Bulb Onion Culture and Management

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THE NEW MEXICO INDUSTRY

The late 1930s saw the emergence of the New Mexico onion industry, which was based on New Mexico Early Grano, a variety developed by NMSU's Agricultural Experiment Station. Growth in acreage was sporadic until about 1980, when the planted acreage was about 3,000. Since 1980, the acreage has grown significantly to a maximum of about 10,000. Since 1990, acreage has fluctuated between approximately 7,000 and 10,000 annually.

The growth was spurred in part by the availability of improved varieties uniquely adapted to the New Mexico environment. Major improvements were made in resistance to bolting (seedstalk development) among fall-planted varieties and in resistance to soil-borne diseases like pink root. The improvements in pink root resistance in spring-planted, intermediate day varieties are especially beneficial for varieties harvested in early July.

New varieties and increases in transplanted acreage have helped to expand the harvest season, providing harvest continuity from late May through August. The continuous harvest season is a significant advantage to growers and shippers, providing efficiencies in the use of facilities, equipment, and labor; and providing increased marketing opportunities.

The growth in acreage since 1980 was accompanied by structural changes in the harvesting and marketing aspects of the industry. Some consolidation of production has occurred, with an increase in the number of growers who grow more than 100 acres of onions. Many growers have integrated vertically, with individual growers controlling much of their harvest and grading operations. In some instances, growers also are brokering their own crop or they may employ a broker exclusively during the New Mexico harvest season.

New Mexico growers have diversified their markets, and an increasing volume of product is now sold to processing outlets. The main processing markets are for onion rings and for frozen, chopped product. Only very small acreages of dehydrator onions have been grown up to this time. Initially the industry developed in the Mesilla and Hatch Valleys. Small acreages have been grown in eastern counties. A few hundred acres are grown near Clovis and Portales in eastern New Mexico, and some in the Pecos Valley near Roswell. Much of the recent growth has been in Luna County near Deming and Columbus. Approximately 500 acres are grown in northwestern New Mexico, near Farmington. The northwestern acreage is stored and marketed through the winter months. All other production is sold as fresh-market (nonstorage) onions, except that which is sold to processors.

Recently, several New Mexico growers and shippers have been promoting and marketing "sweet" onions, or onions with low pungency. Nationally, sweet onion marketing has expanded rapidly, with promotional programs in most of the short-day production regions. Improved varieties are needed to extend the sweet onion marketing season into late summer and fall.

This circular should help promote an understanding of the principles and factors involved in onion crop management. Growers who understand reasons for various management decisions are better able to choose the best option from among the many that are available. Some topics—like variety and planting dates, insect and disease control, and weed control—are covered briefly in this circular because more detailed guides are or will be available.

RISKS AND REWARDS

Onions in southern New Mexico are a perishable product, and as such, they are subject to wide swings in prices received by growers, depending on the balance between supply and demand at any specific time. Prices can change from day to day, and price can vary at any time for different sizes and colors. Prospective growers should recognize that at times, prices received are less than the costs to produce and market the crop.

There are different approaches to minimize the risks associated with onion production and marketing in New Mexico. One approach is to produce the same acreage

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annually and to expect that the average income per year over several years will be positive. In addition, risk can be further minimized by producing yellow, red, and white onions in various size categories for market over as long a period as possible in each year. The earliest varieties from fall planting can be marketed starting in mid- to late May, followed by later maturing varieties, providing a continuous harvest until mid- to late August. Typical crop budgets for onions are available online (1).

SITES AND SOILS

Onions are grown on soil textures ranging from sandy to clay loams. Sandy soils usually are well drained, so they dry quickly following rainfall or irrigation. This characteristic is an advantage for onions because there is less risk of bulb disease problems when fields are dry at harvest time. Sandy soils also may be cultivated more quickly following rainfall; therefore, the precise timing of planting dates needed for the fall-planted crop can be easier to achieve. Sandy soils have the disadvantages that they require more frequent irrigation, and nitrogen leaching may be more of a concern than in other soils. By adjusting the irrigation frequency according to crop demand, and by frequent nitrogen applications, growers can usually produce optimum yields on sandy soils. It's not easy to solve the problem of wet fields inherent to the finer textured soils. If the grower has the option to plant in a different soil texture, the more sandy soils are preferable.

Internal soil drainage is critical. Poorly drained soils (those with impervious layers at shallow depths) often are high in soluble salts, and onion is relatively sensitive to high soluble salt levels. Poorly drained soils are slow to dry following rainfall or irrigation, and therefore have a greater probability of being wet at harvest time. Poorly drained soils are not recommended for onion production, especially because frequent problems with bulb diseases at harvest time lead to more problems in marketing.

Water quality is a critical factor in onion production. Excessively high soluble salts in the irrigation water slow the rate of seed germination, delay stand establishment, and adversely affect plant growth rates and yields. Also, when furrow irrigation is used, soluble salts tend to accumulate at the soil surface on the tops of the beds. This accumulation causes little concern—until it is washed back into the soil by rainfall. When salty irrigation water is used or when the soil contains high soluble salt levels, these surface accumulations may become relatively high, even with few irrigations. Under these conditions, small onion seedlings are susceptible to injury by the surface-accumulated salts following a rain of less than about $^{1}/_{2}$ inch. Larger amounts of rainfall tend to leach the surface salts to lower levels in the soil profile and dilute them enough that obvious plant injury does not occur. However, unless rainfall amounts are sufficient to leach the salts below the root zone, the salts are still present and may adversely affect plant growth rates.

GREEN MANURE CROPS AND CROP ROTATION

Crop rotation is more critical for onions than for most other crops. Rotation helps maintain good soil structure, resulting in improved crop growth; reduces the incidence of pathogens that cause diseases; aids in weed management; and can result in nutritional benefits, like nitrogen residues following a leguminous crop. Some diseases that are partially controlled by rotation include fusarium basal rot, soil line botrytis, and bacterial diseases. Rotation is not an effective control of pink root.

For most effective disease control, we suggest that onions not be grown on the same site more often than once in five years. Grain crops and other crops that contribute large amounts of crop residues and perennial crops like alfalfa are most effective in improving soil structure and tilth. Winter cover crops like small grains and summer crops like sudan and sorghum incorporated as green manure crops also help improve soil structure.

LAND PREPARATION

Soil structure is important for onion stand establishment. Ideal structure is a mixture of small granules about the size of English peas, mixed with enough finer textured soil particles to provide a firm, smooth planting surface. Extremely fine particles found in a powdery soil work well if the beds do not become crusted by rainfall or flooding of the beds before germination. However, the crusts that form on a powdery soil tend to be tougher than crusts that form on soils with a more granular structure. Larger size granules (clods) may interfere with precision seed placement, and if the large granules are not mixed with finer textured particles, seeds may settle to greater than desirable depths. At best, seeds planted in cloddy soils tend to have uneven and erratic germination.

A desirable planting surface requires pre-irrigation on most soils. The sequence of operations in soil preparation starts with plowing, followed by discing, leveling, listing, pre-irrigating, rotary cultivating, shaping, and applying preplant fertilizer. The preplant fertilizer is most effective if applied after pre-irrigation. If the fertilizer is banded, banding can be done by mounting the fertilizer applicator with the bed shaper. If the fertilizer is broadcast, it can be applied following rotary cultivation and incorporated by running the rotary cultivators a second time.

SEEDING

Nearly all onions in New Mexico are grown on standard 38- or 40-inch vegetable beds. Seeds are planted in 4 to 6 rows per bed at the rate of 1.5 to 4 pounds of seed per acre. The lower seeding rates are used when large-sized bulbs are desired. The higher seeding rates produce higher yields of smaller bulbs. Precision planting results in single plants spaced equidistant in the row. Various kinds of planting equipment are used. Some equipment can space raw seeds with good singulation, while other equipment requires coated seeds. When seeds are precision planted, the bulbs tend to have a narrow size range, so one or two size categories will predominate. To have graded product in all size categories, you may need to plant several fields at different spacings to have the entire range of sizes from prepack through jumbo or colossal. When raw seeds are planted with traditional planters like the Planet Jr., the lack of precision in seed placement results in a wider range of bulb sizes and a greater diversity in the marketable size categories than bulbs produced from seeding with a precision planter.

Poor stand establishment of small-seeded crops like onion is a recurrent problem in New Mexico. Seed placement must be near the soil surface, and irrigation for seed germination must be scheduled to maintain high soil moisture levels at very shallow depths. Two to three irrigations are usually needed for onion germination. When rainfall occurs before germination, a tough crust forms at the soil surface, preventing seedling emergence.

The most difficult time for onion stand establishment is with the early-fall-seeded crop, in which germination occurs in relatively warm weather. If a soil crust is formed following a rain, irrigate to soften the crust so that seedlings can emerge. If seedlings encounter a crust during germination, the seedlings buckle as they attempt to push through the crust. The seedlings lose their leverage to push to the surface, or they may start to grow horizontally and may never emerge. Irrigation timing is critical when seeds are germinated in warm weather (mid- to late September). Check seedling development frequently before seedlings emerge. If the soil is crusted, an irrigation just before the seedlings reach the crust may permit normal emergence and good stands.

During mid- to late September, seed germination usually occurs in about a week. We have had success with very shallow planting at this time ($^1/_2$ to $^3/_4$ inch depth). Seedling emergence from shallow depths is quicker, and crusting seems to be less detrimental than for deeper seed placement. However, one risk of shallow seeding is that heavy rainfall can sometimes wash the seed from the row. For later planting, or for the January and February plantings in cooler weather, seed placement can be deeper (about 1 to $1^1/_4$ inches) than for the early fall plantings. Seed germination in January or February requires 15 to 30 days, depending on temperature.

VARIETIES AND PLANTING DATES

In southern New Mexico it is possible to select combinations of varieties, seeding dates, and transplanting to schedule continuous harvest from late May through mid-August. To assist growers in scheduling harvests we have prepared (table 1) as a guide. Several combinations of variety and planting date are given to achieve a particular harvest period, but additional options are available and others will become available with the introduction of new varieties.

The options presented in table 1 employ varieties released by NMSU's Agricultural Experiment Station plus several other commonly grown varieties that have been tested extensively by the Experiment Station. Several additional varieties have been released by various seed companies, and no doubt others will become available in the near future.

The fall planting dates, in most instances, are the earliest possible date for the variety to avoid a bolting problem, and these apply throughout southern New Mexico. The spring seeding and transplanting dates can vary depending on variety and location. The maturity dates are for the Las Cruces area. In other areas (like Hatch, Deming, or the Uvas Valley), maturity dates will be later than those given, but the relative order of maturity should be the same. Descriptions of varieties released by NMSU's Agricultural Experiment Station are available online (2).

OVERWINTERING FALL-PLANTED VARIETIES

Planting date affects the winter survival of onion plants. Throughout southern New Mexico, extremely cold winter temperatures periodically cause onion plant loss. Some plant loss occurs when air temperature reaches about 12°F, and even greater loss occurs at lower temperatures.

Planting date affects the winter survival potential of onion plants because very small plants sustain greater losses than larger ones. For the southern part of Doña Ana County, the latest recommended planting date to avoid excessive winter-killing is about November 15. In the Hatch area, this date is about October 5, and for the Deming and Uvas areas, about September 25. Bolting

Table 1. Onion variety planting date-transplanting options that can be used to schedule a continuous harvest from May 20 to August 10. Dates are for Las Cruces, New Mexico.

Time of harvest	Variety	Skin color	Seeding or transplanting date
May 20 to June 1	NuMex Sunlite	Yellow	Seeded September 20
	NuMex Sweetpak	Yellow	Seeded October 1
	NuMex Mesa	Yellow	Seeded September 20
	Buffalo	Yellow	Seeded September 20
	Daybreak	Yellow	Seeded October 1
	Ibex	Yellow	Seeded September 20
June 1 to June 10	NuMex Starlite	Yellow	Seeded September 25
	NuMex Dulce	Yellow	Seeded October 1
	Caribou	Yellow	Seeded September 25
	NuMex Crispy	White	Seeded October 1
	Texas Grano 1015Y	Yellow	Transplanted February 15
June 10 to June 20	NuMex Vado	Yellow	Seeded October 1
	NuMex Starlite	Yellow	Transplanted February 15
	NuMex Dulce	Yellow	Transplanted February 15
	NuMex Luna	Yellow	Seeded September 25
	NuMex Crispy	White	Transplanted February 15
	Texas Grano 1025Y	Yellow	Transplanted February 15
June 20 to July 1	NuMex Luna	Yellow	Seeded October 5
	NuMex Bolo	Yellow	Transplanted March 1
	NuMex Jose Fernandez	Yellow	Transplanted March 1
	Cimarron	Yellow	Transplanted March 1
	Candy	Yellow	Transplanted March 1
	Utopia	Yellow	Transplanted March 1
	NuMex Casper	White	Transplanted March 1
July 1 to July 10	NuMex Bolo	Yellow	Seeded February 1
	NuMex Jose Fernandez	Yellow	Seeded February 1
	Cimarron	Yellow	Seeded February 1
	Candy	Yellow	Seeded February 1
	Utopia	Yellow	Seeded February 1
	NuMex Casper	White	Seeded February 1
	NuMex Centric	Yellow	Transplanted March 1
July 10 to July 20	NuMex Centric	Yellow	Seeded February 1
	Riviera	Yellow	Seeded February 1
	Yula	Yellow	Seeded February 1
July 20 to August 1	Armada	Yellow	Seeded February 1
	Vega	Yellow	Seeded February 1
	Durado	White	Seeded February 1
August 1 to August 10	Vaquero	Yellow	Seeded February 1
	Ringmaster	White	Seeded February 1

(flowering) resistance permits earlier fall planting and helps to reduce the risk of plant losses by winter-killing because overwintering plants are larger. Data from Las Cruces indicate that plants begin acclimation in November or early December and reach their maximum hardiness level in January. For any given temperature extreme, we would expect greater plant loss in December than in January.

Soil moisture also affects onion winter-killing. The critical tissue for plant survival is the stem plate, which contains the terminal bud and is the structure from which roots originate. Since the stem plate is below ground level, any factor that influences soil temperature will affect the amount of winter-killing.

Temperature drops occur more slowly in moist than in dry soils because as water freezes, it releases large quantities of heat. Therefore, for any given low air temperature, a relatively dry soil will reach a lower temperature than a soil that has more moisture. The difference in soil temperatures between moist and dry soils applies only for short-term low temperature extremes, because as soil is exposed to freezing temperatures over long periods, all the soil water becomes frozen, and then the rate of drop in a moist soil may be nearly the same as in a dry one.

However, in southern New Mexico, extremely low temperatures nearly always occur on clear, still nights as a result of radiant cooling, and the lethal temperatures don't usually last long. Growers can reduce the extent of winter-killing by irrigating to maintain high soil moisture levels when extremely low temperatures are expected.

Variety selection can help to minimize onion winter plant losses. Many of the varieties of Japanese origin are more winter hardy than the typical Grano and Granex types most commonly grown in the southwestern United States. In cold hardiness testing at NMSU, Buffalo (a Japanese variety) has consistently shown about 3°F greater hardiness than the typical Grano varieties like NuMex Sunlite.

TRANSPLANTING

Onions in New Mexico are transplanted from mid-January through mid-March. A wide range of varieties are transplanted, but the transplants are later maturing short-day and intermediate varieties. Before 1996, there were no acceptable fall-seeded varieties that mature in mid- to late June. By transplanting the later maturing short-day varieties, like NuMex Starlite, growers are able to harvest and market onions from June 10 to 20. Also, intermediate varieties that mature in early July often have poor size and yields when they are spring seeded. So the intermediates are commonly transplanted to improve their yield and size potential. Transplanted intermediates mature earlier than spring-seeded intermediates and help to bridge the harvest season between fall- and spring-seeded varieties.

Varieties released by the Experiment Station in 1995 provide for fall-seeding to mature in mid- to late June. NuMex Vado seeded October 5 matures about June 15, while NuMex Luna seeded October 1 matures about June 25. If these varieties are successful as fall-seeded crops, they will likely replace some of the transplant acreage.

Among the short-day varieties, the earlier maturing ones (like NuMex Sunlite, NuMex Sweetpak, and NuMex BR 1), when grown from transplants, tend to produce small bulbs and low yields. Varieties in this early group should be fall-seeded. The later-maturing NuMex Starlite and NuMex Dulce can produce high yields and large bulbs from transplants when well managed. However, transplant yields of varieties in this group are lower than potential yields from fall seeding.

Yields and bulb size from transplanted intermediate varieties are higher than for the same varieties spring seeded. For the later maturing long-day varieties, either transplanting or spring seeding has the potential to produce very high yields. Maturity dates of short-day transplants tend to be later than for the same varieties fall-seeded, but maturity dates for intermediate and long-day varieties are earlier from transplanting than from direct seeding in the spring. For example, NuMex Jose Fernandez transplanted at Las Cruces matures June 25 to 30, but NuMex Jose Fernandez spring-seeded at Las Cruces matures after July 1.

Transplant onions have different shapes than the same varieties from fall seeding. When onions are overwintered, they develop an extensive root system that anchors the stem plate and tends to create a downward force at the base of the bulb. The result is a tendency for relatively long and, in some cases, top-shaped bulbs. Bulbs from transplants are weakly anchored, and the tendency is for a more rounded shape in the lower half of the bulb. For example, bulbs of NuMex Starlite from fall seeding tend to be somewhat top-shaped, but when transplanted, the bulbs are more nearly round.

Transplants are obtained from warmer winter areas in Texas and Arizona. Growers commonly contract with transplant growers for their transplant needs. Plants that are grown in warmer climates may lack the winter hardiness necessary to survive New Mexico's mid-winter temperatures, so transplanting imported plants before about February 10 is not advised. Recently, some New Mexico growers have begun growing transplants locally. Locally grown plants are acclimated to low winter temperatures and can be transplanted as early as mid-January.

Bolting can be excessive in transplanted onions. The amount of bolting depends on variety, time of transplanting, transplant size, and environment. For bolting-resistant varieties like NuMex Starlite, NuMex Dulce, NuMex Vado, NuMex Luna, and NuMex Sundial, plants with a pencil-sized or smaller diameter can be planted from January 15 without too much bolting. For bolting-susceptible varieties like NuMex Bolo, NuMex Jose Fernandez, NuMex Casper, Cimmaron, Candy, Utopia, and most other intermediate and long-day varieties, transplanting should be delayed at least until February 15, and plant diameter should be somewhat less than pencil size. The bolting percentage is highest during years in which temperatures are relatively low in late spring (April and May).

Much of New Mexico's transplant acreage is planted to late-maturing, short-day varieties like NuMex Starlite, NuMex Dulce, Texas Grano 1015 Y, and Texas Grano 1025 Y for maturity in mid- to late June. The factors that affect maturity date become important when transplanting short-day types for later maturity. Our research has shown that the use of small transplants and later transplanting dates tend to delay maturity. However, the later transplanting dates also result in smaller bulbs and lower yields. We suggest that for NuMex Starlite and other varieties of similar maturity, you can transplant a relatively small plant from February 20 to March 1 to obtain maturity 10 or more days later than for the same varieties fall-seeded. In our tests at Las Cruces, seeding for transplants near October 10 has given us the desired transplant size in late February.

Growers of transplant onions usually desire large bulbs. By transplanting two rows per 40-inch bed and spacing the plants 4 inches apart in the rows, we have been able to produce yields at the rate of 1000 to 1500, 50-pound sacks per acre with relatively large bulb size. At this spacing, the number of transplants required per acre is about 80,000.

FERTILIZATION

Onions grown in the Southwest's alkaline soils nearly always respond to both nitrogen and phosphorus fertilizers. You can apply all of the phosphorus for the crop preplant. Our soils usually have large supplies of total phosphorus, but the available levels are nearly always deficient for onions. To know exactly the minimum phosphorus rate for maximum yield, it would be necessary to conduct experiments on each farm and, in some instances, each field. Soil analysis for available phosphorous can be used a s a guide. Our suggestion is that each grower experiment with different rates so that over a period of several crops you can determine the minimum rate that gives maximum growth.

One source of available phosphorus is associated with soil microbiological activity, which is greater in warm soils. The rates needed for the fall-seeded crop that germinates in relatively warm soils may be less than for the spring-seeded crop germinating in January or February. Until you have more specific information, we suggest a preplant application of 250 lb/A of P_20_5. Banding the phosphorus about 3 to 4 inches below the seed rows may result in more efficient phosphorus use by the plants, and then lower rates may provide maximum growth and yields.

Phosphorus fertilizer should be applied immediately before planting. When it is applied several weeks before planting, most may precipitate as an insoluble salt and become unavailable to the plants. This is especially true if soils are wet by pre-irrigation or rainfall. Applied phosphorus fertilizer in alkaline soils tends to become unavailable over time. However, the greatest need for added phosphorus is during the early growth of the crop. In effect, you need to provide a soluble phosphorus source at germination to support early growth. As the crop develops an extensive root system, it becomes more self-sufficient in obtaining phosphorus from the native soil supply, so sidedress applications of phosphorus during the growing season should not be needed.

Some preplant nitrogen (N) fertilizer is needed, up to about 50 lb/A. When larger amounts of nitrogen are supplied at planting, much of it is leached by irrigation water before it can be absorbed by the plant. The use of ammonium forms of nitrogen delays the leaching process for a short time because the positively charged ammonium ions adsorb to the soil colloids and are held in place. However, eventually even the ammonium forms are converted to nitrate by soil microorganisms and then are susceptible to leaching. The most efficient use of nitrogen would be to apply about 50 lb/A of nitrogen preplant as ammonium sulfate; after germination, start adding nitrogen at about 10 lb/A with each irrigation. As the crop develops and starts to use more nitrogen, you could increase rates to 15 to 20 lb/A with each irrigation. Too much nitrogen late in the season delays maturity and may cause bulbs to be soft, contributing to poor handling qualities. Discontinue nitrogen application at least four to six weeks before harvest.

When onions follow a leguminous crop like alfalfa, the residual nitrogen from the alfalfa crop makes it difficult to know the exact nitrogen fertilizer needs for the onions. Certainly a preplant nitrogen application is needed, and a positive response to later sidedress applications is probable. However, it may be advisable to terminate sidedress applications about 60 days before anticipated maturity to avoid excessive nitrogen as the onions mature.

Partially decomposed manure is an excellent source of both nitrogen and phosphorus. Twenty tons of manure per acre can contribute more than 100 lb of nitrogen and significantly improve phosphorus nutrition. Use manure as a supplement to the regular fertilizer program. The nutrient elements in manure become available to plants over an extended time. In addition to the nutrients added with manure, the organic material supplied by manure improves soil structure and helps to make other fertilizer elements more readily available to the plant.

Zinc deficiency has occurred in New Mexico onions, but the incidence is rare and occurs primarily on sandy soils in late spring following a few weeks of unusually cool weather. Even when zinc deficiency symptoms occur, they tend to self-correct with the advent of warmer weather. Yields may be improved by zinc applications when symptoms are evident, but there is some question about whether zinc sprays improve yields in onion crops that show no zinc deficiency symptoms.

There is little or no evidence to support the use of micronutrients other than zinc on onions in New Mexico. The use of soil amendments like gypsum or sulfuric acid should be based on a soil test that indicates high levels of exchangeable sodium. Such high sodium levels can occur in New Mexico soils, but they are not common.

WATER REQUIREMENTS AND IRRIGATION

Onions are a shallow-rooted crop. Managing the timing and amount of applied irrigation water is critical to achieve optimum yields and quality. Ideally, light, frequent irrigations are needed, either by furrow, sprinkler, or drip irrigation. Excessive applications waste water and leach nitrogen to the groundwater. Irrigation frequency varies by the kind of crop (fall- or spring-seeded, or transplants), by the size and development of the crop, by the type of irrigation (furrow, sprinkler, drip), and by the environment. When plants are small and when temperatures are low, furrow irrigation intervals can be two to three weeks on clay soils that have large water-holding capacities, while intervals as short as three or four days are common for a crop on a sandy soil with a full canopy in June and July. Irrigation intervals for a drip system can be as short as one day.

Irrigation Methods

Most onions in New Mexico are grown with furrow irrigation. In areas where surface water is available and the land is level or has been benched, furrow irrigation is relatively inexpensive. Once delivery structures are in place, water application is convenient. However, furrow irrigation is relatively inefficient in the amount of water required to produce a crop. The least amount of water that can be applied per furrow irrigation is about 2 surface inches. During seed germination and early crop growth, the need to maintain available water near the surface requires frequent irrigation, and the excess water is leached below the root zone.

Sprinkler irrigation permits frequent application of small amounts of water (which is ideal for seed germination and early crop growth) and sprinklers can be used to deliver water to land that is not level. Therefore, sprinkler irrigation is used where onions are grown on land that has significant slope, as in eastern and northwestern New Mexico. In some parts of the United States, sprinklers are commonly used during seed germination and early crop growth, and furrow irrigation is used to finish the crop. Sprinklers can be used for the entire crop season, but there is some concern that wetting the foliage during late season causes greater incidence of foliage diseases and a subsequent increase in bulb disorders.

Drip irrigation provides the most efficient irrigation in terms of the amount of water required for a crop. Small amounts of water can be delivered at frequent intervals as needed by the plants, and water losses to evaporation are less than with sprinklers. Also, water is delivered at or below ground level, so that wetting of the foliage is not a problem, as with sprinklers. Drip irrigation requires very clean water to avoid clogging the emitters, so filtration is required. Even well water that appears clean and clear usually has enough solids to require filtration. The filtration structures and plumbing required for drip irrigation amount to a significant cost.

The economics of drip as contrasted to furrow or sprinkler methods depend on the cost of water (or the cost of pumping); the yield increases that can be obtained with drip irrigation; and other economies, like lower weed-control costs. An Excel spread sheet to evaluate the economics of converting to drip irrigation is available online (3).

The ability to employ drip lines for longer than one crop is an important cost saving and, in some instances, can be the deciding economic factor. Long-term use of drip lines depends on preventing clogging the emitters, which requires excellent filtration and regular use of acids and antimicrobial additives. Drip irrigation lends itself to automation, more so than either furrow or sprinkler irrigation.

Because onions are shallow rooted, placement of drip lines deeper that about 6 inches results in some water loss by leaching. At the research center, we install lines only 2 to 4 inches deep to hold them in place. This shallow placement results in the most efficient water use and it facilitates wetting of the seed rows by lateral water movement. However, shallow placement makes it difficult or impossible to renovate the beds and re-use the lines for another crop, and it results in wetting the surface at each irrigation, which contributes to weed seed germination.

Water in the Soil

For practical purposes, soil water and water characteristics can be classified as

1) gravitational water—the water that drains quickly by gravity following rainfall or an irrigation,
2) field capacity—the percentage of water that is held against gravity and therefore remains after gravitational water has drained,
3) the permanent wilting point—the percentage of water that is held so tightly by the soil that plants cannot extract it, and
4) available water—the water that is held by the soil between field capacity and the permanent wilting point.

The amount of available water-holding capacity depends on soil texture. The available water in a sandy soil at field capacities may be about 1 surface inch per foot of soil depth, and in a clay soil up to about 2.7 inches per foot of depth. If you assume the effective rooting depth for onion is about 1.5 feet, then for a sandy soil the maximum amount of water available to the crop between irrigations is about 1.5 surface inches, and for a clay soil 2.7 x 1.5, or about 4 inches. Most soils used for onions probably fall somewhere between these two values.

The amount of water that can be removed before the plants show water stress and reduced yield is the managed allowed depletion (MAD), which for onions is about 30 percent of the available water supply. For onion, maximum growth rate and yield are obtained when the MAD is not greater than 30 percent. If the percentage of available water is permitted to go below about 70 percent of the total available before irrigating, then some yield reduction will occur.

Evapotranspiration

Evapotranspiration (ET) is the rate of water loss from the soil per unit time, including that lost by evaporation from the soil surface plus that lost by transpiration from the plants. It is commonly expressed in surface inches per day. Estimates of potential ET (PET) are available online on the NMSU bulletin board (4). These PET estimates are obtained by measuring losses from soil with a grass-covered surface. For an onion crop, the loss will be different because the crop has a different transpiration rate, which depends on the stage of crop growth and the amount of foliage cover (the crop coefficient).

Seasonal ET losses from a spring-planted onion crop were estimated over a period of three years at Las Cruces, New Mexico (fig. 1). Daily water losses ranged from 0.05 inches per day early in the season (primarily evaporation from the soil surface) to 0.45 inches per day near crop maturity (fig. 2). Data are not available for a typical fall-planted crop, but we estimate that the maximum evapotranspiration rate during our warmest weather is similar to the maximum for the spring-planted crop, about 0.45 inches per day.

Irrigation Frequency and Amounts

Growers can use various approaches to determine when to irrigate. When using furrow irrigation, one of the simplest approaches is to estimate the available water-holding capacity in the onion root zone, obtain estimates of ET, and plan to irrigate at some depletion level.

For example: On a medium-textured soil you can assume about 1.8 inches of available water storage per 1 foot depth. If the effective root zone is 1.5 feet, then the available water storage at field capacity is 1.8 x 1.5, or 2.7 surface inches. If we delay irrigation until all the available water is used, the crop becomes stressed because as water is extracted, the remaining water is held by the soil with greater force, resulting in plant stress.

If you arbitrarily decide to irrigate at 50 percent depletion of the available water, then you would plan to irrigate after the crop has extracted half the 2.7 inches, or 1.35 inches. If the crop has a full canopy, and temperatures are relatively high, ET might be estimated at 0.40 inches per day because of the slight moisture stress. Divide 1.35 by 0.40 = 2.8, or 3 days. However, you may assume that following an irrigation there is adequate gravitational water to support the crop for at least one day before the field drains to field capacity. Then you would add that day to your calculated interval. Using this model, the shortest irrigation interval you would use, with a full crop canopy and the most stressful conditions, would be 3 + 1, or 4 days. Allowing MAD of 50% results in some moisture stress.

In another example based on experimental data, for a silty clay loam soil having a water-holding capacity of 2.5 inches available water per foot, the irrigation interval for non-moisture-stress conditions would be 5 days averaged over the growing season (fig. 3) and 3 days during the period of peak ET. As the irrigation interval increases, yield decreases. Figure 3 is based on a potential non-stress yield of 1600, 50-pound sacks per acre.

Ideally we would like to irrigate to replace the amount of water lost since the last irrigation, or enough to bring the root zone back up to field capacity. With furrow irrigation this is not always possible because adequate water application may require a minimum of about 2 inches of water at each irrigation. For example, in the above calculation on a medium-textured soil, it may not be possible to apply only 1.35 inches. In that case, the excess water above 1.35 inches will be leached to groundwater.

To estimate ET at earlier stages of crop development, you can extrapolate from figure 2 for a spring-planted crop. You also can obtain PET from the Climate Center bulletin board and estimate the crop coefficient by estimating the fraction of surface area that is covered by onion foliage. To estimate ET, multiply PET by the crop coefficient.

The above approach is useful after there is sufficient foliage development that transpiration is significantly higher than evaporation from the soil surface. However, during seed germination and early plant development, irrigations must be timed to maintain available moisture in the seed zone and around the base of the plant. Onion roots branch sparingly, and the intensive rooting that is required for rapid growth depends on continuous root development from the stem plate (sometimes called the root plate). Following germination, if the soil surface is permitted to dry to a depth below the stem plate (1 to 2

(Please see hard copy for Figures 1,2, and 3.)

inches deep), root development from the stem plate can be severely inhibited.

For this reason, it is important to irrigate onion often enough to maintain moisture at the stem plate level. The interval to do this will vary with weather conditions. During October it may be as often as one week; in December and January, as long as two to three weeks. These early irrigations are important for early plant development, and they contribute to improved yields, but they also result in lowered irrigation efficiency as calculated in the above model. In general, as the irrigation interval increases, so does the irrigation efficiency, but the trade-off is decreased yield as the MAD is increased (fig. 4).

Sprinkler irrigation is employed in eastern and northwestern New Mexico, where onions are grown on sloping lands. Sprinklers are more efficient than furrow irrigation during germination and early crop development because small amounts of water can be delivered at frequent intervals. In areas where furrow irrigation predominates, there is potential to improve irrigation efficiency by using sprinklers during germination and early crop development.

The economics of converting from furrow to sprinkler irrigation are strongly influenced by the availability and cost of irrigation water. Once significant foliage development occurs, the above model (irrigating at an estimated 50 percent available soil water depletion in an amount adequate to replace the depletion) may be used to determine when and how much to irrigate with sprinklers. Sprinkler irrigation may be more efficient than furrow irrigation in that we can replace the precise amount of water that is depleted and minimize the extent of leaching. Also, smaller amounts of water can be applied at each irrigation, so you can irrigate at a lower depletion level. Some research indicates that yields are highest when depletion is not allowed to go below 30 percent of the available water supply.

Drip irrigation has recently received attention from New Mexico onion growers because of its potential for water conservation and because it may improve yields over furrow irrigation. Several companies provide equipment and services, including consulting expertise, to install and operate an efficient drip irrigation program. A drip system is ideal to employ the water depletion model above, except that depleted water can be replaced on a daily basis and soil textural properties and available storage potential do not enter into the equation.

For example, each day, the ET for the previous day would be replaced to maintain soil water levels at or near field capacity. For onions, some growers irrigate every two days, replacing ET for the previous two days before the irrigation. However, using our depletion model above, for a sandy soil and ET at 0.45 inches per day, alternate-day irrigation would result in MAD below 30 percent of available water and likely result in some plant water stress.

During germination and early seedling development, it is important to irrigate to wet the entire width of the bed, which results in some loss in irrigation efficiency. Some soils have very poor capillary conductivity after planting until the soil has been wetted. This occurs on fine-textured soils that have a very granular structure. You can conserve water by pulsing (watering frequently at short intervals) until the seed zones are wet. In extreme cases it may be necessary to irrigate by furrow for one or two irrigations to establish capillary conductivity between soil particles so that lateral and upward water movement from the drip line is adequate.

For any of the above irrigation methods, tensiometers may be used to determine when to irrigate. We suggest placing the tensiometer at the 6 inch depth in early season, then moving it to the 12 inch depth later as plant roots explore greater depths. For furrow irrigation, water when the tensiometer shows 20 cbars for a sandy soil, 30 cbars for a medium-textured soil, and 40 cbars for a clay soil, which is equivalent to a MAD of 30 percent.

Ideally, we would like to irrigate to remove all water stress. In practice, this is not always possible or practical. We can approach this ideal with drip irrigation more nearly than with other methods. With furrow irrigation, some trade-offs are necessary. For example, if we follow the 50 percent MAD model above, on sandy soils at times we would need to irrigate every two days. Some growers have used furrow irrigation intervals as short as three or four days during the later part of the growing season when foliage cover is extensive and temperatures are high, and they have been able to produce unusually high yields. However, frequent furrow irrigation maintains high moisture levels at the soil surface and tends to increase the frequency of foliage and bulb diseases.

For growers who wish to irrigate on a fixed schedule, we suggest that on sandy soils in June and July, you irrigate on a four- or five-day schedule; on medium-textured soils, a five- or six-day schedule; and on clay or clay loam soils, a six- or seven-day schedule. A water balance spread sheet to calculate intervals for onion can be acquired online (5).

Irrigation Efficiency

All applied irrigation water is not absorbed by the plant. Especially during early crop growth, leaching losses may be significant, and at any stage of crop growth it is difficult to provide the exact amount of water used by the crop without inducing some degree of moisture stress. Therefore, to reduce crop stress to a minimum, it is necessary to supply more water than that actually used by the crop. At higher efficiencies (less applied water), crop stress increases, ET decreases, and yield decreases.

A three-year study comparing yields at various irrigation efficiencies using drip irrigation with buried drip lines on a spring-seeded crop shows the relationship between irrigation efficiency and yield. In these experiments, maximum yield was achieved with an average of 89 inches of water and an irrigation efficiency of 52 percent. The average yield for New Mexico (approximately 800 sacks/acre) was obtained with an efficiency of 80 percent and the application of 32 inches of water (fig. 4). A general discussion of vegetable crop irrigation is available online (6).

WEED MANAGEMENT

Weeds compete with crop plants for nutrients, water, and light. The effect of weed competition is a reduction in crop vigor, yield, and quality. In addition, weeds interfere with harvest operations. The magnitude of weed competition and resulting crop loss is related to the timing of weed emergence in relation to crop emergence, the growth form of the weed and crop, and the density of weeds present in the crop. Weeds also serve as alternate hosts for diseases and insects, and during rainy periods they can maintain high humidity around the onion plants, contributing to greater incidence of foliar diseases.

Weed control is especially troublesome in fields in which weed seeds or perennial weeds have built up. In onions, the planting arrangement does not permit cultivation close to the plants, but onions do not compete well with weed populations. Weeds emerging late in the season may not affect yield; however, these late-emerging populations may influence disease incidence and harvest. In addition, any weeds that are allowed to set seed will increase weed problems in the field in following years. Individual weeds can produce from 2000 to over 200,000 seeds per plant on average, depending on the species and growing conditions. Weed seeds present in soil usually germinate over a period of years, so the seed that is produced one year will be a problem for a number of following years. Another source of weed seed in southern New Mexico onion fields is surface irrigation water.

Complete elimination of all weeds in a field is not possible because of the characteristics of weeds and the constant reintroduction of weed seed from outside

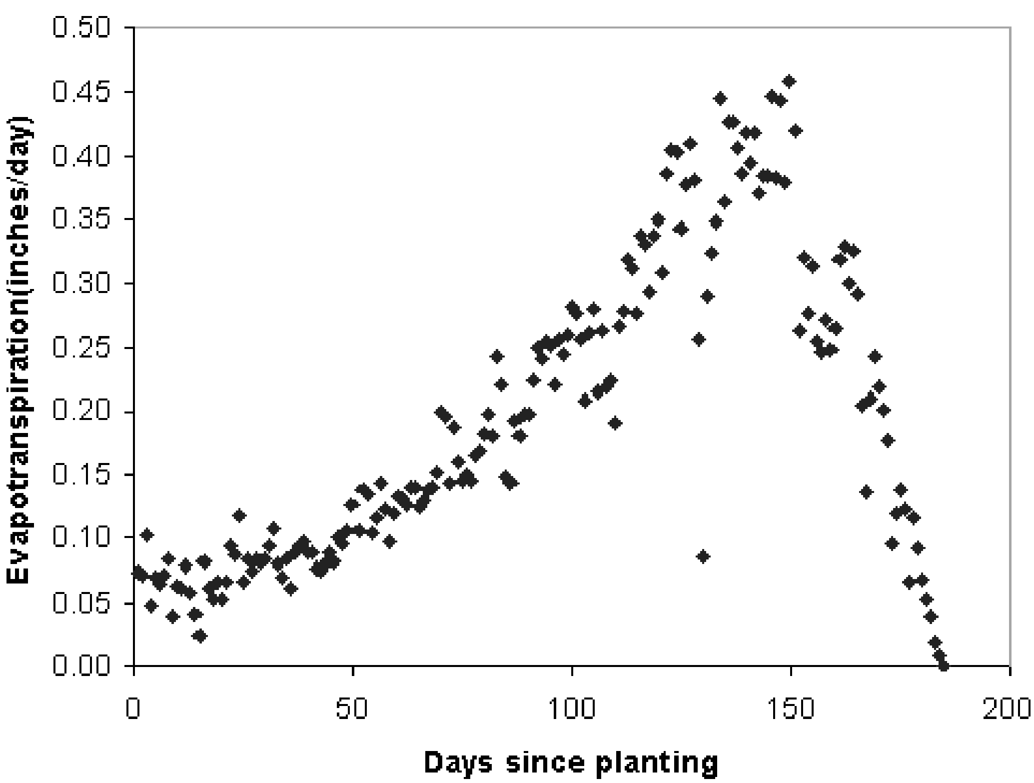

Figure 4. Irrigation efficiency (IE) and Management Allowed Depletion (MAD) for onions that are furrow irrigated.

sources. Therefore, management of the weed populations through integrated practices to maintain them at a low density is the goal for weed-control efforts.

Integrated weed management includes using cultural, mechanical, and chemical methods to control and reduce the impact of weed populations. An important component of integrated weed management is to prevent the movement of new weeds into fields by controlling the weeds along headlands, canals, ditches, and fence-rows. In addition, weed control in onion needs to be integrated across all of the crops that are grown in rotation with onion. Good weed-control practices across years is important in maintaining low weed seed populations. Also, good weed control in each crop up to and through the harvest period helps in reducing the weed problem in the following crop.

Planting onion in rotation with crops that can compete with weeds (such as corn, sorghum-sudangrass, or alfalfa) is an important cultural method of weed control. These crops compete vigorously with weeds and have a different life cycle than onion, which helps reduce the number of weeds present in the following onion crop. In addition, for these crops there are a number of registered herbicides that can be used to control some of the weeds that will pose a greater problem for onions. Cultural practices that promote vigorous growth of the onions, such as good water and fertility management, will also aid in controlling weeds. Control methods within the onion crop also include limited cultivation, hoeing, and the use of registered herbicides.

Several herbicides are registered as soil-applied or foliar treatments in onion. NMSU's Cooperative Extension Service, independent crop consultants, and chemical manufacturers and distributors have information concerning which products are registered for use in onions. When using herbicides, follow label instructions carefully to avoid crop damage, to make certain that the product will control the problem weeds, and to stay within EPA limits for residues and environmental concerns. In addition, to achieve maximum performance from any herbicide, apply the herbicide at the appropriate time in relation to the crop and weed growth stage.

Pre-emergence, foliar herbicides such as Round-up Ultra™ or Gramoxone™ are used to control weeds that emerge prior to onion emergence or transplanting. These herbicides are not active in soil and will not provide residual weed control. They will injure onions, however, if applied after the crop begins to emerge from the soil. Pre-emergence, soil-active herbicides will provide residual weed control, but they must be applied before the weed seed begins to germinate. Postemergence herbicides are applied after onion and weed emergence and can be used once the onions are big enough to avoid crop damage, but they must be used before the weeds are too large to be effectively controlled.

Numerous weed species, both annual and perennial, are problems for onions in particular fields. The weed species that occur in an onion crop will be influenced by whether the onions are planted in the fall or spring and whether they are direct seeded or transplanted. Some of the more common weed problems include the warm-season annual and perennial grasses, warm- and cool-season broadleaf weeds, and perennial nutsedges.

The warm-season annual and perennial grasses, including barnyardgrass (watergrass) and Johnsongrass, are among the most competitive annual weeds in onion. Both grasses emerge from seed that begins to germinate in the spring (mid-March) and continue to emerge throughout the crop season. Johnsongrass is a perennial grass that also reproduces vegetatively by rhizomes (underground stems). Therefore, in addition to seed germination, the Johnsongrass rhizomes sprout in early spring and are more difficult to manage because pre-emergence herbicides do not control these plants. Control of perennial Johnsongrass in onions relies on mechanical removal and the use of postemergence herbicides.

Broadleaf weed problems include the warm-season annual broadleaves such as Russian thistle, kochia, and common lambsquarters, which germinate primarily in the late winter or early spring; and the pigweeds (carelessweed), which germinate in early or late spring. Spurred anoda (cottonweed), Wright's groundcherry, and tall morningglory are warm-season annual broadleaf weeds that begin to emerge in late spring and are often a problem in spring-planted onions.

Cool-season broadleaf weeds germinate in the late summer or fall and include sowthistle and the mustards (tansy mustard, flixweed, and London rocket). Common lambsquarters and pigweeds can germinate in the fall after a fall-planted crop of onions is irrigated. These weeds will die naturally with the first frost. The mustards, however, will germinate with the onion crop in the fall and will continue to grow with the crop throughout the winter. The mustards are common weeds in alfalfa and, if permitted to re-seed in the alfalfa, pose a difficult problem in onion when planted as the following crop. Controlling mustards in alfalfa reduces the problem in fields rotated to onion. This is important because mustards can get too large for herbicides to be effective before the onions are large enough to avoid damage from the treatment.

The perennial nutsedges (nutgrasses) are the most difficult weeds to manage in onions. The nutsedges are in a different plant family than grasses; therefore, the herbicides used for grass-control in onions are not effective on nutsedge. Two species of nutsedge are found in New Mexico: yellow nutsedge and purple nutsedge. Both species reproduce primarily by tubers, which are below-ground, perennial vegetative structures. Each tuber can sprout several times after cultivation or hoeing, which makes their control extremely difficult. In addition, the new sprouts will emerge within a day after removal, making the cost of hand labor for controlling these species very high.

Yellow and purple nutsedge are, however, susceptible to shading and dry conditions. The most effective management practices for nutsedge include either a cultivated fallow (which may include timely herbicide applications) where the nutsedge tubers are left on the soil surface to dry, or a competitive rotational crop such as corn or sorghum-sudangrass that will emerge and grow quickly to shade out the nutsedge. In addition, herbicide alternatives are available in rotational crops such as corn or cotton, which, along with aggressive cultivation, can reduce the nutsedge population prior to planting onion.

ONION INSECTS

Although thrips is the primary insect pest of economic importance to New Mexico onion production, cutworms, cucumber beetles, and maggot species also have reached levels of economic concern in some fields.

Cutworm Species

Cutworms encompass a number of species that are economically important to crops. Those with a history of importance to New Mexico onions are included in a group known as surface cutworms (dingy cutworm, black cutworm). Species of this group generally produce one generation per year and overwinter in the soil as larvae. As spring temperatures increase, overwintering larvae from eggs oviposited in the soil the previous year emerge from the soil at night, feed on leaves near ground level, and return to the soil by daylight. Although larvae are rarely seen during the day, excavation of the disturbed soil near the plants normally reveals a gray and hairless larvae. Feeding damage consists of onion leaves that are partially chewed or cut in two near the soil line. Economics for cutworm damage in onions depends on the plant age and number of damaged plants within a field. Leaf damage on young onions can substantially retard growth or, in the case of complete leaf removal, kill the plant.

Fields should be thoroughly scouted before treating the entire area. Cutworm infestations may be localized, requiring only a portion of the field to be treated. Insecticide applications should be directed toward the base of the plant and the soil using a flat fan nozzle. Subsequent generations of cutworms are not of economic importance in onions. Onions planted to fields that previously had grass and weed problems or were planted in grain or alfalfa for several years tend to have a higher incidence of cutworm pressure.

Spotted Cucumber Beetle

Although not normally of economic concern, damage caused by the spotted cucumber beetle is evident in most of the onion fields in southern New Mexico. Spotted cucumber beetles are approximately $^{1}/_{4}$ inch long and lime yellow with distinct black spots on the back. Overwintering adults emerge in the spring and begin feeding on the leaf tissue of young onion plants.

Onions are particularly attractive to spotted cucumber beetles early in the spring because few alternate hosts are available during that period. As the year progresses, beetle populations disperse into cabbage, lettuce, corn, chile, melons, and numerous other crops.

Damage caused by spotted cucumber beetles in onions is confined to leaf-feeding by the adults. Adults typically skeletonize several leaves within a small area. Adults are present throughout the growing season, but they are a potential economic threat only to young onions in early spring. Because eggs are laid in the soil of numerous host plants, the larvae are potential pests in many of the vegetable crops grown in New Mexico. However, although adults may be numerous, spotted cucumber beetle larvae are seldom of economic concern in onions.

Onion-Infesting Maggots

Several fly maggot species in the genus *Delia* are occasionally found in New Mexico onion fields. Fields planted in short rotation with cabbage, lettuce, or onion may have an increased risk of damage by maggot species.

Maggots infesting onions may overwinter as adults or larvae in southern New Mexico. Depending on the species, adult flies lay eggs in the soil or in the leaf axis of onion plants. The eggs hatch and maggots migrate to the below-ground structures (germinating seed, roots, stems of young plants, or bulbs). The small, legless, white maggots feed within these structures, eventually destroying the structures and possibly the plant. Aboveground symptoms may appear as individual plants that are chlorotic, stunted, drought-ridden, or dead. Extensive feeding and tunneling by maggots is evident in infested plant structures.

Maggots pupate in the soil and adults emerge within one week. Several generations can occur in New Mexico. Decaying organic matter found in short rotational fields (onions following lettuce or cabbage) may attract adult flies to that field. Insecticide applications should be directed at the leaf axis to kill hatching eggs and at the soil surrounding the plant to help suppress emerging adults. Timing of insecticide applications is critical. Once maggots have entered the plant tissue, they become very difficult to control.

Thrips Species

By far, the most common and damaging insect found in New Mexico onions is thrips. Two species of thrips, western flower thrips and onion thrips, are the most common species within the complex. Thrips are present throughout the year, with adults surviving the winter on weeds, on overwintering crops (including alfalfa and onions), and on ornamental trees and shrubs. Typically, early spring onions are infested primarily with western flower thrips. As temperatures increase, onion thrips begin migrating into the fields and may dominate the complex toward the end of the year.

Adult thrips insert eggs into the plant tissue. The nymphs move to their primary feeding location within the confined leaf area of the neck. Nymphs are yellow and, although they are visible without magnification, it is difficult to distinguish individual characteristics. Adults are winged, dark colored, and can be found feeding on the leaves within the neck or on the outer portions of the plant. The length of the life cycle depends on temperature, but during the summer it is approximately two weeks or less. Each thrips may lay up to 300 eggs. The large number of eggs coupled with a short life cycle contribute to rapid build-up of populations.

Feeding damage is indistinguishable between the two thrips species. The nymphs and adults puncture the epidermal layer of the leaves, then suck up the ruptured cellular contents. The ruptured epidermal layers result in death of the tissue and loss of photosynthetic area. As leaves increase in size, damaged tissue takes on a silver appearance. In cases of severe infestation, damaged leaves may die, significantly reducing bulb size and yield. Regional research has demonstrated that bulbing onions are particularly sensitive to thrips feeding, losing up to 20 percent of the yield. Onions normally are capable of recovering from thrips damage before bulbing; feeding damage during sizing usually results in early neck collapse.

Several factors inherent in thrips biology contribute to potential insecticide resistance problems. Thrips have a high biotic potential, so as the number of individuals increases, the chance of expressing a resistant mechanism in the population increases. Another factor is that thrips reproduction is primarily thelotoky (asexual reproduction, females producing females). Therefore, identical copies of insecticide-resistant clones are quickly produced in the population.

To minimize resistance problems, changes in insecticide classes should be incorporated in the spray regime. Insecticides applied to actively growing or to heavy populations may require more frequent applications to suppress thrips. After an insecticide application, thrips eggs continue to hatch, with larvae moving to areas of new, untreated growth. Because of the heavy wax layer on onion leaves, all insecticide applications should include a wetting agent.

Natural rainfall is one of the best control factors. In years when frequent rains occur, thrips control is relatively good, but in dry years, available control measures are less effective. However, the degree of control that can be achieved by insecticides is beneficial to crop yields.

Foliage characteristics affect the extent of thrips damage. Onion varieties with glossy (nonglaucous) foliage seem to have less thrips damage than the waxy, blue (glaucous) foliage types. We have been able to control thrips on the fall-planted glaucous foliage types like Buffalo, but for spring planting, we suggest you use varieties that have dark-green, nonglaucous foliage. In fact, most varieties that produce well in New Mexico are the nonglaucous types, probably because they are less attractive to thrips.

DISEASES

Soil-borne diseases in New Mexico include pink root, fusarium basal rot, and soil line botrytis. Pink root is partially controlled by use of resistant varieties. Fusarium basal rot can be controlled to some extent by crop rotation, growing onions on the same land no more often than once in five years. Soil line botrytis occurs only in short-day onions maturing in late May and June. It occurs in years in which spring (March 15 to May 1) temperatures are relatively cool. Under these conditions the cool, wet soils are favorable for disease development. Some control of soil line botrytis is achieved by avoiding excessively wet fields.

The foliage diseases caused by fungi (botrytis leaf spot and purple blotch) are not usually a problem in New Mexico because of our low humidity and hot summer weather. However, bacterial foliage and bulb diseases are a major concern, especially during periods of recurrent rainfall. For recommendations for disease prevention and control, read NMSU Extension Circular 538, *Onion Diseases in New Mexico*, which is available online (7) or by calling Agricultural Communications at (505) 646-3228.)

HARVEST AND HANDLING

When onions are fall seeded, they develop an extensive root system and must be undercut prior to harvest. Spring-seeded and transplanted onions tend to be poorly anchored, so they usually can be pulled without undercutting. Undercutting onions cuts the roots and interrupts the flow of water to the bulb and tops. If the tops are still green, they continue to lose water. The effect is bulb dehydration. As bulbs dehydrate, they shrink, tending to shrink away from the dry outer scales. The result is that bulbs have very little scale attached. The solution is to run the undercutter immediately in front of the harvest crew. Undercutting several hours or a day before harvest often results in greater loss of scale, but it is most severe in onions that are harvested at less than 80 to 100 percent tops down. As the bulbs become completely mature and the tops begin to die, undercutting has less effect on bulb dehydration.

Nearly all onions in southern New Mexico are harvested by hand. Workers trim the roots, cut the tops, and transfer the bulbs into hemp or burlap sacks to cure outdoors. Curing involves drying of the neck tissues where the top was cut and some drying of the outer scales. After three to five days of curing, bulbs are loaded on special dump trucks and hauled to a grading shed. Unmarketable bulbs are discarded, and the marketable ones are sized and usually packed into 50-pound open mesh bags for shipment. Some growers now pack in boxes to avoid some of the bulb injuries that are prevalent with sacks. The sweet onions are commonly packed in boxes. Red onions are usually packed in 25-pound bags.

Size classifications for onions range from small to colossal (table 2). Onions are graded according to USDA standards (United States Standards for Grades of Bermuda-Granex-Grano Type Onions, USDA-AMS, Wash. D.C., Oct. 1995). A U.S. #1 grade is uniform for varietal characteristics, mature, fairly firm, and well-shaped. U.S. #1 onions are free of splits, seedstems, dry sunken areas, sunburn, sprouting, staining, dirt or foreign material, mechanical damage, roots, tops, translucent or watery scales, moisture, disease, and insects. Not more than 10 percent of the onions in a lot may fail to meet the requirements for the grade. However, for decay or wet sunscald, the tolerance level is 2 percent. For size, not more than 5 percent of the onions in a lot may be smaller than the minimum diameter specified, and not more than 10 percent may be larger than the maximum diameter specified (table 2).

Some growers grade in the field. After the onions are cured, they are loaded onto a field grader and culled, sized, and packaged for shipment—all with field equipment. There also is extensive interest in machine harvest. Several machines have been developed and tested for machine harvest, but as yet, none have been entirely satisfactory. Eventually, the New Mexico onion crop will likely be harvested by machine. This switch to mechanized harvest will dictate varieties that are harder and tougher, and that have more layers of dry outer scales than many that are now grown.

In the very warm and sometimes moist climate of southern New Mexico, bulb onions are highly perishable. As bulbs mature, they seem to become more susceptible to several bulb disorders such as black mold (*Aspergillis*) or to various bacterial infections. These infections can occur in the field before harvest, during the harvesting and grading operations, and after grading during common storage before shipment. At high temperature and humidity, open wounds become ports of entry for pathogenic fungi and bacteria. Infections that occur before shipment often lead to further breakdown in transit. These bulb disorders and other defects can be minimized by the following:

1. Avoid harvest delays. Ideal harvest time is when about 80 percent of the bulbs are mature as evidenced by collapse of the neck tissues and falling of the top. Plan your harvest schedule before planting so that maturity of a particular field will correspond to your harvest schedule. If your shipper (or your own grading operation) can handle only a certain volume of onions per week, then find combinations of varieties and planting or transplanting dates to provide that volume each week of the harvesting season. Shippers and brokers can help by coordinating between growers to provide an orderly supply of product for their own operation.
2. Avoid excessive field moisture at harvest time. Timing of the last irrigation will vary depending on soil texture and drainage, and weather conditions. With sandy soils and high temperatures, the interval between the last irrigation and harvest could be from five to eight days, while on finer textured soils that interval should be longer. However, delaying harvest too long after the last irrigation can result in deterioration of the tops, exposure of bulbs to the sun, and significant heat damage. Rainfall occurring during the harvesting season causes serious disruption of harvesting schedules.
3. Minimize the amount of bulb damage in harvesting and grading. Evaluate the potential for damage in each step of the harvest and grading operations and design equipment and systems to reduce the damage to a minimum. Teach your employees about the need to handle onions as gently as possible.
4. Cure the bulbs in field sacks only long enough for the necks to dry. This may be only two to three days for bulbs harvested at full maturity in dry weather, up to four to five days for less mature bulbs or in humid weather. Too much time in field bags leads to disorders that can cause serious losses.
5. Rotate fields so that onions are grown in a field only once in five years. Most growers are aware of the need to rotate to minimize the build-up of soil-borne diseases like pink root or fusarium basal rot. Rotation also helps control other bulb disorders that cause losses in handling.

6. For fall-planted onions, select bolting-resistant varieties that can be planted early. Provide nutrients and water to get as much fall, winter, and early spring growth as possible, and terminate nitrogen applications about six weeks before harvest. The result is early maturity and maximum firmness. Fall-planted fields that are stunted during the winter by lack of water and nitrogen may be induced to provide high yields by very heavy spring and summer nitrogen application, but they mature later in warmer weather and their bulbs tend to be soft and retain less of the outer scales.
7. Select fields that have relatively coarse textured (sandy) soils. The finer the soil texture, the more potential for harvest delays and other problems associated with rainy weather. You could select your coarsest textured soils for the spring-planted crop that matures in July or August when rainfall is most prevalent.
8. To the extent possible, select varieties that tend to retain their dry outer scales. These scales help to protect the bulbs from injuries that lead to infection.
9. When market conditions dictate harvest delays, be prepared to abandon fields that cannot be harvested, graded, and sold in a timely manner.

ADDITIONAL RESOURCES

1. Typical crop budgets for onions: weather.nmsu.edu/nmcrops/onions/budget-fall-onions.htm
2. Descriptions of onion varieties released by NMSU's Agricultural Experiment Station: onion.nmsu.edu
3. Excel spreadsheet for evaluating the economics of converting to drip irrigation: weather.nmsu.edu/teaching_material/tutorials.html
4. NMSU's Climate Center Bulletin Board for estimates of potential evapotranspiration (PET): weather.nmsu.edu
5. Spread sheet for calculating irrigation intervals for onion: weather.nmsu.edu/nmcrops/onions/onions_irrigation.htm
6. General discussion of vegetable crop irrigation: www.ces.ncsu.edu/disaster/drought/dro-13.html
7. *Onion Diseases in New Mexico*, NMSU Extension Circular 538 cahe.nmsu.edu/pubs/-circulars/circ538.html

Table 2. Size classifications for fresh-market onions.

Class	Minimum diameter (inches)	Maximum diameter (inches)
Small	1	2.25
Prepacker	1.75	3
Medium	2	3.25
Large or jumbo	3	none
Colossal	3.75	none

Source: United States standards for grades of Bermuda-Granex-Grano type onions, USDA-AMS.

February 2000 **Las Cruces, NM**
5C