COLORADO ONION PRODUCTION AND INTEGRATED PEST MANAGEMENT

547A

Colorado State University Cooperative Extension

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Introduction and Background

Colorado is one of the largest fresh market onion (*Allium cepae* L.) producers in the United States, with more than 18,000 acres planted (Table 1). The three growing regions in the state are the West Slope, the Arkansas Valley, and Northeastern Colorado, which comprise 20, 25, and 55 percent of the onion acreage, respectively. Most of the onions grown in Colorado are long-day, storage onions grown from seed. However, 10 to 15 percent of the acreage is devoted to transplants grown for the early and fresh crop market. Yields often average 400 to 500 hundredweight per acre unless problems such as soil-borne pathogens, foliar and bulb pathogens, weeds, insects, or environmental stresses become serious enough to limit production.

DURING THE MIDDLE AGES, ONIONS WERE SO VALUABLE, THEY WERE USED AS RENT PAYMENTS AND WEDDING GIFTS. TODAY, ONIONS ARE AN IMPORTANT PART OF THE TYPICAL AMERICAN'S DIET.

The onion is a biennial herb (monocot), normally grown as an annual for its bulbs and only carried forward into a second year when seeds are required. It is a member of the lily family and is closely related to other crops such as the shallot, leek, garlic, and chives. The onion originated in Central Asia (Iran-West Pakistan). It is one of the world's oldest cultivated vegetables, having been grown since at least 3,000 B.C. in Egypt and India for food and use in art, medicine, and mummification. Onions were considered sacred by ancient Egyptians, who believed the spheres of an onion symbolized eternity. Egyptian officials took office with their right hand on an onion.

During the Middle Ages, onions were so valuable, they were used as rent payments and wedding gifts. Today, onions are an important part of the typical American's diet. The average American consumes about 16 pounds of onions each year. Over the last two decades, per capita consumption has steadily increased 1 percent to 3 percent every year. With sustained growth in domestic demand and an expanding export market, onion production is projected to grow well into the 21st century.

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. Colorado State University 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 their negative impacts on this important food crop. This handbook will not review the wealth of 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 best management strategies.

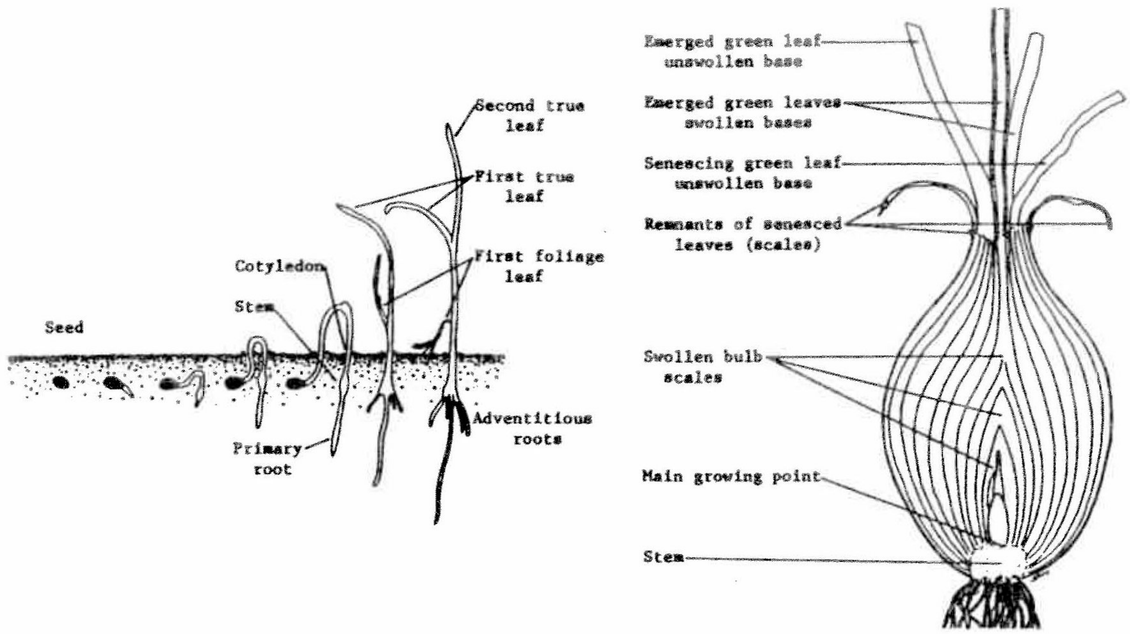


Figure 1: Onion Plant Development (drawings by Bill Stump, Colo. State University).

Varietal Reviews

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 daylength and thus, can be classified as short-, intermediate- and long-day types. Onions are further categorized by shape (flat, globe, grano, torpedo), skin color (yellow, red, white), pungency (sweet, pungent), and market use (fresh, storage, and processing). Most onion varieties grown in Colorado are long-day types (Spanish or Northern) that respond to our long daylengths during the growing season. Yellow, sweet Spanish varieties with moderate to long-term storage capabilities are the predominate long-day onions grown in Colorado.

Choosing a Variety

Selection of the proper onion variety is one of the most important decisions a grower can make. There are many onion varieties currently on the market and each year seed companies introduce new ones that are potentially well adapted for different regions in Colorado. Some commonly grown sweet Spanish varieties include 'Colorado 6,' 'Brown Beauty,' 'Valdez,' and 'El Charro.' Field trials are an excellent way to screen other promising onion varieties. Independent trials are conducted on an annual basis in Northern Colorado and in the Arkansas Valley by Colorado State University Cooperative Extension and Colorado Agricultural Experiment Station personnel.

In addition, individual seed companies often have trials of their own. Besides yield potential, field trials reveal other

Table 1: Colorado Onion Production Statistics, 1918 - 1994.

YEAR	ACREAGE	CWT / ACRE	$ / CWT	$ CROP VALUE
1918	700	139	1.74	170,000
1923	2,620	142	1.90	707,000
1928	3,760	188	2.48	1,760,000
1933	4,150	157	0.80	522,000
1938	7,900	210	1.00	1,029,000
1943	9,300	265	2.40	5,914,000
1948	11,000	250	1.90	5,225,000
1953	5,900	250	1.00	1,475,000
1958	7,800	280	2.95	6,443,000
1963	6,300	260	3.95	6,470,000
1968	6,100	290	3.80	5,244,000
1973	4,800	290	7.72	8,878,000
1978	7,800	350	8.27	18,359,000
1983	10,400	330	14.60	39,084,000
1988	13,500	410	12.30	55,830,000
1993	16,000	370	18.80	88,360,000
1994	18,000	400	12.10	77,440,000

Data from Colorado Agricultural Statistics Reports – Colo. Dept. of Agriculture

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 Colorado State University Cooperative Extension county office for more information.

Onions harvested for bulbs go through the following three distinct phases of growth and development.

Establishment Phase

For seeded onions, the establishment phase lasts from planting until the end of May. Onion seeds germinate at temperatures above 40 degrees F, with optimum at 75 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 1). 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 origin.

Vegetative Phase

FOR MOST SEEDED VARIETIES, THE VEGETATIVE STAGE ENDS ABOUT THE FIRST OR SECOND WEEK IN JULY.

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 being 20 to 25 inches in length. For most seeded varieties, the vegetative stage ends about the first or second week in July.

Bulbing Phase

Bulb initiation occurs when the diameter of the bulb is twice that of the neck. Nearly all of the onions grown in Colorado are long-day onions. That is, they are genetically programmed to 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, newer leaves are growing. 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.

Figure 2 and Table 2 illustrate a typical growth and development pattern for 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 daylength, and overall solar radiation. All of these factors contribute to growth patterns.

Planting Procedures

Seed-bed Preparation

CAREFUL TIMING IS ESSENTIAL TO KILL THE COVER CROP BY TILLAGE OR WITH HERBICIDES TO AVOID SUPPRESSING ONION GROWTH.

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 mulcher or disk. 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 and planted.

Whether beds are made in the fall, spring, or not at all, the soil must be left in such a state that it doesn't blow. Plant cover crops in the fall or early spring to minimize damage to onion seed and seedlings from blowing. Careful timing is essential to kill the cover crop by tillage or with herbicides to avoid suppressing onion growth.

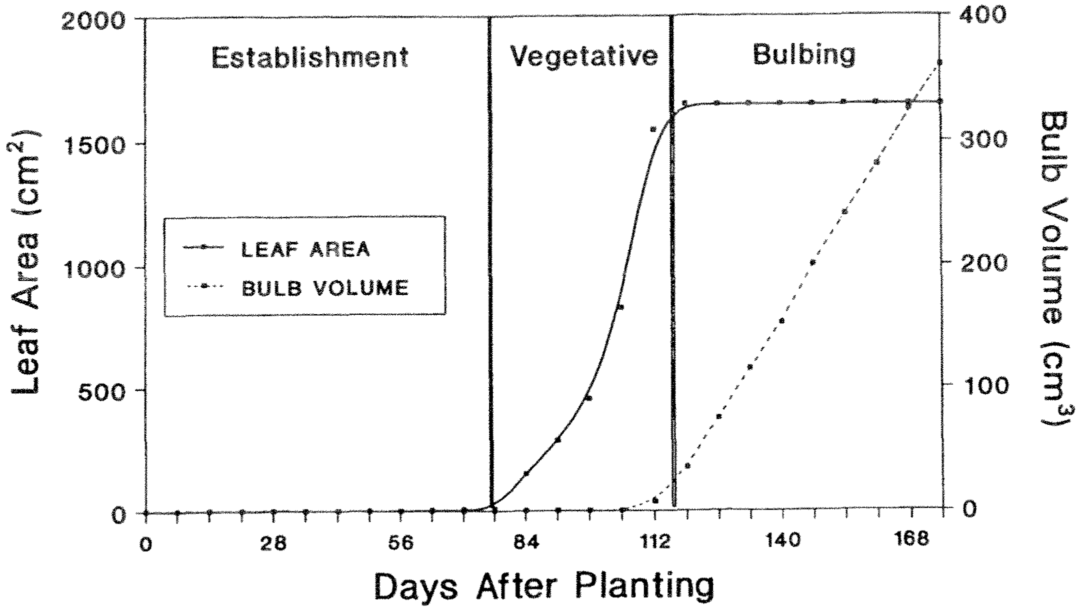


Figure 2: Developmental stages of seeded variety 'Colorado 6' at Rocky Ford, CO (courtesy of M. E. Bartolo).

Seeding Rates and Spacing

Onion seed may be planted after the first of January, however, they usually will not germinate until after March to early April. 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 inches bed, they generally are 12 to 18 inches apart.

Uniform seed placement and spacing is critical to good stand establishment. Seed are planted 0.5 to 1-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 spacings that promote large bulbs with thick necks. Generally, an in-row spacing of 3 to 4 inches will give both high total yield and a high percentage of onions in the larger market classes.

Many types of planters can be used to seed onions and all must be carefully set 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 from Texas, Arizona, or California after inspection for quality and absence of contamination by pests. Transplants arrive in bundles with tops and occasionally roots pruned to facilitate

Table 2: Description of Onion Growth Stages (APS Compendium of Onion and Garlic Diseases).

Stage	Days After Seeding	Description of Plant Growth Stage
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 - 1.5 inches
7	130 - 150	Bulb diameter of 1.5 - 3 inches
8	150 - 170	Bulb enlargement complete, greater than 50 percent topped
9	170+	Dry down period, pre-harvest to harvest

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

handling. Upon arrival at the farm, promptly unload transplant bundles to discourage heat buildup, moisture condensation, and disease development.

Transplanting takes place from late March to the end of April. When planted earlier, cool weather may induce them 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 sticking 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 properly take root. Soil should be loosely textured and free of clods. Transplanting depth does not have a major effect on ultimate yield, however, the transplant should be set in the ground as erect 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 plant disease- and insect-free, vigorous transplants that are about 0.25 inch in diameter. Minimize mechanical wounding during transplanting to reduce later-season problems from diseases such as Botrytis soil-line rot, Fusarium basal rot, and the bacterial complex.

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. Take extra care 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

Common rotation crops include sweet corn, field corn, alfalfa, potatoes, dry beans, melons, sugarbeets, and small grains such as oats, barley, and wheat.

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 escaped the herbicides and mechanical cultivation. Additional field operations may include application of various pesticides for weed, insect, and disease control. Minimize soil compaction by avoiding unnecessary field operations especially when the soil is wet.

Other Cultural Practices

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 serious outbreaks from soil-borne problems such as Pink Root and Fusarium Basal Rot 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, sugarbeets, 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 mellower 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, carefully inspect transplants for diseases and insects. Reduce weed pressure by screening surface irrigation water. Small mesh screens can remove some weed seeds before they are deposited in the field.

Fertility Requirements

It is extremely important that growers are aware of all sources of nutrient inputs including what is already in the soil (residual), manure, crop residue, and irrigation water.

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. Always conduct a soil test (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 (residual), manure, crop residue, 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 what is needed rather than risk limiting yields. However, over-fertilizing can have negative effects on bulb quality and may contribute to ground water contamination.

Nitrogen

Like most other crops, nitrogen is one of the most important nutrients for onions. A typical onion crop will use

Leaching not only renders the nutrient unavailable to the crop, but also can be a source of groundwater contamination.

about 150 pounds of actual 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. Carefully apply the nitrogen in low enough dosages and far enough away from the plant to avoid burning. Do not use aqua or anhydrous ammonia forms 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 rapidly converted 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 ground-water 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	200
10	150
20	100
30	50
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 below the seed. Avoid excess applications that may increase the incidence of seed stalks. Fumigated soil may require slightly higher levels of phosphorus.

P (ppm) in 12" Depth	P_2O_5- Application (lbs/A)
0	250
5	200
10	150
15	100
20	50

Potassium

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

K (ppm) in 12" Depth	K_2O - Application (lbs/A)
0	240
20	190
40	140
60	90
80	40
100 +	0

Micronutrients

Onions are responsive to several micronutrients, most notably zinc, manganese, molybdenum, and copper. Many micronutrients occur naturally in Colorado soils and 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. Broadcast and work either 10 lb/A of Zn into the soil prior to planting or 3 to 4 lb/A of Zn banded with other fertilizer at planting. To correct Zn deficiency during the growing season, wet plants with a solution containing 1 pound zinc in 50 to 100 gallons of water.

Irrigation Practices

ONIONS REQUIRE HIGH AMOUNTS OF GOOD QUALITY IRRIGATION WATER.

Onions require high 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 seriously affected 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 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 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 surface soil.

Uniform applications of water is critical. Probing the soil with a smooth metal rod 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.

Stop irrigation seven to 10 days before onions are lifted to help the crop mature.

THE NECK AREA MUST BE DRIED COMPLETELY.

Harvest Procedures

Field Operations

Harvest of storage onions normally begins when 75 to 80 percent of the tops are down. Rod weeders or wide sweeps normally are used to sever the root system several inches below the bulb. The onions are then allowed to cure until the tops have thoroughly dried. The harvester or 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 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 percent of the tops are down and the foliage is still green and can transmit the inhibitor to the bulb. Do not apply sprout inhibitors when the crop is too immature, since soft, puffy bulbs may result.

Handling

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

Post-Harvest Procedures

CURING PRACTICES IN THE STORAGE SHED SHOULD FINISH THE PROCESS INITIATED IN THE FIELD.

Curing

It is important to thoroughly dry the neck area so that storage diseases do not develop later. 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 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. Carefully monitor the temperature of the pile and humidity in the shed.

Storage Conditions

Maintain temperature at 35 to 40 F (or refrigerated at 32 F) with 65 to 70 percent 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, warm to about 50 F for 24 to 36 hours before packing. It is all right to allow cold air to contact warm onions, but not the other way around. When this happens, moisture condenses on the onions. That moisture must be evaporated quickly by additional blowing with cold air.

USDA Size Classifications

Small	-	1 to 2.25 inches in diameter
Medium	-	2 to 3.25 inches in diameter
Jumbo (large)	-	3 inches or larger in diameter
Export small	-	1.5 to 2 inches in diameter
Export medium	-	2 to 2.75 inches in diameter
Export large	-	2.75 to 3.5 inches in diameter

Industry Size Classifications

Colossal	-	4 inches or larger in diameter
Jumbo	-	3 to 4 inches in diameter
Medium	-	2.25 to 3 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

Causes of Production Problems

Overview

Various constraints can influence plant survival as well as bulb size and quality, and thereby affect crop productivity and profitability. This section will review some of the general aspects of these types of pests (see Figure 3).

Viruses are the smallest infective agents that can cause diseases in onions such as onion yellow dwarf. They are invisible under an ordinary light microscope but their shape and size can be determined with an electron microscope. They are composed of complex protein and nucleic acid substances, and multiply rapidly in the plant. They are transmitted by insects, physical contact, or sometimes in seed, depending upon the specific virus.

VARIOUS CONSTRAINTS CAN INFLUENCE PLANT SURVIVAL AS WELL AS BULB SIZE AND QUALITY, AND THEREBY AFFECT CROP PRODUCTIVITY AND PROFITABILITY.

Mycoplasmas are microscopic single-celled organisms that lack cell walls. They are transmitted by insects such as leafhoppers, and cause aster yellows.

Bacteria are microscopic single-celled organisms that possess cell walls and multiply rapidly in onion foliage and/or bulbs to produce diseases such as bacterial soft rot and slippery skin. Infection and spread are favored by moisture and wounds that may occur during mechanical cultivation and storms.

Fungi are microscopic plants that depend on higher plants or decaying organic matter for their existence. Generally, fungi produce large numbers of spores or survival structures that are carried to their host plants by wind, rain, insects, machinery, or man. Under favorable conditions of temperature and moisture, the spores germinate and infect healthy plants. Common fungal diseases include Fusarium basal rot (soil-borne), purple blotch foliar, and Botrytis neck rot (storage). Between growing seasons, many fungi survive in plant residues or in soil as dormant spores, mycelia, or sclerotia.

Nematodes are microscopic worm-like organisms that live in the soil. The principal nematode problem of onions is the stem and bulb nematode. If they move into the roots of the

ALTHOUGH SOME INSECTS FEED UPON PLANTS AND MAY BECOME PLANT PESTS, THE GREAT MAJORITY HAVE INNOCUOUS OR BENEFICIAL HABITS.

plant to feed, they are called endoparasites. If they remain outside the root while feeding, they are termed ectoparasites. When nematodes are present in large numbers, they weaken the plants, reducing their yields and possibly predisposing root systems to infection by other soil-borne pests.

Insects such as thrips and maggots are an extremely common and diverse group of animals. Physically, adult insects are characterized by having three pairs of legs, three body segments (head, thorax, abdomen), and a winged adult stage. However, insects undergo changes in form (metamorphosis) as they develop, and can have a wide range of forms and habits. Although some insects feed upon plants and may become plant pests, the great majority have innocuous or beneficial habits.

Onions do not compete well with weeds. Competition research has shown that onions must be maintained weed-free for a minimum of six weeks for maximum yields. In western areas, growers rely upon a few herbicides such as Dacthal, Goal, Buctril, and Fusilade. Pre-emergence herbicides suppress weed seedlings and allow onion seedlings to gain a developmental and height advantage. Post-emergence herbicides and mechanical cultivation provide later-season control of weeds that escaped control at planting or germinated after earlier treatments.

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 (Plate 1) possess roots and leaves, and germinate from seeds. They do not photosynthesize, and feed on other plants such as onions by producing pegs (haustoria) which penetrate host tissue. Dodder lacks chlorophyll and is usually yellow or orange in color in infested fields in Colorado. The plant is spread by seed and tissue pieces during cultivation or human involvement.

Environmental and other abiotic stresses can adversely affect plant growth 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 (ozone).

General Management Recommendations

BECAUSE IT GENERALLY IS EASIER AND MORE ADVANTAGEOUS TO PREVENT PESTS THAN TO ELIMINATE THEM, CROP SANITATION ALWAYS SHOULD BE PRACTICED.

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

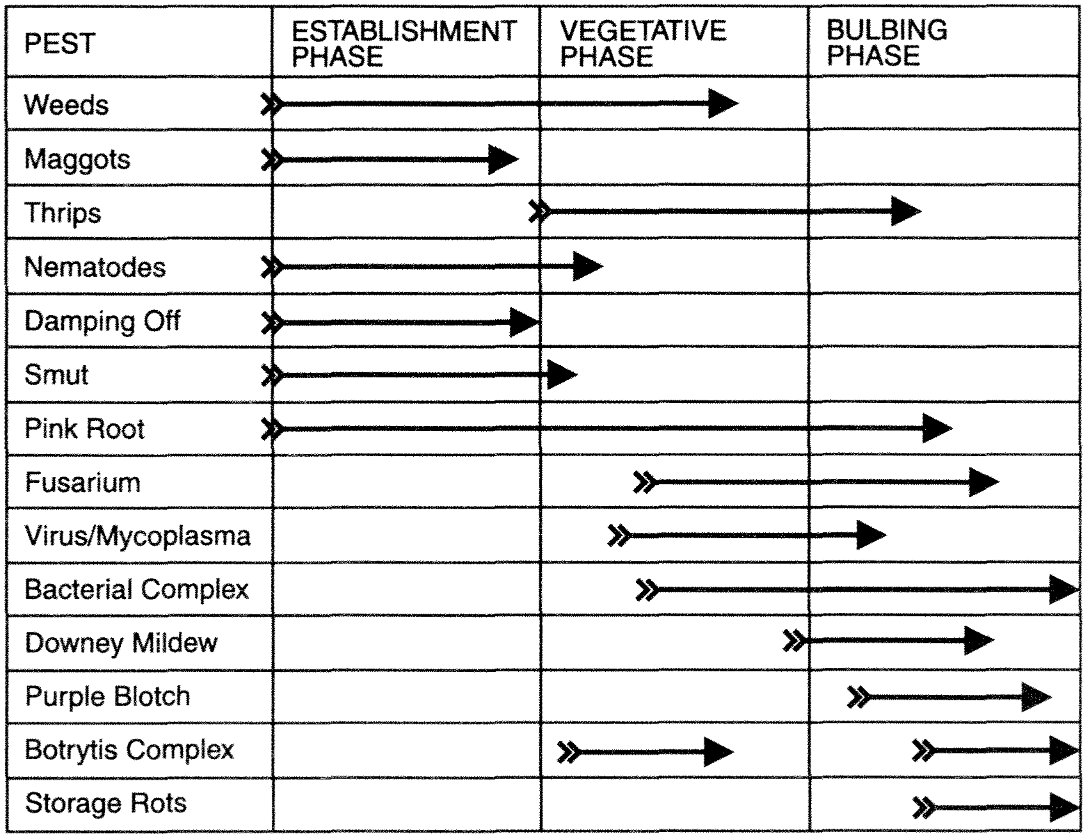


Figure 3: Colorado State University Onion Pest Calendar (H. F. Schwartz, M.E. Bartolo and M. S. McMillan)

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.

The remainder of this publication will review individual pest management problems and specific recommendations based upon research results from Colorado State University and elsewhere. Always consult chemical labels and updated university and industry guidelines for specific pesticides and application rates.

Weed Review

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 (Figure 4). 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.

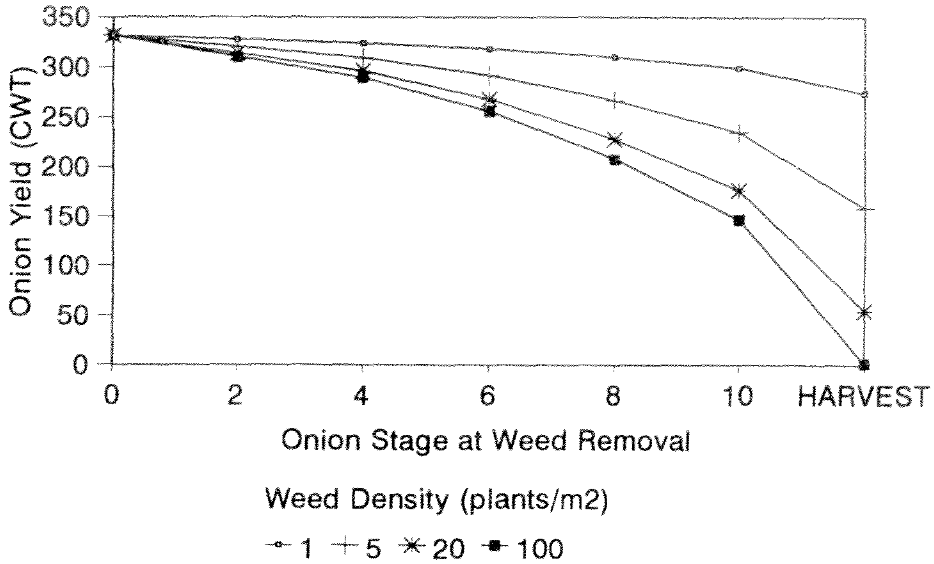


Figure 4: Onion yield as a function of time of weed density and removal (Dunan et al., Colorado State University)

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 dictate 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.

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.

Weed Management

Timely cultivations and handweeding can help provide effective weed control in onions. Weeds in irrigation furrows can often be controlled with early-season cultivations. Late-season handweeding can remove large weeds that could interfere with production (see Figure 4) or harvesting operations. A well integrated onion weed management program will include effective prior crop rotation, mechanical, and chemical weed control. Weeds commonly encountered in Colorado onion fields are shown in Plates 19 through 24.

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

Chemical weed control relies upon preemergence and postemergence herbicides. DCPA (Dacthal) is applied before weed emergence for general weed suppression in onions. Dacthal requires moisture to be effective. A half inch of moisture or overhead irrigation within two weeks of application is needed for best results with Dacthal. Dacthal will provide four to six weeks of weed suppression. This is a critical time to provide a competitive growth advantage to the onions over the weeds until postemergence herbicides such as oxyfluorfen (Goal) and bromoxynil (Buctril) can be used. Dacthal can be used at seeding, transplanting and/or layby. Dacthal can be sprayed directly over transplants. Since Dacthal does not control emerged weeds, cultivation is necessary to remove emerged weeds prior to Dacthal application.

Pendimethalin (Prowl) is currently labeled for use in onions between the 2- to 9-true leaf stages. Since Prowl will not control emerged weeds, remove existing weeds in a separate operation. Prowl will provide four to eight weeks of residual control of grassy weeds and small-seeded broadleaf weeds (i.e., pigweed, lambsquarter, and kochia). Irrigation is needed to move the herbicide into the portion of the soil where weed seeds germinate. Do not apply with other pesticides.

Trifluralin (Treflan) can be applied preplant incorporated to transplanted onions for control of grassy weeds and some broadleaf weeds. Apply to established onions as a soil incorporated treatment with the spray directed between onion rows. Avoid covering exposed bulbs with treated soil when incorporating.

DO NOT TREAT ONIONS INJURED BY SAND, INSECT, OR DISEASE.

Buctril is a postemergence herbicide used for control of seedling or young broadleaf weeds (less than 4-leaf stage or 2 inches tall). It is a contact herbicide and should be applied in 50 to 70 gallons of water per acre. Higher gallonage will increase safety to sensitive onion tissue. Apply Buctril to onions in the 2- to 5-true leaf stage. Apply during warm sunny days with low humidity so that the thick onion leaf cuticle will minimize leaf tissue injury. Do not apply if dew is present on the leaves. Onions injured by sand, insects, or disease can increase potential Buctril injury.

Goal is a postemergence herbicide used for control of seedling or young broadleaf weeds (less than 4-leaf stage or 2 inches tall). Goal can be used immediately after transplanting. Apply Goal to onions with two or more true leaves in 40 gallons of water per acre or more. Do not treat onions injured by sand, insect, or disease.

Fluazifop-butyl (Fusilade) and sethoxydim (Poast) are both postemergence herbicides that provide good control of grassy weeds. Neither herbicide will control broadleaf weeds. Both herbicides need a crop oil concentrate added to the spray mixture for effective control. Neither herbicide should be tank mixed with Buctril or Goal.

Insect Review

Maggots

Maggot problems are relatively minor in western onion states. High summer temperatures, dry weather, and low soil organic matter all help minimize outbreaks in the region.

Two species of onion-infesting maggots occur. The *seedcorn*

Plate 1. Dodder infestation of onions.

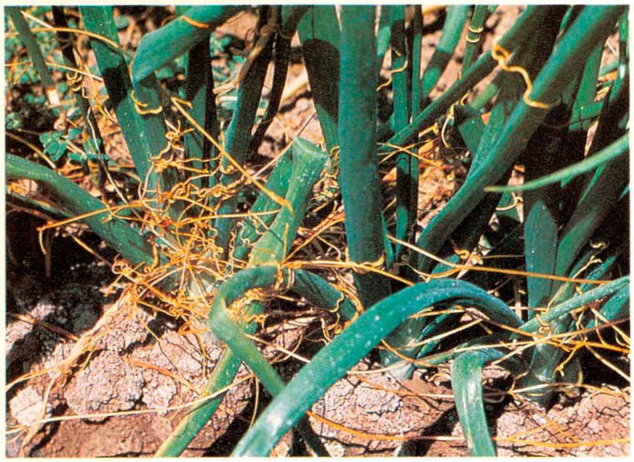


Plate 2. Yellow dwarf; older leaves are crinkled and folded downward.

Plate 3. Aster yellows; older leaves are flat and streaked, but not twisted.

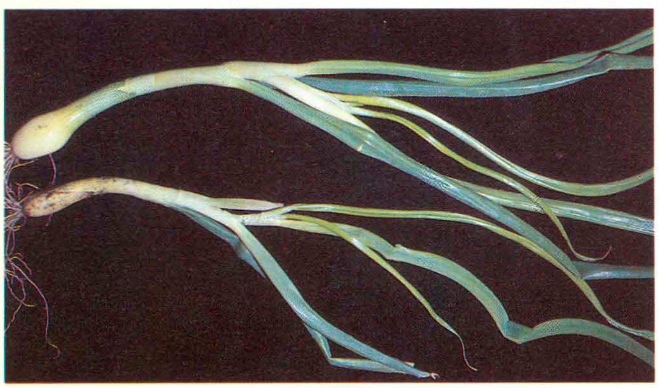


Plate 4a. Slippery skin; note watery rot of inner scales.

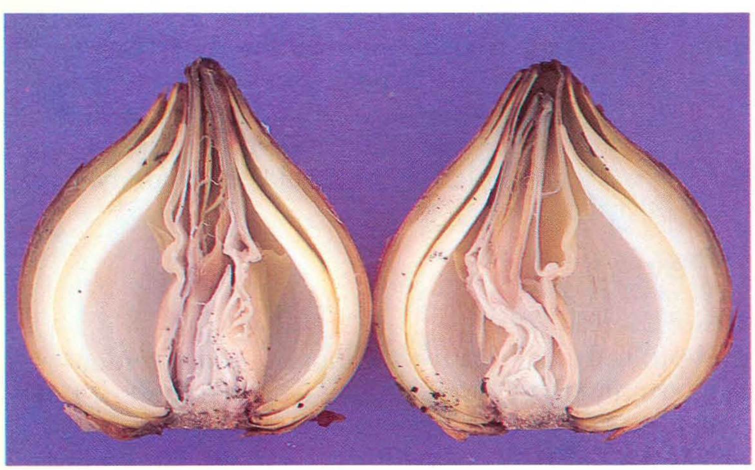


Plate 4b. Sour skin; note rotting of outer scales which are not water-soaked.

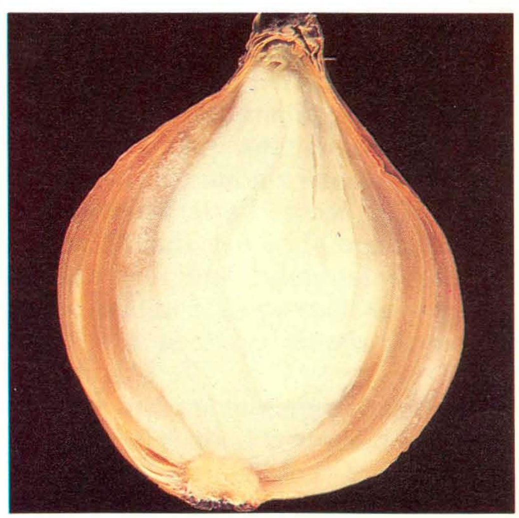


Plate 5a. Bacterial soft rot; note white color and death of younger leaves.

Plate 5b. Bacterial soft rot of inner scales; note water-soaking.

Plate 6a. Smut lesions on cotyledons and young leaves.

Plate 6b. Smut lesions (blisters) on developing bulb.

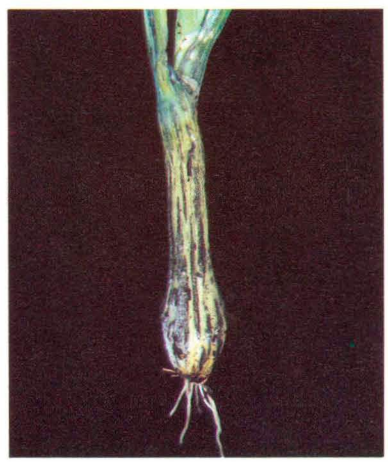


Plate 7. Pink root symptoms on roots and outer scales.

Plate 8. Initial Fusarium basal rot symptoms; note death of older leaves.

Plate 9. Advanced Fusarium basal rot.

Plate 10. White rot; note white mycelial mat with numerous black sclerotia.

Plate 11a. Downy mildew symptoms on leaf.

Plate 11b. Downy mildew affected foliage.

Plate 12a. Purple blotch lesion on leaf.

Plate 12b. Purple blotch affected foliage.

Plate 13. Improperly disposed onion culls.

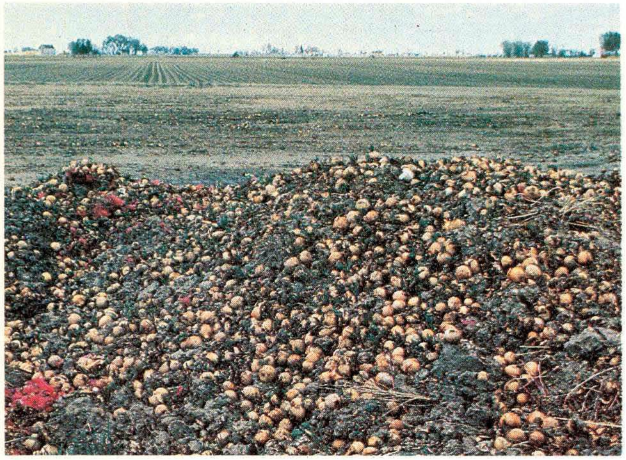


Plate 14. Botrytis neck rot symptoms.

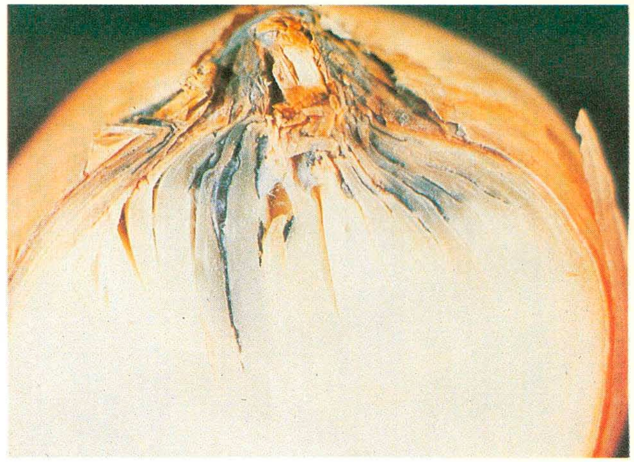


Plate 15. Smudge symptoms.

Plate 16a. Nematode symptoms on young plant; note swelling at base and deformed leaves.

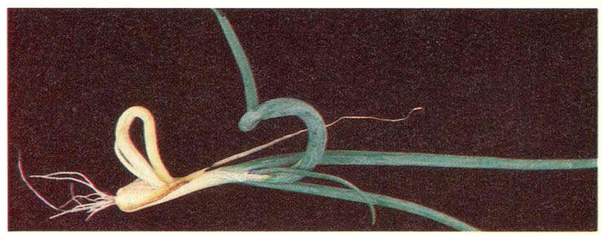


Plate 16b. Nematode damage; note splitting of bulbs.

Plate 17. Maggot larvae in damaged onion bulb.

Plate 18a. Thrips damage to onion foliage.

Plate 18b. Onion thrips.

Plate 19. Kochia.

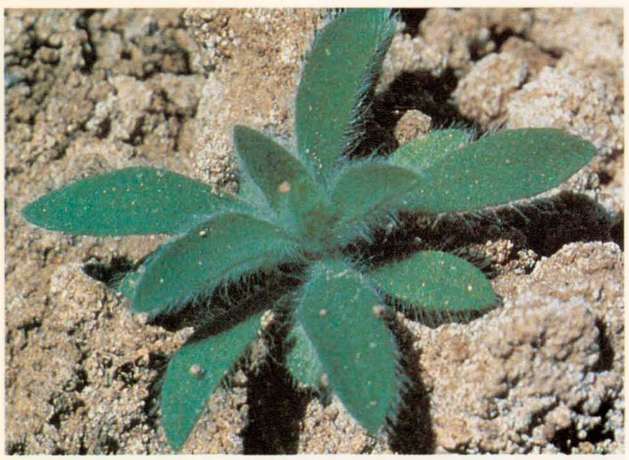


Plate 20. Redroot pigweed.

Plate 21. Russian thistle.

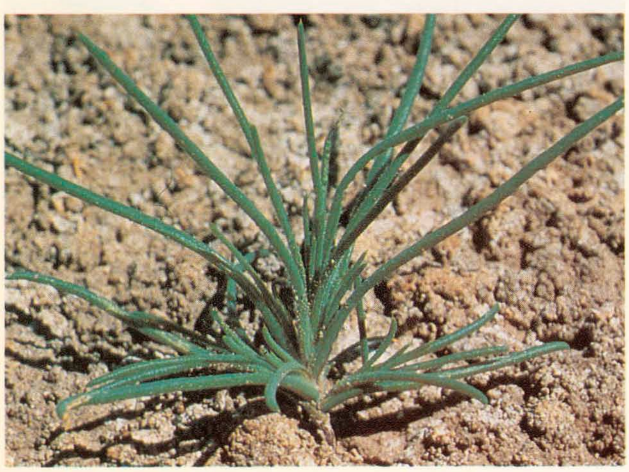


Plate 22. Venice Mallow.

Plate 23. Wild proso millet.

Plate 24. Barnyard grass.

Plate 25. Leaf bruising by hail.

Plate 26. Translucent scales; second fleshy layer shows watery texture and is pale brown to gray.

Plate 27. Life miner damage to seeded onions.

Plate 28. Xanthomonas leaf blight symptoms.

maggot is very common and occasionally causes injury to crops such as beans and corn. Onion damage usually is confined to plants previously affected by wounds or plant diseases. The *onion maggot* occurs infrequently. They develop within onions causing young plants to wilt and die. Mature bulbs may be infested late, although egg laying is concentrated around previously damaged bulbs.

Both seedcorn and onion maggot flies become active in late April and May (Plate 17). Eggs are laid at this time in soil cracks near plants and germinating seeds. Three generations are likely to occur with the second flights in late June and July followed by a late summer flight of flies. The greatest incidence of maggot injury occurs in fields with abundant, decaying organic matter. Green onions grown in short rotation with other vegetables have been particularly susceptible.

THE GREATEST INCIDENCE OF MAGGOT INJURY OCCURS IN FIELDS WITH ABUNDANT, DECAYING ORGANIC MATTER.

Under most conditions, adequate control of onion-infesting maggots is possible by crop rotation and avoidance of wounds and disease. Planting time treatment with insecticides can be used in a preventive manner. However, plant injury may occur with some onion maggot insecticides on low organic matter soils.

Thrips

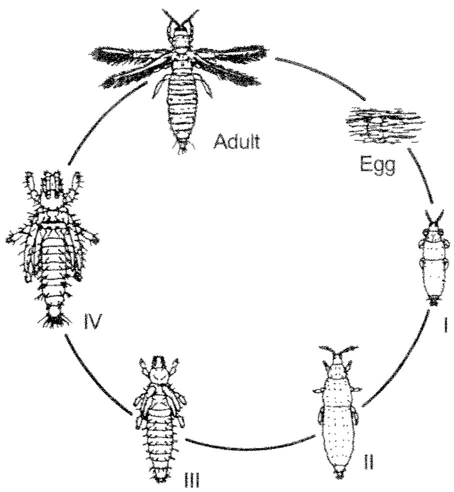
The most serious insect pest of onions in western states is the onion thrips, *Thrips tabaci*. Thrips feed upon developing leaves by rasping the leaf tissue and sucking out cell contents. Leaves damaged by thrips feeding injuries have a characteristic silvery appearance and are marked by small dark spotting (Plate 18). Thrips injury reduces the ability of plants to produce nutrients and also causes some water loss. On rare occasions when thrips populations are extremely high, thrips may also reduce stand establishment. In general, low numbers of thrips can be tolerated with little or no loss of yield. Plants are most sensitive to thrips injury during the early stages of bulbing. During this time, yield reductions in bulb size of approximately 3 percent may occur for every 10 thrips/plant.

PLANTS ARE MOST SENSITIVE TO THRIPS INJURY DURING THE EARLY STAGES OF BULBING.

Thrips problems have been most severe on transplant onions that arrive already infested to some degree by the insect. Since thrips thrive in the cover of the neck area, plants with a more open growth habit tend to be less infested than those with a tighter neck. Varieties with a waxier leaf also have some resistance to onion thrips.

The life cycle of onion thrips (see Figure 5) primarily takes place on the plant with the "pre-pupa" and "pupa" stages usually occurring in the soil around the base of the plant. During warm weather, the entire life cycle can be completed in a few weeks and numerous, overlapping generations occur during a growing season. Despite the name, onion thrips occur on a wide range of broadleaf plants and are damaging to a number of regional crops, notably cabbage and dry edible beans. The overwintering stage of the onion thrips is mostly as adults in protected sites which can include winter wheat.

Rainfall is the most important natural control of onion thrips. Thrips may be crushed by rains (or overhead irrigation water) and thrips pupae are trapped by crusting soils. Thrips



1. Adult thrips fly to plant and feed
2. Eggs are laid in leaf slits
3. Instars I and II feed on plant
4. Instars III (prepupae) and IV (pupae) are non-feeding and occur at base of plant or lodged in leaf axils.

Figure 5: Life cycle of onion thrips.

problems tend to be greatest following extended periods of hot, dry weather. Some predators of onion thrips occur, such as minute pirate bugs and predatory thrips. However, these are rarely important in onion fields.

Resistance to insecticides has become an increasingly severe problem in recent years. Localized infestations of thrips resistant to organophosphate and carbamate insecticides have occurred annually, particularly in transplanted onion fields. Temporary emergency use (Section 18) registrations have been granted for use of the pyrethroid cypermethrin (Cymbush, Ammo), but full federal registration is still pending. There is some indication that mixture with other pesticides that have high mineral contents and other inert ingredients may reduce insecticide efficacy. Also, check with the pesticide supplier on the use or not of adjuvants for specific chemistry.

The problem of insecticide resistance is likely to increase in the future and is the most serious threat to long-range management of this insect. No effective alternative treatments have been identified which differ significantly in chemistry from cypermethrin. It is therefore important that onion growers undertake management practices that slow resistance development. This includes: 1) use of insecticides only when needed, based on field surveys; and 2) rotation of insecticides between chemical classes (but not in combination!). Currently registered insecticides in the organophosphate class include azinphosmethyl (Guthion) and methyl parathion; in the carbamate class, Lannate; and in the pyrethroid class, Ammo. Registration for another pyrethroid, Karate, is pending.

Recent reports indicate that use of cypermethrin insecticides may increase problems with another species of thrips, the western flower thrips (*Frankliniella occidentalis*). The potential damage from this species is unknown.

Vegetable Leafminer

The vegetable leafminer, *Liriomyza sativae*, is occasionally associated with onion as it is with most vegetable crops grown in the state. However, under the proper conditions it can become a significant pest, particularly of green onions. Damage to this latter crop includes disruption of even stand 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. These wounds frequently girdle the leaf causing tip dieback (Plate 27).

Although vegetable leafminer is a key vegetable insect pest in many areas of the country, its biology has been little studied in Colorado. Reportedly, optimal temperatures are in the mid 70s (F), and it has been a late-season pest in the state. Pupation has been observed to occur both within the leaf mine or, more commonly, in the soil at the base of the plant. Regardless, the pest status of this insect in Colorado 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 induces problems. Lannate and various organophosphate insecticides are among the treatments that are most commonly associated with vegetable leafminer outbreaks.

Limiting insecticide treatment frequency, particularly with those products associated with leafminer problems, can prevent outbreaks from developing. A crisis exemption for cypermethrin did successfully allow control of leafminers in 1994 in green onions. However, a report from the west slope of Colorado indicated that leafminers were abundant in bulb onions that had repeatedly received cypermethrin applications.

Stem Maggot

An unidentified species of fly larva has been found to occasionally damage onions in northeastern Colorado. Injury involves tunneling of the base of developing leaves, causing them 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. Thrips infestations may also be exacerbated.

Disease Review

Virus and Mycoplasma Diseases

Onion Yellow Dwarf Virus

DO NOT CONFUSE VIRUS SYMPTOMS WITH THOSE OF NORMAL-SHAPED LEAVES WITH ALTERNATE YELLOW/GREEN BANDS CAUSED BY GENETIC OR VEGETATIVE MUTATIONS.

This disease is caused by a virus that is transmitted by various aphid species or mechanically to onions and other crops such as garlic, leek, and some narcissus species. The first symptoms appear on the youngest leaves that turn pale and develop many yellow streaks along the veins. Leaves may crinkle and flop over (Plate 2). 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 is 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. Do not confuse virus symptoms with those of normal-shaped leaves with alternate yellow/green bands caused by genetic or vegetative mutations.

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

Aster Yellows – Mycoplasma

This disease is caused by the aster yellow mycoplasma that affects many weeds and crops including onions, carrots, lettuce, and celery. The pathogen is transmitted by the aster leafhopper (*Macrosteles quadrilineatus* Forbes). 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 (Plate 3). Flower stems are abnormally elongated, and have malformed, sterile floral clusters.

THIS DISEASE IS CAUSED BY THE ASTER YELLOW MYCOPLASMA THAT AFFECTS MANY WEEDS AND CROPS INCLUDING ONIONS, CARROTS, LETTUCE, AND CELERY.

Disease management recommendations include crop rotation out of onions for three years; elimination of weed hosts in and around onion fields; insect control; and isolation from other susceptible crops or volunteer onions.

Bacterial Diseases

Slippery and Sour Skin

Slippery skin is caused by *Pseudomonas gladioli* pv. *allicola* (Burkh.) Young et al., and sour skin is caused by *P. cepacia* Burkh. The most common initial symptoms are softening of bulbs around the neck. Slippery skin rot spreads from the neck to the base of the bulb, where bacteria are transmitted from one fleshy scale to another until the central part becomes rotted and watery (Plate 4). Simple pressure at the base of the bulb causes the rotted portion to slide out through the neck, hence the name slippery skin. Sour skin rot is found on the outer layers without necessarily affecting the surface skin of the bulb. Affected tissue becomes yellow and viscous, but not watery (Plate 4). 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.

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; control of insect pests such as maggots; although research is lacking, application of copper-based bactericides (Kocide, Champ) may reduce spread and infection, especially on storm-damaged plants; do not damage bulbs during harvest or handling; wet onions should be dried artificially with forced heated air before being stored dry; store onions at 32 F with a relative humidity less than 70 percent and provide adequate ventilation during storage.

Xanthomonas Blight

This disease is caused by *Xanthomonas campestris*, and was detected on storm-damaged onions in southeastern Colorado during 1994. 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 (Plate 28). The symptoms evolve further into tip dieback and extensive blighting of outer older leaves, resulting in stunted plants and undersized bulbs. Limited

INOCULUM SPREAD IS THROUGH RAIN, HEAVY DEWS, OR SPRINKLER IRRIGATION WATER.

information is available on the disease cycle and epidemiology of bacterial blight. Inoculum spread is 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 temperature under humid or overcast conditions. No control measures have been worked out for this disease.

Bacterial Soft Rot

This disease is caused by *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey et al., a pathovar of that also causes blackleg of potatoes (usually caused by *E. c.* pv. *atroseptica*) and rots of other vegetables such as carrots. Disease symptoms may develop directly in the field, especially near the end of the season, after heavy rains and when leaves are drying (Plate 5). The pathogen enters the bulb through the neck when leaves wilt or through injuries caused by mechanical bruises, 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 soft rot, caused by *Kluyveromyces marxianus* (Hansen) van der Walt var. *marxianus*, causes a similar type of rot in areas of Washington and Oregon. This pathogen has not been isolated in Colorado to date.

THE PRIMARY SOURCE OF BACTERIAL CONTAMINATION ORIGINATES FROM INFESTED CROP RESIDUE IN THE SOIL OR IRRIGATION RUNOFF.

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 while feeding. Bacteria also are spread by rain and multiply very quickly in warm weather. Infection can continue in storage and transit when the temperature exceeds 37 F. The pathogen may be transmitted in water droplets between bulbs in storage when the humidity is high.

Disease management recommendations include crop rotation out of onions for three years; control of insect pests such as maggots; copper-based bactericides (Kocide, Champ) may reduce spread and infection, especially on storm-damaged plants; do not damage bulbs during transplanting, harvesting or handling; wet onions should be dried artificially with forced heated air before being stored dry; store onions at 32 F with a relative humidity less than 70 percent and provide adequate ventilation during storage.

Fungus Diseases

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* can be involved. Plants often are infected at the soil line or slightly below; tissue turns tan to brown, watersoaked, and shrinks rapidly while aboveground parts 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 three years; plant seed treated with a fungicide such as Thiram and/or metalaxyl (Ridomil); 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. A 7 to 10-inch banded fungicide such as Ridomil applied at planting provided an average increase in plant stand of 13 percent (range from 5 to 22 percent) in commercial fields of seeded onions (see Figure 6).

Smut

ONIONS ARE SUSCEPTIBLE TO SMUT INFECTION ONLY DURING GERMINATION AND EMERGENCE, AFTER WHICH PLANTS BECOME RESISTANT.

Smut is caused by soil-borne fungi, *Urocystis colchici* (Schlecht.) Rabenh. or *U. cepulae* Frost (syn. *U. magica* Pass. ap. Thum), which primarily affect seedling plants. Symptoms appear on cotyledons and young leaves as longitudinal blisters that are blackish with a silver sheen. Seedlings often die before or within six weeks after emergence (Plate 6). 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 blisters splits, fungus spores 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 includes crop rotation out of onions for three or more years; plant seed treated with Thiram or a systemic fungicide such as carboxin (Vitavax) when labeled in the United States; plant transplants instead of seed in infested soil; and do not introduce infested soil or contaminated equipment, plants or onion debris into clean fields.

Pink Root

THE FUNGUS CAN SURVIVE FOR MANY YEARS IN A FIELD, EVEN IN THE ABSENCE OF A HOST.

Pink root is caused by a soil-borne fungus, *Phoma terrestris* E. M. Hans. (Syn. *Pyrenochaeta terrestris* (E. M. Hans.) Gorenz, Walker and Larson), which affects yield by reduced bulb size and aggravated losses from other diseases such as Fusarium basal rot. Infected roots have a typical pink color, which turns to red, then purple, and finally brown to black (Plate 7). Severe infection may reduce the root system mass, 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 F). Transplants should be produced on pathogen-free soil.

Disease management recommendations include crop rotation with cereals (wheat, barley and corn) for three or more years; plant resistant varieties and non-infected transplants; treat seed with a fungicide (Thiram); good seedbed preparation; reduction of other stresses soil compaction, avoid root pruning during cultivation, heat and moisture extremes; and fall fumigate (Telone C-17, Chlor-o-pic).

Fusarium Basal Rot

Fusarium basal rot is caused by *Fusarium oxysporum* Schlectend.:Fr. f. sp. *cepae* (H. N. Hans.) Snyd. and Hans., 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 becomes covered with a whitish mycelium. Leaf tips yellow, entire leaves wilt beginning with the older outer leaves, scattered plants are stunted, and eventually die (Plate 8). A semi-watery decay progresses from the basal plate upward and secondary invaders (bacteria) cause a watery, foul-smelling breakdown (Plate 9). 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 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 irrigation water.

Disease management recommendations include crop rotation with cereals (wheat, barley and corn) for four or more years; plant resistant varieties and non-infected transplants; treat seed with a fungicide (Thiram); good seedbed preparation and drainage; reduction of other stresses such as soil compaction, root pruning during cultivation, and

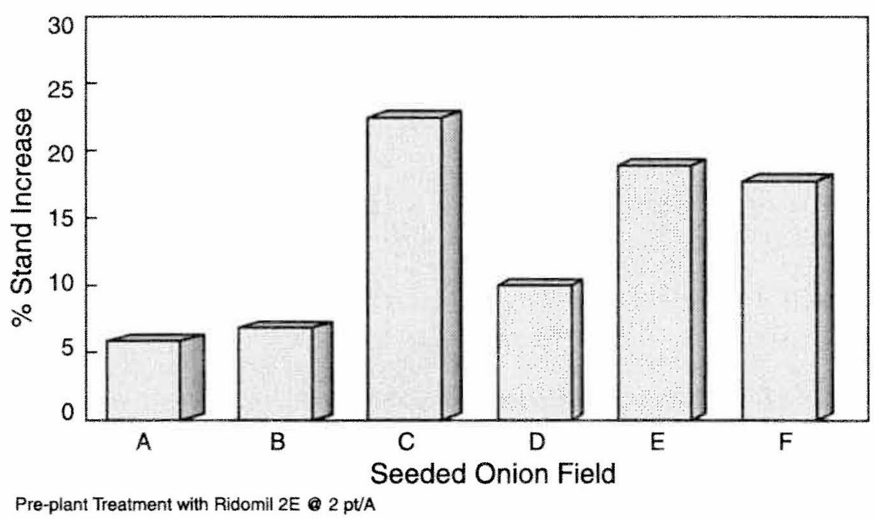


Figure 6: Effects of pre-plant fungicide treatment upon seeded onion plant stands in northern Colorado commercial fields in 1993. Data kindly provided by G. Hankins - Ciba Plant Protection and L. Duell - Centennial Ag Supply.

moisture extremes; use nitrate, not ammonium fertilizers; and fumigate in the fall (Telone C-17, Chlor-o-pic) (see Table 3). Busan reduced Pink Root but not Fusarium losses in recent trials in northern and western Colorado.

White Rot

White rot has not been identified in Colorado, but is a potential threat to productivity if introduced. This disease is caused by the soil-borne fungus *Sclerotium cepivorum* Berk. The disease appears on isolated plants, usually at bulb formation. However, young plants also may be affected. Symptoms become obvious as older leaves yellow, wilt, and fall to the ground. A semi-watery soft rot gradually destroys the bulb and roots. The pathogen can continue to develop and spread between bulbs in storage. Affected plant parts are covered with a thick white mycelial mat bearing numerous small (1/32 inch diameter) black sclerotia (Plate 10). Sclerotia allow the pathogen to survive for more than 15 years in soil until susceptible host root exudates stimulate them to germinate. Sclerotia are spread within and between fields by cultivation equipment and irrigation water. White rot is favored by cool weather (20 C or 68 F) and low moisture.

Disease management recommendations include crop rotation out of onions for at least five years; plant non-infected transplants; good water drainage; and planting-time treatment with fungicides such as thiophanate methyl (Topsin M), vinclozolin (Ronilan), and iprodione (Rovral).

Downy Mildew

This foliar disease is caused by *Peronospora destructor* (Berk.) Casp. ex Berk. Symptoms appear on older leaves as elongated patches which vary in size and are slightly paler than the rest of the foliage. With moisture, these areas become covered with a violet gray mycelium, which contain spores that may be spread to surrounding healthy tissue. Leaves generally fold over at affected areas, and leaf tips die (Plate 11). Another fungus (*Stemphylium botryosum* Wallr.) may develop on primary 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 fungal mycelium. Bulb size and quality are reduced by infection occurring before maturity. Infection is favored by cool temperatures less than 22 C and free moisture from rain or dew in early spring

Table 3: Effects of fumigation with Telone C-17 (24 - 30 gal/A) upon pink root and fusarium basal rot of seeded onions in Colorado State University Trials during 1985.

Response	White Sweet Spanish - Kersey	Brown Beauty - Olathe
Percent Stand Increase	16 percent	28 percent
Pink Root Incidence	light	light
Percent Fusarium Reduction	40 percent	52 percent
Percent Yield Increase	33 percent	200 percent
Net Return @ $ 10/cwt	$ 850	$ 2500

Untreated control plots had moderate to severe Pink Root and Fusarium Basal Rot.

or late summer. The fungus overwinters in crop residue and contaminated culls.

Disease management recommendations include crop rotation out of onions for three years; onion debris and cull sanitation; plant clean seed and transplants at moderate plant densities; timely applications and rotations of effective fungicides such as coppers, chlorothalonil (Bravo), mancozeb (Manzate), and metalaxyl (Ridomil) mixtures which are specific for this pathogen (see Table 4).

Purple Blotch

This foliar disease is caused by *Alternaria porri* (Ellis) Cif. It 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 (Plate 12). Concentric light and dark zones later appear over part or all of the purple area. These blotches may enlarge (up to 4 inches long) and become covered with black fruiting bodies (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 three years; onion debris and cull sanitation; plant clean seed and transplants at moderate plant densities; do not apply excess nitrogen fertilizer, especially after bulbing; apply effective fungicides such as mancozeb (Manzate), chlorothalonil (Bravo), vinclozolin (Ronalin), and iprodione (Rovral) after bulbing begins (see Table 5) and weather conditions favor infection; harvest at full maturity when necks top over naturally and ideally during dry weather; air-dry bulbs before storage to heal injuries and the neck region; and store at 32 F with a relative humidity less than 70 percent.

Table 4: Management of downy mildew with timely applications of fungicides (excerpts from Fungicide and Nematicide Reports, Plant Disease articles since 1985).

Location - Fungicides	Disease Reduction	Yield Increase
Colorado*		
Bravo	59 percent	22 percent
Aliette/Rovral	63 percent	--
New York		
Bravo	35 - 100 percent	--
Mancozeb	88 - 100 percent	--
Canada		
Bravo	87 percent	20 percent
Mancozeb	29 - 100 percent	44 percent
Ridomil/MZ	73 - 100 percent	60 percent

* **Note:** Net returns of more than $1000/Acre recorded for Bravo applied four times during moderate disease pressure in Colorado in 1991.

Botrytis Diseases

These diseases may be caused by one or more of the following pathogens: *Botrytis allii* Munn, *B. squamosa* J. C. Walker, and *B. cinerea* Pers. The first fungus is the principal species affecting onions in western states. 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 (Plate 13). Colorado State studies during 1988-89 recorded an average of six to 23 Botrytis spores/hour while monitoring diseased culls from June through September. A leaf blight may occur as leaf tips die and small oval, whitish to yellowish spots form on leaves (blast). 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 F), moist weather. Blighting and girdling of onion scapes (seed stalks) shows up as whitish, necrotic, shrivelled tissue usually with sporulation on the surface or below the epidermis of the lesion.

Storage symptoms appear as a softening of the tissue in the upper part of the bulb, especially around the neck area, and progresses downward toward the basal plate. Infected tissue is brownish and soft, and often exhibits gray mycelium and thin black sclerotia on and between infected scales (Plate 14). Larger sclerotia may form on the surface of the neck and outer scales. Infection is favored by high moisture conditions near maturity. The fungus may spread to other bulbs in storage under moist conditions. Germinating spores (of *Botrytis cinerea* Pers. ex. Fr.) also can induce a superficial discoloration (brown stain) of dry, outer scales with no further development.

Table 5: Management of purple blotch with timely applications of fungicides (excerpts from Fungicide and Nematicide Reports, Plant Disease articles since 1985).

Location - Fungicides	Disease Reduction	Yield Increase
Colorado*		
Bravo	34 - 50 percent	12 percent
Cupric Hydroxide	34 percent	9 percent
Maneb/Mancozeb	46 - 62 percent	4 - 22 percent
Ronilan	43 percent	11 percent
Rovral	69 - 75 percent	15 - 30 percent
Florida		
Mancozeb	31 - 63 percent	--
Michigan		
Ronilan	28 percent	6 percent
Rovral	62 - 75 percent	7 - 21 percent
Texas		
Rovral	48 percent	64 percent

***Note:** Net returns of $ 450 - 700/Acre recorded for cupric hydroxide, Bravo, Mancozeb and Rovral applied three to four times during light to moderate disease pressure in 1994; and up to $ 1500/Acre for Mancozeb and Rovral applied three times during moderate to severe disease pressure in 1986 in Colorado.

Disease management recommendations include crop rotation out of onions for three years; sanitation of cull pile and onion debris; use of clean seed and transplants; planting early maturing varieties at moderate plant densities; no application of nitrogen fertilizer after bulbing; apply effective fungicides such as mancozeb (Manzate), chlorothalonil (Bravo), and iprodione (Rovral) after bulbing begins and weather conditions favor infection (see Table 6); undercut onion roots or harvest at full maturity when necks top over naturally (see Figure 7) and ideally during dry weather; air-dry and/or heat treat (at 90 to 95 F) bulbs before storage to heal injuries and cure the neck region; store at 32 F with a relative humidity less than 70 percent.

Smudge

Smudge, or anthracnose is caused by *Colletotrichum circinans* (Berk.) Voglino which 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 (Plate 15). 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 F) moist weather, especially near harvest.

Disease management recommendations include crop rotation out of onions for three years; use clean seed and non-infected transplants; good drainage; timely applications of fungicides such as mancozeb (Manzate), chlorothalonil (Bravo), and iprodione (Rovral); let onions dry out completely at harvest and/or heat treat before storing; store dry onions at 32 F and less than 70 percent R.H.

Storage Molds

INFECTION BY BOTH WIND-BLOWN PATHOGENS IS FAVORED BY HIGH MOISTURE, RECENT WOUNDS OR BRUISES, AND COOL TO MODERATE TEMPERATURES (LESS THAN 90 F).

Other fungi can also damage onions in storage and include Black Mold, caused by *Aspergillus niger* Tiegh, 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 bacteria cause secondary breakdown. Bulbs can be infected without evidence of surface symptoms. Lengthwise or cross-sections reveal at least one inner scale is water-soaked and blackened between healthy and diseased parts.

Blue mold is principally a storage problem. It produces a soft, watery rot; and tissue becomes punky as it dries. The decay is accompanied by blue-green mold on the surface. Infection by both wind-blown pathogens is favored by high moisture, recent wounds or bruises, and cool to moderate temperatures (less than 90 F).

Disease management recommendations include crop rotation out of onions for three years; timely application of effective fungicides such as mancozeb (Manzate), chlorothalonil (Bravo), and iprodione (Rovral); and proper harvest (minimize bruises and wounds), curing, and storage.

Table 6: Management of Botrytis Diseases with Timely Applications of Fungicides (excerpts from Fungicide and Nematicide Reports, Plant Disease articles since 1985).

Location - Fungicides	Disease Reduction	Yield Increase
Colorado*		
Bravo	10 - 33 percent	10 - 33 percent
Rovral	62 percent	62 percent
Florida		
Mancozeb	68 - 75 percent	--
Michigan		
Bravo	71 percent	--
Ronilan	65 percent	6 percent
Rovral	65 percent	7 percent
New York		
Bravo	37 percent	17 percent
Maneb	16 percent	18 percent
Ronilan	37 percent	13 percent
Rovral	62 percent	15 percent

***Note:** Net returns up to $ 350/A for Bravo and $ 850 for Rovral recorded under moderate to severe disease pressure from Botrytis Neck Rot in Colorado in 1985.

Nematode Diseases

Stem or Bulb (Bloat)

The stem or bulb nematode, *Ditylenchus dipsaci* (Kuhn) Filipjev, 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. 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 (Plate 16). Secondary breakdown by bacteria and fungi is common. Nematodes survive on seeds,

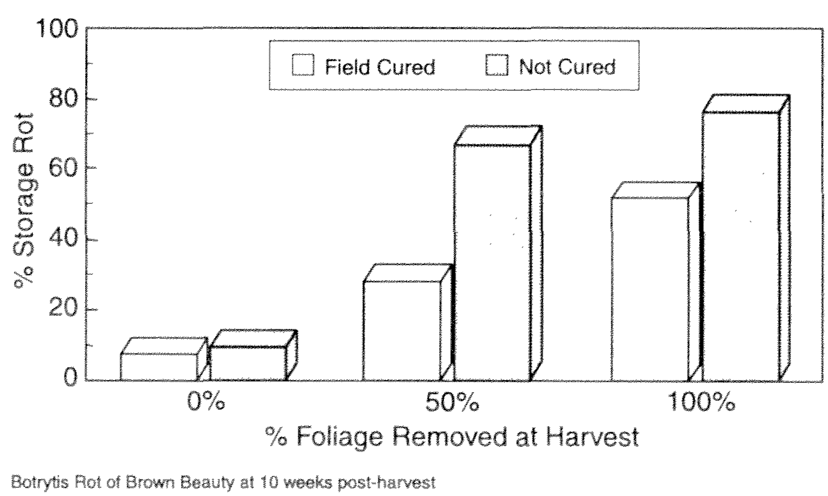


Figure 7: Cultural practice effects upon botrytis storage rot losses (Colorado State University results, 1984).

onion debris, weeds, and in infected transplants. The pathogen is favored by free moisture and an optimum soil temperature of 70 F. Its life cycle is completed within 23 days at 15 C 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 hosts for four or more years; debris sanitation and weed control; 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 with dicloropropene (Telone C-17).

Environmental Modeling and Disease Forecasting

RATHER THAN SPRAYING ON A WEEKLY OR MONTHLY BASIS (REGARDLESS OF THE PEST PRESSURE), APPLICATIONS SHOULD BE MADE ONLY WHEN THERE IS AN ACTUAL PROBLEM AND WHEN IT IS ECONOMICALLY AND BIOLOGICALLY FEASIBLE TO DO SO.

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 closely 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 (regardless of the pest pressure), applications should be made only when there is an actual problem and when it is economically and biologically feasible to do so.

Automated electronic weather stations are located in the major onion production areas in the state and are part of the larger Colorado Agricultural Meteorological Network (COAGMET); selected stations from onion areas in northern, southern and western Colorado are also referred to as ONIONET. The weather stations are equipped with sensors to measure a variety of parameters including air and soil temperature, humidity (vapor pressure deficit), rainfall, and solar radiation. The stations also contain a cellular telephone and modem that enable weather data to be transferred to the main computer network at Colorado State University in Fort Collins. These weather stations are an important part of the Integrated Pest Management program and its application to the needs of onion growers (see Table 7).

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 improperly disposed in and near next season's onion fields, insects and plant pathogens contaminate the new onions and seriously 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 proper treatment of onion culls before the new onion crop becomes established in early spring.

Onion culls can be disposed of in various means according to Mike Thornton of the University of Idaho. One ton of cull onions contains approximately 215 gallons of water, 180 pounds of organic matter, 3 pounds of potassium, 2 pounds of nitrogen, 2 pounds of sulfur, 0.9 pounds of iron, 0.8 pounds of phosphorus, 0.6 pounds of calcium, and trace amounts of other minerals.

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 incorporation at 4 to 6 inches into marginal soils (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 percent of the diet. (4) composting with wheat straw and other organic material for at least 30 days with adequate aeration and moisture.

Abiotic Review

Herbicide Injury

Improper use of herbicides can cause temporary or permanent injury to onions. Damage occurs when herbicides are applied at excessive rates, more often than recommended, when the onion leaf surface is compromised by injury, and when onion (and often weed) plants are at the wrong stage of development. Contact herbicides cause burns and necrotic spots on leaves and leaf tips. Systemic herbicides may cause leaves to yellow and/or curl. Generally the plants recover and symptoms disappear over time. Damage may also occur if onions are sensitive to "carryover" herbicides used on the previous crop. Closely follow label recommendations provided by chemical manufacturers.

Salinity

Onions are more sensitive to salinity than most other crops. High soil salinity impairs the plants ability to extract water from the soil. Nutrient uptake may also be restricted. Soil salinity is determined by finding the electrical conductivity (EC) of the soil and is measured in millimhos per centimeter

Table 7: IPM action based onion fungicide schedule.

Disease	Occurrence/Protection Period	Pesticide Spectrum*	Spray Interval (days)
Bacterial Problems	vegetative - late bulbing	copper-based bactericides*	7 - 14
Purple Blotch	mid to late bulbing	chlorothalonil, mancozeb, vinclozolin, iprodione*	7 - 14
Downy Mildew	mid to late bulbing	copper-based bactericides, chlorothalonil, mancozeb, metalaxyl mixtures*	7 - 14
Botrytis Neck Rot	late bulbing	chlorothalonil, mancozeb, iprodione*	7 - 14

*Note: most specific and effective pesticide chemistry for this disease and its pathogen; rotate with other fungicides if available for economics and to minimize the selection of pathogen strains resistant to a particular chemistry.

YIELD REDUCTIONS CAN OCCUR IN ONIONS WHEN THE SOIL SALINITY EXCEEDS 1.2 MMHOS/CM.

(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 in them than water from shallow 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. It 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 is 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 *Botrytis* and possibly other pathogens. There are currently no control measures for this type of pollution problem.

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 (Plate 25). 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 plant pathogens. Onions 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 pesticides to protect against disease infection. Their use is often supported in Colorado by pest and crop consultants.

Figure 8 illustrates the effects of mechanically removing 33 percent and 67 percent of the foliage at different times prior to maturity. At both levels, defoliation had a greater impact on total marketable yield and yield of individual market classes when it occurred near the onset of bulbing. The jumbo class was most consistently reduced by defoliation. Both a moderate (33 percent) and severe (67 percent) loss of foliage delayed crop maturity, decreased total marketable yield and potential market value, and changed the market class distribution of Colorado 6, a sweet Spanish type onion.

Temperature Extremes

High temperature and intense sunlight may damage young, sensitive seedlings by killing tissue at or near the soil

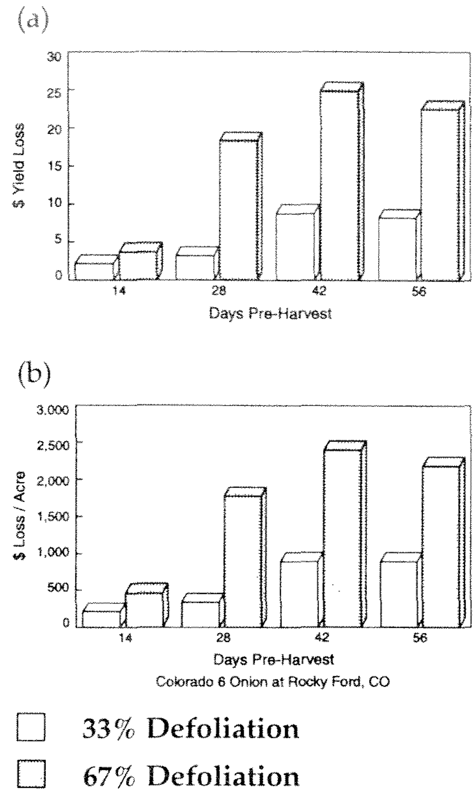


Figure 8: Effects of foliage removal or damage to Colorado 6 at Rocky Ford during 1991-92 on (a) marketable onion yield loss and (b) economic loss.

line. Older plant and bulb (shoulder) tissue may be scalded at harvest, especially after lifting and windrowing. Injured 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 F for long periods. Onion bulbs freeze at 30 F, however, they can be supercooled to 25 F without injury as long as they are not moved. Symptoms of freezing 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 F than at a higher temperature. Varieties may differ in their response to low temperature. Those low in solids are more sensitive.

Other Disorders

Bolting

The initiation of flowering by the formation of a seedstalk 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 (Plate 26). 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 to 50 F for a few weeks before final storage at 32 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 shoulders of onions 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. These patterns cause abnormal development of the plants and bulbs. Individual leaves or typically the entire plant may express variegations.

Supplemental References

Binkley, A. M., Ferguson, A. C., and Fauber, H. 1951. *Onion production in Colorado.* Colo. State Univ. Bull. 414-A, 45 pages.

Brown, B. D., Simpson, W. R. and McDole, R. E. 1976. *Idaho Fertilizer Guide: Onions.* Univ. of Idaho Curr. Info. Series no. 315, 2 pages.

Crete, R., L. Tartier and A. Devaus. 1981. *Diseases of Onions in Canada.* 37 pages. Pub. 1716E, Information Services, Agriculture Canada, Ottawa, K1A OC7.

Davis, H. R., R. B. Furry and F. M. R. Isenberg. 1978. *Storage Recommendations for Northern Grown Onions.* 22 pages. Agr. Eng. Ext. Bull. 428, Dept. of Agr. Eng., Cornell Univ., Ithaca, NY 14853.

Dudek, T. A. and R. J. Vanklompenberg (editors). 1987. *Michigan Onion Growers Handbook.* Mich. State University Coop. Ext. Serv. and Michigan Onion Committee Series of onion production and pest control bulletins, East Lansing, MI 48823.

Ells, J. E., Schwartz, H. F., and Cranshaw, W. S. 1986. *Commercial vegetable production: bulb onions.* Colo. State Univ. Service in Action Bull. no. 7.619, 4 pages.

Hoffmann, M. P., Petzoldt, C. H. and Frodsham, A. C. 1995. *Integrated Pest Management for Onions.* Cornell Coop. Ext. Bull., 100 pages.

Jones, H. A. and L. K. Mann. 1963. *Onions and Their Allies: Botany, Cultivation and Utilization.* Interscience Publishers, NY 286 pages.

Mansour, N. S., Burr, J., Mack, H. J., Gardner, E. H., and Doerge, T. 1983. *Fertilizer Guide for Onions - Mineral Soils.* Oregon State Univ. Bull. no. FG 65, 2 pages.

Moore, F. D., S. J. Wallner, J. E. Ells, P. A. Richwine, D. B. Bosley and A. E. McSay. 1987. *Timing of onion irrigations.* Colo. State Univ. Agr. Exp. TB87-1, 26 pages.

Painter, C. G. 1980. *The Effect of Nitrogen, Phosphorus, Potassium and Micronutrients on Yield, Grade and Storage of Onion Bulbs in Southwestern Idaho.* Univ. of Idaho Bull. no. 574, 10 pages.

Pelter, G. Q., E. J. Sorensen, R. E. Thornton and R. Stevens. 1992. *Dry bulb production in the Columbia Basin.* Washington State Univ. Coop. Ext. Bull. EB1693, 18 pages.

Schwartz, H. F. and J. K. Mohan. 1995. *Compendium of Onion and Garlic Diseases.* Amer. Phytopathol. Society, St. Paul, MN, 54 pages.

Service in Action Bulletins. Colo. State Univ. Coop. Ext., Fort Collins, CO 80523.

Sherf, A. F. and A. A. Macnab. 1986. *Vegetable Diseases and Their Control,* 2nd Edition. J. Wiley and Sons, NY, 728 pages.

Tindall, H. D. 1983. *Vegetables in the Tropics.* AVI Pub. Co., Westport, CT, 533 pages.

Voss, R. E. 1979. *Onion Production in California.* Univ. of Calif. Bull. no. 4097, Oakland, CA, 50 pages.

Ware, G. W. and J. P. McCallum. 1980. Onions. Pp. 359-377 in, *Producing Vegetable Crops,* 3rd Ed. The Interstate Printers and Publishers, Danville, IL.

Yamaguchi, M. 1983. *Alliums: onion, garlic and others.* Pp. 184-195 in, World Vegetables. AVI Pub. Co., Inc. Westport, CT.

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