XXXX	XXXX					
Insecticide application		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Nematicide application				XXXX	XXXX	XXXX						
Nematode testing									XXXX	XXXX	XXXX	
Scout for diseases				XXXX	XXXX	XXXX	XXXX	XXXX				
Scout for insects/mites				XXXX	XXXX	XXXX	XXXX	XXXX				
Scout for mouse/vole damage			XXXX	XXXX								
Scout for weeds				XXXX	XXXX	XXXX	XXXX		XXXX	XXXX	XXXX	

Activity Table for Western Oregon

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Cultivation (for weed control)						XXXX						
Cover crop establishment									XX	XXXX		
Cover crop removal		XXXX	XX									
Fertilization			XX	XXXX								
Hand hoeing						XXXX	XXXX	XXXX				
Harvest (lifting, topping, loading)								XX	XX			
Irrigation installation					XXXX							
Irrigation					XXXX	XXXX	XXXX	XXXX				
Planting			XX	XXXX	X							
Soil amendments (lime, etc.)			XX							XXXX	X	
Soil preparation (for planting)			XX	XXXX								
Soil testing for nutrients		XXXX	XXXX									

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application (soil)				XXXX	XXXX	XXXX	XXXX	XXXX				
Herbicide application			XX	XXXX	XXXX	XXXX	X					
Insecticide application			XX	XXXX	XXXX	XXXX	XXXX	XX				
Nematicide application			X	XXXX								
Nematode testing									XXXX			
Scout for diseases					XX	XXXX	XXXX	XXXX				
Scout for insects/mites				XXXX	XXXX	XXXX	XXXX	XXXX				
Scout for weeds				XXXX	XXXX	XXXX	XXXX					

Seasonal Pest Occurrence for Colorado (Excluding Western Colorado)

Seasonal Pest Occurrence
(Time when pest causes problems or is targeted for control)

Insects & Mites	J	F	M	A	M	J	J	A	S	O	N	D
Leafminers							XXXX	XXXX				
Onion thrips						XXXX	XXXX	XXXX				
Western flower thrips						XXXX	XXXX	XXXX				
Diseases												
Bacterial soft rot							XXXX	XXXX	XXXX			
Bacterial leaf spot						XXXX	XXXX	XXXX				
Black mold								XXXX	XXXX	XXXX		
Botrytis diseases							XX	XXXX	XXXX			
Damping off			XXXX	XXXX								
Downy mildew						XXXX	XXXX	XXXX				
Fusarium basal rot							XXXX	XXXX				
Iris yellow spot virus						XXXX	XXXX	XXXX	XXXX			
Pink root						XXXX	XXXX	XXXX				
Purple blotch							XXXX	XXXX				
Smut				XXXX	XXXX	XXXX						
Weeds												
Annual Grasses:												
Barnyardgrass				XXXX	XXXX	XXXX	XXXX	XXXX				
Crabgrass						XXXX	XXXX	XXXX				
Green foxtail				XXXX	XXXX	XXXX	XXXX	XXXX				
Sandbur, field						XXXX	XXXX	XXXX				
Wild proso millet					XXXX	XXXX	XXXX	XXXX				
Perennial Grasses:												
None												
Annual Broadleaves:												
Buffalobur				XX	XXXX	XXXX						
Common purslane						XXXX	XXXX	XXXX				
Common ragweed					XX	XXXX	XXXX	XXXX				
Kochia			XXXX	XXXX	XXXX	XXXX						
Lambsquarters				XXXX	XXXX	XXXX	XXXX	XXXX				
Mallow, common				XXXX	XXXX	XXXX	XXXX					
Mallow, Venice				XXXX	XXXX	XXXX	XXXX					
Nightshade, black				XX	XXXX	XXXX	XXXX					
Nightshade, hairy				XX	XXXX	XXXX	XXXX					
Pigweed, redroot				XXXX	XXXX	XXXX	XXXX					
Pigweed, prostrate				XX	XXXX	XXXX						
Puncturevine						XXXX	XXXX	XXXX				
Russian thistle			XX	XXXX	XXXX	XXXX						
Spurge, prostrate					XXXX	XXXX	XXXX					
Spurge, toothed					XXXX	XXXX	XXXX					
Sunflower					XX	XXXX	XXXX					
Velvetleaf					XXXX	XXXX	XXXX					
Volunteer potatoes				XXXX	XXXX	XXXX						

	J	F	M	A	M	J	J	A	S	O	N	D
Perennial Broadleaves:												
Canada thistle				XXXX	XXXX	XXXX	XXXX					
Field bindweed				XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			
Other weeds:												
Dodder					XXXX	XXXX	XXXX					
Yellow nutsedge				XXXX	XXXX	XXXX	XXXX					
Nematodes												
Lesion						XXXX	XXXX	XXXX				
Northern root-knot						XXXX	XXXX	XXXX				
Stem or bulb						XXXX	XXXX	XXXX				
Stubby-root						XXXX	XXXX	XXXX				

Seasonal Pest Occurrence for Treasure Valley (Idaho and Eastern Oregon)

Seasonal Pest Occurrence
(Time when pest causes problems or is targeted for control)

Insects & Mites	J	F	M	A	M	J	J	A	S	O	N	D
Armyworms/cutworms				XXXX								
Brown wheat mite								XXXX				
Bulb mite				XXXX								
Onion maggot			XXXX	XXXX								
Onion thrips					XX	XXXX	XXXX	XXXX				
Seed corn maggot			XXXX	XXXX								
Western flower thrips					XX	XXXX	XXXX	XXXX				
Wireworm				XXXX								
Diseases												
Bacterial soft rot						XXXX	XXXX	XXXX				
Botrytis diseases								XXXX				
Damping off			XXXX	XXXX								
Downy mildew						XX	XXXX	XXXX				
Fusarium basal rot						XXXX	XXXX	XXXX				
Iris yellow spot virus							XXXX	XXXX	XX			
Pink root					XX	XXXX	XXXX	XXXX				
Purple blotch						XX	XXXX	XXXX				
Weeds												
Annual Grasses:												
Barnyardgrass				XXXX	XXXX	XXXX	XXXX	XXXX				
Crabgrass				XXXX	XXXX	XXXX	XXXX	XXXX				
Field sandbur				XXXX	XXXX	XXXX	XXXX	XXXX				
Green foxtail			XX	XXXX	XXXX	XXXX	XXXX	XXXX				
Volunteer cereals		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Wild oats		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Wild proso millet				XXXX	XXXX	XXXX	XXXX	XXXX				
Yellow foxtail				XXXX	XXXX	XXXX	XXXX	XXXX				
Perennial Grasses:												
None												
Annual Broadleaves:												
Clover			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Common purslane			XX	XXXX	XXXX	XXXX	XXXX	XXXX				
Kochia		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Lambsquarters			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Mallow, common			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Mustard, purple		XX	XXXX									
Mustard, annual		XX	XXXX									
Nightshade, hairy			XX	XXXX	XXXX	XXXX	XXXX	XXXX				
Pigweed, prostrate			XX	XXXX	XXXX	XXXX	XXXX	XXXX				
Pigweed, redroot			XX	XXXX	XXXX	XXXX	XXXX	XXXX				
Puncturevine				XXXX	XXXX	XXXX	XXXX	XXXX				
Russian thistle			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Spurge, prostrate				XXXX	XXXX	XXXX	XXXX	XXXX				
Volunteer potato				XX	XXXX	XXXX	XXXX	XXXX				

	J	F	M	A	M	J	J	A	S	O	N	D
Perennial Broadleaves:												
Canada thistle		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Field bindweed		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Other weeds:												
Dodder			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Yellow nutsedge				XX	XXXX	XXXX	XXXX	XXXX				
Nematodes												
Note: Nematodes occur in the soil year-round; treatment is usually pre-plant soil fumigation												
Lesion												
Northern root-knot												
Stem or bulb												
Stubby-root												

Seasonal Pest Occurrence for Utah and Western Colorado

Seasonal Pest Occurrence
(Time when pest causes problems or is targeted for control)

Insects & Mites	J	F	M	A	M	J	J	A	S	O	N	D
Armyworms/cutworms				XX	XXXX	XX						
Onion maggot			XX	XXXX								
Onion thrips					XX	XXXX	XXXX	XXXX	XX			
Seed corn maggot			XX	XXXX								
Western flower thrips					XX	XXXX	XXXX	XXXX	XX			
Diseases												
Bacterial soft rot							XXXX	XXXX				
Bacterial leaf spot							XXXX	XXXX				
Damping off			XXXX	XXXX	XX							
Downy mildew					XX	XXXX	XXXX	XXXX				
Fusarium basal rot						XX	XXXX	XXXX	XXXX			
Iris yellow spot virus						XXXX	XXXX	XXXX	XXXX			
Pink root						XX	XXXX	XXXX				
Purple blotch						XX	XXXX	XXXX				
Weeds												
Annual Grasses:												
Barnyardgrass					XX	XXXX	XXXX					
Crabgrass					XXXX	XXXX						
Foxtail, green					XXXX	XXXX						
Foxtail, yellow					XXXX	XXXX						
Sandbur					XXXX	XXXX						
Perennial Grasses:												
Bermudagrass						XX	XXXX	XXXX				
Quackgrass				XX	XXXX	XXXX	XXXX					
Annual Broadleaves:												
Buffalobur						XXXX	XXXX	XXXX				
Common purslane					XX	XXXX	XX					
Common ragweed					XXXX	XXXX						
Groundsel			XXXX	XXXX								
Kochia				XXXX	XXXX	XXXX						
Lambsquarters					XX	XXXX	XXXX	XX				
Mallow, common				XX	XXXX	XXXX	XX					
Mustards			XXXX	XXXX	XXXX							
Nightshade, black				XX	XXXX	XXXX	XXXX	XX				
Pigweed, prostrate				X	XXXX	XXXX	XXXX	XX				
Pigweed, redroot				X	XXXX	XXXX	XXXX	XX				
Prostrate knotweed				X	XXXX	XXX						
Puncturevine					XX	XXXX	XXXX	XXX				
Shepherdspurse			XXXX	XXXX								
Smartweed					XXXX	XXXX	XXXX					
Perennial Broadleaves:												
Canada thistle				XX	XXXX	XXXX	XX					
Field bindweed						XXXX	XXXX	XXXX	X			
Other weeds:												
Dodder					XX	XXXX	XXXX					
Yellow nutsedge				XX	XXXX	XXXX	XXXX	X				

Nematodes	J	F	M	A	M	J	J	A	S	O	N	D
Note: Nematodes occur in the soil year-round; treatment is usually pre-plant soil fumigation												
Lesion												
Northern root-knot												
Stem or bulb												
Stubby-root												

Seasonal Pest Occurrence for Washington

Seasonal Pest Occurrence
(Time when pest causes problems or is targeted for control)

Insects & Mites	J	F	M	A	M	J	J	A	S	O	N	D
Armyworms/cutworms				XXXX	XXXX							
Leafminers					XXXX	XXXX	XXXX					
Onion maggot		XX	XXXX	XXXX								
Onion thrips					XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		
Seed corn maggot		XX	XXXX	XXXX								
Western flower thrips					XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		
Wireworm				XXXX	XXXX							
Diseases												
Bacterial soft rot						XXXX	XXXX	XXXX				
Botrytis diseases						XX	XXXX	XXXX				
Damping off			XXXX	XXXX								
Fusarium basal rot							XXXX	XXXX				
Iris yellow spot virus						XXXX	XXXX	XXXX				
Pink root				XXXX	XXXX	XXXX	XXXX	XXXX				
Smut				XXXX	XXXX	XXXX						
Weeds												
Annual Grasses:												
Annual blue grass		XXXX	XXXX	XXXX	XXXX							
Barnyardgrass				XXXX	XXXX	XXXX	XXXX	XXXX				
Foxtail, yellow and green				XXXX	XXXX	XXXX						
Volunteer cereals				XXXX	XXXX							
Perennial Grasses:												
Quackgrass					XXXX	XXXX	XXXX	XXXX				
Annual Broadleaves:												
Clover				XXXX	XXXX	XXXX	XXXX	XXXX				
Common purslane					XXXX	XXXX	XXXX	XXXX				
Groundsel												
Kochia				XXXX	XXXX	XXXX	XXXX	XXXX				
Lady's thumb					XXXX	XXXX	XXXX	XXXX				
Lambsquarters				XXXX	XXXX	XXXX	XXXX	XXXX				
Mallow, common					XXXX	XXXX	XXXX	XXXX				
Mallow, Venice												
Nightshade, black					XXXX	XXXX	XXXX	XXXX				
Nightshade, hairy					XXXX	XXXX	XXXX	XXXX				
Pigweed, prostrate												
Pigweed, redroot					XXXX	XXXX	XXXX	XXXX				
Russian thistle			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Smartweed					XXXX	XXXX	XXXX	XXXX				
Volunteer carrots			XXXX									
Volunteer potatoes				XXXX	XXXX	XXXX	XXXX	XXXX				
Perennial Broadleaves:												
Canada thistle					XXXX	XXXX	XXXX					
Field bindweed				XXXX	XXXX	XXXX	XXXX	XXXX				
Other weeds:												
Yellow Nutsedge					XXXX	XXXX	XXXX	XXXX				

Nematodes	J	F	M	A	M	J	J	A	S	O	N	D
Lesion				XXXX	XXXX							
Northern root-knot				XXXX	XXXX							
Stubby-root				XXXX	XXXX	XXXX						

Seasonal Pest Occurrence for Western Oregon

Seasonal Pest Occurrence
(Time when pest causes problems or is targeted for control)

Insects & Mites	J	F	M	A	M	J	J	A	S	O	N	D
Garden symphyla			XXXX	XXXX	XXXX	XXXX	XXXX					
Leafminers							XXXX	XXXX				
Onion maggot			XX	XXXX	XXXX	XXXX						
Onion thrips						XX	XXXX	XXXX				
Western flower thrips						XX	XXXX	XXXX				
Wireworm				XXX	XXXX	XXXX	XXXX	XX				
Diseases												
Bacterial soft rot							XXXX	XXXX	X			
Bacterial leaf spot							XXXX	XXXX	X			
Botrytis diseases						XXXX	XXXX	XXXX				
Damping off				XXXX								
Downy mildew							X	XXXX				
Fusarium basal rot								XXXX				
Neck rot						XX	XXXX	XXXX				
Pink root							XXXX					
Smut (on muck soils)				XXXX								
White rot							XX	XXXX				
Weeds												
Annual Grasses:					XXXX	XXXX	XXXX					
Annual bluegrass					XXXX	XXXX	XXXX					
Barnyardgrass					XXXX	XXXX	XXXX					
Crabgrass					XXXX	XXXX	XXXX					
Wild proso millet					XXXX	XXXX	XXXX					
Perennial Grasses:												
Bermudagrass					XXXX	XXXX	XXXX					
Perennial ryegrass					XXXX	XXXX	XXXX					
Quackgrass					XXXX	XXXX	XXXX					
Annual Broadleaves:												
Chickweed					XXXX	XXXX	XXXX					
Clover					XXXX	XXXX	XXXX					
Common purslane					XXXX	XXXX	XXXX					
Groundsel					XXXX	XXXX	XXXX					
Lady's thumb					XXXX	XXXX	XXXX					
Lambsquarters					XXXX	XXXX	XXXX					
Mallow, common					XXXX	XXXX	XXXX					
Mallow, Venice					XXXX	XXXX	XXXX					
Mayweed (dog fennel)					XXXX	XXXX	XXXX					
Mustards					XXXX	XXXX	XXXX					
Nightshade, black					XXXX	XXXX	XXXX					
Nightshade, hairy					XXXX	XXXX	XXXX					
Pigweed, redroot					XXXX	XXXX	XXXX					
Pigweed, prostrate					XXXX	XXXX	XXXX					
Prostrate knotweed					XXXX	XXXX	XXXX					
Shepherdspurse					XXXX	XXXX	XXXX					
Smartweed					XXXX	XXXX	XXXX					
Spurge, prostrate					XXXX	XXXX	XXXX					

Wild carrot					XXXX	XXXX	XXXX					
Wild radish					XXXX	XXXX	XXXX					
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Perennial Broadleaves:												
Canada thistle					XXXX	XXXX	XXXX					
Field bindweed					XXXX	XXXX	XXXX					
Other weeds:												
Dodder					XXXX	XXXX	XXXX					
Horsetail					XXXX	XXXX	XXXX					
Yellow nutsedge					XXXX	XXXX	XXXX					
Nematodes												
Stubby-root (muck soils)			X	XXXX	X							

Efficacy Ratings for INSECT and MITE Management Tools Against Onion Pests

Rating scale: **E** = excellent (90-100% control); **G** = good (80-90% control); **F** = fair (70-80% control); **P** = poor (<70% control); **?** = efficacy unknown, more research needed; ***** = used but not a stand-alone management tool; **blank space** = not used for this pest.

MANAGEMENT TOOLS	Armyworm/Cutworm	Bulb mite	Garden symphyla	Leafminers	Onion maggot	Onion thrips	Seed corn maggot	Western flower thrips	Wireworm	COMMENTS
Registered chemistries										
Azadirachtin (Neemix, Aza-Direct)	P-F			P-F	?	P-F	?	P-F		
Bacillus thuringiensis (Bt)	P-F									Works best on young larvae
Chlorpyrifos (Lorsban)	G			?	G	P-F		P-F		
Cypermethrin (Ammo)	G-E			F-G	F	F	F-G	F		
Cyromazine	P			P	P-F		P-F			Seed treatment
Diazinon	P			P-F	F-G	P-F	F-G	P-F	F	Efficacy dependent on contact with insect
Dichloropropene (Telone II)	?	?	?						G	PPI soil fumigant
Dichloropropene + Chloropicrin (Telone C-17)	?	?	?						G	PPI soil fumigant
Horticultural Oils	P			P						
Kaolin (Surround)	P			?		P		P		
Lambda-cyhalothrin (Warrior)	G-E			G	G	F		F		
Malathion	P			P-F		F		F		
Methomyl (Lannate)	F-G			F		F		F		More efficacious at warm temperatures
Methyl parathion (Penncap-M)						F-G		F-G		
Oxamyl (Vydate)	P	?	?	P-F		G		G		For thrips, works best with center pivot or drip chemigation; ineffective with furrow irrig.
Oxydemeton-methyl (Metasystox-R)						P-F		P-F		
Permethrin (Ambush, Pounce)	G			F-G	F	P-F		P-F		
Pyrethrin (PyGanic, others)	P			P-F	?	P	?	P		
Rotenone (Pyrellin)	G			P-F	?	P	?	P		
Soaps (M-Pede)	P			P	P	P	P	P		
Sodium methyldithiocarbamate (Metam Sodium)		?	?							
Sulphur (Microthiol Disperss)	P			P						
Zeta-cypermethrin (Mustang)	G-E			F	G	F		F		
Unregistered / New Chemistries										
Abamectin (Agrimek)	?	?								
Dinotefuran (Starkle)				?		?		?		
Fipronil (Regent)					?	P-F		P-F		
Flonicamid				?		?		?		
Imidacloprid (Provado, Admire)			?		P-F	F-G	P-F	F-G	?	
Methoxyfenozide (Intrepid)	?									
Pyriproxyfen (Esteem, Knack)	?				?	?	?	?		
Spinosad (Success, Entrust)	G			?	F	?	?	F		
Thiamethoxam (Actara, Platinum)			?		P-F	?	P-F	?	?	

Biological										
Big-eyed bug										All these beneficial arthropods help suppress populations of insect and mite pests (especially thrips) providing that “soft” pesticides are used, which have minimal negative effects on their survival.
Damsel bug										
Lacewing										
Lady beetle										
Minute pirate bug										
Spiders										
Cultural / Non-Chemical										
Adjacent area management	*				*	*	*			
Cull and crop residue management		*			*		*			
Cover crops					*		*			
Crop rotation		*	*		*		*			
Cultivation	*				*		*			
Enhancing habitat for beneficials	*	*		*	*	*	*	*		
Straw mulch						*		*		
Weed control	*									

Efficacy Ratings for DISEASE Management Tools Against Onion Pests

Rating scale: **E** = excellent (90-100% control); **G** = good (80-90% control); **F** = fair (70-80% control); **P** = poor (<70% control); **?** = efficacy unknown, more research needed; **blank space** = not used for this pest; ***** = used but not a stand-alone management tool.

MANAGEMENT TOOLS	Bacterial soft rot	Bacterial leaf spot	Black mold	Botrytis diseases	Damping off	Downy mildew	Fusarium basal rot	Iris Yellow spot virus	Pink root	Purple blotch	Smuts	White rot	COMMENTS
Registered Chemistries													
Azoxystrobin (Quadris)										E			
Bacillus subtillis (Serenade)	P	P		P									
Boscalid (Endura)				E		F				E			
Boscalid + Pyraclostrobin (Pristine)				E		G				E			
Captan					F					P			
Carboxin											G		Seed treatment
Chlorothalonil (Bravo)				F		F				F			
Chloropicrin			P		F		F-G		F-G		F	F	PPI soil fumigant
Copper + Zinc + Maneb (ManKocide)	G	F		F		F				F			
Cyprodinil + Fludioxonil (Switch)				E						E			
Diallyl sulfide (Alli-up)												F	Pre-plant sclerotia stimulant
Dichloran (Botran)				?									
Dichloropropene + Chloropicrin (Telone C-17, C-35)			P		F		F-G		F-G		F	F	PPI soil fumigant
Dimethomorph (Acrobat)						G							
Fixed Copper (Champ, Kocide)	F	F				F				F			Tank mix with EBDC fungicides
Fludioxonil (Maxim)					E								Seed treatment
Fosetyl-al (Aliette)		P			F								
Harpin Protein (Messenger)		P											
Iprodione (Rovral)				F						E			
Mancozeb (Dithane, Manzate)				F		G				G	G		
Maneb				F		G				G	G		
Mefenoxam (Ridomil Gold)					G								Soil drench; apply pre-emergence only.
Mefenoxam + Chlorothalonil				F		E				F			Tank mix
Mefenoxam + fixed copper				F		E				F			Tank mix
Phosphorous acid (Fosphite)						?							
Pyclostrobin (Cabrio)										E			
Sodium methyldithiocarbamate (Metam Sodium)			P		F		F		F-G		F	F	Soil fumigant
Streptomycin (MycoStop)													Seed treatment
Thiophanate methyl (Topsin-M)				F						G			
Thiram					F								Seed treatment
Ziram				F		F				G			
Unregistered/ New Chemistries													
Acibenzolar (Actigard)	G	G						G					
Carboxin + Thiram (Vitavax CT)											?		Seed treatment
Famoxadone + Cymoxanil (Famoxate)						?							
Fenamidone (Reason)						E							

MANAGEMENT TOOLS	Bacterial soft rot	Bacterial leaf spot	Black mold	Botrytis diseases	Damping off	Downy mildew	Fusarium basal rot	Iris Yellow spot virus	Pink root	Purple blotch	Smuts	White rot	COMMENTS
Fenhexamid (Elevate)				?								?	
Imidacloprid (Provado) insecticide								F-G					For control of the virus vector (onion thrips)
Pyrimethanil (Scala)				E						E			
Tebuconazole (Elite)												?	
Thiamethoxam (Actara) insecticide								?					For control of the virus vector (onion thrips)
Trifloxystrobin (Compass)				?						?			
Biological													
Bacteriophage	?	G											
Pantoea agglomerans	?	F											
Cultural / Non-Chemical													
Adjacent area management	G	G	G	G	P	G	P	G	P	G	P	P	
Certified seed/planting stock	E	E	E	E	P	P	G	P	G	P	P	G	
Crop rotation	E	E	G	E	G	E	F	E	F	E	F	P	
Cull and crop residue management	E	E	G	G	P	E	P	E	P	E	P	P	
Harvesting, curing & storage practices	G	P	G	F-G	P	P	P	P	P	P	P	P	
Irrigation management	G	G	F	G	G	G	G	G	G	G	F	F	
Maintain/enhance drainage	G	P	P	P	G	P	G	G	G	P	G	P	
Nitrogen management	G	F	F	G	F	F	G	G	G	F	F	F	
Resistant/tolerant cultivars	P	P	P	P	P	P	G	?	G	P	P	P	
Sanitation	G	G	G	G	P	G	P	G	P	G	P	G	
Weed control	P	P	P	G	P	G	P	G	P	G	P	P	

Efficacy Ratings for WEED Management Tools Against Onion Pests

Rating scale: E = excellent (90-100% control); **G** = good (80-90% control); **F** = fair (70-80% control); **P** = poor (<70% control); **S** = suppression, only; **?** = efficacy unknown, more research needed; **blank space** = not used for this pest; ***** = used but not a standalone management tool.

Note: Weed size or stage of weed growth is an important consideration with most post-emergence herbicides.

	Annual Broadleaves																														
MANAGEMENT TOOLS	**Type***	**Buffalo bur**	**Chickweed**	**Clover**	**Common purslane**	**Common ragweed**	**Common water hemp**	**Groundsel**	**Kochia**	**Lady's thumb**	**Lambsquarters**	**Mallow, common**	**Mallow, Venice**	**Mayweed (dog fennel)**	**Mustards**	**Nightshade, black**	**Nightshade, hairy**	**Pigweed, prostrate**	**Pigweed, redroot**	**Prostrate knotweed**	**Puncturevine**	**Russian thistle**	**Shepherdspurse**	**Smartweed**	**Spurge, prostrate**	**Spurge, toothed**	**Sunflower**	**Wild carrot**	**Wild radish**	**Velvetleaf**	**Volunteer potato**	***COMMENTS***
Registered Chemistries																															
Bensulide (Prefar)	Pre							G			F								F				?								
Bromoxynil (Buctril, Bromox)	Post	F	?	?	F	F	F	?	G	?	G	F	F	?	?	G	G	F	F	?	P	F	?	?	?	P	P	?	?	P	P	
Clethodim (Select)	Post																														Controls only grasses.
DCPA (Dacthal)	Pre	P	?	?	P		P		F	?	F	P	P	?	?	F	F	P	F			P			P	P		?	?		?	
Fluazifop (Fusilade)	Post																														Controls only grasses.
Glyphosate (Roundup)	Post	G	G	G	E	E	G	G	G	G	G	G	G	G	E	F	G	G	G	G	G	F-G	G	G	G	G	G	G	G	G	G	Apply prior to onion emergence
S-metolachlor (Dual Magnum)	Pre	F	?	?	P	F	F	?	P	?	G			?	?	G	G	F	?	G	P		?	?	P			?	?			
Oxyfluorfen (Goal)	Post	F	?	?	?	F	F	?	F	?	G	P	P	?	?	F	F	F	G	?		F	?		F	P	F	?	?	F	P	
Sodium methyldithiocarbamate (Metam Sodium)	Pre																															

	Annual Broadleaves																														
MANAGEMENT TOOLS	**Type***	**Buffalo bur**	**Chickweed**	**Clover**	**Common purslane**	**Common ragweed**	**Common water hemp**	**Groundsel**	**Kochia**	**Lady's thumb**	**Lambsquarters**	**Mallow, common**	**Mallow, Venice**	**Mayweed (dog fennel)**	**Mustards**	**Nightshade, black**	**Nightshade, hairy**	**Pigweed, prostrate**	**Pigweed, redroot**	**Prostrate knotweed**	**Puncturevine**	**Russian thistle**	**Shepherdspurse**	**Smartweed**	**Spurge, prostrate**	**Spurge, toothed**	**Sunflower**	**Wild carrot**	**Wild radish**	**Velvetleaf**	**Volunteer potato**	***COMMENTS***
Paraquat (Gramoxone)	Post	?	G	P	?	G	?	G	G	?	G	F	?	F	G-E	?	?	?	G	?	?	G	E	P	?	?	E	F	?	G	P	Apply prior to onion emergence
Pendimethalin (Prowl)	Pre	F	?	?	F	F	P	?	G	?	G	F	P	?	?	F	F	?	F	F	P	P	?	?	F	P		?	?			
Sethoxydim (Poast)	Post																															Controls only grasses.
Trifluralin (Treflan)	Pre	P	?	?	F			?	F	?		F		?	?	P	P	P	G	?		F	?	?	P	P		?	?		?	
Unregistered / New Chemistries																																
Bentazon (Basagran)																																
Carfentrazone-ethyl (Aim)	Post	G	?	?	G	F	F	?	G	?	F	F	F	?	?	G	G	G	G	?	P	G	?	F	F	F	F	?	?	G	?	
Dimethamid-P (Outlook)	Pre	P	?	?	F	F	P	?	P	?	G	P	P	?	?	G	G	F	G	?	F	P	?	P	P	P		?	?	P	?	
Ethofumesate (Nortron)	Pre								F		F					F	F		G													
Flumioxazin (Valor)	Pre	G	?	?	G	?	G	?	G	?	G	G	G	?	?	E	E	G	G	?	F	?	?	F	F	F		?	?	G	?	
Fluroxypyr (Starane)	Post								G							G	G														G	
Biological																																
None known																																
Cultural / Non-Chemical																																
Cover crop	Efficacy is F-G; suppresses weed seed germination.																															
Crop rotation	Efficacy is F-G, depending on the crop rotation partners																															
Cultivation	Effective between the onion rows.																															
Flaming	Not widely used; efficacy is F-G.																															
Hand hoeing	Efficacy is F-E, dependent upon stage of weed growth.																															

Type*: Pre = soil-active against pre-emerged weeds; Post = foliar-active against emerged weeds

		Perennial Broadleaves		Annual Grasses								Perennial Grasses			Other			
MANAGEMENT TOOLS	Type*	Canada thistle	Field Bindweed	Annual bluegrass	Barnyardgrass	Crabgrass	Field sandbur	Fine fescues	Green foxtail	Wild proso millet	Yellow foxtail	Bermudagrass	Perennial ryegrass	Quackgrass	Dodder	Horsetail (equisetum)	Yellow nutsedge	COMMENTS
Registered Chemistries																		
Bensulide (Prefar)	Pre			?	G	G		?	G		?							
Bromoxynil (Buctril, Bromox)	Post	P	P															
Clethodim (Select)	Post			G	G	G	G	G	G	G	G	?	?	S				Controls only grasses.
DCPA (Dacthal)	Pre		?	?	G	P		?	G		?							
Fluazifop (Fusilade)	Post			G	G	G	G	G	G	G	G	?	?	S				Controls only grasses.
Glyphosate (Roundup)	Post	S	S	G	E	E	E	G	E	E	E	G	G	G	E		F	Apply prior to onion emergence
S-metolachlor (Dual Magnum)	Pre			F	G	G		?	G		G						F	
Oxyfluorfen (Goal)	Post		P															
Sodium methyldithiocarbamate (Metam Sodium)	Pre																G	
Paraquat (Gramoxone)	Post	P	P	P	F-G	G	F		F-G		F-G	P	F	F		P	G	
Pendimethalin (Prowl)	Pre			?	G	P		?	G		F				P			
Sethoxydim (Poast)	Post			F-G	G	G	F	F-G	F	F	G	S	?	S				Controls only grasses.
Trifluralin (Treflan)	Pre			?	G	F		?	G		F				P			
Unregistered / New Chemistries																		
Bentazon (Basagran)																	G	
Carfentrazone-ethyl (Aim)	Post	?	?												?	?	?	
Dimethamid-P (Outlook)	Pre			?	G	F		?	G		F							

		Perennial Broadleaves		Annual Grasses								Perennial Grasses			Other			
MANAGEMENT TOOLS	Type*	Canada thistle	Field Bindweed	Annual bluegrass	Barnyardgrass	Crabgrass	Field sandbur	Fine fescues	Green foxtail	Wild proso millet	Yellow foxtail	Bermudagrass	Perennial ryegrass	Quackgrass	Dodder	Horsetail (equisetum)	Yellow nutsedge	COMMENTS
Ethofumesate (Nortron)	Pre			?	F	F		?	G		F						S	Controls only grasses.
Flumioxazin (Valor)	Pre	?	?												?	?	?	Controls only broadleaf weeds.
Fluroxypyr (Starane)	Post	?	?												?	?	?	Controls only broadleaf weeds.
Propachlor (Ramrod)																		
Biological																		
None known																		
Cultural / Non-Chemical																		
Cover crop		P-F	P-F	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	P-F	P-F	P-F	P-F	P-F	P-F	
Crop rotation		F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	Efficacy is F-G, depending on the crop rotation partners.
Cultivation		P	P	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	P	P	P	P	P	P	
Flaming																		Not widely used; efficacy ranges from P to G.
Hand hoeing		P	P	F-G	F-G	F-G	F-G	F-G	F-G	F-G	F-G	P	P	P	P	P	P	

Type*: Pre = soil-active against pre-emerged weeds; Post = foliar-active against emerged weeds

Efficacy Ratings for NEMATODE Pest Management Tools Against Onion Pests

Rating scale: **E** = excellent (90-100% control); **G** = good (80-90% control); **F** = fair (7-0-80% control); **P** = poor (<70% control); **?** = efficacy unknown, more research needed; **blank space** = not used for this pest; ***** = used but not a standalone management tool.

MANAGEMENT TOOLS	Lesion nematode		Stem or bulb nematode		Northern root-knot nematode		Stubby-root nematode	
	Pre-plant	Post-plant	Pre-plant	Post-plant	Pre-plant	Post-plant	Pre-plant	Post-plant
Registered Chemistries								
Dichloropropene (Telone II)	G		G		G		F	
Dichloropropene + Chloropicrin (Telone C-17, C-35)	G		G		G		F	
Oxyamyl (Vydate)								F
Sodium methyldithiocarbamate (Metam Sodium)	F		F		F		P	
Unregistered/ New Chemistries								
Dichloropropene + Chloropicrin (Inline)								
Fosthiazate								
Iodomethane (Midas)	?		?		?		?	
Biological								
None								
Cultural / Non-Chemical								
Crop rotation	F		F		P		F	
Cover crops (green manure)	F		F		F		F	
Weed control	*	*	*	*	*	*	*	*

Lesion Nematode: *Pratylenchus* spp.
Stem or Bulb Nematode: *Ditylenchus dipsaci*
Stubby-Root Nematode: *Paratrichodorus* or *Trichodorus* spp.
Northern Root-Knot Nematode: *Meloidogyne hapla*

Toxicity Ratings for Beneficials in PNW Onions

Key to Beneficials:

BEB = Big-eyed bug (*Geocoris pallens*)
DB = Damsel bug (*Nabis alternatus*)
HB = Honey bee (*Apis mellifera*)
LW = Lacewings (*Chrysopa* spp.)
LB = Lady beetles (*Hippodamia convergens*)
MPB = Minute pirate bugs (*Orius* spp.)
PM = Predatory mites (*Acari: Phytoseiidae*)
PN = Parasitic nematodes
PW = Parasitic wasps (*Ichneumonidae* and *Braconidae* families)
S = Spiders (*Arachnida: Araneae*
SF = Syrphid flies
TF = Tachinid flies

Rating Scale: O = Non-toxic; **L** = Slightly toxic; **M** = Moderately toxic; **H** = Highly toxic; **ND** = No Data

	BEB	DB	HB	LW	LB	MPB	PM	PN	PW	S	SF	TF	Comments
Registered Material:													
Insecticides / Miticides:													
Azadirachtin (Neemix, Azatin, Azatrol)	L	L	L	L	L	L	L	ND	L	L	L	L	
Bacillus thuringiensis (Bt)	O	O	O	O	O	O	O	O	O	O	O	O	
Chlorpyrifos (Lorsban)	H	H	H	H	H	H	H	H	H	H	H	H	
Cypermethrin (Ammo)	M	M	O	M	M	M	M	ND	M	H	M	M	
Cyromazine	O	O	O	O	O	O	O	O	O	O	O	O	Seed treatment
Diazinon	M	M	H	M	M	M	H	ND	L	M	H	ND	
Horticultural oils (Stylet oil, others)	M	M	ND	L	L	M	M	ND	L	L	ND	ND	
Kaolin (Surround)	ND	ND	O	ND	ND	ND	L	ND	L	ND	ND	ND	
Lambda-cyhalothrin (Warrior)	M-H	M-H	O	M-H	M-H	M-H	H	ND	M-H	H	M-H	M-H	
Malathion	M	M	H	M	H	M	H	ND	M	M	H	M	
Methomyl (Lannate)	H	H	H	H	H	H	H	H	ND	M	H	H	
Oxamyl (Vydate)	H	H	H	H	H	H	H	H	H	H	H	H	
Oxydemeton-methyl (Metasystox-R)	H	H	H	H	H	H	H	H	H	H	H	H	
Permethrin (Ambush, Pounce)	M	M	O	M	M	M	M	ND	M	M	M	M	
Pyrethrin (Pyganic, others)	M	M	O	L	M	M	H	ND	M	H	M	M	
Rotenone (Pyrellin)	ND	ND	O	M	M	ND	H	ND	M	ND	ND	ND	
Soaps (M-Pede)													No data but general mode of action may prove toxic to leaf-borne beneficials
Sulphur (Microthiol Disperss)	L	ND	O	M	M	H	L	ND	M	ND	M	M	
Zeta-cypermethrin (Mustang)	M-H	M-H	O	M-H	M-H	M-H	M-H	ND	M-H	M	M-H	M-H	
Soil Fumigants:													
Dichloropropene (Telone II)													Not toxic to foliage-borne beneficials
Dichloropropene + chloropicrin (Telone C17, C35)													Not toxic to foliage-borne beneficials
Chloropicrin													Not toxic to foliage-borne beneficials
Methyl bromide + chloropicrin													Not toxic to foliage-borne beneficials
Sodium methyldithiocarbamate (Metam Sodium)													Not toxic to foliage-borne beneficials
Fungicides:													
Azoxystrobin (Quadris)													ND
Bacillus subtillis (Serenade)													ND
Benzene hexachloride (Lindane)													Seed treatment; no data.
Boscalid (Endura)													ND

	BEB	DB	HB	LW	LB	MPB	PM	PN	PW	S	SF	TF	Comments
Boscalid + Pyraclostrobin (Pristine)													ND
Captan	ND	ND	ND	L	M	L	L	ND	L	ND	M	L	
Carboxin													Seed treatment; no data
Chlorothalonil (Bravo)													ND
Copper + Zinc + Manneb (ManKocide)													ND
Cyprodinil + fludioxonil (Switch)													ND
Diallyl sulfides (Alli-Up)													Pre-plant sclerotia stimulant; no data
Dichloran (Botran)													ND
Dimethomorph (Acrobat)													ND
Fixed Copper (several brands)	ND	ND	ND	ND	ND	ND	L	ND	ND	ND	ND	ND	
Fludioxonil (Maxim)													Seed treatment; no data
Fosetyl-al (Aliette)													ND
Harpin Protein (Messenger)													ND
Iprodione (Rovral)	ND	ND	ND	ND	ND	ND	L	L	ND	ND	ND	ND	
Mancozeb (Dithane, Manzate)													ND
Maneb													ND
Mefenoxam (Ridomil Gold)	ND	ND	ND	ND	ND	ND	L	H	ND	ND	ND	ND	
Mefenoxam + fixed copper	ND	ND	ND	ND	ND	ND	L	H	ND	ND	ND	ND	
Phosphorous acid (Fosphite)													ND
Pyraclostrobin (Cabrio)													ND
Streptomycin (MycoStop)													Seed treatment; no data
Thiophanate-methyl (Topsin-M)													ND
Thiram													Seed treatment; no data
Ziram	ND	ND	ND	ND	ND	L	ND	ND	ND	ND	ND	ND	
Herbicides:													
Bensulide (Prefar)													ND
Bromoxynil (Buctril, Bromox)													ND
Clethodim (Prism)													ND
DCPA (Dacthal)													ND
Fluazifop (Fusilade)													ND
Glyphosate (Roundup, others)	M	ND	ND	ND	ND	ND	H	ND	L	ND	ND	ND	
S-metolachlor (Dual Magnum)													ND
Oxyfluorfen (Goal)													ND
Paraquat (Gramoxone)	ND	ND	ND	ND	ND	ND	H	ND	ND	ND	ND	ND	
Pendimethalin (Prowl)													ND
Sethoxydim (Poast)													ND
Trifluralin (Treflan)	ND	ND	ND	ND	ND	ND	ND	ND	M-H	ND	ND	ND	
Unregistered / Potential chemistries													
Insecticides/Miticides:													
Abamectin (Agrimek)	ND	ND	ND	M	M	ND	M	ND	H	ND	L	ND	
Dinotefuran (Starkle)													
Fipronil (Regent)													Seed treatment; no data
Flonicamid	L	L	L	L	L	L	L	ND	L	L	L	L	
Imidacloprid (Admire) soil-applied	L	L	L	L	L	L	L	ND	L	L	L	L	Non-toxic to foliage-borne beneficials
Imidacloprid (Provado) foliar	M	M	M	M	M	M	M	ND	M	M	M	M	
Methoxyfenozide (Intrepid)	M?	M?	ND	ND	ND	ND	ND	ND	O	ND	ND	ND	Low probability of harm to beneficials
Pyriproxyfen (Esteem, Knack)	M	M	O	ND	ND	ND	L-M	ND	M	ND	ND	ND	

	BEB	DB	HB	LW	LB	MPB	PM	PN	PW	S	SF	TF	Comments
Spinosad (Success, Entrust)	M	M	M	M	M	M	M	ND	M	M	M	M	
Thiamethoxam (Platinum) soil-applied													Low probability of harm to beneficials
Thiamethoxam (Actara) foliar	L	L	M	L	L	L	L-M	ND	L-M	L	L	L	
Fungicides:													
Acibenzolar (Actigard)													ND
Carboxin + Thiram (Vitavax CT)													Seed treatment; no data
Famoxadone + Cymoxanil (Famoxate)													ND
Fenamidone (Reason)													ND
Fenhexamid (Elevate)													ND
Pyrimethanil (Scala)													ND
Tebuconazole (Elite)													ND
Trifloxystrobin (Compass)													ND
Herbicides:													
Carfentrazone-ethyl (Aim)													ND
Dimethamid-P (Outlook)													ND
Ethofumesate (Nortron)													ND
Flumioxazin (Valor)													ND
Fluroxypyr (Starane)													ND
Biological:													
Beetles (Rove and Ground)													ND
Parasitic nematodes													ND
Parasitoid wasps													ND
Predatory flies													ND
Cultural / Non-Chemical:													
Adjacent area management	ND	ND	ND	ND	ND	ND	ND	ND	H	H	H	H	May be hazardous if habitat removed
Certified seed/planting stock													Neutral
Cover crops													Provides good habitat, shelter and alternative prey for the beneficials
Crop rotation													Largely neutral
Culls and crop residue management													Neutral
Cultivation													Short term disruption to soil dwellers
Enhancing habitat for beneficials													Provides good habitat, shelter and alternative prey for the beneficials
Field sanitation													Neutral
Flaming	H	H	H	H	H	H	H	O	H	O	H	H	Hazardous to foliage dwellers
Hand hoeing	H	H	H	H	H	H	H	O	H	O	H	H	Hazardous to foliage dwellers
Irrigation management													Neutral
Maintain/enhance drainage													Neutral
Nitrogen management													Neutral
Resistant/tolerant cultivars													Neutral
Straw mulch													May provide good habitat and shelter for some beneficials
Weed control													May remove habitat or alternative prey for some species

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