ONION Health Management & Production

Colorado State University

Preface

The purpose of this *Onion Health Management and Production* publication is to provide an updated, comprehensive, and authoritative account of onion plant health and production practices commonly employed throughout irrigated regions of North America. It is national in scope and practical in emphasis. It is designed to assist in the diagnosis of onion diseases and pests whether in the field, laboratory, or diagnostic clinic, and to provide an overview of pest management strategies that can be employed to reduce their impacts. In addition, an overview of primary production practices is provided. To simplify technical terminology, trade names of products and equipment occasionally will be used. No endorsement of products named is intended nor is criticism implied of products not mentioned.

This handbook resulted from the efforts of many people as authors, photographers, reviewers, and sponsors to whom we express our deepest thanks. The editor gratefully acknowledges the support, time and facilities provided by our sponsors and the home institutions of our authors to this effort on behalf of the national onion community.

We also wish to thank the many individuals who supplied figures and photographs for this handbook.

Howard F. Schwartz

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Contributing Authors:

Diane G. Alston, Entomologist, Utah State Univ., Dept. of Biology, Logan, UT

Michael E. Bartolo, Vegetable Crop Specialist, Colorado State Univ., Arkansas Valley Research Center, Rocky Ford, CO

Chris Cramer, Plant Breeder, New Mexico State Univ., Dept. of Plant and Environ. Sci., Las Cruces, NM

Whitney S. Cranshaw, Entomologist, Colorado State Univ., Bioagr. Sci. & Pest Management, Fort Collins, CO

Dan Drost, Horticulturist, Utah State Univ., Dept. of Biology, Logan, UT

Lindsey J. du Toit, Seed Pathologist, Washington State Univ., Mt. Vernon NWREC, WA

Bhabesh Dutta, Bacteriologist, Univ. of Georgia, Plant Pathology Dept., Tifton, GA

Ronald D. Gitaitis, Bacteriologist, Univ. of Georgia, Plant Pathology Dept., Tifton, GA

Janet Hardin, Entomologist, Colorado State Univ., Bioagr. Sci. & Pest Management, Fort Collins, CO

Brian A. Nault, Entomologist, Cornell University, Dept. of Entomology, Geneva, NY

Scott Nissen, Weed Scientist, Colorado State Univ., Bioagr. Sci. & Pest Management, Fort Collins, CO

Hanu R. Pappu, Plant Virologist, Washington State Univ., Plant Pathology Dept., Pullman, WA

Kimberly Reddin, Director of Public & Industry Relations, National Onion Association, Greeley, CO

Howard F. Schwartz, Plant Pathologist, Colorado State Univ., Bioagr. Sci. & Pest Management, Fort Collins, CO

Brenda K. Schroeder, Bacteriologist, Washington State Univ., Plant Pathology Dept., Pullman, WA

Rajagopalbab Srinivasan, Entomologist, Univ. of Georgia, Entomology Dept., Tifton, GA

Stephanie Szostek, Plant Pathologist, Colorado State Univ., Bioagr. Sci. & Pest Management, Fort Collins, CO

Mark E. Uchanski, Vegetable Physiologist, New Mexico State University, Dept. of Plant and Environ. Sci., Las Cruces, NM

Tim Waters, Area Extension Educator, Washington State Univ., Pasco, WA

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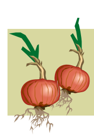

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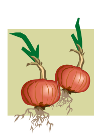


Introduction and Background

By H. F. Schwartz and M. E. Bartolo

Onions, *Allium cepa*, are biennial monocots grown as an annual for their edible bulbs and as a biennial for their seed. The majority of onion acreage is planted to dry bulb onions for storage, with smaller acreages grown for specialty onions, seed and non-storage purposes. Over 90% of the onion crop is grown in western states. Southeastern states like Georgia are important to sweet onion production, and New York provides significant production for eastern storage onions.

The onion bulb is comprised of thickened fleshy leaf bases that grow partially underground. The stem of the onion from which the leaves and roots originate is located at the bottom of the bulb and is relatively small. The pseudo-stem is what is generally referred to as the neck and is actually tightly bunched leaves above the fleshy leaf scales. Onions may produce 7 to 12 leaves during a normal growing season. The size and yield of the crop is generally related to the number of leaves produced.

Cultivated onions are a diverse crop classified by different means. They can be classified by their bulbing response to day length. Onions form bulbs in response to a critical day length and thus, can be classified as short-, intermediate-, and long-day types. Onions may also be classified by shape (flat, globe, grano, torpedo), skin color (yellow, red, white), pungency (sweet, pungent), and market use (fresh, storage, processing). Onion cultivars grown in the Northern tier of states are long-day types that respond well to the long day length during the growing season at these latitudes. Short-day length onions are generally grown in southern regions where the day length is less than 14 hours during the time that bulbing should occur. Short-day onions generally bulb too early when the plants have not had time to develop enough leaves to achieve good market size. The long day onions may not bulb at all in short day climates. There is much variation in bulbing response to the environment and many genetic variations exist in day length types, so growers need to determine varietal responses in their growing areas. Cultivars that include some sweet Spanish parentage are the predominate onions grown in Colorado, Idaho, Oregon, Utah, and Washington. In the Great Lakes region, most onions grown can be classified as pungent long-day types with moderate to long-term storage capabilities.

Worldwide, 58 million tons of onion bulbs are harvested annually from 7.4 million acres. A significant portion of the U.S. and world supply of onion seed is produced in the western U.S., primarily in the Pacific Northwest. Onion is an economically important crop in the U.S. (Figure 1), generating over 900 million dollars annually in farm receipts from 2005 to 2010. U.S. onion production acres ranged from 148,000 to 153,000 acres during this time period, with over 80% of the summer production (123,000 acres) in western states. In 2008-2010, California, Colorado, Idaho, Michigan, New York, Oregon, Utah, Washington, and Wisconsin produced nearly all of the dry bulb storage (summer) onions in the United States, on nearly 70% of the acreage, which accounts for more than 60% of the U.S. dry bulb onion crop value. Non-storage and other onions (spring) were produced primarily in Arizona, California, Georgia, Nevada, New Mexico, Texas, and Washington on 30% of the acreage and accounted for nearly 40% of the U.S. onion crop value.

Average production costs for onions in the U.S. vary from $3000 to $6000/acre, depending on the type of onion, irrigation system, land value, and other variables. Net returns for onion production generally average $1000 to $5000 or more per acre, with average prices that vary from $15 to $30/cwt, depending on the market type and season.

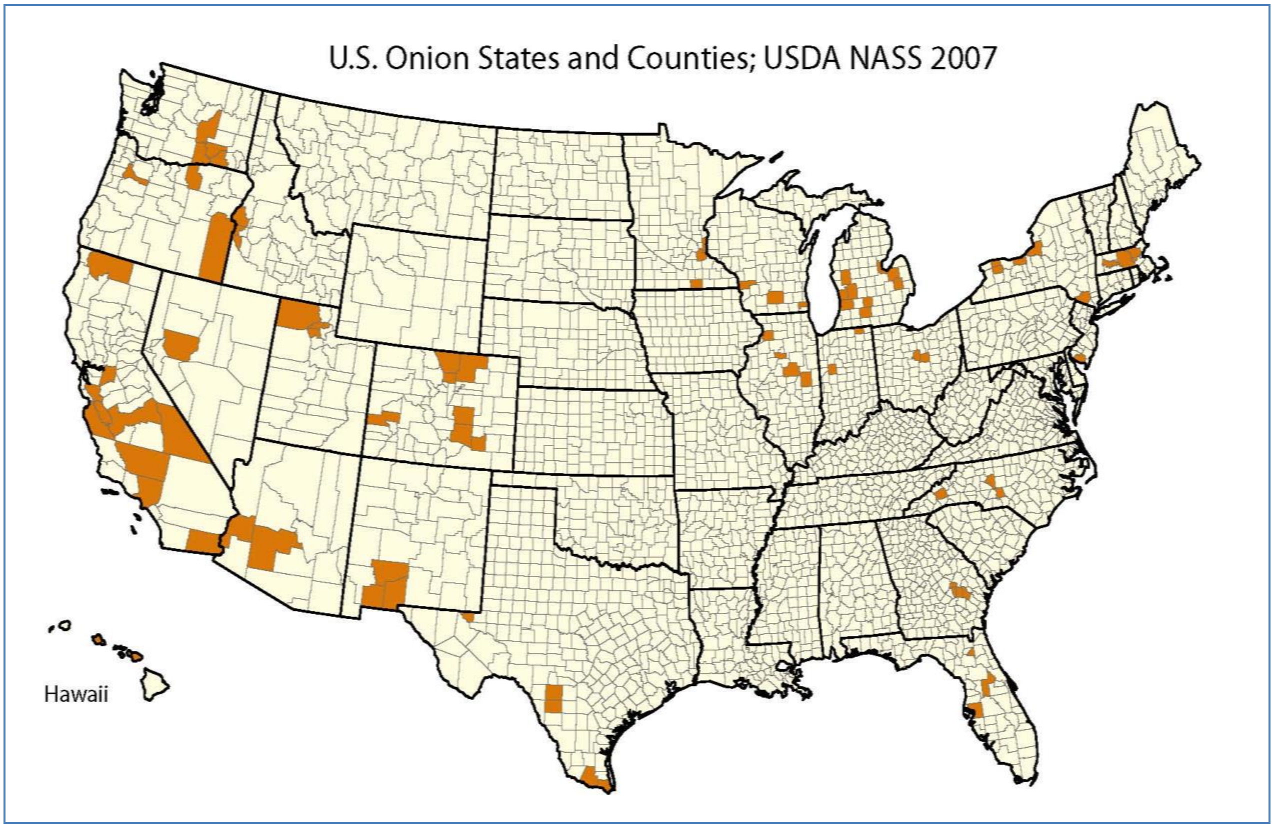


Figure 1. USDA reported that onions were grown and marketed from highlighted counties of the U.S.

The onion crop requires timely applications of irrigation water, fertilizer, and other inputs according to the needs of the market type, variety, and production system. University and USDA research and extension personnel have worked in cooperation with the onion industry to identify important production problems and to investigate measures which could effectively and economically reduce negative impacts on this important food crop. This handbook will not review the wealth of variety information available from other sources such as onion processors, seed companies, crop consultants, and your local county extension office. Rather, the objectives of this handbook are to provide a coordinated review of the major cultural practices, production problems and timely management approaches to economically produce a nutritious crop for marketing to consumers in the U. S. and worldwide.

NUTRITIONAL and CULINARY REVIEW

By K. Reddin and S. Szostek

In the rush to gather health information on the processed foods we eat, it can be easy to forget to check the nutritional facts of vegetables like the onion. Onions are high in vitamin C, a good source of fiber, and with only 45 calories per serving, add abundant flavor to a wide variety of food. Onions are fat- and cholesterol-free, contain only a trace amount of sodium, and provide a number of other key nutrients. Research has made the benefits of knowing the nutritional facts of vegetables clear: An active lifestyle combined with a high intake of fruits and vegetables have been associated with a variety of health benefits.

<u>Notable Quotable Onions</u> (from the National Onion Association web site):

"It's hard to imagine civilization without onions." - *Julia Child*
"If you hear an onion ring, answer it." - *Anonymous*
"Life is like an onion. You peel it off one layer at a time; and sometimes you weep." - *Carl Sandburg, American poet*
"I will not move my army without onions!" - *Ulysses S. Grant*
"Banish (the onion) from the kitchen and the pleasure flies with it. Its presence lends color and enchantment to the most modest dish; its absence reduces the rarest delicacy to hopeless insipidity, and dinner to despair." - *Elizabeth Robbins Pennell, American columnist*

Onions not only provide flavor, they also provide important nutrients and health-promoting phytochemicals. High in vitamin C, onions are a good source of dietary fiber and folic acid. They also contain calcium, iron, and have a high protein quality (ratio of mg amino acid/gram protein). Onions are low in sodium and contain no fat. Onions contain quercetin, a flavonoid (one category of antioxidant compounds). Antioxidants help delay or slow the oxidative damage to cells and tissues of the body. Studies have indicated that quercetin helps to eliminate free radicals in the body, inhibit low-density lipoprotein oxidation (an important reaction in atherosclerosis and coronary heart disease), protect and regenerate vitamin E (a powerful antioxidant), and inactivate the harmful effects of chelated metal ions.

Consumption of onions may prevent gastric ulcers by scavenging free radicals and by preventing growth of the ulcer-forming microorganism, *Heliobacter pylori*. University of Wisconsin-Madison researchers found that more pungent onions exhibit strong anti-platelet activity. Platelet aggregation is associated with atherosclerosis, cardiovascular disease, heart attack, and stroke.

A recent study at the University of Bern in Switzerland showed that consumption of one gram of dry onion per day for four weeks increased bone mineral content in rats by more than 17% and mineral density by more than 13% compared to animals fed a control diet. These data suggest onion consumption has the potential to decrease the incidences of osteoporosis. Several studies have shown quercetin to have beneficial effects against many diseases and disorders including cataracts, cardiovascular disease as well as cancers of the breast, colon, ovaries, stomach, lungs, and bladder.

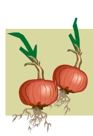
In addition to quercetin, onions contain the phytochemicals known as disulfides, trisulfides, cepaene, and vinyl dithiins. These compounds have a variety of health-functional properties, including anticancer and antimicrobial activities.

Onion Nutrition Facts	Serving Size 1 cup (160 g)	Percent Daily Values*
Calories	64	3%
Total Carbohydrate	14.9 g	5%
Total Fat	0	0%
Cholesterol	0	0%
Dietary Fiber	2.7 g	11%
Sugars	6.8 g	
Protein	4.9 g	
Vitamins		
Vitamin A	3.2 IU	0%
Vitamin C	11.8 mg	20%
Vitamin B6	0.2 mg	10%
Folate	30.4 mcg	8%
Minerals		
Calcium	36.8 mg	4%
Iron	.3 mg	2%
Magnesium	16 mg	4%
Phosphorus	46.4 mg	5%
Potassium	234 mg	7%
Sodium	6.4	0%
Zinc	.2mcg	1%
Copper	0.1 mg	3%
Manganese	0.2 mg	10%
Selenium	0.8 mcg	1%
Fluoride	1.8 mcg	
Other		
Alcohol	0.0 g	
Water	143 g	
Ash	0.6 g	
Caffeine	0.0 mg	

*Percent (%) Daily Values are based on a 2,000 calorie diet.

Your Daily Values may be higher or lower depending on your calorie needs.

http://www.onions-usa.org/all-about-onions/nutritional-facts-vegetables



Onion Color, Flavor, Usage Guide

This chart was created to serve as a guide for helping you choose what kind of onion to use in a recipe. Feel free to let your own tastes, preferences, and creativity along with this chart guide you to your own decision. The most important thing to remember is "bring on the onions" and enjoy!

Note: Crop size in the chart below is approximate. Remember, flavor and usage info are general guidelines for each color and type.

Color	Variety or Type	Availability	Raw Flavor/Texture	Best Usage
Yellow Onion:  All-purpose and most popular, approximately 87% of the U.S. onion crop is comprised of yellow varieties. The most well-known sweet onions are yellow. The best type of onion for caramelizing is a yellow storage variety. Cooking brings out this variety's nutty, mellow, often sweet, quality when caramelized.	Sweet	March-September	Crisp, juicy, mild flavor with a slightly sweet ending with little to no after-taste	Raw, lightly cooked, sautéed, or grilled
	Fresh, Mild	March - August	Crisp, juicy, mild to slightly pungent with a faint after-taste	Raw, lightly cooked, sautéed, or grilled
	Storage	August-May	Strong onion flavor, mild after-taste	Grilled, sautéed, caramelized, baked, or roasted
Red Onion:  About 8% of the U.S. onion crop is red. They have gained popularity in the past decade, especially on salads and sandwiches because of their color.	Sweet	March-September	Crisp, very mild onion flavor	Raw, grilled, or roasted
	Fresh, Mild	March-September	Bright tones, slightly less water content than yellow with a slightly pungent ending	Raw, grilled, or roasted
	Storage	August-May	Sharp, spicy, and moderate to very pungent	Raw, grilled, or roasted

White Onion:  Approximately 5% of U.S. onion production is dedicated to white onions. They are commonly used in white sauces, potato and pasta salads, and in Mexican or Southwest cuisine. Due to the compact nature of their cell structure, white onions do not store quite as long as other varieties.	Fresh, Mild	March-August	Moderately pungent and clean finish, very little after-taste	Raw, grilled, sautéed, or lightly cooked
	Storage	August-May	Moderately pungent to very pungent and full flavored, but finishes with a cleaner and crisper flavor in comparison to yellow and red storage varieties	Raw, grilled, sautéed, or lightly cooked

Preparation Tips:

1. Cut onions as close to cooking or serving time as possible. Onion flavor deteriorates and its aroma intensifies over time.
2. High heat makes onions bitter. When sautéeing onions, always use low or medium heat.
3. Chopped or sliced onions can be refrigerated for up to 7 days in sealed containers.

*Crop size is approximate. Flavor and usage info are general guidelines for each color and type.

Selection and Home Storage

Choose onions that feel firm with dry, papery outer scales. The neck should be small and closed. Avoid onions that feel soft (especially around the neck), are damaged, are beginning to decay, or sprouting. When selecting white onions, avoid bulbs with green spots which indicate sun damage.

Onions can be stored in a cool, dry place for up to 30 days; they do not need to be washed before storage. Cut onions can be wrapped and stored for up to seven days in the refrigerator.

VARIETAL REVIEWS

By C. Cramer and M. E. Bartolo

Onion (*Allium cepa*) is a diploid (2n=2x=16) herbaceous biennial, i.e., it requires two years per generation. The bulb is a modified stem with fibrous roots and fleshy leaves. Bulb formation in onion is affected by temperature and photoperiod. Onion populations have been classified on the basis of the length of daylight required to initiate bulb formation; short-day populations need about 12 hr of daylight and long-day types require up to 16 hr. Onion is an insect-pollinated crop. The seed is formed within a three-celled capsule, which usually contains two black seeds. Although most of the world's onions are grown from seed, shallot is commonly grown from bulbs in tropical areas where seed production is difficult.

Market Types

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 day-length 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, and processing). Most onion varieties grown in western states of the U.S. are long-day types (Spanish or Northern) that respond to long day-lengths during the growing season. For example, yellow, sweet Spanish varieties with moderate to long-term storage capabilities are the predominant long-day onions.

Growing Degree Day Criteria

Onion varieties have been classified on the basis of the length of daylight required to initiate bulb formation: short-day onions need about 12 hours of daylight while long-day onions require up to 16 hours, and intermediate-day onions respond to 12 – 16 hours of daylight.

Choosing a Variety

Selecting the proper onion variety is one of the most important decisions a grower can make. Many onion varieties are currently available on the market and each year seed companies introduce new ones that are potentially well adapted for different regions. Field trials are an excellent way to screen other promising onion varieties. In addition, individual seed companies often have trials of their own. Besides yield potential, field trials reveal other important horticultural traits. These traits include days to maturity, pest tolerance, and storage capacity. In general, avoid late-maturing varieties that may produce more tonnage per acre, but often experience more disease and quality problems due to their large, soft bulbs that are more difficult to harvest, cure and store. Growers should contact their local extension and research offices, as well as seed company representatives, for more information.

Onions harvested for bulbs go through the following three distinct phases of growth and development: establishment phase, vegetative phase, and bulbing phase. Start/finish dates of these phases vary for different regions in the U.S. Dates described below are typical for the western states.

Establishment Phase

For spring-seeded onions, the establishment phase lasts from planting until the end of May. Fall-seeded onions may initiate with planting in August to September, depending on the location. Onion seeds germinate at temperatures above 40^{o}F, with optimum germination at 75^{o}F. Cool air and soil temperatures cause slow protracted growth during this initial phase of development. Depending on the soil temperature, the seed may take 15 to 25 days to emerge. The first stage of emergence is called the **loop stage** (Figure 2). The loop stage is followed by the flag stage and the appearance of the first true foliage leaf. At the end of the establishment phase, the plant has three to four leaves with the older leaves usually 8 to 10 inches in length. Transplanted onions have essentially been taken through this initial stage at their place of original production.

Vegetative Phase

This phase represents a time of rapid leaf area development. Depending on the variety, both leaf number and leaf size increase rapidly. At the beginning of this phase, each successive leaf is larger than the previous leaf. Later, each new leaf will attain the same size. Many yellow varieties will have 12 to 16 leaves at the end of the vegetative phase, with the longest leaves reaching 20 to 25 inches in length. For most varieties seeded in the spring, the vegetative stage ends about the first or second week in July.

AUTHOR: H. F. Schwartz (Colorado State University) and C. S. Cramer (New Mexico State University)
PHOTOGRAPHS: Courtesy of H. F. Schwartz [01/2011]

ALLIUM TYPE: Fresh Market and Storage Onion

Both pre- and post-bulb production are technically *vegetative growth phases* that occur during the first cycle of growth after planting (seeds, transplants, sets).

PRE-BULB GROWTH STAGES

1 • radical and flag leaf emergence (10–30 days post seeding) [Fig. 1]
2 • one to two true leaves (30–50 days p.s.)
3 • three to four leaves (50–70 days p.s.) [Fig. 2]
4 • five to seven leaves (70–90 days p.s.) [Fig. 3]
5 • eight to 12 leaves, bulb initiation (90–110 days p.s.) [Fig. 4]

POST-BULB GROWTH STAGES

6 • bulb diameter of 2.5 to 4.0 cm (110–130 days p.s.)
7 • bulb diameter of 4.0 to 7.5 cm (130–150 days p.s.) [Fig. 5]
8 • bulb diameter greater than 7.5 cm (150–170 days p.s.)
9 • bulb enlargement complete, greater than 50% cropped to dry down (more than 170 days p.s.) [Fig. 6]

Reproductive Stages do not technically begin until the second cycle of growth after vernalization of the mature bulb; the bulb will then produce a scape or seed stalk [Fig. 7] and umbel [Fig. 8] which produces true seed after fertilization.

Figure 2. Onion Plant Development (courtesy of Onion ipmPIPE Project).

Bulbing Phase

Bulb initiation occurs when the diameter of the bulb is twice that of the neck. Nearly all of the onions grown in western states are long-day onions. Onions are programmed genetically to begin bulbing after being exposed to sunlight for specific lengths of time. For example, long day onions start to bulb after being exposed to days with 14 hours or more of sunlight. During the bulbing phase, leaves continue to grow and elongate. However, the total leaf area and number of leaves stay about the same.

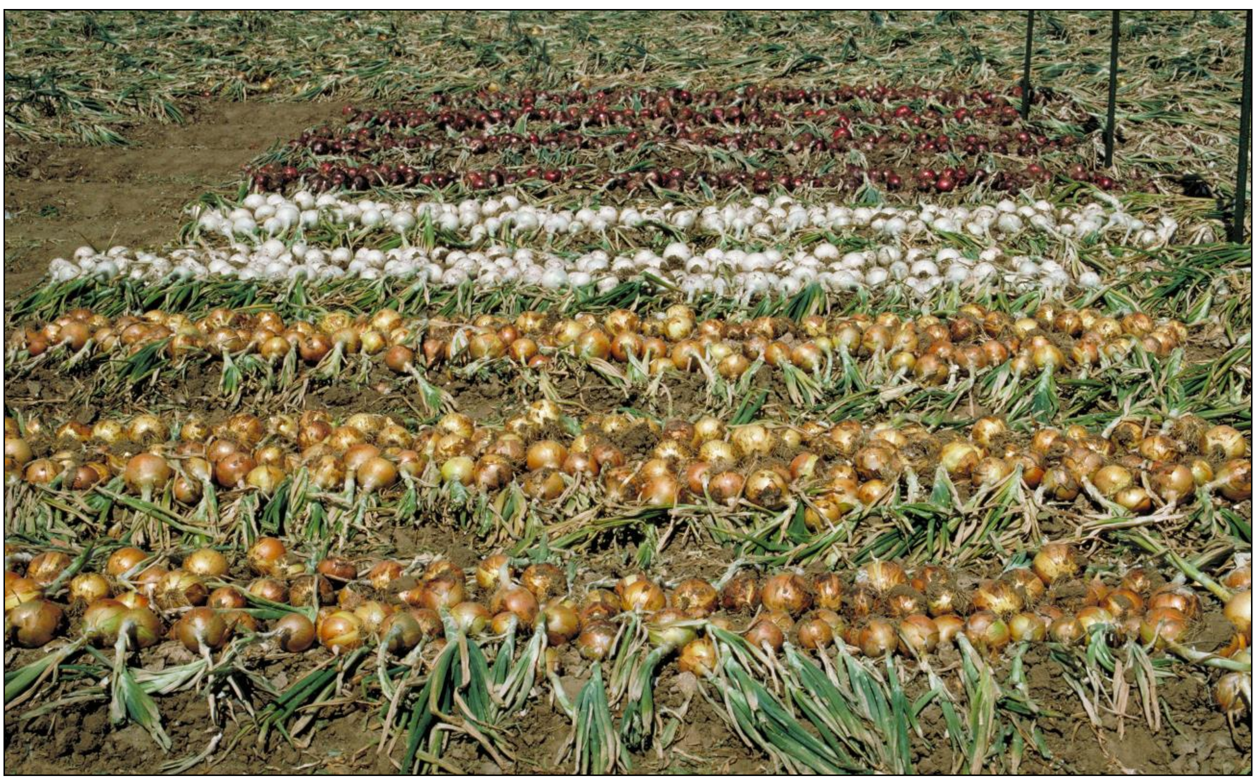
As older leaves dry up, new leaves emerge. Generally, the larger the onion plant is when bulbing starts, the greater the potential for a large bulb at harvest. Bulbing declines at maturity when the neck softens and the tops fall over.

The following table illustrates a typical growth and development pattern for spring-seeded onions. Note that during each phase of development, the environment can have a major influence on onion growth and yield. Onions are extremely sensitive to changes in temperature, soil moisture, and day length, and overall solar radiation. All of these factors contribute to growth patterns.

Table 1. Description of Onion Growth Stages (APS Compendium of Onion and Garlic Diseases and Insect Pests, 2nd Ed.).

Stage	Days After Seeding	Description of Plant Growth Stage (see Figure 1)
1	10 - 30	Radicle and flag leaf emergence
2	30 - 50	1 - 2 true leaves
3	50 - 70	3 - 4 leaves
4	70 - 90	5 - 7 leaves
5	90 - 110	8 - 12 leaves, bulb initiation
6	110 - 130	Bulb diameter of 1.0 - 1.5 inches
7	130 - 150	Bulb diameter of 1.5 – 3.0 inches
8	150 - 170	Bulb enlargement complete, greater than 50% topped
9	170 +	Dry down period, pre-harvest to harvest

[Scale adapted from information published by Voss and the National Crop Insurance Company]



PLANTING and POST-PLANTING PROCEDURES

By M. E. Bartolo, C. Cramer, and D. Drost

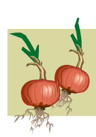
The following table and illustrations in Appendix I summarize many of the timely activities associated with the production of onions in conventional, organic and/or homeowner systems. These guidelines may be useful to plan for production and pest management calendars and needs.

Table 2. Production Activities	J	F	M	A	M	J	J	A	S	O	N	D
Bed and soil preparation		■	■	■						■	■	
Cultivation				■	■	■	■					
Cover crop establishment		■	■	■					■	■		
Cover crop removal				■	■							
Fertilization			■	■	■	■	■			■	■	
Hand hoeing						■	■	■				
Harvest (lifting, topping, loading)								■	■	■		
Irrigation installation			■	■	■	■						
Irrigation				■	■	■	■	■	■			
Planting		■	■	■	■	■	■					
Rolling beds for soil crust removal			■	■	■							
Soil amendments (lime, etc.)									■	■	■	■
Soil testing for nutrients			■	■	■				■	■	■	■
Straw mulch				■	■	■	■	■				
Tissue testing for nutrients					■	■	■	■				

Planting Procedures

Onion transplants are also sometimes planted in early spring for a very early harvest in western states. However, most dry bulb onion crops in the western U.S. are direct-seeded with precision planters. Planting occurs primarily in spring, from early March through April in northern tier states. A small percentage of the western 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 can contain pesticides, nutrients and inert materials to modify the shape of the irregular onion seed. The pesticides help manage soil-borne diseases such as smut and damping-off and insects such as maggots and wireworms. Once the seed germinates, the onion plant grows vegetatively for 5 to 8 weeks, producing upright leaves. 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 (growth stages depicted in Figure 2), can take up to 8 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 inches or more apart, depending on the cultivar and planting scheme. Plants spaced too widely due to skips or other factors produce larger bulbs but are likely to develop thick necks, which are slow to cure and can result in greater storage losses.



Onions are usually planted in multiple lines on beds. Beds may be formed in the fall or the spring, depending on regional weather patterns, with 2 to 12 lines planted per bed. A typical arrangement is two double lines spaced about 12 inches 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 can create 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 onion plants is not practiced in the western states.

Seed-bed Preparation

Onion seeds need a firm and finely textured seed bed for good germination and stand establishment. Seed-bed preparation may be initiated in the fall as the field is plowed, or deeply ripped and worked down with a mulch or disk implement. The ground is then listed into rough beds that are mellowed by frost action. In the spring, just prior to planting, the rough beds are smoothed with a bed shaper or roller.

Whether beds are made in the fall, spring, or not at all, the soil must be left in such a state that it isn't blown away. Cover crops (such as a cereal) are planted in the fall or early spring to minimize exposure of onion seed and damage to seedlings from blowing soil. Careful timing is essential to kill the cover crop by tillage or with grass herbicides to avoid suppressing onion growth or promoting infection of onion seedlings by the soil-borne pathogen *Rhizoctonia*.

Seeding Rates and Spacing

Onion seed may be planted after the first of January in most areas of the U.S.; however, it usually will not germinate until after late-March to early April in northern tier states. In most locations, onion seed is planted from the first of March until mid-April. Onions are seeded on beds of varying width, depending on the cropping system and equipment constraints of the individual grower. Bed width may be 30 to 44 inches from center to center for two to four seed rows, or 22 inches for single row beds. When two rows are planted on a 40 inch bed, the rows generally are 12 to 18 inches apart.

Uniform seed placement and spacing is critical to good stand establishment. Seed is planted 0.5 to 1.0-inch deep. With a uniform sprinkler system, seed planted as shallow as 0.25-inch deep can produce a good plant stand. In-row plant spacing has a major influence on how large an individual bulb will get. Avoid wide spacing that promotes large bulbs with thick necks. Generally, an in-row spacing of 3 to 4 inches will give both greater total yield and a greater percentage of onions in the larger market classes.

Many types of planters can be used to seed onions and all must be set carefully to maintain proper seeding depth and rate. Vacuum and other types of precision planters are most effective at controlling plant spacing and reducing the amount of seed used.

Transplanting

Onion transplants usually are shipped to Colorado, New York, Washington and other states from Texas, Arizona or California after inspection of the transplants for quality and absence of contamination by pests. Transplants arrive in bundles with the tops, and occasionally the roots, pruned to facilitate handling. Upon arrival at the farm, transplant bundles are unloaded promptly to discourage heat buildup, moisture condensation, and disease development; bundles are spread out and stored in a dry, cool location until used. Tops and roots may dry completely before use, with no effect on plant regrowth from the firm basal plates after transplanting. Transplanting takes place from late March to the end of April. When planted earlier, cool weather may induce the transplants to produce seed stalks rather than marketable onion bulbs.

The majority of transplants are placed in the field by hand; however, mechanical transplanters have been adapted for onions with some success. The usual method for planting transplants is to furrow the field and pre-irrigate to moisten the bed, or irrigate immediately after transplanting. Transplants must have good contact with the soil to take root properly. Soil should be loosely textured and free of clods. Plant depth does not have a major effect on yield; however, the transplant should be set in the ground as upright as possible. Transplants that lay flat on the ground will have reduced yields and overall smaller bulb size compared to those that are placed in the ground erect. Only disease- and insect-free, vigorous transplants that are about 0.25 inches in diameter should be used. Mechanical wounding should be minimized during transplanting to reduce later-season problems from diseases such as Botrytis soil-line rot, Fusarium basal rot and the bacterial complex.

Onion transplanting in New York. (Photo courtesy of B. A. Nault, Cornell University.)

Post-Planting Procedures

Spring-time weather can bring hard-driving rain or snow storms that can lead to soil crusting in heavy-textured soils. To break soil crusts during onion emergence, use a harrow, spiked rollers, or other finger-type cultivators are used. Extra care should be taken not to disturb the seed row.

Cultivation begins as soon as the onions can be rowed out by the tractor operator. Many types of equipment are used to cultivate; however, the standard set-up uses disks, knives, duck feet and furrow openers. The disks are placed on either side of the onion rows to cut the crust. A knife is mounted behind each disk to undercut weeds on either side of the onion row and fill in the furrows made by the disks. A single duck foot might be centered in the furrow to undercut weeds, followed by a furrow opener which remakes the ditch for the next irrigation. It generally is necessary to send a hoeing crew through the field at least once to eliminate weeds which escape the herbicides and mechanical cultivation. Additional field operations may include application of various pesticides for weed, insect and disease control. Soil compaction should be minimized by avoiding unnecessary field operations, especially when the soil is wet.

OTHER CULTURAL PRACTICES

By M. E. Bartolo, C. Cramer, and D. Drost

Dry bulb storage onions are often grown in 3- to 4-year rotations with other crops in the western U.S., but rarely rotated on muck soils in the Great Lakes region. Rotations differ among the growing regions. In general, the main rotational crops include potatoes, carrots, and sweet corn. Other rotation partners may include field corn, wheat, peas, cole crops, 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 the pests of those crops typically entails fumigation.

Cover crops, e.g., wheat or other cereals, are usually planted prior to planting onions in the western U.S.; however, pre-formed beds with no cover crop are also used on heavier soils that are less prone to wind erosion. In the Great Lakes region, onion is co-planted with barley, which is either planted in rows between onions or broadcast in the field. In both cases, the cover/companion crop is utilized 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. In the western U.S., overwintered cover crops are commonly sprayed with herbicides in spring, before the cover crop gets large enough to compete with onion seedlings. The herbicide application usually occurs before the onion crop is planted, but may be applied after the onion crop is planted if the cover crop is not tall enough to protect onion seedlings at the time of planting. Spring-planted cover crops have proven more problematic due to the difficulty of killing the cover crop before significant 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 and harborage for beneficial insects and arachnids.

Crop Rotation

Onions are used in a rotation once every three to four years (or more) depending upon the history of diseases in the field and region. A history of outbreaks from soil-borne problems such as pink root and Fusarium basal rot may require that the field be rotated out of onions for at least four years, if not longer.

Common rotation crops include sweet corn, field corn, alfalfa, potatoes, dry beans, melons, sugar beets, and small grains such as oats, barley and wheat. Large-rooted crops like corn or alfalfa are not recommended in the year before the onion crop because of the potential debris problem in the seed-bed. Small grain crops are often preferred before the next season of onions because of softerr ground and reduction of soil-borne pathogens.

Sanitation

Good overall sanitation will help reduce pest problems. Eliminating culls and onion residue from previous crops will help protect the current crop from disease infection. Before setting in the field, transplants should be inspected carefully for diseases and insects. Weed pressure should be reduced by screening surface irrigation water. Small mesh screens can remove some weed seeds before they are deposited in the field.

FERTILITY REQUIREMENTS

By D. Drost and M. E. Bartolo

Soil type and quality are critical factors in onion production. Onions need a moderate to highly fertile soil, and/or amendments to infertile soils with fertilizers that result in bulbs expanding.

Onions require timely applications of nutrients to achieve maximum plant development and yield under varying production conditions. Onion roots mostly are confined to the top 18 inches of soil, which can make supplying nutrients to the crop difficult. A soil test should be conducted (0 to 12 inches deep) to quantify nutrient carryover from the previous crop. It is extremely important that growers are aware of all sources of nutrient inputs, including what is already in the soil prior to planting (residual nutrients), manure, crop residues, and irrigation water.

Fertility costs are generally less than 5 percent of the total production cost. As a result, there may be a tendency to add more fertilizer than needed rather than risk limiting yields. However, over-fertilizing can have negative effects on bulb quality and may contribute to ground water contamination, as well as favor the development of some pathogens and insects in the field and/or storage.

Nitrogen

Like most other crops, nitrogen is one of the most important nutrients for onions. A typical onion crop will use about 150 pounds of total nitrogen per acre during the season. The majority of the nitrogen is taken up after the plant has started to bulb. If the soil tests over 40 ppm nitrate-nitrogen, no additional fertilizer is needed to reach maximum yield. Apply pre-plant nitrogen only if the soil test values are low (< 20 ppm). Side-dressing nitrogen during the course of the season is the most efficient means of applying nitrogen. The nitrogen should be applied carefully in low enough dosages and far enough away from the plant to avoid burning plants. Aqua or anhydrous ammonia forms should not be used in sprinkler irrigation systems. Young onions are especially sensitive to ammonia burn.

A major concern with nitrogen fertilizer is keeping the nutrient in the root zone. Most forms of nitrogen are converted rapidly to nitrate by organisms in the soil. Nitrate is prone to leaching in the soil. Leaching not only renders the nutrient unavailable to the crop, but also can be a source of groundwater contamination. Because of the leaching problem, fall applications of nitrogen are NOT recommended. In addition to leaching, excessive nitrogen, especially after bulb initiation, can result in late maturity, large necks that are difficult to cure, soft onion bulbs, and overall poor storage quality.

NO_3-N (ppm) in 12" depth	**N - Application (lbs/A)**
0	175-250
10	125-175
20	75-125
30	25-75
40	0

Phosphorus

Soil test values should be in the range of 20 to 30 ppm for phosphorus. Unlike nitrogen, phosphorus is relatively stationary in the soil profile and carryover from the previous crop may be significant. A soil test will determine the carryover and amount that should be banded 2 inches to the side and 2 inches below the seed. Excess applications that may increase the incidence of seed stalks should be avoided. Fumigated soil may require slightly higher levels of phosphorus.

P (ppm) in 12" depth	P_2O_5 - Application (lbs/A)
0	200-300
5	150-200
10	100-150
15	50-100
20	50

Potassium

Potassium naturally occurs in abundance in most western state soils, and is rarely a fertility consideration. A soil test, however, is again the best way to determine potassium levels accurately.

K (ppm) in 12" depth	K_2O - Application (lbs/A)
0	200-300
20	150-200
40	100-150
60	50-100
80	50
100 +	0

Micronutrients

Onions are responsive to several micronutrients, most notably zinc, manganese, molybdenum, and copper. Many micronutrients occur naturally in western states, as well as in irrigation waters (surface and shallow wells). Since micronutrients are used by the onion crop in such small quantities, only minute amounts need to be present in the soil. Rarely is there a response from micronutrient applications. Of all the micronutrients, zinc (Zn) is of the most concern. Zinc may be required if the soil test value is below 0.8 ppm, which can be broadcast and worked into the soil at 10 lb Zn/A prior to planting, or 3 to 4 lb Zn/A banded with other fertilizer at planting. To correct Zn deficiency during the growing season, plants can be sprayed with a solution containing 1 pound Zn/50 – 100 gallons of water.

Liquid nitrogen fertilization equipment.

IRRIGATION PRACTICES

By M. E. Bartolo and D. Drost

Onions require large amounts of good quality irrigation water. Nearly all onion roots are located in the top 18 inches of soil and about 90 percent in the top 12 inches. Because of the limited root system, onion yields can be affected significantly by even short periods of soil water deficits. Intervals between irrigations will depend upon the soil type, stage of crop development, weather conditions, disease pressure, and irrigation system. During warm summer weather, onions may use 0.15 to 0.25 inches of water per day, and thus, may require an irrigation application every seven to 10 days. Onions grown on sandy soil may require irrigations even more frequently. In most years, seeded onions receive between 10 to 15 furrow irrigations during the course of the season, with each irrigation application consisting of 2 to 3 acre inches of water. For sprinkler-irrigated fields, several light irrigations may be required during the first 30 to 60 days after planting to enhance seed germination, promote root initiation, and leach salts from the soil surface.

Uniform application of water is critical. Probing the soil with a smooth metal rod until resistance is met is an easy way to determine soaking depth and uniformity of application. Furrow-irrigated fields with long runs may be especially prone to nutrient leaching and uneven water distribution.

Irrigation is stopped 3 to 14 days before onions bulbs are undercut (lifted), to allow the crop to cure.

Sprinkler, drip and furrow irrigation of onions.

HARVEST and POST-HARVEST PROCEDURES

By M. E. Bartolo, C. Cramer, and D. Drost

The majority of dry bulb storage onions are lifted and harvested mechanically in the late summer or early fall. The sprout suppressant maleic hydrazide is used widely by Washington growers prior to harvest but is not used as commonly 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, when the onions are removed from the field. Mechanical toppers and loaders are used to cut the tops and pick up and load the field-cured bulbs in one operation. Some producers windrow their onions with mechanical toppers to allow more field curing with the bulbs completely out of the soil. After about 3 days, the windrows may be loaded. Windrowing is helpful in places where harvest-time rains can occur. On some acreage where transplanted onions produce thin-skinned bulbs, onions are lifted mechanically but topped by hand.

Field Operations

The initial stages of harvest of storage onions normally begins when 50 to 80 percent of the tops are down. Rod weeder or wide sweep implements normally are used to sever the root system several inches below the bulb. The onions are then cured until the tops have dried thoroughly. The harvester or field workers then lift the onions and remove the tops. Topping removes most of the dried foliage from the bulb, allowing air flow through the crop later in storage. The onions are then windrowed or bagged for further field curing before loading. The neck area must be dried completely. Moisture in the necks favors contamination by storage diseases such as Botrytis neck rot and black mold, which then cause a neck and shoulder rot or discoloration in storage. Storage onions sometimes are treated with a sprout inhibitor (maleic hydrazide) when about 50% of the tops are down and the foliage is still green and can transmit the inhibitor to the bulb. Sprout inhibitors should not be applied when the crop is too immature, since soft, puffy bulbs may result.

Handling

When loading and unloading cured onions, mechanical damage to bulbs can be minimized by reducing drop height and by padding all sharp edges. Transplanted onions are generally sweet Spanish types that are sensitive to mechanical bruising. Therefore, hand operations are used for all stages of harvest after undercutting.

Post-Harvest Procedures

A properly field-cured bulb, ready for storage, should have a well-dried neck and at least one, 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 (shrinkage). Even with well field-cured bulbs, additional post-harvest curing in storage is typically essential. During this time, final drying of the onion neck occurs and wounds caused during harvest will dry and heal. External scales dry most rapidly during the post-harvest curing period. Some storage managers heat the onion bulbs to about 95^{o}F for a short period (24 to 72 hours) immediately after harvest to further the curing process and reduce incidence of storage rots. However, excessive post-harvest heat curing can exacerbate black mold and/or bacterial storage rots.

Once cured, onions store best under dry, cool conditions with positive air circulation. Most storage facilities in the northern tier states are not refrigerated but are maintained at 35 to 40°F when weather conditions permit. Low relative humidity (approximately 70%) is essential in storage to inhibit disease development and root sprouting. However, relative humidity less than 70% can result in a greater degree of shrinkage. 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.

Curing

The neck area of bulbs must be dried thoroughly so that storage diseases do not develop. Curing practices in the storage shed should finish the process initiated in the field. The onions should be blown (50 ft^3 per minute (cfm) per ton of bulbs) with warm to hot (90 to 95^{o}F) air until the curing process is completed. In some cases, this may require a few days to a week or more, depending on the quality and maturity of the onions from the field. The temperature of the pile and humidity in the shed should be monitored carefully. Longer periods of heat curing can also promote black mold and some bacterial storage rots.

Storage Conditions

Storage temperature should be maintained at 35 to 40^{o}F (or refrigerated at 32^{o}F) with less than 70% relative humidity for maximum storage life. After curing, the air flow rate should be 1 cfm per ton of onion bulbs. If bulbs are removed from refrigeration, the bulbs should be warmed to about 50^{o}F for 24 to 36 hours before packing. Cold air can contact warm onions without increasing the risk of condensation, but not the other way around. When the latter happens, moisture condenses on the onions. That moisture must be evaporated quickly by additional blowing with cold air.

USDA Size Classifications

Export large	2.75 to 3.50 inches in diameter
Export medium	2.00 to 2.75 inches in diameter
Export small	1.50 to 2.00 inches in diameter
Jumbo (large)	3.00 inches or larger in diameter
Medium	2.00 to 3.25 inches in diameter
Small	1.00 to 2.25 inches in diameter

Industry Size Classifications

Colossal	4.00 inches or larger in diameter
Jumbo	3.00 to 4.00 inches in diameter
Medium	2.25 to 3.00 inches in diameter
Pre-Pack	1.75 to 2.25 inches in diameter
Boiler	1.75 inches or smaller in diameter
Culls	rots, doubles, sprouts, scallions

Onion Cull Disposal

Thousands of tons of onion culls are discarded each year due to the effects of pests, off grades and/or poor markets. When cull onions are disposed improperly in and near next season's onion fields, insects and plant pathogens may contaminate the new onion crops and threaten productivity and quality. Therefore, it is vital that proper sanitation be exercised each season to clean up processing facilities by removal of all onion waste and residual soil, and properly treating onion culls before the new onion crop becomes established in early spring.

Idaho and Oregon personnel have successfully disposed of onion culls by: (1) burial beneath a few to many inches of soil in pits and landfills; however, regulations regarding water quality are making it more difficult and expensive to utilize landfills; (2) chopping, spreading and incorporating culled bulbs 4 to 6 inches deep in marginal soils (at 80 tons/acre) that will not be planted to onions; (3) feeding chopped or crushed onions to sheep and beef cattle but not finishing cattle at rates up to 10 – 25 % of the cattle diet; (4) composting with wheat straw and other organic material for at least 30 days with adequate aeration and moisture. One ton of cull onions contains approximately 215 gallons of water, 180 lb of organic matter, 3 lb of potassium, 2 lb of nitrogen, 2 lb of sulfur, 0.9 lb of iron, 0.8 lb of phosphorus, 0.6 lb of calcium, and trace amounts of other minerals.

Onion harvest and curing operations.

Improper disposal of onion culls.

Alternative Onion Production Systems

By H. F. Schwartz and M. E. Uchanski

The following table summarizes many of the timely activities associated with the production of onions in conventional, organic and/or homeowner systems. These guidelines may be useful to plan for production and pest management calendars and needs.

Table 3. Common Activities for Production of Onions.

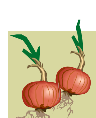
Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed and soil preparation		X	X	X						X	X	
Cultivation				X	X	X	X					
Cover crop establishment		X	X	X					X	X		
Cover crop removal				X	X							
Fertilization			X	X	X	X	X			X	X	
Hand hoeing						X	X	X				
Harvest (lifting, topping, loading)								X	X	X		
Irrigation installation			X	X	X	X						
Irrigation				X	X	X	X	X	X			
Planting		X	X	X	X	X	X					
Rolling beds for soil crust removal			X	X	X							
Soil amendments (lime, etc.)									X	X	X	X
Soil testing for nutrients			X	X	X				X	X	X	X
Straw mulch				X	X	X	X	X				
Tissue testing for nutrients					X	X	X	X				

Organic Production

Organic agriculture is based on the minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony. The principal guidelines for organic production are to use materials and practices that enhance the ecological balance of natural systems and that integrate the parts of the farming system into an ecological whole. In practice, a crop is certified as organic if a certifying agency approves the field in which it is grown and the inputs used to produce it (http://www.nal.usda.gov/afsic/pubs/ofp/ofp.shtml). Organic chemicals such as urea fertilizer and most pesticides are not permitted in organic production of crops, including onion.

Organic production should generally implement many of the same management practices recommended for conventional production to enable plants to be healthy and maximize yield. However, some practices are more important for organic growers than conventional growers, because there are fewer options for preventing or correcting problems in organic production. Organic producers are required to consult the appropriate organizations and certifying agencies (e.g., USDA National Organic Program) for standards, guidelines, and approved inputs in both the production area and the market destination.

The field should not have a history of onion pests, diseases, or high weed seed reservoirs that will out-compete onions for nutrients and moisture throughout the growing season. A certified field should be selected that has not had any onion or other allium crop production for 4 years. Green manure and other crops incorporated into the rotation reduce soil erosion, add carbon to the soil, and capture and recycle residual nutrients. Bio-fumigants released from certain green manure crops can be useful in suppressing some weeds, insect pests and pathogens, including nematodes.



Varieties should be selected that are well adapted to local growing conditions, and that can mature before estimated first frost date. Organically-produced seeds or sets/transplants are planted to a depth of 2 or 4 inches, respectively; ideally after soil temperatures remain above 50^{o}F, and the danger of spring frost (temperatures less than 30^{o}F for extended periods during the evening) has passed. Exposure of germinated seed and actively growing sets or transplants to cold temperatures may result in death or vernalization, with production of a seed stalk (scape) that reduces quality and storability of the harvested bulb. Seeds typically are space 2 inches apart, and thinned, if needed, to 3 inches apart after seedlings produce 2-3 true leaves. Good quality, firm sets and transplants are spaced 3 inches apart at planting.

The field should have good soil and water resources to avoid issues with compaction, salts, extreme pH, nutrient deficiencies or toxicities, and other stress factors. Weed management is one of the major issues to reduce competition with the developing onion plants for sunlight, water and nutrients. Cultivation, flaming, hand labor, and cover crops can help reduce weeds and establish onion canopy cover over the ground quickly to provide shading. Straw mulch (applied 4-6 inches deep) may be applied around the base of onion plants that are bulbing to help reduce weed pressure and water loss from bare and hot soil during mid to late summer.

High quality irrigation water should be provided as needed for good development of roots, foliage and bulbs; onions may need 1 – 1.5 inches of water per week during seedling establishment to cropping. Runoff should not be used from other organic fields that may contain plant pathogens released upstream from infected plants. Onions should not be irrigated after the tops drop (crop) over and begin to dry, as bulb quality and storability may suffer.

Plants should be inspected weekly for signs and symptoms of insect pests and plant pathogens. If present, the integrated pest management strategies reviewed in other sections of this publication should be followed.

Whole onion plants are cured by removing (lifting) the plant carefully from the dried soil, and allowing the entire lifted plant to dry in warm sunlight or in a dry environment (warehouse) for 5 – 10 days. Bruising of the bulbs and neck tissue should be avoided. Then the dried roots, soil and foliage are removed, leaving 4-6 inches of the dried neck tissue to protect the bulb until removal for sorting and transportation to the marketplace. Dried bulbs are stored in a cool (> 34^{o}F), dry place in the dark or with low light intensity.

Homeowner Production

Holistic health management is needed in the home garden just as in commercial conventional or organic agriculture. Many of the same principles explained above apply to onion production in small garden plots as well as to large commercial farms. In addition, onions in the home garden can be hosts of insect pests and pathogens, as well as be negatively impacted by weeds.

Onions are adapted to a wide range of soil conditions, and should be planted in a site that has not had any onions present for at least 4 years, has good drainage, plenty of sunlight, and can be cultivated and irrigated as needed. Onions do not require a large amount of soil amendment, but they may benefit from the incorporation of well-decomposed compost, manure, and a modest amount of fertilizer containing elements such as nitrogen. Onions should not be over-fertilized or fertilizer applied after the onset of bulbing; this can delay maturity of the plants, reduce storability of softer bulbs, and aggravate losses from pathogens and insects. Soil should be tilled (and amendments incorporated) to a depth of 12 inches prior to preparation of the bed, which should be moistened but not wet prior to planting.

Varieties should be selected that are well adapted to local growing conditions, and that can mature before the estimated first frost date. Seeds or sets/ transplants are planted to a depth of 2 or 4 inches, respectively; ideally after soil temperatures remain above 50^{o}F, and the danger of spring frost (temperatures less than 30^{o}F for extended periods during the evening) has passed. Exposure of germinated seed and actively growing sets or transplants to cold temperatures may result in death or vernalization with production of a seed stalk (scape) that reduces quality and storability of the harvested bulb. Seeds should be spaced 2 inches apart, and thinned to 3 inches apart after the seedlings produce 2-3 true leaves; good quality, firm sets and transplants should be spaced 3 inches apart at planting.

Irrigation water should be provided as needed for good development of roots, foliage and bulbs; onions may need 1 – 1.5 inches of water per week during seedling establishment to cropping. Onions should not be irrigated after the tops drop over and begin to dry, as bulb quality and storability may suffer. Throughout the growing season, soil should be tilled carefully without pruning the roots to reduce weeds and provide good aeration and drainage. A grass or straw mulch (2-4 inches deep) may be applied around the base of onion plants that are bulbing to help reduce weed pressure and water loss from bare and hot soil during mid to late summer. Plants should be inspected weekly for signs and symptoms of insect pests and plant pathogens; and if present, the integrated pest management strategies followed that are reviewed in other sections of this publication.

Whole onion plants are cured by removing the plants carefully from the dried soil, and allowing the entire lifted plant to dry in warm sunlight or in a dry environment (warm shed or garage) for 5 – 10 days, while avoiding bruising of bulbs and neck tissue. Then the dried roots, soil and foliage are removed, leaving 4-6 inches of the dried neck tissue to protect the bulb until selection for kitchen use. Dried bulbs should be stored in a cool (> 34^{o}F), dry place in the darkness or low light intensity.

Cover Crops

Cover crops used as plant-based mulches and their associated organic materials offer many benefits to vegetable producers, particularly in the arid southwest where water is a limited resource. Some benefits of cover crops and organic mulches include a decrease in evapotranspiration, buffering of soil temperature, moderating evaporation, inhibiting weed seed germination and establishment, and creating a refuge for beneficial and/or competitive insects. In addition, cover crops contribute to a diverse rotation schedule, a critical consideration for onions, which should only be planted on a three- to four-year cycle. A long rotation cycle can help relieve onion disease pressure from Fusarium basal rot, Botrytis soil line rot, and bacterial diseases.

The use of cover crops and their associated residues may be desirable for soil moisture management in alternative onion cropping systems. For example, a cereal cover crop may be planted in the fall and terminated by cold or chemical means, leaving a standing residue in the field. This standing residue can be referred to as a killed cover crop and onions may be sown directly into the associated mulch. In the desert southwest and other arid production regions, the use of killed winter cover crops as a pre-plant practice may be one way to improve soil moisture management for the summer cash crop. In New Mexico, four annual cover crop species were evaluated for the ability to maintain soil moisture content in a furrow irrigated onion field: oats (*Avena sativa* 'Monida'), annual ryegrass (*Lolium multiflorum* 'Gulf'), cereal rye (*Secale cereale*) and wheat (*Triticum aestivum* 'Promontory'). The cereal rye and oats treatments were the top performers for soil moisture retention. Straw was often intermediate, and annual rye was the lowest in most scenarios. Despite some challenges, the killed cover crop treatments maintained greater season-long soil moisture content in most scenarios, presumably due to slowed evaporative losses, indicating the potential of cover crops for furrow irrigated soil moisture management. Cover crop and their residues can provide soil moisture retention benefits, but must be managed carefully if they are integrated into an onion production system to avoid competitive yield losses.

Numerous studies have examined the role of various mulches, cover crops, and intercropping for thrips control in the field. An integrated alternative thrips control program has been developed involving straw mulch between rows and the use of "soft insecticides" such as spinosad (Success, Spintor) and azadirachtin (Ecozin, AzaDirect). This combination has been successful in reducing season-long thrips populations, increasing natural predator populations, decreasing IYSV injury, and increasing onion quality and yields in Oregon, Idaho, and other onion producing western states. Thrips damage and IYSV incidence have some relationship to plant stress, particularly soil moisture stress. Straw mulch placed between rows in furrow irrigated onions has shown to reduce thrips populations by 48% and increase yields by 14% or greater. Through the use of cover crops, there is also potential for indirect control of *Iris yellow spot virus* (IYSV), which is transmitted by onion thrips (*Thrips tabaci*) and possibly western flower thrips (*Frankliniella occidentalis* and *F. schultzei*).

Significant increases in onion yield and quality (grade) have been reported by means of mechanical straw application to irrigation furrows. In the absence of thrips pressure, yields were increased 64-74% compared to a bare soil check plots. It is proposed that this yield increase was related to an increase in plant health (decreased water stress), more uniform water distribution, and a decrease in evaporation from the soil surface. These modifications, in turn, affect water runoff and increase lateral water movement for this shallow-rooted crop. In a hot and dry field environment, this increase in water availability can bolster the crop's ability to tolerate thrips feeding, and perhaps IYSV transmission. However, in the absence of insecticidal spray applications, a cover crop residue alone will not be effective in controlling thrips populations.

CAUSES OF PRODUCTION PROBLEMS

By H. F. Schwartz

A plant is diseased as the result of an interaction among the plant, its environment, and one or more harmful agents, including insect pests, or other factors in the environment. Biotic agents that cause disease are called *pathogens*. These harmful agents may be infectious organisms, such as fungi, bacteria, nematodes, and phytoplasma organisms, or infectious agents such as viruses, viroids, and related entities that can reproduce only in the living plant. Plant problems are also caused by abiotic factors, such as toxic chemicals, nutrient deficiencies, drought, and heat. The visible indications of distress shown by diseased plants are called *symptoms* and may include yellowing (chlorosis) of leaves, discoloration, dead spots or patches (necrosis), wilting, stunting, malformations, and numerous other abnormalities. The abnormal functioning of the plant generally leads to reductions in quantity and quality of yield. Parts of the pathogen seen on diseased plants are called *signs* of the disease. Symptoms and signs are very useful in determining the cause of a disease. Accurate disease diagnosis is critical to developing and recommending effective disease management procedures.

Plant Damage Description

The following series of scales (Figures 3 to 8) is designed to help describe the extent of damage (infestation, infection, etc.) caused by one or more biotic and abiotic problems that can affect the onion plant and crop throughout the field season and marketing period.

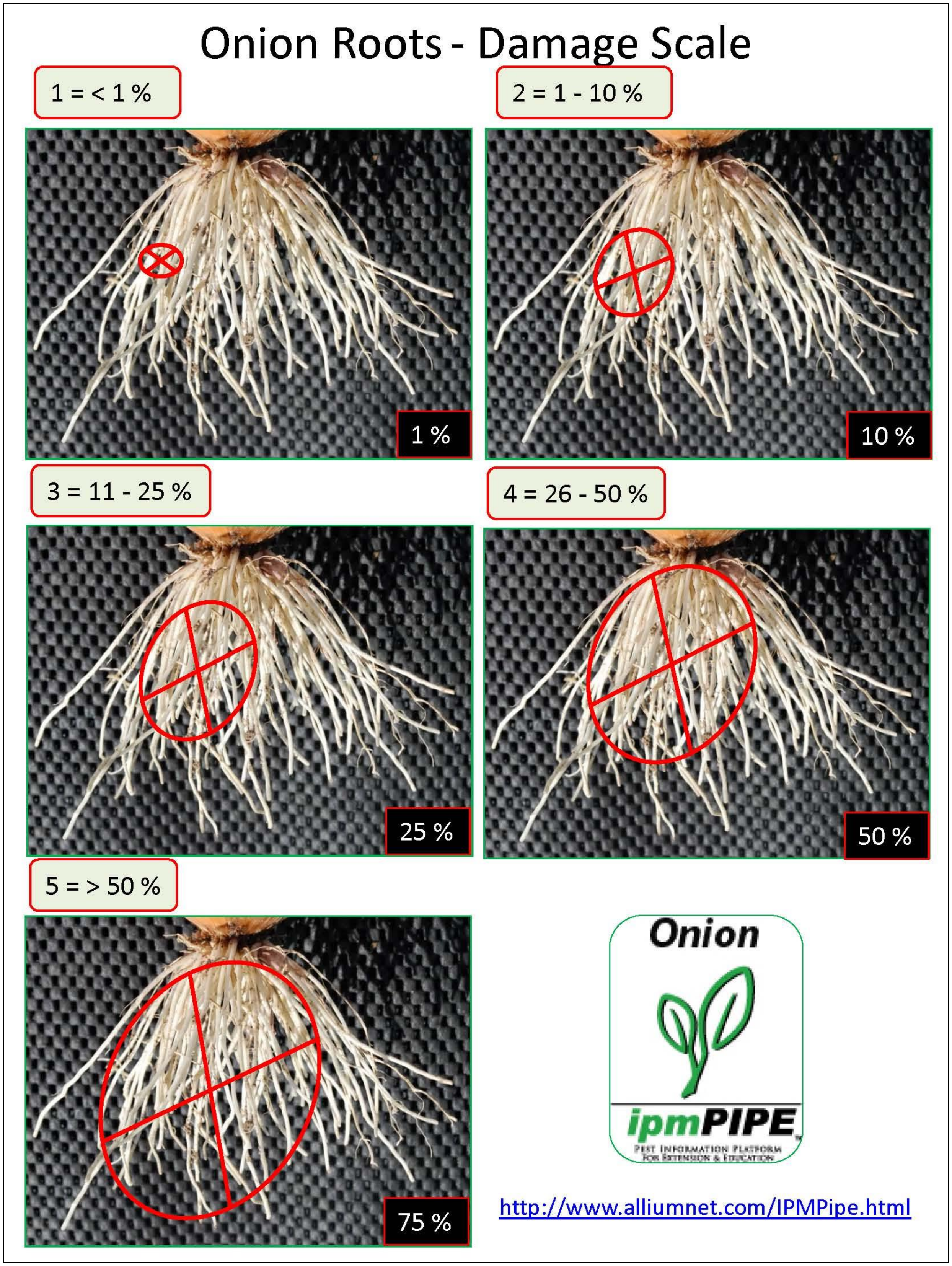


Figure 3. Root damage rating scale.

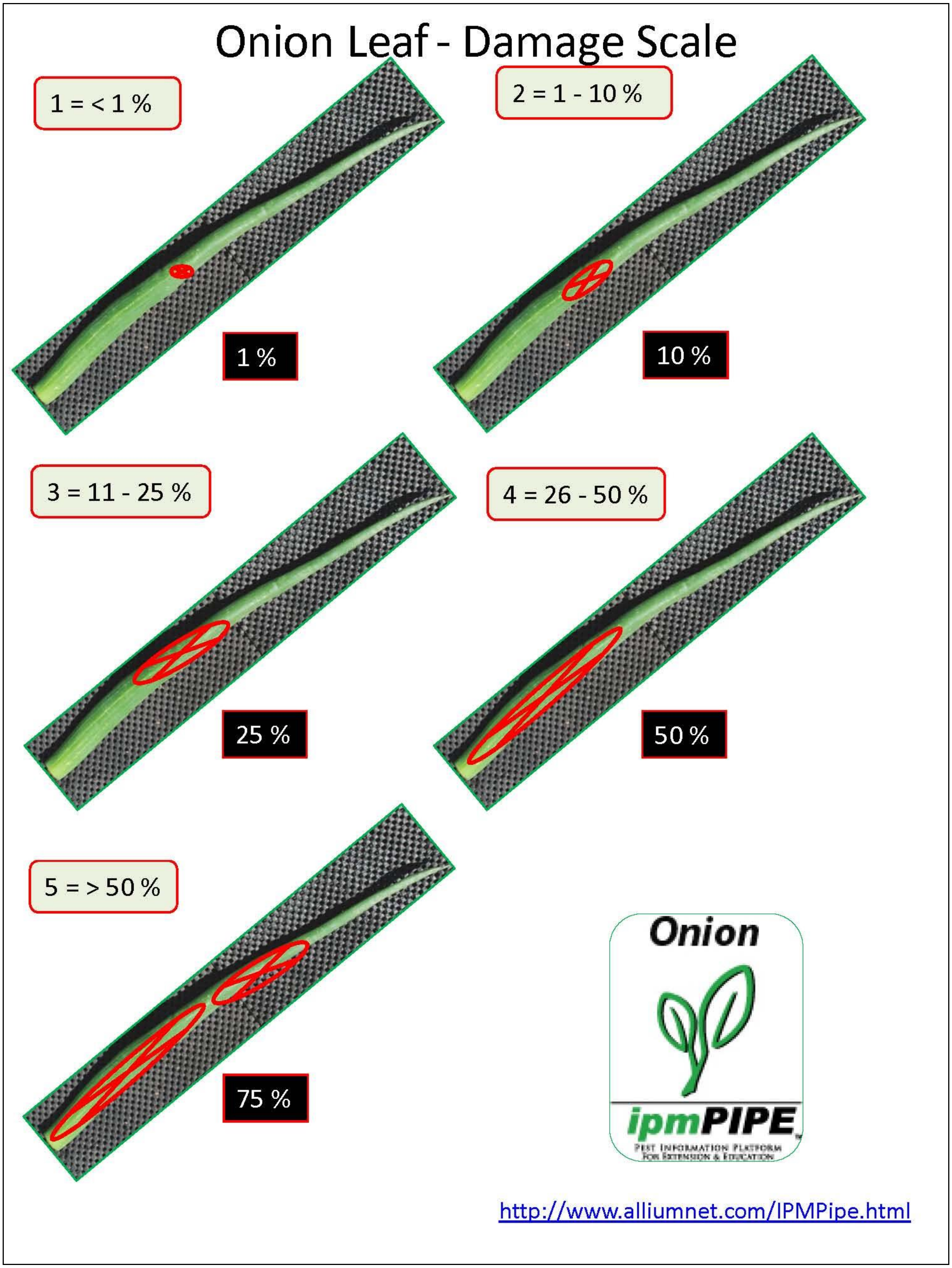


Figure 4. Leaf damage rating scale.

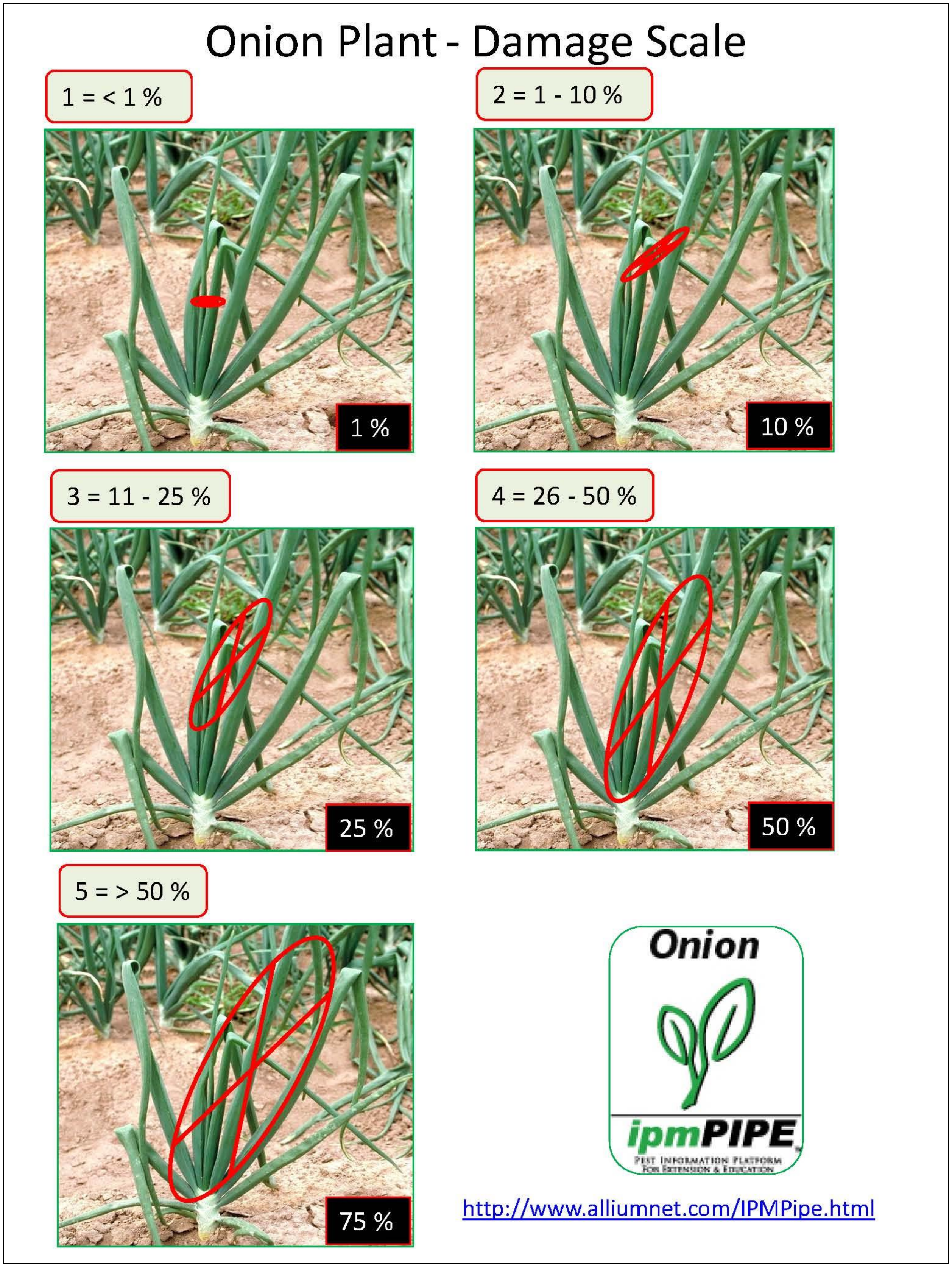


Figure 5. Plant damage rating scale.

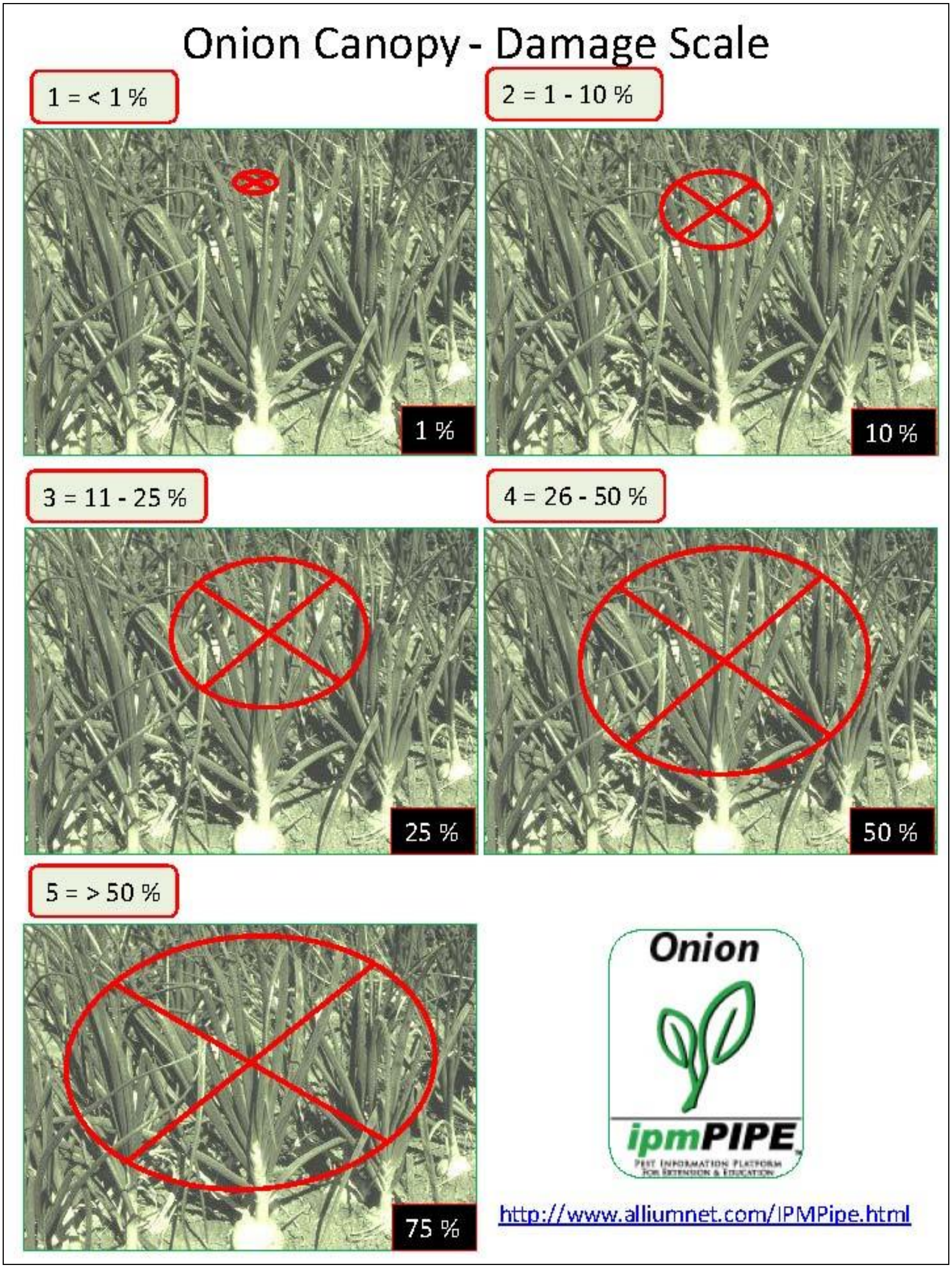


Figure 6. Canopy damage rating scale.

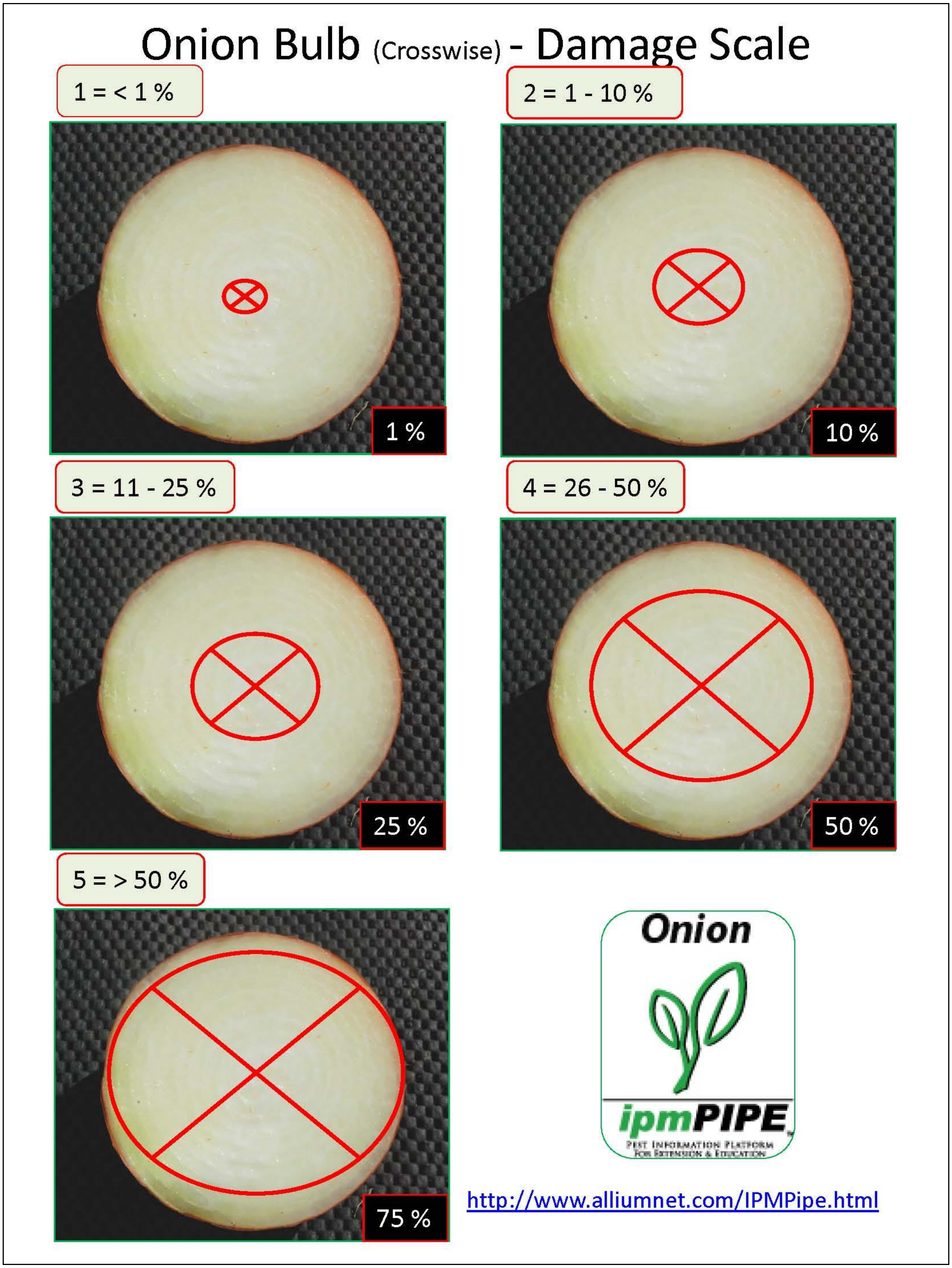


Figure 7. Bulb (crosswise) damage rating scale.

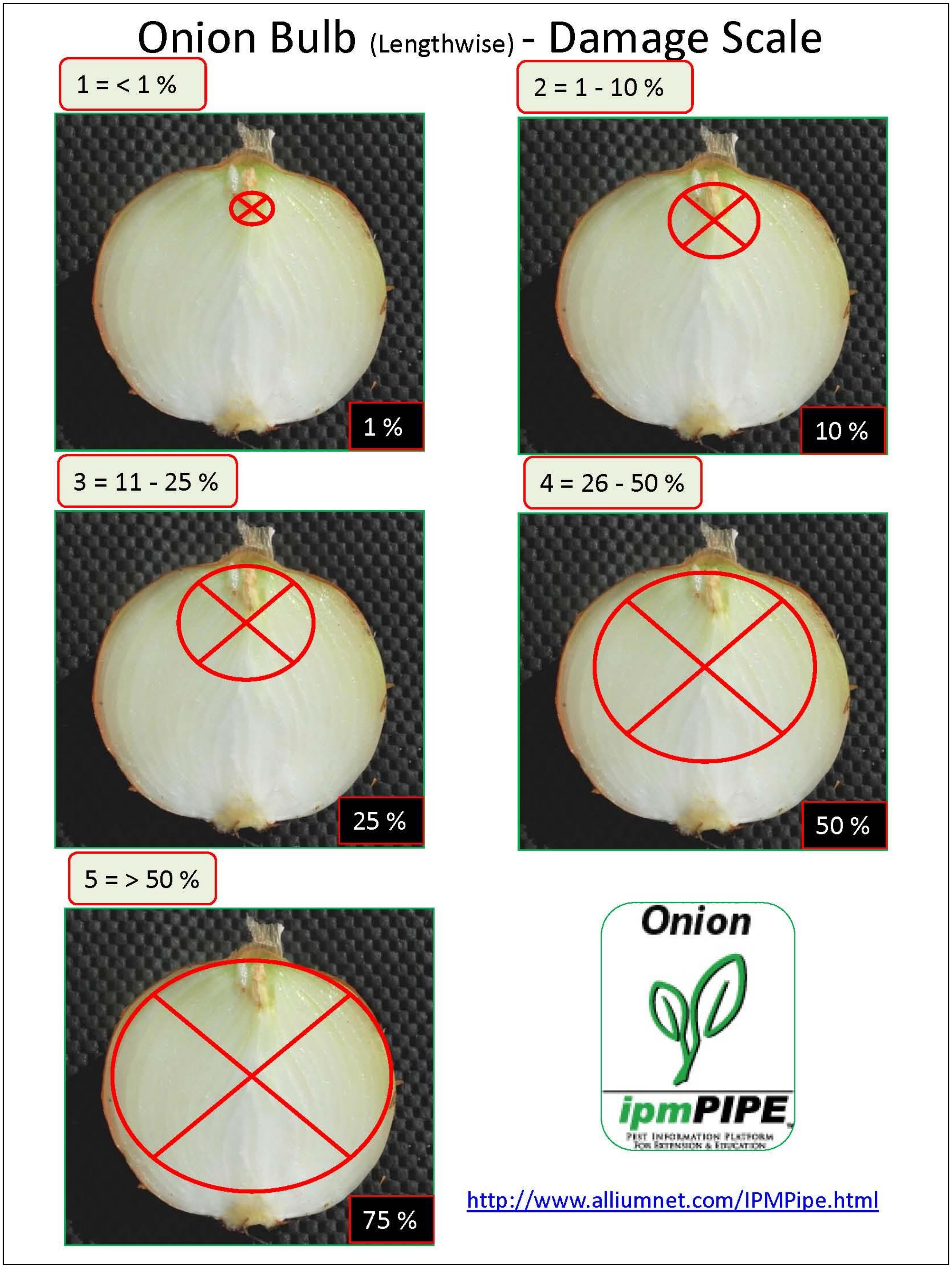


Figure 8. Bulb (lengthwise) damage rating scale.

Pest and Disease Forecast Criteria

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 pest pressure, growers strive to make 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. 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 usually 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 [DOWNCAST], and Botrytis leaf blight [BLIGHT-ALERT, BOTCAST]; as well as for insect pests such as onion maggot and onion thrips. 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 or pest. Disease forecast models integrate these variables to provide growers and crop consultants with a risk potential for diseases and appropriate responses such as including the timely application of registered pesticides and bio-pesticides.

The following series of Onion ipmPIPE pest and disease forecast models (Figures 9 to 13) is intended to serve as guidelines for scouting the onion crop in relation to environmental factors (events, forecasts), crop growth stage, pest and disease history, and presence in local fields or regions to help develop effective scouting calendars and implement timely IPM strategies to minimize damage to the onion crop and its marketability.

Pesticide spraying of an onion field in New York. (Photo courtesy of B. A. Nault, Cornell University)

Thrips & Iris Yellow Spot (*Iris yellow spot virus*) Forecast				
Total rainfall (mm), summarize cumulative rainfall weekly up to 'late bulbing' growth stage				
Less than 2.5 mm [4]	2.5 –12.5 mm [3]	12.6 – 25.4 mm [2]	More than 25.4 mm [1]	
Daily high temperature (°C), summarize weekly average up to 'late bulbing' growth stage				
Less than 20°C [1]	20 - 25°C [2]	25.1 - 30°C [3]	More than 30°C [4]	
Humidity (%) or hours of dew or free water on foliage, week average				
>75% (< 24 hrs) [1]	50-75% (< 18 hrs) [2]	25-50% (< 12 hrs) [3]	< 25% (< 6 hrs) [4]	
Forecasted total rainfall (mm), weekly up to 'late bulbing' growth stage				
Less than 2.5 mm [4]	2.5 –12.5 mm [3]	12.6 – 25.4 mm [2]	More than 25.4 mm [1]	
Forecasted daily high temperature (°C) weekly up to 'late bulbing' growth stage				
Less than 20°C [1]	20 - 25°C [2]	25.1 - 30°C [3]	More than 30°C [4]	
Forecasted average wind speed (kph) weekly up to 'late bulbing' growth stage				
Less than 2 kph [1]	2 – 8 kph [2]	8.1 – 16 kph [3]	More than 16 kph [4]	
Onion rotation and/or thrips + initial infection (symptoms) confirmed in the field or nearby onion field				
	No onions for 3 years, and no thrips or IYSV symptoms [1]	Recent onion crop OR thrips / IYSVsymptoms nearby [2]	Recent onion crop AND thrips/IYSV symptoms nearby [4]	
Varietal reaction to thrips and/or IYSV				
	Resistant [1]	Unknown [2]	Susceptible [4]	
Crop height (vigor)				
0 - 30 cm [1]	30.1 - 60 cm [2]	60.1 - 90 cm [3]	>90 cm [4]	
Irrigation practice/schedule				
	Drip-line [4]	Furrow or gated pipe [2]	Sprinkler or centre pivot [1]	
Total **irrigation water applied** (mm), summarize weekly total (starting at 4-5 pairs of true leaves) **ASSUMPTION**: daily water use = 6.35 mm applied by furrow, drip or sprinkler system				
More than 55 mm [1]	45.1 - 55 mm [2]	35 - 45 mm [3]	Less than 35 mm [4]	
Total **Nitrogen** Fertilizer applied (kg/ha), total from split applications until following stage **ASSUMPTION**: maximum rate of 280 - 336 kg/ha applied + carryover				
bulb initiation [1]	bulb diam < 2.5 cm [2]	bulb diam > 2.5 cm [3]	bulb diam > 7.5 cm [4]	
Onion Thrips and Iris Yellow Spot Risk – TOTAL SCORE				0

Onion ipmPIPE

High risk = > 30
Medium risk = 20 -30
Low risk = < 20

If the susceptible variety is planted in a field or region with a history of thrips / disease and the total score was 20 or higher (moderate to high risk), treatment with a labeled conventional insecticide or biopesticide (adjuvant, adequate gallonage, good coverage) and plant protectant (e.g., Actigard) should be considered during the mid vegetative (4 to 6 weeks pre-bulbing)) to the mid bulbing growth stages. Follow a 7 to 14 day interval between sprays, depending upon thrips pressure and forecasted weather conditions, and rotate pesticide classes and chemistry. Pesticide Information available at: http://www.highplainsipm.org/

_[Strategy adapted by Onion ipmPIPE personnel and collaborators from South Africa – Fall 2011]

Figure 9. Thrips and *Iris yellow spot virus* forecast model.

Purple Blotch (*Alternaria porri*) Forecast				
Total rainfall (mm), summarize cumulative rainfall weekly up to 'late vegetative' growth stage				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	12.6 – 25.4 mm [3]	More than 25.4 mm [4]	
Daily high temperature (°C), week average up to 'late vegetative' growth stage				
Less than 18°C [1]	18.1 – 22°C [3]	22.1 – 28°C [4]	More than 28°C [2]	
Humidity (%) or hours of dew or free water on foliage, week average				
0-25% (< 6 hrs) [1]	25.1-50% (< 12 hrs) [2]	50.1-75% (< 18 hrs) [3]	>75% (< 24 hrs) [4]	
Forecasted total rainfall (mm), weekly between 'late vegetative' and 'late bulbing' growth stages				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	12.6 – 25.4 mm [3]	More than 25.4 mm [4]	
Forecasted daily high temperature (°C), weekly average between 'late vegetative' and 'late bulbing' growth stages				
Less than 18°C [1]	18 – 22°C [3]	22.1 – 28°C [4]	More than 28°C [2]	
Forecasted average wind speed (kph), weekly between 'late vegetative' and 'late bulbing' growth stages				
Less than 2 kph [4]	2 – 8 kph [3]	8.1 – 16 kph [2]	More than 16 kph [1]	
Onion rotation of less than 3 years and/or initial infection (symptoms) confirmed in the field or nearby onion field				
	No onions for 3 years, and no purple blotch symptoms [1]	Recent onion crop OR purple blotch symptoms nearby [2]	Recent onion crop AND purple blotch symptoms nearby [4]	
Varietal reaction to the fungal disease threat				
	Resistant [1]	Unknown [2]	Susceptible [4]	
Crop height (vigor)				
0 - 30 cm [1]	30.1 - 60 cm [2]	60.1 -90 cm [3]	>90 cm [4]	
Irrigation practice/schedule between 'bulbing' growth stage to 'dry down' (pre-harvest)				
	Drip-line [1]	Furrow or gated pipe [2]	Sprinkler or centre pivot [4]	
Total **irrigation water applied** (mm), summarize weekly total (starting at 4-5 pairs of true leaves) **ASSUMPTION**: daily water use = 6.35 mm applied by furrow, drip or sprinkler system				
Less than 35 mm [1]	35.1 - 45 mm [2]	45.1 -55 mm [3]	More than 55 mm [4]	
Total **Nitrogen** Fertilizer applied (kg/ha), total from split applications until following stage **ASSUMPTION**: maximum rate of 280 - 336 kg/ha applied + carryover				
bulb initiation [1]	bulb diam < 2.5 cm [2]	bulb diam > 2.5 cm [3]	bulb diam > 7.5 cm [4]	
			Onion Disease Risk – TOTAL SCORE	0

High risk = > 30
Medium risk = 20 -30
Low risk = < 20

If the susceptible variety is planted in a field or region with a history of fungal disease(s) and the total score was 20 or higher (moderate to high risk), treatment with a labeled fungicide (adjuvant, adequate gallonage, good coverage) as a protectant should be considered during the late vegetative (2 to 3 weeks pre-bulbing)) to the late bulbing (cropping or dry down) growth stages. Follow a 5 to 10 day interval between sprays, depending upon disease pressure and forecasted weather conditions. Pesticide Information available at: http://www.highplainsipm.org/ [Strategy adapted by Onion ipmPIPE personnel and collaborators from South Africa – Fall 2011]

Figure 10. Purple blotch forecast model.

Downy Mildew (*Peronospora destructor*) and Botrytis Leaf Blight (*Botrytis squamosa*) Forecast

Total rainfall (mm), summarize cumulative rainfall weekly (starting at 4-5 pairs of true leaves)				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	12.6 – 25.4 mm [3]	More than 25.4 mm [4]	
Daily high temperature (°C), summarize weekly (starting at 4-5 pairs of true leaves)				
Less than 18°C [4]	18 – 22°C [3]	22.1 – 28°C [2]	More than 28°C [1]	
Humidity (%) or hours of dew or free water on foliage, week average				
0-25% (< 6 hrs) [1]	25.1-50% (< 12 hrs) [2]	50.1-75% (< 18 hrs) [3]	>75% (< 24 hrs) [4]	
Forecasted total rainfall (mm) weekly (starting at 4-5 pairs of true leaves)				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	12.6 – 25.4 mm [3]	More than 25.4 mm [4]	
Forecasted daily high temperature (°C) weekly (starting at 4-5 pairs of true leaves)				
Less than 18°C [4]	18 – 22°C [3]	22.1 – 28°C [2]	More than 28°C [1]	
Forecasted average wind speed (m/sec) weekly (starting at 4-5 pairs of true leaves)				
Less than 2 kph [4]	2 - 8 kph [3]	8.1 - 16 kph [2]	More than 16 kph [1]	
Onion rotation of less than 3 years and/or initial fungal infection (symptoms of disease) confirmed in the field or a nearby onion field				
	No onions for 3 years, no disease symptoms [1]	Recent onion crop OR disease symptoms nearby [2]	Recent onion crop AND disease symptoms nearby [4]	
Varietal reaction to the fungal disease threat				
	Resistant [1]	Unknown [2]	Susceptible [4]	
Crop height (vigor)				
0 - 30 cm [1]	30.1 - 60 cm [2]	60.1 - 90 cm [3]	>90 cm [4]	
Irrigation practice/schedule between 'bulbing' growth stage to 'dry down' (pre-harvest)				
	Drip-line [1]	Furrow or gated pipe [2]	Sprinkler or centre pivot [4]	
Total **irrigation water applied** (mm), summarize weekly total (starting at 4-5 pairs of true leaves) **ASSUMPTION**: daily water use = 6.35 mm applied by furrow, drip or sprinkler system				
Less than 35 mm [1]	35.1 - 45 mm [2]	45.1 -55 mm [3]	More than 55 mm [4]	
Total **Nitrogen** Fertilizer applied (kg/ha), total from split applications until following stage **ASSUMPTION**: maximum rate of 280 - 336 kg/ha applied + carryover				
bulb initiation [1]	bulb diam < 2.5 cm [2]	bulb diam > 2.5 cm [3]	bulb diam > 7.5 cm [4]	
			Onion Disease Risk – TOTAL SCORE	0

Onion ipmPIPE

High risk = > 30
Medium risk = 20 -30
Low risk = < 20

If the susceptible variety is planted in a field or region with a history of fungal disease(s) and the total score was 20 or higher (moderate to high risk), treatment with a labeled fungicide (adjuvant, adequate gallonage, good coverage) as a protectant should be considered during the late vegetative (2 to 3 weeks pre-bulbing)) to the late bulbing (cropping or dry down) growth stages. Follow a 5 to 10 day interval between sprays, depending upon disease pressure and forecasted weather conditions. Pesticide Information available at: http://www.highplainsipm.org/ [Strategy adapted by Onion ipmPIPE personnel and collaborators from South Africa – Fall 2011]

Figure 11. Downy mildew and Botrytis blast forecast model.

Bacterial Foliar and/or Storage Rots Forecast

(*Burkholderia cepacia* , *Burkholderia gladioli* **pv.** *alliicola* , *Dickeya* , *Entobacter cloacae* ,

Total rainfall (mm), summarize cumulative rainfall weekly from 'late bulbing' growth stage				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	12.6– 25.4 mm [3]	More than 25.4 mm [4]	
Daily high temperature (°C), summarize weekly avergae from 'late bulbing' growth stage				
Less than 18°C [1]	18 – 23°C [2]	23.1 – 30°C [3]	More than 30°C [4]	
Humidity (%) or hours of dew or free water on foliage, week average				
0-25% (< 6 hrs) [1]	25.1 - 50% (< 12 hrs) [2]	50.1 - 75% (< 18 hrs) [3]	>75% (< 24 hrs) [4]	
Forecasted total rainfall (mm), weekly from 'late bulbing' growth stage				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	12.6 – 25.4 mm [3]	More than 25.4 mm [4]	
Forecasted daily high temperature (°C), weekly average from 'late bulbing' growth stage				
Less than 18°C [1]	18 – 23°C [2]	23.1 – 30°C [3]	More than 30°C [4]	
Forecasted average wind speed (kph), weekly from 'late bulbing' growth stage				
Less than 2 kph [4]	2 – 8 kph [3]	8.1 – 16 kph [2]	More than 16 kph [1]	
Onion rotation of less than 3 years and/or symptoms of bacterial infection in the field or a nearby onion field or cull pile				
	No onions for 3 years, no symptoms of bacterial diseases in onion fields, and no cull piles nearby [1]	Recent onion crop OR bacterial foliar or soft rot symptoms in nearby onion fields or cull piles [2]	Recent onion crop AND symptoms of bacterial diseases in nearby onion crops or cull piles [4]	
Varietal reaction to the bacterial disease threat				
	Resistant [1]	Unknown [2]	Susceptible [4]	
Crop height (vigor)				
0 - 30 cm [1]	30.1 - 60 cm [2]	60.1 - 90 cm [3]	>90 cm [4]	
Irrigation practice/schedule between 'bulbing' growth stage to 'dry down' (pre-harvest)				
	Drip-line [1]	Furrow or gated pipe [2]	Sprinkler or centre pivot [4]	
Total **irrigation water applied** (mm), summarize weekly total (starting at 4-5 pairs of true leaves) **ASSUMPTION**: daily water use = 6.35 mm applied by furrow, drip or sprinkler system				
Less than 35 mm [1]	35 - 45 mm [2]	45.1 -55 mm [3]	More than 55 mm [4]	
Total **Nitrogen** Fertilizer applied (kg/ha), total from split applications until following stage **ASSUMPTION**: maximum rate of 280 - 336 kg/ha applied + carryover				
bulb initiation [1]	bulb diam < 2.5 cm [2]	bulb diam > 2.5 cm [3]	bulb diam > 7.5 cm [4]	
			Onion Disease Risk – TOTAL SCORE	0

Onion ipmPIPE

High risk = > 30
Medium risk = 20 -30
Low risk = < 20

If the susceptible variety is planted in a field or region with a history of bacterial disease(s) and the total score was 20 or higher (moderate to high risk), treatment with a labeled bactericide (adjuvant, adequate gallonage, good coverage) as a protectant should be considered during the late vegetative (2 to 3 weeks pre-bulbing)) to the late bulbing (cropping or dry down) growth stages. Follow a 5 to 10 day interval between sprays, depending upon disease pressure and forecasted weather conditions. Pesticide Information available at: http://www.highplainsipm.org/ [Strategy adapted by Onion ipmPIPE personnel and collaborators from South Africa – Fall 2011]

Figure 12. Bacterial disease forecast model.

Botrytis Neck Rot (*Botrytis aclada* , *B. allii* , *B. byssoidea*) Forecast

Total rainfall (mm), summarize cumulative rainfall weekly from 'late bulbing' growth stage				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	12.6– 25.4 mm [3]	More than 25.4 mm [4]	
Daily high temperature (°C), summarize weekly from 'late bulbing' growth stage				
Less than 18°C [4]	18 – 23°C [3]	23.1 – 30°C [2]	More than 30°C [1]	
Humidity (%) or hours of dew or free water on foliage, week average				
0-25% (< 6 hrs) [1]	25.1-50% (< 12 hrs) [2]	50.1-75% (< 18 hrs) [3]	>75% (< 24 hrs) [4]	
Forecasted total rainfall (mm), weekly from 'late bulbing' growth stage				
Less than 2.5 mm [1]	2.5 – 12.5 mm [2]	2.6– 25.4 mm [3]	More than 25.4 mm [4]	
Forecasted daily high temperature (°C), weekly from 'late bulbing' growth stage				
Less than 18°C [4]	18 – 23°C [3]	23.1 – 30°C [2]	More than 30°C [1]	
Forecasted average wind speed (kph), weekly from 'late bulbing' growth stage				
Less than 2 kph [4]	2 – 8 kph [3]	8.1 – 16 kph [2]	More than 16 kph [1]	
Onion rotation of less than 3 years and/or *Botrytis* sporulation confirmed in the field or a nearby onion field or cull pile				
	No onions for 3 years, no evidence of *Botrytis* sporulation in fields, and no cull piles nearby [1]	Recent onion crop OR *Botrytis* sporulation in nearby onion field or cull pile [2]	Recent onion crop AND *Botrytis* sporulation in nearby onion crop or cull pile [4]	
Varietal reaction to the fungal disease threat				
	Resistant [1]	Unknown [2]	Susceptible [4]	
Crop height (vigor)				
0 - 30 cm [1]	30.1 - 60 cm [2]	60.1 - 90 cm [3]	>90 cm [4]	
Irrigation practice/schedule between 'bulbing' growth stage to 'dry down' (pre-harvest)				
	Drip-line [1]	Furrow or gated pipe [2]	Sprinkler or centre pivot [4]	
Total **irrigation water applied** (mm), summarize weekly total (starting at 4-5 pairs of true leaves) **ASSUMPTION**: daily water use = 6.35 mm applied by furrow, drip or sprinkler system				
Less than 35 mm [1]	35 - 45 mm [2]	45.1 -55 mm [3]	More than 55 mm [4]	
Total **Nitrogen** Fertilizer applied (kg/ha), total from split applications until following stage **ASSUMPTION**: maximum rate of 280 - 336 kg/ha applied + carryover				
bulb initiation [1]	bulb diam < 2.5 cm [2]	bulb diam > 2.5 cm [3]	bulb diam > 7.5 cm [4]	
			Onion Disease Risk – TOTAL SCORE	0

Onion ipmPIPE

High risk = > 30
Medium risk = 20 -30
Low risk = < 20

If the susceptible variety is planted in a field or region with a history of fungal disease(s) and the total score was 20 or higher (moderate to high risk), treatment with a labeled fungicide (adjuvant, adequate gallonage, good coverage) as a protectant should be considered during the late vegetative (2 to 3 weeks pre-bulbing)) to the late bulbing (cropping or dry down) growth stages. Follow a 5 to 10 day interval between sprays, depending upon disease pressure and forecasted weather conditions. Pesticide Information available at: http://www.highplainsipm.org/ [Strategy adapted by Onion ipmPIPE personnel and collaborators from South Africa – Fall 2011]

Figure 13. Botrytis neck rot forecast model.

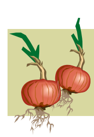
General Management Recommendations - The objective of pest management for cultivated plants such as onions is to limit economic losses and protect the value of the crop. Management measures are justified to the extent that their cost, in terms of money and effort, is less than losses caused by the problem. The control measures chosen must also be compatible with production systems, marketing objectives, and consumer preferences. Because it generally is easier and more advantageous to prevent pests than to eliminate them, crop sanitation always should be practiced. Methods include: crop rotation; selection of resistant varieties; use of appropriate cultural practices to reduce plant stress and/or not to favor pest spread and development; soil fumigation; and pesticide treatment of seed, soil and foliage. Foliage protection, especially during the last few weeks of crop development, is important to achieve acceptable bulb size, yield and quality.

Table 4a. Pest Management Activities typical for Spring-Seeded Onion Crops in Western and Northern U.S. Onion Production Regions.

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

Table 4b. Pest Management Activities for Southern and Southeastern U.S. Onion Production Regions.

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



ONION HEALTH MANAGEMENT & PRODUCTION

The most common management practices for onion diseases includes the use of: disease-resistant cultivars, pathogen-free seed and bulbs, and other cultural practices (e.g., crop rotation and crop residue management) that suppress the pathogen or restrict the ability of pathogens to spread to or infect the plant. Another common avenue of disease management is the treatment of soil, seed, or crop with chemical pesticides and bio-pesticides. The most effective and sustainable management of onion diseases is obtained when several disease management methods are integrated with the onion production practices. The remainder of this publication reviews individual pest management problems and management recommendations based upon research results from university sources and other resources. Always consult chemical labels and updated guidelines for specific pesticides and application rate; and regularly calibrate pesticide application equipment to ensure proper and accurate delivery.

Onion IPM Tactics:

- ✓ Rotate to exclude susceptible hosts (i.e., onion volunteers, weeds) for 3 + years; examples of non-host crops include small grains and corn.
- ✓ Avoid planting in fields with a history of disease during the last 3 years or near cull piles.
- ✓ Plant resistant or less susceptible varieties if available.
- ✓ Follow recommended plant populations based on in-row and between-row plant spacing.
- ✓ Test the soil and use a moderate fertility program. Do not apply nitrogen post-bulb as this can aggravate disease losses.
- ✓ Incorporate fall and/or spring tillage to eliminate carryover debris, cull piles and volunteer onions (bulbs) in the previous year's onion fields.
- ✓ Promote root health and good soil drainage. Assure good air flow between onion lines and rows in onion fields.
- ✓ Monitor irrigation scheduling to avoid splashing and canopy saturation over prolonged periods.
- ✓ Utilize scouting, disease forecasting, and weather monitoring services.
- ✓ When justified, use timely applications of recommended fungicides at the late vegetative growth stage, and maintain protection throughout bulbing until cropping and dry-down.
- ✓ Cure onion tops well in the field, and keep bulbs dry and cool in storage

WEEDS & THEIR MANAGEMENT

By S. Nissen and T. Waters

A wide range of broadleaf and grass weed types are found in the U.S. onion-growing regions (see examples in Appendix IV). 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, venice mallow and kochia, are particularly problematic (see Table 5 for a list of weed common names and Latin bionomials). Fields heavily infested with perennial weeds should not be planted to onions. The more common weeds that concern onion producers include: barnyardgrass, foxtails, bindweed, yellow nutsedge, kochia, lambsquarters, black nightshade, pigweed, ragweed, and Russian thistle.

Parasitic plants such as dodder germinate from seeds and possess leaves and roots. They do not photosynthesize, but feed on other plants such as onions by producing pegs (haustoria) which penetrate the host plant tissue. Dodder lacks chlorophyll and is usually yellow or orange in color, appearing like strings within and on the top of plant canopies. The plant is spread by seed and tissue pieces during cultivation or other human activities. An integrated approach to weed control in onion crops 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 that an onion crop is 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 the 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, particularly in the northern tier states. Weeds that germinate during the winter can be controlled with a non-selective herbicide prior to planting onions. In some areas, broad spectrum herbicides 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. When using pre-emergent herbicides, 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 applied too deep, the product will be out of the area where the weeds geminate and may be in direct contact with the onion seed, which can cause injury.

Table 5. List of weeds commonly encountered in onion production; see selected illustrations of common weeds in Appendix IV.

Common Name	**Scientific Name**
Barnyardgrass	*Echinochloa crus-galli*
Bermudagrass	*Cynodon dactylon*
Bluegrass	*Poa annua*
Bristly starbur	*Acanthospermum hispidum*
Broadleaf signalgrass	*Brachiaria platyphylla*
Buffalobur	*Solanum rostratum*
Canada thistle	*Cirsium arvense*
Carolina geranium	*Geranium carolinianum*
Carpetweed	*Mollugo verticillata*
Clover	*Trifolium* species

Common chickweed	*Stellaria media*
Common cocklebur	*Xanthium strumarium*
Common fumitory	*Fumaria officinalis*
Common mallow	*Malva neglecta*
Common purslane	*Portulaca* species
Common ragweed	*Ambrosia artemisiifolia*
Corn spurry	*Spergula arvensis*
Crabgrass	*Digitaria* species
Cudweed	*Gnaphalium* species
Curly dock	*Rumex crispus*
Cutleaf evening primrose	*Oenothera laciniata*
Dandelion	*Taraxacum officinale*
Dodder	*Cuscuta* species
Field bindweed	*Convolvulus arvensis*
Field sandbur	*Cenchrus incertus*
Florida beggarweed	*Desmodium tortuosum*
Florida pusley	*Richardia scabra*
Foxtail, green	*Setaria viridis*
Foxtail, yellow	*Setaria glauca*
Henbit	*Lamium amplexicaule*
Horsetail, field	*Equisetum arvense*
Horseweed	*Conyza canadensis*
Knotweed, prostrate	*Polygonum aviculare*
Kochia	*Kochia scoparia*
Ladysthumb	*Polygonum persicaria*
Lambsquarters	*Chenopodium album*
Mayweed chamomile (dog fennel)	*Anthemis cotula*
Mustards	Various species
Nightshade, black	*Solanum nigrum*
Nightshade, hairy	*Solanum sarrachoides*
Pigweed, prostrate	*Amaranthus blitoides*
Pigweed, redroot	*Amaranthus retroflexus*
Puncturevine	*Tribulus terrestris*
Quackgrass	*Elytrigia repens*
Russian thistle	*Salsola iberica*
Shepherd's-purse	*Capsella bursa-pastoris*
Smartweed	*Polygonum* species
Spurge, prostrate	*Chamaesyce maculata*
Spurge, toothed	*Euphorbia dentata*
Sunflower	*Helianthus annuus*
Velvetleaf	*Abutilon theophrasti*
Venice mallow	*Hibiscus trionum*
Volunteer cereals (wheat, rye)	Various species
Volunteer vegetables	Various species
Wild proso millet	*Panicum* species
Yellow nutsedge	*Cyperus esculentus*

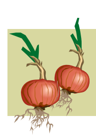


Table 6a. Common Weeds in Western and Northern U.S. Onion Production Regions.

Common Name	J	F	M	A	M	J	J	A	S	O	N	D
Barnyardgrass				X	X	X	X	X				
Buffalobur				X	X	X	X					
Canada thistle		X	X	X	X	X	X	X				
Clover			X	X	X	X	X	X				
Common chickweed					X	X	X					
Common mallow			X	X	X	X	X	X				
Common purslane			X	X	X	X	X	X				
Common ragweed					X	X	X	X				
Crabgrass			X	X	X	X	X	X				
Dodder			X	X	X	X	X	X				
Field bindweed		X	X	X	X	X	X	X	X			
Field sandbur				X	X	X	X	X				
Foxtail, green			X	X	X	X	X	X	X			
Foxtail, yellow				X	X	X	X	X	X			
Horsetail					X	X	X					
Knotweed, prostrate					X	X	X					
Kochia		X	X	X	X	X	X	X	X			
Ladysthumb					X	X	X	X				
Lambsquarters			X	X	X	X	X	X				
Mayweed chamomile					X	X	X					
Mustards			X	X	X	X						
Nightshade, black			X	X	X	X	X	X				
Nightshade, hairy			X	X	X	X	X	X				
Pigweed, prostrate			X	X	X	X	X	X				
Pigweed, redroot			X	X	X	X	X	X				
Puncturevine									X	X		
Quackgrass					X	X	X	X				
Russian thistle			X	X	X	X	X	X				
Shepherd's-purse			X	X	X	X	X					
Smartweed					X	X	X	X				
Spurge, prostrate				X	X	X	X	X				
Spurge, toothed					X	X	X	X				
Sunflower					X	X	X					
Velvetleaf					X	X	X					
Venice mallow				X	X	X	X					
Volunteer cereals		X	X	X	X	X	X	X				
Volunteer vegetables		X	X	X	X	X	X	X				
Wild proso millet				X	X	X	X	X				
Yellow nutsedge									X	X		

Table 6b. Common Weeds in Southern and Southeastern U.S. Onion Production Regions.

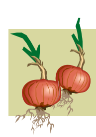
Common Name	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bermudagrass			■	■	■	■	■	■	■	■	■	
Bluegrass	■	■	■	■	■				■	■	■	■
Bristly starbur				■	■	■	■	■	■	■		
Broadleaf signalgrass				■	■	■	■	■	■	■		
Carolina geranium	■	■	■	■	■				■	■	■	■
Carpetweed				■	■	■	■	■	■	■		
Common chickweed	■	■	■	■	■				■	■	■	■
Common cocklebur				■	■	■	■	■	■	■		
Common fumitory	■	■	■	■	■				■	■	■	■
Common purslane				■	■	■	■	■	■	■		
Common ragweed			■	■	■	■	■	■	■	■		
Corn spurry	■	■	■	■	■				■	■	■	■
Crabgrass				■	■	■	■	■	■	■		
Cudweed	■	■	■	■	■				■	■	■	■
Curly dock	■	■	■	■	■				■	■	■	■
Cutleaf evening primrose	■	■	■	■	■				■	■	■	■
Dandelion	■	■	■	■	■				■	■	■	■
Florida beggarweed				■	■	■	■	■	■			
Florida pusely				■	■	■	■	■	■			
Henbit	■	■	■	■	■				■	■	■	■
Mayweed chamomile (dog fennel)			■	■	■	■	■	■	■	■	■	

Weed Effects

Because onions develop relatively little leaf area or ground cover during the growing season, weeds cause greater yield and quality losses in onions than in most other crops. Onion yields are reduced from very early season weed competition as well as late emerging weeds. Onions compete poorly with weeds because they grow slowly early in the season compared to cool-season weeds such as kochia and lambsquarters. Weeds reduce onion net economic return by reducing both total yield per acre and the size of individual onions. Smaller sized onions reduce crop value.

Heavy weed pressure in an onion field can reduce the amount of insecticide and fungicide that reaches the onion canopy, thereby reducing the performance of these pesticides. Weeds also can serve as alternate hosts for insect and disease pests of onions. Additionally, heavy weed pressure may hinder harvest operations by clogging machines or otherwise disrupting undercutting of the crop. Heavy weed pressure can also prevent onion tops from falling which hinders proper field curing of the bulbs prior to harvest and long term storage.

Avoid planting onions in fields with a history of heavy weed pressure. A high weed seed bank level combined with poor onion competition against weeds dictates that an onion producer will need to develop a very intensive weed management program. Crop rotations that provide good weed control one or two seasons before planting onions will set the stage for more effective weed management in the onion crop.



Weed Management

Timely cultivations and hand weeding can help provide effective weed control in onions. Weeds in irrigation furrows often can be controlled with early-season cultivations. Late-season hand weeding can remove large weeds that could interfere with harvesting operations. A well-integrated onion weed management program will include effective prior crop rotation, as well as effective mechanical and chemical weed control.

Perennial weeds such as field bindweed and Canada thistle cannot be controlled effectively in onions. Perennial weeds need to be controlled in other rotational crops such as corn or barley. Fields severely infested with perennial weeds should not be used for onion production.

Chemical weed control is dependent on pre-emergence and post-emergence application of herbicides. A 0.5 acre inch of moisture or overhead irrigation within two weeks of application may be needed for best results with some of these early herbicide applications. Some herbicides are labeled for use as post-emergence treatments in onions between the 2- to 9-true leaf stages. Irrigation is needed to move the herbicide into the portion of the soil where weed seeds germinate.

When herbicides are applied, the following are suggested: do not apply herbicides with other pesticides; avoid covering exposed bulbs with herbicide-treated soil when incorporating herbicides; check the product label for application restrictions during warm, sunny days with low humidity so that the thick onion leaf cuticle will minimize leaf tissue injury; and avoid herbicide application when dew is present on the onion leaves or if onions have recently been injured by sand, insects, or disease.

Other weed management strategies can include: flaming directed to actively growing grass or broadleaf weeds prior to cultivating the soil for planting; deep tillage to bury seed of small-seeded weeds and prevent seed germination, although this is only effective if the rest of the soil profile is relatively free of weeds; shallow cultivation to destroy newly germinated annual weeds; Planting rotational crops that allow the use of herbicides effective for controlling perennial or problematic weeds; and Planting a cover crop to help prevent weed seed germination and to compete against weeds.

NEMATODES & THEIR MANAGEMENT

By H. F. Schwartz

Nematodes are categorized as either ecto-parasitic (those that feed externally on roots) or endo-parasitic (those that penetrate roots and feed internally); both types are considered pests of onions. Population levels of these nematodes prior to planting are one of the factors to be considered while implementing management options. Usually, the number of nematodes will be greater in fields following a rotation of alfalfa, corn, potatoes, vegetables, cereals, or grasses. High populations can limit bulb yield, quality, and vigor significantly; the severity of damage depends on the species of nematode present and nematode population densities in the soil at the time of planting. Pre-plant soil sampling and testing can determine the occurrence and distribution of the nematodes. Since nematode distribution is seldom uniform and can change rapidly, one of the primary components in determining nematode populations is the collection of representative soil samples from fields prior to planting.

Management strategies include: controlling weeds because weeds may act as an alternate host and reservoir for numerous nematode species, so weed control can help reduce nematode populations and thus reduce damage from nematodes; avoiding rotations that include mint, cereals, alfalfa, garlic, corn, or grasses; planting nematode-resistant cultivars of alfalfa or beans in rotation with onions, which can reduce the damage considerably caused by nematodes; and planting green manure crops (crops that are incorporated into the soil while still green to release bio-fumigants called glucosinolates) which can be used early during the pre-plant stage to promote beneficial organisms and suppress nematode populations.

Table 7. Nematodes Associated with or Reported to Attack Onion; illustrations in Appendix II.

Common Name	Scientific Name
Lesion	*Pratylenchus penetrans*
Needle	*Longidorus africanus*
Root-knot	*Meloidogyne* species
Stem or bulb	*Ditylenchus dipsaci*
Sting	*Belonolaimus longicaudatus*
Stubby-root	*Paratrichodorus allius, P. minor*

Table 8. Seasonal Occurrence in Western and Northern U.S. Onion Production Regions.

Nematode	J	F	M	A	M	J	J	A	S	O	N	D
Lesion												
Needle												
Root-knot												
Stem or bulb												
Sting												
Stubby-root												

Lesion

Root-lesion nematodes are migratory endo-parasites. They are of concern to onion growers because they reduce yield indirectly by reducing plant vigor and increasing stress on the plants, and 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 of 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.

Northern Root-Knot

Symptoms of damage by this endo-parasitic nematode' include plant stunting, chlorosis (yellowing), wilting, and premature death. Below-ground symptoms include small galls on the roots, and infected plants 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.

Needle

Shoot symptoms include yellowing, stunting and low bulb yield. Root symptoms include excessive branching and swelling of root tips.

Stem or Bulb (Bloat)

The stem or bulb nematode can attack over 400 plant species including alfalfa, onion, bean, soybean, potato and many common weeds. It has been a minor problem on onions in western regions of the U.S.

Infected seedlings become dwarfed, twisted and abnormally white with swollen split areas. Plant stands may be erratic. In older onion bulbs, tissue softens near the top of the bulb and at the base of leaves of stunted plants. Older plants often crack or produce doubles. Secondary breakdown by bacteria and fungi is common. Nematodes survive on seeds, onion debris, weeds and in infected transplants. The pathogen is favored by free moisture and an optimum soil temperature of 70^{o}F. Its life cycle is completed within 23 days at 59^{o}F with four molts and four juvenile stages, and adults live up to 73 days. Damage occurs in many crops at infestation levels as low as 10 nematodes per 500 grams of soil.

Disease management recommendations include: crop rotation out of onion and other host plants for four or more years; debris sanitation and weed control; planting nematode-free seed and transplants; absence of infested soil or contaminated equipment; reduction of stresses such as soil compaction and poor water drainage; and fall fumigation.

Stubby-Root

Stubby-root nematodes are migratory ecto-parasites; they don't enter the onion plant but remain in the soil and feed on the outer surface of roots. Their feeding causes the roots to be short and yellow-brown in color, and plants become stunted. With continued feeding, the root tips become darker, stubby, and more branched, and bulb size may be reduced. Stubby root nematodes have the ability to adapt to unfavorable conditions (e.g., warm summer temperatures) by migrating deep into the soil profile.

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.

INSECTS & THEIR MANAGEMENT

By D. G. Alston, B. Nault, W. S. Cranshaw, J. Hardin, R. Srinivasan and T. Waters

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 (see examples in Appendix I). Although some insects feed upon plants and may become plant pests, the great majority have innocuous or beneficial habits. Armyworms and cutworms are often present prior to planting, but control measures are not usually initiated at that 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, incorporating previous onion crop residues, and destroying cull piles. When economically feasible, maintaining a fallow season for onion fields will also reduce the survival of soil-borne insects that have a limited ability to seek out new hosts.

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

Table 9. Primary Arthropod Pests Affecting Onion; illustrations in Appendix III.

Common Name	**Scientific Name**
Aphid	*Myzus ascalonicus*
Armyworms/cutworms	*Agrotis ipsilon, Peridroma saucia, Spodoptera exigua, S. ornithogalli*
Aster leafhopper	*Macrosteles quadrilineatus*
Brown wheat mite	*Petrobia latens*
Bulb mite	*Rhizoglyphus* species
Bulb fly	*Eumerus strigatus, E. tuberculatus*
Leafminers	*Liriomyza* species
Leek moth	*Acrolepiopsis assectella*
Onion maggot	*Delia antiqua*
Onion thrips	*Thrips tabaci*
Seedcorn maggot	*Delia platura*
Tobacco thrips	*Frankliniella fusca*
Western flower thrips	*Frankliniella occidentalis*
Wireworm	*Elateridae* species

Table 10a. Seasonal Occurrence in Western and Northern U.S. Onion Production Regions.

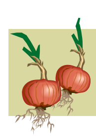
Pest	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aphids					■	■	■	■				
Armyworms/cutworms				■	■	■						
Aster leafhopper					■	■	■					
Brown wheat mite							■	■				
Bulb mite				■	■							
Bulb fly							■	■				
Leafminers					■	■	■	■				
Leek moth							■	■				
Onion maggot			■	■	■	■	■					
Onion thrips					■	■	■	■	■	■		
Seedcorn maggot			■	■	■							
Tobacco thrips						■	■	■	■			
Western flower thrips					■	■	■	■	■	■		
Wireworm			■						■			

Table 10b. Seasonal Occurrence in Southern and Southeastern U.S. Onion Production Regions.

Pest	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Onion thrips		■	■	■								
Seedcorn maggot			■	■						■	■	■
Tobacco thrips		■	■	■								

Armyworms and Cutworms

- Beet armyworm (*Spodoptera exigua*)
- Bertha armywor m *(Mamestra configurata)*
- Black cutworm *(Agrotis ipsilon)*
- Variegated cutworm (*Spodoptera ornithogalli*)
- Yellow striped armyworm (*Spodoptera praefica*)



The larval stage of these lepidopteran insects, in the family Noctuidae, feed on the young leaves of onions as they are growing. The larvae vary in color and range in size from 1 to 2 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 onion 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.

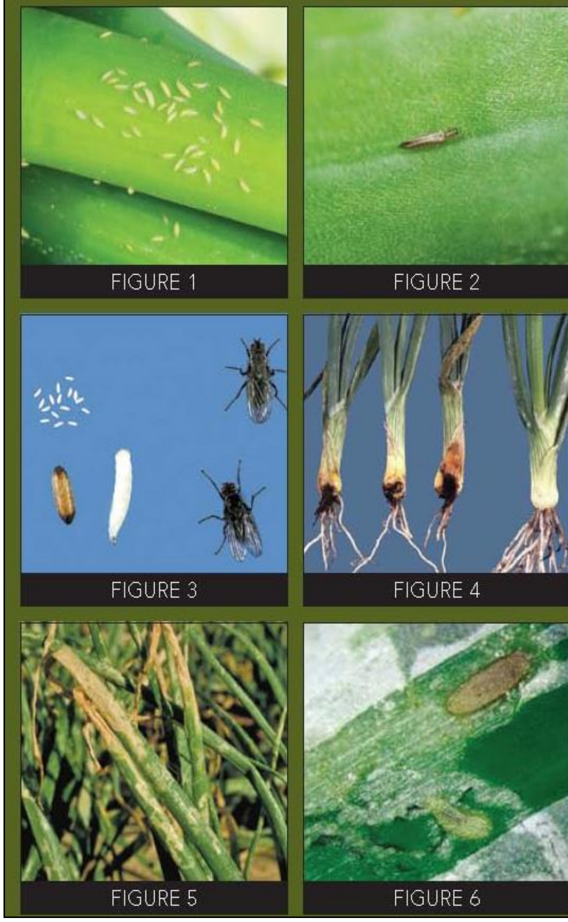
Aster Leafhopper

Nymphs and adults transmit a phytoplasma that causes aster yellows disease. The aster leafhopper transmits the phytoplasma that can affect a large number of cultivated and wild plants including onion, carrot, celery and lettuce. When infected, the youngest onion leaves begin turning yellow at the base, and then become flattened and streaked green and yellow. Most leafhoppers migrate into susceptible crops in the spring on wind currents from the south; however, small populations are known to overwinter in the northern states on plant material. The phytoplasma has a wide host range including many crop and weed species that may act as reservoirs of pathogen inoculum. Frequent aster leafhopper flights in and out of onion crops, and the relatively short residence time in the crop make management difficult.

Populations may be held in check with insecticides applied for the control of onion thrips, and weed control of alternate hosts in and around fields. Adjacent fields should be scouted for leafhoppers and aster yellows. Yellow sticky traps are a good tool to monitor for leafhoppers. Yellow sticky cards can be placed on wooden or wire stakes at the edge of the field on the upwind side at about 12 – 20 inches off the ground.

Onion Insect Pests

Thrips (*Thrips tabaci, Frankliniella* species), Maggots (*Delia antiqua, D. platura*), Leafminers (*Liriomyza species*)



AUTHORS: B. Nault (Cornell University), W. Cranshaw (Colorado State University) & D. Alston (Utah State University) **PHOTOGRAPHS:** Courtesy of B. Nault & J. Ogrodnick (Cornell Univ.), and W . S. Cranshaw & H. F. Schwartz (Colorado State Univ.) [01/2011]

COMMON HOSTS: Onion, Garlic

SYMPTOMS (ON ONION):

FIGURES 1 & 2 • Thrips (onion, western flower) feed primarily on leaves reducing bulb growth. Larvae are 0.5–1 mm (0.02–0.04 inch) long, yellow and elongate (cigar-shaped). Adults (2 mm or 0.8 inch) are winged and darker (gray to brown) in color. Onion thrips transmit Iris yellow spot virus (IYSV).

FIGURES 3 & 4 • Maggot larvae tunnel in roots, seedlings and young bulbs causing reduced stands and stunted plants. Larvae are cream colored and legless (8 mm or 0.3 in long). Adults are brownish gray flies (10 mm or 0.4 in) similar in appearance to a housefly.

FIGURES 5 & 6 • Leafminers are the larvae of small flies that make meandering tunnels under the surface of onion (and other crop) leaves. Flies are small (1.5–2 mm or less than 0.08 inch), and yellow and black. Larvae are pale-colored maggots found only within the leaf mines, and may have pale green or yellow coloration as they become full grown.

FACTORS FAVORING:

- High temperatures greater than 30°C (86°F) favor thrips, while lower temperatures favor maggots.
- Moisture stress (drought) also favors thrips; while excess moisture favors maggots.
- These insect pests are favored by frequent cropping to Alliums (every 3–4 years), early-season planting; and variable plant density (thrips).

Figure 14. Onion Insect Pests (courtesy of Onion ipmPIPE Project).

Maggots

Onion maggot and seedcorn maggot larvae are nearly identical, but can be differentiated morphologically by structures on the posterior end. The seed corn maggot larva is generally smaller than the cream colored onion maggot larva; and is white to whitish yellow, cylindrical, and tapered with the smaller end in front. Both species feed on the roots, below-ground portions and leaves of developing onion plants (Fig. 14). Larval feeding reduces plant vigor and often results in plant death, and plant stand can be reduced substantially if the onions are not protected at planting. Larval feeding also can increase rots when bulbs are placed in storage. Feeding by onion maggot larvae has been implicated in spreading bacteria that cause bacterial soft rot.

Pupae of these insects overwinter in the soil, and adults (flies) emerge in the spring. The onion maggot has three generations per season, whereas the seedcorn maggot has at least three generations in northern states. First-generation larvae are the most damaging to the crop compared with subsequent generations because their damage often results in seedling death. A single larva can destroy up to 30 seedlings and can move between adjacent plants. Onion maggot and seedcorn maggot are most problematic in fields with muck soil and in other soils with high organic content, such as those coming out of pasture or where manure was applied the previous year. Maggot problems are relatively minor in western states; however, in Washington State, fields near rivers that may have a warmer microclimate are more likely to be infested with seedcorn maggot despite a low soil organic matter content. High summer temperatures, dry weather, and low soil organic matter all help reduce maggot outbreaks in the western U.S.

Under most conditions, adequate control of onion-infesting maggots is possible by crop rotation and avoidance of wounds and disease. Planting onions as late as possible will reduce the attractiveness of the onion plant to ovipositing flies and reduce the duration that the crop is exposed to egg laying flies. Planting cannot be delayed too much in the spring, however, because this could reduce the period the onion plant can invest in bulbing, which is necessary to achieve large bulbs. Cull onions can also be a source of maggots and should be removed fully from production fields. Onion crop residues should be chopped and incorporated into the soil as soon as possible after harvest so as not to attract flies. Maggots do not travel far from fields in which the pupae overwinter, so growers should consider the distance when selecting fields for planting onions. Rotating to fields farther from previous onion plantings (at least 0.5 mile) can lessen the likelihood of maggot infestation. Planting onions on raised beds helps warm and drain field soil, which helps reduce maggot infestation. Treatment with insecticides at planting with in-furrow or seed treatments can be a preventive manner; however, plant injury (phytotoxicity) may occur from some onion maggot insecticides applied to soils with low organic matter.


Onion maggot damage to bulb (Photos courtesy of B. A. Nault, Cornell University)

Thrips

The onion thrips is prevalent from early vegetative stages (3- to 4-leaf stage) until harvest in nearly all onion-production regions in the U.S. In some western U.S. locations, western flower thrips is common toward the end of the vegetative growth period (closer to when onion bulbs are forming). In the southeastern U.S., tobacco thrips is the most common pestiferous thrips species. Thrips species that attack onions are very similar in appearance and they are difficult to distinguish without the use of a microscope. The adults are very small, slender insects (2 mm or 0.08 inches long) with two pairs of wings fringed with long hairs; they are pale yellow to light brown in color (Fig. 14). 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. When onion plants are small, adults and larvae feed under the leaf folds and in the protected inner leaves of the neck near the onion bulb. As populations build, thrips will feed on all portions of the leaf, but still tend to aggregate on the newer, emerging leaves. Feeding reduces chlorophyll content of the leaves, with the result that the plants take on a silvery appearance. Damage also occurs to the onion bulb, with thrips infesting the bulb beneath the dry scales, potentially promoting decay losses during storage and causing cosmetic damage to the outer scales that is particularly noticeable on red cultivars. Thrips are difficult to control because they live in tight spaces and cracks between plant structures. They also have a short reproductive cycle and high fecundity that allows them to produce multiple generations in a season, produce several protected life stages (eggs within leaves and prepupae in the soil), attack a wide host range, and are very mobile as adults.

Onion thrips and tobacco thrips have been documented as vectors for *Iris yellow spot virus* (IYSV). IYSV can reduce plant and bulb size and can cause plant death. Once a thrips larva obtains the virus during feeding, it remains infective for the rest of its life as it moves between host plants.

Rainfall is the most important natural control of onion thrips. Thrips may be crushed by rain drops (or overhead irrigation water) and pupae can be trapped by crusting soils. Thrips problems tend to be greatest following extended periods of hot, dry weather. Some insects prey on onion thrips, such as predatory thrips, minute pirate bugs and big-eyed bugs. Predator populations typically do not increase until later in the season when economic losses from thrips feeding have already occurred. Growers sometimes avoid planting onions near grain fields as a way to reduce thrips migrating from drying cereal fields. Applying reduced levels of nitrogen to the onion crop may delay the time onions are colonized by thrips and may reduce the size of the population during the season. This tactic has other benefits (less expensive, and may reduce excess nitrogen in the environment) and should be used with other management practices. The impact and degree of thrips damage varies depending on the varieties, but varietal selection is not very effective as a stand-alone approach in controlling thrips populations or preventing damage. Straw mulch provides protection for beneficial insects and, when used in combination with a bio-pesticide, may help reduce thrips populations. This strategy may be more feasible for small plantings of onions, as time and labor for spreading mulch can be expensive.

Crop rotation can also be used as a thrips management strategy. Avoiding consecutive years of onion production in a field and growing corn before onion can reduce thrips populations. Corn is a major nitrogen user and depletes the amount of nitrogen carried to the following year when onions are planted, compared to wheat. Within a season, thrips densities were greatest on alfalfa, moderate on wheat, and least on corn when fields adjacent to onion were sampled for thrips populations. Weeds have also been shown to be reproductive hosts for onion thrips, and can contribute to thrips populations within and across (over winter) seasons.

Resistance of thrips to insecticides has become an increasingly severe problem in recent years. The problem of insecticide resistance is likely to increase in the future and is the most serious threat to long-term management of this insect. It is, therefore, important that onion growers undertake management practices that slow resistance development. This includes: 1) using insecticides only when needed, based on field surveys; and 2) rotating between insecticide chemical classes (but not in combination!). When used in combination with other cultural management approaches, such as crop rotation, reduced nitrogen application rates, selection of cultivars that are less susceptible to damage by thrips, and weed management within and adjacent to fields, onions can be grown in a more sustainable manner with less thrips population pressure.

Vegetable Leafminer

The vegetable leafminer is occasionally associated with onion as it is with most vegetable crops. However, under the proper conditions it can become a significant pest, particularly for green onions.

Damage to this latter crop includes uneven crop growth, which affects harvest, and direct destruction of marketed parts of the plants. Damage is caused by larvae, which form meandering (serpentine) mines under the surface of the leaf (Fig 14). These wounds frequently girdle the leaf, causing tip dieback. 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 0.25 inches long when mature. Eggs are white, cylindrical, and laid singly or in small groups. Reportedly, optimal temperatures for development are near 75°F, and in some regions the leafminer has been a late-season pest. Pupation has been observed to occur both within the leaf mine or, more commonly, in the soil at the base of the plant.

The pest status of this insect can be related to insecticide use. Several parasitic wasps keep this insect at a high degree of control in unsprayed areas. However, repeated use of insecticides devastates these natural enemies and can induce leafminer problems.

Leek Moth

The leek moth has been detected on leeks and garlic in small gardens in northern New York, but has not yet been detected in commercial onion fields. The young larva feeds within leaf tissue, making mines. As the larva gets larger, it feeds on the inside of leaves that are hollow (onions, shallots and chives). Damage may stunt onion, garlic and leek plant growth and may allow entry of pathogens that may cause rots in storage.

Stem Maggot

An unidentified species of fly larva has been found occasionally to damage onions in western regions like northeastern Colorado. Injury involves tunneling around the base of developing leaves, causing the leaves to to be girdled and die.

Problems have occurred in fields where small grain strips are grown adjacent to onions as a measure to protect seedlings from blowing soil. The onion damage is suspected to be caused by wheat stem maggot, or a similar species, that incidentally damages onions when they are grown next to the primary small grain host.

Wireworm

Wireworms are the soil-dwelling larvae of click beetles. The adults are slender, tan to nearly black and about 0.375 inches long. The larvae are hard, segmented, 0.375 to 0.750 inches long, and dark yellow or brown. Larvae can be found in the soil prior to planting, especially if the field has been rotated recently out of pasture or non-row crops. Wireworms are found in most onion production areas.

Pre-plant soil fumigation may be practiced to control wireworms and other insects that are found in the soil prior to planting. Rotating onions with non-susceptible crops such as cereals or legumes may reduce wireworm populations in some but not all production areas due both to the lack of susceptibility of the rotation crop and to cultural practices used to produce those crops.

Bulb Mite

Bulb mites are shiny, creamy white, bulbous shaped, and less than 0.06 inches long. The mites overwinter in decaying vegetation such as weeds or a previously planted vegetable crop that remains in the soil. Injury to the base of onion plants may occur from germination to early vegetative growth stages, resulting in death of seedlings (pre- or post-emergence). Symptoms closely mimic those associated with damping-off. Most damage results from incidental fungal and bacterial rots that develop around points of injury produced by bulb mite feeding.

Pre-plant soil fumigation can be used to control insect and mite pests that are found in the soil prior to planting. Growers discourage bulb mite build-up by avoiding successive allium crops. Bulb mite populations can be reduced by allowing crop residues to decompose fully prior to planting onions. Fallowing to allow complete decomposition of organic matter reduces field populations of the bulb mite but is seldom feasible economically. Growers should examine transplant seedlings carefully for bulb mites prior to planting.

VIRAL AND PHYTOPLASMA DISEASES & THEIR MANAGEMENT

By H. R. Pappu, R. Srinivasan and H. F. Schwartz

Viruses of onion and garlic are infectious molecules composed of a nucleic acid core, usually ribonucleic acid (RNA), and a protein coat. They can be seen with an electron microscope but not with a light microscope. Virus particles (virions) may be short or long rods or polyhedral in shape. They reproduce only in the living plant and generally inhabit the phloem. They may be transmitted among plants in sap (mechanical transmission), in seed or bulbs, or by insects such as aphids, thrips, and leafhoppers. Common symptoms of virus infections include leaf mosaics or streaks (light and dark green or yellow areas), malformations (twisting), and plant stunting.

Phytoplasma organisms are single-celled organisms that range in size from 175 nm to 150 μm. They are of various shapes, including spherical, ovoid, and filamentous. They lack a cell wall, are bounded by a three-layered membrane, and contain cytoplasm, ribosomes, and strands of nuclear material. They reside in phloem sieve tubes in host plants, and are transmitted by leafhoppers. Symptoms of phytoplasma infection often include yellowing, stunting, malformation, and reduced yield.

Table 11. Viral and Phytoplasma Diseases of Onion; illustrations in Appendix II.

Common Name	Scientific Name
Aster Yellows (Phytoplasma)	Class *Mollicutes*
IYSV	*Iris yellow spot virus*
OYDV	*Onion yellow dwarf virus*

Table 12a. Seasonal Occurrence in Western and Northern U.S. Onion Production Regions.

Disease	J	F	M	A	M	J	J	A	S	O	N	D
Aster Yellows (Phytoplasma)												
IYSV												
OYDV												

Table 12b. Seasonal Occurrence in Southern and Southeastern U.S. Onion Production Regions.

Disease	J	F	M	A	M	J	J	A	S	O	N	D
IYSV												

Iris Yellow Spot (IYSV)

Iris yellow spot virus is a tospovirus that causes the disease Iris yellow spot, and belongs to the same group of viruses as *Impatiens necrotic spot virus* (INSV) and *Tomato spotted wilt virus* (TSWV). Disease symptoms include straw-colored, dry, tan, spindle- or diamond-shaped lesions on the leaves and seed 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. The virus does not appear to be seed-borne in onion.

Control of onion thrips should help reduce incidence of IYSV; some onion varieties appear to be less susceptible to thrips and/or the virus. Destroying onion debris, including volunteers, and culls; locating new plantings away from overwintering onions or previous onion crops with a history of the disease; and avoiding planting annual bulb crops in close proximity to biennial seed crops because the 'green bridge' effect of overlapping crops promotes rapid buildup of thrips and IYSV, all help reduce losses to IYSV in onion crops.

Onion Yellow Dwarf (OYDV)

This disease is caused by a virus that is transmitted by various aphid species or transmitted mechanically to onions and other crops such as garlic, leek and some narcissus species. The first symptoms appear on the youngest leaves, which turn pale and develop many yellow streaks along the veins. Leaves may crinkle and flop over. Symptoms are more pronounced on leaves that develop from an infected bulb or transplant, and the yellow streaks begin at the base of the first leaves and successive leaves as they emerge. Later, there may be more pronounced yellowing, and leaves crinkle, flatten, twist and fall to the ground. Flower stems are shortened, streaked with yellow, and twisted. Generally the plant appears dwarfed, and has a wilted appearance. Symptoms of virus infection should not be confused with those of normal-shaped leaves that have alternate yellow/green bands caused by genetic or vegetative mutations (chimeras).

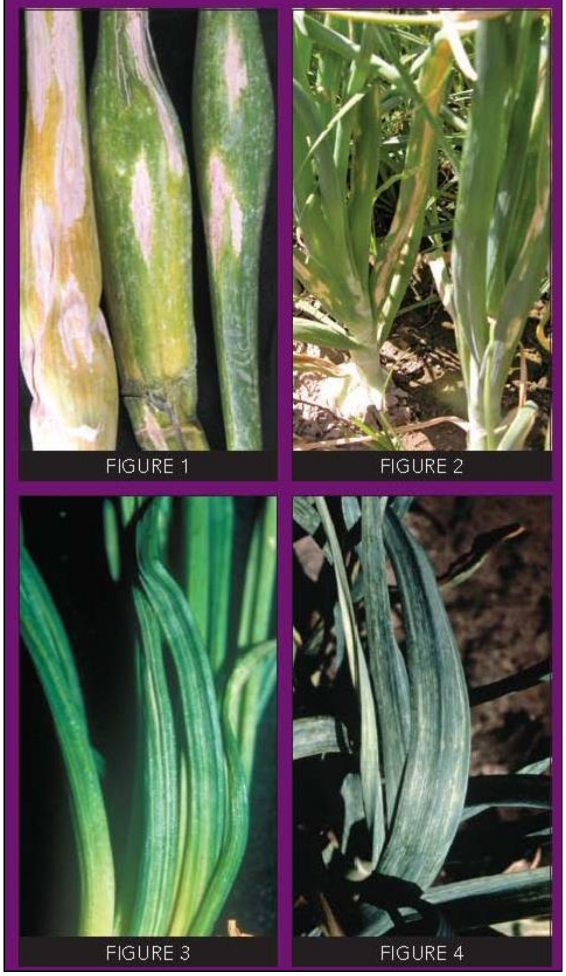
OYDV is not spread by seed, but infected bulbs (transplants, volunteers) always produce diseased plants and serve as sources of contamination for subsequent seasons, especially when aphid populations are large. Therefore, planting disease-free transplants and rotating out of onion production for at least three years are recommended. Other disease management recommendations include isolation from other susceptible crops or volunteer onions, and aphid control.

Aster Yellows - Phytoplasma

This disease is caused by the aster yellow phytoplasma that affects many weeds and crops including carrot, celery, lettuce and onion. The pathogen is transmitted by the aster leafhopper. Symptoms initially appear as a yellowing at the base of young leaves, which then spread toward the top. Leaves flatten, become marked with green and yellow streaks, but do not twist. Flower stems are abnormally elongated, and have malformed, sterile floral clusters. Disease management recommendations include crop rotation out of onions for at least three years; elimination of weed hosts in and around onion fields; insect vector control; and isolation from other susceptible crops or volunteer onions.

Virus Diseases

IYSV ***(Iris yellow spot virus),***
OYDV ***(Onion yellow dwarf virus),***
Garlic Mosaic ***(OYDV, Leek yellow stripe virus)***



AUTHOR: H. R. Pappu (Washington State University)
PHOTOGRAPHS: Courtesy of H. R. Pappu, Agri-Food Canada and R. M. Davis (APS Onion & Garlic Compendium) [01/2011]

COMMON HOSTS: Onion, Garlic

SYMPTOMS (ON ONION):

FIGURES 1 & 2 • IYSV symptoms include dry, straw-colored, diamond-shaped lesions on leaves and scapes. Lesions often develop on the margins of the youngest, fully developed leaves or the swollen part of the scape. Lesion centers may have a green or concentric rings of green and white tissue. Lesions may coalesce, cause tip blight and extensive death of foliage and lodging of scapes.

FIGURE 3 • OYDV appears as yellow streaks at the bases of leaves which may appear crinkled, flattened, and fall over. Scapes may show extensive yellowing, twisting and curling with small flower heads and poor quality seed.

FIGURE 4 • Garlic Mosaic appears as a mild to strong mosaic, chlorotic mottling, striping and streaking of leaves. Infected plants are stunted.

FACTORS FAVORING:

- High temperatures greater than 30°C (86°F) may stress plants and favor pests and IYSV vectors like thrips.
- Moisture stress (drought) also favors thrips which in turn may aggravate IYSV if present in the region.
- Viral diseases are affected by planting of contaminated transplants and sets; insect vectors like onion and tobacco thrips (IYSV) and aphids (OYDV, Garlic Mosaic); variable plant stands; and plant stress (fertility, moisture, temperature).

Figure 15. Onion Virus Disease Symptoms (courtesy of Onion ipmPIPE Project).

BACTERIAL DISEASES & THEIR MANAGEMENT

By B. K. Schroeder, R. D. Gitaitis, B. Dutta and H. F. Schwartz

Bacteria that cause onion diseases are microscopic, single-celled organisms that are Gram-negative, rod shaped, motile, and they do not form spores. They survive in infected plant material, such as leaves and bulbs. However, in natural environments, they survive only for short periods apart from living plants or plant residues. They are dispersed by movement of water, soil, seeds, infected plant parts, aerosols, insects, and by human activities. They enter onion and garlic plants and bulbs through natural openings or wounds and cause water-soaked (then brown) lesions, streaks, leaf blights, and bulb rots.

Table 13. Bacterial and Yeast Diseases of Onion; illustrations in Appendix II.

Common Name	Scientific Name
Bacterial stalk and leaf necrosis	*Pantoea agglomerans*
Brown rot	*Pseudomonas aeruginosa*
Center rot [complex]	*Pantoea ananatis* (with *P. agglomerans, P. allii*)
Enterobacter bulb decay	*Enterobacter cloacae*
Leaf streak and bulb rot	*Pseudomonas viridiflava*
Slippery skin	*Burkholderia gladioli* pv. *alliicola*
Soft rots	*Dickeya, Erwinia, Pectobacterium, Pseudomonas* species
Sour skin	*Burkholderia cepacia*
Xanthomonas leaf blight	*Xanthomonas axonopodis* pv. *allii*
Yeast soft rot	*Kluyveromyces marxianus* var. *marxianus*
Yellow bud	*Pseudomonas* species

Table 14a. Seasonal Occurrence in Western and Northern U.S. Onion Production Regions.

Disease	J	F	M	A	M	J	J	A	S	O	N	D
Bacterial stalk and leaf necrosis							X	X	X			
Brown rot							X	X	X			
Center rot [complex]	X	X					X	X	X	X	X	X
Enterobacter bulb decay	X	X						X	X	X	X	X
Leaf streak and bulb rot							X	X	X			
Slippery skin	X	X					X	X	X	X	X	X
Soft rots						X	X	X	X			
Sour skin	X	X					X	X	X	X	X	X
Xanthomonas leaf blight						X	X	X				
Yeast soft rot							X	X	X			

Table 14b. Seasonal Occurrence in Southern and Southeastern U.S. Onion Production Regions.

Disease	J	F	M	A	M	J	J	A	S	O	N	D
Bacterial stalk and leaf necrosis			X	X	X				X	X		
Center rot [complex]			X	X	X				X	X		
Leaf streak and bulb rot	X	X	X									X
Slippery skin				X	X	X						
Sour skin				X	X	X						
Xanthomonas leaf blight				X	X	X			X	X		
Yellow bud	X	X	X							X	X	X

Bacterial Leaf Spots

These bacteria overwinter on and in seed, crop debris, and other crops that act as alternate hosts. The pathogens are spread in the field by tillage equipment, surface water, 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

Disease management recommendations include: crop rotation out of onions for three years; wider plant spacing to increase leaf drying and promote air circulation; planting less susceptible varieties; use of drip or furrow instead of sprinkler irrigation; and control of insect pests such as maggots. Application of copper-based bactericides may reduce spread and infection, especially on storm-damaged plants, but are not curative.

Bacterial Soft Rot

Soft rot symptoms may develop directly in the field, beginning near the middle of the season, after heavy rains and when leaves are drying. The pathogen enters the bulb through the neck when leaves wilt or through wounds caused by mechanical injury, sunscald, maggots, transplanting damage, storm damage, or other bulb diseases. Bacteria initially cause a softening of scale tissue, which then becomes spongy, watery and pale yellow to grayish. Later the whole interior of the bulb breaks down and forms a sticky mass. When the bulb is squeezed, a viscous liquid oozes from the neck, emitting a characteristic foul odor.

A yeast causes a similar type of rot in areas of Washington and Oregon; but to date has not been reported to be found in eastern U.S.

The primary source of bacterial contamination originates from infested crop residue in the soil or irrigation runoff. Flies of onion and seedcorn maggots may carry the bacteria and introduce them to onion while feeding. Bacteria also are spread by rain and multiply very quickly in warm weather. Bulb rot can progress in storage and transit when the temperature exceeds 37^{o}F.

Disease management recommendations include: crop rotation out of onions for three years; plant spacing to increase leaf drying and promote air circulation; planting less susceptible varieties; use of drip or furrow instead of sprinkler irrigation; control of insect pests such as maggots. In the field, copper-based bactericides may reduce spread and infection, especially on storm-damaged plants. Do not damage plants during transplanting, or bulbs during harvest or transit. Wet onion bulbs should be dried artificially with heated forced air before being stored dry. Take care that condensation does not form on the bulbs as the temperature is reduced for long-term storage. Store onions at 32^{o}F with a relative humidity less than 70% and provide adequate ventilation during storage.

Center Rot

Center rot of onion and a similar disease (bacterial stalk and leaf necrosis) are caused by the bacteria, *Pantoea agglomerans, P. alli* and *P. ananatis* individually and together in a disease complex. Although these bacteria have been reported elsewhere as being disseminated by wind and splashing water, observations in the southeastern U.S. indicate little if any transmission occurs in that manner. In the southeastern, short-day onion production areas, these pathogens are predominantly transmitted by thrips. In Georgia, center rot has been associated consistently with dry years and when thrips are present in large numbers. To date, tobacco thrips (*Frankliniella fusca*) and onion thrips (*Thrips tabaci*), have been identified as vectors of these pathogens. Studies also indicate transmission appears to be passive, as experimental results show contaminated thrips feces disseminate the bacterium into the infection court where they can gain ingress through natural openings or feeding wounds. Disease symptoms include irregular shaped to linear streaks of necrotic and bleached areas on young leaves. The infected young leaves wilt and the pathogens progress into the bulb, but alone these pathogens are not aggressive bulb rot organisms. Rather, they seem to pave the way for opportunistic, soft rot microbes to colonize affected tissues. Under favorable conditions this disease can cause up to 100% yield loss in highly susceptible cultivars. In addition, infected bulbs are particularly difficult to grade as most symptoms occur in the center directly below the neck. Thus, these pathogens account for significant postharvest losses in onions that may pass visual inspection of the bulb exteriors.

This disease has multiple sources of inocula that include seeds, weeds, soil and insects. The bacterium is a very successful epiphyte and can colonize leaf surfaces and blossoms of many weed hosts without causing disease symptoms. The bacterium can also colonize seed successfully and be transmitted through contaminated seed. Thus, management recommendations include use of clean seed, clean transplants, planting less susceptible varieties, vigilant weed control and management of the thrips vector.

Enterobacter bulb decay

Enterobacter bulb decay is caused by the bacterium, *Enterobacter cloacae*. This is a postharvest disease that may develop during field curing in California and during curing and storage in the Pacific Northwest and elsewhere. Development of this disease is exacerbated by curing temperatures above 94^{o}F. With this in mind, curing temperatures below 94^{o}F are recommended. Symptoms include light necrosis of single scales with necrosis beginning at the neck and progressing toward the basal plate. Progression of the disease from scale to scale is limited. Interestingly, the inoculation of this bacterial pathogen to leaf tissue does not respond in lesion formation.

Leaf Streak & Bulb Rot

This disease is favored by cooler weather, extended periods of rain and high fertility, particularly excess levels of nitrogen. The causal agent, *Pseudomonas viridiflava,* is an ice-nucleating active, fluorescent bacterium. The bacterium produces pectinolytic enzymes capable of rotting onion bulb tissue. The primary sources of inoculum are weeds that are either symptomatic hosts or asymptomatic resident hosts of epiphytic populations. Under the right conditions, this disease can cause significant losses as a postharvest problem. Symptoms in the field include dark green-to-black, water-soaked streaks running the length of the leaf. Often the tissues at the base of leaves and above the neck of the bulb exhibit a soft rot and leaves collapse. Depending on the age and severity of the infection, cross-sections of infected bulbs display rot in a single scale giving a rot in a ring formation or an irregular, multi-scale rot ranging in color from yellow to reddish-brown, occasionally with areas containing speckles of a dark “metallic” blue-green material. The bacterium survives primarily on weeds and is spread by wind and splashing water droplets. At harvest, the bacterium can enter wounds caused by topping or removing leaves from mature bulbs. In addition, the clippers can become contaminated and spread the pathogen from bulb to bulb. If plants are not fully mature during topping (clipping) or not dried adequately in the sun prior to clipping, the bacterium can cause a bacterial neck rot symptom.

Management strategies include controlled and timely application of fertilizers, spraying with fixed-copper bactericides, and vigilant weed control. Avoid the harvest of immature onions, and cure onions in the field for a minimum of 48 hours prior to harvest.

Slippery and Sour Skin

Slippery skin and sour skin symptoms include softening of bulbs around the neck. Slippery skin rot spreads from the neck to the base of the bulb, where bacteria can be transmitted from one fleshy scale to another until the central part becomes rotten and watery. Simple pressure at the base of the bulb can cause the rotted portion to slide out through the neck, hence the name slippery skin. However, this is not always a diagnostic feature of slippery skin. Symptoms of sour skin rot are found on the outer layers or scales of the bulbs but do not necessarily affect the outermost skin of the bulb. Affected tissue becomes yellow and viscous, but not watery. The central portion remains firm but slides out if the bulb is pressed. The rot has an acrid odor, hence the name sour skin. Little is known about the life cycles of these pathogens, but they reproduce quickly during warm weather. Their spread and mode of infection are similar to that of soft rot bacteria and are favored by storm damage.

Disease management recommendations include: crop rotation out of onions for three years; wider plant spacing to increase leaf drying and promote air circulation; planting less susceptible varieties; use of drip or furrow instead of sprinkler irrigation; control of insect pests such as maggots; and application of copper-based bactericides to reduce spread and infection, especially on storm-damaged plants. Avoid damage to bulbs during harvest or handling. Wet onions should be dried with forced heated air post-harvest and before being stored dry. Store onions at 32^{o}F with a relative humidity less than 70% and provide adequate ventilation during storage.

Xanthomonas Leaf Blight

Xanthomonas leaf blight symptoms on leaves appear as white flecks, pale spots or elongated lesions with water-soaked margins, which elongate into chlorotic streaks, commonly on the flat side of older leaves. The symptoms evolve further into tip dieback and extensive blighting of outer older leaves, resulting in stunted plants and undersized bulbs. Limited information is available on the disease cycle and epidemiology of bacterial blight. Inoculum is spread through rain, heavy dews or sprinkler irrigation water. Abrasions caused by wind and sandblasting of leaves may favor the infection process. Disease development is favored at high temperatures under humid or overcast conditions.

Disease management recommendations include: crop rotation out of onions for three years; wider plant spacing to increase leaf drying and promote air circulation; planting less susceptible varieties; use of drip or furrow instead of sprinkler irrigation; and control of insect pests such as maggots. Application of copper-based bactericides may reduce spread and infection, especially on storm-damaged plants.

Yellow Bud

This is an emerging disease in the southeastern U.S. caused by a *Pseudomonas* sp. Other pathogen characteristics include being an ice-nucleating active bacterium, and non-fluorescent on King's medium B agar. The bacterium is capable of producing the toxin coronatine. It is the toxin that is most likely responsible for the striking, bright yellow chlorotic symptoms. Incidence of yellow bud has been progressively increasing in the southeastern onion-growing area and has also been observed in seedbeds in the warmer fall months in the southeastern U.S., despite normally being associated with onion production during cooler weather that occurs from late December to early March.

Unconfirmed reports of similar-appearing onions elsewhere have been made, but identity of the causal organism is not known in these cases. Long-term exposure of the infected plant to the toxin and eventual colonization of the plant by bacteria cause blight. Although no bulb rot is produced, necrotic tissues offer avenues of ingress for secondary soft-rotting microbes. Long-term infections cause reduced bulb size and yield loss. However, if environmental conditions turn unfavorable for disease development, affected plants can revert to producing green leaf tissues if necrosis has not yet developed. Even though plants do sometimes grow out of the disease, there still can be an impact on yield. The pathogen can be transmitted through seed, as demonstrated by inoculation of seeds, and it can over-season on weeds. In the southeastern U.S., over-seasoning refers to over-summering. The bacterium has been detected on multiple asymptomatic weeds but seems to have an affinity for Italian ryegrass and curly dock, and it can over-summer on both of those weeds. Recent data indicated that the pathogen can be spread as an aerosol and deposited onto onion leaf surfaces in irrigation water.

Yellow bud symptoms (Photo courtesy of R. D. Gitaitis, Univ. of Georgia)

Bacterial Diseases

Xanthomonas Leaf Blight *(Xanthomonas axonopodis pv. allii)*, Slippery Skin *(Burkholderia gladioli pv. alliicola)*, Sour Skin *(B. cepacia)*, Center Rot *(Pantoea ananatis)*, Enterobacter Bulb Decay *(Enterobacter cloacae)*, Soft Rots *(Dickeya chrysanthemi, Pectobacterium carotovorum subsp. carotovorum)*

AUTHORS: B. K. Schroeder (Washington State University) and H. F. Schwartz (Colorado State University) **PHOTOGRAPHS:** Courtesy of H. F. Schwartz, L. J. du Toit and B. K. Schroeder [01/2011]

COMMON HOSTS: Onion, Garlic

SYMPTOMS (ON ONION LEAVES AND BULBS):

FIGURE 1 • Xanthomonas leaf blight lesions appear as irregularly shaped, white flecks, pale spots, or lenticular lesions with water-soaked margins. Lesions enlarge, become tan to brown, cause extensive water-soaking, dieback and blighting of foliage, but not bulb infection.

FIGURE 2 • In the field, early stages of bacterial leaf infection will appear as watersoaking along the entire length of the leaf; FIGURE 3 • later stages appear bleached (white to tan) and desiccated. No fungal structures will be present.

FIGURE 4 • Soft rot may appear in the field or in storage as water-soaked tissue of leaves, neck and/or bulb; usually progressing from leaves to the neck to the bulb. The interior of the bulb may break down and a watery, foul-smelling liquid may ooze from the neck if the affected bulb is squeezed.

FIGURE 5 • Bacterial bulb infection can be observed while plants are in the field or in storage. Softening of the neck may be observed and bulb tissue may appear translucent or water-soaked.

FIGURE 6 • Enterobacter bulb decay appears firm and healthy until cut to expose interior scales which are brown, soft and rotten; progressing downward from the neck.

FACTORS FAVORING:

Most bacteria are favored by:

- Harvest and storage temperatures above 30°C (86°F); some are favored by lower temperatures.
- Free moisture and high humidity (greater than 75%) during production and harvest.
- Planting of contaminated seed, transplants, sets
- Irrigation water; storm damage; excess nitrogen after bulb initiation; insects like thrips and maggots; and bruising during harvest.

Figure 16. Onion Bacterial Disease Symptoms (courtesy of Onion ipmPIPE Project).

FUNGAL DISEASES & THEIR MANAGEMENT

By H. F. Schwartz, L. J. du Toit and R. D. Gitaitis

Many onion diseases are caused by fungi. Fungi are microscopic organisms whose bodies are made of threadlike tiny tubes called *hyphae* which, en masse, form a mycelium. Hyphae may have partitions, called septa, and obtain nutrients from the plant. Most fungi reproduce by forming specialized structures called *spores*, which serve the fungus in many important ways. Some spores tolerate adverse conditions and enable the fungus to survive in the absence of onion or garlic plants; some spores are disseminated by wind, soil, water, or other agents and serve as inoculum to produce new hyphae that penetrate the onion or garlic plant through wounds or natural openings, or penetrate the intact surface. Spores also may differ genetically and, thus, enable new strains or races of the fungus to develop. Fungal pathogens are identified mostly by the size, shape, and color of their spores. These and other structures produced by fungal pathogens of onion, such as sclerotia and sexual fruiting bodies, are described more fully below for each pathogen. Fungal pathogens cause a wide range of symptoms on onion. Most frequently, they cause variously colored (brown, yellow, gray, purple, or black) spots or areas on leaves, seed stalks, bulbs, and roots.

Table 15. Soilborne Diseases of Onion; illustrations in Appendix II.

Common Name	**Scientific Name**
Charcoal rot	*Macrophomina phaseolina*
Fusarium diseases	*Fusarium* species
Pink root	*Phoma terrestris*
Pythium diseases	*Pythium* species
Rhizoctonia diseases	*Rhizoctonia* species
Smut	*Urocystis colchici, U. cepulae*
Southern blight	*Sclerotium rolfsii*
White rot	*Sclerotium cepivorum*

Table 16. Seasonal Occurrence in Western and Northern U.S. Onion Production Regions.

Disease	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Charcoal rot							■	■	■			
Fusarium diseases						■	■	■	■			
Pink root				■	■	■	■	■	■			
Pythium			■	■	■	■						
Rhizoctonia seedling blight			■	■	■	■						
Smut				■	■	■						
Southern blight							■	■	■			
White rot							■	■				

Damping-Off and Seedling Blights

Death of seedlings before and after emergence can be caused by various species of *Pythium* and *Fusarium*. Older reports also claim that *Rhizoctonia* species can be involved. Plants often are infected at the soil line or slightly below. Infected tissues turn tan to brown, water-soaked, and shrink rapidly while aboveground parts may wilt and fall over. Root systems of seedlings and transplants are rotted by these fungi or damaged by nematodes. Therefore, roots are killed directly or weakened and predisposed to additional damage by other stress factors such as cold, wet soil, compaction, herbicides, and salts from alkaline soil or fertilizer.

Disease management recommendations include crop rotation out of onions for at least three years; planting seed treated with fungicide; good seedbed preparation that promotes adequate drainage and rapid emergence; and reduction of other stresses such as cold soil, soil compaction and poor drainage, or improper fertilizer placement.

Smut

Smut is caused by soil-borne fungi which primarily affect onion seedlings. Symptoms appear on cotyledons and young leaves as longitudinal blisters that turn blackish with a silver sheen. Seedlings often die before or within six weeks after emergence. Onions are susceptible to smut infection only during germination and emergence, after which plants become resistant. If plants survive, the pathogen becomes systemic in embryonic tissue and plants remain vegetative for the entire growing season. Developing bulbs become covered by blackish lesions, and are predisposed to infection by other organisms that cause secondary rots. When the skin of smut blisters splits, black fungus spores (resembling soot or smut, hence the name) are released onto soil where they remain infectious for many years. Infection is favored by cold, damp weather in the spring which delays emergence and favors infection. Transplanted onions generally are not affected by the pathogen.

Disease management recommendations include: crop rotation out of onions for three or more years; pre-plant fumigation of soil; use of plant seed treated with appropriate fungicide such as carboxin; use of transplants instead of direct-seeding in infested soil. Do not introduce infested soil or contaminated equipment, plants or onion debris into clean fields. Avoid planting in cold, wet soils and plant resistant varieties when available.

Pink Root

Pink root affects yield by reducing bulb size and aggravating losses from other diseases such as Fusarium basal rot. Infected roots have a typical pink color, which turns to red (particularly the innermost part of the root called the stele), then purple and finally brown to black. Severe infection may reduce the root mass of a plant, and cause stressed leaf tips to turn yellow or tan and wilt. The fungus can survive for many years in a field, even in the absence of a host. The pathogen can be spread within and between fields by cultivation equipment and irrigation water. Infection is favored by high soil temperatures (80^{o}F). Transplants should be produced on pathogen-free soil.

Disease management recommendations include: crop rotation with cereals (wheat and barley) for three or more years; use of resistant varieties and non-infected transplants; seed treated with a fungicide; good seedbed preparation; reduction of other stresses such as soil compaction. Avoid root pruning during cultivation, as well as heat and moisture extremes, and fumigate in the fall.

Fusarium Basal Rot

Fusarium basal rot is caused by a soil-borne pathogen that can survive in soil for many years as chlamydospores or as a saprophyte on crop residues. The pathogen infects the onion root and basal plate area, causing a pinkish brown rot that eventually becomes covered with a whitish mycelium. Leaf tips yellow, wilt begins with the older outer leaves, scattered plants become stunted, and plants eventually die. A semi-watery decay progresses from the basal plate upward and secondary invaders (bacteria) cause a watery, foul-smelling breakdown of the basal plate and bulb. Infected plants may appear after bulbs develop, and are easily pulled from soil as most of the root system becomes rotted. Late-season infection may not be visible until storage. The disease is more serious when soil temperatures exceed 80^{o}F and soil moisture is high. Maggots are attracted to rotting bulbs and may contribute to secondary breakdown. The pathogen can be spread within and between fields by equipment and water.

Disease management recommendations include: crop rotation with cereals (wheat, barley and corn) for four or more years; use of resistant varieties and non-infected transplants; seed treated with a fungicide; good seedbed preparation and drainage; and reduction of other stresses such as soil compaction, root pruning during cultivation, and moisture extremes. Use nitrate, not ammonium fertilizers, and fumigate in the fall. Cultivars with resistance are available for some market types.

Rhizoctonia seedling blight

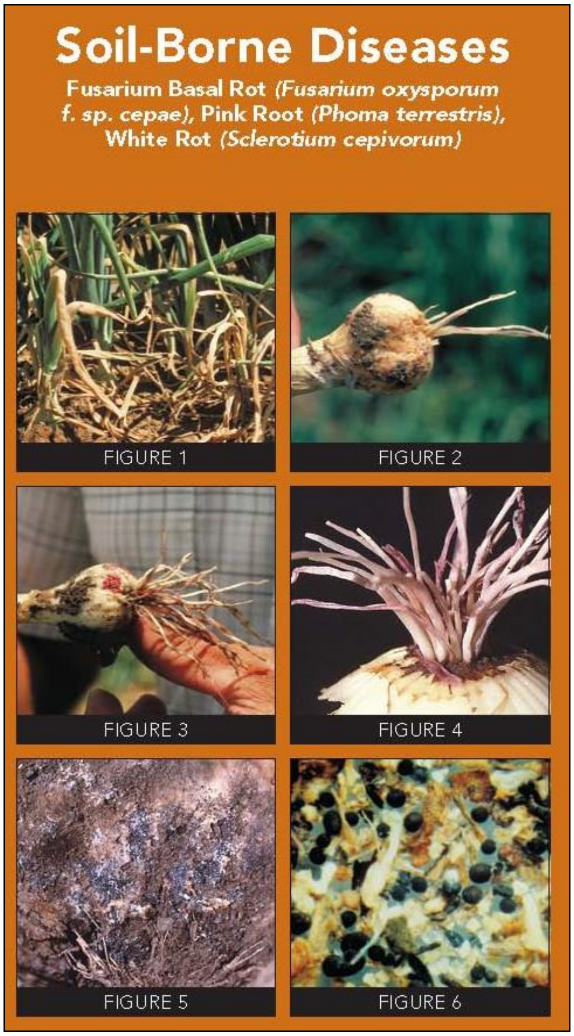
The pathogen can cause stunting of onion seedlings post-emergence. Stunting appears in patches ranging from a few feet to >30 feet in diameter, and the patches are most evident at the 4- to 6-true leaf stage. This seedling blight mainly occurs when onion seed is planted into very sandy soils with significant amounts of residues from a previous cover crop. The disease has been quite significant in areas of the Columbia Basin of Oregon and Washington where winter cereal cover crops are used widely to help protect spring-planted onion crops against wind and sandblasting.

Pre-plant soil fumigation and seed treatment with fungicide can help reduce the severity of damping-off. Avoid planting in cold, wet soils. Timing of herbicide application in the spring to winter cover crops (planted to help protect spring-planted onion bulb crops against wind- and sand-blasting in very sandy fields), can have a significant effect on the severity of stunted patches caused by *Rhizoctonia* spp. The longer the interval between herbicide application to the cover crop and planting of onion seed, the less sever the stunting. Ideally, onion seed should not be planted less than 2 to 4 weeks after applying herbicide to the cover crop.

White Rot

White rot is caused by a fungus that produces hardy sclerotia (masses of mycelium) 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. Sclerotia are spread within and between fields by cultivation equipment and irrigation water. White rot is favored by cool weather (68^{o}F) and low soil moisture.

Disease management recommendations include: crop rotation out of onions for at least five years; use of non-infected transplants; good water drainage; and treatment at planting with appropriate fungicides. 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. Flooding may reduce populations of this fungus.



AUTHORS: H. F. Schwartz and N. A. Tisserat (Colorado State University) **PHOTOGRAPHS:** Courtesy of H. F. Schwartz, S. K. Mohan (Univ. of Idaho) and F. J. Crowe (Oregon State University-retired) [01/2011]

COMMON HOSTS: Onion, Garlic

SYMPTOMS (ON ONION):

FIGURES 1 & 2 • Fusarium basal rot appears as yellow and tan to brown leaves, usually beginning at the leaf tips and developing downward. Plants may wilt and then die; infected bulbs appear discolored (tan to brown) and roots and basal plates are rotted.

FIGURES 3 & 4 • Pink root appears as discolored roots (yellow to brown to red to purple); infected roots may disintegrate. Leaf number and bulb size may be reduced by severe infection.

FIGURES 5 & 6 • White rot appears as yellowing and dying of older leaves, stunting of plants, and death of foliage. Infected roots will exhibit white, fluffly mycelium on the basal plate with presence of small, poppy-sized brown to black sclerotia in and on tissues.

FACTORS FAVORING:

- Temperatures greater than 28°C (82°F) during late vegetative to mid bulbing stages favor infection by Fusarium basal rot and pink root; while white rot is favored by lower temperatures.
- Moisture stress (deficiency or excess) may predispose the crop to infection by Fusarium and pink root.
- These soil-borne diseases are favored by frequent cropping to Alliums (every 3–4 years), planting of contaminated transplants and sets of susceptible varieties, and injury to roots by cultivation and insect feeding.

Figure 17. Onion Soil-borne Fungal Disease Symptoms (courtesy of Onion ipmPIPE Project).

Table 17. Foliar and Bulb Fungal Diseases of Onion; illustrations in Appendix II.

Common Name	Scientific Name
Anthracnose	*Colletotrichum coccodes*
Black mold	*Aspergillus niger*
Blue mold	*Penicillium* species
Botrytis diseases	*Botrytis* species
Cercospora leaf spot	*Cercospora duddiae*
Cladosporium Leaf blotch	*Cladosporium allii-cepae*
Diplodia stain	*Lasiodiplodia theobromae*
Downy mildew	*Peronospora destructor*
Mushy rot	*Rhizopus microsporus, R. stolonifer*
Phyllosticta leaf blight	*Phyllosticta allii*
Powdery mildew	*Leveillula taurica*
Purple blotch	*Alternaria porri*
Rust	*Puccinia allii*
Smudge	*Colletotrichum circinans*
Stemphylium leaf blight	*Stemphylium vesicarium*
Twister	*Glomerella cingulata*

Table 18a. Seasonal Occurrence in Western and Northern U.S. Onion Production Regions.

Disease	J	F	M	A	M	J	J	A	S	O	N	D
Anthracnose										X	X	X
Black mold				X	X							
Blue mold										X	X	X
Botrytis diseases	X	X	X	X	X						X	X
Downy mildew		X	X	X								
Purple blotch		X	X	X	X							
Smudge										X	X	X
Stemphylium leaf blight		X	X	X	X							
Twister										X	X	X

Table 18b. Seasonal Occurrence in Southern and Southeastern U.S. Onion Production Regions

Disease	J	F	M	A	M	J	J	A	S	O	N	D
Anthracnose										X	X	X
Black mold				X	X							
Botrytis diseases	X	X	X	X	X						X	X
Downy mildew		X	X	X								
Purple blotch		X	X	X	X							
Stemphylium leaf blight		X	X	X	X							
Twister										X	X	X

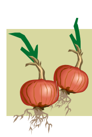
Anthracnose (Leaf and Neck)

Leaf and neck anthracnose appears to be more prevalent during warm, humid conditions. The pathogen has been shown to be seed-borne in tomato and potato but has not been confirmed on onion seeds. The disease can also spread to uninfected fields from people or equipment that have come into contact with diseased tissue. Reports of leaf and neck anthracnose for Michigan in 2011 demonstrated that the pathogen is capable of overwintering in colder climates. The disease forms elliptical bleached lesions that become tan to salmon colored in the center. The salmon colored lesions contain spores in fruiting bodies that allow the pathogen to spread by splashing water, wind, and on equipment or people. As the disease progresses, the center of the lesions develop small dark circles that contain the overwintering structures of the pathogen (micro sclerotia). Because of the recent development of this disease in onion, management practices are still being tested.

Downy Mildew

Foliar downy mildew symptoms appear on older leaves as elongated patches which vary in size and are slightly paler than the rest of the foliage. In the presence of moisture, these areas become covered with a violet gray mycelium, which contains spores that may be spread to surrounding healthy tissue. Leaves generally fold along the lesions, and leaf tips may die. Another fungus (*Stemphylium botryosum*) may develop on the primary downy mildew lesions and produce a brown to black fungal growth. Affected plants may be dwarfed and leaves become pale green, deformed and often are covered by mycelium and spores of the pathogen. Bulb size and quality are reduced if infection occurs before foliage maturity and cropping. Infection is favored by cool temperatures (less than 72^{o}F) and free moisture from rain or dew in early spring or late summer. The pathogen overwinters in crop residue and contaminated culled bulbs.

Disease management recommendations include: crop rotation out of onions for at least three years; onion debris and cull sanitation; use of clean seed and transplants planted at moderate densities; use of



timely applications and rotations of effective fungicides which are specific for this pathogen to avoid development of resistance to fungicides in the pathogen population.

Purple Blotch

The purple blotch pathogen can infect all above-ground parts of the plant in addition to the bulb. Initial symptoms appear on older leaves, usually late in the summer as spores are blown from infested debris. Lesions are elongate, small, sunken and whitish with a purple center. Concentric light and dark zones later appear over part or all of the purple area; blotches may enlarge (up to 4 inches long) and become covered with black spores. Leaves wilt and die. Bulbs can be infected at harvest if the pathogen enters neck wounds. Storage symptoms appear as a dark yellow to wine-red spongy rot of outer or inner scales of bulbs. The fungus overwinters on infected debris.

Disease management recommendations include: crop rotation out of onions for at least three years; destroying or burying culls, onion debris and volunteer onions; use of clean seed and transplants planted at moderate densities to promote leaf drying and air circulation; and use of less susceptible varieties. Manage irrigation to minimize the duration of leaf wetness. Do not apply excess nitrogen fertilizer, especially after bulb initiation. Apply effective fungicides after bulb initiation and weather conditions favor infection. Harvest bulbs at full maturity when necks top over naturally and, ideally, harvest during dry weather. Air-dry bulbs before storage to heal injuries and the neck region, and store at 32^{o}F with a relative humidity less than 70%.

Stemphylium leaf blight

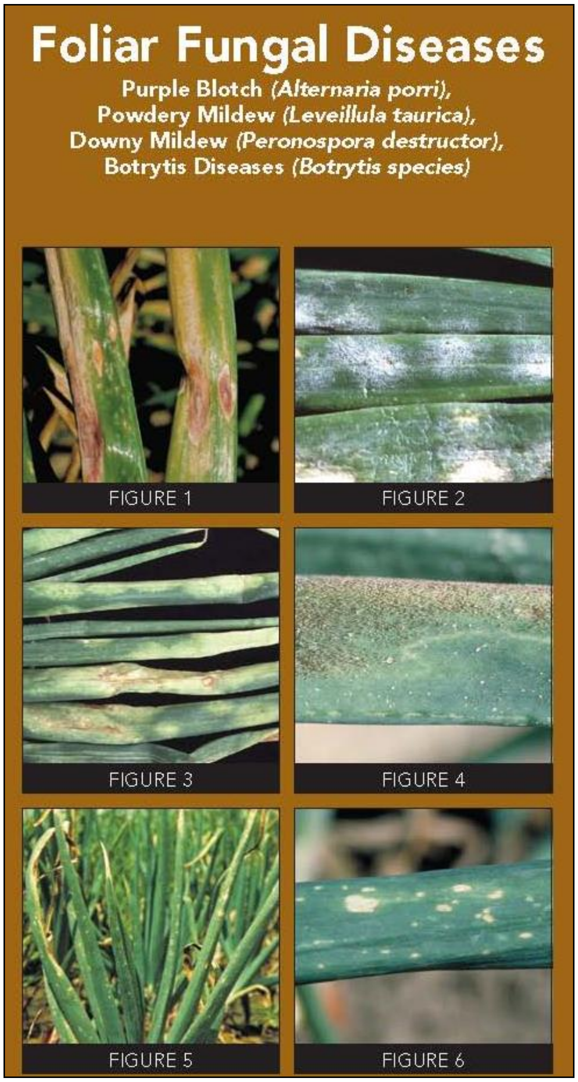
Infection causes yellow or brown water-soaked lesions on leaf tissue. As the fungus spreads, the lesions turn black from sporulation. Lesions can also develop a purple discoloration that is difficult to distinguish from that of purple blotch without microscopic examination of the lesions for spores. The fungus can be seed-borne. This pathogen may enter the bulb through mechanical wounding and insect damage. Senescing leaves as a result of pink root, downy mildew, and even iris yellow spot are susceptible to Stemphylium leaf blight. Disease may be held in check through fungicides applied for the control of other foliar diseases, especially purple blotch.

Botrytis Diseases

These diseases may be caused by one or more *Botrytis* species. Neck rot is primarily a storage disease, although infection originates in the field as leaves and necks mature or are injured, and become infected by spores blown from infested onion debris and improperly disposed cull piles. In addition, latent foliar infections can become active during senescence of the leaves and necks if moisture is deposited in the necks (e.g., from rain, dew, or late irrigation). A leaf blight may occur as leaf tips die, and small, oval, whitish to yellowish spots form on leaves (‘blast’ caused by *B. squamosa*). A soil-line rot and scape blight can also occur on onions grown in western regions. The soil line rot appears to be more severe on transplanted onions and during periods of cool (less than 75^{o}F), moist weather. Blighting and girdling of onion scapes (seed stalks) shows up as whitish, necrotic, shriveled tissue usually with sporulation on the surface or below the epidermis of the lesion. Scape infections are most commonly caused by *Botrytis aclada* and *B. allii*.

Storage symptoms appear as a softening of the tissue in the upper part of the bulb, especially around the neck area, that progresses down toward the basal plate. Infected tissue is brownish and soft, and often exhibits gray mycelium and thin black sclerotia on and between infected fleshy scales. Larger sclerotia may form on the surface of the neck and outer scales. Infection is favored by high moisture conditions in the field close to harvest. The fungus may spread to other bulbs in storage under moist conditions, but not if the bulbs are dried down adequately prior to storage. Germinating spores (of *Botrytis cinerea*) also can induce a superficial discoloration (brown stain) of dry, outer scales with no further development of a bulb rot.

Disease management recommendations include: crop rotation out of onions for at least three years; sanitation of cull pile and onion debris; use of clean seed and transplants; use of appropriate fungicide seed treatments; planting early maturing varieties at moderate plant densities; and no application of nitrogen fertilizer after bulb initiation. Apply effective fungicides as foliar sprays after bulbing begins and weather conditions favor infection. Undercut onion roots or harvest at full maturity when necks top over naturally and, ideally, undercut during dry weather. Air-dry and/or heat treat (at 90 to 95^{o}F) bulbs before storage to heal injuries and cure the neck region thoroughly. Store bulbs at 32^{o}F and a relative humidity less than 70%.



AUTHORS: S. K. Mohan (Univ. of Idaho), M. K. Hausbeck (Michigan State University) and N. A. Tisserat (Colorado State University) **PHOTOGRAPHS:** Courtesy of S. K. Mohan and H. F. Schwartz [01/2011]

COMMON HOSTS: Onion, Garlic

SYMPTOMS (ON ONION):

FIGURE 1 • Purple blotch may appear on leaves or seed stalks as small, water-soaked lesions that develop white centers. The lesion margin is a shade of red or purple, surrounded by a yellow zone that may extend 1 inch [2.5 cm] or larger. Lesion centers may contain brown to dark gray spores of the fungus.

FIGURE 2 • Powdery mildew includes circular to oblong, white to grayish white patches of fungal growth with irregular margins; often after initiation of bulbing.

FIGURES 3 & 4 • Downy mildew commonly starts in spots in a field and spreads to surrounding areas. Initial symptoms appear as pale, elongate patches that turn light tan to brown on the foliage, affected leaf or seed stem tissues during moist periods.

FIGURES 5 & 6 • Botrytis (blast, leaf blight) may appear as a small white, sunken, elliptical lesion (less than 1/8 inch or 2 mm) with necrotic center. Multiple lesions may develop on the leaf, and cause a tip die-back and blighting of the leaf.

FACTORS FAVORING:

- Most of these fungi are favored by temperatures below 27°C (80°F); but can be active up to 32°C (90°F).
- These pathogens are favored by free moisture and high humidity (greater than 75%) during production and pre-harvest.
- These foliar diseases are favored by frequent cropping to Alliums (every 3–4 years), planting of contaminated seed (Botrytis), transplants and sets of susceptible varieties; high plant density; and storms.

Figure 18. Onion Foliar Fungal Disease Symptoms (courtesy of Onion ipmPIPE Project).

Smudge

Smudge, or anthracnose, primarily affects white onions at harvest and during storage. Small, dark green or black spots appear around the neck and on outer scales, often in concentric rings. These spots may spread on inner scales and form small yellow lesions. The fungus can survive on onion debris and in soil for several years. Infection is favored by warm (80^{o}F), moist weather, especially close to harvest.

Disease management recommendations include: crop rotation out of onions for at least three years; use of clean seed and non-infected transplants; good drainage; and timely applications of foliar sprays of appropriate fungicides. Let onions dry out completely at harvest and/or heat treat before storing; store dry onions at 32°F and less than 70% relative humidity.

Figure 19. Onion Foliar Fungal Disease Symptoms (courtesy of Onion ipmPIPE Project).

Storage Molds

Other fungi can also damage onions in storage and include black mold, caused by *Aspergillus niger*, and blue mold, caused by *Penicillium* species. Infection by the black mold fungus usually starts at the top of the bulb where leaves have dried or were cut, and infection may progress downward. Invaded tissue first becomes water-soaked, a white mold develops between fleshy scales, and small black sclerotia and spore masses then form. This tissue dries and shrivels, or becomes watery if secondary bacterial infections cause breakdown. Bulbs can be infected without evidence of external symptoms. Lengthwise or cross-sections reveal at least one inner scale is water-soaked and blackened between healthy and diseased parts.

Blue mold or green mold caused by *Penicillium* spp. is principally a storage problem. It produces a soft, watery rot; and tissue becomes pithy and fibrous as it dries. The decay is accompanied by blue-green mold on the surface. Infection by both wind-blown pathogens, *Aspergillus* and *Penicillium*, is favored by high moisture, wounds or bruises close to harvest, and cool to moderate temperatures (less than 90^{o}F).

Disease management recommendations include: crop rotation out of onions for at least three years; timely application of effective fungicides; and appropriate harvest practices to minimize bruises and wounds, with good in-field and post-harvest curing, and good storage conditions.

Black Mold

This fungal pathogen, *Aspergillus*, overwinters in cull piles, crop debris, and soil. It can be transmitted via infested seed. Damage from black mold affects the bulb; infected bulbs have a black discoloration at the neck, on the outer scales, and/or between the internal fleshy scales. Advanced stages of the disease can cause the onion bulb to shrivel.

Pre-plant soil fumigation can help reduce the severity of black mold; however, the pathogen can easily re-contaminate treated soil by fungal spore movement from other sites. The fungus is readily airborne and wind-dispersed. Eliminate cull piles and onion debris from the field. Rotate out of *Allium* crops for at least three years. Assay seed lots and select lots with low *Aspergillus* levels. Seed treatment with appropriate fungicides can reduce seed infection levels and seed transmission.

ABIOTIC PROBLEMS & THEIR MANAGEMENT

By H. F. Schwartz

Environmental and other abiotic stresses can affect plant growth adversely and predispose plants to further damage by other production problems, such as plant pathogens and insects. Temperature and moisture extremes can induce obvious stresses, as can fertility imbalances, soil alkalinity, high salt concentrations, poor drainage, or air pollution (e.g., ozone).

Table 19. Abiotic Problems of Onion; see illustrations in Appendix I. .

Common Name	**Description**
Air pollution	Ozone, peroxyacetyl nitrate, sulfur dioxide
Chemical	Improper application, carryover, drift of pesticides and fertilizer
Genetic abnormality	Chimera or variegation
Greening	Curing in sunlight, late application of N, alkalinity
Hail, rain and lightning injury	Storm damage
Mineral extremes	Deficiency and toxicity of nutrients (Bo, Cu, Mg, Mn, Mo, N, P, K, S, Zn)
Pinking	Bruising of white onions
Soil and water problems	Acidity, alkalinity (pH), salinity
Sunscald	Bulb exposure to high temperature and sunlight
Temperature stress	Exposure to extremes during growth and harvest
Translucent and leathery scale	Bulb exposure to high temperature, sunlight, bruising

Table 20. Seasonal Occurrence in Western and Northern U.S. Onion Production Regions.

Problem	J	F	M	A	M	J	J	A	S	O	N	D
Air pollution						■	■	■				
Chemical			■	■	■	■	■	■	■			
Genetic abnormality				■	■	■	■	■				
Greening								■	■	■		
Hail, rain and lightning injury				■	■	■	■	■	■			
Mineral extremes				■	■	■	■	■				
Pinking								■	■	■		
Soil and water problems			■	■	■	■	■	■	■			
Split bulbs							■	■	■	■		
Sunscald								■	■	■		
Temperature stress			■	■	■	■	■	■	■	■		
Translucent and leathery scale								■	■	■		

Herbicide Injury

Improper use of herbicides can cause temporary or permanent injury to onions. Damage occurs when herbicides are applied at excessive rates, more frequently than recommended, when the onion leaf surface is compromised by injury resulting in increased risk of phytotoxicity from herbicides, and when onion (and often weed) plants are at the wrong stage of development at the time of herbicide application. Contact herbicides cause burns and necrotic spots on leaves and leaf tips. Systemic herbicides may cause leaves to yellow and/or curl. Generally the onion plants recover and symptoms disappear over time. Damage may also occur if onions are sensitive to "carryover" herbicides used on the previous crop, as a result of residual activity of the herbicide in the soil. Drift of herbicides from applications to adjacent crops may also result in injury to onion crops. Closely follow label recommendations provided by chemical manufacturers.

Salinity

Onions are more sensitive to salinity than most other crops. High soil salinity impairs the plant's ability to extract water from the soil. Nutrient uptake may also be restricted. Soil salinity is determined by measuring the electrical conductivity (EC) of the soil in millimhos per centimeter (mmhos/cm). A standard soil test contains an EC measurement. Yield reductions can occur in onions when the soil salinity exceeds 1.2 mmhos/cm. Salts from irrigation water and fertilizer are major contributors to soil salinity. Use good quality irrigation water whenever possible (surface waters usually have less salt than water from shallow or deep wells).

Apply fertilizer in small increments and place far enough from the seed row to prevent burning. Improper placement of fertilizer near seeds and seedlings may cause death of roots and plants.

Pollution

Ozone is a common pollutant produced through the action of light on hydrocarbons and nitrogen oxide, by-products of internal combustion engines. Ozone can also be generated during electric storms. Damage to sensitive crops such as onions occurs on warm, humid, relatively calm days in mid-summer to early fall, if pollution levels are high. Symptoms appear one to three days later on well-developed leaves as translucent flecks or small sunken and irregular spots that turn white. Leaf tips frequently wilt and die. Injury is most evident on the side of the leaf directly exposed to the sun. Tissues affected by ozone are often more susceptible to subsequent infection by the Botrytis leaf blight pathogen, *Botrytis squamosa*, and possibly other pathogens. There are currently no control measures for this type of pollution problem.

Split Bulbs

Excessive rates of nitrogen fertilizer, or application of nitrogen after bulb initiation can lead to excessively rapid growth of the bulb, resulting in splitting of several outermost layers of fleshy scales in the bulbs. The wounding caused by splitting of fleshy scales can lead to secondary infection by bacteria and fungi, particularly soil-borne bacteria and fungi. Wide fluctuations in soil moisture after bulb initiation can result in splitting of the basal plate as a result of variable growth rates of the bulb. The wounding to the basal plate can lead to secondary infection by soil-borne fungi and bacteria. A balanced fertility program (particularly nitrogen), avoiding late-season nitrogen applications, and using irrigation practices to avoid wide fluctuations in soil moisture can minimize the risk of these problems.

Storm Damage

Severe storms with high winds, hail and blowing soil particles can injure onion leaf and neck tissues. White to yellow spots, round to irregular in shape and size, develop on damaged tissue. Rain injury is seldom serious. On the other hand, defoliation caused by hail is one of the most damaging effects of a storm. Hail damage reduces functional leaf area and predisposes the plant to infection by fungal and bacterial pathogens. Onion leaves not only supply materials for plant growth but also contain the chemical receptor that stimulates bulbing. Thus, defoliating hail storms may have compounding effects on bulb growth and development. Experts disagree on the value of post-damage uses of foliar fertilizer to help plants replace damaged tissue more quickly, and application of pesticides to protect against disease infection. Their use is often supported in Colorado by pest and crop consultants.

Temperature Extremes

High temperature and intense sunlight may damage young, sensitive seedlings by killing tissue at or near the soil line. Partially damaged seedlings that survive may develop a bright yellow band at the soil line, which is pushed up as the plant continues to grow. Older plant and bulb (shoulder) tissue may be scalded close to or during harvest, especially after lifting and windrowing. Injured bulb areas lose moisture, become sunken, leather-like, and turn white.

Low temperatures may damage seedlings by causing tissue at or near the soil line to turn yellow. Newly transplanted onions may be injured if the temperature falls below 20^{o}F for long periods. Onion bulbs freeze at 30^{o}F; however, they can be super-cooled to 25^{o}F without injury as long as they are not moved. Symptoms of freeze damage appear on fleshy scales as water-soaked, gray to yellow areas. Usually, an entire scale is injured all the way around the bulb, but adjacent inner and outer scales may or may not show injury. The skin is often loose on the concave side of affected tissue which develops a granular texture. Frozen onions are injured less severely if thawed out at 40^{o}F than at a higher temperature. Varieties may differ in their response to low temperature. Those low in solids are more sensitive.

Bolting

The initiation of flowering by the formation of a seed stalk is referred to as bolting and is an undesirable trait in onions grown for bulbs. Bolting can occur at many stages during onion development depending on the environmental conditions. The principal factors that influence bolting are temperature, variety, and size of plant. Transplants are especially prone to bolting if they are too large and/or exposed to prolonged periods of cold weather. Sweet Spanish varieties are particularly susceptible if the crop is seeded or transplanted early.

Translucent Scale

This physiological disorder is characterized by grayish, water-soaked tissue on one or more scales, which makes them appear translucent. The problem may appear on all scales, or more often on only the second and third fleshy scales. In cross-section, the affected scales are brown. Translucent scales can be confused with freeze damage. However, freeze damage always affects bulbs from the outside in, and usually also affects neck tissue. The cause of translucent scales is unknown. It may be associated with storage because it appears after harvest and worsens with length of storage. Onions kept at 40-50^{o}F for a few weeks before final storage at 32^{o}F may exhibit more damage. Excessive relative humidity and exposure to intense sunlight during harvest may predispose onions to this problem.

Greening

The greening of bulbs is caused by the formation of chlorophyll in the outer fleshy scales. Greening may occur if onions are allowed to cure too long in moderate light, or when the shoulders of bulbs are exposed to sunlight during production. Excess and late-season applications of nitrogen delay maturity and also enhance greening.

Genetic Abnormalities

Onion plants occasionally exhibit physiological and genetic abnormalities that may be confused with symptoms induced by plant pathogens or abiotic factors. Abnormal leaf coloration (variegations) may appear as linear patterns of green, yellow, and white tissue (chimeras). These patterns cause abnormal development of the plants and bulbs. Individual leaves or typically the entire plant may express variegations.

Storm Damaged Onions

Allium cepa L.

FIGURE 1

FIGURE 2

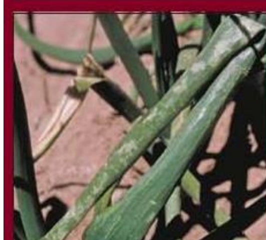


FIGURE 3

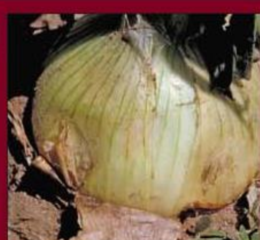


FIGURE 4

AUTHORS: H. F. Schwartz (Colorado State University)
PHOTOGRAPHS: Courtesy of H. F. Schwartz [01/2011]

ALLIUM TYPE: Fresh Market and Storage Onion; protocols based on National Crop Insurance Standards; compare damaged and non-damaged portions of field or fields of the same variety, plant age

____ Record Stage of Plant Growth (V1 to R9)

____ Record Dates of planting, storm event(s), evaluation

____ **ESTIMATE PLANT STAND LOSS** (NUMBER/ACRE) [FIG. 1]

Measure number of plants between furrows (bed width) by 10–20 ft [3–6 m] = 1/1000 Acre [Hectare] at 5 to 6 representative sites in the affected area or field

____ **ESTIMATE DEFOLIATION** (PERCENT LOSS) [FIG. 2 & 3]

Estimate percent of foliage damaged (bruised) or removed by the storm activity (10–20 ft [3–6 m] x 1 bed wide at 5 to 6 sites)

____ **ESTIMATE BULB DAMAGE** (PERCENT AFFECTED) [FIG. 4]

Evaluate percent of 50–100 bulbs at 5 to 6 sites for evidence of storm damage (as cuts, nicks, dents, bruises) on exposed outer 2–3 fleshy scales

Figure 20. Guidelines to evaluate the extent of storm damage to onions.

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APPENDIX I (Illustrations) - Onion Production (www.forestryimages.org)


5367607
Field preparation for planting
Howard F. Schwartz


5361446
Seed planter
Howard F. Schwartz


5366606
Transplanting by hand
M.E. Bartolo


5389397
Transplanting by machine
Howard F. Schwartz


5358553
Cultivation operation
Howard F. Schwartz


5389435
Cultivation operation
Howard F. Schwartz


5362656
Cultivation operation
Howard F. Schwartz


5364555
Cultivation operation
Howard F. Schwartz


5359336
Fertilizer application
Howard F. Schwartz


5358842
Furrow-irrigated field
Howard F. Schwartz


5362031
Drip irrigation
Howard F. Schwartz


5362245
Sprinkler irrigation
Howard F. Schwartz


5366483
Sprinkler irrigation
Howard F. Schwartz


5362266
Crop health inspection (IPM)
Howard F. Schwartz


5362935
Crop health inspection and modeling
Howard F. Schwartz

5362275
Pesticide application
Howard F. Schwartz

5360602
Top roller pre-harvest operation
Howard F. Schwartz

5362019
Rolled onion tops pre-harvest
Howard F. Schwartz

1571243
Pre-harvest undercutting
Gerald Holmes

5361073
Field drying of tops
Howard F. Schwartz

5361453
Curing and storage in crates
Howard F. Schwartz

5361496
Field curing in windrows
Howard F. Schwartz

garden onion Allium cepa by Howard F. Schwartz

Field curing
Howard F. Schwartz

7
Field curing in burlap bags
Howard F. Schwartz

5358843
Field cured
S. K. Mohan

5359374
Mechanical topping
Howard F. Schwartz

5361455
Hand topping operation
Phil Westra

5357407
Topped and bagged for field curing
M.E. Bartolo

5358846
Transfer of field-cured onions
Howard F. Schwartz

5361114
Transfer to truck
Howard F. Schwartz

5359377
Truck transport
Howard F. Schwartz

5361084
Transfer to storage shed
Howard F. Schwartz

5361085
Transfer to storage shed
Howard F. Schwartz

5361087
Storage shed with air movement system
Howard F. Schwartz

5359968
Onion cull dump
Howard F. Schwartz

5360333
Onion cull dump for sheep
Howard F. Schwartz

5366628
Color classes
M.E. Bartolo

1571268
Sorted and bagged for market
Gerald Holmes

APPENDIX II (Illustrations) - Onion Viral & Nematode Diseases

(www.forestryimages.org)

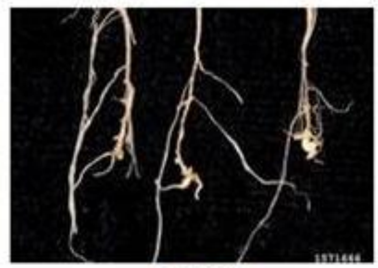
1235020
sting nematode
Belonolaimus spp.
Damage
Clemson University - USDA Cooperative Extension Slide Series

5472602
aster yellows phytoplasma
Candidatus Phytoplasma asteris
Symptoms
Lindsey du Toit

0162062
stem and bulb nematode
Ditylenchus dipsaci
Damage
Central Science Laboratory, Harpenden Archive

5476504
stem and bulb nematode
Ditylenchus dipsaci
Sign
Bruce Watt

5476505
stem and bulb nematode
Ditylenchus dipsaci
Sign
Bruce Watt



1571666
needle nematode
Longidorus africanus
Root(s)
Gerald Holmes

1234195
root-knot nematode
Meloidogyne spp.
Damage
Clemson University - USDA Cooperative Extension

5362284
stubby root nematodes
Paratrichodorus spp.
Damage
Howard F. Schwartz

5474119
phytoplasma (general)
Phytoplasma N/A
Symptoms
Howard F. Schwartz

5435884
lesion nematode
Pratylenchus spp.
Adult(s)
Walter Peraza Padilla

5303068
Iris Yellow Spot Virus
Tospovirus IYSV
Symptoms
Whitney Cranshaw

5365622
Iris Yellow Spot Virus
Tospovirus IYSV
Symptoms
Howard F. Schwartz

5365627
Iris Yellow Spot Virus
Tospovirus IYSV
Symptoms
Howard F. Schwartz

APPENDIX II (Illustrations) - Onion Bacterial Diseases (www.forestryimages.org)

5076069
sour skin - bulb (David Langston @ Bugwood)
David B. Langston

5358538
slippery skin - neck (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5362303
slippery skin - bulb (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5359980
Enterobacter - severe (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5359982
Enterobacter - moderate (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5362310
center rot - foliage (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5362313
center rot - bulb (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5359773
soft rot - bleaching (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5362288
soft rot - foliage (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5361477
soft rot - bulb (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5363741
leaf streak - neck (Howard Schwartz @ Bugwood)

5362298
leaf streak - foliage (Howard Schwartz @ Bugwood)
Howard F. Schwartz

5360013
leaf blight - foliage (Howard Schwartz @ Bugwood)

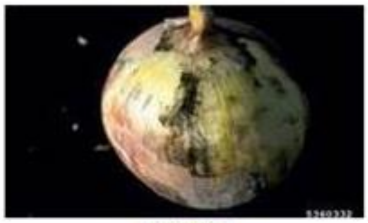
5365860
leaf blight - watersoaking (Howard Schwartz @ Bugwood)
Howard F. Schwartz

APPENDIX II (Illustrations) – Onion Fungal Diseases (www.forestryimages.org)

5361486
purple blotch
Alternaria porri
Research
Howard F. Schwartz

5362728
purple blotch
Alternaria porri
Sign
Howard F. Schwartz

1571309
black mold
Aspergillus niger
Sign
Gerald Holmes



5360332
black mold
Aspergillus niger
Damage
Howard F. Schwartz

5178022
botrytis rot
Botrytis allii
Symptoms
Howard F. Schwartz

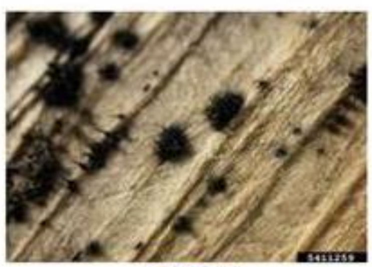
5178023
botrytis rot
Botrytis allii
Sign
Lester E. Dickens

5178025
botrytis rot
Botrytis allii
Symptoms
S. K. Mohan

5365842
botrytis rot
Botrytis allii
Research
Howard F. Schwartz

5361513
gray mold
Botrytis cinerea
Research
Howard F. Schwartz

5361514
onion smudge
Colletotrichum circinans
Research
Howard F. Schwartz



5411259
onion smudge
Colletotrichum circinans
Sign
Cesar Calderon

2169098
Embellisia skin blotch and bulb canke
garlic
Embellisia allii
Symptoms

5411261
Embellisia skin blotch and bulb canker of garlic
Embellisia allii
Asexual Spore
Cesar Calderon

5428820
Embellisia skin blotch and bulb canker of garlic
Embellisia allii
Sign
Bruce Watt

5361500
Fusarium damping-off
Fusarium oxysporum f.sp. cepae
Research
Howard F. Schwartz

5474196
Fusarium damping-off
Fusarium oxysporum f.sp. cepae
Symptoms
Howard F. Schwartz

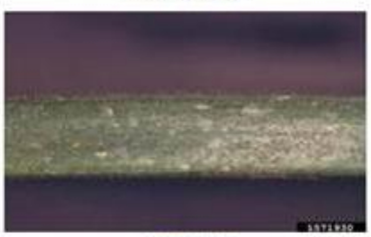
5367338
powdery mildew
Leveillula taurica
Damage
S. K. Mohan

5367339
powdery mildew
Leveillula taurica
Damage
S. K. Mohan

5367335
Penicillium fungi
Penicillium spp.
Symptoms
S. K. Mohan

5367336
Penicillium fungi
Penicillium spp.
Damage
S. K. Mohan

1571070
downy mildew
Peronospora destructor
Symptoms
Gerald Holmes



1571930
downy mildew
Peronospora destructor
Foliage
Gerald Holmes

5361481
downy mildew
Peronospora destructor
Research
Howard F. Schwartz

1571408
pink root of onion
Phoma terrestris
Symptoms
Gerald Holmes

5361504
pink root of onion
Phoma terrestris
Research
Howard F. Schwartz

5366498
onion rust
Puccinia allii
Symptoms
Howard F. Schwartz

5366500
onion rust
Puccinia allii
Symptoms
Howard F. Schwartz

5359354
Pythium diseases
Pythium spp.
Damage
Howard F. Schwartz

5439655
root rot/damping off
Rhizoctonia spp.
Sign
Lindsey du Toit

5440230
root rot/damping off
Rhizoctonia spp.
Symptoms
Lindsey du Toit

5472512
southern blight
Sclerotium rolfsii
Culture
Jason Brock

1570866
Stemphylium leaf blight and stalk rot
Stemphylium vesicarium
Symptoms
Gerald Holmes

1572312
Stemphylium leaf blight and stalk rot
Stemphylium vesicarium
Stem(s)
Gerald Holmes

5361505
smut
Urocystis colchici
Research
Howard F. Schwartz

5361506
smut
Urocystis colchici
Research
Howard F. Schwartz

APPENDIX III (Illustrations) - Onion Insect Pests (www.forestryimages.org)

5486080
leek moth
Acrolepiopsis assectella
Larva(e)
Mariusz Sobieski

5486086
leek moth
Acrolepiopsis assectella
Larva(e)
Mariusz Sobieski

5486092
leek moth
Acrolepiopsis assectella
Pupa(e)
Mariusz Sobieski

5458942
onion maggot
Delia antiqua
Adult(s)
Pest and Diseases Image Library

5458947
onion maggot
Delia antiqua
Adult(s)
Pest and Diseases Image Library

5458949
onion maggot
Delia antiqua
Pupa(e)
Pest and Diseases Image Library

5211077
onion bulb fly
Eumerus strigatus
Adult(s)
Cheryl Moorehead

5364132
western flower thrips
Frankliniella occidentalis
Adult(s)
Frank Peairs

5370035
western flower thrips
Frankliniella occidentalis
Adult(s)
Jack T. Reed

5370036
western flower thrips
Frankliniella occidentalis
Nymph(s)
Jack T. Reed

1243002
vegetable leafminer
Liriomyza sativae
Larva(e)
Whitney Cranshaw

1243003
vegetable leafminer
Liriomyza sativae
Pupa(e)
Whitney Cranshaw

5362731
leafminer fly
Liriomyza spp.
Infestation
Howard F. Schwartz

1243101
aster leafhopper
Macrosteles quadrilineatus
Adult(s)
Whitney Cranshaw

1326230
green peach aphid
Myzus persicae
Life Cycle
Whitney Cranshaw

5402104
onion aphid
Neotoxoptera formosana
Infestation
Lesley Ingram

5364212
variegated cutworm
Peridroma saucia
Larva(e)
Frank Peairs

5460667
variegated cutworm
Peridroma saucia
Adult(s)
Mark Dreiling

1481002
beet armyworm
Spodoptera exigua
Larva(e)
Frank Peairs

5368048
beet armyworm
Spodoptera exigua
Adult(s)
Merle Shepard, Gerald R.Carner, and P.A.C Ooi

5473257
beet armyworm
Spodoptera exigua
Damage
Bob Hammon

5473259
beet armyworm
Spodoptera exigua
Damage
Howard F. Schwartz

5190079
cotton leafworm, tobacco cutworm
Spodoptera litura
Adult(s)
Natasha Wright

1242133
yellowstriped armyworm
Spodoptera ornithogalli
Larva(e)
Russ Ottens

1327111
yellowstriped armyworm
Spodoptera ornithogalli
Larva(e)
Alton N. Sparks, Jr.

5431830
yellowstriped armyworm
Spodoptera ornithogalli
Adult(s)
Lyle Buss

1243059
onion thrips
Thrips tabaci
Nymph(s)
Whitney Cranshaw

5365856
onion thrips
Thrips tabaci
Research
Howard F. Schwartz

5445031
onion thrips
Thrips tabaci
Life Cycle
Diane Alston

5445034
onion thrips
Thrips tabaci
Adult(s)
Diane Alston

APPENDIX IV (Illustrations) - Onion Weeds – Grasses & Perennials (www.forestryimages.org)

5364433
wild oat
Avena fatua
Seed(s)
Howard F. Schwartz

5443370
wild oat
Avena fatua
Seed(s)
Jan Samanek

5362341
longspine sandbur
Cenchrus longispinus
Plant(s)
Howard F. Schwartz

5396742
field sandbur
Cenchrus spinifex
Fruit(s)
Robert Vidéki

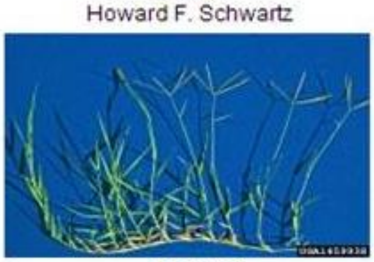
1553262
Canada thistle
Cirsium arvense
Foliage
Ohio State Weed Lab Archive

5362606
field bindweed
Convolvulus arvensis
Plant(s)
Howard F. Schwartz

5389459
field bindweed
Convolvulus arvensis
Plant(s)
Howard F. Schwartz

1391269
dodder
Cuscuta spp.
Plant(s)
John D. Byrd

5362702
dodder
Cuscuta spp.
Plant(s)
Howard F. Schwartz



1459938
bermudagrass
Cynodon dactylon
Plant(s)
Steve Dewey

1459940
bermudagrass
Cynodon dactylon
Foliage
Steve Dewey

5358449
chufa flatsedge
Cyperus esculentus var. leptostachyus
Plant(s)
Howard F. Schwartz


5358452
chufa flatsedge
Cyperus esculentus var. leptostachyus
Plant(s)
Howard F. Schwartz


5387279
crabgrass
Digitaria spp.
Seedling(s)
Joseph M. DiTomaso


1459494
quackgrass
Elymus repens
Plant(s)
Steve Dewey


1550006
field horsetail
Equisetum arvense
Plant(s)
John Cardina


1364153
smooth horsetail
Equisetum laevigatum
Plant(s)
Mary Ellen (Mel) Harte


5387406
Italian ryegrass
Festuca perennis
Plant(s)
Joseph M. DiTomaso


5436257
Canada thistle bud weevil
Larinus planus
Damage
Eric Coombs


5387413
perennial ryegrass
Lolium perenne
Flower(s)
Joseph M. DiTomaso


1571349
alfalfa
Medicago sativa
Feature(s)
Gerald Holmes

1459349
wild-proso millet
Panicum miliaceum
Flower(s)
Steve Dewey

5386229
annual bluegrass
Poa annua
Flower(s)
Joseph M. DiTomaso

5396608
yellow foxtail
Setaria pumila
Plant(s)
Robert Vidéki

5362348
green foxtail
Setaria viridis
Flower(s)
Howard F. Schwartz

5358455
johnsongrass
Sorghum halepense
Seedling(s)
Howard F. Schwartz

5364564
dandelion
Taraxacum spp.
Research
Howard F. Schwartz

APPENDIX IV (Illustrations) - Onion Broadleaf Weeds, Part 1 (www.forestryimages.org)

5362322
garden onion
Allium cepa
Competition
Howard F. Schwartz

1120007
common ragweed
Ambrosia artemisiifolia
Plant(s)
James H. Miller & Ted Bodner

1559044
common ragweed
Ambrosia artemisiifolia
Plant(s)
Ohio State Weed Lab Archive

1211086
field chickweed
Cerastium arvense
Flower(s)
Dave Powell

1363083
field chickweed
Cerastium arvense
Foliage
Mary Ellen (Mel) Harte

5364561
lambsquarters
Chenopodium album
Research
Howard F. Schwartz

5374875
lambsquarters
Chenopodium album
Flower(s)
Joseph M. DiTomaso

5374691
blue mustard
Chorispora tenella
Plant(s)
Joseph M. DiTomaso

5374692
blue mustard
Chorispora tenella
Flower(s)
Joseph M. DiTomaso

1209047
Venice mallow
Hibiscus trionum
Flower(s)
Dave Powell

5362838
Venice mallow
Hibiscus trionum
Seedling(s)
Phil Westra

5362839
Venice mallow
Hibiscus trionum
Plant(s)
Phil Westra

5365870
tall morningglory
Ipomoea purpurea
Infestation
Howard F. Schwartz

5361301
Mexican fireweed
Kochia scoparia
Seedling(s)
Phil Westra

5362330
Mexican fireweed
Kochia scoparia
Infestation
Howard F. Schwartz

5364570
common mallow
Malva neglecta
Plant(s)
Howard F. Schwartz

5364560
mustards, crucifers
Research
Howard F. Schwartz

5273086
Oriental lady's thumb
Persicaria longiseta
Flower(s)
Leslie J. Mehrhoff

5476748
Oriental lady's thumb
Persicaria longiseta
Foliage
Chris Evans

5362869
common purslane
Portulaca oleracea
Plant(s)
Phil Westra

5366614
common purslane
Portulaca oleracea
Plant(s)
M.E. Bartolo

5139090
common groundsel
Senecio vulgaris
Plant(s)
Lynn Sosnoskie

5397850
common groundsel
Senecio vulgaris
Plant(s)
Robert Vidéki

5358673
wild mustard
Sinapis arvensis
Fruit(s)
L.L. Berry

5364569
wild mustard
Sinapis arvensis
Plant(s)
Howard F. Schwartz

5362860
black nightshade
Solanum nigrum
Fruit(s)
Phil Westra

5362863
hairy nightshade
Solanum physalifolium
Plant(s)
Phil Westra

1391373
buffalobur
Solanum rostratum
Fruit(s)
John D. Byrd

5386685
buffalobur
Solanum rostratum
Flower(s)
Joseph M. DiTomaso

5362862
nightshade
Solanum spp.
Flower(s)
Phil Westra

5362356
clover
Trifolium spp.
Plant(s)
Howard F. Schwartz

5397700
mayweed
Tripleurospermum maritimum ssp. inodorum
Plant(s)
Robert Vidéki

APPENDIX IV (Illustrations) - Onion Broadleaf Weeds, Part 2 (www.forestryimages.org)


1459826
velvetleaf
Abutilon theophrasti
Fruit(s)
Steve Dewey


5363867
velvetleaf
Abutilon theophrasti
Plant(s)
Howard F. Schwartz


5374122
prostrate pigweed
Amaranthus blitoides
Plant(s)
Joseph M. DiTomaso


5374123
prostrate pigweed
Amaranthus blitoides
Feature(s)
Joseph M. DiTomaso


5362592
redroot pigweed
Amaranthus retroflexus
Plant(s)
Howard F. Schwartz


1459565
shepherd's-purse
Capsella bursa-pastoris
Plant(s)
Steve Dewey


1459642
prostrate spurge
Chamaesyce humistrata
Foliage
Utah State University Archive


5306097
prostrate spurge
Chamaesyce humistrata
Plant(s)
USDA PLANTS Database


5435916
Russian thistle moth
Coleophora klimeschiella
Damage
Eric Coombs


1380317
Queen Anne's lace, wild carrot
Daucus carota
Plant(s)
Chris Evans


1552203
Queen Anne's lace, wild carrot
Daucus carota
Flower(s)
Ohio State Weed Lab Archive


5365828
carrot
Daucus carota ssp. sativus
Plant(s)
Howard F. Schwartz

5364565
redstem stork's bill
Erodium cicutarium ssp. cicutarium
Research
Howard F. Schwartz

5362595
toothed spurge
Euphorbia dentata
Plant(s)
Howard F. Schwartz

5362323
toothed spurge
Euphorbia dentata var. dentata
Infestation
Howard F. Schwartz

5357369
sunflower
Helianthus spp.
Flower(s)
Howard F. Schwartz

5362085
sunflower
Helianthus spp.
Plant(s)
Howard F. Schwartz

1550197
swamp smartweed
Persicaria hydropiperoides
Plant(s)
Catherine Herms

5398922
prostrate knotweed
Polygonum aviculare
Plant(s)
Robert Vidéki

5379905
wild radish
Raphanus raphanistrum
Flower(s)
Rebekah D. Wallace

5364562
Russian thistle
Salsola kali
Research
Howard F. Schwartz

5364559

potato
Solanum tuberosum
Research
Howard F. Schwartz

5362339

puncturevine
Tribulus terrestris
Plant(s)
Howard F. Schwartz

5362847

puncturevine
Tribulus terrestris
Feature(s)
Phil Westra

MATH CONVERSIONS

U.S. to Metric Units*	**Metric to U.S. Units***
Temperature:	
^{0} Fahrenheit = (C^0 x 1.8) + 32	^{0} Centigrade = (F^0 - 32) / 1.8
Length and Area:	
1 inch = 2.54 centimeters	1 centimeter = 0.39 inch
1 foot = 0.31 meter	1 meter = 3.28 feet
1 yard = 0.91 meter	1 meter = 1.01 yards
1 square foot = 0.09 sq. meter	1 sq. meter = 10.76 sq. feet
1 square yard = 0.84 sq. meter	1 sq. meter = 1.20 sq. yards
1 acre = 0.41 hectare	1 hectare = 2.47 acres

Area of Shapes:

Area of a circle = radius squared x 3.14
Area of a rectangle = length x width
Area of a right triangle = length x width / 2
Area of other triangles = base x height at right angle to base / 2

Weight:	
1 ounce = 28.35 grams (gm.)	1 gram = 0.04 ounce
1 pound = 0.45 kilograms (kg.)	1 kilogram = 2.21 pounds
1 ton = 0.91 metric ton	1 metric ton = 1.10 tons
Volume:	
1 fluid ounce = 29.57 cubic centimeters (ml)	1 cubic centimeter (ml) = 0.03 fl. ounce
1 gallon = 3.79 liters	1 liter = 0.26 gallon
1 fluid ounce/gallon = 7.81 ml/liter	1 ml/liter = 0.13 fluid ounce/gallon
1 pound/acre = 1.12 kg/hectare	1 kg/liter = 0.89 pound/acre
1 gallon/acre = 9.35 liters/hectare	1 liter/hectare = 0.11 gallon/acre

Other Useful Conversions:

1 gallon = 4 quarts = 8 pints = 16 cups = 128 fluid ounces
1 fluid ounce = 2 tablespoons = 6 teaspoons
1 ppm† = 1 mg/liter = 0.0001 % = 0.013 fluid ounce / 100 gallons
1 % = 10,000 ppm = 10 gm./liter = 1.33 ounces/gallon
1 micron = 1 x 10^{-4} cm = 3.94 x 10^{-8} inch

* Conversion values adapted from Agricultural Chemicals by W. T. Thompson and Fungicide & Nematicide Tests – American Phytopathological Society. †Parts Per Million.

Photo Courtesy of Stephanie Szostek

Photo Courtesy of Mike Bartolo

Photo Courtesy of Howard Schwartz