Growing Alliums for Storage & Long Term Sales Resource Booklet

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Cornell Cooperative Extension
Eastern NY Commercial Horticulture Program

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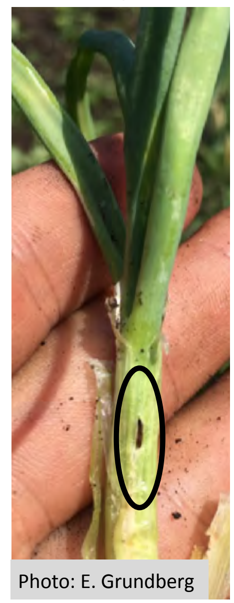

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ALLIUM LEAFMINER LOOKALIKE DAMAGE

Serpentine and/or vegetable leafminer mining

Onion thrips

Herbicide injury

Botrytis leaf blight

Allium leafminer mining

All photos by Ethan Grundberg

Fig. 1 Adult leek moth - ½" long

Leek Moth

(*Acrolepiopsis assectella*)

Host Plants and History

Leek moth is a serious pest of members of the *Allium* family which includes onions, garlic, leeks, chives and shallots. There are about 600 cultivated and wild species of Allium in the United States as potential hosts.

The first confirmed sighting of leek moth in the continental United States was in Plattsburgh, NY during the summer of 2009. It is native to Europe and is now found in Russia, Japan, Algeria and in Ontario and Quebec, Canada. It was first found in Ontario in 1993.

Fig. 2 Larva (caterpillar) on garlic leaf

In 2010 leek moth was found in the same sites as well as additional sites north of Plattsburgh but none to the south. It was confirmed for the first time in the Canton/Ogdensburg area of NY in 2010. There is speculation from growers there that it may have occurred in years prior, but was not confirmed.

In 2011 the same sites were infested again as well as a few new sites. It seems to be spreading slowly at this point.

Fig. 3 Pupa (cocoon)

Description

The adult moth (*figure 1*) is speckled brown, white and black with a distinctive white spot halfway down its outer pair of wings. It is about ½ " long and is nocturnal so it will be rarely seen unless trapped.

The larva (*figure 2*) is a creamy yellow, slender caterpillar, less than a half inch long when fully grown. The pupa (*figure 3*) has a net-like structure over the cocoon and is attached to dying foliage or other nearby structures. The eggs are tiny and translucent. They are laid on the undersides of leaves and are very difficult to see.

Damage

The leek moth larva is a small, leaf-mining caterpillar. The first generation (May-June) feeds on the leaves. The worst damage is done by the second generation (July-August) as it continues to damage emerging leaves (*figure 4*) and moves towards the bulb. Feeding damage stunts plant growth, introduces rot and can compromise the storage life of onions and garlic.

Fig. 4 Characteristic damage to leeks – L. Chilson

Where to Look for Damage

On crops with hollow leaves (onions and chives), the larvae feed on the inside tissue, leaving characteristic 'windowpane' damage to the leaves (*figure 5*). Split open damaged leaves and look for frass (excrement) and debris (*figure 6*). Even after the larvae have left to pupate, the telltale debris remains visible.

On garlic and leeks, larvae feed on the leaf surfaces and sometimes tunnel through the leaves. They are often found in the protection of the folded leaves on leeks and garlic. In June in hardneck garlic, damage will be the most noticeable on the garlic scapes (*figures 7,8*). On both crops check the newest leaves as well.

Fig. 5 'Windowpane' damage on onion

Fig. 6 Onion leaf split open

Fig. 7 Scape on a hardneck

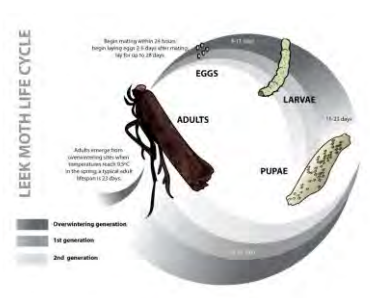
Fig. 8 Damage to garlic scape and leaf

Life Cycle

There are two to three generations a year in Ontario. It overwinters as an adult in plant debris. The female lays about 100 eggs, singly, at the base of the host plant. Eggs hatch in about a week. Larvae (caterpillars) grow in size over the next two weeks then pupate on dead leaves or nearby structures. Adults emerge about 10 days later.

Control

As of 2017 there are no pesticides specifically labeled for use on leek moth in New York, but there is a 2(ee) permit . Efficacy trials are underway in the lab; more field testing is needed. Existing populations in Europe are being studied to find naturally occurring bio-control options. For more information on current pesticides and control options visit: http://web.entomology.cornell.edu/shelton/leek-moth/control.html



Cultural control methods include:

- Using row cover immediately after planting as a barrier to prevent adults from laying eggs on desirable host crop (moths are nocturnal so cover can be removed during the day for weeding)
- Crushing any larvae or pupae found
- Rotating crops, planting in a different location each year
- Raking up and removing host plant debris at the end of the season where adults overwinter

Look-alike Pests
There are a few other pests that damage onions and leeks that may be confused with leek moth:

Thrips, a tiny insect ~1/8" long, are a

Salt marsh caterpillars are

Botrytis leaf blight causes

If you suspect leek moth damage on your onions, garlic, leeks or chives please contact your local Cornell Cooperative Extension office.
http://www.cce.cornell.edu/learnAbout/Pages/Local_Offices.aspx

For more information and resources concerning leek moth visit the Information Center for the U.S. at:
http://web.entomology.cornell.edu/shelton/leek-moth/

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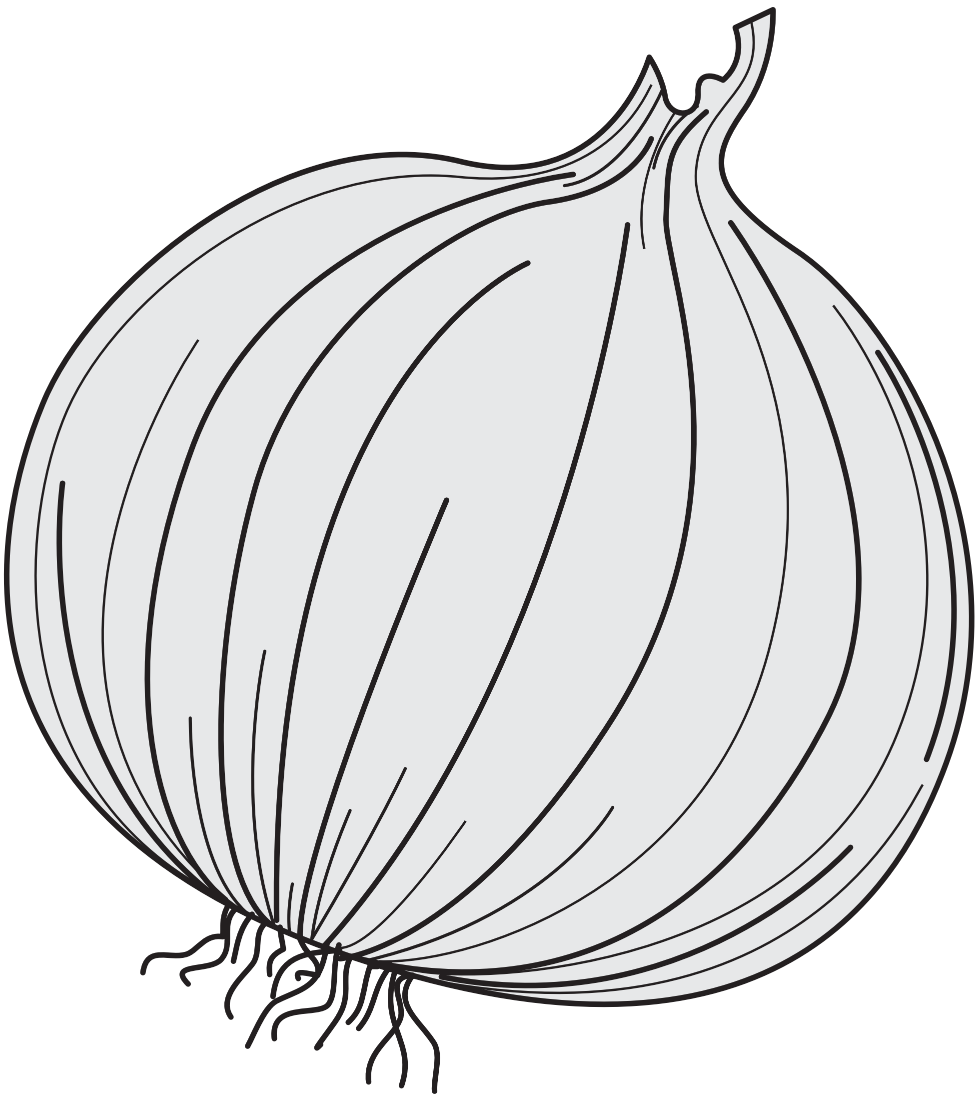
Nutrient Management for Onions in the Pacific Northwest



A Pacific Northwest Extension Publication
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What's inside?

This nutrient management guide is designed to assist onion growers and crop advisors in producing a high-quality crop while protecting the environment from excess nutrients. Nutrient management strategies recommended here are based on data accumulated over many growing seasons with many different onion varieties in Idaho, Washington, and Oregon.

This publication provides current information on:

- How onions grow and how their growth pattern affects nutrient needs
- Timing and amount of crop nutrient uptake
- Keys to managing nitrogen efficiently
- Ways to monitor crop N status during the growing season
- How to assess the need for P, K, S, and micronutrient fertilization
- Fertilizer sources and application methods
- How to assess the need for lime on sandy soils in the Columbia Basin

Key points

Crop nutrient uptake

- The amount of nutrient uptake by an onion crop is very small from germination to bulb initiation.
- The period of rapid nutrient uptake starts at bulb initiation and continues through bulb growth.
- About 80 percent of the nutrients taken up by the crop are removed in the bulbs.

Nitrogen

Use these management strategies to efficiently utilize N:

- Credit N from nonfertilizer sources in determining N fertilizer application rates.
- Apply most or all of the N fertilizer as side-dress applications or through sprinkler or drip irrigation.
- When economically feasible, use improved irrigation practices to minimize deep percolation losses.
- Use plant tissue tests to assess the need for supplemental fertilization.
- Grow deeper rooted crops after onions to recover nitrate-N leached beyond the root zone.

Phosphorus

Take the following soil and crop management factors into consideration when determining P fertilizer application methods and rates:

- Soil test value (ppm)
- Soil free lime (calcium carbonate) concentration
- Fumigation. Soil fumigation prior to seeding onions might increase P fertilizer requirements. Fumigation kills the mycorrhizal fungi that help onion roots take up P from soil.

Acid soils in the Columbia Basin

- Soil acidity (pH less than 5.5) can reduce yield. On sandy soils, soil pH can fluctuate by 1 to 2 pH units during the year, depending on fertilizer and crop management practices.
- Soil acidity can be corrected by applying and incorporating lime before planting.
- Fertilization practices can have a dramatic effect on soil pH on sandy soils.
- Do not apply N and K fertilizers preplant on sandy soils subject to soil acidity problems.
- Reduce or eliminate application of acid-forming fertilizers such as mono-ammonium phosphate (e.g., 11-52-0), urea-sulfuric acid, and ammonium sulfate.

Contents

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Nutrient Management for Onions in the Pacific Northwest

D.M. Sullivan, B.D. Brown, C.C. Shock, D.A. Horneck, R.G. Stevens, G.Q. Pelter, and E.B.G. Feibert

Onions are a high-value crop. Both high yield and quality are important economic considerations. Components of bulb quality include size, appearance, percentage of single-centered bulbs, and susceptibility to sprouting and decay in storage. Nutrient supply interacts with other management, pest, and climatic factors to affect quality and yield.

This nutrient management guide is designed to assist onion growers and crop advisors in producing a high-quality crop while protecting the environment from excess nutrients. Excess nitrate-nitrogen can leach below the root zone and contaminate groundwater, while excess phosphorus can be carried into lakes and streams by surface water runoff.

Nutrient management strategies recommended here are based on data accumulated over many growing seasons with many different onion varieties in Idaho, Washington, and Oregon. The field research database supporting this onion nutrient management guide probably is more extensive than for any other vegetable crop grown in the Northwest, with the exception of potatoes.

This guide focuses primarily on onion production in the Treasure Valley and the Columbia Basin. The Treasure Valley onion production area is within a 50-mile radius of Ontario, Oregon on the Snake River plain and along the tributaries of the Snake River. The Columbia Basin production area in central Washington and north central Oregon includes approximately 750,000 acres irrigated by water from the Columbia and Snake Rivers.

Growth and development

Understanding how the onion plant grows and develops is a key part of developing a strategy to supply nutrients for optimum bulb yield and quality.

An onion bulb is different from a root (such as a sugar beet) or a stem (such as a potato). Each onion “ring” is called a bulb scale in botanical terminology and is comprised of the base of a leaf. We describe onion growth and development during the following growth phases (Table 1):

- Germination
- Leaf growth
- Bulbing, or bulb initiation
- Bulb growth
- Maturation

Table 1.—Growth stages for seeded onions in the Pacific Northwest.

Growth phase	Numerical growth stage	Approximate days after planting	Approximate calendar date (April 1 planting)	Description
Germination	1	7 to 30	Apr 20	Radicle and flag leaf emergence
Leaf growth	2	30 to 50	May 10	1 to 2 true leaves
	3	50 to 70	May 30	3 to 4 true leaves
Bulbing or Bulb initiation	4	70 to 90	June 20	5 to 7 true leaves; bulb diameter is twice that of the neck
Bulb growth	5	90 to 110	July 10	8 to 12 true leaves; bulb diameter 1 to 1.5 inches
	6	110 to 130	July 30	Bulb diameter 1.5 to 3 inches
	7	130 to 150	Aug 20	Bulb diameter greater than 3 inches
Maturation	8	150+	Aug 30	Bulb enlargement near completion; more than 50 percent tops down
	9			Field curing period

Adapted from Schwartz and Mohan (1995).

Germination

Onion seeds can germinate at low soil temperatures. Soil temperatures above 34 to 37°F stimulate seed germination. Seed germination is most rapid and uniform at soil temperatures above 52°F.

Leaf growth

Onions have an unusually long period of slow growth to the 3-leaf stage. Their early vegetative growth rate is about half that of other cool-season crops such as lettuce and beets. The period of slow growth lasts about 50 to 70 days after planting under typical weather conditions. Onions planted in late March or early April typically reach the 3-leaf growth stage by late May or early June. During this early leaf growth phase, nutrient needs are very low.

Other cultural factors such as herbicide damage or soil acidity can further reduce early vegetative growth. Slow early growth caused by weather conditions sometimes is incorrectly attributed to nutrient deficiencies.

Rapid leaf growth begins when the onion plant has three leaves. Each emerging leaf is larger than the previous leaf. Leaf growth rate increases with temperature. Leaf growth requires an air temperature of at least 40°F and reaches a maximum at about 80°F.

Onion root growth occurs at a regular pace during leaf growth. New roots are produced from the bulb basal plate as leaves develop above ground. The shallow, sparsely branched root system of the onion plant has important implications for nutrient management. See "Root growth and development" (at left) for more details.

Root growth and development

Onions have a shallow, sparsely branched root system with most roots in the top foot of soil. Rooting density decreases with soil depth. The sparse, shallow rooting of onions has important implications for management of relatively immobile nutrients (P, K, and some micronutrients such as Zn). The unbranched root system of onions is less effective than most crop plants in extracting immobile nutrients. Therefore, onions are more susceptible than most crops to deficiencies of these nutrients.

The shallow root system of onions also is an important consideration for efficient management of mobile nutrients such as nitrate-N and sulfate-S. Mobile nutrients can be lost from the root zone by over-irrigation. With furrow irrigation, mobile nutrients move to bed centers, where they typically become available later in the season when onion roots proliferate across the beds.

Onions are highly dependent on arbuscular mycorrhizal fungi for uptake of phosphorus from soils with low to medium soil test P concentrations. Mycorrhizal fungi produce a network of threadlike hyphae that extend from the onion roots into the soil, greatly increasing the absorptive surface area of the roots. Mycorrhizal fungi also can increase the uptake of zinc and other micronutrients in some high-pH calcareous soils.

Mycorrhizal fungi usually are abundant in agricultural soils, except when nonhost crops are grown, soil is fumigated, or high soil test P is present. Crops that do not host mycorrhizal fungi include sugar beets and mustards (e.g., canola).

Nematode feeding and root diseases can cause weak, poorly developed root systems.

Bulbing

The bulbing growth stage is considered to begin when bulb diameter reaches twice that of the neck. Most onion varieties initiate bulbs after six to eight leaves have been produced. Bulbing begins in response to increasing day length. Major onion types differ in the minimum day length needed to initiate bulbing. The minimum day length needed for bulbing is much shorter for early, overwintering onions, such as Walla Walla, than for spring-seeded onion varieties.

Temperature and light spectral quality also affect the onset of bulbing, but these effects are minor compared to day length. Once day length initiates bulbing, the higher the temperature, the earlier bulbing will occur. Densely planted onions have more shaded leaves and begin bulbing earlier because of altered light spectral quality. Shading initiates bulbing by providing more far red light and less red light to onion leaves.

Leaves continue to emerge during bulbing and bulb growth. Most onion varieties grown in the Pacific Northwest produce 12 to 14 true leaves.

Bulb growth

The onion plant has the highest demand for water and nutrients during bulb growth. Onion dry matter accumulation rates during bulb growth are comparable to those of a rapidly growing forage crop. Dry matter accumulates at a rate of 100 to 200 lb per acre per day (1,000 to 2,000 lb fresh weight per acre per day) during the peak growth period (Figure 1a).

Maturation

The timing of onion harvest depends on market opportunities, weather, and the planned storage period. As bulb growth slows, the onion neck becomes soft and the plant falls over. Maturation commonly is evaluated by the percentage of tops down and by the amount of dry leaves present.

Achieving a proper degree of maturation before harvest is a key factor in producing high-quality onions for storage. Growers sometimes suspect high levels of nutrients, particularly nitrogen, as the cause of poor maturation in the field and decay in storage. Usually, however, these problems result from a combination of environmental and crop management factors.

Environmental factors that can delay maturation and increase storage loss include hail damage to plants, a cooler than normal growing season, or wet weather for field curing of bulbs. Management factors such as sparse, uneven plant populations, a late planting date, water stress, or nutrient deficiencies also can slow development and maturation.

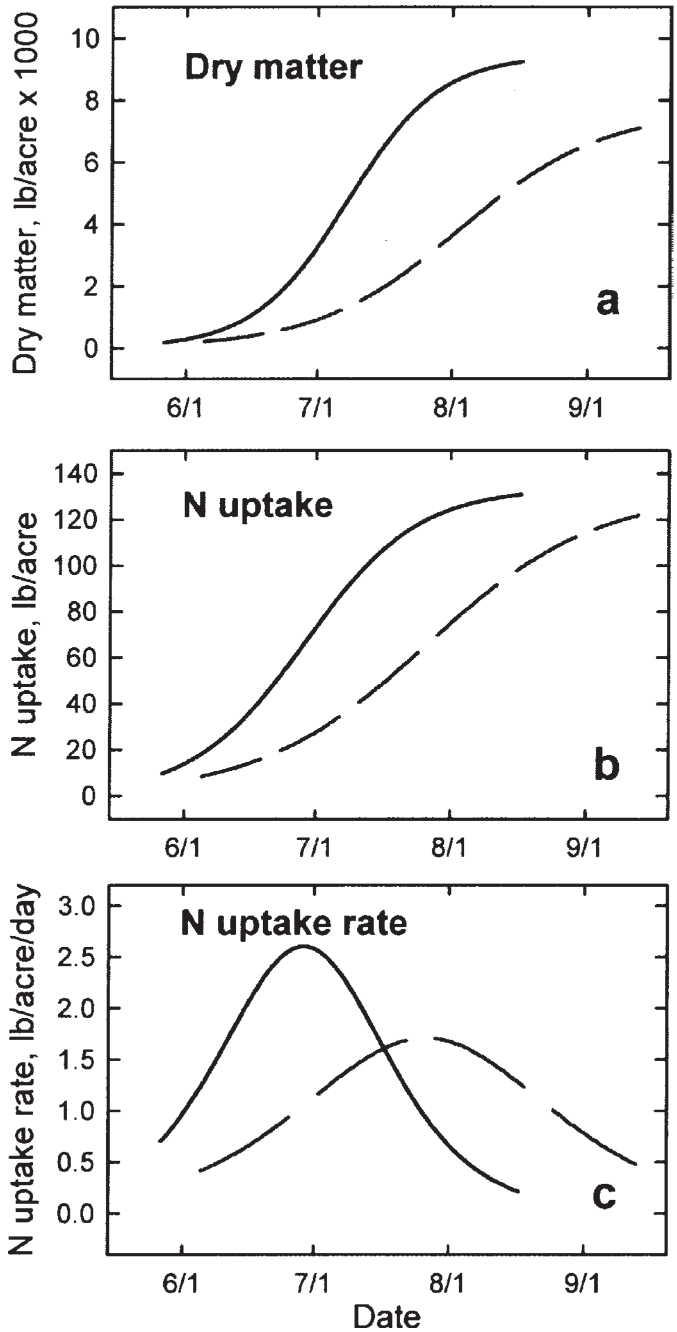


__Figure 1.__—Onion (bulb + leaves) dry matter (a), nitrogen uptake (b), and N uptake rate (c) for yellow onions at a field location in the Columbia Basin near Connell, WA (solid line) and at five field locations in the Treasure Valley near Parma, ID (dashed line). Columbia Basin data is for the 1998 season; it is averaged across two varieties, 'Prince' and 'Vision.' Average bulb yield (fresh wt. basis) for the two varieties was 840 cwt per acre (42 tons per acre) at the Columbia Basin site and 630 cwt per acre (32 tons per acre) at the Treasure Valley sites. Sources: Don Horneck, Oregon State University Extension Service, Umatilla County; Gary Pelter, Washington State University Cooperative Extension; Brad Brown, University of Idaho Parma Research and Extension Center.

Market classes for harvested onions

Premium prices are paid for large onions. After harvest, onions are sorted and marketed in the following size classes:

- Super colossal (Onion count must be 28 to 36 per 50-lb bag; diameter greater than 4¼ in)
- Colossal (> 4 in)
- Jumbo (3 to 4 in)
- Medium (2¼ to 3 in)

Markets for small onions (1 to 2¼ in) are limited.

Nitrogen

Crop N uptake

Nitrogen concentrations in bulbs of red, yellow, and white onion varieties are similar. Crop N removal (tops + bulbs) averaged about 140 lb N per acre in Columbia Basin trials (Figures 2 and 3). Crop N uptake typically ranges from 0.14 to 0.24 lb N per cwt fresh bulb yield. At harvest, about 15 to 40 lb N is present in tops, with the remainder present in bulbs (Figure 2). Crop N uptake rates during bulb growth range from 1 to 3 lb per acre per day (Figure 1c, page 5).

Strategy for N management

These management strategies help increase the efficiency of N utilization:

- Credit N from nonfertilizer sources (N in preplant soil test and irrigation water and N mineralized during the growing season) when determining N fertilizer application rates.
- Minimize preplant N fertilizer application.
- Apply most or all of the N fertilizer as side-dress applications or through sprinkler or drip irrigation.
- When economically feasible, use improved irrigation practices to minimize deep percolation losses.
- Use plant tissue tests to assess the need for supplemental fertilization.
- Grow deeper rooted crops after onions to recover N leached beyond the 2-foot depth.

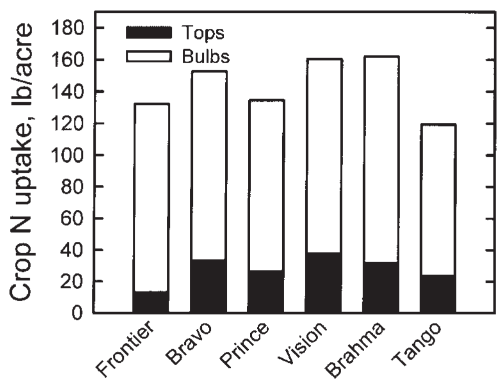


Figure 2.*—Nitrogen uptake for six onion varieties grown at a field location in the Columbia Basin near Connell, WA. Variety descriptions: 'Frontier' is an early Japanese globe, 'Bravo' is a late U.S. Sweet Spanish, 'Prince' is a mid-late Dutch globe, 'Brahma' is a mid-late U.S. globe, and 'Tango' is a mid-late red globe onion variety. Fresh weight bulb yields ranged from 700 to 1,100 cwt per acre, with bulb dry matter of 10 to 12 percent. Sources: Don Horneck, Oregon State University Extension Service, Umatilla County; Gary Pelter, Washington State University Cooperative Extension. 1997 growing season.*

Crop N uptake vs. available N supply

Nitrogen supplied to an onion crop comes from several sources. The available N supply is made up of:

- Preplant soil nitrate N and ammonium N
- N mineralized from crop residues and soil organic matter
- N supplied in irrigation water
- Fertilizer N

Fertilizer N should provide only a portion of the available N needed to grow the crop. We recommend a regular program of soil and irrigation water testing to determine how much available N is supplied by the soil and irrigation water. In some environments, high yields can be grown with small fertilizer N inputs because of the supply of available N in soil and irrigation water.

Estimates of crop N uptake can be used to estimate the available N supply needed for crop production. With good irrigation management, an onion crop can recover 40 to 60 percent of the available nitrogen from all sources.

The 700 to 1,100 cwt-per-acre bulb yields shown in Figure 2 were produced with an available N supply (including nitrate + ammonium-N in the soil before seeding, estimated soil N mineralization, and N added in irrigation water and fertilizer) of approximately 250 to 300 lb N per acre.

Crediting available N from nonfertilizer sources

Site-specific N management requires soil and water testing to estimate the amount of N from nonfertilizer sources.

Preplant soil nitrate-N

Preplant soil nitrate-N testing is a reliable tool for adjusting N fertilizer rates to site-specific needs. Spring sampling is more accurate than fall sampling because it accounts for nitrate

Crop nutrient uptake

One of the goals of nutrient management is to supply nutrients in a timely manner to maximize crop yield and quality. Crop nutrient uptake is calculated from measurements of crop biomass (dry matter) multiplied by crop nutrient concentration. You can use this number to estimate the total supply of available nutrient needed to grow the crop under good management.

Cumulative nutrient uptake by an onion crop follows a sigmoid or s-shaped curve during the growing season. The period of rapid nutrient uptake starts during bulbing (growth stage 4 in Table 1, page 3). Onions take up more than 100 lb per acre of nitrogen, potassium, and calcium, with substantially lower amounts of sulfur, phosphorus, and magnesium (Figure 3). About 80 percent of the nutrients present in the plant at harvest are present in the bulb; the remainder is present in tops.

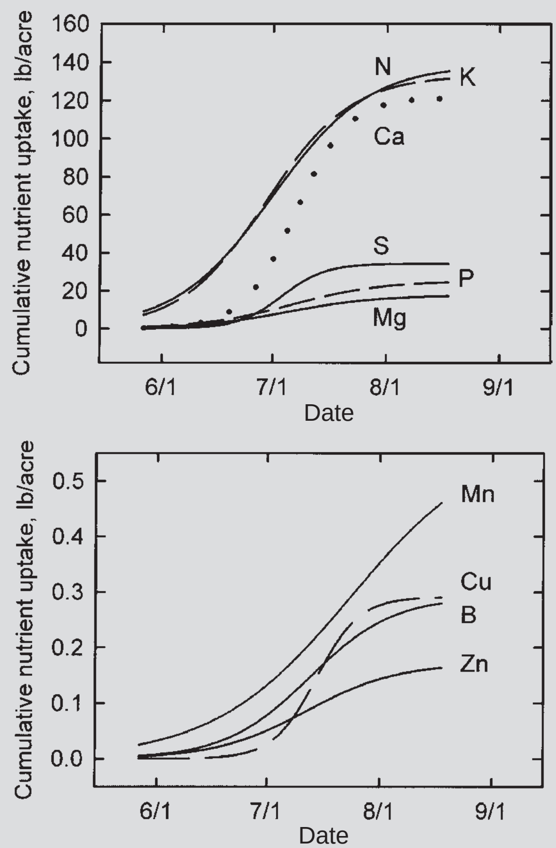


Figure 3.*—Cumulative nutrient uptake by onions (bulb + leaves) for yellow onions grown near Connell, WA. Onion tissue was harvested at 13 dates during the growing season. Data is averaged across two varieties, 'Prince' and 'Vision.' Bulb yield (fresh wt. basis) was 840 cwt per acre (42 tons per acre) under furrow irrigation. Onions were seeded March 29 and harvested September 10. The final sample was collected about 7 days before undercutting. Sources: Don Horneck, Oregon State University Extension Service, Umatilla County; Gary Pelter, Washington State University Cooperative Extension. 1998 growing season.*

Crop N uptake vs. N supplied by nonfertilizer sources

An example of how an onion crop can use nonfertilizer sources of N is shown in Table 2. In the example, available nitrogen supply was estimated for nonfertilizer sources; no fertilizer N was applied. Crop nitrogen uptake efficiency, calculated as a percentage of the available N supply, was 59 percent. This means that for each unit of available N supplied, crop N uptake increased by 0.59 units of N.

Table 2.—Example: Crop N uptake by high-yielding onions vs. available N supply from nonfertilizer sources.[a] Estimated crop N uptake efficiency = 59 percent.

Crop N uptake or available N supply	Line	Component of N budget	Nitrogen (lb/acre)
Crop N uptake	1	Tops plus bulbs[b]	160
Available N supply	2	Preplant soil nitrate + ammonium N (0 to 24 in)	76
	3	Irrigation water N (supplied via drip irrigation)	79
	4	Estimated soil N mineralization (mineralizable N soil test; 0 to 24 in)[c]	116
	5	Fertilizer N	0
	6	Total estimated available N supply (line 2 + line 3 + line 4 + line 5)	271
Crop N uptake efficiency	7	Estimated crop N uptake efficiency (line 1 ÷ line 6) x 100	59% of available N supply

[a]Yellow onions (cv. 'Vision') produced under drip irrigation at Oregon State University Malheur Experiment Station during 1995 growing season. Total bulb yield was 884 cwt per acre, with 71 percent of total yield in jumbo + colossal market grades (> 3 in diameter). In this trial, addition of N fertilizer (data not shown) did not increase bulb yield (as evaluated out of storage in December) or N uptake.

[b]Crop N uptake (tops + bulbs) determined from harvest of bulbs on September 2 prior to crop maturation.

[c]Mineralizable soil N estimated via anaerobic incubation for 7 days at 104°F (40°C).

Source: Feibert, E.B., C.C. Shock, and L.D. Saunders. 1997. Nitrogen management of precision irrigated onions. pp. 60–67. In: Proc. Western Nutrient Management Conference. Salt Lake City, UT.

movement over the winter and changes in nitrate-N that accompany decomposition of crop residues.

Collect samples from onion beds in the spring before the first irrigation. Sampling before the first irrigation is recommended because nitrate movement with irrigation water leads to more variable test results. Sample at two depths: 0 to 12 and 12 to 24 inches. Onion root systems typically reach below 12 inches during bulb growth.

The preplant soil nitrate test is strongly correlated with crop yield response to N fertilizer in the Treasure Valley (see below).

Using the preplant nitrate soil test in the Treasure Valley

Interpretation of the preplant nitrate-N test for onions in the Treasure Valley is based on extensive research. Eighteen field trials were conducted in grower fields from 1991 to 1996. Data from nine on-station trials at Parma (1978 to 1985) is also included in the database.

The objective of the research was to relate preplant soil nitrate-N values to crop yield response. Preplant soil nitrate in onion beds was measured prior to the first irrigation. N fertilizer rates ranging from 0 to 320 lb N per acre were side-dressed at bulb initiation in June or applied preplant. Growers used normal cultural and irrigation practices.

Onions were harvested and graded into market classes. The yield of large onions (jumbo plus colossal; onions > 3 in diameter) was compared among N rates at a field location. "Relative jumbo yield" was calculated for each N rate within a location as:

Relative jumbo yield (%) = A ÷ B x 100, where:

A = onion yield (> 3 in diameter) for a given N fertilizer rate

B = maximum onion yield (> 3 in diameter) for the field site in the year of the test

Relative jumbo yield did not increase in response to applied N fertilizer when preplant soil test N was above 80 lb N per acre for the 0- to 12-in depth or above 100 lb per acre for the 0- to 24-in depth (Figure 4a). Maximum onion yields occurred at much lower preplant soil test levels at many sites, particularly when large amounts of N were mineralized from crop residues and soil organic matter.

Onions required a total of 40 to 160 lb N per acre (preplant soil nitrate-N [0- to 24-in depth] plus side-dress fertilizer N) for maximum jumbo yields (Figure 4b). Onions did not require more than 160 lb N per acre for maximum yield at any site. Onion yield and size were reduced at some locations with more than 160 lb N per acre (preplant nitrate-N plus fertilizer N).

Preplant analyses for soil ammonium-N did not improve prediction of fertilizer N needs.

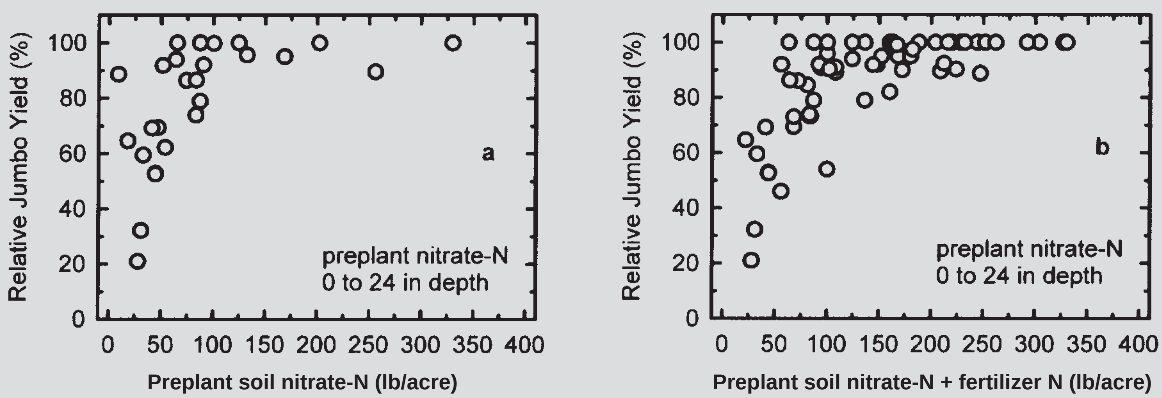


Figure 4.*—Nitrogen supply from preplant soil nitrate-N (a) and preplant N + fertilizer N (b) vs. relative jumbo yield for Treasure Valley field locations near Parma, ID. A relative jumbo yield of 90 percent or above indicates that yields at that N rate were equal to maximum yield. Source: Brad Brown, University of Idaho Parma Research and Extension Center.*

Estimating available N from mineralization

Mineralization process

Onions cannot utilize the organic nitrogen present in soil organic matter and crop residues until microbial activity releases available nitrogen (ammonium and nitrate forms). Onions take up both the ammonium and nitrate forms of nitrogen.

Crop residues decompose much more rapidly than soil organic matter. Crop residues decompose within weeks under favorable soil temperature and moisture conditions, while only a fraction (2 to 5 percent) of stable soil organic matter decomposes during a growing season. Most of the N mineralized accumulates as nitrate if it is not leached or taken up by the crop.

Estimating N mineralization

Estimates or credits for N mineralization that are used in estimating fertilizer N needs (line 8 in Table 3) include N mineralized from both soil organic matter and crop residues. N mineralization supplies a considerable amount of plant-available nitrogen during the key period for onion bulb growth (Figure 5).

The kind of crop residue affects the amount and timing of N mineralization. For example, sweet corn residue decomposes more rapidly and contains more N per acre than wheat residue (Figure 5). In Treasure Valley soils, the amount of N mineralized typically is lower with wheat as the previous crop (0 to 100 lb N/acre) than with a crop such as sweet corn (130 to 220 lb N/acre). Decomposition of wheat residue slows the rate of N mineralization early in the growing season. This effect is completed by about July 1 in the Treasure Valley. Soil N mineralization releases available N during the peak period for onion N uptake in July and August following either wheat or sweet corn.

Mineralizable N test

The mineralizable N test provides a rough prediction of N mineralization during the growing season. Mineralizable N is determined by anaerobic incubation of soil in water at 104°F (40°C) for 7 days. The high temperature used in the mineralizable N test speeds up the mineralization process and provides an estimate of season-long N mineralization in the field.

We recommend this test for trial use in the Treasure Valley. For Treasure Valley soils, there is a correlation between mineralizable N in the 0- to 12-inch and that in the 0- to 24-inch depth. Mineralizable N for the 0- to 24-inch depth is about 1.3 times the amount present in the 0- to 12-inch depth.

Collect soil samples for the mineralizable N test using the same procedure as for preplant nitrate-N. (Use the same samples for both tests.)

The mineralizable N test currently is not widely available at commercial laboratories. Check with your lab to see whether they can do this test.

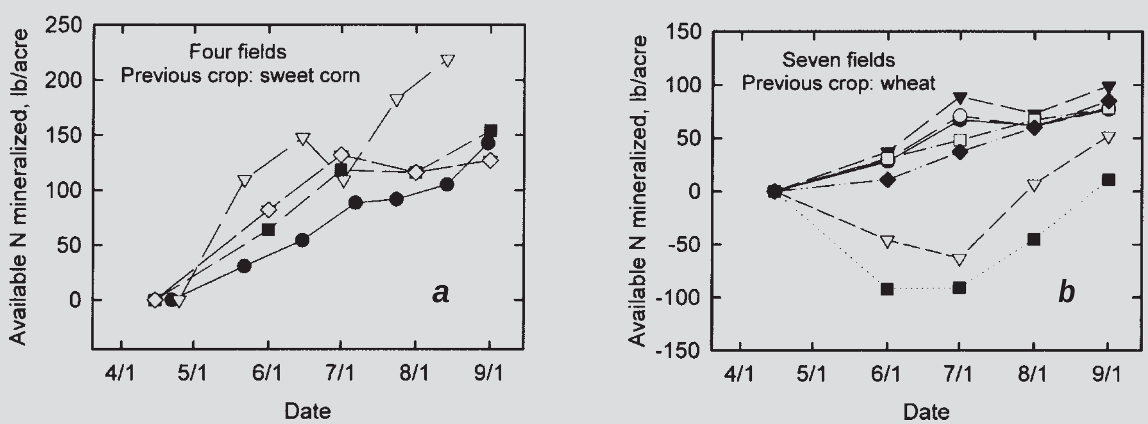


***Figure 5.**—Effect of sweet corn (a) or wheat (b) previous crop on N supplied by mineralization in Treasure Valley soils. Available N was determined by the buried bag method. Sources: Brad Brown, University of Idaho Parma Research and Extension Center, and Oregon State University Malheur Experiment Station (Steiber, et al. 1995).*

Preplant soil ammonium-N

Growers sometimes include preplant ammonium-N as a credit when calculating N fertilizer requirements. Testing for ammonium-N in soil is important when N fertilizer has been applied recently, especially if the soil has been dry or cold since the application. Decomposition of crop residues that are high in N (e.g., alfalfa residue or sugar beet tops) in dry soil over the winter sometimes also results in high concentrations of ammonium-N the following spring.

Nitrogen mineralized from crop residues and soil organic matter

Soil microorganisms decompose crop residues and soil organic matter to produce the mineral forms of N (ammonium and nitrate) utilized by plants. This is an important source of plant-available N. The residue from the previous crop is an important factor determining the quantity of N mineralized. Soil temperature, moisture, and tillage also affect the rate of mineralization.

Current fertilizer guides take into account average soil N mineralization based on the previous crop, but do not require measurement of site-specific soil N mineralization potential. Recent research has focused on improving N mineralization estimates (see "Estimating available N from mineralization" at left). Research in the Treasure Valley has shown that N mineralization cannot be estimated accurately based on soil organic matter concentration.

Nitrogen supplied in irrigation water

You can determine the amount of nitrogen supplied by irrigation water by testing the water. "Effects of irrigation on N and S management" (at right) describes how to calculate an N credit for irrigation water. The efficiency of N supplied from irrigation water is similar to that of side-dress fertilizer N.

The timing of irrigation water N application coincides with crop N demand. Water is applied most frequently in July and August when onions are most active in extracting available N from the soil.

Effects of irrigation on N and S management

Plants take up most nitrogen and sulfur from the soil in the nitrate and sulfate forms. Nitrogen supplied as urea, ammonium-based fertilizers, or N mineralized from crop residues or soil organic matter is converted by microbial action to nitrate. Similarly, sulfur supplied as thiosulfate or S mineralized from soil organic matter or crop residues is converted to sulfate.

Irrigation water management is the most important tool in good management of nitrate-N and sulfate-S. These mobile nutrients move with water and are moved out of the root zone with excessive irrigation.

Irrigation water also can be a source of mobile nutrients. Water from wells or recycled irrigation water can supply significant amounts of nitrate-N or sulfate-S. Nitrate and sulfate can be present in the groundwater or might accumulate in irrigation reuse water. You can determine the amount of nitrate and sulfate in irrigation water by testing.

Only about half of the applied irrigation water is retained with furrow irrigation. Thus, you must estimate water retention when calculating the quantity of N and S applied with furrow irrigation. Calculate the amount of N or S supplied with irrigation as:

Nutrient applied (lb/acre) = A x B x C x 0.227

where:

A = irrigation water applied (inches per acre)

B = nitrate-N or sulfate-S concentration in water (mg/L)

C = decimal fraction of applied water retained in the field (for sprinkler or drip irrigation, C=1; for typical furrow irrigation systems, C = 0.5)

0.227 = conversion factor. The conversion factor is 0.227 for converting mg N/L or mg S/L to lb/acre.

Note: Units of mg per L are equivalent to ppm for water samples.

Example calculation

Your irrigation water contains 10 mg nitrate-N per L and 5 mg SO_4-S per L and you applied 48 inches of water via furrow irrigation during the growing season. Half of the applied water was retained on the field.

Nitrate-N applied = 48 x 10 x 0.5 x 0.227 = 54 lb/acre

Sulfate-S applied = 48 x 5 x 0.5 x 0.227 = 27 lb/acre

Table 3.—Worksheet for estimating fertilizer N application rate for onions.

Line	Estimate	Units	Data Source	How to Calculate	Example
1	Bulb yield	cwt per acre (fresh weight)	Production records	Choose a realistic yield goal based on production records	800
2	Unit crop N uptake	lb N per cwt of fresh bulb yield	University research	Average value is 0.19 lb N per cwt.[a]	0.19
3	Crop N uptake	lb N per acre	Calculation	Line 1 x Line 2	152
4	Crop N uptake efficiency	Percent of available N supply	University research	40 to 60%	50
5	Available N supply needed from all sources	lb N per acre	Calculation	Line 3 ÷ (Line 4 ÷ 100)	304
6	Available N supply from nonfertilizer sources	lb N per acre	Preplant soil test	Nitrate + ammonium N (0 to 24 inches)	60
7			Irrigation water test	Nitrate-N (use calculation from “Effects of irrigation on N and S management,” page 11)	10
8			University research	Estimated soil N mineralization (use local values; consult your agronomist)	60
9			Calculation	Total available N supply from nonfertilizer sources (line 6 + line 7 + line 8)	130
10	Fertilizer N to apply[b]	lb N per acre	Calculation	Line 5 minus Line 9	174

[a]The usual range for bulb N uptake (fresh weight basis) is 0.14 to 0.24 lb N per cwt. The average value given here (0.19 lb N per cwt) is based on field trials with bulb yields of 400 to 1,030 cwt per acre.

[b] See “In-season fertilizer N application,” page 13, for most efficient fertilizer N application methods.

Estimating the N fertilizer application rate

After estimating credits from nonfertilizer N sources, you can roughly estimate the amount of N fertilizer needed (Table 3). The lines in the worksheet with the greatest amount of uncertainty are crop N uptake efficiency (line 4) and estimated soil N mineralization (line 8). Most university fertilizer guides take into account average N uptake efficiency and soil N mineralization, but do not explicitly list these values. We show these factors in our worksheet to demonstrate how important they can be in accurately estimating N fertilizer rates. Consult your agronomist to determine local values for crop N uptake efficiency and soil N mineralization.

Use the worksheet only to roughly assess overall fertilizer N needs. The timing and method of N fertilization is more critical than the total amount of N fertilizer applied.

The worksheet can underestimate fertilizer N needs if soil mineralization is less than expected or the timing of soil N mineralization does not coincide with crop needs. If the worksheet calculates a zero N fertilizer rate, monitor root nitrate-N status to assure adequate N availability. (See "Monitoring crop N status during the growing season," page 14.)

If you apply organic fertilizer sources (e.g., compost) to supply available N, you will need to estimate the fraction of applied N that is available to the onion crop. *Fertilizing with Manure*, PNW publication 533, provides general estimates of first-year compost or manure N availability.

In-season N fertilizer application

Nitrogen fertilizer is utilized most efficiently when it is applied just prior to, or during, the period of rapid crop N uptake (Figure 1, page 5). The period of rapid crop N uptake begins at bulb initiation (growth stage 4; Table 1, page 3).

Application methods

Side-dressing

Side-dressing, the knifing of N into the shoulder of the onion beds, is one of the most efficient application methods for furrow-irrigated onions, especially when delayed until bulb initiation. Side-dress N can be applied only as long as fertilizer application equipment can get into the field without damaging onion plants.

Where leaching losses are high, split applications usually are more effective than a single side-dress application. Regardless of the number of applications, the amount of N applied at one time should not exceed 100 lb N per acre. Typical side-dress N application rates are 40 to 80 lb N per acre per application.

At high side-dress N rates (> 160 lb N per acre), onion yields sometimes were reduced in Treasure Valley trials. The yield reduction at high N rates probably was caused by root injury via ammonia toxicity or high soluble salt concentrations.

Sprinkler or drip irrigation

You can meet crop N needs efficiently by applying N fertilizer with sprinkler or drip irrigation. Consider crop N uptake rates (Figure 1c, page 5) in choosing the timing and amount of drip or sprinkler-applied N. Maximum crop N uptake rates for onions are 2 to 3 lb N per acre per day.

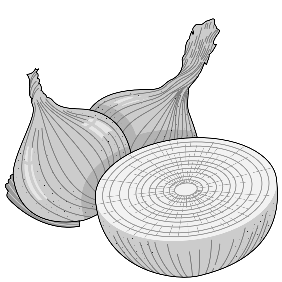
Furrow irrigation

Adding N to water used for furrow irrigation is a less precise method and generally is not recommended. Problems with water-run N applications include:

- Furrow irrigation does not distribute water evenly across the field. More N is applied to the top of the field than to the lower end of the field.
- Water leaving the field contains some of the fertilizer N.
- Adjacent furrows in the same field might be irrigated over a period of days (e.g., irrigation of every fifth furrow), making it difficult to synchronize water application and fertilizer application.

We recommend choosing another method of N application to replace water-run N applications. If water-run application is necessary, the following precautions can reduce or eliminate N loss from the field:

- Begin N application when water has advanced 30 percent of the way through the field. This practice avoids excessive application of N to the top part of the field.
- Shut off the fertilizer injection unit before water reaches the end of the field. This practice avoids N fertilizer loss in irrigation water runoff.
- Collect and reuse irrigation water.



Fertilizer N sources

The timing and method of fertilizer N application is more important than the N source. (See "In-season N fertilizer application," page 13.) In-season application of ammonium nitrate, ammonium sulfate, calcium nitrate, and urea-ammonium nitrate produced similar onion yield and quality in a 2-year Treasure Valley trial. N fertilizers differ in their effects on soil pH. (See "Acid soils in the Columbia Basin" at right.)

Controlled-release N fertilizer products offer promise for efficient utilization of N, particularly in soils prone to leaching. Polymer-coated urea (PCU) fertilizers are being evaluated for onion production in the Pacific Northwest and other western states. The polymer coating slows the release of available N. Coating urea with sulfur also reduces the rate of available N release from fertilizer granules. Sulfur-coated urea increased fertilizer N efficiency compared to uncoated urea in some Treasure Valley trials.

Monitoring crop N status during the growing season

There are two ways to monitor the success of nitrogen management practices during the growing season: soil testing and plant tissue testing. These tools can assist you in managing N to meet goals for crop yield, quality, and environmental protection. You can use them to determine the need for in-season N application when other data (see "Estimating the N fertilizer application rate," page 13) indicates that little or no fertilizer N is needed. They also can help you diagnose the cause of poor crop growth.

Both monitoring methods have limitations. Both are a "picture in time," reflecting current soil and plant N status. To get reliable information from these tools, collect samples periodically during the season.

Acid soils in the Columbia Basin

Soil acidity (pH less than 5.5) has been identified as a contributing factor in stand reduction and poor crop performance on loamy sand or sandy loam Columbia Basin soils. These soils were naturally neutral or slightly alkaline before cultivation; they have been acidified by N fertilization and other cropping practices.

Diagnosis

Soils with identified soil acidity problems are poorly buffered, with cation exchange capacities (CEC) of 5 to 10 meq/100 g. On these sandy soils, pH can fluctuate by 1 to 2 units during the year, depending on fertilizer and crop management practices. Soil pH usually is highest in winter or early spring. Fertilizer salts and soil biological activity reduce pH (increase soil acidity) during the growing season. Thus, preplant soil pH measurements might not reflect soil pH values during the growing season.

Soil acidity problems can occur even in fields that contain areas of calcareous (pH 8) soil. Therefore, pH might need to be adjusted on a site-specific basis within the field.

Soil acidity problems in Columbia Basin fields often look like a seeding or tillage problem. Often, plants in entire rows are missing, while plant stands in nearby rows are acceptable. This phenomenon likely is due to differences in depth of tillage. Deeper tillage often brings higher pH soil to the surface.

Plants affected by soil acidity exhibit slow, stunted growth. Root systems are poorly developed and might have some stubby roots similar to those injured by nematode feeding. Manganese in leaf tissue often is above 150 ppm, and soil pH in the onion row is below 5.

Soil and plant tissue tests for soil acidity

To anticipate and evaluate potential soil acidity problems, use the following soil tests:

- Lime requirement (one-quarter strength SMP buffer). This test measures reserve acidity present on cation exchange sites. It is used to evaluate the potential for pH decline during the growing season and the amount of lime needed to correct soil acidity. The standard lime requirement test (full-strength SMP buffer) cannot accurately determine lime requirements on very sandy soils.
- Exchangeable calcium. Exchangeable Ca below 3 meq/100 g indicates the potential for soil acidity problems.
- Soil pH. This test measures acidity in soil solution. Collect soil from the rooting depth (0 to 6 inches) in the onion row to monitor pH during the growing season.

High manganese (Mn) concentrations in onion leaf tissue can be an indicator of potential soil acidity problems. Further soil testing should be done when leaf Mn is greater than 100 ppm. Leaf tissue Mn concentrations can be misleading if foliar Mn has been applied.

Suggested management practices

Soil acidity can be corrected by applying and incorporating lime before planting. Correcting a soil acidity problem during the season is difficult because liming materials have low water solubility and remain near the soil surface.

Preplant application of 500 to 1,000 lb agricultural lime usually is sufficient to correct soil acidity problems for an onion crop on very sandy Columbia Basin soils. Use shallow tillage to incorporate lime into the top 6 inches of soil.

Fertilization practices can have a dramatic effect on soil pH. If possible, avoid preplant application of N and K fertilizers on sandy soils subject to soil acidity problems. The salt provided by these materials can reduce pH by 1 unit (e.g., from 6 to 5). Chloride from fertilizer sources such as potassium chloride also can increase plant injury by increasing uptake of Mn. Apply N and K in smaller increments during the growing season. Reduce or eliminate application of acid-forming fertilizers such as mono-ammonium phosphate (e.g.,11-52-0), urea-sulfuric acid, and ammonium sulfate.

Soil nitrate monitoring

You can monitor soil nitrate to assess available N in the root zone. It is most valuable early in the growing season when onion root systems are small and root samples are difficult to collect for nitrate analysis. Under furrow irrigation, nitrate concentrations are uneven across the bed, resulting in highly variable test results.

Sampling

To monitor early-season N availability, collect samples to a 6-inch depth within the row. If ammonium-based fertilizers or urea were applied recently, include ammonium-N analyses.

Early-season interpretation

Because of the variability typically observed in soil nitrate testing, we address only in-row nitrate concentrations in the high (above 20 ppm) and low (below 5 ppm) range. High nitrate-N concentrations (above 20 ppm in the root zone) indicate that N currently is not limiting crop growth, and N fertilizer applications should be delayed. Low nitrate concentrations (less than 5 ppm in the root zone) suggest that N might be limiting growth.

Root nitrate monitoring

Onion roots display the greatest response to available N supply of any plant part. Root nitrate-N concentrations vary from more than 10,000 ppm (dry weight basis) after side-dress N fertilizer applications to less than 1,000 ppm for onions that are nitrogen deficient.

You can use leaf N as an indicator of plant N status at the 3- to 5-leaf stage, when root systems are small and root samples are difficult to collect. Leaf tissue concentrations above 3.5 to 4 percent N (dry wt. basis) in the most recently matured leaf are sufficient.

Root sampling

Collect root samples from 20 to 30 representative plants. Remove the plant from the field using a small spade or other lifting tool, being careful not to cut off or lose roots. Wash with water to remove soil and then cut off the roots at the base of the plant. After cutting off the onion roots, pack the washed roots loosely in a paper bag. For overnight shipment to the laboratory, pack the roots so that they start to dry in transit and do not become a slimy mess. Roots should reach the laboratory within 24 hours of sampling.

Interpretation

Root nitrate-N analyses are an indicator of plant N status at a particular time. This test does not reflect nitrate that might become available to the plant as the root system penetrates deeper or spreads laterally. Figure 6 shows adequate and excessive levels of root nitrate-N during a growing season.

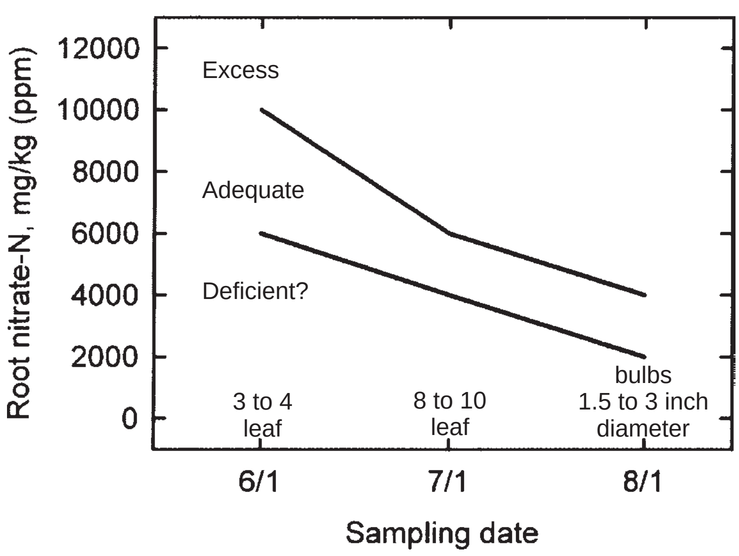


Figure 6.*—Interpretation of onion root nitrate-N test. The adequate range includes root nitrate-N concentrations (dry wt. basis) associated with maximum bulb yield in Treasure Valley field trials. This interpretation is based on N fertilizer trials where side-dress N was applied during bulb initiation (5- to 7-leaf stage) with typical furrow irrigation water management. Maximum onion yield and size can be produced with lower root nitrate concentrations when low concentrations of nitrate are provided consistently by irrigation water, N mineralized from crop residues or soil organic matter, or slow-release N fertilizers. Source: Brad Brown, University of Idaho Parma Research and Extension Center.*

Root nitrate concentrations can help you determine the need for N fertilizer application. If root nitrate concentrations are high, you can delay or omit sidedress N applications. High root nitrate-N concentrations late in the growing season usually reflect available N supply in excess of crop needs. However, root nitrate-N concentrations also can be high if another factor limits growth.

Most research trials have not demonstrated a link between high root nitrate late in the season and bulb shrinkage and rot in storage. Environmental conditions such as hail, poor conditions for field curing, or high humidity early in storage play a larger role than crop N status in determining storage loss.

Postharvest N management

Crop rotations that include a deep-rooted crop following onions (alfalfa, sugar beets, or cereals) can assist in recovering some of the nitrate-N from below the onion root zone. Consult your local Extension agent on cover cropping options for your area.

Phosphorus

Assessing P needs

Phosphorus deficiency reduces bulb size and can delay maturation. Crop P uptake for a bulb yield of 840 cwt/acre was 20 to 25 lb P per acre in Columbia Basin research (Figure 3, page 7). Maximum P uptake rates are 0.3 to 0.5 lb per acre per day during bulb growth.

Consider the following soil and crop management factors when determining P fertilizer application methods and rates:

- Soil test value (ppm)
- Soil free lime (calcium carbonate) concentration
- Fumigation

Collect soil samples from the 0- to 12-inch depth for P analysis. Different soil test methods are used in testing for P availability on alkaline and acid soils. The Bray P1 test is appropriate for acid to neutral soils (pH < 6.5). The Olsen (sodium bicarbonate) method is appropriate at all soil pH values. Check with your laboratory if you are unsure about which test method they use.

Fumigation prior to seeding onions might increase P fertilizer requirements. Fumigation kills the mycorrhizal fungi that help onion plants take up P. (See "Root growth and development," page 4.) In a 2-year Treasure Valley trial (Figure 7), fumigation caused P deficiency at soil test values below 30 ppm P. Without fumigation, adequate P for maximum yield was present at a soil test value of 10 ppm.

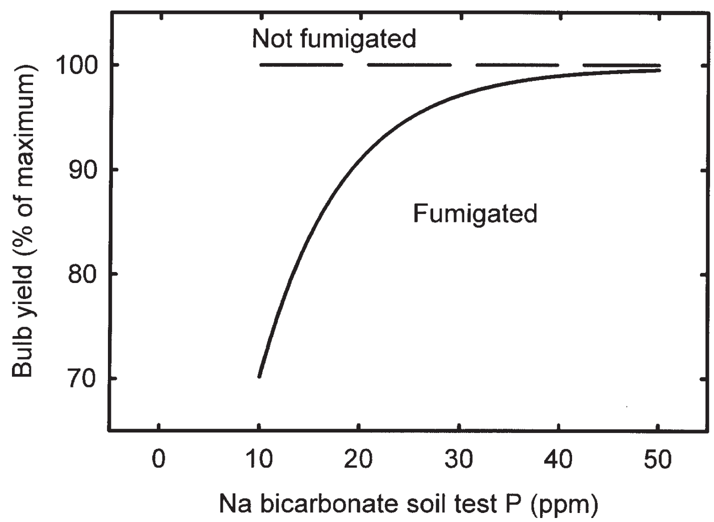


Figure 7.*—Fumigation increases the need for fertilizer P. Without fumigation, maximum onion yields were produced at 10 ppm soil test P (Olsen sodium bicarbonate extractant). With fumigation, onion yields increased with increasing soil test P up to 30 ppm. Soil at the test site contained about 10 percent lime. Source: Mike Thornton, University of Idaho Parma Research and Extension Center.*

Table 4 shows how soil and management factors affect P fertilizer requirements in the Treasure Valley. For other growing areas, research data for onions is more limited; consult a qualified agronomist for assistance.

Application methods

Incorporating P fertilizer in the planting bed is recommended. You can broadcast P prior to bedding or band it in conjunction with the bedding operation. Banded P fertilizer applications have been shown to be more effective than broadcast applications in western Oregon. Banding P below and to the side of the seed was no more effective than broadcast P in Treasure Valley trials. Do not place banded ammonium phosphates with onion seed because of the danger of ammonia toxicity.

Correcting P deficiency via foliar application is not recommended. Onion P requirements are very large compared to the amount of P that can be absorbed by leaf tissue.

Because of water quality concerns, minimizing P loss from the field is becoming an important consideration. Any practice that reduces furrow erosion will reduce total P loss from the field. You can reduce furrow erosion by a variety of methods, including laser

Table 4.—Phosphorus fertilizer rates based on soil test P, lime concentration, and fumigation for onions grown in the Treasure Valley.

Bicarbonate (Olsen) soil test P 0 to 12 inches	**Soil lime concentration (%)[a]**			
	0	**5**	**10**	**15**
(ppm)	P fertilizer application rate (lb P_2O_5 per acre)[b]			
	Not fumigated before planting			
0	160	200	240	280
5	100	140	180	220
10	40	80	120	160
15	0	20	60	100
20	0	0	0	40
above 25	0	0	0	0
	Fumigated before planting			
0	200	240	280	320
5	140	180	220	260
10	80	120	160	200
15	20	60	100	140
20	0	40	20	80
25	0	0	0	20
above 30	0	0	0	0

[a]Soil lime concentration as determined by calcium carbonate equivalent test.

[b]To convert from the oxide (P_2O_5) to the elemental form (P) multiply by 0.43.

Source: Brown, B. 2000. *Onions. Southern Idaho Fertilizer Guide*. CIS 1081. University of Idaho, Moscow, ID.

leveling, filter strips, sediment ponds, irrigation water management, straw mulching, and addition of PAM (polyacrylamide) to irrigation water.

Monitoring crop P status

Limited data exists to interpret crop P status via plant tissue testing. The range between deficient and adequate tissue P concentrations often is narrow because more plant biomass is produced when P deficiency is corrected. In a 2-year Treasure Valley trial, leaf phosphate-P (PO_4-P) was 3,000 ppm (dry wt. basis) in phosphorus-deficient onions, while in phosphorus-sufficient onions it was 3,300 ppm.

In the same trial, root PO_4-P concentrations necessary for maximum colossal production were 2,000 to 2,500 ppm at the 3- to 4-leaf stage and 1,600 to 2,000 ppm at the 8- to 9-leaf stage. Onions producing high yields at two Columbia Basin field locations had 1,500 to 3,500 ppm root PO_4-P during the growing season.

Potassium

Assessing K needs

Onions take up nearly equal amounts of N and K. A 700- to 1,100-cwt crop removed 110 to 160 lb K per acre in Columbia Basin trials (e.g., Figure 3, page 7), with peak uptake rates of 2 to 3 lb K per acre per day. Onions remove less K than potatoes and alfalfa.

Potassium is a positively charged ion that is held on exchange sites in soil. The potassium-supplying capacity of a soil usually is greater for soils with higher cation exchange capacity (CEC).

Potassium-deficient onions are relatively rare in the Treasure Valley. Potassium fertilization often is needed on the sandy soils that have a lower CEC in the Columbia Basin.

Laboratories determine available K status by extracting soils with sodium bicarbonate or ammonium acetate. Both extractants usually produce comparable soil test values and are considered equivalent. Soil test recommendations are based on a 0- to 12-inch sample. Table 5 shows the interpretation of soil test K from the *Southern Idaho Fertilizer Guide.*

Table 5.—Potassium fertilizer rates based on soil test K for onions grown in the Treasure Valley.

Potassium (K) soil test[a] 0 to 12 inches (ppm)	**K fertilizer application rate**	
	(lb K per acre)	**(lb K_2O per acre)**
0	200	240
50	100	120
above 100	0	0

[a]Soil test K as determined by sodium bicarbonate (Olsen) extraction.

Source: Brown, B. 2000. *Onions. Southern Idaho Fertilizer Guide.* CIS 1081. University of Idaho, Moscow, ID.

K fertilizer application

Potassium fertilizers are soluble salts. Apply K fertilizers only when needed, because excess salts can reduce seed germination and plant growth.

Potassium should be applied preplant on most soils. Incorporate it in the fall or during seedbed preparation. In-season application of K might be preferred on some very sandy soils in the Columbia Basin to avoid problems associated with excessive salts early in the growing season (see below).

Water stress and salinity

Onions are very sensitive to water stress. They respond to water stress with reduced rates of transpiration, photosynthesis, and growth. Water stress can be caused by soluble salts in the soil or by a soil water deficit.

During bulb growth, onions are more sensitive to water stress than most other crops. Water stress at this time reduces bulb yield and size. In Columbia Basin studies, water stress at the 3- to 5-leaf stage reduced the percentage of single-centered bulbs by 40 to 60 percent compared to nonstressed onions.

Drip irrigation systems can be managed to maintain consistent soil moisture during bulb development.

In Treasure Valley research with drip-irrigated onions, maximum bulb yield and size were achieved by maintaining soil moisture near field capacity at the 8-inch depth (a soil water potential of about –20 kPa, a reading of 0.2 bars or 20 centibars on a tensiometer). Maintaining soil water potential at –25 kPa requires 11 to 20 furrow irrigations during the growing season in the Treasure Valley, depending on seasonal precipitation and evapotranspiration.

Fertilizers incorporated into planting beds before seeding increase soluble salts. High levels of soluble salts can kill seedlings as they emerge. Onions can tolerate higher salt levels after plants are established. Screening tests for salinity tolerance show that yield reduction begins to occur at a conductivity of 1 to 2 mmhos/cm, and a 50 percent yield reduction occurs at 4 to 5 mmhos/cm.

Salinity problems also can include toxicity of specific elements such as boron or sodium. Boron and sodium toxicity usually are related to irrigation water quality. Extension vegetable crop specialists in California report that onions are more sensitive to salinity, sodium, and boron than are lettuce, cauliflower, broccoli, and cabbage.

Monitoring crop K status

Insufficient data exists to make fertilizer recommendations based on plant tissue K levels. At two adequately fertilized sites in the Columbia Basin, onion leaf tissue contained 2.5 to 3.5 percent K (dry wt. basis) at the 3- to 8-leaf growth stage, and root K concentrations ranged from 3 to 5 percent (dry wt. basis) during the growing season.

Calcium and magnesium

Research on the effects of calcium (Ca) or magnesium (Mg) application on onion bulb yield and quality is very limited.

Onion bulbs usually contain about 0.5 percent Ca (dry wt. basis), and crop uptake averages 50 lb per acre. One trial in the Treasure Valley with added Ca as calcium nitrate showed no response in bulb yield or quality. Higher plant Ca uptake sometimes occurs when calcium nitrate fertilizers are applied (e.g., uptake of 120 lb Ca per acre in Figure 3, page 7). Low Ca supply can be a concern on very sandy Columbia Basin soils with low pH values. (See “Acid soils in the Columbia Basin,” page 15.)

Onion bulbs contain approximately 0.10 to 0.15 percent Mg (dry wt. basis). Crop Mg uptake ranged from 10 to 20 lb per acre in several Columbia Basin field trials (e.g., Figure 3, page 7).

Sulfur

Assessing S needs

Sulfur is an essential plant nutrient and it contributes to the distinctive flavor of onions. Volatile sulfur compounds are released by action of the enzyme allinase when onions are cut or bruised. Onion varieties differ in the amount and kinds of S compounds present in the bulb.

Some of the S compounds responsible for pungency can inhibit the growth of fungi and bacteria and have been shown to reduce storage losses of sweet, short-day onions grown in Georgia. Application of S fertilizer increased onion pungency in Treasure Valley trials, but did not affect bulb storage loss. Increased bulb pungency is a negative characteristic in marketing of most onions.

Onion bulbs contained 0.3 to 0.6 percent S (dry wt. basis) in Columbia Basin trials. The N to S ratio in bulbs ranged from 3 to 1 to about 5 to 1. An 840 cwt/acre crop removed about 35 lb S per acre (Figure 3, page 7). Maximum S uptake rates were 0.6 to 0.9 lb S per acre per day during bulb growth.

Sulfur fertilization is not needed in many locations because adequate S is supplied from other sources. Nonfertilizer sources of S include:

- Preplant soil sulfate-S
- Decomposition of crop residues and soil organic matter during the growing season
- Irrigation water

Soils containing lime can precipitate and store S as gypsum (calcium sulfate). Gypsum accumulated in the top 2 feet of soil serves as another source of plant-available S.

The preplant sulfate-S soil test is less reliable for prediction of plant responses to fertilizer S than soil tests for N, P, and Zn. Collect preplant soil samples for sulfate-S to a 24-in depth. Use the same soil samples collected for preplant nitrate-N analysis. (See "Preplant soil nitrate-N," page 7.)

Fertilizer application

Apply sulfur fertilizers if soil test values for sulfate-S are less than 5 ppm (mg/kg) and irrigation water sulfate-S is less than 5 ppm (mg/L). Apply 30 to 40 lb S per acre when soil and irrigation water tests indicate a need. Apply soluble S sources just prior to or during the period of rapid crop uptake (Figure 3, page 7) for maximum efficiency.

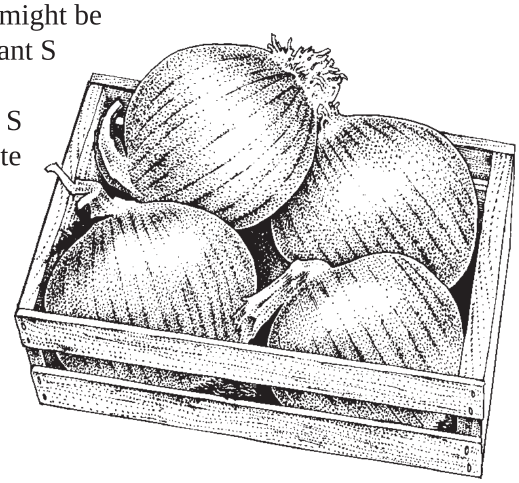
Sulfur salts such as potassium sulfate or ammonium sulfate can supply S. Do not apply ammonium thiosulfate near onion roots. Ammonium thiosulfate usually has a high pH (8) and contains some ammonia, which is toxic to roots. The thiosulfate ion itself also is toxic to roots. After a few days or weeks in soil, ammonia is converted to nontoxic ammonium-N, and thiosulfate is converted to nontoxic sulfate-S.

Urea-sulfuric acid supplies available S and N. It also increases soil acidity (lowers pH). The lower pH produced by urea-sulfuric acid application might temporarily increase availability of Zn on high-pH calcareous soils (those that contain carbonate or lime). It also might increase soil acidity problems on very sandy Columbia Basin soils. (See "Acid soils in the Columbia Basin," page 15.)

Monitoring crop S status

Limited data exists to interpret plant tissue tests for S. Total S in leaves and roots (3- to 8-leaf growth stage) ranged from 0.5 to 0.8 percent (dry wt. basis) for adequately fertilized onions in Columbia Basin trials. Onions supplied with low amounts of S in greenhouse trials had leaf S concentrations of less than 0.4 percent during bulb growth.

Root or bulb SO_4-S might be a useful indicator of plant S status. Bulb sulfate-S increased linearly with S fertilizer application rate in a recent greenhouse study with 'Southport White Globe' onions.



Total bulb S is a poor indicator of pungency. Onion varieties differ in the kinds and amounts of sulfur compounds present in bulbs.

Micronutrients

Onion uptake of micronutrients is most rapid during bulb growth (Figure 3, page 7). Applications of micronutrients are not recommended unless a reliable soil or plant tissue test indicates a need. Data to interpret soil and plant tissue tests for onion micronutrient status is limited. Most interpretations are based on response data from other crops. Research on onion response to Zn and B has been conducted in the Treasure Valley.

You can use soil tests to assess the potential for micronutrient deficiencies and toxicities. The DTPA soil test evaluates deficiencies of zinc (Zn), manganese (Mn), and copper (Cu). The hot-water and sorbitol extraction methods assess soil B availability. You can use leaf tissue tests to monitor total plant tissue concentrations of Zn, Mn, Cu, molybdenum (Mo), and boron (B).

Onions are sensitive to zinc deficiency. Deficiencies usually occur on white, high lime subsoils that have been exposed by land leveling or erosion. Soils are considered marginal at 0.8 to 1.0 ppm DTPA extractable Zn. Deficient Zn concentrations in leaf tissue probably are 10 to 20 ppm (dry wt. basis), based on data from other crops. Zinc deficiency can be corrected by soil or foliar Zn applications. There is insufficient data to support specific recommendations.

Application of manure or compost to other crops in rotation with onions might reduce or eliminate deficiencies of Zn and other micronutrients in onions. Manure or compost application prior to seeding onions generally is not recommended. Salts from manure or compost might reduce seed germination and increase water stress.

Onions did not respond to applied boron in Treasure Valley field tests even at low soil test levels of hot-water extractable boron (less than 0.5 ppm). Sufficient soil B levels on low organic matter, sandy soils in the Columbia Basin are about 0.3 ppm. If soil or plant tissue tests indicate a potential B deficiency, apply B fertilizer at low rates. Boron toxicity can occur if B is excessive. There is insufficient data to support specific recommendations.

Molybdenum (Mo) deficiency might occur on recently acidified, sandy soils in the Columbia Basin. Onions with leaf tissue Mo concentrations of less than 0.15 to 0.30 ppm (dry wt. basis) might respond to Mo application.

No research has been performed to assess manganese and copper response in onions grown in the Columbia Basin or the Treasure Valley.

Iron deficiency of onions has not been documented in the Pacific Northwest. DTPA soil tests and plant tissue tests for iron are not as reliable as those for other micronutrients. Trial applications of foliar iron might be warranted when soil pH is above 8.5. Soil applications of iron generally are ineffective in high pH soils.

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Exploring the Relationship Between Nitrogen, Plant Spacing and Bacterial Diseases of Onion in New York:

Reduced Nitrogen and Closer Spacing Could Result in Less Rot

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It is important to emphasize that "exploring" is in the present tense. In New York, we are just beginning to delve into the fascinating relationship between nitrogen, plant spacing and bacterial diseases of onions. Our preliminary results suggest that reduced soil nitrogen and tighter plant spacing results in less bacterial decay. In this article, we report preliminary findings from exploratory studies and the observations that lead to these trials. We stress that we are not making recommendations at this time. However, we are hopeful that further studies will lead to specific recommendations.

Bacterial diseases are a serious threat to sustainable onion production: Bacterial diseases of onions have become a serious threat to the sustainability of the New York onion industry. The bacterial pathogens, *Burkholderia cepacia*, *Pantoea ananatis* and *Enterobacter cloaceae* are the most common that plague onions in New York. Because bacterial bulb decay often affects only a single internal bulb scale while the outer scales remain firm (Fig. 1), such infected bulbs are virtually impossible to detect on the grading line. When such onions are shipped and consequently rejected, this often results in entire loads being dumped, despite only a small percentage of bulbs being infected, resulting in significant economic losses for growers.

The solution lies in an integrated approach: Ultimately, an Integrated Pest Management (IPM) approach will be required to manage bacterial diseases of onions, which might involve many different tactics including field sanitation, less susceptible varieties, materials that induce plant resistance, bactericides, crop rotation, anti-bacterial cover crops, soil amendments, strategic curing conditions, imaging technology to detect internal rots prior to shipping, and also, regulating plant spacing and reducing nitrogen fertility. Researchers and Extension professionals at Cornell and Nationwide have been working on several of these components. Here, we report on our exploratory work of reduced nitrogen and closer plant spacing.

High levels of soil nitrogen increase bacterial bulb decay: In 2010, an important observation was made in a small-plot on-farm field trial in onions grown on plastic in Pennsylvania. The plots located at the bottom of the slope had 83% bacterial bulb decay at harvest. The amount of decay decreased progressively in each replicate moving up the slope to 58% to 17% to zero in the replicate at the top of the slope. The trial was located on a diversified farm that had been heavily manured. Perhaps, heavy rainfall had caused nitrogen to leach from the top to the bottom of the slope, and thus, increased nitrogen at the bottom of the slope may have contributed to the higher levels of bacterial bulb decay.

Also in 2010, incidence of bacterial bulb decay at harvest was assessed in a study that was designed to evaluate the effect of nitrogen on onion thrips. In that study, onions grown with only

2.0 lb/A of applied nitrogen had 0.7% bacterial rot at harvest (Fig. 2). Onions grown with the Cornell recommended rate of 125 lb/A of nitrogen had 10.8% bulb decay, which was 15 times more than the rot that occurred at the 2.0 lb/A rate. Compared to the recommended rate, onions grown with reduced rates of applied nitrogen, 62 and 94 lb/A, had significantly less than half (4.9%) and one third (7.3%), respectively, of bacterial decay without any significant differences in yield.

In-depth studies initiated: In 2011, two major studies were undertaken to further investigate the relationship between nitrogen, plant spacing and resulting bacterial diseases of onions. The objective of the first study was to identify the most important factors associated with bacterial diseases of onion in commercial onion fields in both New York and Pennsylvania. In New York, 22 muck land direct seeded onion fields were surveyed from seven growers in seven counties, and included six varieties. A similar survey was conducted in Pennsylvania, which focused on onions grown from transplants on plastic.

The second on-farm study investigated the effect of reduced applied nitrogen and reduced plant spacing on bacterial bulb rot. This trial was a follow-up to studies conducted by Hoepting *et al.* (2009, 2010) which showed that reduced plant spacing in small-scale production of onions on plastic provided 53 to 64% control of bacterial bulb decay at harvest. Whether reduced plant spacing also impacts bacterial bulb decay in direct seeded onions grown on muck lands with higher planting densities was unknown.

In this study, three rates of nitrogen, 0, 45 and 90 lb per acre, and three seeding rates, 5.3, 7.5 and 10 seeds per foot, were evaluated in each of two varieties, Nebula and Prince. Onions were direct seeded into 32" wide raised beds with two single rows of onions spaced 12 inches apart on the bed. The trial was established in muck soil by a grower cooperator in Oswego County, New York. Unfortunately, soil test results showed no difference between the 0 and 45 lb per acre rates of nitrogen, so they were pooled together as "low nitrogen 0-45 lb/A".

Results:

In NY, in 2011 there were low levels of bacterial bulb decay with incidence in the observational survey ranging from 0 to 17.4% at harvest. The variety, Hendrix had the widest range of bacterial rot. In this variety, we found that the strongest correlation occurred among percent bacterial bulb decay at harvest and available nitrate-nitrogen (NO_3-N) in the mid-season at the 7-9 leaf stage. The fields with the highest available nitrogen also had the highest incidence of bacterial rot at harvest. Across the 66 survey sites available NO_3-N in mid-season ranged from 70 to 936 ppm with an average of 296 ppm. **These results suggest that there is opportunity to manage nitrogen fertility more efficiently and effectively with the potential benefit of reducing losses from bacterial diseases.**

Fortunately for our grower cooperator, but unfortunately for us, in the Oswego County trial, there was an average of 0.44% and 1.5% bulb rot at harvest and out of storage, respectively. Therefore, we need to carry out similar studies in which the incidence of bacterial decay is much higher. Nevertheless, this trial suggested some interesting relationships and revealed several horticultural effects.

Variety had an effect on bacterial decay: Variety was the only variable where there were significant differences in bacterial decay. Nebula had almost double bulb decay as Prince (Fig. 3). Assuming this difference was to transfer to situations where bacterial disease pressure is higher, then selecting less susceptible varieties may be a very important factor in managing bacterial diseases of onion. This warrants further investigation and a preliminary study is underway in New York to evaluate the relative susceptibility of onion varieties commonly grown in New York to bacterial diseases.

Low nitrogen and high seeding rate had less bacterial decay: As expected, when the results were pooled across variety and seeding rate, the incidence of bacterial disease was 1.5 times higher with the high rate of nitrogen (90 lb/acre) than the low rate (0 to 45 lb/acre) (Fig. 3). Similarly, the highest seeding rate (10 seeds/ft) had only about half the bacterial bulb decay as the standard seeding rate (7.5 seeds/ft) (Fig. 3). However, not as expected, the lowest seeding density (5.3 seeds/ft) did not have higher incidence of bacterial decay than the standard. A breakdown of the data indicated that Prince had higher incidence of bacterial rot as seeding rate decreased in both rates of nitrogen, especially at the high rate of nitrogen, but Nebula did not exhibit any consistent trends. Thus, it seems that different varieties respond differently to reduced nitrogen and increased spacing, which may be related to plant vigor, and future studies should aim to understand these interactions.

An integrated approach should not compromise yield: Our preliminary results indicate that applying less nitrogen and decreasing plant spacing may be useful for managing bacterial diseases of onions. For either of these strategies to be feasible, they must not reduce yield. When the results were broken down, the highest seeding rate consistently had the highest yield in both varieties only with the high nitrogen rate. At the low nitrogen rate, seeding rate did not have an effect on marketable yield in the larger variety, Prince. In Nebula, the lowest seeding rate had 49 (= 6.5%) and 57 (=7.6%) cwt/A less total marketable yield than the high and standard seeding rates, respectively. These results remind us that increasing seeding rate and reducing nitrogen to the extent that each component works best independently may compromise yield due to nitrogen deficiency. Different varieties with different vigor and days to maturity may also respond differently to these factors. Small and medium sized onions tend to fetch lower prices and may be in limited demand. Of course, if high nitrogen rates and low seeding rates result in high levels of bacterial bulb decay, increased yields from smaller sized onions may very well be more feasible economically than larger rotten bulbs.

We also observed that the high rate of nitrogen and seeding rate delayed maturity. In some cases, delayed maturity is not a desirable trait. All of these factors must be considered as we develop an IPM approach to managing bacterial diseases of onions.

Opportunity to reduce nitrogen inputs in New York: Regardless of whether reduced nitrogen rates can significantly reduce bacterial diseases of onion, the results from all of these studies strongly suggest that there is opportunity to reduce the use of nitrogen fertilizer in onion production. In the nitrogen and seeding rate study, the "high" rate of nitrogen of 90 lb/A is actually only 72% of the Cornell recommended rate of 125 lb/A and yet this field still yielded 893 cwt per acre of marketable onions. Even more impressive, the low rate (0-45 lbs/A) yielded 832 cw per acre! Soil samples collected for these studies consistently showed that the majority of onion fields have excessive levels of available nitrogen in mid-season. Preliminary findings warrant further study. In the meantime, **we strongly encourage onion growers to "experiment" on their own farms with reduced nitrogen inputs for onion production.**

This information was presented at the 2012 Empire State Fruit and Vegetable Expo on January 26, 2012 by Christy Hoepting, Vegetable Specialist with the Cornell Cooperative Extension Vegetable Program, cah59@cornell.edu; 585-798-4265 x38. A copy of the presentation is available online at http://www.hort.cornell.edu/expo/2012proceedings.php. Funding for studies mentioned in this project was provided by the Northeast IPM Partnership and Competitive grants in collaboration with Steve Beer, Cornell and Beth Gugino, Penn State.

Figure 1. Inner scale(s) of onion bulb is infected with bacterial decay, while outer scales remain firm making detection on grading line challenging. Photo courtesy of Steve Beer.

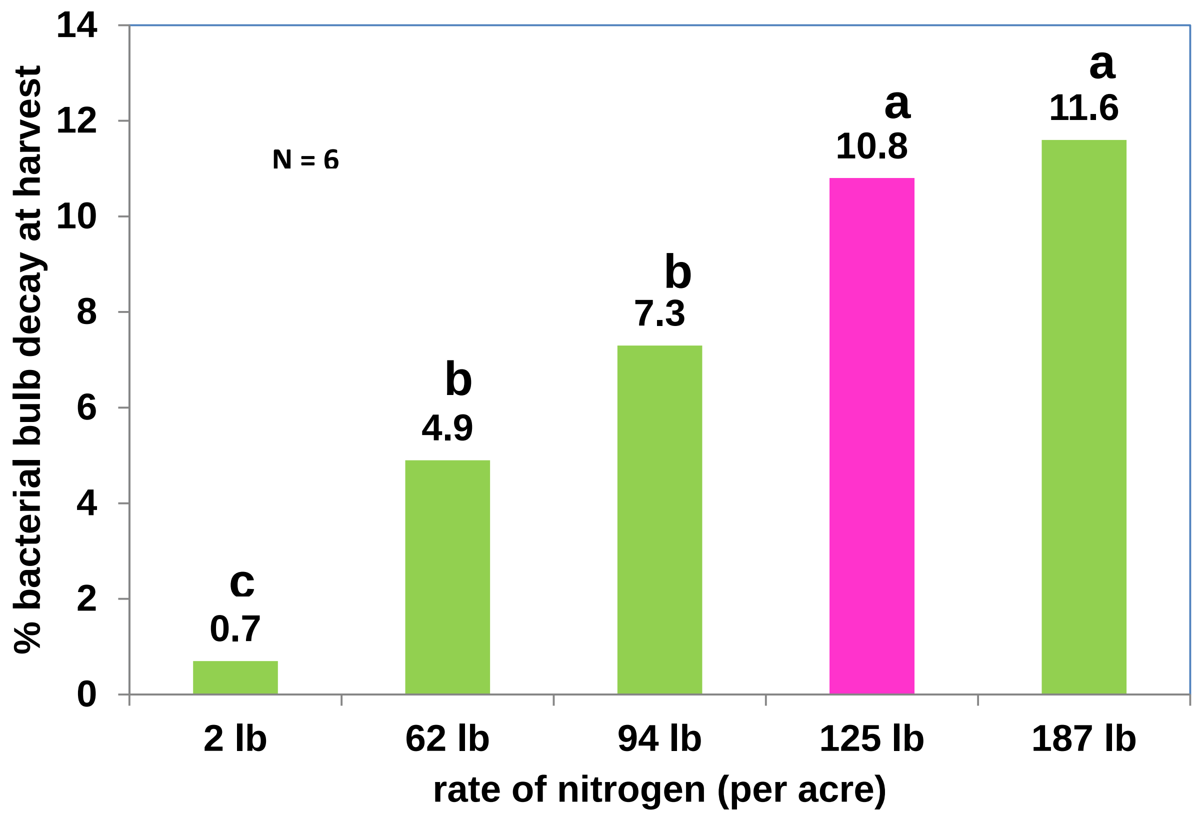

Figure 2. Effect of amount of applied nitrogen on bacterial bulb decay at harvest. The trial was an on-farm, small-plot replicated field study in muck land in Elba, NY, 2010 (Hoepting, Hsu and Nault, 2010). Data bars with the same letter are not significantly different, Fisher's Protected LSD test ($p<0.05$). The pink bar indicates the recommended rate of nitrogen.

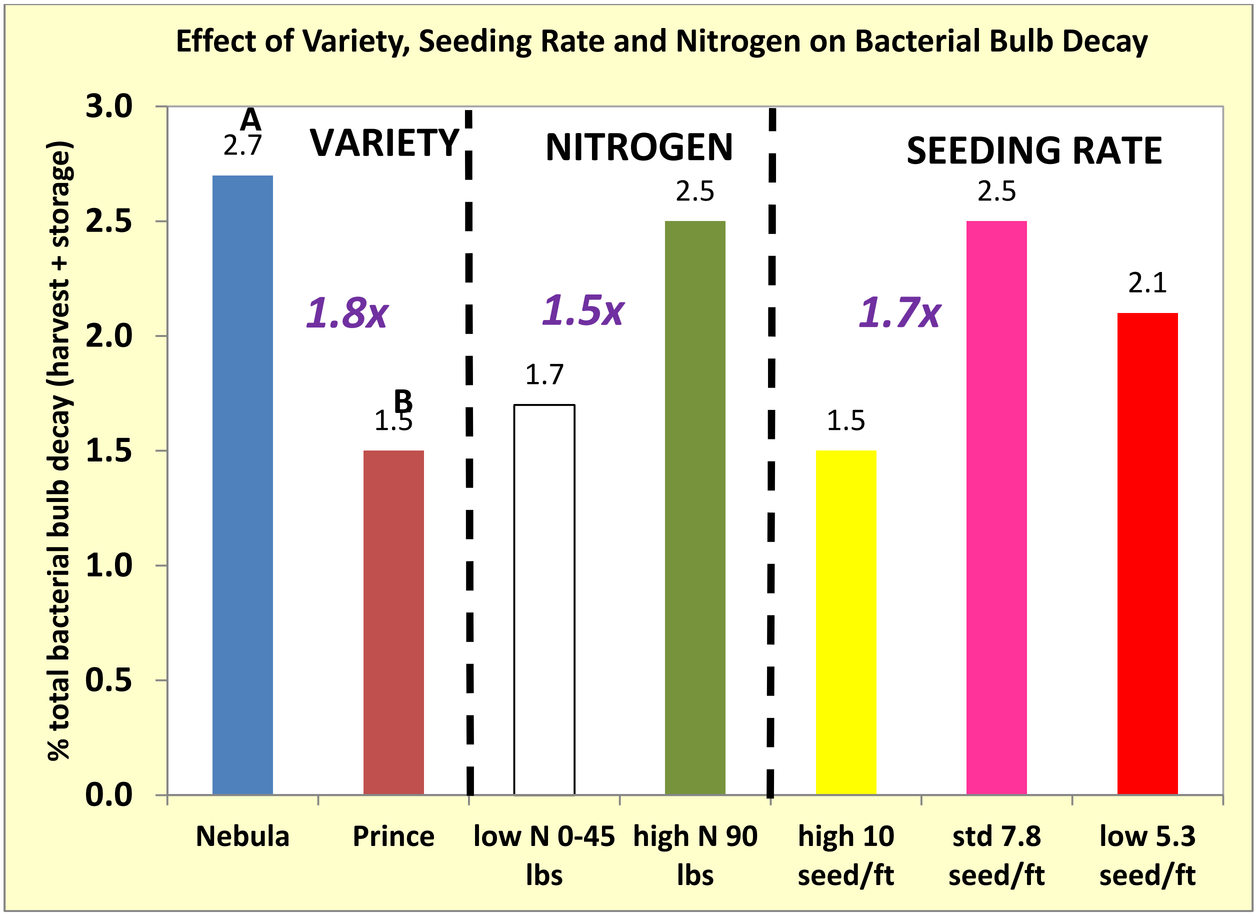

Figure 3. Effect of variety, reduced nitrogen and seeding rate on bacterial bulb decay following storage, Oswego Co., 2011 (Hoepting & Beer). With a category such as variety or nitrogen, bars followed by the same letter are not significantly different according to Fisher's Protected LSD test ($p<0.05$). Purple numbers indicate the "fold" difference (e.g. Nebula had 1.8x more rot than Prince) between adjacent bars.

Stop the Rot!
Using Cultural Practices to Reduce Bacterial Bulb Decay in Onions

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[1]Cornell Cooperative Extension Vegetable Program
[2]Dept. of Plant Pathology, Pennsylvania State University

Narrow plant spacing reduced bacterial bulb decay by 53 to 64%
Do you know how easy this is? A simple modification to adjust your planting configuration is all it would take to drastically reduce losses from bacterial bulb decay. Our studies showed that when plant spacing was reduced from 6 or 8 inches to 4 inches with 3 or 4 rows per 3-foot plastic mulch bed (row spacing: 4 rows = 6 inch; 3 rows = 8 inch), this provided 53 to 64% control of bacterial bulb decay at harvest (Table 1). Marketable yield also increased by 1.4 to 2.4 times, representing an increased net economic return of $43 to $258 per 100 feet of bed, due to increased weight of marketable jumbo-sized bulbs (Table 1). We learned that wide plant spacing produces big bushy plants with more leaves, thicker necks, delayed maturity and bigger bulbs. Unfortunately, it was these bigger bulbs that rotted! By narrowing plant spacing, we got fewer colossal-sized bulbs, which we more than made up for by having significantly more healthy jumbo-sized bulbs to market (Table 1).

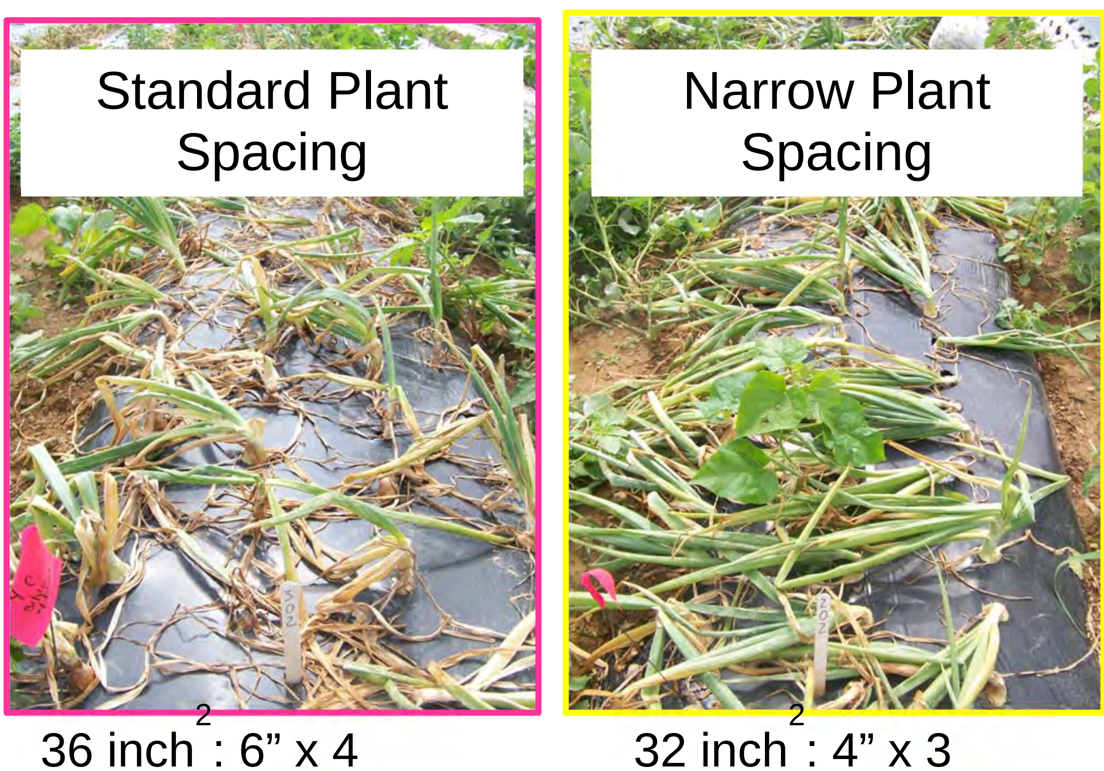

Figure 1. Compared to the standard plant spacing, narrow plant spacing with fewer rows per bed controlled bacterial bulb rot by 53 to 66%. New Holland, PA: July 20, 2010.

Alternatives to black plastic reduced bacterial bulb decay by 59 to 75%

This is also a very simple and easy modification for small-scale growers producing onions on plastic mulch to make to their cultural practices that could go a very long way towards reducing bacterial bulb decay. Our studies showed that reflective silver mulch, biodegradable black plastic and bare ground had significantly 1.8 to 2.8 times higher marketable yield than black plastic (Table 2). Reflective silver and biodegradable black plastics had significantly 3.7 and 3.6 times, respectively, higher jumbo weight than black plastic, which resulted in an increased net return of $96 to $215 per 100 feet of bed compared to black plastic (Table 2). All of the alternatives to black plastic had significantly lower soil temperatures compared to the black plastic; we suspect that the higher temperatures of the black plastic are more favorable for development of bacterial diseases.

Figure 2. Compared to black plastic, reflective silver mulch controlled bacterial bulb decay at harvest by 53%. New Holland, PA: July 20, 2010.

Bacterial bulb decay is a serious problem in onion production

Small-scale diversified fresh market growers who grow onions intensively in New York and Pennsylvania are constantly challenged by yield losses due to bacterial diseases, which greatly compromise profitability. If bacterial diseases cannot be managed, this onion industry will not be sustained or expanded. Bacterial diseases are also an economically very important disease of large scale onion production, which occurs in New York predominantly on muck soil.

In New York, Sour Skin caused by *Burholderia cepacia*, is the most common cause of bacterial bulb decay, although *Pantoea ananatis* and *Enterobacter cloacae* have also been identified, and several others are likely part of the complex. In Pennsylvania, the most frequently isolated bacterial pathogens include soft rot pathogens, *Pseudomonas marginalis* and *Pectobacterium caratovora*; and center rot pathogens, *Pantoea ananatis* and *P. agglomerans*; *Xanthomonas axonopodis* and *Pseudomonas* *viridiflava*. Bulbs with bacterial decay are not marketable, although sometimes they are sold unknowingly to detriment, because, a single internal scale can be infected as the outer scales remain firm making the decay undetectable. Losses to bacterial bulb decay have increased steadily over the past decade where onions are grown intensively on plastic mulch. It has become common for the incidence of bacterial bulb decay to be 35 to over 50% in parts of both PA and NY. In 2008 in PA, 34 growers lost a total of $140,000 to bacterial bulb decay. In NY, large scale onion producers report annual losses of 20 to 30% due to bacterial bulb decay.

It is very important to note that this simple technique of reducing plant spacing was equally effective at reducing bacterial bulb rot with different bacterial pathogens. In NY, *B. cepacia* was the main bacterial pathogen with a few *P. ananatis* identified, while in PA, *P. carotovora*, *P. marginalis* and *P. agglomerans* were the main pathogens with some minor *B. cepacia*.

Figure 3. *Left and Middle* – above-ground symptoms of bacterial diseases of onions showing yellowing, bleaching and wilting of inner leaves. *Right* – bacterial bulb decay (pathogen not identified).

How does plant spacing work to reduce bacterial bulb rot?

We don't know for sure, but we suspect that narrow plant spacing produces plants that are less suitable hosts for bacterial diseases to become established and to develop and spread. Our studies showed that wider plant spacing produces larger plants with more leaves, thicker necks with delayed maturity (data not shown). Large bushy plants are more conducive to holding water in the leaf axils, which can favor bacteria entering into the plant. Thick necks take longer to dry and remain succulent and green for a longer time, which provides ideal conditions for bacterial diseases to spread from the leaves into the bulb. Delayed maturity interferes with proper lodging and curing of the neck and bulbs, allowing for increased risk for bacterial infections in the leaves to spread into the bulbs. Alternatively, the smaller plants with thinner, tighter necks that mature earlier in narrow plant spacing configurations are less conducive to bacterial bulb decay.

Does narrow plant spacing reduce bacterial rot for large-scale production of onions?

We suspect that it would make a difference, but have not yet researched this phenomenon in large-scale onion production on the muck. Our results from small-scale production suggest that bacterial bulb decay decreases when planting density is higher than 36 inch^2 per bulb, and continues to decrease as planting density increases (Table 1). This could explain why we often see higher incidence of bacterial bulb decay in transplanted onions than we do in direct seeded onions of the same variety. For example, direct seeded onions planted at 7 seeds per foot with 15 inch row spacing have a planting density of 26 $inch^2$ per bulb, which is 2.3 times denser than transplanted onions that are planted at 3 plants per foot with the same row spacing (60 $inch^2$ per bulb).

Our data collected from Interlaken, NY in 2010 suggests that row spacing is a very important factor related to rot: when we increased row spacing from 6 inches (4 rows per bed) to 8 inches (3 rows per bed), incidence of bacterial bulb decay at harvest increased 2 to 4 fold for each plant spacing (4", 6' and 8"). Therefore, in direct seeded onions, would onions planted with 12 inch row spacing (= 21 $inch^2$ per bulb) have less bacterial rot than onions grown with 15 inch row spacing (= 26 $inch^2$ per bulb)? Another unknown is whether row type (single vs. double) effects bacterial bulb decay?

Our results from small-scale production suggest that reducing planting density to 36 $inch^2$ per bulb or less greatly reduces incidence of bacterial bulb decay at harvest. Therefore, with respect to large-scale production of onions from transplants, our data suggests that if growers decreased their row spacing from 15 inches (= 60 $inch^2$ per bulb with 4 inch plant spacing) to 8 to 6 inches, and adjusting plant spacing to achieve a planting density of 36 $inch^2$ per bulb or less (e.g. 6 inch row spacing with 5 or 6 inch plant spacing = 30 to 30 $inch^2$ per bulb) would result in 50% or more control of bacterial bulb rot. It would be very interesting to see whether bulb size could still be met with these different planting configurations on onions grown on muck. We also do not know the effect that the number of plants per hole (1 vs. 2 vs. 3) has on incidence of bacterial diseases?

How does mulch type reduce bacterial bulb decay?

Growers' standard black plastic absorbs sunlight, thus increasing soil temperature, which in turn, promotes early crop development of onions. However, during the heat of June and July, the warmer soil temperatures provided by the black plastic may actually be creating a more favorable environment for bacterial diseases to develop and spread. In contrast, reflective silver mulch keeps soil temperatures cooler, and black biodegradable mulch provides early season added heat, which gives way to cooler soil temperatures as it degrades during the heat of summer. The lower temperatures provided by these alternative mulches could be the difference between optimum and below optimum temperatures for bacteria to grow. Similarly, soil temperatures of bare ground would be cooler than under black plastic, but extra effort would be required to provide effective weed control.

How does the mulch study relate to large-scale production?

Our theory is that the significantly warmer temperature of the black plastic compared to the reflective silver plastic, biodegradable plastic or bare-ground is creating a microclimate that is more conducive to the development and spread of bacterial disease. If black plastic is somewhat analogous to the dark color of the muck soil, than theoretically, onions grown on muck soil would have less bacterial rot if it was possible to reduce the temperature of the muck. In our work with developing a minimum tillage production system for onions, we found twice as much rot in the conventional system (58.1% bacterial canker) compared to the minimum tillage system (27.5% bacterial canker) which had 30% ground cover of winter wheat residue and was cooler.

Ultimately, an integrated approach is needed to manage bacterial disease of onions

We are not telling you that all you have to do is reduce your plant spacing and bacterial diseases will be a thing of the past. Ultimately, managing bacterial diseases of onions will involve an integrated approach for both small and large scale producers. We have several projects planned that are designed to develop different components of an Integrated Pest Management (IPM) program for managing bacterial diseases of onions. Plans beginning in 2011 include:

1) small-scale grower demonstration and adoption of narrow plant spacing configurations;
2) continue trialing alternatives to black plastic to elucidate which consistently performs best;
3) trial combinations of narrow plant spacing and alternatives to black plastic in combination;

4) Elucidate the relationship between bacterial disease of onions and nitrogen fertility. We have anecdotal evidence and preliminary data that shows that as soil nitrogen increases, incidence of bacterial bulb decay increases.
5) Determine the most important sources of bacterial pathogens and how they infect onions. Soil, transplant samples, onion thrips, weeds and seeds will be assayed for presence of bacterial pathogens of onions. We eventually will also study the effect of wind, herbicide and onion thrips injury on incidence of bacterial bulb decay.
6) Various chemical tactics including Actigard and other plant defense inducers, copper bactericides and antibiotics will be trialed for their ability to control bacterial bulb decay of onions. Used alone, chemical tactics have provided virtually no relief from bacterial decay in onions. When used as part of an IPM program that incorporates various cultural tactics including alternative mulches, narrow plant spacing and reduced nitrogen fertility, and starting with clean transplants, etc., proper timing of chemical tactics could prove effective.

Join our STOP the ROT Campaign! Growers Needed

If you are an onion grower of small scale growing onions on plastic or a large-scale grower of onions on muck, and you are interested in experimenting with narrow plant spacing to reduce incidence of bacterial bulb decay on your farm, please contact Christy Hoepting (585-721-6953; cah59@cornell.edu) or Judson Reid (585-313-8912). We would like to meet with you individually to discuss the most appropriate planting configuration for your operation and then follow up with how well it worked in the field. We are also interested in onion growers of all size who are interested in reducing nitrogen inputs in order to reduce bacterial bulb decay.

Funding

Funding for these projects was provided by NESARE Partnership and NE IPM Partnership grants.

Table 1. Evaluation of onion spacing for reducing incidence of bacterial bulb decay and improving profitability in onion, Interlaken, NY 2009 & 2010 and New Holland, PA, 2010: marketable yield and grade, incidence of bacterial bulb decay at harvest and net return.

At harvest, per 100 feet of bed:

Onion Spacing				Total	Onion Grade (lb)				% bacterial	Net Economic Return[5]		
Planting Density (inch²/bulb)	**No. rows /bed[6]**	**Plant Spacing (inch)**	**No. plants /100 ft of bed**	**Market-able Yield (lb)**	**Colossal (>4")**	**Jumbo (3-4")**	**Medium (2.25-3")**	**Small (<2.5")**	**bulb decay by weight**	**Cost of transplants[2]**	**Variable Price[3]**	**Uniform Price[4]**
Interlaken, NY: 2009 (cv. Nebula) on silver plastic												
24 inch²	4	4	1200	510 a[1]	130 b	330 a	36 a	10 a	13.3 % b	$40.50	$229	$410
32 inch²	3	4	900	460 a	270 a	190 b	10 b	2.0 b	13.8 % b	$30.38	$230	$384
48 inch² standard	4	8	600	330 b	270 a	50 c	6.0 bc	0.0 b	37.3 % a	$20.25	$160	$277
60 inch²	4	10	480	220 bc	200 ab	20 c	0.0 c	1.0 b	41.5 % a	$16.20	$111	$181
80 inch²	3	10	360	160 c	130 b	10 c	1.0 c	0.0 b	53.6 % a	$12.15	$70	$132
			P Value (α=0.05):	***0.0001***	***0.0352***	***0.0000***	***0.0000***	***0.0046***	***0.0064***	--	--	--
Interlaken, NY: 2010 (cv. Candy) on silver plastic												
24 inch²	4	4	1200	873 a	399	434 a	39 a	0	3.1 %	$40.50	$412	$745
32 inch²	3	4	900	716 b	447	253 b	16 b	0	6.0 %	$30.38	$348	$614
36 inch²	4	6	800	697 bc	510	182 b	4.7 c	0	3.6 %	$27.00	$346	$600
48 inch²	3	6	600	559 c	497	59 c	1.3 c	0	7.3 %	$20.25	$283	$483
48 inch² standard	4	8	600	595 bc	525	67 c	4.0 c	0	6.4 %	$20.25	$303	$516
64 inch²	3	8	360	369 d	349	20 c	0.7 c	0	23.3 %	$15.19	$202	$317
			P Value (α=0.05):	***0.0001***	***NS***	***0.0000***	***0.0001***	**--**	***NS***	--	--	--
New Holland, PA: 2010 (cv. Candy) on black plastic												
24 inch²	4	4	1200	339 a	0.0	187	108 a	43 a	29.5 %	$24.00	$315*	$242
32 inch²	3	4	900	277 ab	8.7	197	54 b	17 b	29.4 %	$18.00	$110*	$216
36 inch² standard	4	6	800	151 bc	6.7	122	21 b	1.3 b	63.1 %	$16.00	$57	$118
60 inch²	4	10	480	90 c	8.7	65	15 b	0.7 b	70.8 %	$9.60	$34	$71
80 inch²	3	10	360	77 c	25	43	6.7 b	2.0 b	70.1 %	$7.20	$31	$60
			P Value (α=0.05):	***0.0178***	***NS***	***NS***	***0.0012***	***0.0002***	***NS***	--	--	--

[1]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, p <0.05. [2]**cost of transplants:** NY **-** $1.35 for 40 plants or $0.03375 per plant (plugs); PA - $0.02 per plant (bare roots from Texas). [3]**Variable Price:** According to PA Simply Sweet prices: Colossal - $0.55/lb; Jumbo - $0.50/lb; Medium - $0.40/lb; Small - $0.20/lb; no more than 30% total marketable weight can be sold as small + medium. [4]**Uniform Price:** According to Interlaken road side stand prices: all grades except small (<2.25" not marketable) - $0.90/lb. [5]**Net return:** gross (data not shown) minus cost of transplants. [6]row spacing: 4 rows = 6"; 3 rows = 8").

Table 2. Evaluation of different mulch types for reducing incidence of bacterial bulb decay and improving profitability in onion (cv. Candy), New Holland, PA, 2010: marketable yield and grade, incidence of bacterial bulb rot at harvest and net return.

At harvest (Jul-20-2010) per 100 feet of bed:									
		Onion Grade (lb)					**Net Economic Return[6]**		
Treatment	**Total Market-able Yield (lb)**	**Colossal (>4")**	**Jumbo (3-4")**	**Med. (2.25-3")**	**Small (<2.25")**	**% bacterial bulb decay by weight**	**Cost of Mulch/ herbi-cides[3]**	**Variable Price[4]**	**Uniform Price[5]**
Black plastic (std)	119.5 c[1]	13	65 a	24 c	16 b	57 %	\$2.38	\$64	\$90
Silver Plastic	331 a	27	242 b	46 bc	16 b	23 %	\$4.20	\$166	\$279
Biodegradable Black Plastic	321 a	14	231 b	54 b	22 b	17 %	\$7.00	\$160	\$262
Bare ground	213 b	0	85 a	82 a	46 a	14 %	\$0.11	\$121	\$150
P Value (α=0.05)	***0.0008***	***NS[2]***	***0.0011***	***0.0026***	***0.0063***	***NS***			

[1]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, p <0.05. [2]**NS:** Not significant, Fisher's Protected LSD test, p > 0.05. [3]**cost of herbicides:** Prowl H2O @ 8 fl oz + Goal Tender @ 24 fl oz = \$16.67 per acre. [4]**Variable Price:** According to PA Simply Sweet marketing program: Colossal - \$0.55/lb; Jumbo - \$0.50/lb; Medium - \$0.40/lb; Small - \$0.20/lb; no more than 30% total marketable weight can be sold as small + medium. [5]**Uniform Price:** According to Interlaken road side stand prices: all grades except small (<2.25" not marketable) - \$0.90/lb. [6]**Net Economic return:** gross (data not shown) minus cost of mulch/herbicides.

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ONION
DISEASE GUIDE

A PRACTICAL GUIDE FOR SEEDSMEN, GROWERS AND AGRICULTURAL ADVISORS

BACTERIAL SOFT ROT

SYMPTOMS:

Bacterial soft rot is mainly a problem on mature bulbs. Affected scales first appear water-soaked and pale yellow to light brown when infected by *Dickeya chrysanthemi* or bleached gray to white when infected with *Pectobacterium carotovorum* subsp. *carotovorum*. As the soft rot progresses, invaded fleshy scales become soft and sticky with the interior of the bulb breaking-down. A watery, foul-smelling thick liquid can be squeezed from the neck of diseased bulbs.

CONDITIONS FOR DISEASE DEVELOPMENT:

Bacterial soft rot is most common on onions in storage or transit; however, this disease can develop on onions in the field before harvest, after heavy rains and when leaves are drying. The main sources of inoculum are contaminated soil and crop residues. The bacteria is spread by splashing rain, irrigation water and insects. Entry into bulbs is only through wounds such as those caused by transplanting, mechanical injuries or sunscald. Also, onion maggots can carry soft rot bacteria and introduce them while feeding. This disease is favored by warm, humid conditions with an optimum temperature range of 20-30°C (68-86°F). However, during storage or transit soft rot can develop when temperatures are above 3°C (37°F).

CONTROL:

Avoid overhead irrigation where possible, and control insect pests such as the onion maggot. Disease spread and infection may be reduced by copper-based bactericides. Allow onion tops to mature before harvesting and avoid damaging bulbs during harvest. Store onion bulbs only after they have been properly dried, and provide the appropriate temperature and humidity with good ventilation to prevent moisture condensation from forming on the bulbs.

Foliar collapse of an infected plant.

Early season soft rotting of a bulb.

Soft rot developing late in the season in two bulbs.

Causal Agents:
Dickeya chrysanthem i (syn. *Erwinia chrysanthemi*),
Pectobacterium carotovorum subsp. *carotovorum* (syn. *E. carotovora* subsp. *carotovora*)

Distribution:
Mexico and USA (*D. chrysanthemi*), Worldwide (*P. carotovorum* subsp. *carotovorum*)

CENTER ROT

SYMPTOMS:

Symptoms first appear as whitish to tan lesions with water-soaked margins, often on interior leaves. Foliar lesions can rapidly coalesce, progressing to wilt and dieback of affected leaves. The pathogen moves from the leaves into the neck and bulb causing yellowish to light-brown discoloration. With severe infections, all leaves can be affected giving a bleached appearance to plants. Secondary bacterial infections rot interior bulb tissue and produce a foul odor. Under conditions favorable to the disease, yield losses may approach 100 percent.

CONDITIONS FOR DISEASE DEVELOPMENT:

Both pathogens are seedborne and can survive on a few reported alternate hosts (corn, cotton, melon, pineapple, rice and sugar cane). They may also survive epiphytically on weeds and crop debris. Spread can occur by wind, splashing water and thrips. Infection is favored by moderate to warm temperatures and rainfall during bulb initiation.

CONTROL:

Seed produced in high risk areas should be tested for *Pantoea ananatis* and *Pantoea agglomerans* before sowing. Some onion varieties are known to be more susceptible to this disease than others. Avoid planting these varieties where disease pressure is high. Control weeds, volunteer onions and thrips. Consider drip rather than sprinkler irrigation if possible, and avoid working in fields when foliage is wet. Avoid excessive nitrogen fertilization. If applied preventively, copper-based bactericides may provide control under low to moderate disease pressure. Initiate sprays two weeks before bulbing and continue every 5-7 days thereafter. Deep cultivate after harvest to promote decomposition of crop debris. Where this disease occurs, a minimum three-year rotation to non-hosts is recommended.

Wilt and dieback of onion leaves infected with Pantoea ananatis.

Bacterial decay of interior bulb tissue associated with center rot.

Causal Agent:
Pantoea ananatis (syn. *Erwinia ananatis*), *P. agglomerans* (syn. *E. herbicola*)

Distribution:
Peru, Poland, South Africa and USA (Colorado, Georgia, Michigan and New York)

ENTEROBACTER BULB DECAY

SYMPTOMS:

The exterior of the bulb remains asymptomatic while the inner scales show a brown to black discoloration and decay.

CONDITIONS FOR DISEASE DEVELOPMENT:

This disease was observed in mature bulbs in the field after a period where air temperatures had reached 40-45°C (104-113°F). The bacterium is common in many environments and is considered to be an opportunistic pathogen on onions.

CONTROL:

No control measures have been reported.

Bulb longitudinal-section showing infected internal scales.

Bulb cross-section showing infected internal scales.

Causal Agent:
Enterobacter cloacae

Distribution:
Poland and USA (California, Colorado, New York, Utah and Washington)

SLIPPERY SKIN

SYMPTOMS:

Field symptoms often appear as one or two wilted leaves in the center of the leaf cluster. These leaves eventually turn pale yellow and dieback from the tip while older and younger leaves maintain a healthy green appearance. During the early stages of this disease, the bulbs may appear healthy except for a softening of the neck tissue. In a longitudinal section, one or more inner scales will look watery or cooked. The disease progresses from the top of the infected scale to the base where it can then spread to other scales, rather than by spreading crosswise from scale to scale. Eventually, all the internal tissue will rot. Finally, the internal scales dry and the bulb shrivels. Squeezing the base of infected plants causes the rotted inner portion of the bulbs to slide out through the neck, hence the name slippery skin.

CONDITIONS FOR DISEASE DEVELOPMENT:

This bacterium requires moisture for infection and grows in the temperature range of 5-41°C (41-106°F). Severe disease can occur during periods of high rainfall combined with strong winds or hail. Heavy irrigation and persistent dews are also conducive to this disease. This bacterium is soil-borne and can be readily water-splashed to the foliage and necks where it can enter through wounds. As the plant matures it increases in susceptibility with the mature plant being highly susceptible. In warm weather, approximately 30°C (86°F), infected bulbs can decay within 10 days. However, in storage decay moves slowly, often requiring 1-3 months for a bulb to decay completely.

CONTROL:

Harvest onions when bulbs have reached full maturity. Do not store bulbs until they have been properly dried. Minimizing stem and bulb injury and avoiding overhead irrigation when the crop is approaching maturity can reduce losses from this disease. Bulbs should be stored at 0-2°C (32-36°F) with adequate ventilation to prevent condensation from forming on the bulbs.

Bulb cross-section showing collapse and shriveling of internal scales.

Causal Agent:
Burkholderia gladioli pv. *alliicola* (syn. *Pseudomonas gladioli* pv. *alliicola*)

Distribution:
Worldwide

SOUR SKIN

SYMPTOMS:

Field symptoms often appear as one or two leaves that have turned a light brown color. A watery rot develops at the base of the leaves and proceeds into the neck, allowing the leaves to be easily pulled from the bulb. As the disease progresses the outer bulb scales are infected. However, the outer most bulb scales and inner bulb scales may not become infected, which distinguishes sour skin from slippery skin where inner bulb scales are infected first. Infected scales develop a slimy pale yellow to light brown decay and may separate from adjacent scales allowing the firm center scales to slide out when the bulb is squeezed. Infected bulbs often have an acrid, vinegar-like odor due to secondary invaders, especially yeasts, colonizing decaying bulbs.

CONDITIONS FOR DISEASE DEVELOPMENT:

Burkholderia cepacia is commonly spread by heavy rains, overhead irrigation and flooding which splash the bacteria onto young or wounded foliage. Infection typically occurs through wounds including those made when onions are cut at harvest. Infection can also occur when water lands on upright leaves and flows into leaf blade axils carrying the bacterium with it. Sour skin is favored by rainstorms and warm weather, and develops rapidly at temperatures above 30°C (86°F).

Causal Agent:
Burkholderia cepacia
(syn. *Pseudomonas cepacia*)

Distribution:
Worldwide

CONTROL:

The use of furrow irrigation, instead of overhead and recycled irrigation water, will reduce losses from this disease. Do not damage foliage prior to harvest or bulbs during harvest since *B. cepacia* enters the plant primarily through wounds. Onion crops should be harvested at maturity and the bulbs dried quickly. Storing onions at cool temperatures 0°C (32°F) with adequate ventilation to prevent condensation on the bulbs will reduce storage losses resulting from this disease.

Cross-section through bulb showing separation of scales.

Light brown discoloration of infected inner leaves.

Yellowing of infected inner leaves.

Cross-section through bulb showing water-soaking of infected scales.

Longitudinal-section through bulb showing yellow brown discoloration of infected outer scales.

BASAL ROT

SYMPTOMS:

The first above ground symptoms are yellowing, curling and necrosis at the tip of leaf blades. With time, whole leaf blades show symptoms and eventually wither and decay. Infected roots are dark brown, flattened, transparent and sometimes hollow. When affected bulbs are cut vertically, they show a watery, brown discoloration of the outermost layer of the stem plate, which may progress up through the storage leaves. White mycelium of the fungus may colonize the stem plate and, eventually, roots may rot completely. Infected plants can be pulled easily because of their stunted, decayed root system. Infected bulbs may show no decay at harvest but may rot in storage.

CONDITIONS FOR DISEASE DEVELOPMENT:

Optimum temperature for disease development is 27°C (80°F) and infection is limited when temperatures are below 15°C (59°F). Onion plants can be infected directly by the pathogen at any stage, but injury to the roots, the basal plate or bulbs by onion maggots or other insects appears to increase the incidence of this disease. The fungus can persist in soil as resting spores called chlamydospores for several years. Spread of this fungus often occurs by movement of infested soil on equipment, in irrigation water or on infected onion sets.

Causal Agent:
Fusarium oxysporum f. sp. *cepae*

Distribution:
Worldwide

CONTROL:

Growing varieties with tolerance to basal rot can reduce losses from this disease. Long term rotation with non-host crops for four years or longer may also help to reduce losses. Dipping seedlings in fungicide before transplanting can also reduce disease severity. Additionally, control of soil insects and foliage diseases, the use of healthy onion sets and avoidance of fertilizer injury all help to reduce basal rot losses.

Foliar symptoms showing withering and necrosis of leaves.

Foliar symptoms and extensive root loss on infected seedlings.

White mycelial growth on the basal plate.

Bulb and basal plate rot.

Basal plate rot.

BLACK MOLD

SYMPTOMS:

Black mold generally develops at the neck of the bulbs on injured or necrotic leaf tissue. However, it can develop on injured or diseased roots, or on bruised or split outer scales along the side of bulbs. Infected bulbs may develop a black discoloration at the neck. Clusters of black spores generally form along veins and on or between the outer papery scales of bulbs. Infected tissue first has a water-soaked appearance and over time will dry and shrivel. No external symptoms may be visible on some infected bulbs. Soft rot bacteria can follow infection by this fungus.

CONDITIONS FOR DISEASE DEVELOPMENT:

Spores of this fungus are very common in the air and soil. Black mold is most common when temperatures are higher than 30°C (86°F) in the field or 24°C (75°F) in storage. Free moisture for six hours or longer on the onion surface is necessary for infection to occur.

CONTROL:

Fungicide applications to seeds, seedlings and bulbs may be helpful. Storage conditions should be cool and dry, and bruising of bulbs should be avoided.

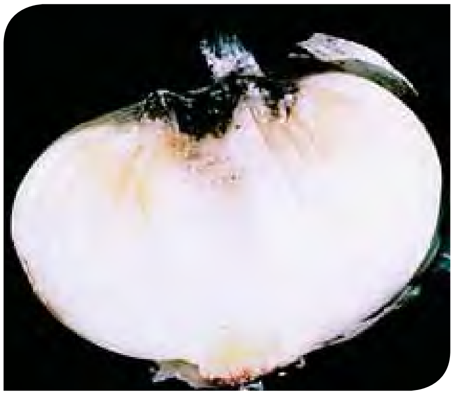
Causal Agent:
Aspergillus niger

Distribution:
Worldwide

Black fungal spores are visible under the outer papery scales of the bulb.

Exposed black fungal spores under the outer papery scales.

Bulb longitudinal-section showing extensive infection of the scales (right).



Bulb longitudinal-section showing initial infection of scales at the bulb neck.

BLACK STALK ROT

Black spore production on a scape.

SYMPTOMS:

Early symptoms of black stalk rot and purple blotch may be confused because they are similar in appearance. However, black stalk rot will eventually cover the infection site with a dense carpet of black spores. The affected areas generally progress along the length of leaves and flower stalks. Initially yellow then tan, these lesions later darken when spore production is at its highest. Seed stalks may become girdled and break before the seed matures. Surface infection of bulbs results in a black sooty appearance.

CONDITIONS FOR DISEASE DEVELOPMENT:

This fungus can infect and survive over a wide range of environmental conditions, causing the most severe damage in warm, humid climates. It generally attacks old, diseased, weakened host tissue and will often follow downy mildew.

CONTROL:

The crop should be kept free from downy mildew, leaf blight and other diseases. Although chemical sprays can be effective, cultural control may also be achieved with proper plant spacing, fertilizer applications and irrigation to ensure the healthiest plant possible. Controlling insects such as thrips, which may injure the plant and provide access for the fungus, can be beneficial. Also, bulbs should not be bruised when harvested and should be properly dried before storage.

Causal Agent:
Stemphylium botryosum (teleomorph: *Pleospora tarda*)

Distribution:
Worldwide

BLUE MOLD ROT

SYMPTOMS:

First symptoms include pale yellowish lesions and watery soft spots. These affected areas are soon covered with characteristic blue-green spores. Fleshy scales may show water-soaking and a light tan or gray color when affected bulbs are cut open. As decay continues, bulbs may become soft and tough or may develop a watery rot. A musty odor is usually present.

CONDITIONS FOR DISEASE DEVELOPMENT:

Penicillium spp. can be found in soil, on plant and animal debris or on senescing tissues. Infection of bulbs is usually through tissues damaged by bruising, freezing injury or sunscald. The pathogen grows well at 21-25°C (70-77°F) and under moist conditions.

CONTROL:

A minimum of bruising and wounding of bulbs during harvest and prompt drying of harvested bulbs is recommended. Low temperature, approximately 5°C (41°F), and relative humidity are recommended for storage. Fungicide treatment of bulbs can be effective in controlling this disease.

Lesion development on the side of a bulb.

Blue-green fungal sporulation develops within a lesion.

Causal Agent:
Penicillium species

Distribution:
Worldwide

BOTRYTIS LEAF BLIGHT

SYMPTOMS:

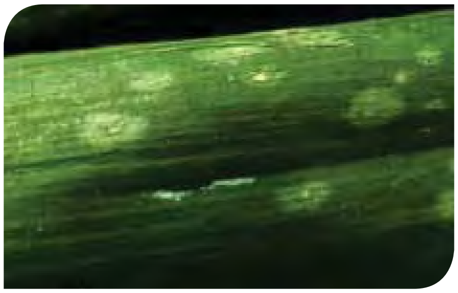
The fungus primarily attacks the leaves. The first symptoms begin as small white spots that are surrounded by a greenish halo. Centers of spots often are tan, making it difficult to distinguish between leaf blight and damage from insect feeding, mechanical damage or herbicide injury. Lesions expand with age and when numerous, may cause leaf tips to dieback. Eventually, leaf death results and severely affected onion fields develop a blighted appearance. Bulbs from infected plants may be small because growth is reduced by leaf loss.

CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus may over-winter in infected plant material or may survive in the soil as small, dark brown sclerotia. During moist periods with moderate temperatures, fungal spores are dispersed from sclerotia, infected leaves and debris to initiate infection. This disease can spread rapidly when environmental conditions are favorable for development.

CONTROL:

A good preventive fungicide spray program is important. Disease forecasting systems have been developed for some areas and these are very useful for determining the optimum timing for sprays. Destroying onion or debris cull piles will help reduce sources of inoculum. Orienting plant rows and spacing to maximize air movement helps reduce the time that leaves are wet and results in less disease incidence and severity. Cultural practices such as deep plowing and crop rotation will help reduce numbers of sclerotia in the soil.



White spots surrounded by a greenish halo.

White spots surrounded by a greenish halo.

Tan colored leaf spots.

Black sclerotia develop on an infected bulb.

Causal Agent:
Botrytis squamosa

Distribution:
North America and Europe

DOWNY MILDEW

SYMPTOMS:

Typically the first symptom observed is the brownish-purple velvet-like sporulation of the pathogen on healthy green leaves. As the disease progresses lesions which are slightly paler than the normal leaf color, enlarge and may girdle the leaf. These lesions progress to a pale yellow followed by brown necrosis resulting in collapse of the leaf tissue. Infected seed stalks tend to remain pale yellow and, as with the foliage, are often invaded by other fungi, typically *Stemphylium* or *Alternaria* species. Field infections usually begin in small patches and progress rapidly throughout the field. Bulbs can be infected and may either rot in storage, or if planted, give rise to pale green foliage.

CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus survives in volunteer onion plants, onion sets, plant debris or in the soil. The fungal spores are disseminated onto plants by winds and splashing rain during cool wet weather, which is essential for disease development. Rain, dew or high humidity (>95%) is required for fungal spore germination and infection. The fungus grows internally and continues to produce spores as long as the weather remains cool and wet.

Pale yellow lesions on scapes.

Causal Agent:
Peronospora destructor

Distribution:
Disease occurs worldwide in temperate and cool growing regions.

CONTROL:

A regular fungicide spray program based on climatic conditions can reduce crop losses. Avoid planting onion sets that are contaminated with the fungus. Eliminate plant debris and cull piles. Plant rows in the direction of the prevailing winds and use furrow irrigation rather than sprinkler irrigation. A 3-4 year rotation out of onions in areas where the disease is present can help reduce losses.

Sporulation on an infected leaf.

Extensive foliar damage in the field.

Peronospora destructor infection may be followed by invading secondary organisms, often leading to plant collapse.

Symptom development on an affected scape.

Peronospora destructor sporulation on leaves.

Brownish-purple sporulation on healthy green leaves.

NECK ROT

SYMPTOMS:

The growing crop seldom shows symptoms until harvest. However, this disease can be very destructive on stored onions. The fungus can invade the young healthy leaf tissue, but it usually infects the neck directly or through wounded tissue. This tissue becomes soft and spongy as the fungus continues to grow into the bulb. Affected parts of the bulb are brown and water-soaked, and the diseased tissue eventually collapses and becomes spongy. A white to gray mycelial growth eventually develops between the bulb scales and masses of small black sclerotia may develop on the outer scales around the neck. In addition to neck rot, *Botrytis allii* has been implicated in causing a soil-line rot. Other *Botrytis* species can also cause this disease. The fungus penetrates the outer scales of the bulb initiating a rot that is exacerbated by secondary invaders.

CONDITIONS FOR DISEASE DEVELOPMENT:

Under prolonged wet conditions the fungus can sporulate on dead and decaying tissue in the field as well as from sclerotia. Wind readily disseminates these conidia to other plants where they can infect the neck of the plant through wounds or cuts. Disease spread is most rapid during moderate temperatures with high humidity, rainfall or overhead irrigation. The condition of plants at harvest is important since infection can be more severe if necks are still succulent. Also, storing uncured onions at temperatures and humidity that are too high can promote disease development and spread. Soil-line rot is often more severe when onions are transplanted and during cool, moist weather.

Causal Agent:
Botrytis allii (teleomorph: *Botryotinia allii*)

Distribution
Worldwide

CONTROL:

Use varieties that are adapted to the growing area to ensure that the plants mature by harvest. Avoid excessive late season fertilizing, which may delay maturity. Adjust plant spacing and row orientation to obtain the best air movement through the plants. Avoid injury to the onion neck and damage to the bulbs, especially at harvest. Field applications of fungicides prior to harvest may reduce disease severity. Destroy onion cull and debris piles that may serve as a source of inoculum. Deep plow fields with a history of the disease to bury the sclerotia and rotate out of onions in these fields for several years. Be sure bulbs are cured and remove damaged bulbs before storage. Do not allow moisture condensation to form on the bulbs and use cool temperatures and moderate humidity for bulb storage.

Bulb longitudinal-section showing early symptoms of neck rot.

Bulb longitudinal-section showing advanced symptoms of neck rot.

Soil-line neck rot development on a bulb.

Botrytis allii mycelia and sclerotia on a bulb.

PINK ROOT

SYMPTOMS:

The term “pink root” reflects the most obvious symptom of this disease. Infected roots show a light pink color that become deeper pink or red with time and finally purple-brown as the roots shrivel and disintegrate. New roots may continue to form and then be killed by the fungus. Plants with severe infections appear to suffer from nutrient deficiencies or drought, and the leaves turn white, yellow or brown starting at the tips and eventually die. Leaf number and size are reduced and the plants are easily uprooted. Plants infected early in the season start bulbing prematurely and show more damage than those infected later. Note that the older roots of resistant cultivars will also display the pink color due to fungal infection as the roots senesce. However, resistant cultivars suffer very little loss of yield in the presence of the pathogen. Bulbs from infected plants are usually undersized and of reduced market value.

CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus is generally considered ubiquitous and can survive in the soil, in diseased roots and the debris of susceptible crops for several years. The fungus can be spread through soil movement and in surface water. This disease can develop at all soil moisture levels that allow onion growth. This pathogen will attack healthy crops in warm onion growing regions. Optimum temperatures for growth of the pathogen and disease development are 24-28°C (75-82°F). Little disease will develop when temperatures drop below 16°C (60°F).

Causal Agent:
Phoma terrestris (syn. *Pyrenochaeta terrestris*)

Distribution:
Worldwide

CONTROL:

Resistance to the pathogen varies among cultivars, thus resistant cultivars should be planted when possible. Resistance may be overcome if soil temperatures of 28°C (82°F) or higher occur. Planting so the bulk of the root growth occurs prior to reaching soil temperatures that favor disease development can minimize severe losses from this disease. Long term rotation (4-6 years) with non-host crops, such as cereals, helps reduce losses. Also, soil solarization or fumigation can help to reduce pink root and increase marketable bulbs.

Leaf tip dieback is apparent on the infected plants in the foreground.

Infected roots turn reddish-purple in color.

Pink root-resistant bulb (left) and susceptible bulb (right).

Seedlings with severe root infection.

PURPLE BLOTCH

SYMPTOMS:

Older leaves tend to be more susceptible than younger leaves. Symptoms begin as water-soaked lesions that usually have a white center. Edges of lesions become brown to purple and the leaf turns yellow above and below the lesions. With time, dark brown to black concentric rings form throughout the lesions. These are areas of sporulation of the fungus. As the disease progresses, lesions may girdle the leaf causing it to collapse and die. Similar symptoms occur on seed stalks and infected stalks can collapse resulting in shriveled seed development. When bulb infection occurs, it is normally through the neck. If the fungus invades the bulb, the infected area is initially bright yellow, but eventually turns a characteristic red wine color.

CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus over-winters as mycelium in leaf debris and cull piles. Spores are formed during humid nights and leaf wetness periods greater than 12 hours. As the morning dew dries, spores become air-borne and are disseminated to susceptible onion tissue. 1-4 days are needed for symptoms to develop after infection. Disease development is greatest during prolonged periods of leaf wetness.

CONTROL:

A fungicide spray program with broad spectrum protective fungicides applied prior to infection can provide good protection. Minimizing leaf wetness by using surface rather than sprinkler irrigation, good field drainage and correct plant spacing can reduce disease development. A rotation out of *Allium* to unrelated crops for several years can reduce disease as well.

Brownish-purple leaf lesion.

Brownish-purple foliar lesions.

Expanding brownish-purple lesion showing concentric rings of sporulation.

Causal Agent:
Alternaria porri

Distribution:
Worldwide

SMUT

SYMPTOMS:

Infected seedlings often die within six weeks of emergence. Dark areas can be seen first on cotyledons soon after their emergence from soil. On older plants raised, blister-like lesions can occur near the base of the scales, and large lesions cause leaves to curve downward. Streaks may develop within the leaves, leaf sheaths and bulbs. Mature lesions contain a black, powdery mass of spores. Infected plants are stunted as infection progresses inward from leaf to leaf.

CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus can over-winter as resting spores in the soil for several years. Spread of the fungus occurs through infected onion sets, transplants and when spores are transported by wind, equipment and water. Onion seedlings are susceptible to infection from just after germination until they reach the first true leaf stage. As each new leaf emerges it goes through a growth phase where it is susceptible to infection. After that growth phase, infection does not occur. Optimum temperatures for spore germination and growth are 13-22°C (56-72°F) while both are decreased above 25°C (77°F).

Causal Agent:
Urocystis colchici, U. cepulae (syn. *U. magica*)

Distribution:
Worldwide

CONTROL:

Chemical seed treatments can protect seedlings through the susceptible stage. In addition, any cultural practice that is favorable for rapid growth can shorten the susceptible stage of the onions. Healthy onion sets and transplants that are planted into infested soil may escape infection. A crop rotation out of onions for three or more years also reduces disease.

Early symptoms of smut infection manifest as black streaks on leaves.

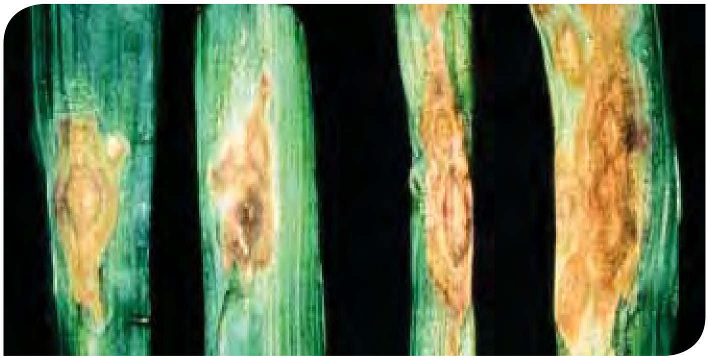
Infected seedlings showing dark streaks that contain masses of fungal spores.

Infected seedlings are stunted (one healthy seedling on the left and three infected seedlings on the right).

STEMPHYLIUM LEAF BLIGHT

SYMPTOMS:

Initial infections on the leaves and leaf sheaths are small, light yellow to brown, and water-soaked. As the lesions expand they coalesce causing extensive blighting of the leaves. Typically, lesions are found in higher numbers on the side of leaves facing the prevailing wind. The centers of lesions turn brown to tan, then dark olive brown and finally black as the fungus sporulates. Sometimes fruiting bodies called perithecia may appear in infected tissue as small, black, pinhead-like raised bodies. Symptoms of stemphylium leaf blight are very similar to those of purple blotch, which often results in misidentification.



Dark brown to black sporulation on leaves.

Dark brown to black sporulation on senescing leaves.

CONDITIONS FOR DISEASE DEVELOPMENT:

Extended periods of leaf wetness from dew formation, rainfall or overhead irrigation during bulb formation and development can result in severe leaf blighting. Bulb size can be greatly reduced due to loss of foliage. Infection is usually limited to leaves and does not extend down to the scales of the bulb.

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CONTROL:

Chemical control with fungicides is effective in reducing disease development. Long term rotation with unrelated crops may reduce losses. Also, good field drainage and reduced plant density may lessen disease severity.

Causal Agent:
Stemphylium vesicarium

Distribution:
India and USA, however, the pathogen may occur in other onion growing regions of the world.

WHITE ROT

SYMPTOMS:

This disease can be one of the most damaging on onions with the first symptoms including yellowing, wilting and dropping of the older leaves. As the fungus invades the root system and basal plate it causes a rot, which eventually results in the collapse of the foliage. A soft rot gradually develops in the bulb and a thick white mycelial growth develops on the base of the bulb. Numerous sclerotia form on the diseased tissues. This disease usually appears on groups of plants in the field that are often widely spaced. However, large groups of plants may die suddenly when the fungus is abundant in the soil and conditions are favorable for disease.

CONDITIONS FOR DISEASE DEVELOPMENT:

This disease is most severe in cool soils when soil moisture is favorable for root growth. The fungus can survive as sclerotia in the soil for many years and it can over-winter in infected onion debris and in diseased onion sets. Within rows this disease can spread laterally from root system to root system. The fungus is spread by movement of infested soil, infected onion sets and transplants.

Causal Agent:
Sclerotium cepivorum

Distribution:
Worldwide

CONTROL:

White rot is difficult to control. Use healthy sets of plants and avoid introducing infested soil and water into the field. If the disease is just beginning in the field, removing and disposing of infected plants will help reduce the amount of the fungus in the soil. Spot treatments of soil with fumigants or fungicides may provide some control when the disease is limited in the field. Flooding, soil solarization and the use of natural and synthetic sclerotia germination stimulants have been shown to reduce sclerotia populations in the soil, and therefore may reduce losses from this disease.

Localized plant death in the field.

Many small black sclerotia on an infected bulb.

White mycelia and small black sclerotia on mature bulbs.

White mycelia and small black sclerotia on bunching onions.

ROOT-KNOT NEMATODE

SYMPTOMS:

Small, swollen galls 1-2 mm (0.06 in.) in diameter can be found on the roots when infected plants are carefully lifted from the ground and freed from soil particles without damaging the roots. Depending on the species causing infection, the shape of the galls can be round or spindly, and with or without short root branches that rise from the upper part of galls. It is often possible to see white to dark brown egg masses on the surface of the roots. Above ground symptoms may include stunting and yellowing that resembles water and nutrient deficiency and poor or irregular plant stands.

CONDITIONS FOR DISEASE DEVELOPMENT:

Damage is more severe in sandy and muck soils than in clay soils. Temperatures for infection range from 10-35°C (50-95°F). However, *Meloidogyne* spp. are inactive above 40°C (104°F) or below 5°C (41°F). The nematodes are moved within and between fields by irrigation water or cultivation equipment, and can be introduced into fields in vegetative material such as bulbs and transplants.

CONTROL:

Soil fumigation, crop rotation to a non-host or a long fallow period helps to reduce populations of root-knot nematodes.

Causal Agent:
Meloidogyne spp.

Distribution:
Worldwide

Root galls caused by Meloidogyne hapla.

Extensive branching of an infected root system. Healthy plant (left) and infected plant (right).

Stunting of infected plants in the field caused by Meloidogyne hapla.

Seedling root symptoms caused by Meloidogyne chitwoodi.

ASTER YELLOWS

SYMPTOMS:

In bulb crops foliar symptoms begin as yellow and green streaks at the base of young leaves. Affected leaves will flatten and occasionally twist and intertwine. Eventually, entire leaves become yellow. In seed crops the umbel will have a star-burst appearance with elongated pedicels and distorted flowers. Occasionally, small bulbs will form in the flowers instead of seed.

CONDITIONS FOR DISEASE DEVELOPMENT:

The aster yellows phytoplasma is transmitted during feeding by the aster leafhopper, *Macrosteles quadrilineatus*. Conditions that favor succulent plant growth may result in more leafhoppers being attracted to these plants and increase the incidence of this disease.

CONTROL:

This phytoplasma can over-winter in adult leafhoppers, grains, weeds and ornamentals and therefore, a good weed and leafhopper control program can be effective in reducing the incidence of this disease. Isolating onion seed crops from other host crops and weed sources may also be effective.

Foliar symptoms showing yellow and green streaks.

Affected umbel showing elongated pedicels.

Severely affected umbel showing "star-burst" appearance.

Aster yellows affected seed crop showing umbel distortion.

Causal Agent:
The Aster Yellows Phytoplasma
(syn. The Onion Yellows Phytoplasma)

Vector:
The aster leafhopper (*Macrosteles quadrilineatus*), many other species of leafhoppers

Distribution:
Europe, Japan and North America

IRIS YELLOW SPOT

SYMPTOMS:

Infections remain localized and occur where thrips feed, resulting in an uneven distribution of the disease within the plant. Iris yellow spot virus (IYSV) can only be detected in or adjacent to lesions. Infected leaves are generally dull in appearance. Initially, lesions can be irregular to diamond-shaped and chlorotic to bleached white in color. Distinctive, defined borders may or may not develop as lesions elongate. Leaves dieback as lesions enlarge and coalesce. Lesions may completely girdle the scape and cause lodging before seeds mature. Infected onion plants usually produce undersized, asymptomatic bulbs. Infected leek plants are stunted.

CONDITIONS FOR DISEASE DEVELOPMENT:

Onion thrips (*Thrips tabaci*) transmit IYSV in a persistent manner. Disease severity is positively correlated with thrips populations in the field. This virus is not seed transmitted. Over-wintering onions, volunteers from prior productions, infected transplants and alternate hosts can all serve as sources of both vector and virus. Bulb to plant transmission of IYSV has not been demonstrated in bulbs collected from infected plants.

Causal Agent:
Iris yellow spot virus (IYSV)

Vector:
Onion thrips (*Thrips tabaci*)

Distribution:
Worldwide

CONTROL:

All onion and leek varieties are susceptible to IYSV; however some varieties appear less susceptible than others. Many pesticides are available to help manage and control weeds, alternate hosts and the thrips vector. In addition, culled onions from packing operations should immediately be removed from the vicinity of all onion productions to provide further control of the thrips vector.

Developing IYSV lesion.

Uneven distribution of IYSV lesions on scapes.

Irregular to diamond-shaped lesions on leaves.

Numerous IYSV lesions resulting from intense thrips feeding activity.

FREEZE DAMAGE

SYMPTOMS:

Affected seedlings become yellow at or near the soil line when temperatures are below freezing for prolonged periods. Upon freezing and thawing the soft tissues lose their integrity and become translucent and watery in appearance and texture. Freeze damaged scales become a grayish yellow color. Often, individual scales are injured entirely but adjacent inner and outer scales may or may not show freeze damage. The innermost sections of an onion may escape damage. However, the bulb may still be unmarketable.

CONDITIONS FOR DISEASE DEVELOPMENT:

Freezing of onions becomes a problem at temperatures below -2°C (28°F). When soil is repeatedly frozen and thawed the plants can be heaved to the surface of the soil where they die from root damage and desiccation. Bulbs in the ground are less likely to be freeze damaged than those on the soil surface.

CONTROL:

Onion bulbs vary greatly in their ability to tolerate freezing temperature. Onions least tolerant to freezing are usually those lowest in solids such as the Grano types.

Cross-section of a bulb showing water-soaking of freeze-damaged tissue.

Longitudinal-section of a bulb showing water-soaking of freeze-damaged tissue.

Causal Agent:
Environmental

Distribution:
Worldwide

GREENING

SYMPTOMS:

Sunlight causes the formation of chlorophyll in the outer scales, which results in the scales turning green.

CONDITIONS FOR DISEASE DEVELOPMENT:

Excessive or late season nitrogen applications can delay maturity and enhance the greening of onion bulbs. Greening can occur if onion bulbs are exposed to sunlight during the growing season or the bulbs are allowed to cure for extended periods under moderate light.

CONTROL:

An early fertilization program that promotes foliar development can reduce losses from greening at bulb maturity. Avoid excessive and late season nitrogen application. Do not cure bulbs for extended periods in the field.

Green outer bulb scales.

Green outer bulb scales.

Causal Agent:
Sunlight

Distribution:
Worldwide

NUTRIENT DISORDERS

SYMPTOMS:

The following symptoms are indicative of nutritional deficiencies, however, soil and foliar fertilizer analyses should be conducted to verify nutritional needs:

Nitrogen: Deficiencies result in stunted plants with pale green to yellow leaves that dieback from the tips. Also, the foliage tends to be erect and the bulbs are smaller than normal and mature earlier. Excess nitrogen causes rapid plant growth and delays maturity. The bulbs tend to be softer and more susceptible to storage rots.

Phosphorus: Deficiencies result in slow growth, delayed maturity and a high percentage of thick necked bulbs at harvest. Leaves become a dull green color and dieback from the tips without the yellowing associated with nitrogen and potassium deficiencies.

Potassium: Deficiencies result in the foliage initially becoming darker green and the tips of the older leaves begin to wilt, especially on the upper surface. Eventually the leaves droop and take on a satiny progressing to paper-like appearance and develop chlorosis similar to that caused by nitrogen deficiencies.

Magnesium: Deficiencies result in slow plant growth with the older leaves becoming uniformly yellow along their entire length.

Zinc: Deficiencies result in stunted plant growth with noticeable twisting and faint interveinal chlorosis of the leaves. Onions are very sensitive to zinc deficiencies.

Molybdenum: Deficiencies result in poor emergence and seedling death. As the plant grows, leaves will dieback from the tip with a noticeable soft transition zone between the healthy and necrotic tissue. Onions are very sensitive to molybdenum deficiencies.

Manganese: Deficiencies result in slow growth, delayed maturity and a high percentage of thick necked bulbs at harvest. The older leaves develop interveinal chlorosis, which progresses to a tip-burn, and they may curl and eventually become necrotic. Onions are very sensitive to manganese deficiencies.

Boron: Deficiencies result in distorted and stunted plant growth. Leaves become brittle and may turn a gray-green to a blue-green color. Young foliage may be a mottled yellow green while older leaves become chlorotic with tip dieback and sunken areas. Transverse yellow lines that develop into cracking can occur near the base of the leaves.

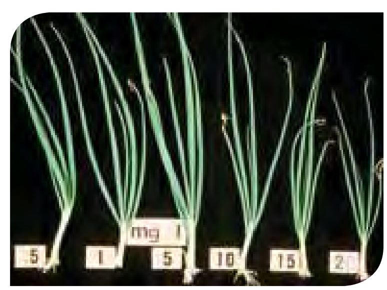
CONDITIONS FOR DISEASE DEVELOPMENT:

Acid or alkaline soils often lead to nutrient deficiencies due to the immobilization of the nutrients. Some soils are naturally low in specific nutrients due to their composition. The excessive, or unbalanced, use of fertilizer may also cause some nutrients to become unavailable to the plants.

CONTROL:

Use a balanced fertilizer program. Soil and foliar nutrient analysis can give valuable information on nutritional deficiencies and excesses. Altering the soil pH and using foliar nutrient sprays can correct some deficiencies.

Nitrogen deficient (left) and healthy (right).



Foliar response to increasing boron concentrations.

Causal Agent:
Insufficient nutrients

Distribution:
Worldwide

SUNSCALD

SYMPTOMS:

Sunscald is primarily a problem on young seedlings and mature bulbs. High soil temperatures damage seedling tissue at the soil line, resulting in shriveling and collapse of plants. On onion bulbs, affected tissue collapses and becomes bleached, soft and slippery. Affected areas dry and shrivel rapidly, and scales eventually become brown and necrotic. Soft rot organisms can invade and decay the bulbs if sun-scalded onions are not dried and cured rapidly.

Affected tissue collapses and becomes bleached in appearance.

CONDITIONS FOR DISEASE DEVELOPMENT:

Direct sun can heat dark soils to temperatures as high as 65°C (149°F) resulting in tissue death at the soil line. Harvesting and curing onions in direct sunlight can result in sunscald on the bulbs.

At the soil line affected tissue shrivels and collapses.

CONTROL:

Sow onion seed to avoid high soil temperatures when seedlings are succulent and most susceptible to sunscald. Onions can be cured in the field only after day-time high temperatures are below 29°C (85°F). If curing is done in the windrows, the tops of one set can be used to cover the bulbs of the previous set.

Causal Agent:
Direct sunlight and high temperatures

Distribution:
Worldwide

THRIPS DAMAGE

SYMPTOMS:

Thrips damage results from the piercing and rasping action of the cone-shaped mouth parts of the insect. At first, tiny, dark green spots appear on the leaf. These spots become white or silver with time and if widespread, can impart a silvery streaked appearance to the leaves, which will appear as a bright sheen in direct sunlight. Severely affected leaf tissues wither and collapse when plants are water stressed. Thrips are most commonly found between the newest growing leaves or in seed heads.

CONDITIONS FOR DISEASE DEVELOPMENT:

Thrips over-winter in bulbs, as larvae or pupae in leaf litter or in the soil and on alternate hosts. The life cycle of these insects from egg to adult can be completed within two weeks. Thrips damage is greatest after periods of hot, dry weather. Cool, rainy weather reduces thrips populations and thrips damage.

CONTROL:

Good crop management and sanitation generally keep thrips damage to a minimum. Healthy leaf tissue will endure thrips feeding better than stressed tissue. *Thrips tabaci* has a wide host range including numerous weed species; thus, weed control in and around an onion crop may reduce thrips levels. Also, cultivation and plowing to eliminate debris near the soil surface will reduce thrips populations. Insecticide control is feasible, however, several applications are usually required and resistance to insecticides has been reported.

Thrips feeding on the leaf surface.

A high population of thrips feeding results in white-silvery spots and streaks on the foliage.

Causal Agent:
Thrips tabaci (the onion thrips),
Frankliniella occidentialis (the western flower thrips) and numerous other species

Distribution:
Worldwide

Cornell Onion Fungicide "Cheat-Sheet" for Leaf Diseases in New York

Compiled by Christy Hoepting, Cornell Cooperative Extension Program, July 2017.

Trade name	Active ingredient	FRAC[1] code	Relative Disease Control Rating[2]			Rotation restrictions	Rate (product/A)	Maximum allowable per season	
			BLB[3]	SLB	DM			Total Amount	No. of max rate apps
Bravo & generics	chlorothalonil	M5	**Best**	Fail	Fail	none	1-3 pt	20 pts	6 (3 pt)
Penncozeb & generics	mancozeb	M3	Fail	Fail	M-G	none	2-3 lb	32 lbs	10 (3 lb)
Rovral & generics	iprodione	E3	M	Fail	Fail	none	1 pt (in tankmix) 1.5 pt (alone)	10 pts (in tank mix) 7.5 pts (alone)	10 (1 pt) 5 (1.5 pt)
Bravo 1.5 pt + Scala 9 fl oz	chlorothalonil pyrimethanil	M5 9	**Best**	M	Fail	none			6
Scala	pyrimethanil	9	M-P	M-P	Fail	none	9*-18 fl oz	54 fl oz	3 (18 fl oz)
Rovral 1 pt + Scala 9 fl oz	iprodione pyrimethanil	E3 9	VG	VG	Fail	none			6
Luna Tranquility	Fluopyram pyrimethanil	7 9	VG	**Best**	Fail	**No more than 2** sequential apps before rotating to non-7 or 9 group fungicides	16-27 fl oz	54.7 fl oz[4]	3 (16 fl oz)
Luna Experience	Fluopyram tebuconazole	7 3	??[5]	**Best?[5]**	Fail	**No more than 2** sequential apps before rotating to non-3 or 7 group fungicides	12.8 fl oz	25.6 fl oz[4]	2 (12.8 fl oz)
Merivon	fluxapyroxad + pyraclostrobin	7 11	VG	**Best**	M	**No more than 2** sequential apps before rotating to non-7 or 11 group fungicides	5.5-11 fl oz	33 fl oz 3 apps	3 (11 fl oz)
Quadris Top	azoxystrobin + difenoconazole	11 3	Fail	VG	M-G	**No more than 1** application before rotating to non-11 or 3 group fungicides	12-14 fl oz	56 fl oz[4]	4 (14 fl oz)
Inspire Super	difenoconazole + cyprodinil	3 9	M	VG	Fail	**No more than 2** sequential apps before rotating to non-3 or 9 group fungicides	16-20 fl oz	80 fl oz[4]	4 (20 fl oz)
Endura	boscolid	7	M	VG	Fail	**No more than 2** sequential apps before rotating to non-7 group fungicides	6.8 oz	41 oz 6 apps	6 (6.8 oz)

Trade name	Active ingredient	FRAC[1] code	Relative Disease Control Rating[2]			Rotation restrictions	Rate (product/A)	Maximum allowable per season	
			BLB[3]	SLB	DM			Total Amount	No. of max rate apps
Tilt & generics	propiconazole	3	M	VG	Fail	none	4-8 fl oz (alone) 2-4 fl oz (in tank mix)	16 fl oz	2 (8 fl oz) 4 (4 fl oz)
Viathon	Phosphorous acid tebuconazole	33 3	M?	VG	M	none	2-3 pt	6 pt	2 (3 pt)
Quadris	azoxystrobin	11	Fail	Fail[6]	M	**No more than 1** application before rotating to non-11 group fungicides	9-15.5 fl oz	92.3 fl oz	6-8 11-15 fl oz
Cabrio	pyraclostrobin	11	Fail	Fail[6]	M	**No more than 1** application before rotating to non-11 group fungicides	8-12 fl oz	72 fl oz	6 (12 fl oz)
Ridomil Gold Bravo	Mefanoxam chlorothalonil	4 M5	M	Fail	**Best**	none	2.5 pt	12.5 pt	5 (2.5 pt)
Tanos	Cymoxanil famoxadone	27 11	??[5]	??[5]	M	**No more than 1** application before rotating to non-11 group fungicides	8 oz	84 oz	10 (8 oz)
Zampro	Dimethomorph ametostradin	40 45	Fail	Fail	M	**No more than 2** sequential applications	14 fl oz	42 fl oz	3 (14 fl oz)
Revus	mandipropamid	40	Fail	Fail	M	**No more than 2** sequential application before rotating to non-40 group fungicides	8 fl oz	32 fl oz	4 (8 fl oz)
Omega	fluazinam	29	??[5]	M-P	M-P	None: Do not use with adjuvant	1 pt	6 pt	6 (1 pt)
Gavel	zoxamide mancozeb	22 M3	??	P	M	None: Do not contact exposed bulbs	1.5-2 lb	16 lb	6 apps
Rampart, etc.	Phosphorous acid	33	Fail	Fail	M	none	1-3 qt		
Switch	Cyprodinil fludioxinil	9 12	P	P	Fail	**No more than 2** sequential application before rotating to non-40 group fungicides	11-14 oz	56 oz	4 (14 oz)

[1]**FRAC:** Fungicide Resistance Action Committee Chemical class code. [2]**Relative disease control ratings** are based on fungicide trials, 2006-2013 (Hoepting *et. al*). SLB trialed 2013-2015. **Best:** best (or one of the best) of all fungicides tested; **VG:** very good; **G:** good; **M:** mediocre/middle of the pack; **P:** poor; **Fail:** failed to control disease, not different than untreated control. **inconsistent results showing range of results across trials. **??**: No trial data by Hoepting. [3]**BLB:** Botrytis Leaf Blight; **SLB:** Stemphylium Leaf Blight; **DM:** Downy mildew. [4]**Maximum allowable limit of active ingredient per acre per season:** pyrimethanil – 2.1 lb (= 0.024 lb/fl oz Luna Tranquility; = 0.039 lb/fl oz Scala); difenoconazole – 0.46 lb (= 0.0057 lb/fl Inspire Super; = 0.0082 lb/fl oz Quadris Top); fluopyram – 0.446 lb (= 0.013 lb/fl oz Luna Experience; = 0.008 lb/fl oz in Luna Tranquility); tebuconazole – 0.335 lb (= 0.013 lb/fl Luna Experience; = 0.003 lb/fl oz Viathon). [5]?Not tested in Cornell trials. Expect FRAC 3 & 7 to be very good on SLB. [6]SLB has been found to be resistant to FRAC 11 fungicides in New York. For more information on relative performance of fungicides for management of leaf diseases in onions, visit the Cornel Vegetable Program website http://cvp.cce.cornell.edu/.

Timing Onion Sprout Inhibitor Application and Managing Black Mold
Ethan Grundberg

Properly timing the application of Royal MH-30 (*maleic hydrazide*) sprout inhibitor is equal parts art and science. Here are some tips on how to make the most of your inhibitor:

- In general, sprout inhibitor should be sprayed once onions are fully mature (a good rule of thumb is that about 50% of onion tops should be down) on storage varieties that will be kept past November.
- Spraying inhibitor before bulbs are fully mature can result in loose and spongy bulbs that are unmarketable and more prone to mold and rot in storage.
- However, waiting too long is equally problematic. Onions should still have 5-8 green leaves per bulb in order to provide enough living tissue for the inhibitor to be absorbed and translocated to the bulb. If fewer than 5 leaves remain green or if plants have severe foliar disease pressure, there is a serious risk that the maleic hydrazide will not be taken up by the plant.
- Sprout inhibitor is not a silver bullet for guaranteeing good storage, either. If MH-30 is sprayed more than two weeks in advance of harvest and the bulbs are exposed to temperature extremes and rain in the field, bulbs may be triggered to break dormancy regardless of inhibitor application and uptake.
- Care must be taken to avoid applying inhibitors at temperatures above 85 degrees. Given the weather forecast for the next several weeks, it does not appear that high temperatures should be a concern, but check the forecast before making the decision to apply!
- Sprout inhibitor will not magically make a sweet onion store as well as a storage variety. Applications should only be made to varieties that are bred for long-term storage.

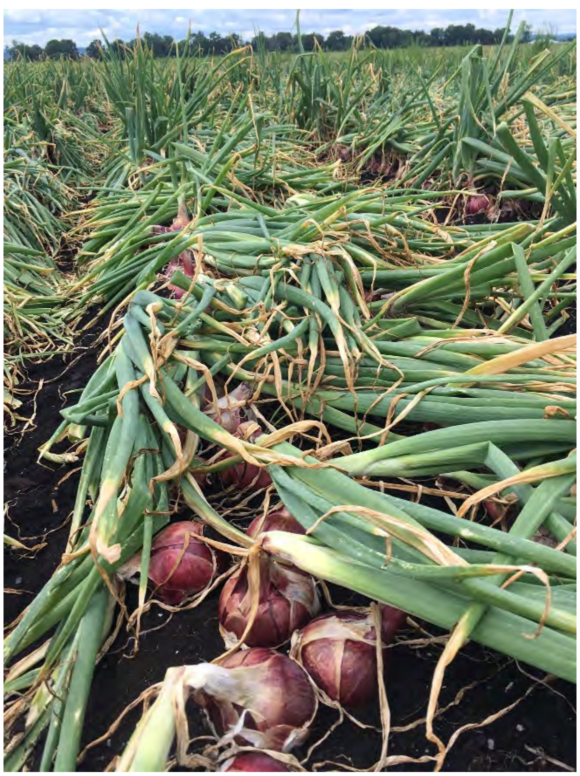
One final consideration on sprout inhibitor application timing: studies have repeatedly demonstrated that bulb onions size up significantly in the last month prior to 100% falling over. One study by Davis and Jones showed that yields per acre increased by 10,500 pounds/acre in the time from 10% tops down to 100% tops down. However, other studies have shown that, in order to achieve maximum storage life, harvest should be timed around 40% lodge. So, depending upon your goals (maximum yield or maximum storage life) the timing of your inhibitor application and harvest may vary slightly.

Another question that often arises when discussing inhibitor application is whether to tank mix it with any adjuvants or fungicides. To answer the first question on adjuvants, the Royal MH-30 clearly states NOT to mix inhibitor with any adjuvants for onions grown east of the Rocky Mountains. The arid conditions of western grown onions at harvest often accelerates leaf dry down and requires the addition of a non-ionic surfactant to be added to facilitate absorption and translocation by the onions. However, the issue of whether to apply with a fungicide is more complicated. MH-30 is compatible with most fungicides, but it is recommended NOT to tank mix them. Growers also need to consider the mode of action of the fungicide being sprayed; inhibitor is formulated to penetrate the cuticle and move around the plant, so fungicides like copper and chlorothalonil that are effect on the leaf surface as protectants don't make sense to use with MH-30. Growers also need to assess the percentage of leaves that are still green, too. If leaves are mostly dry, they will not benefit from another foliar fungicide application.

What about late season fungicide applications for black mold (*Aspergillus niger*)? Multiple field experiments conducted both by Cornell and University of Georgia faculty have shown that **there is no statistically significant improvement in black mold reduction from late season fungicide applications once leaves have dried**. The same studies have, however, concluded that in-season foliar fungicide programs that are targeted to manage other foliar diseases (botrytis, stemphylium, and purple blotch) **DO** reduce the incidence of black mold in storage. Those interested in more detail on these trials should refer to the research done by Hunt Sanders et al in 2013-14 starting on page 37 at https://secure.caes.uga.edu/extension/publications/files/pdf/AP%20114_1.PDF.

So if late season fungicide applications don't reduce the presence of black mold on onions, what will?

- As already mentioned, keeping up with an effective foliar fungicide spray program in season
- Ensuring the onions are fully mature and dry at harvest, which can be facilitated by deeper undercutting early in the harvest process or lifting later in the season once sunburn is less of a concern
- Minimizing bruising and physical injury to onions during the harvest process
- Most importantly, focusing on creating the ideal post-harvest curing and storage conditions! Ideal curing conditions are 75°F-80°F at 70% humidity for about 2 weeks. Once curing is complete, both temperature and humidity should be gradually lowered to near 33°F and 50%, respectively. Since black mold thrives at temperatures above 60°F and at relative humidity of 80% and higher, hot and humid storage and curing conditions create a prime environment for it to grow.



Onions about 15% down and still not ready for inhibitor

Onions about 60% down, but still with adequate green foliage for a well-timed inhibitor application

Organic Garlic Fertility Trial Results

Introduction: Rates and timing of fertility applications on garlic vary greatly due to a lack of definitive recommendations. Nitrogen needs are of particular interest because of the concern that mistimed nitrogen applications will not be available to the garlic when it needs it. This study focused on finding the nitrogen levels that optimize yield and determining what percent of nitrogen should be applied in the spring versus in the fall.

About the trials: Three organic farms on Long Island, in the Hudson Valley, and in the Mohawk Valley Region were selected for trialing. The soils on these farms ranged from sandy to gravelly loam with a high organic matter content. Soil tests were taken using Agro-One testing laboratory in September of 2012 to guide fertility recommendations. Fertilizer was then applied to thirty-foot plots as a banded application in-furrow at planting. Phosphorus and potassium were both brought to the optimal levels as indicated by the soil tests and based on current recommendations (Table 1), and nitrogen was applied at 6 different levels (Table 2). Nitrogen recommendations were reduced based on the percent organic matter in the soil. Recommendations were reduced by 10 lbs/A for every percentage of organic matter in the soil.

Table 1: Phosphorus and Potassium recommendations for garlic. These nutrients are always applied before planting.

Garlic	Phosphorus (P2O5) Lbs/A					Potassium (K2O) Lbs/A				
Soil Test Results	**Very low <3lbs/A**	**Low 3-6**	**Medium 7-13**	**High 14-40**	**Very High >40**	**Very low <50**	**Low 51-100**	**Medium 101-200**	**High 201-300**	**Very High >300**
Incorporate at planting	200	150	100	50	0	200	150	100	50	0
TOTAL	150	100	75	50	0	150	100	75	50	0

Table 2: Six treatments were applied to the garlic, in 30 foot blocks replicated twice. N levels were reduced based on organic matter.

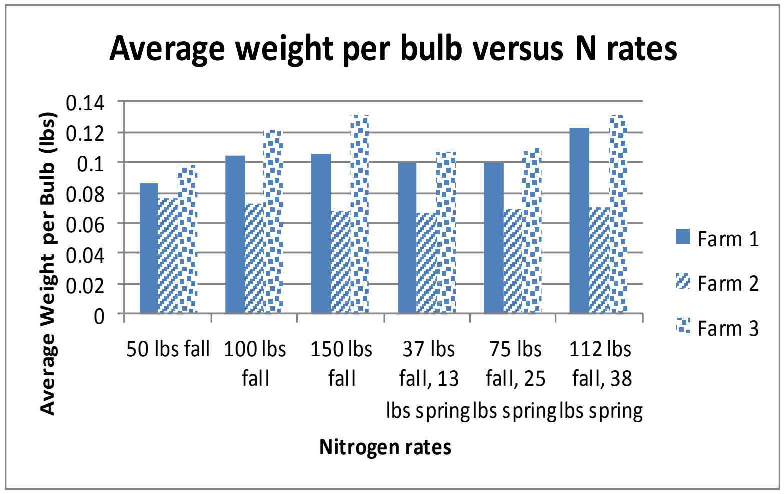
50 lbs total Nitrogen	**100 lbs total Nitrogen**	**150 lbs total Nitrogen**
All fall	All fall	All fall
75% fall, 25% spring	75% fall, 25% spring	75% fall, 25% spring

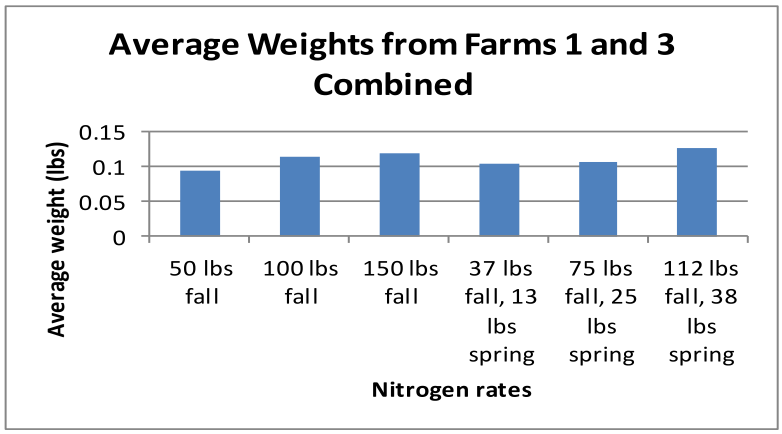
Slow release forms of nitrogen including alfalfa meal and pelletized chicken manure were applied in the fall. All nitrogen applied in the spring was in the form of fish emulsion, which was considered quick release. Care was taken not to fertilize excessively with phosphorus or potassium in order to reach optimal nitrogen levels. For example, pelletized chicken manure might supply half the needed nitrogen, but once phosphorus was optimized the remainder of the nitrogen was applied as alfalfa meal.

Existing recommended call for splitting the spring nitrogen applications. However, research by Angela O'Callaghan indicates that splitting the application does not increase yields. Therefore, we applied spring nitrogen in one application, as close to when garlic begins growing as possible.

Results:

Two of the farms showed clear trends related to the fertility treatments: Farms 1 and 3. Farm 2 did not show clear trends, which might be explained by the high weed pressure on this farm. The weeds might have both consumed most of the nitrogen and competed with the garlic, suppressing yields. When this farm is removed from the data, it becomes clear that 50 lbs of nitrogen is not enough to maximize yield, regardless of timing. What is not as clear is what the effects of timing and rates are once we jump to 100 lbs of nitrogen. According to the data, 100 lbs of fall nitrogen leads to better yields than 100 lbs of nitrogen split between the fall and spring. 150 lbs of nitrogen yields better than 100 lbs both in the fall and as a split application, but the difference is fairly small—if a grower produced 1000 pounds of garlic using the 100 lbs of N in the fall rate compared to the 150 lbs of N in the fall rate, he or she would only increase yield by about 50 lbs, or 5%. Comparing the 100 lb rate to the 150 lb rate with a split application increases the yield gain to 139 lbs, or about 14%.





Discussion: Although it is clear that more work needs to be done to determine the best relatively high rate of nitrogen to use to maximize garlic yield, it is clear that applying at least 100 lbs of nitrogen is necessary to maximize yield. Whether all of the nitrogen is applied in the fall or some is held back until the spring is a question we will continue to examine. In the mean time, growers are encouraged to look at their cropping systems and make decisions based on the expense of additional nitrogen application in the spring versus the possible returns. If a spring nitrogen application is relatively easy to accomplish through drip or by side-dressing, I would not hesitate to split the nitrogen application. If making a spring application is extremely difficult, using a higher fall application rate can nearly make up the difference. To make your own complete comparisons, please see Table 3, which has the average weight bulbs from each treatment, averaged over the trials at farms 1 and 3.

Table 3: The average weight per bulbs averaged over trials 1 and 3

Treatment	Average Weight
50 lbs fall	0.093
100 lbs fall	0.113
150 lbs fall	0.119
37 lbs fall, 13 lbs spring	0.104
75 lbs fall, 25 lbs spring	0.105
112 lbs fall, 38 lbs spring	0.127

NORTHEAST SARE Sustainable Agriculture Research & Education

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Cornell University
Cooperative Extension

Garlic Post-Harvest Study

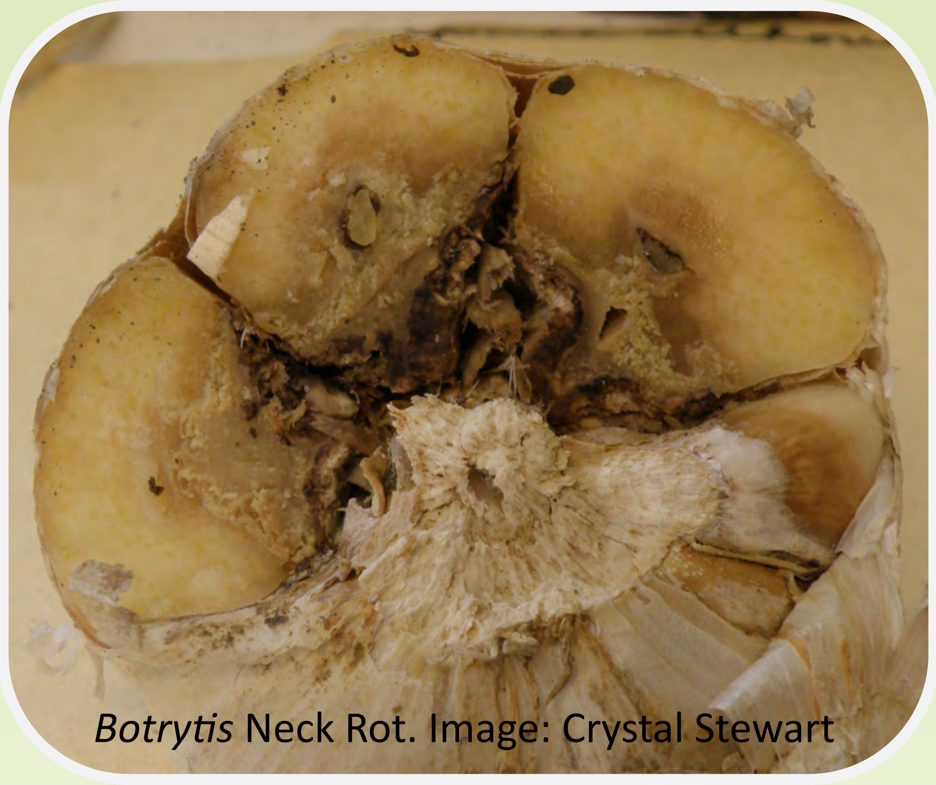
Year Two

Garlic is a 20 million dollar industry in New York, and it represents an important and growing niche crop across the Northeast. As production continues to expand it is increasingly important for growers to use the most effective methods to grow, dry, and store garlic in order to maximize quality. The results of this two-year study provide insights into which practices yield the best results.

Aspergillus (black mold) Image: Crystal Stewart

Embellisia Image: Crystal Stewart

Diseases such as Botrytis neck rot, Penicillium, and surface molds such as Embellisia Skin Blotch and Aspergillus are common in curing areas with variable moisture, such as barns and sheds. Effects of poor post-harvest treatment can be devastating. The simplest way to address issues with post-harvest diseases is to change the environment where garlic is cured. Based on the research available and consultation with the Garlic Seed Foundation, a series of treatments were developed to test this hypothesis:



Botrytis Neck Rot. Image: Crystal Stewart

Fusarium Basal Rot Image: Crystal Stewart

Hypothesis: Optimizing post-harvest handling of garlic will reduce post-harvest loss and improve seed stock.

Treatments used to test hypothesis:

A	Trim Roots flush with basal plate
B	Trim tops to 1.5” long
C	Trim tops to 6” long
D	Trim tops 10” long
E	Cure in High Tunnel
F	Cure in open-air structure
G	Leave Roots and tops un-cut

Treatments were applied either at harvest or as garlic was brought into the drying areas. Each treatment was replicated three times on either 30 bulbs or on set number of row feet. All top cutting treatments had the roots intact. Root pruned garlic was top pruned to the farm default height (approximately 6 inches on two farms; uncut on a third farm). All treatments were placed both in open air sheds and in the high tunnel.

Materials & Methods

Three farms were included in year two of the post-harvest study; one in the Hudson Valley and two in the Mohawk Valley Region. Based on last year's results, the washing treatment was removed from this year's trials and garlic stems were cut at three lengths: 1.5 inches, 6 inches, and 10 inches. Additional treatments were the same as in year one, and are detailed below. This year bulbs were selected for relative uniformity of size to reduce sample variation. Each treatment contained 30 bulbs and was replicated three times per farm.

A. Root Pruning. Roots were cut shortly after harvest using shears. Care was taken not to damage the basal plate.

B. Top cutting at 6-10 inches: Garlic was cut with shears or a sickle-bar mower to a height of 6 or ten inches. Garlic was re-cut when cleaned and weighed.

C. Top cutting at 1.5 inches: Garlic was cut with a pruning shear to 1.5 inches from the top of the bulb. This treatment was added to see if the garlic could be cut just once before sale to reduce the amount of labor used.

D. Curing in high tunnels: Garlic was moved to high tunnels immediately after other treatments were completed. All high tunnels had a shade cloth and were ventilated with fans, preventing temperatures from exceeding 110 degrees F.

E. Open-Air Curing: These treatments were placed in solid but well-ventilated buildings such as barns and sheds to dry without supplemental heat from the sun.

F. **Leaves roots and tops uncut:** Garlic was left completely uncut in this treatment. It was spread out on drying racks to leave space for the bulbs to be one layer deep or it was tied into bundles of 6-10 and hung.

About High Tunnel Drying

The high tunnel drying temperatures for this year were maintained as close to 110° F as possible during the day. Temperatures were at times lower due to cloudy conditions or to accommodate workers. When temperatures exceeded 110° F tunnels were vented using roll-up sides or built in ventilation fans. It is important that garlic never be allowed to exceed 121°F, the temperature at which waxy breakdown is initiated. Growers took care not to approach this temperature.

Even when not externally vented, both high tunnel drying systems included internal fans to move air throughout the tunnel, keeping temperature and humidity relatively uniform. Night time temperatures were the same as external temperatures. Both growers who used high tunnels closed up the structures at night to exclude humidity. Both also employed dehumidifiers at night in the high tunnels.

Both high tunnel drying systems used shade cloths to regulate temperature and to protect the garlic. One to two layers of shade cloth were used to cover the parts of the high tunnel which contained garlic. Sun damage was not observed in either tunnel.

Results

High Tunnel vs. Open Air: Across six trials conducted over two years, high tunnels consistently dried garlic more quickly (by an average of 3 days); yielded garlic with less Aspergillus, Botrytis, and Embellisia; and importantly high tunnels never damaged any of the garlic that was dried in them. The addition of dehumidifiers at night in the closed high tunnels removed an additional 10-15 gallons of water from the air each night, further speeding the drying process. *Image: Botrytis porri on garlic from open-air shed drying system.*

Tops trimmed vs. tops untrimmed: Trimming the tops mechanically in the field greatly increased the speed of harvest and reduced the space needed for drying. Top trimming did not have a significant effect on disease incidence in cured bulbs, but in year one there were differences in bulb weight at two of the farms, with un-cut bulbs being slightly heavier (Table 1). During year two this weight difference was not observed (Table 2). The selection of relatively uniform starting bulbs may have reduced variability in year two and yielded more reliable results.

Table 1: Bulb weight comparison from year one-tops cut at 6 inches

Treatment	Average weight/ head	Count
Cut at 6”	0.113	1036
Uncut	0.130	972

Table 2: Bulb weight comparison from year two—more cutting lengths are included

Treatment	Weight/bulb	Count	Average weight/head
10 inch	24.4	206	0.118
1.5 inch	23.7	183	0.129
6 inch	22.7	186	0.122
Uncut	39.4	302	0.130

Roots trimmed vs. roots untrimmed: No statistically significant differences were observed between these treatments in regards to bulb quality, weight, or disease incidence. Roots can be pruned any time during the drying process.

Washed vs. unwashed: Washed garlic looked very good initially, but became more discolored than the unwashed garlic during the drying and curing process. Most discoloration could be removed by removing 1-3 wrapper leaves, but this extra step is time consuming. Disease incidence, particularly Aspergillus and Embellisia, was slightly higher in washed garlic. This treatment was not repeated in year two due to the lack of benefits.

Images, from left to right: root and stem pruning treatments arranged in an open air drying system, 10-inch stem-pruned garlic dried in a high-tunnel, a bulb with slightly loose wrapper leaves and a small amount of fungal infection within the scape stem from an open air drying system, and a pair of razor blade anvil pruners, the preferred tool for both root and stem pruning.

Next Steps:

The next step in maximizing post-harvest handling is the examination of longer-term storage conditions to determine optimum temperature and humidity ranges to maintain dried garlic weight while minimizing disease incidence.

For more information on this study please contact:

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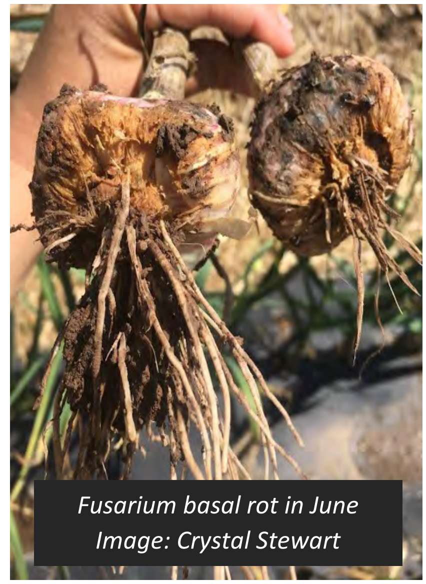
Effects of Growing Techniques on Yield, Grade, and Fusarium Infestation Levels in Garlic

By Crystal Stewart, Eastern NY Commercial Horticulture Program and Robert Hadad, Cornell Vegetable Program



Fusarium basal rot in June
Image: Crystal Stewart

Fusarium Bulb Rot
Image: Crystal Stewart

Background: Almost every garlic grower struggles to a greater or lesser extent with Fusarium diseases, which are naturally found in most soils. Two primary Fusarium diseases historically concern garlic growers: Fusarium Bulb Rot, caused by *F. proliferatum ,* causes brown to reddish sunken lesions on the bulb surface; and Fusarium Basal Rot, caused by organisms *F. culmorum,* causes the basal plate and gradually the entire bulb to break down. Because the diseases are nearly almost always present, the focus for growers and researchers alike is on management rather than eradication.

Fusarium diseases tend to be worse in fields with poor drainage, but we were unsure of the impact that other techniques such as the use of straw mulch or black plastic might have on Fusarium levels.

We decided to trial different common and novel techniques growers use to cultivate garlic and track both the levels of Fusarium and the quality of the garlic in each approach. We separated the work into two sets of trials: one focusing on cultural changes such as variety selection, raised beds and mulches; and another focusing on inputs that growers can use to affect disease levels such as fertility and organic soil or bulb treatments. The trial including raised beds and mulches was located in the Hudson Valley and replicated in western New York, while the trial looking at inputs was located on Long Island and replicated in western New York.

During the growing season, each of the treatments was monitored for disease development as the garlic grew. Diseased garlic was sent to a Cornell lab in Geneva, NY where the Fusarium was genetically tested to see if the disease is always the same, or if there are different species or pathovars of Fusarium in different locations or situations.

In July the garlic was harvested in all four sites and brought to high tunnels to be dried. When it was dry, all the garlic was cleaned, roots and tops were trimmed, and it was graded into small (less than 1.5 inches in diameter), medium (1.5 to two inch diameter) and large (greater than two inch diameter) categories.

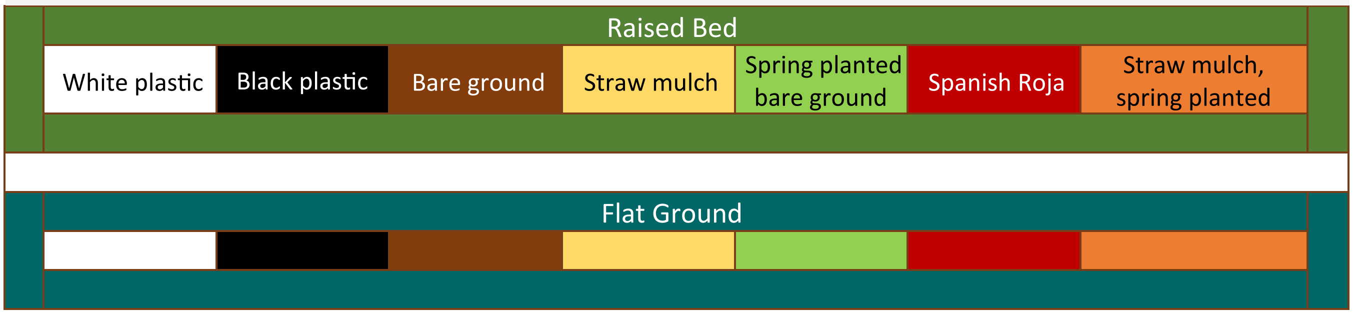
Samples of each treatment were kept in storage and are being assessed during the winter of 2017/18 to determine if Fusarium severity varied by treatment. Ten randomly selected cloves from ten different bulbs were rated for percent of total surface area infested with Fusarium.

This report will focus on the techniques and results used in the cultural controls trials. The results of the nitrogen fertility and organic controls will be discussed in a separate report.

Trial Overview: the cultural controls trial included 9 different treatments, which are listed below. Two of the treatments, raised beds and flat ground, were blocked (not randomized) because of the difficulty of switching between raised beds and flat ground in one row. One row of the trial was a 4-inch raised bed, the other was flat ground. The other seven treatments were randomly replicated three times within the rows. Each treatment was twenty feet long, with a small buffer between treatments.

Fall planted garlic was planted in Mid-October, and spring planted garlic was planted in April. All garlic was harvested in mid July. Many of the treatments were also chosen for their excellent weed control. The bare ground treatments were regularly hand weeded so that weed pressure would not interfere with the results of the trial.

Map of the first of three replications of the garlic treatments. Following replications in the same row were randomized.



Bare Ground cultivation of garlic is common because it allows for mechanical weed control as well as side-dressing nitrogen in the spring. Mechanical weed control is very time sensitive, so growers need to be quite attentive to keep weeds from competing with the crop. In a field with high weed pressure, up to 6 cultivations may be necessary for weed control.

An additional consideration in growing garlic in a bare ground system is that the soil becomes more compacted than in a system with straw or plastic mulch.

Straw Mulch is commonly used in organic garlic production where all fertility is applied in the fall, at planting. Straw mulch can help protect garlic from freezing and thawing in the winter and spring, can moderate soil moisture and temperature, and can suppress annual weed growth. It also reduces soil compaction and contributes to soil organic matter and soil health.

Concerns about using straw mulch focus on two main issues: the potential for mulch to hold too much moisture in wet years and contribute to fungal disease issues (Fusarium); and weed control failures, which can lead to increased labor weeding compared to bare ground mechanical cultivation. We were careful to use weed-free straw, applied at about 5 inches deep in fall which compressed to 2.5 inches deep after the winter.

Black Plastic is used as another option for weed control. Moisture levels under black plastic tend to stay relatively constant, because not much rainfall makes it under the plastic and because evaporation is minimized. Black plastic also warms the soil more quickly in the spring, encouraging earlier top growth than straw mulch or bare ground systems.

There are two primary concerns that growers have about black plastic. The primary concern is that it can actually get too hot under black plastic during the growing season, restricting garlic sizing in late June and early July. The second concern is that plastic can shed snow during the winter, leaving garlic more exposed to winter injury than in other growing systems. A third concern is that in very dry years, it may be necessary to irrigate garlic under plastic, which necessitates the use of drip tape.

White plastic has similar properties to black plastic related to weed control and moisture moderation. However, because it reflects light rather than absorbing it, it keeps the soil cooler rather than warming it. This reflective property might also provide more light to the garlic. White plastic has typically been used in brassica production during parts of the growing season, but has not traditionally been used in garlic production.

White plastic may shed snow during the winter similarly to black plastic, which was a concern with this treatment as well. The effect that temperature moderation would have on early growth was a question mark with this treatment, as was the cooler soil temperature during the summer.

Variety selection plays a role in disease susceptibility and adaptability to various environments. For this trial, we selected two varieties grown by the majority of garlic growers: a Porcelain variety (German White) as our primary, and a Rocambole (Spanish Roja) as a treatment for comparison.

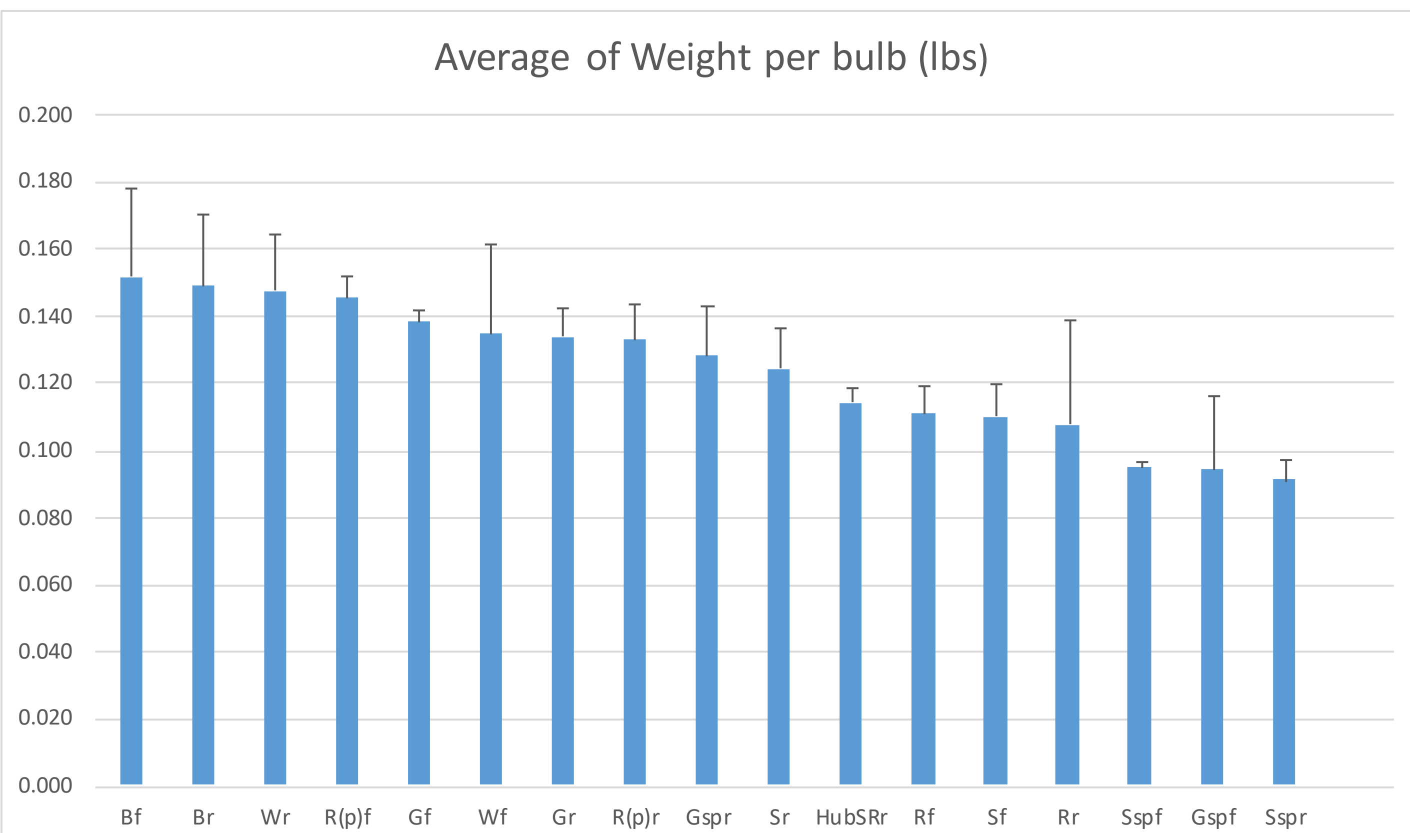
Porcelain varieties are very vigorous and perform well under most growing conditions; Rocambole varieties are often considered to have better flavor but seem more susceptible to disease under many conditions.

Spring planting of garlic is something that growers tend to avoid if possible, but occasionally we are asked if it is possible to do. We also wanted to know if winter injury is contributing to Fusarium levels on garlic. For this trial we cracked seed at planting time and then stored it in a standard refrigerator at 40 degrees F over the winter. As soon as the ground was thawed in the spring, we planted garlic into bare ground and straw mulch.

Cultural Control Trial Results:

After harvest, garlic from both the Hudson Valley and Western NY trials was dried at the Hudson Valley Farm Hub, in high tunnels. Each of the plots was kept in enough separate bags to allow for good airflow for optimum drying. All treatments had their tops clipped in the field at approximately 4 inches. When the garlic was dried, determined by the innermost wrapper leaf being dry to the touch, the marketable bulb and cull counts and weights were recorded by plot. Data analysis was based on the average weight per bulb, as well as by the size distribution. The average weight per bulb was used rather than weight per plot because some of the plots were damaged by factors not considered part of the trial, such as crows picking garlic from the mulched sections. This damage changed bulb number per plot.

The average weight per bulb metric showed black plastic providing the highest yield, followed by white plastic, bare ground, and then straw. Not surprisingly, spring planted garlic had the lowest yields.



While there are numerical differences between the treatments, only the black flat ground treatment was significantly different. White plastic (raised and flat), bare ground, and black raised were all statistically indistinguishable, and straw mulch and Spanish Roja were statistically indistinguishable from white plastic and bare ground. Only spring planted garlic was significantly smaller than all other treatments.

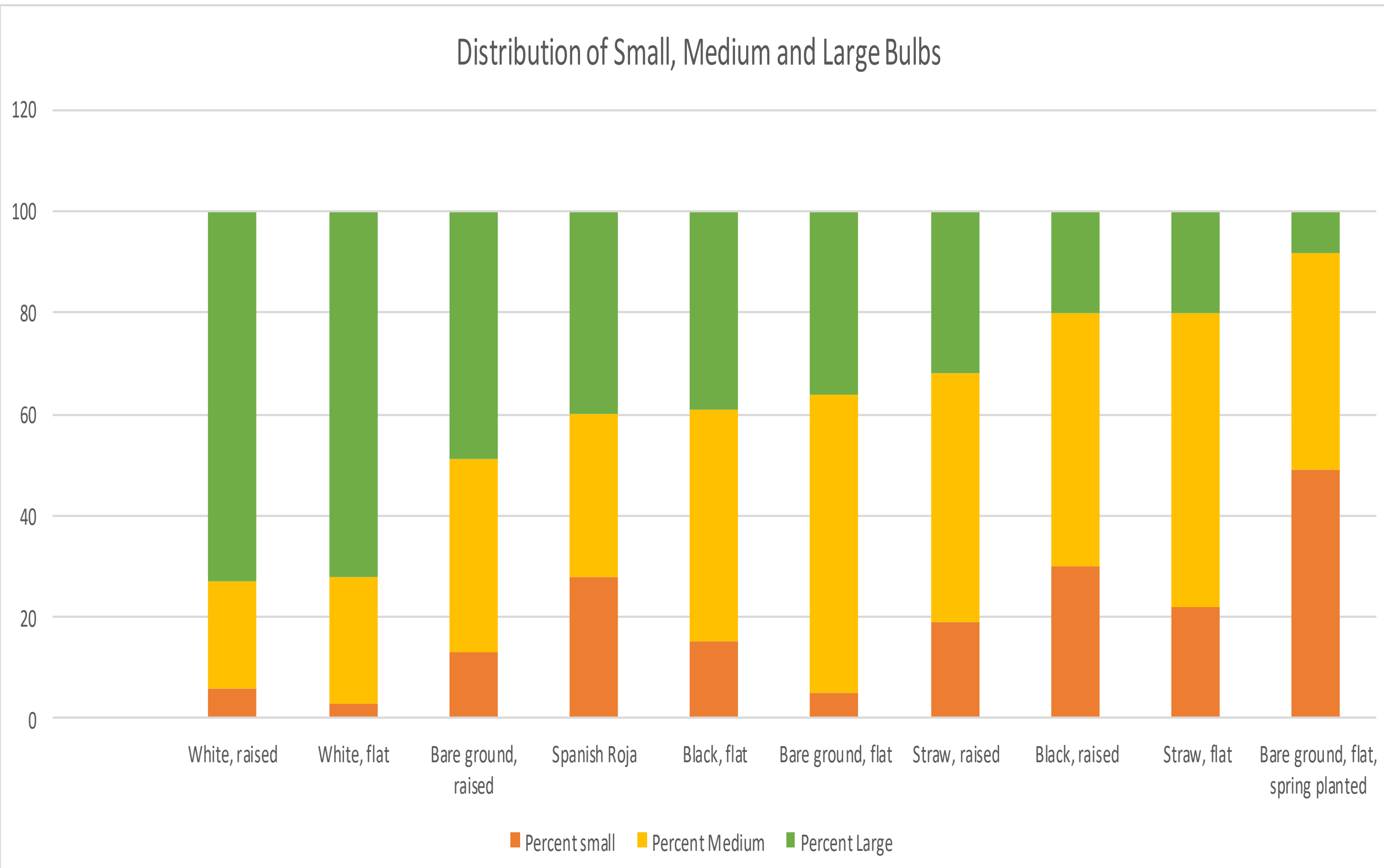
Besides total yield, we also examined the distribution of small, medium and large bulbs.

Small Bulbs: 1.5 inches or smaller

Medium Bulbs: 1.5-2 inches

Large Bulbs: 2 inches or larger

White plastic mulch yielded the highest percentage of large bulbs on both flat ground and raised beds. Spanish Roja had the most even distribution of small, medium and large bulbs. Black plastic, raised beds, and straw mulched garlic all yielded more medium bulbs than the white plastic. Not surprisingly, the spring planted garlic yielded the most small bulbs.



Next Steps in 2018…

The final pieces of data to analyze from this trial are the Fusarium ratings, which are happening now. This information will be available on the website and in the newsletter by the end of February.

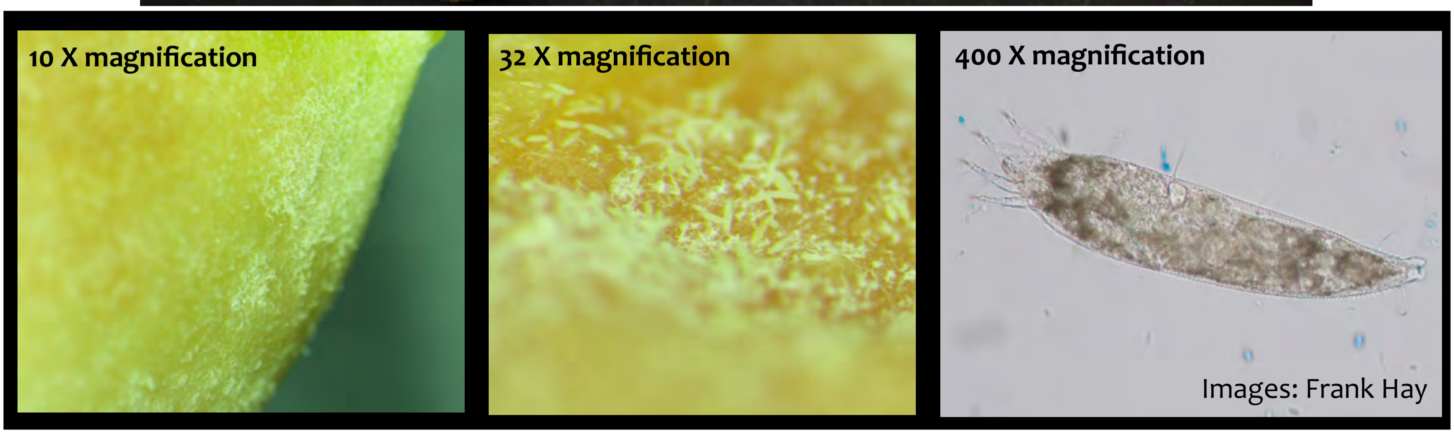
The trial is being replicated in 2018 in Eastern and Western New York. We have eliminated the spring planted garlic due to the obvious yield suppression of spring planting. This year we are paying close attention to the effects of winter on garlic quality, and have begun qualitative assessments of field conditions of garlic as it sprouts. We are documenting winter injury, field conditions which may negatively affect garlic such as winter flooding, and winter predation/disease pressure.

After data is collected this summer we will compare results across the two years and two locations, and verify or adjust the information reported during 2017.

Eriophyid Mites: Micro-Scourge of Garlic

We've been getting a lot of calls from growers remarking that their garlic just isn't holding up the way it should this season. Cloves are drying out and discoloring much earlier than would be expected. Dr. Frank Hay at the Geneva Experiment station popped some of this suspect garlic under a microscope and found some very unwelcomed visitors: Eriophyid mites. These mites are small. I mean really small. Hugely small! Invisible to the naked eye, and unrecognizable under a hand lens. Only at 32x magnification do we start to see them clearly, but honestly you might not want to. I will show you anyway:


Peeled suspicious cloves. Image: Frank Hay



Images: Frank Hay

Yikes! This was not what I was expecting to see on the surface of those desiccated cloves. Yet as I started digging with the help of our dedicated entomologists, it became clear that this is an issue we as an industry have been dealing with for a while. We may not have been seeing the mites, but we have been seeing their symptoms, and writing them off as poorly cured garlic in storage and as environmental stress/viruses in the field.

Examination of the symptoms:

Garlic can degrade in storage for a variety of reasons. Poor post-harvest handling, sub-optimal storage conditions (too warm, too wet, etc), and high disease pressure can all play roles in garlic storing poorly. To determine which of these issues affects your garlic, peel 10-15 cloves and examine them closely. One way to differentiate mite damage from other issues, particularly if you are having issues shortly after garlic enters storage, is to look for a dull surface to cloves as opposed to a shiny surface. The mites rasp at the surface of the clove, and are themselves dusty looking on the surface. From here, find the highest magnification hand lens you can to look at the surface, and look for what look like very, very small thrips. Or you can send samples to the diagnostic clinic to have the presence or absence of mites verified.

In the field, mite damage can be seen early in the growing season as stunted, twisted growth with streaking (Lange and Mann, 1960). Notably, the plants tend to out-grow this damage. The first few leaves may emerge stunted and twisted, but later growth may appear fine.

Control Measures:

There are two methods of control of Eriophyid mites which show promise. The first, which comes from Oregon State (Jepson and Putnam, 2008), is to soak seed stock for 24 hours immediately prior to planting in a 2% soap and 2% mineral oil water bath. I'd recommend this as a control if you detect an issue prior to planting, but after drying the garlic.

A second control measure is heating the garlic to between 113° and 119° F briefly during the drying process. At 113° mite eggs are killed within an hour (Courtin et al, 2000). This process should be done with great attention to prevent bulbs reaching the temperature of 120°, at which point waxy breakdown occurs. Bringing garlic to this temperature while monitoring the crop, then dropping back to between 100° and 110° for the remainder of drying should yield good control and maintain crop quality. Check for mites before putting the garlic into storage, to determine storage protocol.

If mites are detected in garlic which is being kept for consumption rather than planting, the best method to stop population increase is to store the garlic cold. Maximum population growth occurs at 77° and 80-95% RH (note, this temperature would be considered fine for most other storage considerations, so if you have a mite issue, storage as usual will not work). As the temperature drops from here, reproduction slows, stopping at 43°. Hence, a moderate infestation could be held static by storing garlic at 43° or lower. If you store cool to cold, remember that the garlic is being vernalized, and will sprout if brought to warmer temperatures. Keep it cold until its being sold or distributed.

Additional best practices can help to reduce mite pressure over time. Mites may reside in the soil, so make sure to practice crop rotation(as a general rule a 3 year rotation is good; 4 is better). Periods of field saturation can greatly reduce mite numbers, so the wet fall and winters we have been having could actually play in our favor.

This pest will be receiving additional attention over the coming years, with more control recommendations being evaluated, including rotations and chemical controls (organic and conventional), as well as biocontrols. When considering chemical controls, remember this is a mite, not an insect, and that acaricides, not insecticides, will be most effective. That said, at this point there do not appear to be any acaricides labeled for eriophyid mite control in garlic in New York that this time.

What is an eriophyid mite, anyway?

It turns out that if you are confused by mites, you aren't alone. Some garlic growers have heard of wheat curl mite in the past (*A. tosichella)* and now we are adding in dry bulb mite (*A. tulipae*) as another worry. The two have been confused by entomologists for years, and the differences are still being teased out (Skoraka et al, 2013) . Notably, there is still work needed to understand which mites will feed on garlic and other alliums, and to what extent.

One key difference to be aware of, however, is that eriophyid mites are different from bulb mites. Bulb mites feed primarily on damaged or decaying tissue, while eriophyid mites will feed on healthy tissue.

For more information on this or other garlic issues, visit our website at http://enych.cce.cornell.edu and click on the garlic icon or email me at cls263@cornell.edu. -Crystal Stewart

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Bloat Nematode on Garlic

Cornell University
College of Agriculture and Life Sciences
New York State Agricultural Experiment Station

Nematodes are microscopic, nonsegmented roundworms that cause disease in many plants. Bloat nematode (*Ditylenchus dipsaci*) was first reported in the United States in 1935 and affects many crops, including **garlic**. The first report of bloat nematode in NY was in 1929/30 on onion in Madison Co. An outbreak of this nematode on garlic in NY was discovered in 2010. Crop loss from the bloat nematode in NY was as high as 90% in areas of affected fields. A follow-up survey analyzing several hundred samples documented the high prevalence of bloat nematode on garlic with 28% of samples testing positive.

Symptoms

Foliar symptoms on severely infected garlic include:

- Stunting;
- Yellowing and collapse of leaves; and
- Premature defoliation (Fig. A);

Symptoms on the bulb begin as light discoloration and later become shrunken, soft, light, and their cloves are dark brown in color (Fig. B). Cracking is often visible around the basal plate at later stages of development (Fig. C).

Where does bloat nematode come from?

The primary source is ***infested seed.*** The nematode is able to survive and reproduce in seed during the season and in storage.

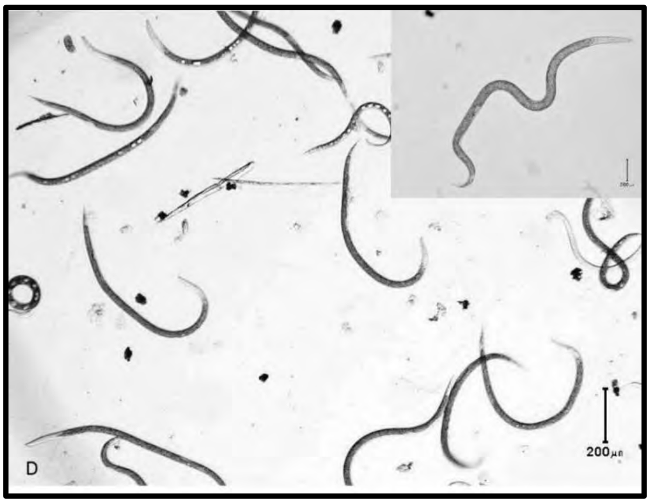
Other plants: Bloat nematode (Fig. D) occurs as many races. The race affecting garlic and onion also causes disease on leeks, chives, celery, lettuce, and flower bulbs. This race is also able to survive on hairy nightshade and Canadian thistle.

Soil: Bloat nematodes move from diseased plant tissue into the soil at later stages of bulb decay. Movement of infested soil on equipment or in conjunction with surface water can contribute to their distribution.

Prevention is better than cure!

Use ONLY clean garlic seed. Although hot water treatment of infested garlic seed either alone or in combination with various chemicals is available, this is often impractical and only provides incomplete control. **No treatment** should be considered as a substitute for the use of clean seed.

Select fields for planting that have been tested several times to be free of bloat nematode. Low populations of bloat nematode (≤ 10/500 cc soil) have been reported to later cause significant damage and crop loss.



CLEAN SEED + CLEAN SOIL = NEMATODE FREE AND HIGH QUALITY GARLIC

Management

Prior to planting, bloat nematode populations may be reduced by:

- *Fumigation* of sites with registered nematicides in conventional garlic production. No non-fumigant nematicides are currently registered in NY for use on garlic.
- Consider the planting of biofumigant cover crops (e.g. mustard or sorghum-sudangrass) and incorporation prior to planting.
- ***Rotation*** with non-host plant species (e.g. carrots, potatoes, corn, grain, etc). **Four years** between *Allium* species is recommended.
- Monitor plants regularly and remove any unthrifty plants to ensure diseased bulbs and crop debris are removed. Do not discard in an area that may distribute the nematode across your farm from surface water run-off.

For more information contact:
Sarah Pethybridge (315) 744-5359
Crystal Stewart (518) 775-0018
Or your local Cornell Cooperative Extension Agent

Photos courtesy of Professor George Abawi
June 2015

Testing for Bloat Nematode

Testing of garlic and soil samples for bloat nematode can be conducted at The New York State Agricultural Experiment Station, Geneva, NY. **Only samples from within NY State are accepted**. Keep samples at room temperature and send as soon as possible after collection.

Garlic: Select up to 10 bulbs (per sample) with potential damage caused by bloat nematode. Place in moist paper towel within a sealed, plastic bag.
Soil: Collect 15-20 sub-samples from the top 6 to 8" of the soil in an X or V pattern across the field or area to be planted with garlic. Mix the sub-samples and send ~ 1 quart of soil for testing.

Cost: $40/sample (bulbs or soil). ***Results:*** E-mailed or posted within 10 days.

Submission Form:

Collection Date: ____

Business Name: ____

Contact Person: ____

Address: ____

____

Phone: ____________________________Email:__________________________

Has bloat nematode been detected on the farm previously (yes/no)?______________

Description/Notes: ____

____

Note seed for sale (off farm): should be sent to the Plant Disease Diagnostic Clinic, Cornell University, Ithaca, NY. Details at: **http://plantclinic.cornell.edu/**

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New York State Agricultural Experiment Station

Bulletin #1207, Botrytis Neck Rot in Maine Garlic

extension.umaine.edu/publications/1207e/

Botrytis Neck Rot in Maine Garlic

Developed by Steven B. Johnson, Extension Crops Specialist, and David Fuller, Extension Professional

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Botryotinia (Botrytis) porri is the fungal pathogen that causes neck rot in garlic. This is a relatively new pest in Maine, but because it is readily spread through the planting of infected garlic cloves, it has the potential to become a long-term problem. The pathogen can cause severe damage to garlic grown in backyard gardens as well as on commercial farms.

Botrytis porri is limited to the onion family and also causes neck rot of leek. The disease can cause considerably more damage to garlic under wet conditions than in dryer years. Pathogens that infect garlic bulbs are a threat to seed crops as well as to the commercial garlic industry in Maine, and Botrytis neck rot has damaged garlic and caused losses in recent years. Understanding how the Botrytis neck rot pathogen spreads will help to minimize the serious and long-lasting effects of this harmful crop pest.

Biology

Mold caused by *Botrytis porri* generally develops on the neck of the garlic plant, later forming sclerotia (rough black masses of hardened fungal mycelium) as large as ¾ inch but typically ¼ inch in diameter. Sclerotia are fungal resting structures that allow the *Botrytis porri* long-term survival as well as survival under periods of unfavorable environmental conditions. *Botrytis porri* survives the winter as sclerotia in the soil or as sclerotia on infected bulbs.

Moist, cool weather favors sclerotia germination, in which small mushroom-like structures are produced. These structures release tens of thousands of spores that are wind-carried to susceptible plants in the onion family and start the disease cycle anew each season. These spores may enter through a wound or directly penetrate the neck (pseudostem); therefore initial symptoms of the disease may appear near the soil line on garlic necks. *Botrytis porri* moves rapidly along the neck region of garlic plants, often causing a water-soaked appearance. Warm, wet conditions favor infection and subsequent disease development—excessive water from irrigation or rain is highly conducive to the disease.

Symptoms

In the field, plants infected with Botrytis neck rot are stunted, with dead or dying outer leaves. Symptoms of infection are often first seen at the soil line on the neck as water-soaked lesions. Under warm and wet conditions, the disease progresses quickly, spreading up the leaves and down the neck. At this time, the large, distinct sclerotia may be present around the rotting neck.

Botrytis porri sclerotia on garlic neck.

Botrytis porri sclerotia on garlic neck.

Garlic bulbs infected with *Botrytis porri.*

Garlic bulbs infected with *Botrytis porri.*

Photos by Steven B. Johnson. (Click on the images to view enlargements.)

Extensive lesion development can lead to wilting or entire plant death and stand reduction.

Plants affected early in the growing season may die completely and be unharvestable. Plants may die mid-season or recover, depending on weather conditions. Infected bulbs that die and decay may have other pathogens attacking them, masking the true cause of the problem. At harvest, alive but badly infected bulbs can be culled. Bulbs that died and remain in the field will be quite likely crusted with sclerotia. These sclerotia serve as initial inoculum for following seasons.

Under dry conditions, disease progress slows or stops and the lesions may dry out and turn brown. Infected bulbs that do not die may have the pathogen present without noticeable symptoms. For this reason, healthy-appearing bulbs from an infected crop should not be used as seed. Disease may develop in storage or in a subsequent crop planted from bulbs that are asymptomatic but infected.

Management

High humidity and wet foliage with prolonged soil wetness will promote *Botrytis porri* infection and subsequent disease development. Weed control and adequate plant spacing, both in-row and between-row, will allow air movement, deterring pathogen infection. *Botrytis porri* sclerotia can survive in the soil for a length of time, so crop rotations in both time and space are crucial in maintaining a Botrytis neck rot-free crop of garlic.

Practices to avoid Botrytis neck rot infestation:

- Use disease-free seed stock.
- Use adequate plant spacing and good weed control to encourage air movement.
- Remove infected plants from the area and do not compost.
- Try to harvest mature plants with a minimum of injury.
- Properly cure garlic bulbs with good air movement.
- Practice proper crop rotation. Do not plant garlic or other alliums in a field where the pathogen is present.

Call 800.287.0274 (in Maine), or 207.581.3188, for information on publications and program offerings from University of Maine Cooperative Extension, or visit extension.umaine.edu.

education, and all other programs and activities. The following person has been designated to handle inquiries regarding non-discrimination policies: Director, Office of Equal Opportunity, 101 North Stevens Hall, Orono, ME 04469, 207.581.1226, eoinfo@umit.maine.edu.

Leek Production

FACTSHEET
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Written by: Randy Baker - Horticultural Experiment Station; Rhonda Burns - OMAFRA

Introduction

The leek (*Allium porrum*) originated in Middle Asia, with secondary centres of development and distribution in Western Asia and the Mediterranean countries. The leek has been cultivated in Western Europe since the middle ages and found its way to North America with early settlers from Europe. It is a more popular vegetable in Europe than in North America, but potential exists in Ontario for replacement of imports from the United States and market expansion by increased domestic consumption as consumers' eating habits become more varied.

Nutrition

Leeks may be grown successfully on a wide range of soil types but deep topsoil is preferred for vigorous plant growth and above average yields. Soil pH 6.5-7.0 is most desirable. Coarse sands should be avoided because sand particles under the leaf sheaths are not palatable to the consumer. The soil should be prepared with green manure plough down or farmyard manure to enhance organic content and provide nutrients and extra moisture holding ability for the crop. Leeks require about 200-250 kg N (nitrogen) per hectare, preferably in three installments - one-third pre-plant incorporated, one-third as a side dressing, and one-third as a top dressing when the leaves are dry. Phosphate requirements of leeks are not very substantial and applications of 50 to 100 kg P_20_5 per hectare are adequate. Potash requirements are also low and 150 to 200 kg K_20 per hectare as sulfate of potash are adequate.

Varieties

There are four basic groups of leek based on season of maturity:

1. Summer leek
2. Autumn leek
3. Autumn and Winter leek
4. Winter leek

In Ontario only the first two groups are feasible as the climate does not allow overwintering leek to be of suitable quality to market in the early spring.

Leek cultivars differ significantly in growth habit which affects the final product. They vary from long, green narrow-leaf types with long slender white stems to long wide-leaf types with thicker shorter white stems and blue green leaves.

Growers should check with seed company representatives for varieties most suitable for the climate and market requirements.

Transplanting

Traditionally, transplants for summer leeks are started in flats with soilless mix in early March in the greenhouse and transplanted into the field in late April or early May.

If "288 cell" trays are used for raising transplants a four cone type or carousel type transplanter can be utilized to plant the young plug cell plants.

Bare-root transplants for late fall maturing should be seeded in outside seedbeds late April or early May to be of sufficient size to transplant late June early July. Seedbed row spacing is determined by the equipment available to keep the seedbed weed free. In-row spacing of seeds should be such that 70 vigorous plants per metre of row can be produced for transplanting.

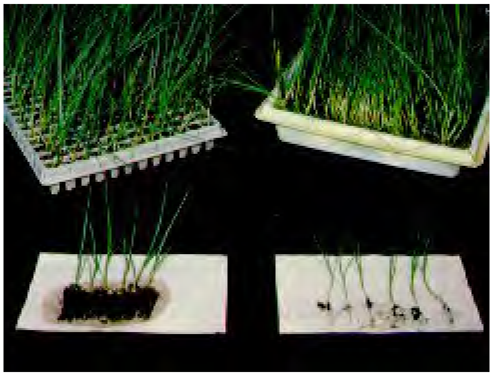

Figure 1. Plug transplants offer greater uniformity and labour saving with mechanical transplanting over bare-root plants.

Figure 2. In-row spacing is important to maintain uniform sizes till maturity.

Spacing of the leek crop in the field is critical to maximize returns per unit area. Usually the in-row spacing is 10-15 cm and the between-row spacing is more dependent on available equipment to maintain a weed free crop. Depending on weather conditions, a post planting irrigation is desirable to ensure rapid establishment. Further irrigation will be necessary if rainfall is deficient during the hot summer days when rapid growth should take place.

Weed Control

There are no registered chemicals for weed control. Alternatives that can be useful are: stale-seedbed technique preplanting, selecting fields with a low weed population (crop rotation), and using row spacing that can be easily cultivated. If the size of the crop warrants, special row crop tillage equipment is a good acquisition.

Insects and Disease

Thrips (*Thrip tabaci*)

Onion thrips are quite common and migration from surrounding grassy weed hosts is likely to occur. When thrips infest leeks, feeding produces silvery-white mottled lesions on the leaf surface To examine for thrips (if they are suspected) remove leeks from the soil and peel back leaves one at a time to reveal younger emerging leaves in the center of the plant (see OMAF Factsheet, Thrips on onions and Cabbage, Order No. 99-027).

Onion Maggot (*Hylemya antiqua*)

Onion maggot is widespread and three generations of maggots occur during the growing season. Visual checking of the plants is required to determine if there is maggot activity (see OMAF Factsheet, Onion Maggot, Order No. 91-005.

White Rot (*Sclerotium cepivorum*)

This soil-borne fungal disease can be devastating if present in farm soils. The fungus survives as sclerotia in the soil for long periods. Leeks should be grown on lands that have not grown an onion family crop recently. Sanitation through cleaning of field equipment and disposing of cull leeks away from production areas is important in preventing the spread of this disease. The first signs are yellowing and dying back of the leaves beginning at the tips and progressing downwards. Young plants wilt and collapse and are easily dislodged from the soil, revealing a dense white mass of mycelium in which minute black sclerotia are embedded. Cool, wet growing seasons favour the development of white rot.

White Tip Disease (*Phytophthora porri*)

White Tip disease is a fungal disease that can become prevalent after heavy rainfalls later in the summer. Affected areas have a water-soaked appearance at the leaf margins near the tip of the leaf. Older plants when slightly affected, wilt rapidly after harvesting. Fields with low lying areas where drainage is poor are the most likely places for white tip disease to develop. This disease can persist in crop residues.

Rust (*Puccinia porri*)

Rust is a fungal disease that shows up frequently in a mature crop in dry summers. It can reduce market value and yield of the crop severely. The disease is recognizable by the rust-coloured spores on the upper and lower leaf surface.

Leeks are also subject to diseases that are usually found on onions i.e. pink root, purple blotch, downy mildew, botrytis leaf spot, botrytis neck rot, and smudge. See OMAF Factsheet, Identification of Diseases and Disorders of Onions, Order No. 95-063.

In case of any problems in the leek crop, contact an OMAF Vegetable Specialist for appropriate remedial action where possible.

Harvesting

When leek plants are mature, the outside lower leaves display some senescence that is readily detectable. Physical size should meet market requirements for thickness and length.

Many different methods of harvest are possible but the main method is with an undercutting knife similar to one used to loosen cole crop seedbeds. A modified version of this under cutting knife incorporates a vibrating share of various widths.

Figure 3. A vibrating lifter loosens plants and removes a large part of the soil from the roots.

Equipment is available for mechanical harvesting, leaf trimming and root trimming in the field. The machine undercuts the roots of the leek plants with a vibrating knife that aids in removing excess soil from the roots. As the machine travels forward, the stems of the leek plants are held upright between two belts and in an almost simultaneous operation, the excess roots and the leaf tops are trimmed by sets of rotating disk knives. Small scale growers cannot justify the cost of this extensive mechanization, hence, all the above operations after lifting and loosening are done by hand. The dead outer leaves are stripped in a packing shed after which roots and leaves are cut off on a trimming and rinsing table. Once rinsed off by spray nozzles, the stalks are packed into cartons, 12 bunches per carton.

The harvesting season starts about mid-August and continues until the ground freezes in November. Most growers then start marketing from storage. During the warmer days of summer and autumn it is most desirable to ice the product before shipment to retain maximum freshness. Some growers pack with ice all season long.

Storage

Leeks store well for 2-4 months at 1-3°C and high humidity provided they are harvested and placed immediately into storage. For ease of handling, leeks are stored in 40 cm high pallet bins made of planks for better aeration and conditioning while in storage. The bins may be stacked several levels high depending on storage facilities. The leek crop can then be removed from storage as time and market conditions permit over a four month period.

Table 1. Leek Seedling Transplanting and Harvesting Schedule.

Seeded	Transplanted	Harvested
Feb. 15-28	Apr. 20-30	July 20-Aug. 10
Mar. 15-30	May 5-20	Aug. 15-Sept. 10
Apr. 10-30	June 25-July 10	Sept.25 - (till freeze up)

Some growers of early leeks will harvest all of their crop at peak maturity and place into cold storage for a short period and pack out of storage for uniform, continuous marketing.

Marketing

Markets usually accept a wide range of stalk sizes. The standard method of packaging leeks is three uniform sized stalks per bunch and twelve bunches per box. The grower usually selects bunches to give a uniform grade standard in a box. Physical size of leek is not important but bigger stalks command better prices than petite stalks. Wholesalers prefer bunches that are uniform within the bunch and uniform throughout the box.

Figure 4. Uniformity of bunches is more critical than physical size in a bunch.

Yield Potential

Leek yield potential is dependent on plant population. Row spacings of 60 cm (24 in.) and plant spacings of 10 cm (4 in.) will give a stand in excess of 160,000 plants per hectare. If we consider a harvestable crop at 80% of original stand, approximately 3600 cartons containing 12 bunches of leeks will be marketed. Similarly, a row spacing of 91 cm (36 in.) and plant spacing of 15 cm (6 in.) will give a stand in excess of 70,000 plants with harvestable crop yield of approximately 1600 cartons containing 12 bunches.

Quality

Leeks of good quality have fresh green tops and well-blanched stems or shanks. In order to attain 15-20 cm or more of white shank, a common practice is to plant the young transplants in a shallow trench 10-15 cm deep and as the plant grows the rows are cultivated and gradually hilled to promote more white stalk development. The greater the length of white shank, usually the more premium is the product. Wilting and yellowing of the top will downgrade the quality. Bruised tops are unimportant if they can be trimmed without spoiling the appearance.

Crooked stems and bulbous bases are not desirable characteristics and should be avoided in order to maintain a premium pack.

Figure 5. Leek plants that are hilled in the row yield greater quantities of high-quality blanched shanks.