Organic Allium Production

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By Katherine Adam
NCAT Agriculture Specialist

Alliums are a cool-season crop grown in most regions of the U.S. This publication addresses commercial culinary alliums, except garlic. A brief history of the onion is presented and some of the major varieties, growing regions, and types of bulbs are presented. Marketing and economic considerations of the varieties of dehydrator and fresh bulb onions are also discussed. Production and processing issues are briefly reviewed, as are crops such as shallots and leeks. Soils, climate, and planting considerations are also discussed. Weed management and an overview of major pests and their control are also presented. Post-harvest handling and storage issues are mentioned along with a brief review of current research. References and resources follow the narrative.

Contents

Introduction

Alliums are biennial monocots that are cultivated as annuals, a cool-season crop requiring temperatures of at least 55 degrees Fahrenheit to emerge from seed. Optimum leaf growth rates occur at temperatures of 68 degrees Fahrenheit to 77 degrees F. Alliums include various bulbing and nonbulbing species, used for both culinary and ornamental purposes. This publication covers culinary alliums (except for noncommercial types), with the exception of garlic. See the ATTRA publication *Organic Garlic Production*. For an exhaustive discussion of alliums worldwide, including ornamentals, see Rabinovitch and Currah. (1)

History

Onions (*Allium cepa*) are now thought to have originated in southwest Asia, but a wild progenitor has yet to be found. (1) The onion is one of the oldest cultivated vegetables. The dry onions first brought to this country by settlers were northern European types adapted to the temperate climate found throughout the Northeast. Varieties from warmer regions of the Mediterranean eventually made their way to the southeastern United States. In particular, varieties from Spain and Italy would become important to the Vidalia onion industry. The first of these varieties came through Bermuda and were thus referred to as Bermuda onions.

Yellow Granex, the standard for Vidalia onions, has its origin from Early Grano. The variety Early Grano 502 resulted in the Texas Early Grano 951C, which became one of the parents for Yellow Granex hybrid. The other parent, YB986, was selected from Excel, which in turn was derived from White Bermuda. These are short-day, sweet onions that formed the basis of the Vidalia industry, beginning in 1931. Dry onions from northern European parentage are now

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referred to as "American" types. Those deriving from southern Europe, via the Caribbean, are called "European" types.

Onions are classified as dry (bulb) or green. Bulb onion varieties are generally classified by day-length (short, intermediate, long), market use (fresh bulb, dehydrator bulb, or storage type), and bulb color within the fresh market class. Sweet onion types are most commonly marketed as fresh bulbs. In general, short day-length onions are suitable for warm climates; long day-length onions for those northern regions that grow onions. Intermediate length can be selected for intermediate zones, such as Oklahoma or the Central Valley of California. There is some production of Vidalias as "green onions."

There are, of course, related wild allium species in North America, and these are still gathered. In Tahlequah, Oklahoma, home of the Western Cherokee Tribe, the "egg and wild onion supper" has a long tradition in the spring. *Allium cernuum* is the probable species of small, clumping onion. It should not be confused with *A. vineale*, or "crow bait," a very strong-flavored native of Eurasia naturalized in North America, that usually occurs singly.

Onions are greatly affected by weeds, insects, and diseases. One of the most important challenges in onion production today is how to produce onion crops in ways that are sustainable and environmentally responsible while not losing the yields achieved by use of crop-protection chemicals as a substitute for costly hand labor. (1) Many alternative strategies have already been implemented by the industry—especially in New York and California, where there is some indication that insect pests are becoming resistant to insecticides. In Georgia, a 2002 trial of organically produced onions met with some success.

Six geographic areas have federal market orders for onions, and onions are among the top five crops raised in two other states. USDA market orders are initiated by growers and are renewable by vote of growers every six years.

Latest figures on the value of onion crops in Oregon are $74 million for 2004; onions now rank tenth among Oregon crops. (2) Federal crop profiles have been published for onion production in several states—including California, Colorado, New Mexico, Washington, Oregon, New York, Wisconsin, Georgia, Texas, and Ohio (green onions). Some states have recently begun to focus on becoming onion-producing areas—especially sweet onions, for which there appears to be a growing market. Wide year-to-year fluctuations in onion acreage in the U.S. appear in USDA Economic Research Service reports going back to 1961. (*www.ers.usda.gov*)

The U.S. exports onions and onion products to Canada, Australia, Germany, Japan, The Netherlands, South Africa, Sweden, and the United Kingdom. India, Peru, and China are the major exporters to the U.S. Significant foreign competition from Peru, especially with the South Texas sweet onion crop, is expected in the future. China exported $403 million of onions, shallots, garlic, and leeks in 2002—a 50 percent increase over the preceding year. Alliums are considered an area of vegetable production in which China will seek increasing domination of U.S. and Asian markets. (3)

According to NASS statistics, Mexico is the chief foreign source of green onions. There are strict grading standards; Mexican dry storage onions and onions for processing are allowed in if they meet the same

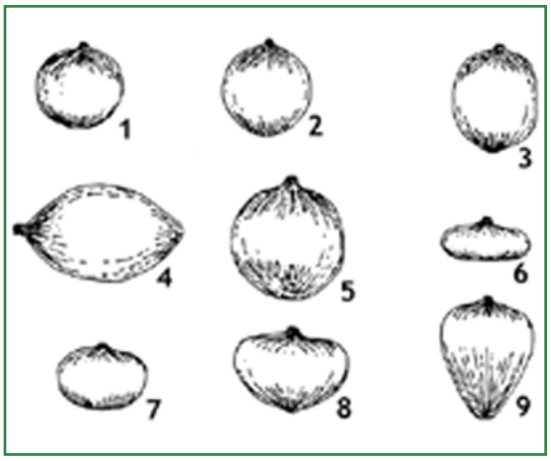

Figure 1. Bulb Shapes – 1. flattened globe; 2. globe; 3. high globe; 4. spindle; 5. Spanish; 6. flat; 7. thick flat; 8. Granex; 9. top.

Related ATTRA Publications

Resource Guide to Organic and Sustainable Vegetable Production

Organic Garlic Production

NCAT's Organic Crops Workbook

Organic Marketing Resources

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standards of size and quality as the U.S. Fresh market imports of both green and dry onions are more closely regulated.

Sweet onions grown for the fresh market often have a state-sponsored identity—Walla Walla Sweets, South Georgia Vidalias, Oklahoma Candy, etc.—and must be grown in the specified locality to bear the name. Regional growers search for other marketing ideas conferring "perceived value."

Marketing and Economics

There is usually a direct correspondence between day-length sensitivity and the latitude where onions are produced, with short day-length types being produced at lower latitudes. However, differences in this sensitivity (as well as stand densities) can be manipulated to produce specialty crops like pearl onions. Pearl onions are short-day types that can be grown in northern states (under the long days of summer) for early bulbing and pearl production.

Dehydrator onions include both short-day and long-day varieties. Short-day varieties (Creole, Creoso, and Primero) are selected for their high dry matter content with soluble solid contents ranging from 15 to 25 percent. Long-day dehydrators (Southport White Globe varieties) have soluble solid contents ranging from 20 to 25 percent. (5) Production is vertically integrated and the process is totally mechanized. The processer with whom the grower has a contract determines varieties and often provides seed. The University of California has published a six-page bulletin on growing dehydrator onions. (*http://anrcatalog.ucdavis.edu/pdf/7239.pdf*)

Fresh market bulb onions have the greatest number of varieties. Short-day types are usually Grano or Granex-Grano and include yellow, red, and white varieties. "Imperial Sweet" and other short-day varieties grown in Southern California range from five to seven percent soluble solid content, 2 to 6 moles of pyruvic acid per Kg of bulb, and a high sugar to pyruvic acid ratio. California short-day varieties begin to bulb at 12 to 15-hour day lengths, and Georgia short-day onions, at 11 to 12-hour day lengths. Short-day types are the sweetest. The higher the pyruvic acid content, the more pungent the bulb.

Intermediate-day fresh market bulbs grown in the central California valley range from seven to nine percent soluble solid contents and 5 to 9 moles of pyruvic acid per Kg of bulb. (5)

Long–day fresh market bulb onions range from 8 to 12 percent soluble solids and 10 to 20 moles of pyruvic acid per Kg of bulb. (5) Fresh-market bulb production is not characteristic of Northern California and the infrastructure is not present.

Federal marketing orders, initiated by a group of growers for a locality, set regulations for some commodities (currently including milk and some fruits and vegetables). Marketing orders aim to match supply with potential demand at prices reflecting the costs of producing and marketing the commodity by the typical well-managed firms in the industry. Regulations also set product standards to reflect the interests of consumers.

Currently, federal marketing orders for onions currently exist for six U.S. geographic regions.

- Vidalia Onions (GA)
- Garlic and Onions (CA)
- Sweet Onions (CA)
- South Texas Onions
- Walla Walla Sweets (WA)
- Idaho-Eastern Oregon Onions

The Georgia Department of Agriculture publishes a list of recommended cultivars to be grown and marketed as Vidalia onions, but any similar cultivar that meets certain guidelines can be used by Vidalia growers. Recently, however, three experimental cultivars partially derived from *A. fistulosum* in an attempt to improve shallow

Pyruvic acid is a measure of the sulfur content and is usually dependent on soil type.

Definition: A marketing order is a legal mechanism under which regulations issued by the Secretary of Agriculture are binding upon all growers and handlers of the regulated product in a specific geographic area.

onion root systems were rejected as tending to have an "off" flavor. The marketing order regulates the shape of the Vidalia bulb (see Illustration, item no. 9). (4)

In California there are five recognized size grades. At a packing shed or during field packing, bulk trailer loads of onions cured in the field for three days to two weeks are sorted. Packing grades are Colossal, greater than 4 inches in diameter, Jumbo, 3 to 4 inches, Medium, 2 to 3 inches, Repacks 1.5 to 2 inches, and Boilers, less than 1.5 inches.

Short-day onions, typically grown in the low desert and Central Valley, are preferred by the onion ring industry (45 percent of California production) because varieties such as Grano or Grano-Granex types typically have only a single center and numerous, thick fleshy rings. Harvested slightly immature, they have a high sugar to pyruvic acid ratio. The larger sizes are preferred. Fall-planted, short-day onions are adapted to the desert regions of Southern California, although as transplants they can be grown up to a maximum latitude of 36 degrees north.

An estimated 49.4 billion pounds of frozen onions are produced annually in the U.S.

Onion production also supplies the frozen food industry. A USDA publication estimates that 49.4 billion pounds of frozen onions are produced annually in the U.S. In addition, many of the fresh-market onions, as well as high-solids dehydrator onions, produced in Washington state are processed after export to Pacific Rim countries.

Production Budgets

A Michigan State Agricultural Extension Publication comments that it is "relatively easy to get into and out of onion production, as the market is often saturated." *http://web1.msue.msu.edu/imp/modsr/sr599201.htm.*

Production budgets (except in California, where more processing is done) place fixed costs at between 1 percent and 11 percent for onions. Production budgets found on some Web sites are discussed below. Florida and Oklahoma budgets reflect a recent risk-benefit assessment of onions as a potential crop, extrapolated from production figures published in onion-producing states. Costs to produce a crop in New Mexico and Wisconsin were double those of some other states.

University of California Vegetable Research and Information Center. *http://vric.ucdavis.edu/selectnewcrop.onion.htm*

New Mexico

Onion Cost and Return Estimates (NM) *http://www.cahe.nmsu.edu/pubs/_circulars/CR-603.pdf.* Fixed costs 1 percent. Variable costs double those of other states due to irrigation.

Onion Production and Marketing in New Mexico. *http://cahe.nmsu.edu/pubs/_circulars/CIRC577.pdf*

Mississippi

Commercial Production of Bulb Onions in Mississippi. *http://msucares.com/pubs/infosheets/is1506.htm*

Washington

Estimates Cost and Returns for Producing Onions, Columbia Basin, Washington. *http://farm.mngt.wsu.edu/Research/onions.htm*

New York

Crop Profile: Onions in New York *http://pmep.cce.cornell.edu/fqpa/crop-profiles/onion.html*

Michigan

Cost of Onion Production in Southern Michigan. *www.msu.edu/user/blackj/staff_Paper_2002-37.pdf.* 10 p.

Georgia

Sweet Onion Production. *http://pubs.caes.uga.edu/caespubs/pubcd/B1198.htm.* 40 p.

Two states looking at onion production

Florida

Alternative Opportunities for Small Farms: Bulb Onion Production [1998]

http://edis.ifas.ufl.edu/profiles/AC/AC00900.pdf

- 10 percent fixed costs; 90 percent variable costs

Other constraints:

- severe freezes in recent years in northern Florida
- very labor intensive crop, needing good management skills
- need for machines—especially for planting and harvesting
- curing facilities for storage do not exist
- markets for fresh crop onions must be determined in advance
- capital intensive crop (initial investment costs high)
- potential for processing limited by lack of facilities
- existing harvesters for dry onions do not work for fresh onions

Oklahoma

Oklahoma Candy Onion Production (three related papers)

1) Projected Net Income, Price Risk, and Yield Risk [Based on field trials with one cooperating farmer in southeast Oklahoma]

http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-968/p_1005web.pdf

- Fixed costs for Oklahoma determined to be only 5 percent, variable costs 95 percent (for southeast Oklahoma)

Advantages:

- National consumption of produce on the rise
- Success of Texas 'Candy' onion (intermediate day onion, did well in trials) a knockoff on success of Georgia 'Vidalia'

Disadvantages:

- Major challenges of weed control and foliar disease
- Assumption that ungraded product can be sold on fresh market within two weeks of harvest (to avoid curing, processing, handling costs of Florida study, but does not answer contention that machinery available for harvesting dry onions cannot be used for fresh. May plan to use hand labor.)

2) Using Contracts to Reduce Marketing Risk; Applied Study of Oklahoma Onion Production

http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2843/FAPC-131web.pdf

A farmer-friendly summary of the research study.

3) Recent Experience with Fresh Bulb Onion Production in Oklahoma. National Allium Research Conference (2004).

www.colostate.edu/Depts/CoopExt/TRA/Allium/Abstracts/RecExpFreshBulb.htm

Had to raise their own greenhouse starts for 'Candy' and '1015-Y.' Found that 'Candy' had 11 percent bolting rate (a culling rate not accounted for in previous crop budget calculations).
Suggested seed supplier was to blame.

Other Types of Bulb Onion Crops

- Apaz onion – a wild relative of leek, a small bulb marketed with a short green top. " Apaz" has been recently promoted as an Oregon specialty crop. It is listed in the 2005 *The Packer* yearbook. Only a very few companies sell seed for it, and no production information has been published.
- Cippolino onion – U.S. supplies imported from Italy. *Cipol* is Spanish for "shallot," but the Cippolino onion of commerce is a small reddish true onion; *A. cepa*. *The Packer* suggests marketing Cippolino onions as part of an Italian cuisine display.
- "Boiler" onions are marketed as a specialty item. A boiler onion is simply the smallest of five recognized sizes of fresh market onions in California, defined as smaller than 1.5-inches in diameter. *The Packer* recommends including boilers as part of Hispanic produce displays.

Green Onions

Pearl onions are produced by planting a short-day onion in a northern latitude. They are produced in North Dakota, Minnesota, and Washington. An Extension bulletin by the North Willamette Research and Extension Center is a good source of further information. Pearl onions are often pickled or otherwise processed. *http://oregonstate.edu/Dept/NWREC/onionprl.html*

Processing Onions

Onions for dehydration (California)

- Dehydrator Bulb Onion Production (Voss) *http://anrcatalog.ucdavis.edu/pdf/7239.pdf*
- Onion Dehydration (John W. Lund and Paul L. Lienau) *http://geoheat.oit.edu/pdf/tp86.pdf*

Frozen onions

- Production of all types of frozen onions is concentrated on the West Coast, with some companies doing a broad range of operations—everything from fresh-peeled to frozen rings. A fledging frozen onion ring operation in Pecos, Texas, closed in 2002 when a competitor bought the operation and consolidated it with an existing facility in Nebraska, which had in 1985 initiated onion and potato processing as a value-added rural development strategy. Growers in Oswego County, New York, in response to poor sales of fresh onions due to nationwide overproduction in 2005, have proposed to spend $2.9 million on a frozen onion processing plant to help the local economy.

Onions for seed (California)

- Onion Seed Production for California. *http://anrcallog.ucdavis.edu/pdf/8008.pdf*

  In minor onion-growing areas, onion seed is often produced by commercial growers in a separate field away from the commercial onion crop. For various reasons, growers prefer to produce commercial onion crops from transplants, rather than seed. Care must be taken to avoid seed-borne diseases. A recommended strategy is to raise seed in a field where alliums have never been grown before. Transplants are produced from the seed and then precision set in the commercial field. For details of seed production in California (the

number one U.S. onion producing region), see the UC-Davis publication. Commercial onion seed is produced also in the Columbia Basin region in Washington.

Green Onions (Scallions, Bunching Onions)

Bunching onions may be produced from immature, thickly planted white onion varieties of *Allium cepa* and from *Allium fistulosum* (commonly known as Japanese bunching types), or, rarely, from an interspecific hybrid of *cepa x fistulosum*. *Allium fistulosum* varieties are often referred to as "Welsh" onion, derived from the German word "welsche," meaning foreign.

Green bunching onions are known by several names depending on the region of the country. Some of the names used are "scallions," "green onions," and "spring onions." All these terms can be used for immature onions, but in reality, the "green bunching onion" of commerce is most likely a different species from that of the bulb onion. Green onions today are most often *Allium fistulosum*, which is further classified into four taxonomic groups. For a complete description, refer to "Alliums and Allied Crops," Vol. III by H. Rabinowitch and D. Brewster.

A considerable amount of *Allium cepa* (the regular bulb onion) is still used for green onion production under certain conditions and in certain areas. *Allium cepa* can be planted thickly and harvested immature for this purpose. An example is "Vidalia" scallions produced in Southeast Georgia from Grano-Granex types. Bunching onions are harvested at pencil-thickness and sold in bunches.

One can identify the species by looking carefully at the bottom of the green leaves near where they turn white. If the leaf cross section is "D"-shaped (or has a flat side), it is *A. cepa*. If "O" or round, it is *A. fistulosum*. *http://oregonstate.edu/Dept/NWREC/oniongr.html*

Common home garden types such as Egyptian onions and multiplier onions are NOT used for commercial green onion production, but may sometimes be found in farmers' markets in the spring. For a complete description of how commercial green onions are produced, see *http://oregonstate.edu/Dept/NWREC/oniongr.html*. Green onions imported from Mexico have come under increasing scrutiny in recent years because of outbreaks of bacterial illness traced to such imports.

Yellow Storage Onions
www.extension.umn.edu/distribution/cropsystems/DC7060.html

Ohio ranks seventh in the country in green onion acreage. Onion maggot is a serious pest on green onions in Ohio, but a new seed treatment with cyromazine, an insect growth regulator, shows promise. (6) For more information on green onion production in Ohio, see the USDA Crop Profile *http://pestdata.ncsu.edu/CropProfiles/docs/OHonions-green.html*.

Other Extension bulletins on green onion production:

- Green Onion Production in California (Voss). *http://vric.ucdavis.edu/veginfo/commodity/onion/oniongrn.pdf*
- Commercial Green Onion Production (Georgia). *http://pubs.caes.uga.edu/caespubs/pubcd/C821.htm*. About Vidalia green onion production governed by a federal marketing order. In 2003, higher prices for Vidalias pushed the value of onion production up by more than 50 percent.

- Green Bunching Onions. *http://oregonstate.edu/Dept/NWREC/oniongr.html*
- Green Bunching Onion Production *www.ces.ncsu.edu/depts/hort/hil/hil18.html*
- Growing Scallions (Green Onions) for Market Gardeners, NF04-607. *http://ianrpubs.unl.edu/epublic/page/publicationD.jsp?publicationID=245*
- Crop Profile for Onions (Green) in Ohio (1999), 7 p. *http://pestdata.ncsu.edu/CropProfiles/docs/OHonions-green.html*

Other Allium Crops

Shallots are affected by the same diseases as onions.

Shallots (*A. cepa 'aggregatum'*)

University of Florida Extension says that U.S. commercial shallot production is established only in southern Louisiana, but this may be a reference to the "Giant white shallot" identified by Rabinowitch and Kamenetsky (1) as a cross between "the bulbous shallot and Japanese bunching onion, *A. fistulosum*," resulting in an amphidiploid plant that is heat-tolerant and prolific with only a short dormancy period. Red shallots are one of the top imports from France. Shallot is a perennial that produces a cluster of small, pointed bulbs from a single planted bulb. Bulbs may be of varying color, but the French Red is the only shallot of commercial importance. Other types may be found occasionally in local markets and home gardens, as are various related types of white multiplier onions. Oregon State University notes that planting stock is difficult to obtain in large quantities, but offers trial quantities of "true shallot seeds" sourced from a Dutch company to growers in Oregon. Either dry bulbs or bulbs with foliage are marketed. Shallots are affected by the same diseases as onions and should not be planted where any related crop has been grown before. They are also affected by harmful nematodes. Oregon State University Vegetable Production Guides has published complete information on commercial production of shallots, *http://oregonstate.edu/Dept/NWREC/shallot.html*. Also see the University of Florida Extension bulletin: *http://edis.ifas.ufl.edu/pdffiles.MV/MV13300.pdf*. Garden Medicinals and Culinaries is a source of bulbs of shallots and other multiplier onions.

Leeks (A. ampeloprasum)

Leeks, which require a cool to moderate climate and a growing season of 80 to 100 days, are a very minor specialty crop in the U.S., as market demand is not nearly as large as in northern Europe. Commercial production centers in the Pacific Northwest Willamette Valley and Oregon Coast, where both the transplants and mature crops are grown. Field seeding is not recommended. Transplants are often set into 3 to 4 inch holes in order to produce the long white stems desired in the market. The major pest on leeks is thrips. In 2004 a viral infection began to show up on garlic in Washington State. The "leek yellow stripe virus" was implicated. For more information, see *www.seedquest.com/News/releases/2005/february/11388.htm*.

For information on commercial leek production, see Oregon State University Vegetable Production Guides *http://oregonstate.edu/Dept/NWREC/leek.html*

So-called "elephant garlic" (*A. ampeloprasum*) is actually a leek. Very large bulbs of this leek relative are marketed as a mild "garlic." There are a number of named cultivars, as this is a popular crop in some regions. As noted above, the "Apaz" onion is a specific type of leek.

Are Onion Crops Alternative?

Onion crops cannot be considered "alternative"; they are well-established, major U.S. crops with definite marketing channels for different types. Some states sponsor research or legislate to protect a "logo" or name in order to gain an edge in the market. States have even been known to commercialize a "new" allium for the same purpose. As a testament to efforts of the National Onion Association and state and regional associations, U.S. onion consump-

tion rose from 12.2 pounds per person in 1982 to 18 pounds per person in 2002. (7)

Surplus commercially grown onions that do not meet size criteria may be donated to food banks or other feeding programs, although those with physiological defects or disease are usually culled soon after harvest. Although imports are increasing, there is no domestic shortfall in onion production. Vidalia growers in Georgia have recently been told to look for export markets for up to half of their crop. Large, perfect yellow onions typically retail for three pounds for a dollar. Farmers markets sell slightly smaller sizes of whatever type they have available for about a dollar a pound. Local farmers' markets always have a few onions for sale, especially in the spring. Community Supported Agriculture (CSA) organizations like to provide some onions in the late fall as part of a "root vegetable share."

Contrary to marketing order specifications, smaller sizes of onions are ideal for the one-person household now so prevalent in the U.S. Once cut, a large onion will keep for only a limited time in the refrigerator. However, there is a market demand for fresh, whole peeled onions.

Cornell University is a leader in innovative alternative marketing for onions and other vegetable crops. Cornell University's Smart Marketing series (*http://hortmgt.aem.cornell.edu/smart_marketing*) and related materials recommend 1) expansion of agri-tourism, 2) agricultural awareness programs, and 3) ag-based economic development initiatives as key to promoting sales of New York commodity vegetables, including onions. (*http://hortmgt.aem.cornell.edu/pdf/resources/NYvegmarketingneeds.pdf*)

A very recent development in onion marketing is the formation of a consortium of U.S. and foreign growers of sweet onions. Sweet Clover Produce, Seattle, Washington, is a new cooperative formed to provide year-round sweet onion supplies to the food trade. For eight months of the year Bland Farms' "Peruvian sweet onions" will be marketed; the other four months Walla Walla Sweets and Vidalias. Peruvian onions are grown in sandy, low-sulfur soils and tested for high sugar content, low pyruvic acid, and mellow flavor. Grown in the Southern Hemisphere, they fit an off-season niche for U.S. markets for fresh, non-storage onions. They will also keep busy the Seattle packing facilities operated by another member of the consortium. The new consortium hopes to promote sweet onions to the food service trade as a salad bar item. For more information see the September 26 issue of *The Packer* and the article by Tom Burfield.

Yellow Storage Onions in Minnesota

The October 10, 2005 issue of *The Packer* had disturbing news for the South Texas onion industry. "Shipments of Peruvian onions to the U.S. and Canada continue to gain momentum." Peru has ideal rich soils in a wide range of microclimates at varying altitudes, irrigated by water from the Andes, to produce more and more sweet onions for fresh market. est and disease buildups are absent, as this is largely a cool, dry, desert area only recently put into large-scale agriculture for export. Peruvian sweet onions are now being actively marketed as a "high-quality sweet onion whose taste meets or exceeds expectations year-round." Peruvian onions usually rate from 3.5 to 4.5 on the pyruvic scale, which measure sulfuric compounds. Vidalias score 2 to 4.3, and Texas 1015s rate 3.7 to 4.5. The South Texas industry is most at risk for direct competition from Peru. Peru ideal for sweet onions;

Retailers, suppliers working together. Oct. 10. p. B5. In a development that has shaken the Texas Produce Association, a large produce company in the Rio Grande Valley of Texas closed and was noted on p. 1 of the same issue. Starr Produce marketed South Texas onions. The company has converted to a real estate development firm and will build on its agricultural land. (9)

Soil Fertility and Climate

Onions require fertile, well-drained, non-crusting soils, and are often produced in muck soils, although sandy loams high in mineral content are also favored. Heavy clay soils should be avoided. A slightly acid pH in the 6.0–6.8 range is optimum. Onions require substantial amounts of nutrients. Foliar fertilization is not recommended for some parts of the country, although many growers use this method for applications of necessary trace elements during the growing season. Ideally, nutrients will be in place in the soil before the crop is planted. Soil tests should be done as a guide to fertilizer applications. Soil pH may determine availability of critical elements such as sulfur and boron. The amount of sulfur present will affect pungency, but some sulfur is necessary even in producing sweet onions. For Vidalia and other sweet, fresh market onions, elements affecting flavor must be carefully controlled.

Growing onions directly from seed has largely been abandoned because of several problems.

Planting Systems

Fall planting. Fall planting for a winter onion crop in Georgia greatly reduces weed, insect, and disease problems, but may increase incidence of physiological problems due to freezing, wind, and hail damage. Bolting, or seed stalk formation, occurs only from fall-planted onions grown through the winter for spring harvest. The size of the overwintering plant and its exposure to cold temperatures are the most critical factors in determining whether or not the plant will bolt due to a warm spell of 45 to 50 degrees during the winter. Early plantings in late August and September are more likely to bolt than are later plantings in October and November. An extended warm period following planting produces a larger overwintering plant (more than one-fourth-inch shank diameter), which results in a high percentage of bolting when exposed to extended temperatures below 50 degrees Farenheit. Some cultivars may be more prone to bolting than others. (Note the experience of Oklahoma researchers with 'Candy,' above.)

In southern states onions are likely to be raised from transplants; in New York State, most are direct seeded. Short-day Vidalia onions in Georgia are always raised from transplants.

> Short-day onions can be grown from both seed and transplants; however, growing onions directly from seed has largely been abandoned because of several problems. First, onion seed is very small and requires adequate, even moisture during the critical germination process. This is difficult to provide during the extremely hot and dry conditions of the September/October planting season in South Georgia. The center-pivot irrigation systems common to this area are not designed to deliver the one-tenth inch of water several times a day that may be required to produce a stand of onions over an entire field. Finally, direct-seeded onions in South Georgia are more prone to bolting or developing seed stems. This is particularly true when seeded early (September and early October) and cold weather comes in the latter part of the season, particularly in March. Direct seeding onions in late October or early November to avoid seed stem development may not give the plants sufficient time to develop and withstand potential frost and freezing temperatures. (8)

An additional reason to use transplants is more uniform spacing, leading to more uniformity in onion size and fewer physiological anomalies.

Spring planting. In Oregon's Willamette Valley onion growers plant only in the spring, though in some other onion areas both fall and spring-planted onions are grown. In North Dakota onions are not seeded until April or May, since seed will not germinate below 50–55 degrees Fahrenheit soil temperature. Although harvested in late

summer, long-day onions raised in the northern tier states are milder than southern-grown summer onions, thus finding a market niche. An even progression from cold to warmer weather, plus careful regulation of irrigation, reduces the number of splits.

Irrigation

The onion seedbed must be irrigated immediately after planting, and then as necessary to maintain a moist condition until seedlings emerge. When at pencil-thickness, onions should be transplanted and irrigated as soon as possible in the permanent, slightly raised, precision-leveled "panels" in the permanent field, and every week as necessary after bulbing. However when plants start to mature, they should not be irrigated. (In dry climates like New Mexico, irrigation is a significant part of direct expense for onion production.) Irrigation is necessary to produce large, uniform bulbs desired in the market. Because onions are prone to physiological problems without uniform moisture in the top 12 inches of soil for this shallow-rooted crop, overhead irrigation systems are used, although they may increase the risk of bacterial diseases.

All Vidalia onions grown commercially in Georgia are irrigated—either by center pivot, traveling guns, or permanent buried pipes with overhead sprinklers. It is critical that the top 12 inches of soil be kept at a uniform moisture. Drip irrigation is not recommended for the Georgia crop, though it is common in the Pacific Northwest. Peak water demand for onions can be as high as 1.5 to 2.0 inches per week during the latter stages of bulb enlargement in periods of warm weather. A half inch of water applied at transplanting (in December in Georgia) helps establish good contact between the soil and roots and assures a good stand. To determine ongoing need for water for this shallow-rooted crop, tensiometers may be used to monitor soil moisture, at least three times per week in dry weather.

California onion fields tend to be uniformly irrigated with overhead sprinklers. Center pivot sprinkler systems are used on 60 percent of Columbia Basin onions (Washington) and 20 percent drip irrigation, which some growers feel facilitates higher yields and less disease pressure. With sandy soils prone to wind erosion, irrigation is sometimes practiced to reduce soil and crop loss. Twenty percent of farmers still use a furrow or rill irrigation system. Irrigation is selectively used in Wisconsin, and irrigated onion production is increasing in New York. Onions in southern New Mexico are grown with furrow irrigation, with some sprinkler irrigation in the east and northwest. Furrow and drip irrigation are commonly used in Colorado, with sprinkler irrigation used to a lesser extent.

For more information on sustainably managed irrigation, request NCAT's publications, *Energy Saving Tips for Irrigators* and *Measuring and Conserving Irrigation Water.* Call 800-346-9140 to request a copy.

All Vidalia onions grown commercially in Georgia are irrigated.

Control of Weeds, Insect Pests, and Diseases

Commercial onion crops in southern states depend heavily on spraying to control weeds, insects, and diseases. Onion diseases can cause severe losses by reducing yield and quality of marketable onions. These onion diseases can occur in seedbeds, production fields, and in storage. However, diseases and other pests differ in economic importance, depending on the part of the country in which onions are raised.

Weed Management

Weed management is the most significant challenge in onion production. Besides competing for water and nutrients, weeds can harbor destructive insects, can serve as alternate hosts of diseases, and can hamper hand-harvesting efficiency (in regions where crops are hand harvested). Weeds can seriously reduce yields.

Onions are sown at high plant densities (4 to 6 seedlines on top of beds [panels] only 40 to 42-inches wide, shoulder to shoulder) and not thinned in order to have the greatest possible yield per acre. Only shoulders

Most troublesome weeds

Nutsedges – CA (high desert, San Joaquin Valley), OR, GA (early fall plantings), TX, NM, NY, WI, CO

Lambsquarters – CA (San Joaquin Valley, low desert (nettleleaf goosefood)), WA, OR, TX (Lower Rio Grande, Winter Garden), NM (all seasons), NY, WI, CO,

Redroot pigweed (amaranth) – CA (San Joaquin Valley), WA, GA (early fall plantings), TX (all areas), NM (all seasons), NY, WI, CO

Russian thistle – CA (high desert), WA, NM (winter), CO

Mustards – CA (high desert), GA, TX (Lower Rio Grande, Winter Garden), NM (fall)

Mallow – CA (low desert), OR, CO

Purslane – CA (San Joaquin), WA, OR, TX (Lower Rio Grande, Winter Garden), NY, WI, CO

Dodder – CA (San Joaquin), CO

Henbit – TX (Lower Rio Grande, Winter Garden), GA

Groundcherry – CA (San Joaquin), TX (Lower Rio Grande), NM (winter)

Shepherd's purse – CA (San Joaquin), GA, NY, WI

Sow thistle – CA (San Joaquin), GA, TX (Lower Rio Grande, Winter Garden), NM (fall)

Kochia – WA, OR, NM (winter), CO

Nightshades – CA (San Joaquin), WA, TX (Lower Rio Grande), CO

Spurge – OR, TX (Lower Rio Grande), NY, WI

Ragweed - TX (Lower Rio Grande, Winter Garden), NY, WI, CO

Morningglory – GA, NM

Sunflower – TX (Lower Rio Grande), CO

Spurred anoda – New Mexico, CO

London rocket – CA (San Joaquin), TX (Lower Rio Grande), NM (fall)

Field bindweed – TX (Lower Rio Grande), CO

Annual and Perennial grasses: CA (low desert, San Joaquin), and all other states.

and furrows are cultivated. Hand-weeding often does as much harm as good. (10)

In an organic trial of short-day onions conducted in southeast Georgia, 2000–2001, problems with bermudagrass and nutsedge were eliminated by crops being winter-grown. Bermuda hay mulch provided a very satisfactory weed control rating. Yields were about half of those for conventionally raised onions (bags/acre), with most of the reduction coming in reduction of size from Jumbos to Mediums. (11)

Onions should be planted in fields relatively free of troublesome weeds such as nutsedge, field bindweed, and bermudagrass, as well as clovers. Nonchemical controls are mostly employed pre-plant. (5)

Rotational crops that employ tillage can reduce weed levels, as tillage of standing onion crops is not common due to risk of injury to bulbs. A method of stale seedbed weed management that does not involve chemicals consists of several light cultivations of the field before onions are planted to eliminate weeds germinating from the top soil layers. The most common and troublesome weeds are highly influenced by crop planting time, as well.

Additional weeds, by state

California
San Joaquin Valley – cheeseweed.

Washington
Columbia Basin – groundsel, Canada thistle, ladysthumb, volunteer potatoes.

Oregon
Horsetail.

Georgia
Weeds that harbor bacterial streak and bulb rot – Cutleaf evening primrose, dandelion, purple cudweed, Virginia pepperweed.
Persistent weeds – sicklepod, cocklebur.
Also, Texas panicum, Florida pusley, common chickweed.

Texas
Lower Rio Grande Valley – ironweed, barnyard daisy, croton.
Plains – ironweed.

Colorado
Wild proso millet.

In organic production, various strategies are used to minimize weed pressures. Crop rotation, off-season tillage, and cover crops are used to prevent establishment of weeds and weed seed dispersal. Hand weeding when both the crops and the weeds are small is an option in some parts of the country. Sometimes mechanical hoes may be used.

Herbicides used in conventional production should be targeted to specifically mapped weed populations.

Cultural

Shallow tillage after pre-irrigation is a strategy that kills germinated weed seeds in the upper layer of soil and avoids bringing up deeply buried weed seeds. For control of weedy rhizomes, stolons and seed, inspect machinery when moving it from field to field.

Another preventive measure for weed control is soil solarization. It is accomplished by applying clear plastic over a moist, clean-tilled seed bed, for four to six weeks during the hottest part of the summer. Solarization kills pest insects and diseases, but also a wide variety of weed seeds and propagules. Because soil solarization requires a summer fallow season for treatment, it fits in best with a fall-planted crop. (5) For more information on soil solarization, contact ATTRA.

When used, mechanical cultivations must be timely and should be shallow in order to reduce root damage. Cultivation technology has advanced in recent years, and several non-traditional cultivator designs can be found in the marketplace.

Flame Weeding

Flame weeding has been used on seedbeds, less commonly in standing crops, in certain states. Biological weed controls such as weeder geese have not been found to be very satisfactory and are not now used in any commercial production.

Onion Maggot

In New York state, crop rotation can be very effective against onion maggot, but at least one mile of separation is recommended between new seedings and previous crops or cull piles. There are no commercial

Insect Pest Management

Major insect pests of onion crops, by region

C**A – major:** onion (tobacco) thrips, onion maggot. Minor: western flower thrips, seed corn maggot, pea leafminer, army worms, bulb mites, wheat curl mites.

Nematodes – Stem and bulb nematode and the root knot nematode are major onion pests in California, and stubby root nematode, minor.

WA – major: onion thrips and western flower thrips, onion maggot. Minor: seed corn maggots, aphids, armyworms, cut worms, leafhoppers, leafminers, wireworms.

Nematodes – Stubby root nematode a minor problem.

OR – mites, cutworms, armyworms, onion maggots, thrips, leafminers, wireworms.

Nematodes – Stubby root nematode a minor problem.

GA – major: thrips. Minor: seed corn maggots, onion maggot, wireworm, mole cricket.

Nematodes – no.

TX – cutworm, wireworm. Minor: white grub, onion maggot.

Nematodes – patchy occurrence of root knot nematode, onion bloat nematode, root lesion nematode, and stubby root. nematode. Problem is growing.

NM – major: thrips. Minor: cutworms, cucumber beetles, onion maggots.

Nematodes – Southern rootknot nematode.

NY – major: onion maggot, thrips. Minor: bulb mite, cutworms.

Nematodes – patchy and increasing.

WI - major: onion maggot, thrips, aster leafhopper (transmits aster yellows disease).

Nematodes - no.

CO – major: onion thrips, western flower thrips. Minor: aphids, leafhoppers, leafminers, maggots.

Nematodes - no.

Some Major Onion Pests, by State:

	Onion Maggot	Thrips	Seedcorn Maggot	Wireworms	Cutworms	Army-worms	Leafminer
CA	X	X	X			X	X
WA	X	X	X	X	X	X	X
OR	X	X		X	X	X	X
GA	X	X	X	X			
TX	X			X	X		
NM	X	X					
NY	X	X			X		
WI	X	X					
CO	X	X	X				X

varieties with resistance. Onion maggot is particularly devastating in cooler growing areas. Excellent field sanitation is recommended, consisting of cleaning up all cull and volunteer onions out of fields before planting. Fall plowing reduces the populations of overwintering pupae.

In the Vidalia sweet onion producing area of Georgia, insect problems during the winter growing season are not as severe as in areas that produce onions in spring, summer, or fall. Onion maggot and seedcorn maggot are customarily controlled through a preplant application of an appropriate insecticide, either just before seeding plantbeds or just prior to transplanting. An alternative is to use a long rotation, avoiding corn just before planting onions. In California growers avoid planting onions in fields high in organic matter and practice good field sanitation. Natural enemies of onion maggot and seed corn maggot include lady bugs, beetles, birds, parasitic wasps, nematodes, and parasitic fungi. Release of sterile onion maggot flies is being researched. Diatomaceous earth is another nonchemical control sometimes used.

Thrips

Fields should be carefully scouted for presence of either of the two species of thrips that commonly attack onion foliage, leaving it more susceptible to disease. This scouting is done in late winter or spring for southern growers. In California thrips are one of the two most significant insect pests of onions. Growing resistance to insecticides is suspected, although not documented. Cultural controls include planting a thrips-resistant cultivar such as Grano or Sweet Spanish and growing onions during the rainy season; both rainfall and overhead irrigation suppress thrips. Growers also make new plantings upwind of older plantings and sometimes plant in proximity to carrots. Biological controls with beneficial organisms include pink lady beetles, green lacewing larvae, minute pirate bugs, predatory mites, lady bugs, and an insect-specific fungus (*Beauveria bassiana*). None of these methods will provide complete control, however. Thrips must be controlled during the early bulbing stage of onions in order to minimize population buildups, as they go through four life cycles a year in California. Pyrethrins, rotenone, and insecticidal soaps are alternatives to other insecticides.

Disease Management

Economically significant diseases, by state:

CA – major: bacterial soft rots, basal rot, black mold, blue mold, botrytis leafspot, downy mildew, botrytis bulb rot, pink root, purple blotch, stemphylium leafblight, sour skin, white rot, and rust.

WA - major: Botrytis neck rot, Aspergillus black mold, pink root, bacterial soft rot, and Fusarium basal rot. Minor: Damping off, downy mildew, onion smut, white rot, Iris yellow spot virus (new).

OR – major: rots, molds, blight, mildew, rust, blotch, smut, and pink root.

GA – major: pink root, Botrytis neck rot, Botrytis leaf blight, purple blotch, center rot, sour skin, bacterial soft rot. Minor: Downy mildew (rare), bacterial streak and bulb rot (due to excessive fertilization, excessive rain).

TX – major: Botrytis leaf blight (100 percent acres), Downy mildew (100 percent acres), Purple blotch (8 percent acres). Minor: pink root – variable, but increasing in frequency and severity.

NM – pinkroot, fusarium basal rot, botrytis bulb rot, black mold, purple blotch, bacterial soft rots.

NY – Damping off, smut, botrytis leaf blight, purple blotch, Stemphylium leaf blight and stalk rot, downy mildew, bacterial soft rot, slippery skin, and sour skin, fusarium basal rot, pink root, botrytis neck rot.

WI – Botrytis leaf blight, botrytis neck rot, downy mildew, fusarium basal rot, onion smut, pink root, purple blotch.

CO – Botrytis leaf blight, botrytis neck rot, downy mildew, pink root, purple blotch.

Fungicides are commonly applied for control, but recommended cultural controls for fungal diseases include the following:

- Plant resistant cultivars
- Use crop rotations
- Protect plants from injury (by insects, fertilizers, and machinery)
- Store bulbs at proper temperature/humidity with adequate ventilation
- Promptly and adequately dry bulbs after harvest
- Get rid of cull piles and debris (practice good field sanitation)
- Avoid extended overhead irrigation; reduce hours of leaf wetness
- Allow tops to mature before harvest
- Avoid planting in poorly-drained soil
- Eradicate unwanted plants
- Use appropriate levels of nitrogen fertilizer and irrigation
- Plant only disease-free material in disease-free soil
- Wash equipment after use
- Remove infected plants and soil when practical

Nematodes are controlled by sanitizing equipment and preventing the movement of infested soil to uninfested areas, in addition to planting onions in well-drained soil.

Pink root is the most common and damaging bacterial disease in onions grown in Georgia. It is greatly enhanced by stresses imposed on plants such as heat, cold, drought, flooding, and nutrient toxicities/deficiencies. The fungus reproduces and survives indefinitely in soil; therefore, continuous production of onions in the same field results in increasing losses to pink root, which kills plants outright or renders the onions unmarketable.

Disease management requires a systems approach that involves practices such as rotation, sanitation, optimum fertilization, preventive fungicide/bactericide applications, harvest timing, and proper handling. For pink root, using a long rotation to non-related crops (three to seven years) is the key management strategy to reduce losses. In addition, optimum soil tilth, fertility and water management will reduce stresses that enhance disease development. Growing onions in a soil temperature range below 75 degrees Farenheit will also inhibit pink root losses. If a fixed irrigation system is in place, this limits options for crop rotations and other alternatives, especially if there is limited acreage. Solarization of the soil is used in California's San Joaquin Valley to prevent pinkroot.

Botrytis leaf spot is a particular problem in onion seed fields. Seed fields in California should be on a three-year rotation away from onions.

Nematodes

Stem and bulb nematode and the root knot nematode are major onion pests in California, with stubby root nematode causing some damage. Nematodes are controlled by sanitizing equipment and preventing the movement of infested soil to uninfested areas, in addition to planting onions in well-drained soil. Planting when soil temperatures are below 64 degrees Farenheit minimizes nematode damage (especially from root knot nematodes). Growing nonhost crops such as carrots and lettuce for several years helps decrease stem and bulb nematode populations. *Myrothecium verrucaria*, botanical extracts, pathogenic fungus, and diatomaceous earth are biologically derived nematacides used in addition to cultural controls.

In Washington the most important nematode pest of onions is the stubby-root nematode, a particular problem in very sandy soils with grasses or cereals in the crop rotation. However, crop rotation is the primary cultural control method. In Oregon stubby-root nematode overwinters in soil and causes the most problems during cool, damp springs. Cultural controls such as crop rotation are used in addition to preplant field fumigation. In both states, onion growers are cautioned against planting immediately after a mint crop.

In New Mexico heavy infestations of the southern root-knot nematode that inhibits onion growth and bulb development in both

spring- and fall-planted onions are controlled chemically. (Nematode infection is often mistaken for salinity injury because of similarities in above-ground symptoms.)

Nematodes are not a problem in Colorado onion-growing areas, and in Texas, nematodes are only a minor pest at present. Occurrence is variable among fields within a region, but increasing in frequency and severity. Low soil temperatures in winter limit nematode activity and reproduction and mature females are immobile, but eggs can be rapidly spread by running water, equipment, transplants, sets, and bulbs.

Nematodes have not been an economic problem in New York, Georgia, or Wisconsin, but are now increasing in frequency and severity in certain fields and in certain regions, delaying onion maturity and reducing yields. Severe, but patchy, damage is especially apparent during dry periods. Nematodes found in New York are the root knot, onion bloat, root lesion, and stubby root. The main controls are cultural: rotate with nonhost crops (principally grain crops) for two years; use antagonistic crops such as sudangrass and rapeseed, and avoid introducing nematodes to clean fields on infected bulbs or infested soil on equipment. Pre-plant soil fumigants are also used.

Wind/Physiological damage

Physiological problems in Georgia winter onions are often induced by weather. Freezing promotes translucent scale, and lesions can be due to physical damage from wind or hail. Greening and sunscale can occur. Striping is often due to sulfur deficiency, or can be due to a mutation. (4)

Onions raised in New York state are protected from wind damage at the seedling stage by barley windbreaks planted at the same time as onion seeding. Once the onions are established, windbreaks are killed with a selective herbicide (or they could be hand weeded or mowed for organic production). Wind damage can be significant, and total crop loss due to winds in May or early June is not rare, according to Cornell Cooperative Extension.

Harvest/Postharvest Handling/Storage

Optimal conditions for managing all aspects of post-harvest handling and storage have been well studied. An excellent in-depth treatment is Chapter 10, Onion pre- and postharvest considerations by I.RD H.S. MacTavish in *Allium Crop Science: Recent Advances*. (1).

California onions are harvested at a slightly less mature stage for fresh produce than for storage. Determining when to harvest is an art born of experience, rather than an exact science, and is sometimes influenced by marketing opportunities. The amount of tops fallen over is not a precise indicator of maturity, and experts differ about this indicator. Irrigation management is key. Stopping irrigation too soon will reduce yield. Irrigating too late, or applying too much water late in the season can lead to splitting or disease problems.

Yield. A 1980 trial of yellow Granex onion at Beaumont, MS, yielded 14,500 pounds per acre (290 50-pound bags) of onions that were two or more inches in diameter (Repack size and above).

In California, before hand harvesting, tops are rolled to enhance maturity. On a precision-leveled field, onions are undercut using a hand-operated rod weeder, then picked up by hand. However, in some regions, a modified potato lifter is used for the cutting and picking up. Harvesting must start immediately after cutting in Southern California to avoid sunburn. Onions were formerly field cured in burlap sacks for three days to two weeks prior to grading and packing, to allow the bulbs to dry and form a protective outer covering. A preferred method is to move onions into special storage areas immediately after lifting and air-dry them in precisely regulated temperatures up to 20 days. (1) In addition to size standards, bulbs are graded for quality to eliminate immature, decayed, sunburned, and mechanically injured bulbs, doubles, and bulbs that have started to sprout. The exception to use of hand labor is contract onions for dehydration, where the whole process is entirely mechanized. The standard container for graded onions is a 50-pound cardboard box or mesh bag.

Shelf life of fresh market onions harvested before maturity is only 4 to 6 weeks. Fully mature bulbs (either fresh market or dry onions) can be stored up to six months at optimal storage temperature and relative humidity (33 degrees Farenheit, 60 to 70 percent humidity). Air movement between storage containers is essential. Onions that are incompletely cured or improperly handled in storage are susceptible to many kinds of post-harvest mold, which can be initiated by exposure to light rain or dew while field curing.

Research

Research is ongoing in Georgia to develop a cultivar resistant to pink root and at an experiment station in Oklahoma in support of an Oklahoma sweet onion industry, and at New Mexico State University in support of New Mexico's fledgling onion industry. California has called for more research on the role of natural enemies in onion production, particularly for control of thrips. Some Sustainable Agriculture Research and Education (SARE) projects have at least some bearing on onion production. Most ongoing research and development of new varieties is carried on by seed companies, not public institutions.

In 2002–2003 the University of Georgia studied the potential for organic onion production in Georgia (see above). In 1997, a farmer/rancher SARE grant was awarded in support of an organic onion production project in a North Central state (specifically, control of onion maggot). In 2002 a Western SARE research and education project investigated the use of straw mulch to enhance predators in control of onion thrips in dry bulb production. In 2001 a Northeast farmer/rancher project used hardwood ramial woodchips (small branches and twigs) as mulch to control weeds. Biofumigants, field waste disposal, and cover cropping were also investigated for onions.

In December 2004 a national conference on allium research was held at Colorado State University. For more information, see *www.colostate.edu/Depts/CoopExt/TRA/Allium/schedule.html*.

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Further Resources

Crop profiles

Crop Profile for Onions in Colorado (2003). 30 p.
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Crop Profile for Onions in Georgia. 6 p.
www.ipmcenters.org/cropprofiles/docs/gaonions.html

Crop Profile for Onions in New Mexico (2000). 6 p.
http://pestdata.ncsu.edu/cropprofiles/docs/nmonions.html

Crop Profile: Onions in New York (1999). 26 p.
http://pmep.cce.cornell.edu/fqpa/crop-profiles/onion.html

Crop Profile for Onions in Oregon. 6 p.
http://pestdata.ncsu.edu/cropprofiles/docs/oronions.html

Crop Profile for Onions in Texas (2003). 12 p.
http://ipmcenters.org/cropprofiles/docs/txonions.html

Crop Profile for Onions in Washington. 20 p.
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Crop Profile for Onions in Wisconsin (1999). 22 p.
www.ipmcenters.org/cropprofiles/docs/wionions.html

Web sites

UC IPM Online: Statewide Integrated Pest Management Program (2005). Onions (2004).
http://axp.ipm.ucdavis.edu/index.html
Note: Supersedes publication UC IPM Pest Management Guidelines (1990)

North Dakota State University Extension
http://ndsuext.nodak.edu/extpubs/alt-ag/onions.htm

University of Georgia. 40 p.
http://pubs.caes.uga.edu/caespubs/pubcd/B1198.htm

Western Dry Bulb Storage Onions.
http://www.ipmcenters.org/pmsp/pdf/WesternOnion.pdf

Onion Arthropod Pest Management
http://ipmworld.umn.edu/chapters/straub.htm

Onion Links
www.mgo.umn.edu/crops/Onions.htm

Bulb Onion Production in Eastern North Carolina (1997) *www.ces.ncsu.edu/depts/hort/hil/hil-18-a.html*

Oregon State Commercial Vegetable Production Guides—Onions (5 pubs)
http://oregonstate.edu/Dept/NWREC/onion.html

Onions (TX) *http://www.agmrc.org/agmrc/commodity/vegetables/onions*

Agricultural Alternatives: Onion Production (Penn State) *http://agalternatives.aers.psu.edu/crops/oniononions.pdf*

History of the Sweet Texas Onion
http://aggie-horticulture.tamu.edu/plantanswers/publications/onions/onionhis/html

Yellow Storage Onions (MN)
www.extension.umn.edu/distribution/cropsystems/DC7060.html

Onions in Wisconsin
http://ipcm.wisc.edu/piap/onions.htm

Vegetable Production Guide for Commercial Growers Onions
www.ca.uky.edu/agc/pubs/id/id36/id36-04.pdf

Onion Production in Saskatchewan
www.agr.gov.sk.ca/docs/crops/horticulture/onions01.asp

Periodicals

Agricultural Alternatives (Penn State University)
http://agalternatives.aers.psu.edu

- Organic Vegetable Production
- Onion Production

Onion World. Published by the National Onion Association *www.columbiapublications.com/onionworld/*

SARE Research

www.sare.org

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FW00-012 – Residue Management in Furrow Irrigated Reduced Tillage Systems. Final Report.

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LS97-087 – An Integrated Vegetable Production, Postharvest and Marketing System. Final Report.

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AS93-007 – Evaluation of Recycled Paper Mulch as an Alternative to Black Plastic Mulch in Vegetable Horticulture. Final Report.

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By Katherine Adam
NCAT Agriculture Specialist

Paul Driscoll, Editor
Tiffany Nitschke, Production

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