2008 National Allium Research Conference

December 10-13, 2008
Savannah, Georgia

2008 National Allium Research Conference

December 10-13, 2008

Hosted by the
University of Georgia
at the Savannah Marriott Riverfront Hotel
Savannah, GA

Program and Proceedings

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2008 National Allium Research Conference
Program at a Glance

Wednesday, December 10, 2008

9:00 am – 5:00 pm	Registration Location: Hotel Atrium
9:00 am – 5:00 pm	Poster setup Location: Hotel Atrium
1:00 pm – 5:00 pm	W1008: Biology and Management of Iris Yellow Spot Virus (IYSV) and Thrips in Onions Location: Oglethorpe AB Schedule: See below

Thursday, December 11, 2008

6:30 am – 8:00 am	Breakfast
7:00 am – 5:00 pm	Registration Location: Hotel Atrium
7:00 am – 5:00 pm	Poster setup Location: Hotel Atrium
7:45 am – 10:00 am	Session 1 Location: Savannah Ballroom A
10:00 am – 10:30 am	Break & Poster Session Location: Hotel Atrium
10:30 am – 12:00 pm	Session 2 Location: Savannah Ballroom A
12:00 pm – 1:00 pm	Lunch & Business Meeting Location: Savannah Ballroom B
1:00 pm – 3:00 pm	Session 3 Location: Savannah Ballroom A
3:00 pm – 3:30 pm	Break & Poster Session Location: Hotel Atrium
3:30 pm – 5:00 pm	Session 4 Location: Savannah Ballroom A

Friday, December 12, 2008

6:30 am – 8:00 am	Breakfast Location: Hotel Atrium
8:00 am – 10:00 am	Session 5 Location: Savannah Ballroom A
10:00 am – 10:30 am	Break & Poster Session Location: Hotel Atrium
10:30 am – 12:00 pm	Session 6 Location: Savannah Ballroom A
12:00 pm – 1:00 pm	Lunch & Awards Location: Savannah Ballroom B
1:00 pm – 3:30 pm	Session 7 Location: Savannah Ballroom A
3:30 pm – 5:30 pm	Root and Bulb Vegetable Crop Germplasm Committee Meeting Location: Savannah Ballroom A Snacks will be served

Saturday, December 13, 2008

8:30 am	Load tour bus Location: Hotel Entrance
8:45 am – 10:00 am	Travel to Bland Farms
10:00 am – 11:30 am	Tour of Bland Farms
11:30 am – 1:00 pm	Tour Vidalia Onion & Vegetable Research Center & Lunch
1:00 pm – 2:30 pm	Travel to Savannah
2:45 pm – 4:00 pm	Tour of Historic Savannah & arrive at hotel

W1008 MEETING
BIOLOGY AND MANAGEMENT OF IRIS YELLOW SPOT VIRUS (IYSV) AND THRIPS IN ONIONS

Wednesday, December 10, 2008

1:00 pm – 5:00 pm Location: Oglethorpe AB

1. Welcome and Introductions – Chris Cramer, Chair
2. IYSV & Thrips Highlights
   a. 2008 reports by meeting participants – state, ARS, industry, growers
   b. State/Regional Onion Association Comments – various
   c. Specialty Crops Research Initiative Funding
   d. Other - ?
3. Discussion of 2008 Regional Activities
   a. Objective 1 – screen onion germplasm for improved levels of tolerance
   b. Objective 2 – study the biology, epidemiology & management of ISYV and thrips
   c. Objective 3 – transfer of information on progress to the onion industry and others; Allium web site - http://www.alliumnet.com/index.htm
4. Discussion of and Planning for 2009 Regional Activities
   a. Objective 1 – screen onion germplasm for improved levels of tolerance
   b. Objective 2 – study the biology, epidemiology & management of ISYV and thrips
   c. Objective 3 – transfer of information on progress to the onion industry and others; Allium web site - http://www.alliumnet.com/index.htm
5. Other Business - ?
6. W1008 Committee Organization – election of officers (secretary), with rotation of Christy to Vice Chair and Stuart to Chair for 2009/2010 and Chris rotates off.
   a. 2008/2009 Chair – Chris Cramer @ cscramer@nmsu.edu
   b. 2008/2009 Vice Chair – Stuart Reitz @ sreitz@saa.ars.usda.gov
   c. 2008/2009 Secretary – Christy Hoepting @ cah59@cornell.edu
7. Selection of next meeting date / location
8. Adjourn

2008 NATIONAL ALLIUM RESEARCH CONFERENCE PROGRAM

Thursday, December 11, 2008

7:45 am – 10:00 am	**Session I** Location: Savannah Ballroom A
7:45 – 8:10 am	**Welcome & Announcements** George Boyhan
8:10 – 8:30 am	**National Onion Association** Kim Reddin

DISEASE MANAGEMENT

Moderator: Mike Dollar, Evans County Extension

8:30 am – 9:00 am	**Potential Management of Sour Skin by Double-Cropping Onions with Pearl Millet** Ron Gitaitis*, Claudia Nischwitz, Hunt Sanders, George Boyhan, Reid Torrance, and Jeff Wilson
9:00 am – 9:30 am	**Detection of *Pantoea ananatis* in New York Grown Onions and Development of Pathogenicity Tests for *P. ananatis* on Onion** Eric A. Carr*, James W. Lorbeer, and Steven V. Beer
9:30 am – 10:00 am	**Goals of a Grant Funded by the Specialty Crops Research Initiative Grant on Translational Genomics and Pest Resistances in Onion** Michael Havey*, Foo Cheug, Cristopher Cramer, Hanu Pappu, and Howard Schwartz
10:00 – 10:30 am,	**Break & Poster Session** Location: Hotel Atrium
10:30 am – 12:00 pm,	**Session 2** Savannah Ballroom A
10:30 am – 11:00 am	**Evaluation of Seed Treatments for Soilborne Damping-Off Pathogens and Seedborne Fungi of Onion** Lindsey J. du Toit, Mike L. Derie*, Louise M. Brissey, Barbara J. Holmes, and Emily Gatch
11:00 am – 11:30 pm	**Powdery Mildew (*Leveillula taurica*) Incidence On Onion Cultivars and Some Native Flowering Plants in The**

	Treasure Valley Region of Idaho and Oregon R.K. Sampangi*, S.K. Mohan, C.C. Shock, E.B.G. Feibert, and D.A. Glawe
11:30 am – 12:00 pm	**Activity of Fungicides and Biological Control Agents against Garlic White Rot, in Fresno County, 2008** Thomas Turini*, Larry Schwankl, Michael Davis, James Gerik, Kurt Hembree, and Richard Molinar
12:00 pm – 1:00 pm,	**Lunch: Announcements & Business Meeting: Next meeting** Savannah Ballroom B
1:00 pm – 3:00 pm	**Session 3** Location: Savannah Ballroom A
1:00 – 1:30 pm	**Sour Skin Detection in Vidalia Onions Using a Gas Sensor Array** Changying 'Charlie' Li*, Bill Tollner, Ron Gitaitis, Chi Thai, Paul Sumner, and Dan MacLean

CULTURAL PRACTICES

Moderator: Shane Curry, Montgomery County Extension

1:30 pm – 2:00 pm	**Irrigation Scheduling for Drip-Irrigated Onion** Clinton C. Shock*, Erik B. G. Felbert, and Lamont D. Saunders
2:00 pm – 2:30 pm	**Irrigation Intensity, Irrigation Frequency, and Emitter Flow Rate for Drip-irrigated Onion** Erik Feibert*, Clinton Shock, and Lamont Saunders
2:30 pm – 3:00 pm	**Comparison of Onions Grown From Imported Bare Root and Locally Grown Plug Transplants in New York** Christy Hoepting*, Kathryn Klotzback, Guy Smith
3:00 pm – 3:30 pm	**Break & Poster Session** Location: Hotel Atrium
3:30 pm – 5:00 pm	**Session 4** Location: Savannah Ballroom A

POSTHARVEST

Moderator: Jason Edenfield, Toombs County Extension

3:30 pm – 4:00 pm	**A Fast and Uniform Absorbency Reading Time is Essential in Accurate Measurement of Pyruvic Acid When DNPH is Reacted to Undiluted Onion Juice** Kil Sun Yoo*, Eun Jin Lee, and Bhimu Patil

4:00 pm – 4:30 pm **Using Onion Waste to Produce Energy**
Gary Hawkins*

GENETICS AND BREEDING
Moderator: Cliff Riner, Tattnall County Extension

4:30 pm – 5:00 pm **Genomic and Proteomic Analyses of Male-Fertility Restoration in Onion**
Sergio Meigar and Michael Havey*

Friday, December 12, 2008

8:00 am – 10:00 am **Session 5**
Location: Savannah Ballroom A

8:00 am – 8:30 am **Genetics of Carbohydrate Accumulation in Onion**
Michael Havey*, Steven Raines, and Cynthia Henson

IRIS YELLOW SPOT VIRUS (IYSV) AND THRIPS IN ONIONS
Moderator: Cliff Riner, Tattnall County Extension

8:30 am – 9:00 am **Spirotetramat for Management of Thrips in Onions**
Charles Hicks*, John Bell, and John Martin

9:00 am – 9:30 am **Managing Insecticides For Maximum Efficacy Against Thrips in Dry Bulb Onion in The Oregon / Idaho Production Region**
Lynn Jensen*, Clinton Shock, and Lamont Saunders

9:30 am – 10:00 am **Optimizing Spray Coverage for Thrips Control on Onions.**
Jennifer Allen, Mary Ruth McDonald*, Kevin Vander Kool, and Kristy Grigg

10:00 am – 10:30 am **Break & Poster Session**
Location: Hotel Atrium

10:30 am – 11:00 am **Thrips Species Shift in the Vidalia Production Region of Georgia**
Alton 'Stormy' Sparks*, David Riley, Stan Diffie, Reid Torrance, and Cliff Riner

11:00 am – 11:30 am **Impact of Carbamate Insecticides on Thrips Populations and Iris Yellow Spot Virus Incidence in Onions**
Mike Thornton* and William Buhrig

11:30 am – 12:00 pm	**Thrips And IYSV Sources in Colorado Onion Production Systems** Howard. F. Schwartz*, K. Otto, S. Szostek, C. Boateng, W. S. Cranshaw, M. A. Camper, and L. Mahaffey
12:00 pm – 1:00 pm,	**Lunch: Announcements & Awards** Savannah Ballroom B
1:00 pm – 1:30 pm	**Abundance and Population Dynamics of Onion Thrips and Incidence of Iris Yellow Spot Virus in Treasure Valley Region of Idaho and Oregon** R.K. Sampangi*, S.K. Mohan, C.C. Shock, and E.B.G. Feibert
1:30 pm – 2:00 pm	**Identifying Sources of IYSV in New York's Onion Cropping System** Brian Nault*, Cynthia Hsu, Erik Smith, Anthony Shelton, Mar Fuchs, Christy Hoepting, and Antonio DiTommaso
2:00 pm – 2:30 pm	**Genome Characterization and Genetic Diversity of Iris Yellow Spot Virus** Sudeep Bag, Keri Druffel, and Hanu Pappu*
2:30 pm – 3:00 pm	**Onion Variety Response to Iris Yellow Spot Virus** Clinton Shock*, Erik Feibert, Lynn Jensen, Krishna Mohan, and Lamont Saunders
3:00 pm -3:30 pm	**Seasonal Prevalence of Iris Yellow Spot Virus in Transplanted and Direct-Seeded Onion Fields** Cynthia Hsu*, Christy Hoepting, Anthony Shelton, and Brian Nault

ROOT AND BULB VEGETABLE CROP GERMPLASM COMMITTEE MEETING

Moderator: Chris Cramer

3:30 pm – 5:30 pm	Snacks served

Saturday, December 13, 2008

8:30 am	Load tour bus Location: Hotel Entrance
8:45 am – 10:00 am	Travel to Bland Farms
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1:00 pm – 2:30 pm	Travel to Savannah
2:45 pm – 4:00 pm	Tour of Historic Savannah & arrive at hotel

POSTERS

Hotel Atrium

Poster No.	Title
P-1	**Determining Redundancy of Current and Collected Short-Day, Onion Accessions** Rachael Gibson* and Christopher Cramer
P-2	**Does Breeding for Increased Firmness Lead to More Pungent Onions?** Ashish Saxena* and Christopher Cramer
P-3	**Strategies to Improve Early Season Thrips Control and Suppress Iris Yellow Spot Virus in Onions** William Buhrig* and Michael Thornton
P-4	**Survey And Behavior Studies Of T. Tabaci (Thysanoptera: Thripidae) On Onion In India And Georgia** Anitha Chitturi* and David. G. Riley
P-5	**Cultural Management of Onion Thrips And Iris Yellow Spot Virus** Danial Drost*, Jennifer Reeve, Kent Evans, Lincoln Andreasen, and Diane Alston
P-6	**First Report of *Colletotrichum gloeosporioides* Causing 'Twister Disease' Of Onion (*Allium cepa* L.) in Georgia** Ron Gitaitis*
P-7	**Detection and Distribution of Iris Yellow Spot Virus in Spiny Sowthistle in Georgia** Ron Gitaitis*
P-8	**Consistency of Long-Term Marketable Yield of Onion Cultivars Grown on Organic Soils in Ontario, Canada, in Relation to Seasonal Climate** Michael Tesfaendrias, Mary Ruth McDonald*, and Jon Warland
P-9	**Evaluation of Onion Cultivars For Resistance to Downy Mildew** Mary Ruth McDonald*, Kevin Vander Kool, and Shawn Janse
P-11	**Organic Vidalia Onion Production in Southeast Georgia** George E. Boyhan*, Ray J. Hicks, Reid L. Torrance, Cliff M. Riner, and C. Randall Hill
P-12	**Evaluation of New Mexico Autumn-Sown Onion Entries** Ashish Saxena* and Christopher Cramer*

P-13 **Management of Onion Thrips and IYSV with Straw Mulch and Biopesticides**
Howard Schwartz*, David Gent, Scott Fichtner, Whitney Cranshaw, Linda Mahaffey, Matt Camper, Kris Otto, and Mark McMillan

P-14 **Spatial and Temporal Distribution of Thrips and IYSV of Onion in Colorado**
Howard Schwartz*, Scott Fichtner, David Gent, Raj Khosla, Danny Inman, Whitney Cranshaw, Matt Camper, and Linda Mahaffey

P-16 **Cultivar Evaluation For Hoop House Grown Onions**
James Shrefler*, Warren Roberts, Merritt Taylor, and Charles Webber

P-17 **Effect of Curing on Postharvest Quality of Vidalia Sweet Onion**
Dan MacLean*, Anthony Bateman, George Boyhan, Randy Hill and Changying Li

P-18 **Onion Agronomy in The Treasure Valley of Idaho and Oregon**
Robert Simerly*

P-19 **Impact Of Surround Wp Crop Protectant For Management Of Thrips Infestation And Overall Plant Health**
Kurt Volker*

P-20 **Acetic Acid and Weed Control in Onions**
Charles Webber* and James Shrefler

P-21 **Acetic Acid: Crop Injury and Onion Yields**
Charles Webber* and James Shrefler

P-22 **Enhancing Weed Control In Direct Seeded Vidalia Onions Through Fertility Regimes**
Cliff Riner*, Reid Torrance and Randy Hill

ORAL PRESENTATION ABSTRACTS

DISEASE MANAGEMENT

Moderator: Mike Dollar, Evans County Extension

8:30 am – 9:00 am

Potential Management of Sour Skin by Double-Cropping Onions With Pearl Millet

Ron Gitaitis [1]*, Claudia Nischwitz[1], Hunt Sanders[1]*, George Boyhan[2], Reid Torrance[3], and Jeff Wilson[4]
[1]Department of Plant Pathology Coastal Plain Experiment Station University of Georgia - Tifton Campus Tifton, GA 31793-0748
[2]Southeast District Cooperative Extension, University of Georgia, PO Box 8112, GSU 2nd Floor, Nessmith-Lane CE Building Statesboro, GA 30460-8112
[3]Tattnall County Extension, PO Box 580, 200 S. Main Street, Hwy 23, Reidsville, GA 30453
[4]U.S.D.A./ARS Crop Genetics and Breeding Research, Room 134, 115 Coastal Way, Tifton, GA 31793-0748
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Sour skin of onion, caused by the soilborne bacterium Burkholderia cepacia, continues to be a postharvest disease problem in Georgia. It is particularly severe if there are above normal temperatures prior to or at harvest. Preliminary studies conducted at Cornell University in New York have indicated that crop rotations with certain crops, e.g. pearl millet (Pennisetum glaucum), may suppress bacterial populations. In addition, they found that certain other crops, e.g. corn (Zea mays) may increase soilborne populations of B. cepacia. Results from a field study conducted at the UGA Coastal Plain Experiment Station's Blackshank farm, in which corn and pearl millet were evaluated in a double-cropping scheme with Vidalia sweet onions to determine their effect on sour skin levels, are presented here. In two out of three years, onions grown behind pearl millet had significantly less sour skin at harvest than did onions grown behind corn. Although there was no difference in sour skin levels between treatments in year 1 due to extremely low disease pressure, there was a reduction in the number of Burkholderia colonies in soil samples from pearl millet plots plated on PCAT medium.

9:00 am – 9:30 am

Detection of Pantoea ananatis in New York Grown Onions and Development of Pathogenicity Tests for P. ananatis on Onion

James W. Lorbeer
Department of Plant Pathology and Plant-Microbe Biology Cornell University, Ithaca, New York 14853
Email: JWL5@cornell.edu; Phone: 607-255-7875; Fax: 607-255-7471

The center rot disease of onion caused by Pantoea ananatis has been reported to occur in the USA in Georgia, Colorado, and Michigan. P. ananatis also has been reported as a pathogen on other crops in Asia and Australia. Center rot is characterized by necrosis and blighting of green leaves and non-macerating discoloration of the scales of onion bulbs. The latter symptoms render the bulbs unsaleable. We have observed similar symptoms on onion bulbs grown in New York beginning in 2006. From symptomatic bulbs, we isolated bacteria that were identified as P. ananatis based on microbiological and molecular properties in

comparison with pathogenic strains of P. ananatis that had been isolated in Georgia. When several of the isolated strains were introduced into onion bulbs and sets via hypodermic needle and syringe, symptoms reminiscent of center rot developed following 4 to 8 days of incubation at 28°C. Sub-epidermal inoculation on leaves of growing onion plants with suspensions of pathogenic strains of P. ananatis resulted in the development of elliptical lesions that expanded both distally and proximally from the point of inoculation. Some lesions reached the neck and infection extended through the neck into the bulb where specific scales became discolored, but not macerated. Bacteria were recovered from the leading edge of all lesions induced by inoculation. Recovered bacteria proved to have characteristics of the pathogen. Thus, Koch's postulates were completed for P. ananatis that induced both onion leaf and bulb symptoms.

9:30 am – 10:00 am

Goals of a Grant Funded by the Specialty Crops Research Initiative Grant on Translational Genomics and Pest Resistances in Onion

Michael Havey[1]*, Dr. Fu Cheung[2], Dr. Christopher Cramer[3], Dr. Hanu Pappu[4], Dr. Howard Schwartz5
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[2] J. Craig Venter Institute, 9704 Medical Center Drive, Rockville, MD 20850
[3]Department of Plant and Environmental Sciences, New Mexico State University, Las Cruces, NM 88003-0003 USA
[4]Department of Plant Pathology, Washington State University Pullman, WA 99164-6430
[5]Department of Plant Pathology, Colorado State University Ft. Collins, CO
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The use of high throughput DNA sequencing to address important production constraints has been termed translational genomics. Classical breeding of onion is expensive and slow due to a long generation time and the high costs of crossing with insects. Translational genomics will revolutionize onion breeding by reducing the costs of selecting for important traits during the development of superior inbreds and populations. This funded project will establish collaborative research among growers, extensionists, pathologists, and breeders to identify, validate, and deliver resistances to thrips and thrips-vectored Iris yellow spot virus (IYSV), both identified by stakeholders as the most important threats to the sustainability of US onion production. The cost benefits of these resistances will be estimated and communicated to growers. A high-density genetic map of onion will be constructed and used to tag resistances to these two prioritized pests, opening the door for marker-aided selection of onion. Project outcomes will be presented to breeders, growers, horticulturalists, and students by new and expanded web-based resources, articles in trade magazines, and workshops at regional and national grower meetings. The significant research and extension components of this project will address important threats from pests and diseases, exploit genomics to speed the delivery of pest-resistant onion cultivars to growers and consumers, and educate lay and professional horticulturists to improve production efficacy in order to establish the foundation for long-term translational genomics of onions.

10:30 am – 11:00 am

Evaluation of Seed Treatments for Soilborne Damping-Off Pathogens and Seedborne Fungi of Onion

Lindsey J. du Toit, Mike L. Derie*, Louise M. Brissey, Barbara J. Holmes, and Emily Gatch
Washington State University Mount Vernon NWREC, 16650 State Route 536, Mount Vernon, WA 98273
Email: derie@wsu.edu ; Phone: 360-848-6140; Fax: 360-848-6159

A seed lot of a proprietary onion cultivar naturally infected with the causal agents of neck rot (*Botrytis aclada* and *B. allii*), black mold (*Aspergillus niger*), and green mold (*Penicillium* spp.) was used to evaluate 12 conventional and 2 organic seed treatments for management of these fungi. Seed germination and health assays were completed for each treatment. In addition, the treatments were evaluated in greenhouse trials against soilborne inoculum of *Pythium ultimum* and *Rhizoctonia solani*. Non-treated seed planted into infested and non-infested potting mix served as control treatments. Emergence and damping-off were recorded weekly, and dry plant weights were recorded ~5 weeks after planting. In the germination assay, only Coronet (boscalid + pyraclostrobin) significantly increased seed germination at 6 days compared to non-treated seed. In contrast, Farmore D300 (mefenoxam + fludioxonil + azoxystrobin), alone or combined with Actigard (acibenzolar-S-methyl) or Mertect 340F (thiabendazole), significantly reduced early germination. By 10 days, there were no significant differences in germination among treatments. In the health assay, *B. allii* and *B. aclada* were observed on 65.3% of non-treated seeds. All treatments significantly lowered the incidence of *Botrytis* spp. except Farmore D300 and Apron (mefenoxam) + Maxim 4FS (fludioxonil) + A14635 (experimental from Syngenta Crop Protection). AgriCoat 711A and AgriCoat 800A (proprietary organic treatments from AgriCoat LLC), and Rovral 4F (iprodione) were the most effective (<3% *Botrytis*), followed by Coronet (<6%) and Farmore D300 + Thiram 42-S (thiram) (11.8%). Farmore D300 combined with Actigard, Mertect 340F, thiamethoxam, Trigard OMC 75WP (cyromazine), or Vangard WG (cyprodinil) had intermediate efficacy. *A. niger* was detected on 6.5% of non-treated seeds vs. <0.5% of seeds treated with AgriCoat 711A, AgriCoat 800A, or Coronet. Treatments with intermediate efficacy against *A. niger* (1.3-2.8%) included Thiram 42-S alone and with Farmore D300, and Farmore D300 + Actigard. For *Penicillium* spp., AgriCoat 711A, AgriCoat 800A, and Coronet were the most effective (<1.0% vs. 18.3% for non-treated seeds); followed by Rovral 4F and Farmore D300 combined with Thiram 42-S, Actigard or thiamethoxam (<4%). By 35 days after planting flats inoculated with *P. ultimum*, Thiram 42-S and all treatments with mefenoxam had significantly increased emergence compared to non-treated seed. However, only Farmore D300 combined with Mertect 340F, Thiram 42-S, or Vangard WG significantly increased plant dry weights in the *P. ultimum* assay. For *R. solani*, seed treated with Rovral 4F had the highest emergence, followed by Coronet and Apron + Maxim 4FS + A14635. All other treatments had intermediate efficacy, except AgriCoat 711A and AgriCoat 800A. Similarly, all treatments except AgriCoat 711A, AgriCoat 800A, and Thiram 42-S significantly improved plant dry weights in the *R. solani* assay. Rovral 4F and Apron + Maxim 4FS + A14635 resulted in the highest plant weights, followed by Coronet and all Farmore D300 treatments. Overall, the results demonstrate the need for multiple modes of action in seed treatments to control the diverse seedborne and soilborne pathogens of onion. The two organic treatments were highly effective against seedborne fungi but had no effect against soilborne *P. ultimum* or *R. solani*

11:00 am – 11:30 am

Powdery Mildew (Leveillula taurica) Incidence on Onion Cultivars and Some Native Flowering Plants in the Treasure Valley Region of Idaho and Oregon

R.K. Sampangi[1]*, S.K. Mohan[1], C.C. Shock[2], E.B.G. Feibert[2], and D.A. Glawe[3]
[1]University of Idaho, 29603 University of Idaho Lane, Parma, ID 83660
[2]Malheur Experiment Station, Oregon State University, Ontario, OR 97914;
[3]Washington State University and University of Washington, Seattle, WA 98195
R. K. Sampangi,
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A powdery mildew disease of onion (Allium cepa L.) has been observed annually from 2006 to 2008 in Treasure Valley [southwestern Idaho and eastern Oregon]. Powdery mildew of onion is a relatively new disease in North America caused by Leveillula taurica (Lév.) G. Arnaud (= Oidiopsis taurica (Lév.) Salmon). Several onion cultivars at mid- to late-bulbing stage in an onion cultivar trial at Oregon State University, Ontario, OR were found to be infected. Foliar symptoms included infrequent, circular to oblong, chlorotic to necrotic dry lesions with effuse, whitish patches consisting mostly of conidiophores. Diagnostic characteristics indicative of L. taurica included endophytic mycelium with conidiophores emerging through stomata, and dimorphic conidia (lanceolate and cylindrical to ellipsoid conidia). The teleomorph stage was lacking on onions. Disease was apparent only on mature plants, two to three weeks before harvesting. Iris yellow spot virus (IYSV) disease is endemic in this region and induces straw-colored, dry necrotic lesions on leaves, which are often are similar to those caused by powdery mildew. Incidence of powdery mildew in commercial bulb onion varieties was observed on 3 out of 54 varieties (2006), 21 out of 59 (2007) and 2 out of 46 (2008). Search for sources of primary inoculum in the vicinity revealed the following plants infected with L. taurica: Cleome hassleriana, C. lutea and C. serrulata (Capparaceae), Sphaeralcea grossulariifolia, S. parvifolia and S. coccinea (Malvaceae) and Astragalus filipes (Fabaceae). Both anamorphic and teleomorphic states of L. taurica were observed on all these hosts. These flowering plants constitute new alternative hosts records for L.taurica. Additional research is needed to determine whether these newly recognized hosts play any role in the epidemiology of this recurring onion disease.

11:30 am – 12:00 pm

Activity of Fungicides and Biological Control Agents against Garlic White Rot, Fresno Co., 2008

Thomas Turini[1]*, Larry Schwankl[2], Michael Davis[3], James Gerik[4], Kurt Hembree[1], and Richard Molinar[1]
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In the San Joaquin Valley of California over 13,000 acres are infested with *Sclerotium cepivorum*. Growers typically avoid planting allium crops in infested fields, and some growers have very few fields that are not infested. To assess potential control, two trials were conducted in a Fresno County, CA commercial field infested with *S. cepivorum;*one to assess efficacy of materials applied at planting and one to evaluate the potential of control programs including an application at planting in combination with multiple fungicide applications through buried drip. The experimental design of the efficacy trial was a five replication randomized complete block. Materials compared were Endura 6.8 oz, Folicur 20.5 fl oz with and without WatermaxxII 2 qts, Cannonball 50WP 8.0 oz with and without WatermaxxII 2 qts, Cannonball 50WP 4.0 oz, Moncut 2.86 lbs, *Glomes intrardices* 30.0 lbs, Contans 2, 4 and 8 lbs and an untreated control. The experimental design of the control programs trial was a 5 replication split plot; drip application programs were the main plot treatments and the at-planting applications were the sub plot treatments. The main plot treatments included a) Cannonball 8.0 oz on 15 Feb and Folicur 20.5 on 7 Mar, b) Cannonball 8.0 oz on 15 Feb, Folicur 20.5 on 7 Mar and Endura 6.8 oz on 27 Mar, c) Folicur 20.5 on 15 Feb, Cannonball 8.0 oz on 7 Mar and Endura 6.8 oz on 27 Mar, and d) untreated control. The subplot treatments included Endura 6.8 oz, Folicur 20.5 oz, Cannonball 8.0 oz, Cannonball 8.0 oz with Botran 102 oz. In both studies, California Late garlic was planted on 20 Nov 2007. All at-planting treatments were applied with a CO^2-pressurized back pack sprayer in the equivalent of 25 gallons per acre. The spray was applied in a 4 to5 inch band directly into the 2-3 inch-deep before planting. All drip applied materials were pump injected over a 45 to 60 minute period into the drip tape (510-12-220) buried at a 1 to 2 inch depth. On 7 and 15 Feb, 50 cloves were collected from untreated buffers, surface sterilized and incubated at 72°F. After a three week incubation period, *S. cepivorum* was present on 2 cloves sampled on 7 Feb and 1 clove sampled on 15 Feb. On 23 Apr and 14 May, each plot was rated for typical above-ground white rot symptoms including plant death and leaf dieback. Twenty-five feet of each single-bed plot was mechanically harvested on 22 Aug and weighed. In the efficacy trial, Folicur with or without WatermaxxII, Endura, and Cannonball at 8.0 oz with or without the WatermaxxII consistently had lower disease ratings and higher yields than the untreated control. In the control programs trial, all at-planting applications reduced disease as compared to the untreated control except for Contans. However, none of the drip applied programs reduced disease severity, which may be attributable to infection that occurred prior to the first application through the drip.

1:00 – 1:30 pm

Sour Skin Detection in Vidalia Onions Using a Gas Sensor Array

Changying 'Charlie' Li[1]*, Bill Tollner[2], Ron Gitatitis[3], Chi Thai[2] and Paul Sumner[1]
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The Vidalia onion is not only Georgia's most important vegetable crop but also the nation's most preferred sweet onion. However, various plant diseases, including sour skin caused by Burkholderia cepacia, pose a great threat by reducing shelf-life and are responsible for significant postharvest losses in both conventional and CA (controlled atmosphere) storage. This study investigated a new sensing approach to detect sour skin detection using a gas

sensor array. Principal component analysis (PCA) score plots showed two distinct clusters formed by healthy and sour skin infested onions. The MANOVA statistical test further proved the hypothesis that the responses of the gas sensor array to healthy onion bulbs and sour skin infested onion bulbs are significantly different (P-value<0.0001). The support vector machine (SVM) was employed for the classification model development. The study was undertaken in two phases: model training and cross-validation within the training datasets and model validation using new datasets. The classification results showed that with only six internal sensors, the gas sensor array achieved 94% and 85% correct classification rate at training and validation stages, respectively. This study demonstrated the feasibility of using a gas sensor array coupled with the SVM for the detection of sour skin in sweet onion bulbs. Early detection of sour skin will help reduce postharvest losses and secondary spread of bacteria in storage.

CULTURAL PRACTICES

Moderator: Shane Curry, Montgomery County Extension

1:30 pm – 2:00 pm

Irrigation Scheduling for Drip-Irrigated Onion

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Onions are very sensitive to water stress. For optimum yield and grade, onions need to be irrigated frequently to maintain high soil moisture in the root zone. The adoption of drip irrigation of onion has increased, because it allows uniform and precise water applications. Drip irrigation also reduces the leaching and erosion associated with surface irrigation. The Treasure Valley onion production area is located in the mid-Snake River plain and along the tributaries of the Snake River. This region produces high onion yields and large diameter bulbs. Onions are mostly long-day varieties and are marketed starting in August from the field and continuing to April from storage. Research at the Oregon State University Malheur Experiment Station in the Treasure Valley examined the use of soil water tension (SWT) to schedule drip irrigation of onion on silt loam soils. In 1997 and 1998, onions were submitted to five SWT irrigation criteria (10, 20, 30, 50, and 70 kPa). The plots were irrigated automatically applying 1.5 mm of water up to 8 times a day based on SWT readings. In 1997, onion total yield and size were highest with the wettest treatment (10 kPa). However, marketable yield was maximized at a SWT of 21 kPa due to an increase in decomposition in storage with the wettest treatment. Onion profits were maximized by a SWT of 17 kPa. In 1998, onion total yield, size, marketable yield, and profits were maximized by the wettest treatment, 10 kPa, because decomposition in storage was not influenced by irrigation criteria. Total season water applied increased with the increase in SWT, with the 20 kPa treatment applying about the same amount of water as total onion evapotranspiration. A SWT of 17 kPa (SWT that maximized profits in 1998) is suggested as optimum for drip irrigated onion on silt loam soil. While drip irrigation with a SWT lower than 17 kPa can result in higher yields, it can also result in higher leaching and in higher storage losses in some years. In conjunction with the 1997 and 1998 soil water tension trials, the effect of reducing the SWT in the last third of the growing season on onion storage decomposition was also tested. The

soil water tension at which automated irrigations were started was increased from 20 kPa to 30, 50, or 70 kPa after July 15. Any increase of the SWT from 20 kPa did not reduce storage decomposition, but reduced colossal onion yield in 1997 and marketable and total yield in 1998.

2:00 pm – 2:30 pm

Irrigation Intensity, Irrigation Frequency, and Emitter Flow Rate for Drip-irrigated Onion

Erik Feibert*, Clinton Shock and Lamont Saunders
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Drip irrigation can apply small amounts of water (low irrigation intensity) with high uniformity allowing for frequent irrigations that maintain soil moisture within a narrow range of soil water tension. However, very frequent irrigations might not be feasible on a commercial scale. In 2002 and 2003, research at the Malheur Experiment Station investigated the effect of low irrigation intensity (high frequency) on onion yield and grade. Long-day onions were grown on silt loam on 1.1 m beds with two double rows spaced 0.6 m apart and a drip tape buried 10 cm deep in the bed center. Onions were submitted to eight combinations of four irrigation intensities (1.5, 3, 6, and 12 mm of water per irrigation) and two drip tape emitter flow rates (0.5 and 0.25 L•h-1) in 2002 and 2003. The irrigation intensities of 1.5, 3, 6, and 12 mm had irrigations scheduled automatically up to eight, four, twice or once per day, respectively, based on soil water tension readings. Each plot was independently and automatically irrigated if the soil water tension at 0.2 m depth was equal to or higher than 20 kPa. This resulted in an average of 564, 269, 121, and 60 irrigations over 107 days for the 1.5, 3, 6, and 12 mm irrigation intensities, respectively. Onions were harvested and evaluated for yield and grade after 75 days of storage. Irrigation intensities of 12 mm per irrigation produced slightly greater onion yield and grade above the irrigation intensity of 1.5 mm per irrigation. An irrigation intensity of 12 mm did not result in an increase in water applied nor in any significant difference in average soil water tension compared to the other irrigation intensities. The 12 mm irrigation intensity resulted in an irrigation frequency of every 1 to 2 days. Lowering the emitter flow rate from 0.5 L•h-1 to 0.25 L•h-1, resulted in slightly lower onion yield and grade.

2:30 pm – 3:00 pm

Comparison of Onions Grown from Imported Bare Root and Locally Grown Plug Transplants in New York

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Growing onions from transplants is a growing trend in New York, because of the economic benefits of larger sized bulbs and earlier entry into the marketplace with approximately 15% of the 13,000 acres of onions now being grown from transplants. Most transplants are grown from bare root transplants imported from Arizona, which have been found to harbor

Iris Yellow Spot Virus (IYSV), the causal pathogen of neck rot, Botrytis allii and onion thrips. The deterrent to the alternative of purchasing locally grown plug transplants is that they are 3 times more expensive to purchase. In this study, we thoroughly compared all aspects of growing onions from plug and bare root transplants including plug production configurations, labor costs, stand establishment, pest management, yield, grade and economic feasibility. It was concluded that growing onions from plug transplants is a viable option for New York onion growers, especially in light of the availability of a new automated plug transplanter that would offer significant savings in the cost of and frustrations of acquiring labor.

POSTHARVEST

Moderator: Jason Edenfield, Toombs County Extension

3:30 pm – 4:00 pm

A Fast and Uniform Absorbency Reading Time is Essential in Accurate Measurement of Pyruvic Acid When DNPH is Reacted to Undiluted Onion Juice

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Onion pungency has been mostly estimated by measuring enzymatically produced pyruvic acid in onion juice after reacting with dinitrophenyl hydrazine (DNPH) and NaOH. Since the original Schiwimmer and Weston (SW) method was developed in 1961, several modified methods were developed for a faster analysis and significant variation was reported among laboratories. Even in our own tests, we have observed about 20-30% differences in pyruvic acid concentrations between our automated and manual methods. In order to maintain the consistent quality and mildness and to keep the confidence of the consumer, it is pertinent to compare methods and ensure the test results are consistent among laboratories. In this study, we collected juices from 40 onion bulbs of four colors and compared four different methods; an automated system, high performance liquid chromatography (HPLC), manual spectrophotometric (SP), and the original SW methods. The automated, HPLC, and SW methods showed highly significant correlations and had similar pungency levels. However, the SP method has estimated about 10 to 30% less pyruvic acid than the automated and HPLC methods. The absorbency reading of the undiluted juice samples in SP method was decreasing very rapidly and resulted in lower estimation in the pyruvic acid and the difference became greater as the reading time was extended. We, therefore, suggest that the absorbency of the color to be read within 30 second after adding NaOH for more consistent results. The present research was supported by the Designing Foods for Health through the Vegetable & Fruit Improvement Center, USDA Grant No. TAES 06-118409.

4:00 pm – 4:30 pm

Using Onion Waste to Produce Energy

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Onion production in Georgia totaled 3.24 million carton weight for the 2007 growing season. These onions after harvest have to be processed fro repacking and distribution to various locations. During the repacking stage, a portion are culled out and discarded due to blemishes or disease that makes them unmarketable. These discarded onions are at this point a waste material that has to be disposed of in a proper manner. With this in mind, researchers at the University of Georgia are working with growers in the Vidalia Onion Growing region of Georgia to characterize and analyze onion waste as a possible feedstock for anaerobic digestion systems. Characterization data indicates that onion waste (juice fraction) is one of vegetables with the highest energy output, theoretically. The information presented here will compare the varieties grown for sale as Vidalia Onions to see if there is a difference in the energy production potential. Information will also be used to compare onion waste to that of other vegetable waste. Information will also be presented on the anaerobic digestion process that will be used to convert a waste product from the onion industry to an energy that can be used by the onion industry.

GENETICS AND BREEDING

Moderator: Cliff Riner, Tattnall County Extension

4:30 pm – 5:00 pm

Genomic and Proteomic Analyses of Male-Fertility Restoration in Onion

Sergio Melgar[1] and Michael Havey[2]*

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Production of hybrid-onion seed is dependent on cytoplasmic-genic male sterility (CMS). The most commonly used CMS in onion requires the presence of male-sterile (S) cytoplasm and recessive alleles at one nuclear male-fertility restoration (Ms) locus. Molecular markers have been developed that distinguish S and normal (N) male-fertile cytoplasms and a single nucleotide polymorphism (AOB272) has been identified tightly linked to the Ms locus. We are using candidate gene and proteomic approaches in order to clone Ms and develop a marker that can be scored without regard to recombination. Male-fertility restorer loci from other plants often carry degenerated repeats of 35 [pentatricopeptide (PPR)] amino acids. We identified and characterized the sequence motifs of over 40 PPRs from onion. Polymorphisms in these PPR-containing proteins were identified and mapped; however none to date have shown linkage to Ms. Mitochondrial proteins hare being isolated from male-sterile (S msms) and male-fertility-restored (S Msms) plants. 2D gels revealed relatively few differences and partial-protein sequences have been generated by mass spectrometry. Peptide sequences are searched against the DNA databases to identify differentially expressed genes, and polymorphisms mapped to assess linkage to Ms.

Friday, December 12, 2008
8:00 am – 8:30 am

Genetics of Carbohydrate Accumulation in Onion

Michael Havey[1]*, Steven Raines[2], and Dr. Cynthia Henson[3]

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Fructans are soluble carbohydrates composed of fructose chains attached to a basal sucrose molecule and act both as health-enhancing pro- and pre-biotics. In onion, higher fructan concentrations are correlated with greater soluble solids content, dry weights, and pungency. We analyzed dry weights and soluble carbohydrates from replicated field trials of two onion families segregating across chromosome regions known to affect carbohydrate concentrations. One region on chromosome 8 controlled the ability of onion to accumulate fructans. One region on chromosome 5 conditioned greater dry weights, but not soluble carbohydrate concentrations. Regions on chromosomes 5 and 8 showed dominance for increased dry weights or fructans, respectively, but did not interact significantly. A third region on chromosome 3 was previously shown to affect fructan concentrations. Although this region not segregate in this study, the two families were homozygous for contrasting alleles and their genetic backgrounds interacted significantly with regions on chromosomes 5 and 8 to control total carbohydrate concentrations. These results indicate that the ability of onion to accumulate fructans is relatively simply inherited and significantly affected by at least three chromosome regions.

IRIS YELLOW SPOT VIRUS (IYSV) AND THRIPS IN ONIONS

Moderator: Cliff Riner, Tattnall County Extension

8:30 am – 9:00 am

Spirotetramat for Management of Thrips in Onions

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Spirotetramat (MOVENTO™) is a novel active ingredient from the new chemical class of tetramic acids. The product's new mode of action, known as a lipid biosynthesis inhibitor, shows no cross-resistance to currently available chemical classes in the market. When applied to the foliage, this highly systemic insecticide is translocated in a acropetal and basipetal manner via the phloem and xylem within the plant, resulting in effective control of hidden pests infesting roots and shoots. MOVENTO provides excellent initial and long-lasting residual control of a broad range of economically important sucking pests infesting annual and perennial crops, including aphids, whiteflies, mealybugs and others. Studies have shown minimal risk to both predators and parasitoids, making MOVENTO an excellent fit

in IPM programs. Field evaluations conducted by Bayer CropScience and university/private researchers since 2004 have also shown excellent reductions in populations of onion thrips (Thrips tabaci) on bulb onion. Due to the new mode of action that shows no cross-resistance to currently available chemical classes, as well as the product's excellent performance against onion thrips, MOVENTO will serve as a powerful tool for resistance management, IPM programs and management of onion thrips infesting bulb onion. Materials and Methods Efficacy trials were conducted across the major onion producing regions of the United States during 2007 and 2008. The most predominate species across trial locations was Thrips tabaci with some locations also reporting Frankliniella schultzei. Treatments compared a Movento program to a standard insecticide program. Application timing targeted the first sign of a developing thrips population. Application volume ranged from 30-100 gallons /Acre with an average of 50 gallons /Acre. Number of applications ranged from 1-5 with the average being two on a seven day interval. Thrips counts were taken on 5-10 plants per plot, per evaluation. Most trials focused on control of thrips larvae as adults move readily between plots. Results and Conclusions In the majority of trials, the Movento program provided thrips control equal to or better than the current standards. In several trials, the maximum thrips control was not observed until at least 14 days after the initial Movento treatment. Due to the speed of control and the strong nymph activity, Movento applications should be targeted early in the season at the first sign of thrips activity. Although residue trials were initiated in 2008, Movento in not currently registered for use in onions.

9:00 am – 9:30 am

Managing Insecticides or Maximum Efficacy Against Thrips in Dry Bulb Onion in the Oregon/Idaho Production Region

Lynn Jensen*[1], Clinton Shock[2], and Lamont Saunders[2]

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OSU trials in 2005 showed that Carzol SP (formetanate hydrochloride) was effective in controlling thrips and reducing iris yellow spot virus (IYSV) incidence. The EPA granted several states a section 18 registration for Carzol SP use on onions for the 2006 and 2007 growing seasons, but at a lower rate than was considered effective. This project was designed to determine the optimum rate, timing and rotation sequence with other insecticides to maximize thrips control within the parameters of the section 18 label. The thrips makeup in the Treasure Valley onion production region of Oregon and Idaho is about 80% onion thrips and 20% western flower thrips. Synthetic pyrethroid use varied, depending on treatment, from no effect, to significantly less thrips control and lower yields than the untreated control. Multiple applications of Carzol SP at the 8.0 oz. rate appear better than a single 20.0 oz. application. Combinations of Lannate, Carzol SP, Movento and Radiant consistently gave the highest onion yield of colossal, super colossal and total yield.

9:30 am – 10:00 am

Optimizing Spray Coverage for Thrips Control on Onions.

Jennifer Allen[1], Mary Ruth McDonald[2]*, Kevin Vander Kooi[2], and Kristy Grigg[2]

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Field trials were conducted to investigate methods to improve spray coverage of onion leaves and to determine if improving coverage could improve the efficacy of insecticides for the control of onion thrips (Thrips tabaci). Trials were conducted in 2007 and 2008 in the Holland Marsh regions of Ontario, Canada, to investigate how combinations of water volume, spray adjuvant and nozzle angle affect spray coverage and efficacy of insecticides. Water volumes of 400, 500 and 600 L ha-1, in combination with no spray adjuvant, Sylgard 309 (0.375% siloxylated polyether), or Super Spreader (0.25% octyl phenoxypoly ethoxy ethanol) were applied at 120 psi with a tractor-mounted sprayer with AI TeeJet Air Induction Even Flat spray tips (AI9503 EVS for 400 and 500 L ha-1 , AI9504 EVS for 600 L ha-1 ,) at an angle of 0o or 22o. Spray coverage was assessed with water sensitive paper or the fluorescent dye Tinopal CBS-X. The fluorescent dye was best for identifying differences in spray coverage. The highest percent coverage of leaves as indicated by Tinopla, was obtained with Sylgard in a volume of 500 L ha-1 , applied at a 22o angle in 2007 and the same combination at 600 L ha-1 in 2008. Thrips pressure was relatively low in 2008. Insecticides Concept (imidacloprid and deltamethrin) and new material HGW86 looked promising for thrips control and were more effective when applied with Sylgard than with water. Sylgard plus water sometimes reduced thrips counts compared to water alone. The most effective insecticide was Carzol (formetanate hydrochloride). Nozzle angle or surfactant did not improve efficacy of Carzol. Measures to optimize spray coverage and efficacy may be product specific.

10:30 am – 11:00 am

Thrips Species Shift in the Vidalia Production Region of Georgia

Alton 'Stormy' Sparks[1]*, David Riley[1], Stan Diffie[1], and Reid Torrance[2]

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Thrips are the primary arthropod pest of onions in Georgia. Historically, the thrips complex on onions in Georgia has been reported to consist of three species: onion thrips, Thrips tabaci; tobacco thrips, Frankliniella fusca, and the western flower thrips, F. occidentalis. This presentation will present the results of five years of thrips species monitoring in the Vidalia Onion production region of Georgia. A marked shift in species composition has been documented in the last two years. The tobacco thrips represented over 95 percent of thrips collected from commercial onion fields in the first three years of this study. The onion thrips increased dramatically in the last two years, with individual fields in which onion thrips were

the predominant species. In addition to this species shift, field studies on insecticide efficacy have documented differential responses of the two primary species to insecticides and potential insecticide resistance. The potential impacts of the species shift and insecticide response on pest management will be discussed.

11:00 am – 11:30 am

Impact of Carbamate Insecticides on Thrips Populations and Iris Yellow Spot Virus Incidence in Onions

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In recent years, Iris Yellow Spot Virus (IYSV) has become widespread in commercial bulb onion fields throughout Western Idaho and Eastern Oregon. This virus, which is transmitted by onion thrips (Thrips tabaci), but not western flower thrips (Frankliniella occidentalis), appears to cause the most damage when high thrips populations occur together with high levels of plant stress (water, heat, fertility, other pests). Carbamate insecticides such as Lannate and Carzol are commonly used in rotation with other foliar insecticides to control thrips. Recent research with Carzol showed that while foliar applications of this product reduced mid-season thrips populations by more than 50%, the most dramatic impact was seen at the end of the season when plants had less thrips feeding damage, less expression of IYSV symptoms, and significantly higher yields and bulb size than other treatments. In addition to the direct impact on thrips populations, there are at least two other possible mechanisms for the observed effects of Carzol on IYSV. First, carbamate insecticides may directly affect plant growth, making the plant more resistant to infection or expression of virus symptoms. Alternatively, these insecticides may differentially affect onion thrips and western flower thrips, altering the relative size of their respective populations. Field trials were conducted at the Parma Research and Extension Center during 2007 and 2008 to evaluate the impact of carbamate insecticides on onion growth, thrips populations, virus incidence and yield. Applications strategies included no carabmate insecticides, carbamate insecticides after mid-season, and carbamate insecticides throughout the season. Plots received a total of eight foliar insecticide applications. All of the insecticide programs appeared to work well for controlling thrips and limiting IYSV. There was no evidence that applying carbamate insecticides to the plant stimulated plant growth, or increased resistance to IYSV infection. Total seasonal thrips population was highly related to virus incidence and plant health at the end of the season, while the proportion of onion thrips to western flower thrips was not.

11:30 am – 12:00 pm

Thrips and Iysv Sources in Colorado Onion Production Systems

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In addition to feeding injury caused by thrips (Thrips tabaci), the thrips-transmitted tospovirus Iris yellow spot virus (IYSV) has emerged as a devastating and widespread disease of onion and other Allium species including leek in the western U.S. and elsewhere in the world. A survey of red, yellow and/or white transplant cultivars originating in southwestern U.S. states revealed that thrips were recovered from 56 to 100% of the sources sampled during 2004 to 2008; and averaged 0.21 to 1.52 thrips per transplant. IYSV incidence varied from 0 to 56% of the sources (and up to 5% of plants within a source) sampled during the 5-year period. Surveys during this period also confirmed that volunteer onions are an annual source of IYSV in Colorado onion production regions. Mature new crop bulbs (1st generation) with IYSV symptoms on 3 or more green leaves per plant were sampled at harvest, after curing, and after 2nd generation plant development to confirm the distribution of the virus by ELISA and/or RT-PCR within plant tissue such as leaves, necks, scales, basal plates, and root systems in the absence of its thrips vector. During 2008, thrips present on selected onion and weed samples were placed in isolation chambers to facilitate their movement onto clean onion seedlings that were free of contaminating thrips or IYSV. Individual sets of thrips transferred from infected onion plants and infected sources of flixweed, dandelion, blue mustard, bindweed and western salsify were able to transmit the virus to onion seedlings. These studies clearly highlighted a variety of potential sources of thrips and IYSV that could impact onion production in Colorado and influence the effectiveness of IPM strategies that are being implemented. In addition to selection of less susceptible varieties and planting of clean transplants, growers and crop consultants must emphasize crop rotation, sanitation of previously infected host material, plant stress reduction, and aggressive management of weeds and thrips within and around onion fields.

1:00 pm – 1:30 pm

Abundance and Population Dynamics of Onion Thrips and Incidence of Iris Yellow Spot Virus in Treasure Valley Region of Idaho and Oregon

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Iris yellow spot virus (IYSV) is an emerging, potentially devastating and widespread disease of onion (Allium cepa L.). IYSV is reportedly vectored exclusively by onion thrips (Thrips tabaci) is endemic in Treasure valley since 1990's. The objective of this study was to investigate onion thrips abundance by using sticky traps to gain insights on population dynamics in onion fields along with incidence of IYSV. Abundance of onion thrips was monitored at weekly intervals using yellow sticky pads between August and September 2008 along with scoring for incidence of IYSV. Five traps were used per field and two fields [Fruit land, Ontario, OR with a history of endemic occurrence of IYSV and a research field at Parma, University of Idaho, ID] were used for this study. Results showed that, the known vector Thrips tabaci was found at both the sites with peak thrips abundance in middle of August corresponding with increased IYSV incidence. Disease incidence varied among the cultivars, within and among the fields with no distinct disease gradients. Both the disease

incidence and thrips population considerably increased as plants approached maturity with no correlation with either number of thrips captured or the trap locations in the field.

1:30 pm – 2:00 pm
Identifying Sources of IYSV in New York's Onion Cropping System

Brian Nault[1]*, Cynthia Hsu[1], Erik Smith[1], Anthony Shelton[1], Marc Fuchs[2], Christy Hoepting[3], and Antonio DiTommaso[4]

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Identifying concomitant hosts for onion thrips, Thrips tabaci, and Iris yellow spot virus (IYSV) is a critical step in determining the role that such hosts play in the epidemiology of IYSV in onion fields and subsequent management strategies. The primary objective of our project was to identify sources of IYSV in New York's onion cropping system by examining the following: (1) onion plants imported from Arizona for transplanting, (2) onion bulbs imported for repackaging, (3) volunteer onion plants collected from the previous season's onion fields, (4) volunteer onion plants collected from cull piles, and (5) weeds. A related objective was to identify weed species that serve as a reproductive host for T. tabaci. A host plant with both T. tabaci larvae and IYSV is likely important in the epidemiology of this disease because IYSV can only be acquired by immature thrips. Both objectives were addressed in studies conducted throughout commercial onion fields in New York in 2007 and 2008. IYSV was detected in volunteer onion plants growing in the previous year's onion fields and cull piles as well as selected weed species, such as curly dock and dandelion. Immature onion thrips also were found on these weed species. Among these three sources, weeds may contribute the most to annual spread of this disease because their densities far outnumber densities of volunteer onions in the onion-cropping system. However, more research is needed to examine this hypothesis. Elucidating temporal and spatial relationships between IYSV, weed hosts, onion thrips and the onion crop should prove critical for identifying onion fields at risk for IYSV and deployment of management strategies. Thousands of onion plants imported from Arizona for transplanting in New York tested negative for IYSV, and therefore are not likely a source. Imported bulbs discarded into cull piles during repackaging could be a source, but not likely a major one. We learned this summer that many imported bulbs do not sprout even when provided conditions to do so; perhaps these bulbs were treated with a sprout inhibitor prior to harvest. If imported bulbs never produce foliage to support thrips development, transference of IYSV to nearby onion fields cannot occur. Additionally, cull piles are small, concentrated areas of which many are located great distances from onion fields.

2:00 pm – 2:30 pm
Genome Characterization and Genetic Diversity of Iris Yellow Spot Virus

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Thrips-transmitted Iris yellow spot virus (IYSV) has become one of the major constraints to bulb and seed onion production in the US. The disease affects both the yield and grade. The virus belongs to genus Tospovirus, family Bunyaviridae. The viral genome consists of three RNA species, large (L), medium (M) and small (S). Inspite of its economic importance, the complete genomic sequence of IYSV isolates from the US is not available. The genome structure and organization of the medium (M) RNA of a Washington (WA) isolate was determined and compared to the corresponding region of two isolates previously described from Brazil and The Netherlands. Sequence analysis showed that the M RNA was 4,817 nucleotides long and potentially coded for the movement protein (NSm) in the viral sense and the glycoprotein precursor (GN and GC) in the viral complementary sense. The predicated sizes of NSm and Gn/Gc precursor were 34.7 KDa and 128.84 KDa, respectively. The two open reading frames are separated by a 380 nucleotide intergenic region. The intergenic region (IGR) of IYSV-WA isolate shared high sequence identity with that of the isolate from The Netherlands. The IGR is a marker for delineating tospoviruses to species level. Phylogenetic analysis of the NSm and GN/GC genes from the WA isolate showed grouping that reflected their respective serogroups. The WA isolate formed a close cluster with the two previously reported IYSV isolates and the IYSV cluster was distinguishable from other tospovirus species. In addition to the M RNA, the genetic diversity of the nucleoprotein (N) gene coded by the S RNA of IYSV isolates from onion from different parts of the country was determined. Primers specific to the small (S) RNA of IYSV (5'-TAA AAC AAA CAT TCA AAC AA-3' and 5'-CTC TTA AAC ACA TTT AAC AAG CAC- 3') were used to amplify, clone and sequence ca. 1.2 kb region of the S-RNA. This region included the complete N gene. The N gene of IYSV is 822 bp in size, potentially coding for a 223-amino acid protein. Phylogenetic analysis showed the presence of two major clusters. With a few exceptions, a majority of the US isolates formed a cluster which was distinct from those reported from other countries.

2:30 pm – 3:00 pm
Onion Variety Response to Iris Yellow Spot Virus

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Iris yellow spot virus (IYSV, genus *Tospovirus,* family *Bunyaviridae*) was found to be a threat to commercial onion production in the early 2000's. Onion varieties are evaluated annually in replicated trials conducted at the Malheur Experiment Station, located in the Treasure Valley of eastern Oregon and southwestern Idaho. The onions are grown using standard commercial procedures, including weed and pest control. Since 2004, the onion varieties have been evaluated for severity of symptoms of IYSV in addition to bulb yield, market grade, loss to decomposition in storage, and the frequency of single centers. A single

subjective rating was given for each plot on a scale of 0 to 5 of increasing severity of IYSV symptoms, where 0 = no symptoms, 1 = 1% to 25% of foliage diseased, 2 = 26% to 50% of foliage diseased, 3 = 51% to 75% of foliage diseased, 4 = 76% to 99% of foliage diseased, and 5 = 100% of foliage diseased. Varieties showed significant differences in the severity of IYSV symptoms each year. Symptom severity increased over the years from 2004 to 2006. Symptom severity in 2007 was lower than the previous three years. A strong negative correlation of symptom severity with yield occurred in both 2005 and 2006. Averaging over varieties, marketable yield after 3 months of storage was 88, 60, 62, and 106 Mg/ha in 2004, 2005, 2006, and 2007, respectively, while the average virus severity ratings were 1.1, 1.3, 2.7, and 0.6 in 2004, 2005, 2006, and 2007, respectively. The average yield of bulbs larger than 10 cm in diameter was 49 Mg/ha, 6 Mg/ha, 9 Mg/ha, and 63 Mg/ha, in 2004, 2005, 2006, and 2007, respectively. Under considerable virus pressure in 2005 and 2006, a few varieties showed a combination of high yield, large bulb size, and low incidence of virus symptoms. With IYSV becoming an increased risk factor in onion production, tolerance to IYSV has become an important variety characteristic.

3:00 pm – 3:30 pm

Seasonal Prevalence of Iris Yellow Spot Virus in Transplanted and Direct-Seeded Onion Fields

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Iris Yellow Spot Virus was first detected in New York onions in 2006. Since then high levels of IYSV have been found in fields in all major onion growing regions in New York. The potential financial impact of this new virus on New York's onion production industry is still unclear. Approximately 85% of onions in New York are grown from seed and 15% are grown from transplant onions imported from Arizona. Imported transplant onions that contain onion thrips, Thrips tabaci, the only known vector for IYSV, may contribute to higher early-season thrips densities in transplanted fields. In addition, the larger size of transplanted onions early in the growing season may make them more attractive to thrips emigrating from IYSV-infected volunteer onions or weed hosts. Both of these factors could put transplanted onion fields at higher risk for IYSV. The primary objectives for this project were to monitor the prevalence of IYSV over time in direct-seeded and transplanted onion fields, and to determine if densities of thrips were positively correlated with IYSV prevalence. In 2007 and 2008 we monitored a total of 12 pairs of direct-seeded and transplanted fields of the same variety between early June and early September, recorded the number of larval and adult thrips and used DAS ELISA to test plant samples for IYSV. Samples were taken every two weeks in 2007 (8 samples), and in 2008 samples were taken biweekly early in the season and then weekly starting in August (9 samples). We were able to detect IYSV much earlier in 2008 than in 2007, and more of the fields in 2008 had higher IYSV prevalence levels prior to harvest compared with 2007. While we found significantly more larval thrips in transplanted fields early in the season, only the cumulative total number

of adult thrips counts were a significant predictor of late season IYSV levels. This suggests that later season adult thrips behavior may be more important in the epidemiology of IYSV in New York onions than early season thrips populations.

POSTER ABSTRACTS

P-01 Determining Redundancy of Current and Collected Short-day, Onion Accessions

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Germplasm maintenance uses resources, time, and money that would be saved if duplications in the collection were eliminated. Reducing duplicates and adding new, different accessions to the collection also maximizes genetic diversity. This study was conducted to determine redundancies in the current short-day, onion (Allima cepa L.) germplasm collection. Some accessions appear to be duplicates as indicated by their similar cultivar names. Another objective of this project was to evaluate recently-collected germplasm to determine if there are no duplications among them, and between them and the current accessions in the collection. Forty-four different germplasm accessions and collected cultivars, which were grouped into eight different similarity groups, were seeded in October of 2007. As plants of each entry near maturity, plants from each accession were measured for 18 different morphological characters. These characters included bolting percentage, sheath length, sheath diameter, plant height, leaf height, leaf width, leaf thickness, time when 20% of plants in the plot had reached tops down (20% tops down), 50% tops down, and 80% tops down. Bulbs were harvested at 80% tops down, and at that time, harvest date, pink root disease severity, and bulb number, height and diameter were measured. Two weeks after harvest, average bulb weight, bulb firmness, and the percentage of bulbs with a single growing point were measured. PI 385949 White Creole, PI 546170 White Grano, G 32071 Texas Early Grano 502 PRR, PI 546110 Early Texas Yellow Grano, PI 546111 Early Yellow Grano Tex 502, PI 546127 Texas Early Grano 502 were identified as duplicates that may be removed from the collection. Nine newly-collected lines were deemed to be different from accessions already in the collection and may add some diversity to the short-day onion collection. Of the traits measured, the most differences between entries were detected by average bulb weight, while no differences were detected by sheath length and time to maturity.

P-02 Does Breeding For Increased Firmness Lead To More Pungent Onions?

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Onion is an economically important crop in New Mexico that produces one-third of the total US summer production. Currently, NM farmers utilize hand-harvesting, which is expensive and difficult to accomplish due to a shortage of labor. Farmers' desire to switch to mechanical harvesting is increasing, but many 'Grano' cultivars are not suitable for mechanical harvesting. Mechanized harvesting of onions is possible only with firmer bulbs. A 'Grano' cultivar released in 1992, 'NuMex Starlite' is a popular sweet onion cultivar with low pungency, multiple centers, and less firm bulbs; and is still hand-harvested. After its

release, five cycles of selection were made to enhance bulb firmness and to increase the number of bulbs possessing a single growing point. The objective of this experiment was to compare the original and recent generations of 'NuMex Starlite' for firmness, single-centeredness and pungency of bulbs. Both generations were planted together at four environments during 2007 and at three environments during 2008. Bulb firmness was recorded on a scale of 1 - 9 (9 being hardest), and pungency was determined by pyruvate analysis. The study was conducted in randomized complete block design and statistical analysis was performed using mixed model of SAS. A significant interaction was observed between different environments and generations of 'NuMex Starlite'. The results revealed an improvement in bulb firmness with selection when tested in six out of seven environments. The number of centers per bulb decreased with selection when tested in all seven environments. All seven environments showed that bulbs of the recent generation are more pungent than the bulbs of original generation. The correlation between pungency and firmness, and between pungency and number of centers were found to be weak. A future breeding strategy should include pungency as a trait of selection, based upon the independence of pungency with firmness and number of centers.

P-03 Strategies To Improve Early Season Thrips Control And Suppress Iris Yellow Spot Virus In Onions

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Onion thrips (Thrips tabacci) are one of the most damaging and difficult to control insect pests in onions. Conventional thrips control programs have relied almost entirely on foliar applications of pyrethriod, organophosphate and carbamate insecticides. In recent years, thrips control has become even more critical due to the widespread occurrence of Iris Yellow Spot Virus (IYSV) throughout western Idaho and eastern Oregon. Despite the more frequent use of foliar pesticides, damage due to IYSV seems to be increasing. Seed treatment with systemic insecticides offers one potential way to improve control during the early part of the season when thrips migrate into onion fields, possibly bringing the virus from overwintering sources. Field trials were conducted at the Parma Research and Extension Center during 2007 and 2008 to evaluate the role that the experimental seed treatment insecticide Fipronil could play in controlling onion thrips. Onion seed was treated by incorporating Fipronil (24 g a.i. per kg raw seed) into the seed coating. Treated and non-treated seed was planted in replicated plots. Each seed treatment main plot was overlain with several foliar insecticide timings. Onion plants from Fipronil treated seed had lower seasonal thrips populations and lower incidence of IYSV at the end of the season compared to the non-treated seed. Most of the impact of Fipronil on thrips populations occurred early in the season (May and June). It appeared that Fipronil seed treatment reduced the number of foliar insecticide applications required to keep thrips and virus levels below damaging levels.

P-04 Survey and behavior studies of T. tabaci (Thysanoptera: Thripidae) on onion in India and Georgia, USA. Characterizing the settling behavior of T. tabaci (Thysanoptera: Thripidae) on onion foliage.

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T. tabaci behavior on onion plant foliage was characterized by observing settling and oviposition by on whole plant bioassays. This study attempted to identify the preferred foliage sites for settling of adult thrips over time and the oviposition, which we believe are related to potential sites for transmission and acquisition of Iris Yellow Spot Virus. Distribution of settling and oviposition events was reported by leaf number and distance from the apical meristem.

P-05 Cultural Management of Onion Thrips and Iris Yellow Spot Virus

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Iris yellow spot virus (IYSV) and onion thrips threaten sustainable profitable onion production in Utah and the Western US. Onion growers in Utah rely on high-risk insecticides for thrips management, which has increased insecticide resistance and may increase severity of outbreaks of IYSV. Very little is known about how to effectively manage IYSV; if cultural practices affect its spread and if more intensive thrips insecticide programs really reduce IYSV incidence or severity. In collaboration with Utah growers, we surveyed 15 onion fields to determine the incidence of thrips, IYSV pressure, and key timing of pest outbreaks, to determine if these are correlated to commonly used farm practices such as fertility, herbicides, insecticides, fungicides, irrigation, and crop rotation. In 2008 ELISA testing revealed differences in IYSV incidence and severity in and around onion fields with three species of weed also testing positive for IYSV. Differences at the field level were also recorded for thrips. Due to a cold spring, thrips populations were initially low but rose above normal later in the season. Soils and onions were sampled monthly from April to September and soil and tissue N tested. Onions have been collected from all seeded onion fields for storage trials. Field scale differences in thrips and IYSV appear linked to specific farm practices and we will present the first year of our studies.

P-06 First Report Of Colletotrichum Gloeosporioides Causing 'Twister Disease' Of Onion (Allium Cepa L.) In Georgia, USA

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In the fall of 2007, during an unusually warm period (>26C) seedlings with twisted and distorted leaves were observed in seedbeds in the Vidalia onion-growing region of Georgia. Tests for a possible viral or bacterial origin were negative and chemical injury was deemed improbable due to the pattern of disease distribution in the fields. After incubation on potato dextrose agar (PDA) amended with tetracycline, fungal fruiting bodies were observed on the outside sheath of a few of the seedlings. Characteristics of the fungus isolated from symptomatic plants were the same as those described for Colletotrichum gloeosporioides. Sequencing of the internal transcribed spacer region (ITS) region and a BLAST search in GenBank (99% sequence homology with C. gloeosporioides accessions) confirmed the identification. Koch's postulates were completed by spray-inoculating 10 onion seedlings with a suspension of 1 x 107 spores/ml until run-off and four seedlings with water as negative controls. The plants were bagged for 12 hours to maintain a high relative humidity. All plants inoculated with C. gloeosporioides developed distorted and twisted leaves 3 - 5 weeks after inoculation. Seedlings inoculated with water remained healthy. A fungus with similar characteristics of C. gloeosporioides was reisolated from symptomatic plants. Colletotrichum gloeosporioides has been reported to cause an onion disease called twister that was restricted to tropical regions and onion yield losses of up to 100% were observed in fields in Nigeria and Brasil. The unseasonably warm temperatures combined with high humidity and free water from timely rain events and overhead irrigation provided ideal conditions in southern Georgia for the fungus. The pathogen is present on many crops in the United States but to our knowledge this is the first report of C. gloeosporioides causing twister disease of onion in the United States. A host range study conducted with onion isolates of C. gloeosporioides indicated that tomatoes, peppers and eggplants, among others, were susceptible. The impact of infection on the growth of the transplants and subsequent yield in Vidalia onions is currently unknown.

P-07 Detection and Distribution of Iris Yellow Spot Virus in Spiny Sowthistle in Georgia.

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In the fall of 2007, during an unusually warm period (>26C) seedlings with twisted and distorted leaves were observed in seedbeds in the Vidalia onion-growing region of Georgia. Tests for a possible viral or bacterial origin were negative and chemical injury was deemed improbable due to the pattern of disease distribution in the fields. After incubation on potato dextrose agar (PDA) amended with tetracycline, fungal fruiting bodies were observed on the outside sheath of a few of the seedlings. Characteristics of the fungus isolated from symptomatic plants were the same as those described for Colletotrichum gloeosporioides. Sequencing of the internal transcribed spacer region (ITS) region and a BLAST search in GenBank (99% sequence homology with C. gloeosporioides accessions) confirmed the

identification. Koch's postulates were completed by spray-inoculating 10 onion seedlings with a suspension of 1 x 107 spores/ml until run-off and four seedlings with water as negative controls. The plants were bagged for 12 hours to maintain a high relative humidity. All plants inoculated with C. gloeosporioides developed distorted and twisted leaves 3 – 5 weeks after inoculation. Seedlings inoculated with water remained healthy. A fungus with similar characteristics of C. gloeosporioides was reisolated from symptomatic plants. Colletotrichum gloeosporioides has been reported to cause an onion disease called twister that was restricted to tropical regions and onion yield losses of up to 100% were observed in fields in Nigeria and Brasil. The unseasonably warm temperatures combined with high humidity and free water from timely rain events and overhead irrigation provided ideal conditions in southern Georgia for the fungus. The pathogen is present on many crops in the United States but to our knowledge this is the first report of C. gloeosporioides causing twister disease of onion in the United States. A host range study conducted with onion isolates of C. gloeosporioides indicated that tomatoes, peppers and eggplants, among others, were susceptible. The impact of infection on the growth of the transplants and subsequent yield in Vidalia onions is currently unknown.

P-08 Consistency of long-term marketable yield of onion cultivars grown on organic soils in Ontario, Canada, in relation to seasonal climate

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It is important to have onion cultivars that will yield well each year, regardless of the weather. To identify onion cultivars with consistent high yields, data from the onion variety trials of the University of Guelph, Muck Crops Research Station were analyzed. These trials have been conducted in the Bradford/Holland Marsh, Canada, for several decades with an average of 25 onion cultivars per year. Six yellow bulb onion cultivars, 'Corona', 'Fortress', 'Frontier', 'Hamlet', 'Norstar' and 'Prince', were selected because they had been in the variety trials for more than 10 years. Weather data was recorded by a CR21 X data logger at a weather station within 400 m of the trial plots. Onions were grown according to the provincial recommendations. After harvest, cultivars were assessed for total yield, and factors that would make the bulbs unmarketable includingdisease symptoms, insect damage, doubles, off coloiurs, seeders and sprouts. Onions with defects were discarded and sound onions with diameters over 32 mm were included in marketable yield. Cultivar Corona exhibited higher than average marketable yield in 12 of 13 years, Prince had higher than average yields in 11 of 14 years and Hamlet in 9 of 13 years. Corona also had the highest mean marketable yield (74.9 t ha-1) over all the years, but this was not significantly different from that of Prince. The average marketable yield was 63.9 t ha-1 . Marketable yield of the onion cultivars was positively correlated with the number of days with rainfall over 5 mm in June (r= 0.58) and was negatively correlated with the number of days over 30 C in June (r = - 0.55). Yields of Norstar and Hamlet were negatively correlated with the number of days with maximum temperature over 30 C in August (r = -0.54). Cultivar trials can provide

useful data for predicting yields of onions and selecting cultivars that are resistant to weather stresses.

P-09 Evaluation Of Onion Cultivars For Resistance To Downy Mildew

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Downy mildew of onion, caused by *Peronospora destructor* (Berk.) Casp. In Berk., is a devastating disease, but occurs sporadically in the Holland Marsh region of Ontario, Canada. Resistance to downy mildew would be a benefit to growers, but resistant onions must also have the yield and quality attributes that growers and the market demand. A new onion cultivar, Yankee, was recently released by Bejo Seeds. It is a long day yellow bulb onion with resistance to downy mildew. This cultivar was compared to other yellow bulb onions in disease assessment trials in 2007 and 2008 and in the onion cultivar evaluations conducted in 2007 at the Muck Crops Research Station. Field trials for disease assessment did not receive any fungicide application, while onions in the cultivar trials were grown according to provincial recommendations, including sprays to prevent downy mildew. Foliar symptoms of downy mildew were first detected in late August in 2007 and in mid July in 2008 in the disease plots. Downy mildew was assessed on 20 plants per rep and number of lesions per plant were counted. A low number of lesions were observed on 'Yankee' in both years, but this onion had no leaves with downy mildew lesions at the final assessment in the 2008 trial, where other onions had 94 % diseased leaves. In the cultivar trials, Yankee had yields (1327 bu/acre) slightly below the trial average (1393 bu/acre) and a quality score of 7.1 of 10, which was higher than the trial average of 6.8. Yankee has acceptable yield and quality under Ontario coniditons and is this first bulb onion with resistance to downy mildew.

P-11 Organic Vidalia Onion Production in Southeast Georgia

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Research began on producing organic Vidalia onions in 2001 at the Vidalia Onion and Vegetable Research Center in Lyons, GA. Organic Vidalia onion production began in 2003 with a small planting of about 15 acres of certified organic onions. This grower was approached by his buyer to grow these onions and the grower saw them as a loss-leader to

expand his conventional onion production into new markets. Research has shown that locally available poultry litter as well as commercial organic fertilizers are suitable to meet the crop's fertility requirements. Disease and insect problems have largely not been a problem with organic onion production, however, with this relatively new endeavor it is difficult to predict this will continue. Weed control, is by far, the most difficult problem in organic onion production particularly during plantbed production. Plantbeds are often covered with a mulch of weed free compost prior to sowing. The compost offers short term weed control to allow the onions to emerge and begin growing. Approximately 50% of the onions are grown on plastic to control weeds after transplanting, the remainder are grown on bare ground and rely on field cultivation and hand weeding.

P-12 Evaluation of New Mexico autumn-sown onion entries

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NO ABSTRACT

P-13 Management of Onion Thrips and IYSV with Straw Mulch and BioPesticides

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Iris yellow spot virus (IYSV) and its thrips vector, Thrips tabaci Lindeman, are yield limiting pests of onion throughout the western U.S. In experiments conducted in Colorado during 2005 to 2007, straw mulch applied to the center of onion beds reduced early to mid-bulb growth stage thrips populations up to 33% when compared to non-treated plots of transplanted onions. Cumulative thrips-days indicated that straw mulch significantly reduced populations by 10 to 20% compared with bare soil control plots in these studies. The addition of conventional insecticides (methomyl alternated with lambda-cyhalothrin) was associated with 12 to 27% higher cumulative thrips-days by the end of the monitoring period (mid to late-bulb stages) compared to the untreated control in two experiments. In contrast, a reduced-risk biopesticide program (spinosad alternated with azadirachtin) had lower cumulative thrips-days on both bare soil (15%) and straw mulch (36%) compared to untreated controls. Enhanced thrips control generally persisted during mid-season and may have contributed to reduced stress from thrips feeding damage and reduced IYSV incidence and/or severity during the early to mid-bulb stages of plant growth. Total yield and jumbo

yield were increased up to 13 % and 18 %, respectively, by straw mulch compared to bare soil treatments among the individual experiments. Effective long-term management of thrips and iris yellow spot in onion crop systems will depend on a multi-faceted approach that integrates host resistance, modified cultural practices such as straw mulching and irrigation scheduling, and judicious use of reduced-risk pesticides.

P-14 Spatial and Temporal Distribution of Thrips and IYSV of Onion in Colorado

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Iris yellow spot virus and its thrips vector are yield limiting pests of onion in the western U.S. This 3-year project investigated the relationship of iris yellow spot to thrips populations, soil properties, plant stress, and grower management practices in Colorado onion fields. Results show that spatial autocorrelation of iris yellow spot is limited and that secondary spread of the virus occurred randomly within fields. In general, spatial autocorrelation varied by study site. The incidence of iris yellow spot was significantly autocorrelated at three of the seven study sites during 2005 and 2006. At one site that had significant autocorrelation at the first sampling date, autocorrelation was greater at the second and third sampling dates, indicating localized secondary spread within the field. Early season thrips populations were autocorrelated at most study sites, and subsequent thrips populations were significantly autocorrelated, however, later-season populations were randomly distributed. These results suggest that thrips are entering onion fields at a specific point (e.g., field margins and/or other crops) and then migrating randomly to adjacent healthy plants as infested plants become more stressed and damaged. Significant spatial cross-correlation was found between thrips density and the incidence of iris yellow spot at two study sites.

P-16 Cultivar Evaluation for Hoop House Grown Onions

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Onions are produced in Oklahoma for fresh use markets using a combination of short and intermediate cultivars. Recently developed hoop house transplant production techniques

enable the local production of cultivars not available as transplants. Because several new intermediate cultivars are now available 12 onion cultivars were evaluated for productivity using hoop house grown transplants. Trials were conducted beginning November of 2007 with the seeding of transplant beds. In March of 2008 transplants were dug and replanted outdoors. Onions were harvested at bulb maturity and yields and bulb size were determined. The incidence of bolting was also measured. Marketable yields (bulb diameters of 2 inches or greater) ranged from 60 to 166 hundredweight units per acre (CWTA). Eight cultivars produced marketable yields of 100 CWTA or greater and there were no statistical differences in marketable yield among cultivars in this group. The percentage of bulbs in the size category of 3 to 4 inches in diameter was affected by onion cultivars. Up to 50% of bulbs were in this size category. Bolting incidence was as great as 18% but 8 cultivars had 5% or less bolting. Results of this trial suggest that several of the tested cultivars would be useful for fresh market onion production using hoop house grown transplants.

P-17 Effect of Curing on Postharvest Quality of Vidalia Sweet Onion

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Vidalia sweet onions are very susceptible to postharvest infection with *Botrytis allii*, the fungal pathogen responsible for the storage disorder Botrytis neck rot (BNR). Curing is important for reducing the incidence of the disorder. Curing can be performed either in field, or postharvest using a hot-air drier. Controlled atmosphere is also effective at reducing the incidence of BNR. However, this technology is expensive to operate, and will not always control BNR adequately to justify the cost of the treatment. In other systems, such as grape and litchi, fumigation with sulfur dioxide (SO_2) is used effectively to control *Botrytis spp.* mycelial spread and sporolation. However, little is known about the potential application of this fumigant in onion. In this study, an early variety of sweet onion was evaluated for the effect of curing, drying, CA and SO_2 on the incidence rate of BNR. Unnamed early variety 'WI-129' was undercut on April 29th from the Vidalia Onion and Vegetable Research Center, Lyons, GA, then either harvested immediately or field cured for 2 days. A subset of these two field cured bulbs were subsequently heat-cured for an additional 0, 24 or 72 hrs (37-38ºC). Samples were then transported to the Vidalia Onion Research Laboratory, Tifton, GA, and stored for 10 weeks in RA or CA (3% O_2 + 5% CO_2, 60-70% R.H.) with a dual-stage SO_2 releasing sheets (UVASYS, South Africa) and evaluated 1 and 14 days after removal from storage. Field curing resulted in a significant reduction in the incidence of BNR, while heat curing did not. CA storage was very effective in controlling BNR, while the effect of the sulfur dioxide treatment, though not significantly different, was evident, and therefore warrants further study.

P-18 Onion Agronomy in the Treasure Valley of Idaho and Oregon

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This is an informational poster about cultural practices and other general information specific to the Treasure Valley.

P-19 Impact of Surround WP Crop Protectant for Management of Thrips Infestation and Overall Plant Health

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Onion thrips are the known vector for Iris Yellow Spot Virus, a harmful disease that reduces plant health resulting in reduced onion yield and quality. Studies have demonstrated that the use of Surround® can significantly suppress thrips infestation. In addition, studies have demonstrated that Surround is a recognized tool to protect onions from damage caused by sunburn at harvest. In addition, Surround® provides overall plant health benefits by reducing general plant temperature and lessening cellular damage by reflection of IR, UVa, and UVb light. This can result in increased photosynthetic activity over time compared to heat-stressed untreated plants thus higher yield and quality.

P-20 Acetic Acid and Weed Control in Onions

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Weed control is a major challenge in conventional and organic production systems, especially for organically produced sweet onion (Allium cepa L.). Although corn gluten meal shows great promise as an organic preemergent herbicide for onions, research has shown the need for supplemental, postemergent, weed control once the early season effectiveness of corn gluten meal diminishes. Acetic acid is an approved organic postemergent herbicide that may have potential to affectively provide post-emergent weed control. Research was conducted at Lane, OK, to determine the impact of acetic acid applications on broadleaf weed control in onions, 'Candy' and 'Cimarron'. The experiment included 6 weed control treatments (2 application volumes, 2 hand weeding levels, plus an untreated weedy-check and an untreated weed-free) with 4 replications. Nutsedge and grass weeds were selectively removed to investigate the impact of the acetic acid on the broadleaf weeds. Vinegar (20% acetic acid) was applied as an over-the-top broadcast application at 50 or 100 gpa on April

21, 2007 using four 8002 nozzles on 20 inch spacing. Within each application volume (50 and 100 gpa) plots were either handweeded or the uncontrolled weeds were allowed to grow. Weed control ratings were collected throughout the growing season. Weed control peaked at 7 DAT, averaging 95% and 99% total broadleaf weed control for the 50 and 100 gpa application volumes.

P-21 Acetic Acid: Crop Injury and Onion Yields

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Weed control is a major challenge in conventional and organic production systems, especially for organically produced sweet onion (Allium cepa L.). The organic herbicides for sweet onions are limited to non-selective materials, such as corn gluten meal and vinegar. Research in Oklahoma has shown that corn gluten meal can be an affective early season pre-emergence herbicide for onion transplants, but once the residual impact of the corn gluten meal wears off, the resulting weed growth can devastate the onion crop. The post-emergence application of vinegar has the potential to control the weeds emerging after corn gluten meal applications, but the extent of crop injury from broadcast applications of vinegar is unknown. Research was conducted at Lane, OK to determine the impact of a broadcast application of acetic acid on onion crop injury. The experiment included 2 onion varieties ('Candy' and 'Cimarron'), 6 treatments (2 application volumes, 2 hand weeding levels, plus an untreated weedy-check and an untreated weed-free) with 4 replications. Vinegar (20% acetic acid) was applied as an over-the-top broadcast application at either 50 or 100 gpa using four 8002 nozzles on 20 inch spacing. Within each application volume (50 and 100 gpa) plots were either handweeded or the uncontrolled weeds were allowed to grow. Crop injury ratings were collected throughout the growing season. The greatest onion injury was observed at 3 days after treatment (DAT), resulting in 38% onion injury for the 50 gpa rate and 56% for 100 gpa rate. There were no significant differences between onion varieties for injury. The results indicate that the early season crop injury did not significantly impact onion yields.

P-22 Enhancing Weed Control In Direct Seeded Vidalia Onions Through Fertility Regimes

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Direct seeding of onions is cheaper and less labor intensive than transplanting, but weed control is a major challenge. Goal (oxyfluorfen) is necessary for weed control, but should

not be applied prior to the two leaf stage of onion. Weeds emerging at the same time can become too large for control by the time the onions are large enough to treat. Therefore, rapid crop growth is essential for effective weed control. This study evaluated five fertility programs to determine if fertility management could be a tool to stimulate early crop growth, get the onions to the two leaf stage earlier, and allow earlier application of Goal herbicide for adequate weed control. All plots received 600 lbs/acre of 5-10-15 preplant incorporated. Treatments included: DAP applied at planting and calcium nitrate at 6 weeks after planting, DAP 14 days after planting and calcium nitrate 6 weeks after planting, DAP 6 weeks after planting, calcium nitrate 6 weeks after planting, and calcium nitrate 6 weeks after planting with no follow up calcium nitrate in February. All plots were fertilized the same from January 1 through harvest, with the exception of the treatment which had no calcium nitrate in February. The initial herbicide treatment was made across all plots on November 27th, with a sequential treatment on December 11th. The treatment with DAP two weeks after planting had the best yield and herbicide tolerance, yielding 1042 boxes/acre (40% higher than the second best treatment).

MANUSCRIPTS

THRIPS AND IYSV SOURCES IN COLORADO ONION PRODUCTION SYSTEMS

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Introduction

In addition to feeding injury caused by thrips (primarily *Thrips tabaci*), the thrips-transmitted tospovirus *Iris yellow spot virus* (IYSV) has emerged as a devastating and widespread disease of onion (*Allium cepa* L.) and other *Allium* species including leek (*A. porrum*) in the western U.S. and elsewhere in the world. The reasons for the sudden development and dissemination of IYSV on onion bulb and seed crops in the western U.S. remain unclear. Seed transmission does not appear to be epidemiologically important in disease development, although low levels of seed transmission (<0.0001%) have not been disproved. A new vector or strain of thrips that more efficiently acquires or transmits the virus may have been introduced into the western U.S. Alternatively, a more virulent IYSV strain may have been introduced. During recent years, our program has initiated a number of disease and pest surveys and integrated pest management projects with assistance from previous students (David Gent and Scott Fichtner) to investigate potential sources of thrips and IYSV that could impact onion production in Colorado and the effectiveness of IPM strategies that are implemented. The following summaries provide some highlights of results that we have obtained and in many cases are still evaluating for the Colorado onion growers and industry.

Transplant Sources – 1st Generation Cycle

A survey of red, yellow and/or white transplant cultivars originating in southwestern U.S. states including Arizona (Phoenix area), California (Sacramento Valley) and Texas (southern) were obtained from Colorado onion producers as they prepared to transplant the onions in Colorado fields during March to April from 2004 to 2008. Randomly selected bundles of 75 to 100 plants each and passport data (origin, variety, date, grower, and destination field) were collected from cooperators (including growers, processors, extension agents, crop consultants) upon the arrival of transplants (12 – 26 sources annually) in northern and southern transplant-producing counties in Colorado. A total of 500 or more plants per source were visually evaluated for the presence of suspicious IYSV-type symptoms (small linear, light colored streaks and lesions), and these plants were then tested individually with the modified ELISA method (Gent et al., 2004). A second collection of 500 or more plants per source was taken for thrips extraction to determine species composition. Representative thrips were washed from plants using 70% ethanol, collected in a small glass vial containing 70% ethanol, and classified to the species level.

Thrips were recovered from 56 to 100% of the sources sampled during 2004 to 2008; and averaged 0.21 to 1.52 thrips per transplant. Thrips incidence varied from 0.10 to 0.36/plant originating in Texas, 0.01 to 1.26/plant originating in Arizona, and 0.23 to 4.54/plant originating in California. *Thrips tabaci* was recovered each year from all sources. *Franklinella ewarti*, *F. occidentalis*, and *F. schultzei* were recovered 4 of the 5 years from various sources; and *Scirtothrips longipennis* and

Scolothrips sexmaculatus were each recovered from one source one year only. IYSV incidence varied from 0 to 56% of the sources (and up to 5% of plants within a source) sampled during the 5-year period. These surveys implicate incoming transplants as one of the potential early-season sources of the virus and thrips that must be addressed in the production of transplanted and surrounding seeded crops grown in states like Colorado (Gent et al., 2006).

Volunteer Onions – 2nd Generation Cycle

Surveys in Colorado during 2004 and 2005 confirmed that IYSV could be associated with volunteer onion plants (2nd generation plants) originating from bulbs left in the field after harvest of transplanted or seeded 1st generation plants. A portion of these bulbs (especially if buried to a depth of 15 cm) can then successfully overwinter, emerge and develop during ensuing crops of irrigated alfalfa, carrot, dry bean, and field corn (Gent et al., 2006). Recent surveys during 2006 – 2008 continue to confirm that volunteer onions are an annual source of IYSV in Colorado onion production regions (northern, southern and western counties). ELISA (Gent et al., 2004) and Reverse Transcriptase-PCR tests confirmed the presence of IYSV in symptomatic leaf tissue. Symptomatic volunteer onion plants have been detected up to 4 weeks (late March) before emergence and development of the seeded and transplanted summer crops, and therefore could serve as a biological bridge between onion crops and growing seasons. The virus could overwinter within the volunteer plant, adult thrips associated with the plant, or be transmitted by infested thrips that overwintered on the volunteer onion or other plant species as shown in additional tests noted below.

IYSV Carryover Between Bulb Generations

Mature new crop bulbs (1st generation) with IYSV symptoms on 3 or more green leaves per plant were sampled to confirm the distribution of the virus by ELISA and/or RT-PCR within plant tissue such as leaves, necks, scales, basal plates, and root systems during 2006 – 2008. Pre-cropped varietal differences were routinely noted during the 2006 field study as Rumba had 40 % of symptomatic plants positive for leaf and bulb, 20% for neck, and 0 for basal plate and root system tissues; Aspen had 60, 40, 60, 0 and 20 % incidence, respectively, and Yula had 100, 100, 80, 40 and 20 % incidence, respectively. During 2007, infected Exacta pre-cropped had 75, 50, 75, 0 and 0 % incidence, respectively; while, Rumba post-cropped had 100, 0, 60, 0 and 0% incidence for leaf, bulb, neck, basal plate and root system tissues, respectively.

We also sampled bolted plants of Yula that expressed IYSV symptoms on foliage and scapes, and in some cases umbels in 2006; IYSV was detected in 0, 66 and 83 % of senescing leaves, green scapes and non-fertilized umbels, respectively, from these plants at the end of the growing season. During 2008, IYSV was detected in 100% of senescing leaves and green scapes (with poorly developed umbels that were not tested) of bolted plants of Exacta; again highlighting the apparent tissue variability (and transitory nature) of IYSV titer and detection when comparing vegetative to reproductive growth stages of development.

During 2007, we evaluated other symptomatic (visible leaf lesions), post-cropped 1st generation plants/bulbs that were air-dried for 4 weeks. The IYSV incidence was dramatically lower for all tissue samples and varieties that were sampled: 0 for all Rumba tissues; 10% incidence for Aspen bulb tissue; 10 – 20% incidence for Yula bulb, neck or basal plate tissues; and 0 for all other variety – tissue combinations. We also air-dried post-cropped symptomatic 1st generation plants of 4

varieties for 4 – 6 weeks before removal of dried foliage, and transplanting of cured bulbs to individual pots covered by isolation chambers to keep thrips off of the regrowth of 2nd generation plants in the greenhouse. The regrowth was carefully monitored for presence of suspicious IYSV-like symptoms which ultimately developed on 0, 10, 20 and 30% of 2nd generation plants of Yula, Rumba, Candy and Aspen, respectively, 14 – 19 weeks after transplanting 1st generation bulbs in the greenhouse. IYSV was confirmed in leaves of 10%, 30% and 21%; and in basal plates of 20%, 20% and 5% of Rumba, Aspen and Candy plants, respectively, 14 to 19 weeks after 2nd generation growth commenced in the greenhouse in the absence of thrips. During 2007/2008, we confirmed that IYSV could be detected in leaves (but not other plant tissues) of Mercury and Talon 20 weeks after 2nd generation growth commenced in the greenhouse. These studies are being repeated with 2008-1st generation bulbs from infected plants, but confirm that the virus can survive within onion bulbs and plants in the absence of its thrips vector.

Weed Host Sources

Winter annual weeds are known to serve as sources of a related virus, *Tomato Spotted Wilt Virus*, and its thrips vectors in vegetable production areas elsewhere, especially in southeastern U.S. (Gitaitis et al., 1998; Groves et al., 2001 and 2002). IYSV workers (Cosmi et al., 2003; Nischwitz et al., 2007; Sampangi et al., 2007) have reported that asymptomatic weeds (foliage and/or root tissues) commonly found in and around onion fields can be naturally infected by IYSV and included Kochia (burningbush), lambsquarters, pigweed, prickly lettuce, puncturevine, purslane, and spiny sowthistle.

We have suspected that similar weed hosts, especially winter annuals could serve as overwintering hosts for IYSV and/or thrips vectors in Colorado onion production regions.

Plant samples (10 to 25 representative individuals of the target species from in and around the onion field with a history of IYSV) were collected as aliquots of leaf, seed, and stem tissues for assay with ELISA (preliminary verification of IYSV) and RT-PCR (confirmation of ELISA positive samples) (Cortes et al., 1998; Gent et al., 2004; Uga and Tsuda, 2005).

Preliminary surveys during 2006-2008 of common weed species in and around onion fields with a history of IYSV in Colorado detected a low (5-10 %) to high (75-100 %) incidence of the virus (at least 2 of 3 years) in asymptomatic plants of redroot pigweed (*Amaranthus retroflexus*), common purslane (*Portulaca oleracea*), dandelion (*Taraxacum officinale*), field bindweed (*Convolvulus arvensis*), flixweed (*Descurainia sophia*), prickly lettuce (*Lactuca serriola*), blue mustard (*Chorispora tenella*), burningbush (*Bassia scoparia*), western salsify (*Tragopogon dubius*), and nightshade (*Solanum* species). Representative thrips were washed from many of the weed samples using 70% ethanol, collected in a small glass vial containing 70% ethanol, and later classified to the species level. The predominant species recovered from the majority of weed samples was *Thrips tabaci*. Additional species of thrips that are associated with onions and were recovered from overwintering weeds included *Frankliniella occidentalis* and *F. schultzei*. These studies highlight the potential role that common weed species may play in the epidemiology of IYSV and thrips, and their importance to an effective IPM strategy that relies upon crop rotation and weed management in and around onion fields.

IYSV Transfer to Onions and Weeds

During 2008, sets (minimum of 10 larvae) of thrips present on selected onion and weed tissue samples were placed in isolation chambers to facilitate their movement onto clean (non-thrips infested or IYSV-infected) onion seedlings at the 3-4 leaf stage. After 35 to 50 days incubation,

tissue samples from the exposed seedlings were removed to confirm the presence or absence of IYSV by ELISA and RT-PCR protocols. Seven of 11 tests with sets of predominantly onion thrips transferred from infected onion plants (confirmed by ELISA) demonstrated that the insects could successfully transmit the virus to non-infected onions. A similar procedure was used to confirm that thrips (predominantly onion thrips) could transmit the virus from infected weed species (confirmed by ELISA). These sets of thrips from infected sources (one each) of flixweed, dandelion, blue mustard, bindweed and western salsify successfully transmitted the virus to onion seedlings.

Conclusions

These studies have clearly highlighted a variety of potential sources of thrips and IYSV that could impact onion production in Colorado and influence the effectiveness of IPM strategies that are being implemented. In addition to selection of less susceptible varieties and planting of clean transplants (Gent et al., 2006), growers and crop consultants must emphasize crop rotation, sanitation of previously infected host material, plant stress reduction (e.g., use of straw mulch with adequate moisture), and aggressive management of weeds and thrips within and around onion fields.

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SURVEY AND BEHAVIOR STUDIES OF *THRIPS TABACI (THYSANOPTERA: THRIPIDAE)* ON ONION IN INDIA AND GEORGIA, USA.

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Introduction

Thrips-borne tospoviruses are emerging as significant limiting factor in sustainable vegetable production and other economically important crops in South Eastern Asia region and in the USA. Iris yellow spot virus (IYSV) a tospovirus in the family Bunyaviridae has been reported to occur in many countries. *Thrips tabaci,* or onion thrips, is the only known vector of IYSV. Incidence of IYSV on onion has been reported both in India and Georgia, hence a survey in onion was conducted in IYSV hot spots in India in 2006-2008 and currently in Georgia to quantify the distribution of *T. tabaci*. Thrips tabaci settling and reproduction on the plant should be directly related to the spread of IYSV. It is reported that IYSV within the infected leaves is localized in patches and the virus titer is highest in internal leaves than the older leaves close to the bulb indicating there might be an association with thrips feeding or oviposition sites. Studies on *T. tabaci* attempted to identify the preferred foliage sites for settling and oviposition of adult thrips.

Materials and methods

Beat cup method was used to collect the thrips where the selected plants are bent into a 946-ml (11.5cm in diameter, 16.5 cm in depth) Styrofoam cup (Dart Container, Corp., Mason, MI) and shaken vigorously for 5 seconds. Then the plants are removed and the thrips inside the cup are dislodged and counted. The collected thrips are slide mounted for further identification. To characterize the behavior on onion foliage four species of *T. tabaci* are released on the onion plants enclosed in a laboratory cage. To quantify the settling behavior, thrips position on the leaf was recorded for every 30 minutes for 3 hours for 7 days. For oviposition, thrips were allowed to oviposit for 7 days. Oviposition sites are counted by following the lacto- phenol acid fuschin staining technique detailed by Nuessly *et. al* (1995). Stained leaves are then examined under a stereo microscope for oviposition sites indicated by purple rings.

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ACETIC ACID AND WEED CONTROL IN ONIONS (*ALLIUM CEPA* L.)

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Introduction

Weed control is a major challenge in conventional and organic production systems (Bensch et al., 2003; Bridges, 1992; Pimental et al., 2001; Rushing et al., 1985; Zimdahl, 2002). Organic farmers ranked weed management research as their top priority (OFRF, 1999). Organic vegetable producers have many challenges since their weed control tools are mostly limited to cultural methods (Bond and Grundy, 2001) with a strong dependence on excessive tillage, cultivation, and hand-hoeing for weed control (OFRF, 1999). Very few chemical weed control options have been approved for organic use.

Oklahoma producers are interested in sweet onion (*Allium cepa* L.) as an alternative crop for farm diversification (McCraw, 1990; Shrefler, 2004). However, the lack of weed control can result in the total loss of marketable onions (Wicks et al., 1973). Onions do not compete well with weeds due to their slow growth rate (Wicks et al., 1973; Umeda et al., 1998; Bell and Boutwell, 2001), short height (Singh et al., 1992), non-branching plant structure (Singh et al., 1992), low leaf area (Dunan et al., 1996; Bell and Boutwell, 2001), and shallow root system (Singh et al., 1992).

The weed control challenges for onion production are even greater for those considering organic crop production. Organic weed control methods include crop rotations, cover crops, planting systems, mechanical methods, and organic herbicides. Although mechanical weed control through cultivation is useful for controlling weeds between rows, it is not effective for controlling weeds between plants within rows. Although corn gluten meal shows great promise as an organic preemergent herbicide for onions (Webber et al., 2006; Webber et al., 2007a), research has shown the need for supplemental, postemergent, weed control once early season effectiveness of corn gluten meal diminishes (Webber et al., 2007b). Organic onion producers need additional organic herbicides that can affectively provide post-emergent weed control.

Acetic acid (vinegar) is an approved postemergent organic herbicide (Radhakrishnan et al., 2002; 2003). Acetic acid was first reported in the popular press as a potential organic herbicide. Since those earlier reports, research has investigated the efficacy of acetic acid as an organic herbicide (Radhakrishnan et al., 2002, 2003; Johnson et al., 2003). In greenhouse research, vinegar applied with acetic acid concentrations of 5.0, 10.5, 15.3, and 20.2% killed five weed species—common lambsquarter (*Chenopodium album* L.), giant foxtail (*Setaria faberi* R. A. W. Herrm.), velvetleaf (*Abutilon theophrasti* Medik.), smooth pigweed (*Amaranthus hybridus* L.), and Canada thistle (*Cirsium arvense* L. Scop.) (Radhakrishnan et al., 2002). Weed control efficacy increased with acetic acid concentration and decreased with plant maturity. Radhakrishnan et al. (2002) applied vinegar with a hand sprayer to "obtain a uniform wetting of all foliage;" therefore, the application volume is unclear.

Radhakrishnan et al. (2003) evaluated effectiveness of directed-spray applications of vinegar for weed control in corn and soybeans. Weed control in these field trials ranged from 90-100%. It was also determined that a vinegar soil drench reduced total biomass of

Canada thistle and reduced stem numbers by 90%. Johnson et al. (2003) investigated use of a 10% acetic acid for broadleaf weed control in spring-planted wheat in Canada. In pre-seed treatments vinegar applications of 171 gpa or greater decreased shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.) by 80%. Vinegar application volumes of 171 gpa or greater produced at least 80% control of wild mustard (*Sinapis arvensis* L.) and cow cockle (*Viccaria hispanica* (Mill.) Rauschert). Although 171 gpa or greater produced weed control levels comparable to commercial herbicides, the 42.8 and 85.5 gpa application volumes were sufficient to sustain maximum wheat yields.

Household vinegar typically contains 5% acetic acid. Acetic acid does not persist in the environment; rather, it readily breaks down producing water as a by-product. Although acetic acid occurs naturally, care must be taken when handling vinegar, especially when the acetic acid concentration increases above the typical 5%. Vinegars with acetic acid concentrations of 11% or greater are available commercially, but these products can burn the skin and cause serious to severe eye injury, including blindness. Protective clothing that includes eye protection and gloves should be used.

Although previous studies have yielded important information concerning use of vinegar as an herbicide, further research is indicated in order to increase the understanding of the relationship between application volumes, weed species, and weed maturity on herbicidal efficacy. In order to address these issues, field research was conducted in southeast Oklahoma (Atoka County, Lane, OK) to determine the effect of application volume and broadcast applications of acetic acid on weed control efficacy.

Materials and Methods

The field experiment was conducted on 0.5 acre of land [Bernow fine sandy loam, 0-3% slope (fine-loamy, siliceous, thermic Glossic Paleudalf)] at Lane, OK. Intermediate, sweet onion varieties "Candy" and "Cimarron" were transplanted on March 13, 2007 into 2 rows per 6 ft-wide raised beds. Each research plot consisted of two onion rows per 10 ft length of bed. The experiment included 6 treatments (2 application volumes, 2 hand-weeding levels, an untreated weedy-check and an untreated weed-free) and 4 replications. Nutsedge (*Cyperus esculentus* L.) and grass weeds were removed from all plots, including the weedy-check, to investigate the impact of the acetic acid on the broadleaf weeds. Vinegar[1, 2] (20% acetic acid) was applied as an over-the-top broadcast application on April 21, 2007, 39 days after transplanting (DATr) using a tractor mounted CO_2 sprayer equipped with four extended range, stainless steel, 0.20 gallons/min nozzles[3] on 20-inch spacing at a spraying height of 19 inches. The 50 and 100 gpa sprayer application volumes were achieved by adjusting the travel speed to either 1.2 or 0.6 mph, respectively, and holding all other variables (nozzle size, pressure, and mixture volumes) constant. The two hand-weeded

[1] 20% Vinegar, Nature's Guide, Manufactured by Creole Fermentation, Abbeyville, LA, and Distributed by Marshall Distributing Company, 2224 E. Lancaster Ave., Fort Worth, TX 76103-2299.

[2] The mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

[3] XR TeeJet, XR8002VS, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189-7900.

treatments within each application volume (50 and 100 gpa) involved either no hand-weeding, where the uncontrolled weeds were allowed to grow, or a season-long hand-weeding, where all weeds were removed.

Data Collection

The first weed control ratings were collected at 3 days after treatment (DAT) and continued throughout the 107 day growing season (69 DAT) at 1 week intervals starting at 7 DAT. Weed control ratings represent the percent weed control for an experimental treatment compared to the weedy-check. A 0 to 100% visual rating system was used in which 0% represented no weed control, while 100% represented complete weed control. Data were converted using an arcsine transformation to facilitate statistical analysis and mean separation. All data was subjected to ANOVA[4] and mean separation using LSD with P=0.05. The weed control data were prepared for analyses using a square root arcsine transformation.

Results and Discussions

Rainfall

Rainfall during the 2007 growing season, from transplanting to harvest (107 days), was 28.9 inches. The 30-yr. average rainfall for the same location and time period (March 13 to June 30) is 17.9 inches. It's unclear at this time how the excessive rainfall in 2007 affected season-long weed control.

Weed Control

The experiment had very high weed densities with multiple broadleaf species. The weeds present at treatment included spiny amaranth (*Amaranthus spinosus* L.), cutleaf ground-cherry (*Physalis angulata* L.), cutleaf evening primrose (*Oenothera laciniata* Hill), and carpetweed (*Mollugo verticillata* L.). At application spiny amaranth, cutleaf ground-cherry, and cutleaf evening primrose averaged 2-5 leaves and less that 1 inch tall. Carpetweed seedlings were no more than 1 inch wide with 3 or 5 leaves. No other weed species contributed more than 5% to the weed cover. Grass weed species and nutsedge were removed after spaying the vinegar and kept hand-weeding throughout the remainder of the growing season. Only data for combined ratings for total broadleaf weed control are reported.

Weed control from vinegar treatments peaked at 7 DAT (46 DATr), averaging 95% and 99% total broadleaf weed control for the 50 and 100 gpa application volumes without hand-weeding (Table 1). Weed control for the 50 and 100 gpa treatments without hand-weeding decreased from the peak at 7 DAT until harvest at 69 DAT, 55 and 78.5%, respectively. At harvest, the two most dominate weeds in the weedy-check were cutleaf ground-cherry (49%) and cutleaf evening primrose (33%), data not shown.

Conclusions

Broadcast applications of 50 and 100 gpa of 20% acetic acid vinegar can provide good (>80%) to excellent (>95%) broadleaf weed control for up to 5 weeks after application.

[4] SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513.

Acknowledgements

The authors would like to thank Sam McClure, Spring Creek Ranch, Calvin, OK for supplying the onion transplants and Buddy Faulkenberry, USDA, ARS, Research Technician, for his field work, data processing, and leadership. We would also like to thank Tony Goodson, Ron Marble, Tim Abney and John Johnson for helping transplanting the onions and Anamari Holcomb, Brittanie Baze, and Jesy Cochran for plot maintenance and harvesting.

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Table 1. Total weed control percentage at 3, 7, 35, and 69 DAT by weed control treatment.

Weed Control Treatment	Hand-Weeded	3 DAT %		7 DAT %		35 DAT %		69 DAT %	
Vinegar* (50 gpa)	No	89	b**	95	b	84	b	55	c
Vinegar (50 gpa)	Yes	100	a	100	a	100	a	100	a
Vinegar (100 gpa)	No	99	a	99	a	97	a	79	b
Vinegar (100 gpa)	Yes	100	a	100	a	100	a	100	a
Weedy-Check	No	0	c	0	c	0	c	0	d
Weed-Free	Yes	100	a	100	a	100	a	100	a

*Vinegar with 20% acetic acid applied using a broadcast over-the-top application.

**Means within columns followed by the same letter are not significantly different, Least Significant Difference (LSD) test, P=0.05.

ACETIC ACID: CROP INJURY AND ONION (*ALLIUM CEPA* L.) YIELDS

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Introduction

Organic vegetable producers have many challenges since weed control tools are mostly limited to cultural methods (Bond and Grundy, 2001) with a strong dependence on tillage (OFRF, 1999). Few chemical weed control options have been approved for organic use. Acetic acid (vinegar) was first reported in the popular press as a potential organic herbicide. Since those earlier reports, research has investigated the impact of acetic acid on crop injury and yields. Radhakrishnan et al. (2003) conducted field research evaluating the impact of directed-spray applications of vinegar on corn and soybeans. Increasing the acetic acid concentration from 10 to 20% increased crop injury, and foliar applications produced greater crop injury than basal applications. The results further indicated that although soybean plants are more sensitive to vinegar applications than corn, soybean injury decreases with increasing maturity. Johnson et al. (2003) investigated the use of a 10% acetic acid for broadleaf weed control in spring-planted wheat. Vinegar was applied at 21.4, 42.8, 85.5, 171, and 256 gpa, either three days before seeding spring wheat, or after wheat reached the 1-2 leaf stage. In-crop, post-emergence vinegar applications at 42.8 gpa or greater produced significant initial wheat injury; however, 28 days after treatment, crop injury was barely visible.

It has been suggested that acetic acid injures and kills plants by first destroying the cell membranes, which then causes the rapid desiccation of the plant tissues. There is no evidence that acetic acid is absorbed into the plant and translocated to other plant parts to inflict damage; therefore, it is considered to be a contact herbicide rather than a systemic herbicide such as glyphosate. As a contact herbicide, acetic acid should be more damaging to seedlings and annuals than to more mature plants and perennials.

Although previous studies yielded important information concerning use of vinegar as an herbicide, further research is needed to increase the understanding of the relationship between application volumes and crop maturity on crop injury and yields. In order to address these issues, field research was conducted in southeast Oklahoma (Atoka County, Lane, OK) to determine the effect of application volume and broadcast applications of acetic acid on crop injury and onion yields.

Materials and Methods

The field experiment was conducted on a 0.5 acre of land [Bernow fine sandy loam, 0-3% slope (fine-loamy, siliceous, thermic Glossic Paleudalf)] at Lane, OK. Intermediate, sweet onion varieties "Candy" and "Cimarron" were transplanted on March 13, 2007 into 2 rows per 6 ft-wide raised beds. Each plot consisted of two onion rows per 10 ft length of bed. The experiment included 6 treatments (2 application volumes, 2 hand-weeding levels,

an untreated weedy-check and an untreated weed-free) and 4 replications. Vinegar[5, 6] (20% acetic acid) was applied as an over-the-top broadcast application on April 21, 2007, 39 days after transplanting (DATr) using a tractor mounted CO_2 sprayer equipped with four extended range, stainless steel, 0.20 gallons/min nozzles[7] on 20-in. spacing at a spraying height of 19 inches. The 50 and 100 gpa sprayer application volumes were achieved by adjusting travel speed to either 1.2 or 0.6 mph, respectively, and holding all other variables (nozzle size, pressure, and mixture volumes) constant. The two hand-weeded treatments within each application volume (50 and 100 gpa) involved either no hand-weeding, where the uncontrolled weeds were allowed to grow, or a season-long hand-weeding, where all weeds were removed.

Data Collection

The first crop injury visual ratings (phytotoxicity) were collected at 3 days after treatment (DAT) and continued throughout the growing season at 1 week intervals starting at 7 DAT. A 0 to 100% visual rating system was used in which 0% represented no crop injury, while 100% represented crop death. The data were converted using an arcsine transformation to facilitate statistical analysis and mean separation.

The onions were harvested on June 29, 2007, 107 days after transplanting (69 DAT), sorted by size, counted, and weighed. The sorted onion grades included "small" (< 2.0 in.), "medium" (>2.0 to 3.0 in.), "large" (>3.0 to 3.75 in.), and "colossal" (> 3.75 in.) for marketable size. Yield data in this presentation will include only the total marketable yield combined across the 4 onion grades. Split and decomposed onions were placed in the unmarketable group. All data was subjected to ANOVA[8] and mean separation using LSD with P=0.05.

Results and Discussions

Rainfall

Rainfall during the 2007 growing season, from transplanting to harvest (107 days), was 28.9 inches (Table 1). The 30-yr. average rainfall for the same location and time period (March 13 to June 30) is 17.9 inches. Halfway through the growing season (May 4, 14 DAT) the 2007 rainfall 4.3 in. was 45% below the 30-yr average for that date (7.9 in.), but represented only 15% of the total rainfall received during the entire 2007 growing season. Rainfall during the second half of the growing season (24.6 in.) was 240% greater than the 30-yr average from May 5 to June 30 (10 inches). It is unclear how the excessive rainfall in 2007 may have affected onion yields.

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[5] 20% Vinegar, Nature's Guide, Manufactured by Creole Fermentation, Abbeyville, LA, and Distributed by Marshall Distributing Company, 2224 E. Lancaster Ave., Fort Worth, TX 76103-2299.

[6] The mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

[7] XR TeeJet, XR8002VS, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189-7900.

[8] SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513.

Crop Injury

No significant differences were observed between onion varieties for crop injury; therefore crop injury was averaged across varieties. The greatest onion injury was recorded 3 DAT (42 DATr), averaging 38% and 56% for the 50 and 100 gpa applications, respectively (Table 2). Visual crop injury due to vinegar decreased to 2 (50 gpa) and 3% (100 gpa) by 14 DAT (53 DATr). Crop injury then increased for all treatments, even those not sprayed with vinegar, to 5% at 21 DAT and then decreased over time to 1% at 42 DAT (data not shown). It is believed that the injury observed from 21 DAT to 42 DAT for all treatments was due to a 6.8 in. rain event on May 7 (16 DAT, 55 DATr) followed by excessive rainfall for the remainder of the growing season. Although the broadcast over-the-top application of vinegar did injury the onion transplants, the visual symptoms were nearly erased by 14 DAT.

Onion Yields

There were significant differences between onion varieties and among weed control treatments (Table 3). In all cases application of vinegar increased onion yields compared to the weedy-check for each onion variety. "Cimarron" produced greater onion yields than "Candy" for the two 50 gpa vinegar weed control treatments and the weed-free that did not received any vinegar applications. "Candy" had significantly greater yields for the hand-weeded 100 gpa vinegar treatment compared to Cimarron.

Conclusions

Although onion plant populations were not reduced, the over-the-top broadcast application of vinegar caused severe crop injury within the first few days after treatment. The visual injury ratings for the two varieties were not significantly different, but the yield response for the onion varieties varied depending on weed control treatment. The excessive rainfall and adverse soil moisture levels during the second half of the growing season may have had an adverse impact on the onion yields.

Acknowledgements

The authors would like to thank Sam McClure, Spring Creek Ranch, Calvin, OK for supplying the onion transplants and Buddy Faulkenberry, USDA, ARS, Research Technician, for his field work, data processing, and leadership. We would also like to thank Tony Goodson, Ron Marble, Tim Abney and John Johnson for helping transplanting the onions and Anamari Holcomb, Brittanie Baze, and Jesy Cochran for plot maintenance and harvesting.

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Table 1. Monthly and cumulative rainfall in inches for the 2007 growing season and 30-yr average for Lane, OK.

Rainfall Period	2007	2007 Cumulative	30-yr	30-yr Cumulative
	(in)	(in)	(in)	(in)
March 13 - 31	2.01	2.01	2.51	2.51
April	1.98	3.99	4.60	7.11
May	12.45	16.44	6.20	13.31
June	12.50	28.94	4.59	17.90

Table 2. Crop injury averaged across onion varieties at 3, 7, and 14 DAT by weed control treatment.

Weed Control Treatment	Hand-Weeded	3 DAT		7 DAT		14 DAT	
		%		%		%	
Vinegar* (50 gpa)	No	37.5	b**	8.8	a	2	a
Vinegar (50 gpa)	Yes	37.5	b	8.8	a	2	a
Vinegar (100 gpa)	No	56.3	a	10	a	3	a
Vinegar (100 gpa)	Yes	56.3	a	10	a	3	a
Weedy-Check	No	0	c	0	b	0	a
Weed-Free	Yes	0	c	0	b	0	a

*Vinegar with 20% acetic acid applied using a broadcast over-the-top application.

**Means within columns followed by the same letter are not significantly different, Least Significant Difference (LSD) test, P=0.05.

Table 3. Total onion yields for Cimarron and Candy for Lane, OK as a result of weed control treatments.

Weed Control Treatment	Hand-Weeded	Cimarron lb/a			Candy lb/a		
Vinegar* (50 gpa)	No	2379	c**	(a)***	1431	d	(b)
Vinegar (50 gpa)	Yes	3371	a	(a)	1771	b	(b)
Vinegar (100 gpa)	No	1829	e	(a)	1686	c	(b)
Vinegar (100 gpa)	Yes	1947	d	(b)	2294	a	(a)
Weedy-Check	No	1133	f	(b)	1207	e	(a)
Weed-Free	Yes	2519	b	(a)	1475	d	(b)

*Vinegar with 20% acetic acid applied using a broadcast over-the-top application.

**Means within columns followed by the same letter are not significantly different, Least Significant Difference (LSD) test, P=0.05.

***Means within rows columns followed by the same letter within parenthesis are not significantly different, Least Significant Difference (LSD) test, P=0.05.

SEASONAL PREVALENCE OF IRIS YELLOW SPOT VIRUS IN TRANSPLANTED AND DIRECT-SEEDED ONION FIELDS

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Introduction

New York State produces 4,900-5,200 ha of bulb onions annually with a crop value between $45-60 million. In 2007, New York ranked 4th in the United States in total acreage for fresh market onions (NASS 2008). *Iris Yellow Spot Virus* (IYSV), transmitted by onion thrips, *Thrips tabaci*, was first detected in New York in 2006 (Hoepting et al. 2007). Since then, high levels of IYSV have been found in fields in all major onion growing regions in New York. The potential financial impact of this new virus on New York's onion production industry is still unclear and will depend, in part, on how quickly the virus spreads within a field and whether infection levels become high enough to impact yield.

Previous work suggests that the virus is established in New York and the most likely sources for IYSV are volunteer onion plants from the previous year's crop, volunteer onion plants growing in onion cull piles and local weeds (Nault et al. 2008). All of these hosts could provide IYSV inoculum for thrips early in the season, and infected thrips developing on these hosts would then be available to spread the virus into onion fields.

Approximately 85% of onions in New York are grown from seed and 15% are grown from transplant onions imported from Arizona. Plants grown from seed are generally a few weeks behind transplanted onions in development, and onion thrips are frequently detected in transplanted fields before direct-seeded ones. Some imported transplant onions from Arizona are infested with onion thrips when they arrive in New York (C. Hsu, unpublished data) and may contribute to higher early-season densities of thrips in transplanted fields compared with direct-seeded fields. It is also possible that onion thrips preferentially colonize transplanted fields before direct-seeded ones because the plants are larger and may be more attractive to dispersing thrips. This could put transplanted onion fields at higher risk for early season infection. However, transplanted onions are typically harvested sooner than direct-seeded onions and this could lower their risk by reducing the amount of time the virus has to spread and by avoiding the high thrips populations that occur later in the season.

The primary objectives for this project were to monitor the prevalence of IYSV over time in direct-seeded and transplanted onion fields, and to determine if densities of thrips are positively correlated with high levels of IYSV.

Materials and Methods

Onion plants infected with IYSV do not always show diagnostic symptoms, so a serological test, Double Antibody Sandwich Enzyme-Linked ImmunoSorbent Assay (DAS ELISA), was used to determine whether a plant was infected. A standard DAS ELISA

protocol and commercially available antibodies designed for detecting IYSV in onions were used based on the manufacturer's recommendations (Agdia Inc., Elkhard, IN).

Monitor prevalence of IYSV in direct-seeded and transplanted onion fields over time.

Pairs of direct-seeded and transplanted fields of the same variety and within close proximity to each other were sampled in 2007 (12 fields) and in 2008 (12 fields). Each field was divided into a grid with 8-10 sample sites located within each of 6 rows. Sample sites were spaced approximately 23-34 m within a row and distances between rows varied with the width of the field. At each sample site, five plants were pulled within a 4 m radius resulting in a total sample of five plants per site and 250-300 plants per field for each sample date.

Samples were pulled every two weeks in 2007, beginning 11 June and ending on 17 September when the last field was harvested (8 sampling dates). Eight fields were located in the Elba Muck in Orleans County and four were located in the Linwood Muck in Genesee County. In 2008, biweekly samples were taken between 9 June and 4 August, and weekly samples were taken between 4 August and 5 September (9 sampling dates). All 12 fields used in 2008 were located in the Elba Muck.

Plants from each site were analyzed as a 5-plant composite sample using DAS ELISA until the prevalence reached high levels, after which single plant samples were used. A thin slice of leaf tissue from the middle of each plant was sampled to ensure that all leaves of the plant were included in the sample. The reaction was stopped after 20 min using 3 N sodium hydroxide (NaOH). Sites were categorized as "infected" if the ratio of the optical density reading of the sample compared to the negative control was greater than 3.0.

Relationship between thrips densities and IYSV prevalence.

In the same fields described above, the number of larval and adult thrips on one of the plants collected was recorded at each sample site resulting in a total of 50-60 estimates of thrips density per field for each sample date. Linear regressions were used to test: 1) whether there were differences in the number of thrips in direct-seeded versus transplanted fields early in the season; 2) whether early season thrips densities were significant predictors of IYSV prevalence prior to harvest; and 3) whether the cumulative number of thrips over the season was a predictor of IYSV prevalence prior to harvest.

Early season thrips densities were calculated using the cumulative number of larval or adult thrips counted on the first two sample dates. No foliar applications of insecticides were made until after the first two sample dates.

The first regression model included field type (direct-seeded or transplanted), onion variety and year. The second regression model included the average number of thrips per site per field found early in the season, field type, variety and year, and the third regression model included the total average number of thrips per site per field over the whole season, field type, variety and year. Thrips counts were transformed using ln(thrips) or ln(thrips + 0.1) and the proportion of sites testing positive for IYSV was transformed using arcsin(sqrt(IYSV)).

Results

Seasonal prevalence of IYSV in direct-seeded and transplanted onion fields.

In 2008, positive IYSV samples were found on the first sampling date, 9 June, compared with 2007, when all plants tested negative until late July (Tables 1 and 2).

In 2007, almost all fields were harvested before the number of sites testing positive exceeded 10%, except field EM-5, the direct-seeded Sherman field, where more than 50% of the sites tested positive by the end of the season (Table 1). IYSV levels were considerably higher in 2008, between 20-93.3% of the sites tested positive for nine of the 12 fields. Neither of the transplanted Milestone fields tested positive for IYSV (Table 2).

Combining both years of data, direct-seeded fields had a greater percentage of positive sites in six of the field-pairs, and the other six field-pairs had a higher percentage of positive sites in the transplanted fields (Figure 1). All three of the transplanted Red Bull fields had higher levels of IYSV than their direct-seeded counterparts, while both of the Sedona direct-seeded fields had higher levels of IYSV than their transplanted counterparts and both of the 2008 Milestone pairs had higher levels of IYSV in the direct-seeded fields. When direct-seeded fields had more IYSV than their transplanted counterparts, the average difference was 16.8%. When transplanted fields had more IYSV than their direct-seeded counterparts, the average difference was 6.4%.

Conclusions

We were able to detect IYSV much earlier in 2008, and more of the fields in 2008 had higher IYSV prevalence levels prior to harvest compared with 2007. When direct-seeded fields had higher levels of IYSV than their transplanted counterparts, the difference was much greater than when transplanted fields had higher levels of IYSV than their direct-seeded counterparts. This suggests that, contrary to what we original hypothesized, the direct-seeded fields may be more at risk to IYSV than transplanted fields even though transplanted fields had significantly higher populations of thrips early in the season.

In general, direct-seeded fields are harvested later than transplanted fields. This could affect IYSV levels by allowing the virus more time to spread within the field, and by concentrating infected thrips migrating out of harvested fields into the remaining fields that were still standing. The regression results showing that only adult thrips counts were a significant predictor of IYSV levels supports the possibility that later season adult thrips behavior may be more important in the epidemiology of IYSV in New York onions than early season thrips populations.

Future analyses will test whether there are significant differences in the progression of the virus over time between direct-seeded and transplanted fields, and whether the final IYSV levels recorded are significantly different between the two field types. We will also be exploring in more detail the relationship between thrips population densities and IYSV levels over time.

Relationship between thrips densities and IYSV prevalence.

We found significantly more larval thrips per site in transplanted onion fields compared with direct-seeded fields after controlling for year and variety (regression r^2 = 0.62, df = 15, P = 0.0279; field type P = 0.0096) (Figure 2). The regression testing for a

difference between the number of adult thrips in direct-seeded versus transplanted fields was not significant.

We did not find any significant relationships between early season larval or adult thrips counts and the proportion of sites testing positive for IYSV before harvest. However, the cumulative average number of adult thrips per site per field was a significant predictor of IYSV levels prior to harvest (regression $r^2 = 0.60$, df = 16, $P = 0.0182$; adult thrips $P = 0.003$) (Figure 3), but there was no significant relationship between the cumulative average number of larval thrips and the prevalence of IYSV (Figure 4).

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Table 1. Percent of sites testing positive for IYSV in 2007.

Field[1]	Variety[2]	N[3]	11-June	25-June	9-July	23-July	6-Aug	20-Aug	4-Sept	17-Sept
EM-1	Santana – DS	60						1.7	3.3	HARV[4]
EM-2	Santana – TR	60						6.7	10.0	HARV
EM-3	Sedona – DS	60						1.7	8.3	HARV
EM-4	Sedona – TR	60					5.0	5.0	HARV	n/a[5]
EM-5	Sherman – DS	60					3.3	18.3	38.3	53.3
EM-6	Sherman – TR	60					1.7	5.0	HARV	n/a
EM-7	Highlander – DS	60					HARV	n/a	n/a	n/a
EM-8	Highlander – TR	60				1.7	HARV	n/a	n/a	n/a
LM-9	Milestone – DS	60								HARV
LM-10	Milestone – TR	60						3.3	HARV	n/a
LM-11	Red Bull – DS	60								HARV
LM-12	Red Bull – TR	60						1.7	1.7	HARV

[1]EM – fields located in the Elba Muck; LM – fields located in the Linwood Muck
[2]DS – direct-seeded fields; TR – transplant fields
[3]N – number of sites in each field
[4]HARV – harvested
[5]n/a – not applicable because data were not collected after the field was harvested.

Table 2. Percent of sites testing positive for IYSV in 2008.

Field	Variety[1]	N[2]	9- Jun	24-Jun	7- Jul	21-Jul	4-Aug	12-Aug	20-Aug	27-Aug	5-Sep
1	Sedona – DS	60		1.7		1.7	10.0	13.3	28.3	46.7	HARV[3]
2	Sedona – TR	60	1.7			1.7	5.0	3.3	18.3	31.7	HARV
3	Red Bull1 – DS	60	3.3		1.7	1.7	5.0	10.0	23.3	63.3	73.3
4	Red Bull1 – TR	60	1.7		1.7	3.3	21.7	60.0	93.3	HARV	n/a[4]
5	Milestone1 – DS	60		1.7			3.3	dnc[5]	5.0	HARV	n/a
6	Milestone1 – TR	60						HARV	n/a	n/a	n/a
9	Milestone2 – DS	58	1.7					dnc	1.7	1.7	21.7
10	Milestone2 – TR	60						dnc		HARV	n/a
11	Red Bull2 – DS	60					1.7	3.3	8.3	20.0	HARV
12	Red Bull2 – TR	60			1.7				3.3	5.0	25.0
13	Red Zepelin – DS	50				1.7	1.7	3.3	30.0	HARV	n/a
14	Red Zepelin – TR	58		3.3	3.3	3.3	28.3	HARV	n/a	n/a	n/a

[1]DS – direct-seeded fields; TR – transplant fields
[2]N – number of sites in each field
[3]HARV – harvested
[4]n/a – not applicable because data were not collected after the field was harvested.
[5]dnc – did not collect samples on this date

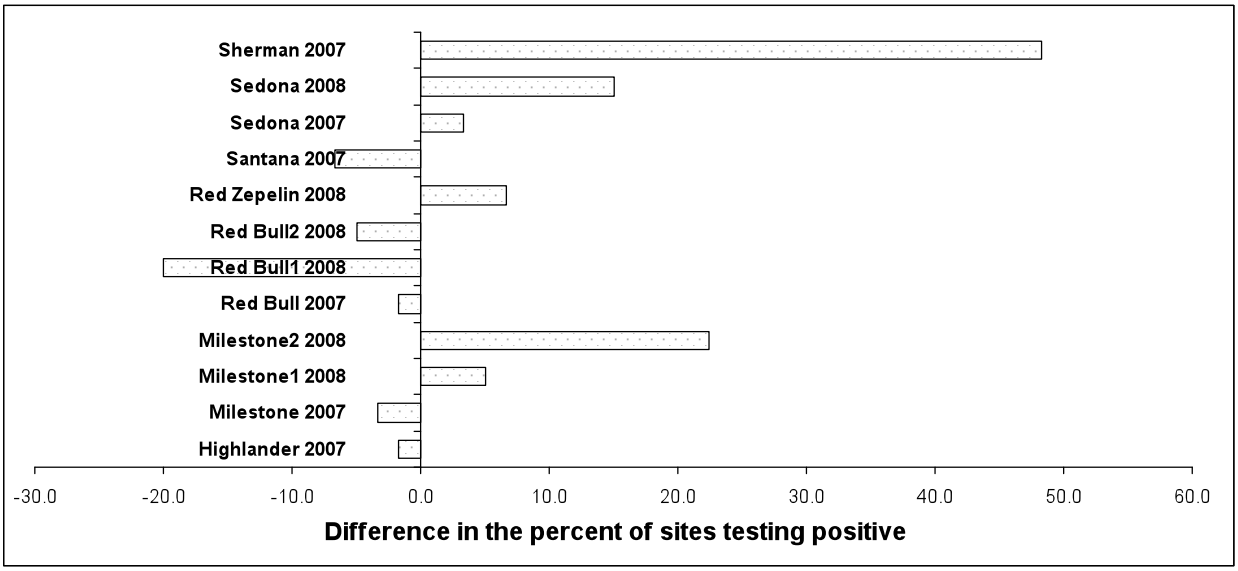

Figure 1. Difference between the percent of sites testing positive in direct-seeded versus transplanted fields for the 12 pairs of fields monitored in 2007 and 2008. Bars to the right indicate a higher percentage of the direct-seeded field sites tested positive and bars to the left indicate a higher percentage of the transplanted field sites tested positive.

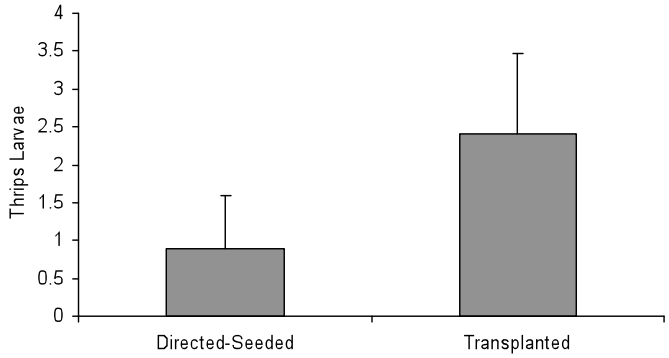

Figure 2. Significant difference between the average number of onion thrips larvae per site per field in direct-seeded and transplanted fields for 2007 and 2008 combined. Mean + SE.

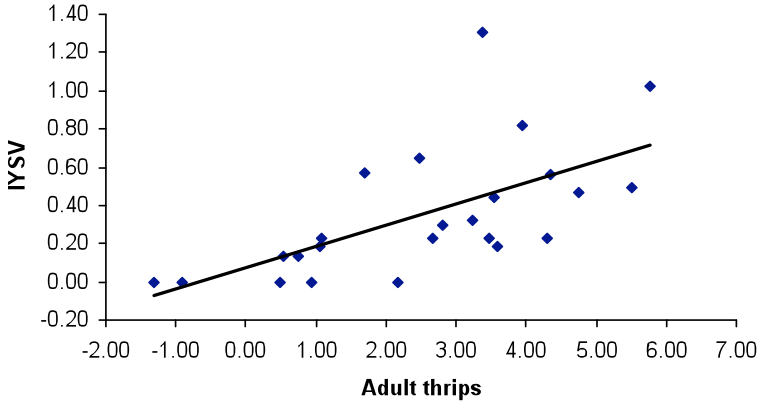

Figure 3. Significant linear relationship between the cumulative average number of adult thrips per site per field and the proportion of sites testing positive for ISYV at the end of the season. Adult thrips presented as ln(thrips) and IYSV presented as arcsin(sqrt(IYSV)).

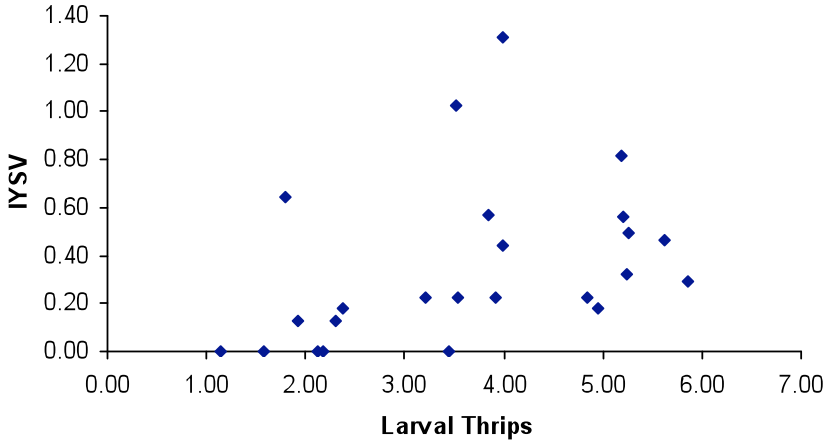

Figure 4. No significant linear relationship between the cumulative average number of larval thrips per site per field and the proportion of sites testing positive for ISYV at the end of the season. Laval thrips presented as ln(thrips) and IYSV presented as arcsin(sqrt(IYSV)).

IDENTIFYING SOURCES OF IRIS YELLOW SPOT VIRUS IN NEW YORK'S ONION CROPPING SYSTEM

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Introduction

Onion thrips, *Thrips tabaci*, is the dominant thrips species attacking onion in NY. Insecticides are used to control thrips infestations, but most registered products perform poorly (Nault and Hessney 2006; 2008a; 2008b) due in part to the development of resistance to pyrethroids in some populations (Shelton et al. 2003; 2006; MacIntyre-Allen et al. 2005). Management of onion thrips in NY has become even more critical since 2006, when the pathogen they transmit, *Iris yellow spot virus* (IYSV), was first detected (Hoepting et al., 2007). High densities of onion thrips and high levels of IYSV were found in all major onion production areas in NY in recent surveys. Grower's profits are already affected by yield reductions and increasing costs of insecticides to combat thrips, and IYSV may increase these losses.

Identifying hosts for both onion thrips and IYSV is a critical step in determining the role that these hosts play in the epidemiology of this disease in NY onion fields, and subsequent management strategies. Onion is grown as an annual crop in NY. So, IYSV is either being introduced into NY each year, is already established in NY and overwintering in a host, or both. Over 2,000 acres of onions are transplanted in NY with plants imported from AZ. Transplanted onions constitute about 15% of the total onion acreage in NY each year. Schwartz et al. (2004) reported IYSV in onion transplants grown in AZ and CA that were imported into Colorado. Thus, AZ plants imported into NY could be an annual source of IYSV. Another possible source of IYSV introduced each year is imported bulbs that are discarded during repackaging once in NY. Infected onions discarded in open cull piles located near onion fields may be colonized by thrips and could be an important early-season source for viruliferous thrips that then migrate into onion fields. Alternatively, IYSV could be established in NY and is overwintering within onion culls (future volunteers) and perennial weeds within and around onion fields. If this occurs, these plants might serve as significant sources for IYSV in the spring. Eliminating major sources of IYSV, especially early in the season, could significantly reduce the negative impacts the virus might have on NY onion production.

The primary objective of this project was to identify sources of IYSV in New York. To address this objective, the following were collected for analysis: (1) onion plants imported from AZ for transplanting, (2) onion bulbs imported for repackaging, (3) volunteer onion plants collected from the previous season's onion fields, (4) volunteer onion plants collected from cull piles, and (5) weeds. A related objective was to identify weed species that serve as a reproductive host for *T. tabaci*. A host plant with both thrips larvae and IYSV is

likely important in the epidemiology of this disease because IYSV can only be acquired by immature thrips.

Materials & Methods

Diagnosis of IYSV based on visual symptoms was not reliable, so we used a Double Antibody Sandwich Enzyme-Linked ImmunoSorbent Assay (DAS ELISA) (Clark and Adams 1977), to determine whether a plant was infected. The standard protocol and commercially available antibodies were used based on the manufacturer's recommendations (Agdia Inc., Elkhart, IN). Some samples that tested positive using DAS ELISA will be verified using reverse transcription (RT)-PCR, using primers derived from the small RNA from IYSV, and then the amplicon will be cloned, sequenced and matched to sequences in GenBank.

Imported onion plants. Eleven yellow and five red dry bulb varieties were inspected for IYSV over a two yr-period. All plants were imported from either Sunbelt Transplant Inc. or Frasier Mellon Farms, which are both located in Buckeye, AZ. These farms produce virtually all of the onion plants that are transplanted in NY. In 2007, 300 to 600 plants per variety were sampled and in 2008, 300 plants per variety were sampled.

Imported onion bulbs. Onion bulbs imported into NY for repackaging were collected from WA, TX, CA, NM and AZ. One-hundred bulbs from each location will be sampled later this fall to test for evidence of the virus.

Volunteer onion plants from onion fields. In early spring 2007, volunteer onion plants were tested from nine fields located in Genesee, Orleans, Oswego, Wayne and Yates Counties. In May 2008, volunteer plants were pulled from 30 onion fields in Orange, Orleans, Oswego, Wayne and Yates Counties. In most cases, 20 to 60 plants were tested from each field. In 2008, volunteers were collected before onion thrips were active in onion fields. Detection of IYSV-positive volunteers in 2008 would indicate that the virus overwinters successfully in onion after inoculated into the plant by thrips the previous year.

Volunteer onion plants from cull piles. In May 2008, 30 volunteer plants were collected from each of 12 cull piles located in Orange, Orleans, Oswego and Wayne Counties.

Weeds. In 2008, 25 commonly encountered weed species were sampled from the Black Dirt region of Orange Co., which accommodates the largest onion acreage in NY, and the Elba muck, which produces the second largest concentration of onions in NY. Up to 60 plants of each weed species were collected from the periphery of onion fields known to have a history of IYSV the previous season. DAS ELISA was used to test for IYSV and will be confirmed by RT-PCR.

Thrips larvae on weeds. In 2008, the most commonly encountered perennial, biennial and winter annual weed species in proximity to onion fields were sampled every two weeks. This study was confined to the Elba muck region where five locations were sampled and up to 5 plants per species were collected per location. Entire plants, or sections of plants, were taken to the laboratory where immature thrips were removed and reared to adulthood on cabbage foliage. Adult thrips were identified to species and then numbers of *T. tabaci* were recorded.

Results

Imported onion plants. In both 2007 and 2008, onion plants imported from AZ tested negative for IYSV (Table 1). Based on this information, it is unlikely that onion plants recently imported into NY are infected with IYSV.

Imported onion bulbs. We collected bulbs from WA, TX, CA, NM and AZ that were imported into NY for repackaging and may have potentially ended up in cull piles. Past studies have shown that detection of IYSV in bulbs from plants known to be infected is not reliable, so we planted bulbs in pots containing soil to generate leaf tissue to assay. Unfortunately, most of the bulbs rotted before sprouting. Another attempt will be made, but this time bulb material will be tested directly.

Volunteer onion plants from onion fields. In 2007, 3 of 5 fields sampled had at least one volunteer onion plant infected with IYSV (Table 2). The percentage of plants infected with IYSV ranged from 5 to 22%. In May 2008, 3 of 30 fields sampled had at least one plant infected with IYSV (Table 2). The range of plants infected was 3 to 9%. Volunteers could be a significant source of IYSV provided that onion thrips can complete a generation on them before migrant field laborers remove them from fields. No thrips data were collected from volunteers.

Volunteer onion plants from cull piles. All cull piles in Orange Co. tested positive and 2 of 5 cull piles in Orleans Co. tested positive (Table 3). None of the volunteers from Wayne or Oswego Counties tested positive. Two of the cull piles in Orange Co. had high levels of plants infected with IYSV (17-20%). Only one of these received bulbs grown solely in Orange Co., whereas the other included culls from both NY and other areas within the US.

Weeds. Three of the 25 weed species tested positive for IYSV using DAS ELISA (Table 4). These species, chicory, curly dock and dandelion, have not had IYSV confirmed using RT-PCR; however, these species will be tested soon using this technique. One species, burdock, has had inconsistent results when tested using DAS ELISA, which is the reason it received a question mark rather than a (-).

Onion thrips larvae on weeds. Onion thrips were capable of reproducing on 18 of the 25 weed species examined (Table 4). However, 11 of these 18 species were considered poor hosts because few onion thrips larvae were found. For several of these species, only a single larva was found during the season-long survey. The seven remaining weed species were considered good to excellent hosts for onion thrips, and two of seven weed species, curly dock and dandelion, were also hosts for IYSV.

Conclusions

Volunteer onion plants growing in the previous year's onion fields and cull piles as well as selected weed species are likely sources of IYSV in NY. These sources are known hosts for both IYSV and onion thrips. Among these sources, weeds may contribute the most to annual spread of this disease because their densities far outnumber densities of volunteer onions in the onion-cropping system. However, more research is needed to examine this hypothesis. Elucidating temporal and spatial relationships between IYSV, weed hosts, onion thrips and the onion crop should prove critical for identifying onion fields at risk for IYSV and deployment of management strategies.

Onion plants imported from AZ for transplanting in NY tested negative for IYSV, and therefore are not likely a source in NY. Imported bulbs discarded into cull piles during repackaging could be a source, but not likely a major one. We learned this summer that many imported bulbs do not sprout even when provided conditions to do so; perhaps these bulbs were treated with a sprout inhibitor prior to harvest. If imported bulbs never produce foliage to support thrips development, transference of IYSV to nearby onion fields cannot occur. Additionally, cull piles are small, concentrated areas of which many are located great distances from onion fields.

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Table 1. IYSV incidence in onion plants imported from Arizona intended for transplanting in New York in 2007 and 2008. The (-) symbol indicates IYSV was not detected in any sample; N/A indicates that the variety was not sampled in that year. Number of plants sampled per variety per year varied between 300 and 600.

Variety (Yellow)	2007	2008	Variety (Red)	2007	2008
Corona	(-)	N/A	Mercury	(-)	(-)
Empire Sweet	(-)	(-)	Red Bull	N/A	(-)
Frontier	N/A	(-)	Red Zepelin	(-)	(-)
Highlander	(-)	N/A	Redwing	(-)	(-)
Kasmer Homegrown	(-)	N/A	Rhumba	(-)	N/A
Milestone	(-)	(-)			
Millenium	(-)	N/A			
Norstar	N/A	(-)			
Prince	N/A	(-)			
Ricochet	(-)	(-)			
Sherman	N/A	(-)			
T-439	N/A	(-)			

Table 2. IYSV incidence in volunteers pulled from NY onion fields in 2007 and 2008.

Year	Sample Date	Location	# Fields	#Fields Positive	# Plants Positive (%)
2007	22 May	Yates Co.	1	1	2 (22%)
	4 June	Genesee Co.	2	0	0
	5 June	Orleans Co.	4	1	1 (5%)
	8 June	Oswego Co.	1	0	0
	8 June	Wayne Co.	1	1	2 (7%)
2008	1 May	Orleans Co.	11	1	3 (9 %)
	7 May	Orange Co.	7	0	0
	13 May	Wayne Co.	1	1	1 (5%)
	13 May	Oswego Co	3	0	0
	30 May	Orleans Co.	5	1	1 (3%)
	30 May	Yates Co.	3	0	0

Table 3. IYSV incidence in volunteers pulled from onion cull piles in NY in 2008.

Sample Date	Location	# Piles	#Piles Positive	# Plants Positive (%)
7 May	Orange Co.	4	4	1 (3%); 5(17%); 2 (7%); 6 (20%)
9 May	Orleans Co.	5	2	4 (13%); 1(3%)
13 May	Oswego Co.	2	0	0
13 May	Wayne	1	0	0

Table 4. Common weeds examined for IYSV and onion thrips larvae, *T. tabaci*, in NY in 2008. A host in which *T. tabaci* larvae were rare, common, or abundant is denoted with a (+), (++), or (+++), respectively.

Species	Biology[1]	IYSV Detected[2]		Larvae
		DAS-ELISA	RT-PCR	
Burdock, *Arctium minus*	biennial	?	N/A	(+++)
Canada thistle, *Cirsium arvense*	perennial	(-)	N/A	(-)
Chicory, *Cichorium intybus*	perennial	(+)	TBD	(-)
Common mallow, *Malva neglecta*	WA/B/P	(-)	N/A	(+)
Common milkweed, *Asclepias syriaca*	perennial	N/A	N/A	(++)
Common mullein, *Verbascum thapsus*	biennial	(-)	N/A	(+)
Curly dock, *Rumex crispus*	perennial	(+)	TBD	(+)
Dandelion, *Taraxacum officinale*	perennial	(+)	TBD	(++)
Evening primrose, *Oenothera biennis*	biennial	N/A	N/A	(+)
Hedge bindweed, *Calystegia sepium*	perennial	N/A	N/A	(+)
Horseweed, *Conyza canadensis*	winter annual	N/A	N/A	(-)
Field pennycress, *Thlaspi arvense*	winter annual	N/A	N/A	(+)
Goldenrod, *Solidago canadensis*	perennial	(-)	N/A	(+)
Perennial sowthistle, *Sonchus arvensis*	perennial	N/A	N/A	(-)
Poison hemlock, *Conium maculatum*	biennial	(-)	N/A	(+++)
Prickly lettuce, *Lactuca serriola*	perennial	(-)	N/A	(-)
Purple deadnettle, *Lamium purpureum*	winter annual	(-)	N/A	(+)
Shepherd's purse, *Capsella bursa-pastoris*	winter annual	(-)	N/A	(++)
Stinging nettle, *Urtica dioica*	perennial	(-)	N/A	(+)
Virginia pepperweed, *Lepidium virginicum*	WA/B/P	(-)	N/A	(+)
White campion, *Silene alba*	SA/B/P	(-)	N/A	(-)
Wild mustard, *Brassica kaber*	WA/B/P	(-)	N/A	(+++)
Wild radish, *Raphanus raphanistrum*	SWA/B	N/A	N/A	(+)
Yellow nutsedge, *Cyperus esculentus*	perennial	N/A	N/A	(-)
Yellow rocket, *Barbarea vulgaris*	WA/B/P	(-)	N/A	(++)

[1] WA is a winter annual; SA is a summer annual; SWA is a summer/winter annual; B is a biennial and P is a perennial.

[2] TBD – to be determined in late December 2008; N/A – information not available.

SPATIAL AND TEMPORAL DISTRIBUTION OF THRIPS AND IYSV OF ONION IN COLORADO

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Introduction

Various thrips species (Thysanoptera:Thripidae) cause damage to onion in western U.S. production regions and are managed primarily with frequent insecticide applications. In spite of chemically-intensive management, thrips continue to cause significant and increasing damage to onion because of widespread insecticide resistance (Al-dosari, 1995; Shelton et al., 2003). Therefore, thrips are a primary constraint to continued productive and sustainable onion production. In addition to feeding injury caused by thrips, the thrips-transmitted tospovirus *Iris yellow spot virus* (IYSV) has emerged as a devastating pathogen and widespread disease of onion and other *Allium* species in the Western U.S. (Gent et al., 2006). Management of iris yellow spot (IYS) is difficult and, currently, incomplete. Current management strategies include selection of cultivars less susceptible to the disease and/or vector (du Toit and Pelter, 2004), increased plant population (Gent et al., 2004), selection of transplants free of IYSV, and isolation of onion bulb and seed crops (Gent et al., 2006). Many growers also have implemented intensive thrips insecticide programs with unknown impacts on disease severity (Gent et al., 2006).

The spatial distribution of IYSV-infected plants varies within and among onion fields depending on cultivar, plant population and location in the field. Diseased plants largely are distributed randomly and secondary spread of IYS within fields appears limited, although the highest IYS incidence was often found on the borders of fields with the lowest incidence near the field centers in Colorado (Gent et al., 2004). The value of insecticides in disease management is unclear. Insecticides may have little effect on disease development in the absence of secondary disease spread in a field since viruliferous thrips originating from outside of the field may be more important, as with other tospoviruses (Gitaitis et al., 1998). Since the introduction of IYSV into Colorado, the pathogen has been confirmed from an increasing number of fields, and continues to expand to new areas each year (Gent et al., 2004).

The goals of our project were to investigate cultural practice effects upon thrips and tospovirus management in Colorado. The specific objectives were to investigate the relationship of onion plant yield to soil properties, thrips populations and iris yellow spot; and (2) develop a strategy for onion growers and crop consultants to identify and avoid high disease risk situations.

Materials and Methods

The spatial and temporal variability of thrips populations (adults and larvae), IYS incidence/severity, and yield components of onion bulbs were mapped and interpolated as described by Gent et al. (2004). Thrips populations were measured by visual counts and the use of sticky traps. Two or more representative fields in a region with a history of IYS in Colorado were selected each for 2004, 2005 and 2006. The perimeter of each field was mapped by walking the border using a differentially-corrected GPS unit and MapInfo Professional version 6.5 FarmGPS software (MapInfo Corp., Troy, NY). A 0.2 ha virtual grid and geo-referenced random systematic sampling points (50 to 60 per 20 to 30 ha field) were superimposed on each field in FarmGPS software, navigated to, and marked with a flag.

Plant population and IYS incidence and severity from a 3 m section of one bed centered on the previously placed flag was recorded periodically, along with the number of thrips and thysenoptera species on 10 randomly selected plants during 3-5 stages of plant development. Onion production systems with seeded and transplanted onions varied from 2 row per 75 cm bed to 3 to 4 rows per 125 to 150 cm bed, with a 8 to 10 cm spacing between lines on the bed.

Near harvest, soil cores were collected from a depth of 30 cm from each site and analyzed for pH, texture, and concentrations of soluble salts and major nutrients by a private laboratory (MDS Harris, Lincoln, NE). As fields with outbreaks of IYS matured, a 3 m plot at each site was mechanically topped and harvested, sorted according to bulb size (e.g., colossal, jumbo, medium and total marketable) and weighed to estimate total and market class yield components. Statistical analyses and correlations were conducted using a variety of programs including SAS, SPLUS, and Moran's I (Moran, 1948).

Results and Conclusions

Aggregation of the incidence of IYS is limited and that of secondary spread of the virus is occurring from a well-distributed or readily dispersible vector. These results are similar to those reported by Gent et al. (2004), and suggest that aggregation of IYS and thrips populations may occur at a scale less than the 0.2. Nonetheless, the random systematic unaligned sampling method resulted in several plots being within a few meters of one another. Even at this distance, autocorrelation of the incidence of IYS and thrips populuations were limited.

In general, significant spatial dependency varied by study site. Early season thrips counts were spatially dependent at most study sites (4 of 6 during 2005 and 2006). Subsequent thrips counts (i.e., 2 and 3) exhibited significant spatial dependency in 3 of 6 sites. Later season thrips populations were randomly distributed. These results suggest that

thrips enter onion fields at a specific point (e.g., field margins or from other crops) and then migrating more randomly to adjacent plants as populations increase.

The incidence of IYS was spatially autocorrelated in three of the six study sites during 2005 and 2006. One trend was clear with the IYSV data: of the sites that exhibited spatial dependency, the second and third sampling dates exhibited stronger spatial auto correlation. The first sampling date was significant at only one study site. Significant spatial cross-correlation was found between thrips count and IYSV incidence at two study sites. These results suggest that areas that have high thrips populations may tend to have greater incidence of IYS as compared to areas with lower thrips populations.

The effect of thrips population and IYS on yield was not consistent in these studies. Yield was negatively affected by thrips at some sites, while at other there was no significant effect. Some sites had a negative relationship between yield and early-season thrips populations and a positive relationship between yield and later counts. Relationships between thrips, IYS, and edaphic properties appear to be weak. In three sites, thrips populations were affected by phosphorus and organic matter, although the strength of the correlations were weak.

We propose that an Onion IYSV Risk Index could be based upon pest and crop history, environmental patterns (e.g., high temperature, low moisture) and forecasts, production stresses (e.g., nutritional deficiencies and excesses, soil compaction), stage of plant development (e.g., vegetative to bulb stages of growth), pest population thresholds, and cultivar susceptibility to one or both pests. Validation of the model could then provide an efficient and uniform vehicle to disseminate critical and time-sensitive information related to IPM strategies that could be employed to address current and future IYS outbreaks in Colorado and elsewhere.

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MANAGEMENT OF ONION THRIPS AND IYSV WITH STRAW MULCH AND BIOPESTICIDES

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Introduction

Onion (*Allium cepa*) is an economically important crop in the U.S., generating over $900 million annually in farm receipts from 2001 to 2006 (National Ag Stats, 2007). U.S. onion production area ranges from 60,000 to 70,000 hectares annually. On average, more than 50 million metric tons of onion bulbs are harvested annually from nearly 3 million hectares worldwide. The tospovirus *Iris yellow spot virus* (IYSV) transmitted by onion thrips, *Thrips tabaci*, is reported to occur in every major onion producing region of the United States and world, and has become a major threat to onion production in most areas (Gent et al., 2006).

Onion growers in the western U.S. rely heavily on insecticides for management of thrips, and many growers have adopted more intensive insecticide management programs for *T. tabaci* in an attempt to reduce iris yellow spot (Cranshaw, 2006; Hammon, 2004). Additionally, several insecticides in the pyrethroid, organophosphate, and carbamate families have become ineffective for thrips control in some regions of onion production because of resistance (Allen et al., 2005; Shelton et al., 2003). Certain reduced-risk insecticides, such as spinosad and azadirachtin, may be suitable alternatives to these for managing thrips based on preliminary research.

Straw mulching has been utilized to improve onion plant development and yield by reducing irrigation water runoff and increasing lateral water movement and soil moisture (Jensen et al. 2003; Shock et al., 1999). In preliminary studies, Jensen and Shock (2004) reported that straw mulching combined with biopesticides enhanced populations of thrips predators, reduced thrips populations 25%, and increased bulb yield 15 to 25% compared to a conventional insecticide program in two years of testing in eastern Oregon. Recently, Larentzaki et al. (2008) reported that straw mulching significantly reduced emergence (by 54%) of populations of *T. tabaci* adults and larvae without compromising overall onion yield on New York muck soils.

A general association between plant stress, thrips severity, and the incidence of iris yellow spot has been noted previously in onions grown on mineral soils in western U.S. states (Gent et al., 2006), and cultural practices such as straw mulching could enhance integrated pest management strategies when combined with other IPM tools.

Materials and Methods

The pesticide experiment in 2004 with seeded red onion 'Flare' near Delta, Colorado was arranged as an insecticide trial in a randomized complete block design with four replications. Plots were fours beds wide by 8 meters long. Pesticide treatments were applied with a backpack sprayer on a weekly schedule and included: abamectin (Agri-Mek 0.15 EC),

emamectin benzoate (Proclaim 5SG and Denim 0.16 EC), thiamethoxam (Actara 25WG), acibenzolar-S-methyl (Actigard 50WG), lambda-cyhalothrin (Warrior), methomyl (Lannate LV), imidacloprid (Provado 1.6F), and spinosad (Success Naturalyte).

Four straw mulch experiments were conducted from 2005 through 2007 at the Colorado State University Agricultural Research, Extension and Education Center near Fort Collins. IYSV and thrips-susceptible onions were seeded (cultivar 'Vantage" in 2005) or transplanted (cultivars 'Teton', 'Candy' and 'Exacta' in 2005, 2006, and 2007, respectively) on 75 cm wide, furrow irrigated beds with 2 lines (rows) spaced 20 cm apart on each bed. Plots were fours beds wide by 16 meters long with 4 reps. In each experiment, a conventional thrips management program (applications of methomyl alternated with lambda-cyhalothrin) were compared to a program of reduced-risk insecticides (spinosad or SpinTor alternated with azadirachtin or Aza-Direct), straw mulch, straw mulch in combination with each insecticide programs, and a non-treated control. Straw mulch was applied uniformly by hand to the treated onion beds approximately 40 to 55 days after transplanting or 84 days after seeding at the broadcast rate of 1120 kg/ha.

In all experiments, thrips counts (adults and larvae) were taken periodically during pre- and post-bulbing stages of plant growth by counting 5 – 10 randomly selected plants per plot or after extracting for 24 hrs with a Burlese funnel (Arnett, 2000). The incidence of iris yellow spot (percentage plants exhibiting symptoms) was estimated by counting the number of symptomatic plants per 100 contiguous plants in the center two rows of each plot at 4 to 8 weeks post-bulbing. Yield samples were collected, and statistics run.

Results and Conclusions

Lannate (methomyl) and Proclaim and Denim (emamectin benzoate) provided the most consistent control, providing 77% and 58% reduction over the untreated control, respectively, when averaged over sample dates` in 2004. The reduced-risk pesticide spinosad significantly reduced thrips populations by 64 % over the untreated control on 23 June and 8 July. Iris yellow spot incidence was variable throughout the experimental plots in this commercial field, and there was not a significant treatment effect on disease incidence. However, there was a positive relationship between thrips populations and the incidence of iris yellow spot. The initial evaluation was approximately 4 to 5 weeks after the final thrips evaluations (when populations were greatest) and was positively correlated with disease incidence ($R^2 = 0.5860$, $P = 0.0060$). Two weeks later, thrips populations were also positively correlated with disease incidence ($R^2 = 0.6086$, $P = 0.0046$).

The addition of conventional (e.g., methomyl alternated with lambda-cyhalothrin) insecticides did not significantly enhance pest control or reduce mid-season thrips populations when compared to the untreated control. Conventional treatments were associated with greater thrips populations in one or more thrips counts in 2 of the 4 straw mulch experiments. This lack of control during mid- to late-season could contribute to additional stress on onion plants and potentially increase severity of iris yellow spot during the critical early to mid bulb stages of plant growth. Reduced-risk (e.g., spinosad alternated with azadirachtin) insecticides significantly reduced thrips populations on bare and/or straw mulch soil treatments in 2 of the 4 mulch experiments. Although not highly efficacious, these treatments could be a component of an overall integrated management approach for thrips since they are relatively selective and would conserve preserve thrips natural enemies.

Straw mulch applied to the center of onion beds with no insecticides reduced thrips populations by as much as 45% (range of 17 to 45%) compared to non-mulched plots, with a corresponding increase in total yield of 13 % and jumbo yield of 18 to 44 % for transplanted and/or seeded onions exposed to light to moderate pressure from *Iris yellow spot virus*. Yield responses were modest to significant (18 – 44%) in these experiments, presumably due to one or more of the following factors: (1) all experiments and treatments on bare and mulched soil received more than adequate irrigation water throughout the season which presumably lessened the negative impacts of environmental stress, thrips feeding damage (Lewis, 1997) and iris yellow spot; (2) the incidence of iris yellow spot and/or density of thrips was below the level where significant crop loss occurs; and/or (3) the suppression in thrips populations and iris yellow spot by any treatment was not great enough to detect a yield effect.

Although there was no apparent effect of the straw mulch treatment on iris yellow spot in these trials, additional research is warranted to determine if straw mulching (or burn-down of grass interplantings with grass herbicides) may suppress this disease; especially in commercial fields where additional plant stress such as limited irrigation moisture availability at critical stages of plant development is more common. We observed an apparent association between environmental stress (days above 32°C and fewer days with measurable rainfall during June and July as plants began to bulb) during 2006 and 2007 when the incidence of iris yellow spot was the highest.

Straw mulch applications can provide an economical and effective component for IPM and Integrated Crop Management as shown by recent studies where straw mulch cost estimates (variability reflects differences in local cost for and availability of straw) in New York on muck soils at $167 for 760 kg straw/hectare and in our Colorado studies on mineral soils at $125 for 1120 kg straw/hectare (exclusive of transportation and application costs). This modest cost for straw could easily be recovered with savings from fewer applications/costs of insecticides, and gains from increased yield presumably as onions are exposed to less stress from thrips, disease, heat and moisture extremes. These encouraging results and IPM recommendations have been summarized for submission to a pest management journal, and are being presented to onion growers and crop consultants throughout Colorado and other onion production regions at various educational meetings. A summary of results will also be posted on the Colorado State University Vegetable Pathology Team web site @ http://www.alliumnet.com/index.htm.

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COMPARISON OF ONIONS GROWN FROM IMPORTED BARE ROOT AND LOCALLY GROWN PLUG TRANSPLANTS IN NEW YORK

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Introduction

Growing onions from transplants is a growing trend in New York, because of the economic benefits of larger sized bulbs and earlier entry into the marketplace with approximately 15% of the 13,000 acres of onions now being grown from transplants. Most transplants are grown from bare root transplants imported from Arizona, which have been found to harbor Iris Yellow Spot Virus (IYSV) (Schwartz et al. 2004), the causal pathogen of neck rot, *Botrytis allii* (Hoepting et al. 2006) and onion thrips (Schwartz et al. 2004, Hsu and Nault, 2008, unpublished data). The deterrent to the alternative of purchasing locally grown plug transplants is that they are 3 times more expensive to purchase. However, there may be labor savings, especially in light of a new automated plug transplanter now available, and improved quality that would more than make up for the higher initial cost of transplants. In this study, we thoroughly compared all aspects of growing onions from plug and bare root transplants including plug production configurations, labor costs, stand establishment, pest management, yield, grade and economic feasibility.

Materials and Methods

This project was a collaborative effort between a commercial onion grower and an Extension Vegetable Specialist. In 2006, comparisons between imported bare root transplants and locally grown plug transplants were made using two onion varieties: i) an early maturing yellow variety that is grown from transplants specifically to gain earlier harvest and entry into the market when prices are high (c.v. Ricochet), and ii) a late maturing long-term storage red variety that is grown from transplants specifically to gain a bulb size advantage (c.v. Red Zepelen). The plug transplants were grown in 288 cell trays with 3 plants per cell. In 2008, comparisons were made using the red variety, Red Zepelen, and bare roots were compared to different production configurations of plug transplants including i) the standard, 288 cell trays with 3 plants per cell; ii) 288 cell trays with 2 plants per cell, and iii) 512 cell trays with 2 plants per tray. Enough plants were commercially produced to grow approximately one acre of onions for each treatment. Bare root transplants were grown by Sunbelt in Buckeye, AZ and plug transplants were grown by Triple P in Oakfield, NY. The different treatments were planted side by side in the same field for each variety. The trials were planted on May 5, 2006 and May 8-9, 2008. All transplants were planted on 60 inch beds with 4 single rows per bed and 15 inch row spacing. Number of plants per hole, plant spacing and transplanting method varied (Table 1).

Return on seed: This is the percentage of the total seed sent to the transplant producer that is returned to the grower as transplant seedlings. For bare root transplants, this value was estimated by the grower cooperator. For plug transplants, percent return on seed was estimated by early stand counts in the field in 2006 and by actual tray counts in the greenhouse in 2008. Four trays per treatment (288-3, 288-2 and 512-2) were randomly selected, and number of plants per cell counted in 10 randomly selected rows per tray.

Field evaluations: Each treatment was approximately 1 acre in size, which was divided evenly into 5 replications. The grower cooperator timed how long it took his crew to plant each transplant type. Stand establishment was measured 2, 6, 11 and 14 weeks after transplanting in 2006, from which an average stand was calculated. In 2008, stand was measured 2 and 12 weeks after transplanting. To measure stand, number of plants per hole were counted in 5 randomly selected sub-samples of 10 holes in a row per replicate. Number of leaves per plant was counted, and height of the tallest leaf per plant measured 2, 5-6, and 10-11 weeks after transplanting in 5 randomly selected sub-samples per replicate as described for stand counts. Pest pressure was also measured on each of the 5 sub-samples per replicate. Number of Botrytis leaf blight lesions per plant was counted on 16-Jun and 20-Jul in 2006, and on 11-Jun and 16-Jul in 2008. Number of purple blotch lesions per plant was counted on 11-Aug in 2006. Number of onion thrips per plant was counted on 16-Jun in 2006, and on 11-Jun and 16-Jul in 2008.

Harvest evaluations: In 2006, Ricochet and Red Zepelen were harvested on Aug 17 and Aug 30, respectively. In 2008, all treatments were harvested on 26-Aug. For each treatment, 5 x 5 ft sections of bed were harvested per replicate. Onions were pulled, windrowed, topped, sorted into size classes (small: 1.75-2"; medium: 2-3"; jumbo: >3"; and culls) and weighed. After natural curing, they were stored in a commercial onion storage.

Transplant Inspection and Bulb Quality Evaluations: Prior to transplanting, 10 bundles (25-100 plants per bundle) of bare roots or 2 randomly selected trays of plug transplants per variety were randomly selected for a latent *B. allii* bioassay which was performed as previously described by Hoepting *et al.* 2006. After 3.5 months in storage, bulbs were evaluated for Botrytis neck rot and bacterial rots.

Statistical analysis: Significant differences among treatments were determined by a General Analysis of Variance and Fisher's Protected LSD test ($p = 0.05$).

Economic Analysis: The grower cooperator kept detailed notes on the cost of seed, transplant production, shipping of transplants, labor, pesticide applications, and the price of the different size classes. Input costs included cost of seed, transplants, and transplanting, including labor. Yield, bulb size, price per bulb size, and storage losses were also included in the economic analysis. Cost estimates were made on a per acre basis. Input costs were estimated in 2008, based on 2006 costs, but will be adjusted when all data has been submitted.

Results and Discussion

Return on seed: In 2006, return on seed was estimated to be approximately 80% for both bare root and plug transplants. Return on seed of bare roots was also approximately 80% in 2008. Plug transplants yielded a higher percent return on seed (80 – 95%) than bare roots in 2008 with the 512 cell trays with 2 plants per cell producing the most plants (Table 2). In bare root transplant production, return on seed can be extremely variable, which can be a barrier for onion growers to efficiently grow and market their crop. For example, in

2007, the rate of return of transplants was about 40-60% due to an untimely frost during emergence in Arizona, which left growers scrambling for alternative strategies to make up for the unanticipated loss. Alternatively, when the rate of return of transplants is higher than expected, growers struggle to find the land and labor to plant the crop in a timely manner.

Although return on seed of plugs is better and more consistent than bare roots, the accuracy of the number of plants per cell was just over 50% in the 288-cell trays, due to high percentages (~ 30%) of cells planted with one less than desired number of plants per cell (Table 2). Even if the germination rate is 90%, than 10% of the cells would have less than the desired number of plants per cell, which is still 3 times less than the number of cells that were short plants. Hopefully, the accuracy of seeding into 288-cell trays could be improved upon. It is unknown why trays are planted more accurately into 512 cell trays.

Stand establishment: In 2006, 79 – 89 % of the bare root holes were planted correctly (1 plant per hole) compared to only 45% of the plugs with 288 cell trays, 3 plants per cell (Table 3). Fifteen to 38% of plug holes had only 2 plants per cell instead of 3. Consequently, plug transplants resulted in 80 – 82% of the target stand (156,816 plants per acre) compared to the bare roots which had 89 – 93% of the target stand (yellow = 139,392; red = 104,544). However, bare roots had 1.6 to 2.3 times more skips (0 plants per hole) than plugs.

In 2008, a higher percentage of the bare roots (72%) were planted correctly compared to the plugs (44 – 56%) (Table 3). However, the bare roots had 111% of the targeted plant population due to 16% and 3% of the holes having 2 and 3 plants instead of 1. The less accurate planting of the plugs grown from 288 cell trays with 38 – 45% of the holes having 1-2 less plants per hole than desired, reflected the inaccuracies of the original seedings in the trays in the greenhouse (Table 2). The actual plant population of the onions grown from plug transplants grown in 288 cell trays was 81 and 84% of the target population for 3 and 2 plants per cell, respectively (Table 3). Of the plug transplants, those grown in 512 cell trays with 2 plants per cell were planted with the most accuracy (56% of holes planted correctly). Because 15% of the cells had one less and 15% had one more plant than desired, the resulting actual plant population was 95% of the targeted population.

Plant size: In 2006, bare root transplants had at least one more leaf per plant and were taller than the plugs from 288 cell trays with 3 plants per cell at 6 and 11 weeks post transplanting in both the red and yellow variety (Table 4). In 2008, the bare root transplants had significantly more leaves per plant than any of the plugs, followed by the plug transplants grown in 288 cell trays with 2 plants per cell, which had significantly more leaves per plant than plug transplants grown in 288 cell trays with 3 plants per cell and plugs grown in 512 cell trays with 2 plants per cell, at 2, 5 and 12 weeks post transplanting. The plugs grown in 288-cell trays with 2 plants per cell had significantly the tallest plants 2 and 6 weeks after transplanting, but by 11-Aug they were not significantly different than the bare roots. Plugs grown in 512 cell trays with 2 plants per cell had significantly the shortest plants all season long. Often, plant size, especially number leaves, directly translates into final bulb size. Large, healthy plants during the growing season are an indication of big bulbs at harvest.

Pest pressure: Onions grown from plug transplants consistently had significantly higher numbers of onion thrips per plant in both the red and the yellow varieties in 2006 and in 2008 (Table 5). These differences were to the extent that the threshold to start spraying insecticides for onion thrips would have been reached sooner in the onions grown from plug transplants. The reason for this difference is that the insecticide treatment used to control onion maggot in bare roots provides 5-6 weeks of thrips control. A different insecticide is

used to control onion maggot in onions grown from plug transplants that does not control onion thrips.

In 2006, number of purple blotch lesions per leaf was significantly higher in onions grown from bare root transplants compared to plugs in mid-August (Table 5), but not to the extent that it would cause additional fungicide sprays. No differences in Botrytis leaf blight was observed between onions grown from bare roots and plug transplants in 2006 or 2008 (Table 5).

Yield and bulb size: In 2006, bare roots yielded 43 and 81 cwt per acre more than plugs in Ricochet and Red Zepelen, respectively (Table 6). Bare roots had twice as much jumbo weight and 1.5 to 3 times less small, medium and cull weight compared to plugs.

In 2008, onions grown from plugs in 288 cell trays with 3 plants per cell had the highest yield in the trial (387 cwt/A), which was 44, 47 and 80 cwt/A higher than plugs in 288 cell trays with 2 plants per cell, bare roots, and plugs in 512 cell trays with 2 plants per cell. The plant population was also highest for plugs in 288 cell trays with 3 plants per cell. Bare roots had significantly 3 times as much jumbo weight and 3.5 times less small weight as plugs in 288 cell trays with 3 plants per cell. Compared to bare roots, plugs in 288 cell trays with 2 plants per cell had similar yield, and significantly the same weight of jumbos and smalls per acre. Plugs grown in 512 cell trays with 2 plants per cell had the lowest yield, no jumbos and similar weight of smalls as plugs in 288 cell trays with 3 plants per cell. Bare roots had the highest cull weight per acre due to rots, double bulbs and undersized bulbs. The 2008 trial was severely damaged by a hail storm on June 16 that caused high incidences of culls, especially to plants that had the most leaves, specifically, the bare roots and plugs in 288 cell trays with 2 plants per cell.

Botrytis allii contamination of transplants and storage quality: In 2006, bare root transplants of both varieties were infected with *B.allii*, the neck rot fungus, before they were transplanted into the ground (Table 7). Comparatively, the plug transplants were free of disease. The bare roots had 3 to 4 times higher incidence of neck rot out of storage than the plugs. In 2008, no disease was found in bare roots or plugs. Bulbs are in storage and will be evaluated for rot in January 2009. It is unknown why the bare roots were clean in 2008, but historically, these transplants were found to be contaminated with *B. allii* (Hoepting et al. 2006). These findings show that starting with transplants that are infected with B. allii results in higher incidences of neck rot in storage.

Economic analysis: In 2006, plug transplants cost 3 times as much as bare roots to purchase (Table 8). Comparatively, transplanting bare roots singly by hand or with an 8-row mechanical transplanter was more labor intensive and cost 1.5 times more than transplanting plugs. However, transplanting plugs in 288 cell trays with 3 plants per cell took more time to plant than bare roots by 42 to 54 minutes per acre. Overall, bare roots were $308 to $433 per acre cheaper to purchase and transplant than plugs in 288 cell trays with 3 plants per cell. Onions grown from bare roots netted 29% and 26% more profit per acre than plugs, values of $1909 and $2156 per acre for Ricochet and Red Zepelen, respectively (Table 9).

Achieving jumbo-sized onions proved to be the most important factor in net profit in the 2006 study. In a year when there are less jumbos and more medium and small sized onions, there could be less differences in net profit between onions grown from bare roots and plug transplants. During the 2006 study, it was observed that when onions were grown from 288 cell trays with 3 cells per cell, rarely were all three bulbs the same size. Rather, there were 2 jumbo sized bulbs and 1 medium, or, 1 jumbo and 2 medium sized bulbs per hole. Comparatively, onions grown from bare root transplants planted singly per hole most consistently yielded jumbo sized bulbs. These observations led to the 2008 study, where

adjustments to the standard plug production (288 cell trays, 3 plants per cell, planted 8 inches apart) were made to improve the economic feasibility of growing onions from plug transplants. To reduce plant competition within a cell/hole, 2 plants per cell in 288 cell trays were trialed. The cost of producing plug transplants in a greenhouse is directly related to the amount of space that the trays take up in the greenhouse. Thus, in an attempt to reduce the cost of producing plug transplants, onions grown from plug transplants grown in 512 cell trays with 2 plants per cell, which require 44% less greenhouse space, were also evaluated in 2008.

In 2008, the target plant population per acre was 104,544 with exception of onions grown from plug transplants in 288 cell trays with 3 cells per plants, which had ⅓ more plants per acre at 156,816 (Table 10). Due to greatly increased cost of shipping bare root transplants due to a 41% increase in the cost of fuel, plug transplants grown in 288 cell trays cost only 2 times more than bare roots, down from 3 times more in 2006. Due to the use of 44% less greenhouse space, plugs grown in 512 cell trays cost only ¼ more to purchase than bare roots. Cost of transplanting in 2008 has not been calculated yet, but the grower cooperator reported that unlike in 2006, transplanting plugs took less time to plant than bare roots. The difference attributing to the speedier transplanting of plugs in 2008 was that the plug seedlings were taller than they were in 2006, which resulted in fewer technical difficulties during the mechanical transplanting process. Faster planting time of plugs should result in lower labor costs, and an even more favorable comparison of the cost of transplanting plugs compared to bare roots. Additionally, faster transplanting will allow the onion crop grown from plugs to be planted sooner. Generally, there is a direct relationship between early planting and increased bulb size, thus, increasing the proportion of jumbo sized bulbs and net profit of onions grown from plug transplants.

Unfortunately, due to severe hail damage that occurred on July 16th 2008, yield and bulb size per acre was down significantly from 2006. For example, in 2008, red onions, cv. Red Zepelen, grown from bare roots yielded 245 cwt/A or 42 % less than they did in 2006. Thus, most of the bulbs were in the lower-valued medium size class and total profit was down $7950 or 58% from 2006 (Table 9 & 11). The onions grown from plugs in 288 cell trays with 3 plants per cell grossed the highest, which was $667, $606 and $1492 more per acre than onions grown from bare roots, plugs in 288 cell trays with 2 plants per cell and plugs in 512 cell trays with 2 plants per cell, respectively (Table 11). The reason that onions grown from plugs in 288 cell trays with 3 plants per cell performed the best was because they were grown at a higher plant population. However, it was at the expense of producing jumbo sized onions. Comparatively, the onions grown from plugs in 288 cell trays with 2 plants per cell grossed only $61 per acre less than the bare roots, and had twice as many jumbos as the plugs in 288 cell trays with 3 plants per cell. When a greater proportion of the yield falls into the jumbo bulb size class, the difference between 2 and 3 plants per cell has a greater economical impact (as previously demonstrated in 2006) with 2 plants per cell being more favorable. Further research is warranted to demonstrate this point.

Once the more expensive cost of producing plug transplants is factored in, onions grown from plugs in 288 cell trays with 3 plants per cell netted $66, $484 and $1025 per acre more than onions grown from bare roots, plugs in 288 cell trays with 2 plants per cell and plugs in 512 cell trays with 2 plants per cell, respectively (Table 11). However, once the savings in transplanting costs of plugs compared to bare roots are factored in, the net profit should shift even more in favor of growing onions from plug transplants.

Conclusions: Growing onions from plug transplants is an economically viable alternative to using imported bare root onion transplants. In addition, onions grown from plugs result in better storage quality, because the transplants are not contaminated with *B. allii*, and, there is opportunity to support the local economy by buying locally grown plug transplants. When jumbo bulb size is important, which is the case for red onions, it is recommended to use plugs grown in 288 cell trays with 2 plants per cell, as opposed to 3. Onions grown from plug transplants in 512 cell trays with 2 plants per cell are not feasible for production of red onions. However, it is worthwhile to further investigate this transplant configuration for yellow onions that are marketed as medium sized bulbs. In addition, a new automated mechanical plug transplanter is now available that requires only one laborer to operate, which would greatly alleviate a grower's reliance on manual labor in the near future, resulting in significant reductions in the cost and frustrations associated with using manual labor. The next step is to demonstrate this new technology to onion growers so that they can be confident that this new system would be capable of producing an onion crop comparable to one grown from bare roots.

Citations

Hoepting, C.A., K.E. Panek and J.W. Lorbeer. 2006. Detection and management of latent *Botrytis allii* in onion transplant seedlings in New York. *In* Proceedings of the 2006 National Allium Research Conference, pp. 50-62. College Station, Texas, USA. December 7-8, 2006.

Schwartz, H. F., D. H. Gent, S. Fichtner, R. W. Hammon, and R. Khosla. 2004. Integrated management of *Iris yellow spot virus* in onion. *In* Proceedings of the 2004 National Allium Research Conference, pp. 207-212. Grand Junction, CO. Colorado State University, Fort Collins.

Table 1. Comparison of bare root and plug transplanted onions: production and planting details.

Treatment	# Cells Per Tray	# Plants Per Cell	Plant Spacing	# Plants Per Hole	Desired Plant Population (plants/acre)	Transplanting Technique
2006: red – cv. Red Zepelen; yellow – cv. Ricochet						
Red Bare root	na	na	4"	1	104,544	By hand into pre-poked holes
Red Plug 288-3	288	3	8"	3	156,816	4-row mechanical transplanter
Yellow Bare roots	na	na	3"	1	139,392	8-row mechanical transplanter
Yellow Plugs 288-3	288	3	8"	3	156,816	4-row mechanical transplanter
2008: all red, cv. Red Zepelen						
Bare root	na	na	4"	1	104,544	8-row mechanical transplanter
Plug 288-3	288	3	8"	3	156,816	"
Plug 288-2	288	2	8"	2	104,544	"
Plug 512-2	512	2	8"	2	104,544	"

Table 2. Return on seed, 2008: percentage of the total seed sent to the transplant producer that is returned to the grower as transplant seedlings. Red, cv. Red Zepelen.

	% return on seed	% plug cells with accurate # of seed	% of cells not planted correctly (# of plants)						
			1	2	3	4	5	6	0
Bare root	~80	na	na	na	na	na	na	na	na
Plug 288-3	86	55.4 b	6.7	31.3	acc[1]	5.6	0.2	0.0	7.1
Plug 288-2	86	53.3 b	29.2	acc[1]	6.3	1.9	1.0	1.0	6.8
Plug 512-2	91	71.3 a	15.6	acc[1]	7.5	0.4	0.0	0.0	0.5

[1]acc: accurate number of holes per cell, see "% plug cells with accurate # of seed" column.

Table 3. Comparison of bare root and plug transplanted onions, 2006 & 2008: stand establishment.

	actual plant population (plants/A)	% of target stand	% of holes planted accurately	% of holes not planted correctly (# of plants)						
				1	2	3	4	5	6	0
2006 (average of 19-May, 16-Jun & 20-Jul) – red cv. Red Zepelen:										
Bare root	96,912	92.7	79.3	acc[1]	5.7	--	--	--	--	7.0
Plug 288-3	128,275	81.8	45.2	3.2	14.7	acc[1]	--	--	--	4.4
2006 (average of 19-May, 16-Jun & 20-Jul) – yellow cv. Ricochet:										
Bare root	124,058	89.0	89.0	acc[1]	5.0	--	--	--	--	7.0
Plug 288-3	126,080	80.4	44.7	5.6	37.9	acc[1]	--	--	--	3.1
2008 (1-Aug) – red cv. Red Zepelen:										
Bare root	116,671	111	72	acc[1]	15.6	2.8	--	--	--	4.0
Plug 288-3	127,326	81	44	11.2	33.6	acc[1]	5.1	1.6	0.8	3.4
Plug 288-2	88,026	84.2	48.3	37.6	acc[1]	8.2	2.4	--	--	3.3
Plug 512-2	98,846	94.5	55.7	14	acc[1]	14.7	4.9	--	--	9.2

[1]acc: accurate number of holes per cell, see "% of holes planted accurately" column.

Table 4. Comparison of bare root and plug transplanted onions, 2006 & 2008: plant size.

	Number of leaves per plant (# weeks post transplanting)			Plant height of tallest leaf (cm) (# weeks post transplanting)		
2006	**2 week (19-May)**	**6 week (16-Jul)**	**11 week (11-Aug)**	**2 week (19-May)**	**6 week (16-Jul)**	**11 week (11-Aug)**
Red cv. Red Zepelen:						
Bare root	1.8	7.6 b	11.0	5.5	21.6 b	33.3 b
Plug 288-3	1.8	6.0 a	11.0	5.1	17.7 a	31.5 a
Yellow cv. Richochet:						
Bare root	1.4 b	7.7 b	9.4 b	11.5	54	74
Plug 288-3	1.7 a	6.0 a	7.9 a	12	45	73
2008	**2 week (22-May)**	**5 week (11-Jun)**	**12 week (16-Jul)**	**2 week (22-May)**	**5 week (11-Jun)**	**12 week (16-Jul)**
Bare root	1.8 a	6.5 a	9.6 a	13 d	41 b	75 a
Plug 288-3	1.4 c	5.0 c	8.6 c	19 b	42 b	74 a
Plug 288-2	1.6 b	5.5 b	9.2 b	21 a	47 a	74 a
Plug 512-2	1.4 c	4.6 d	8.5 c	17 c	37 c	71 b

Table 5. Comparison of bare root and plug transplanted onions, 2006 & 2008: pest pressure.

	Botrytis Leaf Blight (# lesions per plant)		Purple Blotch (# of lesions per plant)		Onion Thrips (# OT per plant)			
	16-Jun 2006	16-Jul 2008	20-Jul 2006	11-Aug 2006	16-Jun 2006	11-Aug 2006[1]	13-Jun 2008	16-Jul 2008
2006 Red cv. Red Zepelen:								
Bare root	1.8 b[2]		1.2	7.7 b	0.1 b	=		
Plug 288-3	2.3 a		0.8	4.6 a	0.3 a	=		
2006 Yellow cv. Richochet:								
Bare root	0.4		0.0	3.0	0.3 b	<		
Plug 288-3	0.1		0.0	2.2	0.9 a	>		
2008 Red cv. Red Zepelen:								
Bare root		3.4					1.4 c	5.4 c
Plug 288-3		2.7					7.7 a	18.9 b
Plug 288-2		1.9					10.7 a	21.3 a
Plug 512-2		2.8					5.7 b	21.3 ab

[1]Thrips observations: in the red variety, there were no observable differences between bare roots and plugs; in the yellow variety, thrips were less in the bare roots than in the bare roots. [2]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, $p > 0.05$.

Table 6. Comparison of bare root and plug transplanted onions, 2006 & 2008: harvest yield and bulbs size.

	Total yield (cwt/A)	% market-able	Size class distribution (cwt/A)				Cull type (% of culls)		
			Small (1.75-2")	Med (2-3")	Jumbo (3-4")	culls	rot	Under size	dble bulbs
2006 Red cv. Red Zepelen (Aug 30):									
Bare root	585	97.2	8 b[1]	96 b	472 b	8	--	--	--
Plug 288-3	504	94.8	22 a	233 a	239 a	11	--	--	--
2006 Yellow cv. Richochet (Aug 17):									
Bare root	500	94.5	9	116	384	6.5	--	--	--
Plug 288-3	457	92.7	18	222	201	12	--	--	--
2008 Red cv. Red Zepelen (Aug 26):									
Bare root	340	88.4	25 b	244	32 a	39	27.8	43.0	30.6
Plug 288-3	387	93.4	88 a	259	12 bc	26	11.7	70.9	17.4
Plug 288-2	343	92.2	59 ab	234	23 ab	27	26.7	47.2	34.4
Plug 512-2	307	95.6	87 a	197	0 c	23	11.4	83.2	5.4

[1]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, $p > 0.05$.

Table 7. Comparison of plug and bare root transplanted onions, 2006 & 2008: Incidence of latent *Botrytis allii* in transplanted seedlings prior to transplanting and incidence of Botrytis neck rot and bacterial diseases after 3.5 months in storage.

Variety and Transplant Type	*Incidence of latent B. allii prior to transplanting (average %)*		*Incidence of bulb rot in storage (% of bulbs)*	
	B. allii per sample	Samples with *B.allii*	Botrytis neck rot	Bacterial rot
2006 Red cv. Red Zepelen:				
Bareroot	3.8	60	6.6	0.9
Plug 288-3	0.0	0	1.6	1.2
2006 Yellow cv. Richochet:				
Bareroot	3.9	73	11.7	4.5
Plug 288-3	0.0	0	3.5	5.1
2008 Red cv. Red Zepelen:				
Bare root	0.0	0	in storage	in storage
Plug 288-3	0.0	0	in storage	in storage
Plug 288-2	0.0	0	in storage	in storage
Plug 512-2	0.0	0	in storage	in storage

[1]Price per cwt are seasonal 2006-2007 averages provided by the grower cooperator. [2]Cost to produce is taken from table 8. All other inputs (i.e. fertilizer, in-season pesticides, etc. were the same for both plug and bare root transplants and not included in this cost of production. [3]Early yellow varieties grown from transplants are generally sold out of the field and not stored. [4]Loss out of storage = NET x (%bacterial rot + % neck rot) from Table 7.

Table 8. Comparison of plug and bare root transplanted onions, 2006: economic analysis of transplant production and planting.

Variety	**Ricochet**		**Red Zepelen**		Comments
Transplant Type	Plug 288-3	bare root	Plug 288-3	bare root	
Cost of transplants:					
Per acre…….	$782.61	**$194.66**	$782.61	**$193.72**	
Shipping……	Na	$78.16	Na	$67.27	
Rate of return……	~80%	~80%	~80%	80%	
Cost of transplanting:					- Labor rate includes crew boss when mechanical transplanter is used. - Transplanting by hand is piece work.
Time to plant 1 acre…..	6 h, 42 min	**5 h, 48 min**	6 h, 42 min	**6 h**	
Cost of labor…….	$8.53/h	$8.53/h	$8.53/h	$0.015 /row ft	
Total cost per acre……	**$389.74**	$593.69	**$389.74**	$552.72	
TOTAL COST[1]:					
Per acre……	**$1498.72**	**$1190.23**	**$1556.63**	**$1123.06**	

[1]differences in cost of seed and pesticides included in final figures, but not presented in the table.

Table 9. Comparison of plug and bare root transplanted onions, 2006: economic analysis of net profit.

Variety	**Ricochet**		**Red Zepelen**	
Transplant Type	plug	bare root	Plug	bare root
Yield and price per size class (per acre):				
Small:				
Price per cwt[1]	$13.50	$13.50	$14.00	$14.00
Cwt	18	9	22	8
Total small	*$243*	*$121.50*	*$308*	*$112*
Medium:				
Price per cwt	$17.25	$17.25	$19.00	$19.00
Cwt	222	116	233	96
Total medium	*$3829.50*	*$2001*	*$4427*	*$1824*
Jumbo + Col:				
Price per cwt	$19.40	$19.40	$25.00	$25.00
Cwt	201	384	239	472
Total jumbo	*$3899.40*	*$7449.60*	*$5975*	*$11,800*
TOTAL	**$7971.90**	**$9572.10**	**$10,710**	**$13,736**
Cost to produce[2]	-$1498.72	-$1190.23	-$1556.63	-$1123.06
Loss out of storage[4]	na[3]	na[3]	-$920.91 (8.6%)	-$2224.91 (16.2%)
NET:				
Per acre	**$6473.18**	**$8381.87**	**$8232.46**	**$10,388.03**

Table 10. Comparison of bare root and plug transplanted onions, 2008: estimated cost of transplant production.

	Plant population (per acre)	**Cost of seed[1] (per acre)**	**# Plants per tray**	**# Trays needed (per acre)**	**Cost of transplant production[2]**	**TOTAL**
Bare root	104,544	$236	--	--	$194 + $110 shipping	**$540**
Plug 288-3	156,816	$358	864	182	$783 $0 shipping	**$1141**
Plug 288-2	104,544	$236	576	182	$783 $0 shipping	**$1019**
Plug 512-2	104,544	$236	1024	102	$438 $0 shipping	**$674**

[1]estimated, based on 2006 prices provided by grower, ⅓ more seeds are needed for 288-3 treatment.
[2]estimated, based on prices provided by grower in 2006, cost of shipping was increased by 41% based on actual national average diesel prices.

Table 11. Comparison of bare root and plug transplanted onions: estimated net profit, 2008.

Red cv. Red Zepelen:	**Bare root**	**Plug 288-3**	**Plug 288-2**	**Plug 512-2**
Yield and price per size class (per acre):				
Small:				
Price per cwt[1]	$14	$14	$14	$14
Cwt	25	88	59	87
Total small	*$350*	*$1232*	*$826*	*$1218*
Medium:				
Price per cwt	$19	$19	$19	$19
Cwt	244	259	234	197
Total medium	*$4636*	*$4921*	*$4446*	*$3743*
Jumbo:				
Price per cwt	$25	$25	$25	$25
Cwt	32	12	23	0
Total jumbo	*$800*	*$300*	*$575*	*$0*
TOTAL	**$5786**	**$6453**	**$5847**	**$4961**
Cost to produce[2]	-$540	-$1141	-$1019	-$674
Loss out of storage[3]	TBA	TBA	TBA	TBA
NET (not including cost of transplanting or loss out of storage):				
Per acre	**$5246**	**$5312**	**$4828**	**$4287**

[1]Price per cwt are seasonal 2006-2007 averages provided by the grower cooperator. They are used again to estimate net profit in 2008, since prices appear to be similar. [2]Cost to produce is taken from table 10. All other inputs (i.e. fertilizer, in-season pesticides, etc. were the same for both plug and bare root transplants and not included in this cost of production. Cost of transplanted has not been calculated and is not included. [3]Loss out of storage will be evaluated in January 2009, and has not been factored in at this time.

CULTIVAR EVALUATION FOR HOOP HOUSE GROWN ONIONS

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Introduction

Onions are produced in Oklahoma by market gardeners and farmer's market growers for fresh-use markets. Growers currently use a combination of short day and intermediate day cultivars. This practice extends the time period over which transplanting and harvesting can be accomplished. The intermediate cultivars available to growers have been limited in number. Newly available intermediate cultivars may offer additional features compared to those currently used. Desirable characteristics that would be beneficial include delayed maturity, greater size uniformity, and improved handling characteristics. The objective of this study was to evaluate and compare onion cultivars for yield, bulb size distribution, and bolting potential using onion transplants locally produced in a hoop house production system (Shrefler et al. 2006).

Materials and Methods

Onions were seeded Nov. 4, 2007 on 4 inch high beds on the floor of hoop houses located at the Wes Watkins Agricultural Research and Extension Center at Lane, Oklahoma. The houses measure approximately 20 feet wide and 40 feet long. On each bed, rows were spaced 5 inches apart and seeds were sown at a density that resulted in plant stands of 20 to 40 plants per foot of row. Soil was irrigated as needed to obtain seedling establishment. No subsequent water was applied after November. Weeds were removed by hoeing and hand weeding. Twelve cultivars were used in the trial as shown in Table 1. Each cultivar was planted in a sub-plot in each of four beds. On March 25 plants were dug and replanted outdoors. These plants were used to establish 4 replications of field plantings. The field planting used raised beds that were 4 feet wide and on 6 foot centers. Plots consisted of 2 rows of onions of the same cultivar with 30 plants per row. Within a bed, rows were spaced 24 inches apart and plants were spaced 6 inches apart within the row. Following transplanting, Prowl 3.3EC and Goal 2XL herbicides were applied at 1 pint each per acre as a tank mix. During field preparation fertilizer was applied and incorporated based on Oklahoma State University soil testing results and recommendations. Nitrogen was applied using 46-0-0 as a side-dress on April 21 and May 9 at 46 lbs. of N per acre at each application. Rainfall provided adequate soil moisture during the period from transplanting until late May. Drip irrigation was used during June.

Data collection included enumeration of seed-stalk formation, bulb diameter and bulb weight. Plant bolting percentage was determined on May 30. Onion cultivars were harvested in early July once appreciable top break over of the tops was observed. Following

harvest, onion bulbs were sorted by diameter. Onions of size categories <2 inches, 2-3 inches, 3-4 inches and >4 inches were counted and weighed. Total and marketable onion bulb yields were calculated and bulb size distribution was assessed. Data were analyzed using SAS ANOVA procedures.

Results and Discussion

Total and marketable onion yields are shown in Table 1. Total yields ranged from 78 to 180 hundredweight units per acre. Five cultivars within the top yielding group did not differ statistically from Sequoia, which had the largest mean. Marketable yield excludes onions having bulb diameters below 2 inches. For marketable yield there was a larger group that did not differ from the top yielding cultivar. A total of 8 cultivars were in this group. All cultivars produced some marketable yield.

Onion bulb size distribution is shown in Table 2. Onion bulbs larger than 4 inches in diameter were found only for the cultivar Chief, with 2% of bulbs being 4 inches or greater. In the bulb diameter categories <2 inches and 2-3 inches, there were no statistical differences among cultivars. In the 3-4 inch category, all cultivars except Red Bull had at least some bulbs in the category. Sequoia had 50% of bulbs in the 3-4 inch category. Five additional cultivars fell within a group that did not differ from Sequoia in percentage of 3-4 inch bulbs. Outside of this group, no cultivar had more than an average of 16% of bulbs within the 3-4 inch bulb category.

Seed-stalk formation became evident on May 2 and was quantified on May 30. The percentage of bolted plants ranged from 0 to 18%. Cultivars with bolting over 5% included Cimarron, Rumba, Renegade and Sequoia. Bolting was also influenced by position in the field as one replication had no bolting. This suggests that variation in management practices, such as side-dress fertilizer application, may have had an influence on bolting. This was the greatest incidence of bolting observed for onions produced from hoop house grown transplants over 5 years of trials in Oklahoma with this plant production technique (Shrefler et al. 2007).

This study shows that several of these cultivars may be useful for producers interested in using the hoop house transplant production system for onion production in Oklahoma. The group of cultivars that includes Sequoia, Renegade, Denali, Cimarron, Chief and White Wing each produced at least 25% of bulbs with a 3 inch diameter or greater. Of this group, all cultivars are yellow with the exception of White Wing which is white. Three of these were also in the group producing greater than 5% seed-stalk formation. However, because this was the greatest incidence of seed-stalk formation observed over 5 years of trials, it does not appear that greater levels of seed-stalk formation are to be expected.

Citations

Shrefler, J, C. Webber, T. Goodson, W. Roberts and S. Upson. 2006. Hoop house production of onion transplants. 2006 Nat. Allium Res. Conf. College Station.

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Table 1. Onion yields in the onion cultivar trial.

Cultivar	Yield			
	Total		Marketable[a]	
	- - - - - - 100 lbs. units acre^{-1} - - - - - -			
Sequoia	182	a[b]	166	a
Renegade	165	ab	157	a
Denali	165	ab	160	a
Cimarron	174	a	159	a
Chief	152	abc	147	ab
White Wing	128	bcd	115	abc
Desperado	118	cde	114	abc
1015Y	128	bcd	106	abc
Virgin	118	cde	93	b
Cowboy	111	bcd	95	b
Rumba	94	de	69	c
Red Bull	78	e	60	c

[a] Marketable yield includes onions having a bulb diameter of 3 inches or greater.
[b] Means within a column followed by a common letter are not different based on Duncan's multiple range test with alpha=0.05.

Table 2. Size distribution of onion bulb diameters in the onion cultivar trial.

Cultivar	Bulb size category (inches)				
	<2	2-3	3-4		>4
	- - - - - - percent of bulbs - - - - - -				
Sequoia	12	37	50	a[a]	0
Renegade	15	41	44	ab	0
Denali	9	49	42	ab	0
Cimarron	12	47	41	abc	0
Chief	9	52	36	abcd	2
White Wing	24	51	25	abcde	0
Desperado	10	74	16	bcde	0
1015Y	26	57	16	bcde	0
Virgin	34	55	11	cde	0
Cowboy	19	71	10	de	0
Rumba	35	61	4	e	0
Red Bull	39	61	0	e	0
	ns[b]	ns			ns

[a] Means within a column followed by a common letter are not different based on Duncan's multiple range test with alpha=0.05.
[b] An "ns" indicates no statistical differences among the cultivars at the 0.05 alpha level.

DETECTION OF *PANTOEA ANANATIS* IN NEW YORK GROWN ONIONS AND DEVELOPMENT OF PATHOGENICITY TESTS FOR *P. ANANATIS* ON ONION

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Abstract

The center rot disease of onion caused by *Pantoea ananatis* has been reported to occur in the USA in Georgia, Colorado, and Michigan. *P. ananatis* also has been reported as a pathogen on other crops in Asia and Australia. Center rot is characterized by necrosis and blighting of green leaves and non-macerating discoloration of the scales of onion bulbs. The latter symptoms render the bulbs unsaleable. We have observed similar symptoms on onion bulbs grown in New York beginning in 2006. From symptomatic bulbs, we isolated bacteria that were identified as *P. ananatis* based on microbiological and molecular properties in comparison with pathogenic strains of *P. ananatis* that had been isolated in Georgia. When several of the isolated strains were introduced into onion bulbs and sets via hypodermic needle and syringe, symptoms reminiscent of center rot developed following 4 to 8 days of incubation at 28°C. Sub-epidermal inoculation on leaves of growing onion plants with suspensions of pathogenic strains of *P. ananatis* resulted in the development of elliptical lesions that expanded both distally and proximally from the point of inoculation. Some lesions reached the neck and infection extended through the neck into the bulb where specific scales became discolored, but not macerated. Bacteria were recovered from the leading edge of all lesions induced by inoculation. Recovered bacteria proved to have characteristics of the pathogen. Thus, Koch's postulates were completed for *P. ananatis* that induced both onion leaf and bulb symptoms.

Introduction

Center rot of onion caused by the bacterium *Pantoea ananatis* initially was described as a new disease in Georgia (USA) in 1997 (3). Subsequently, the disease was reported to occur in Colorado and Michigan (2). *P. ananatis* also has been described as a pathogen on other plants in Hawaii as well as globally in Asia and Australia (2). *P. ananatis* recently was reported to occur on the seed of onions grown in South Africa (8). The appearance of symptoms, reminiscent of those previously reported for center rot, in onions from the 2006 onion crop in New York prompted our investigation of the disease and its pathogen and the nature of its infection of onion plants and bulbs.

In Georgia, typical field symptoms of center rot are initially small water-soaked lesions (bleached white in color) that develop into white streaks extending the length of the leaf. These lesions may darken to light brown, become gray, or remain white. Typically at first only one or two of the young center leaves develop the leaf streak symptoms that develop into blighting (wilting and bleaching) of the leaves (4). In Georgia, all the leaves of

severly infected plants become wilted and bleached. Leaf infection by *P. ananatis* usually is followed by infection of the neck tissues of the onion and then the bulb scales, resulting in non macerated light yellow-brown discoloration on one or more of the infected bulb scales. Frequently other microbes (including bacteria) functioning as secondaries invade the onion bulb tissues infected by *P. ananatis*. This results in necrosis (maceration) of one or more of the bulb scales and decay (liquification of the tissue and a foul odor) of the onion bulb (4).

In New York, we have detected *P. ananatis* in the onion bulbs of plants grown in the 2006, 2007, and 2008 growing seasons. If secondary infection by other microbes does not occur, onion bulbs infected solely by *P. ananatis* remain firm, do not decay, and are difficult to detect on grading lines. This can result in infected onions being packed and shipped to market where they are detected by inspectors who slice the tops off of a number of onions. If sufficient infection is detected, the entire load of onions can be rejected. This represents a huge economic loss to the grower. In New York, *Burkholderia cepacia* that causes bacterial canker and sour skin of onion is a common inhabitant in organic soils cropped to onion (12). *B. cepacia* has caused losses as great as 20% or more in harvested onions, and we have observed that sour skin symptoms usually mask the occurrence of other bacterial and microbe infections including those by *P. ananatis*. This situation frequently has precluded detection of *P. ananatis* in onions grown in New York.

P. ananatis has been reported as a seed borne pathogen of onion in Georgia (7, 15) as well as occurring on onion seed produced in South Africa (8). The pathogen has been transmitted by tobacco thrips (*Frankliniella fusca*) in Georgia from a number of weed species where it is believed to be a resident epiphytic colonizer (5, 16). Recently it has been reported that *Pantoea agglomerans* (syn. *Erwinia herbicola*) which can be associated with tobacco thrips (16) causes a leaf blight and bulb rot of onions in Georgia (1). *E. herbicola* (syn. *P. agglomerans*) previously had been reported as a pathogen in onion seed production in Cuba (13), the cause of a stalk and leaf necrosis of onion in South Africa (10), the cause of a bacterial leaf blight and bulb rot of onion in Peru (6), and as a pathogen of garlic in Israel (11). *P. agglomerans* was not a subject of our present study but its close association with *P. ananatis* on onion in Georgia warrants a future investigation of its possible association with onions in New York.

Material and Methods

Isolation of Pantoea ananatis.

Onion bulbs from plants grown during 2006-08 in New York suspected of infection by *P. ananatis* were collected from several farms for bacterial isolation. Most samples came from farm storages in which harvested bulbs had been stored for several months. Bulbs were transported to the laboratory and if isolation attempts were delayed, the bulbs were stored at 4°C. Each bulb was bisected longitudinally to observe disease symptoms. Digital pictures were taken to document symptoms (Figure 1). Bacterial isolations were made from any bulb that exhibited center rot symptoms, as previously described (2, 3, 4). Each bulb-half was quartered with a sterile blade and healthy inner scales were removed with forceps to expose the symptomatic scale(s). A sterile blade was used to macerate small amounts of tissue from symptomatic scale(s). The macerated tissue was streaked onto nutrient agar (14) and PA 20 (9) which is a semi-selective growth medium for *P. ananatis*. Pure cultures of bacteria were stored for further testing in 1.5 ml sterile plastic tubes containing 1.0 ml of 15% glycerol at -80°C.

Pathogenic strains of *P. ananatis* (97-1, PNA07-1, PNA07-2, 6313, 6314, and 6366) were obtained from R. D. Gitiatis and R. R. Walcott and used as references in comparison to those isolated from onions grown in New York. OC5a was our first isolate and has been used as the New York reference strain of *P. ananatis*.

Identification of Pantoea ananatis

Media. Bacteria were grown on nutrient agar (NA), a non-selective medium used for supporting the growth of many different bacteria, and PA 20, a semi-selective medium for the growth of *P. ananatis* (9). Bacterial isolations from symptomatic bulbs were made on both media and transfers of bacteria were made between the media. Development of the characteristic colony morphology of *P. ananatis* required a minimum of 24 hours and 4 days growth on NA and PA 20, respectively, at 28°C.

The comparative plating efficiency of PA 20 with NA was determined with two strains of *P. ananatis,* Georgia strain 97-1 and New York strain OC5a. Each strain was streaked on NA from -80ºC stock cultures and incubated at 26ºC for 24 hours. Bacterial suspensions were made (OD_{600} = 0.20) and serial dilutions were prepared (10^{-1} to 10^{-6}). Six replicates of 0.5 µl aliquots of each dilution was plated on each of the two media. The plates of NA were incubated at 28°C for 24 hours, while PA 20 plates were incubated for 4-6 days. After incubation, the colony forming units (CFU) on each plate were enumerated.

PCR. Colony polymerase chain reaction (PCR) was used to identify and compare strains of *P. ananatis*. The primer pair used was suggested by R. D. Gitiatis based on his research with strain 97-1 as well as other strains of *P. ananatis*. The forward primer was Panits1 (5'-GTC TGA TAG AAA GAT AAA GAC-3') and the reverse primer was 2As2b (5'-TTC ATA TCA CCT TAC CGG CGC-3').

Bacterial strains from -80ºC stock cultures were streaked on NA and incubated at 26°C for 24 hours. Bacterial templates were prepared by removing one colony from the culture plates with a sterile toothpick and transferred to sterile 1.5 ml tubes containing 1.0 ml sterile water and vortexed. Each 25.0 µl PCR reaction mixture contained 12.5 µl GoTaq® Green Master Mix (Promega, Madison, WI), 0.5 µl from each primer, 7.5 µl high purity autoclaved water, and 4.0 µl of bacterial suspension. Amplification was carried out in a Hybaid Touchdown programmable DNA thermal cycler (Ashford, Middlesex, UK). An initial denaturation period of 5 minutes at 95°C was used. The annealing phases were 1 minute at 50°C and the elongation phases were for 1.5 minutes at 72°C. PCR was completed by incubating the tubes for 40 cycles at the following temperatures and times: 94°C for 1 minute, 50°C for 1 minute, 72°C for 1.5 minutes. An additional annealing phase was conducted for 10 minutes at 72°C and the samples then were stored at 4°C. Amplification of PCR products were detected by gel electrophoresis (80 V for 60 minutes) through a 1.0% agarose gel stained with SyBr Safe (Invitrogen, Carlsbad, CA, USA) in a 1X TAE buffer.

Biolog® Identification System. Different bacteria from the Cornell University (CU) culture collection and those isolated from New York onion bulbs, including *P. ananatis*, were tested for metabolic activity with respect to 95 growth factors in comparison with the metabolic activity of the Georgia reference strain 97-1. Bacteria were streaked from -80°C stock cultures onto Biolog®'s (Hayward, CA, USA) BUG agar (with blood) and incubated at 30°C for 24 hours. A cotton swab was used to extract bacterial colonies from the agar plate and swirled in 20.0 ml of 0.4% NaCl solution. Sufficient bacteria were added to create a transmittance of 61% (+/- 2%). The suspension was mixed vigorously and an aliquot of

150.0 µl was transferred into each of the 96 wells of the GN Biolog® Identification Plate. Biolog® plates were incubated at 30°C for 24 hours and then read with the Biolog® Plate Reader.

Pathogenesis of Pantoea ananatis

Inoculation of Onion Slices. Onion bulbs judged to be free from infections were used to prepare three onion slices 4-6 mm thick cut from near the center of the bulb. The outer two or three rings of scales were discarded. Each slice was placed in a sterile Petri dish containing a sterile Whatman #2 filter paper attached to the inside of the lid. Stock cultures of *P. ananatis* from -80°C storage were streaked onto NA and incubated at 26°C for 24 hours. A sterile cotton swab was used to transfer bacteria from the NA plate to a sterile glass tube containing 10.0 ml of autoclaved water to achieve OD_{600} = 0.20. A trench was cut into all three slices with a sterile toothpick. Fifty microliters of inoculum was transferred to the end of the trench on two slices. Another sterile toothpick was used to drag the inoculum through the trench. The third slice received no inoculum and was used to determine if the bulb was infected prior to incubation. Sterile water was tested concurrently as a negative control. For all Petri dishes, 1.0 ml of sterile water was transferred to the filter paper attached to the lid. All dishes were kept in a plastic bag sealed with a wire-tie. The dishes were incubated at 28°C for 24 hours and then removed for examination. Attempts were made to re-isolate inoculated bacteria from infected slices by rubbing a microbiological loop against symptomatic tissue and then streaking onto PA 20.

Inoculation of Onion Bulbs and Sets. All identified *P. ananatis* strains were inoculated into onion bulbs and sets in an attempt to induce symptoms similar to those associated with center rot. Stock cultures from -80°C storage were streaked onto NA and incubated at 26°C for 24 hours. A sterile cotton swab was used to transfer bacteria from the NA plate to a sterile glass tube containing 10.0 ml of sterile water to achieve OD_{600} = 0.20.

Onion bulbs of a yellow globe variety grown in Orange County, NY and five onion set varieties (Forum, Nube, Red Bull, Sherman, and Talon) kindly provided by Bejo Seeds (The Netherlands) were inoculated with different strains of *P. ananatis*. Onion sets were surface disinfested prior to inoculation by submerging them in 70% (v/v) ethanol for 1 second and then drying them on sterile filter paper for 30 minutes. Onion bulbs were surface disinfested prior to inoculation by submerging them in 0.6% sodium hypochlorite solution for 1 second and then drying them on sterile filter paper for 30 minutes. Stock cultures of *P. ananatis* from -80°C storage were streaked onto NA and incubated at 26°C for 24 hours. A sterile cotton swab was used to transfer bacteria from the NA plate to a sterile glass tube containing 10.0 ml of autoclaved water to achieve OD_{600} = 0.20. Sterile 26 gauge, 0.5 inch hypodermic needles were used to inject 40-50 µl of bacterial suspension into the midsection of onion bulbs and sets (Figure 2). Sterile water controls were tested concurrently.

The inoculum dilution endpoint for inoculation of onion sets also was determined for both OC5a and 97-1. Suspensions of OD_{600} = 0.20 were prepared, diluted 10^{-1}-10^{-4}, and then injected into bulbs and sets as previously stated. Bulbs and sets were incubated at 28°C for 6-7 days. Inoculated material was removed from incubation and dissected for symptom observation. Bulbs and sets that exhibited symptoms were digitally photographed. Attempts were made to re-isolate bacteria from infected bulbs and sets using the procedure for isolation as previously described.

Inoculation of Onion Leaves. Leaves of growing onions plants were inoculated with *P. ananatis* and observed for subsequent symptom development. Forum and Talon onion set varieties were planted in CU potting media with the tops positioned ca. 3 cm below the soil surface in 15 cm diameter round pots. Onion plants were grown from sets in the greenhouse for at least two months or until they had developed at least six leaves prior to inoculation. Plants received water every other day, were fertilized weekly, and received pesticide application for insect control biweekly while growing under greenhouse conditions. Inoculum was prepared in the same manner as for bulb and set inoculations. A 26 gauge, 0.5" hypodermic needle was used to inject 20-40 µl of bacterial suspension into the sub-epidermal layer of two adjacent, young to middle-aged onion leaves, ca. 3 cm from the top of the neck (Figure 3). Sixteen replicate onion plants were tested. Sterile water controls were tested against all inoculated material. Resulting lesions were measured every 2 or 3 days for 16 days. Digital photographs were made to document lesion progression. Seed stalks of mature onions (variety Candy) were inoculated similarly on the middle of the stalk. The inoculum dilution endpoint for leaf inoculation also was determined for strains OC5a and 97-1. Suspensions of OD_{600} = 0.20 were prepared and then diluted 10^{-1}-10^{-4} and inoculations were conducted as previously described.

Inoculation of Onion Leaves Leading to Bulb Infection. Healthy leaves from onion plants (variety Talon) were inoculated in order to produce infection into bulb tissue. Twentyfive Talon seeds and 15 Talon sets were planted on March 15, 2008 in CU potting media and grown under the greenhouse conditions as described previously for 15 weeks prior to inoculation. A 26 gauge, 0.5 inch hypodermic needle was used to inject 20-40 µl of OC5a inoculum (OD_{600} = 0.25) into the sub-epidermal layer of two adjacent, middle-aged onion leaves ca. 3 cm from the top of the neck. Twenty-two replicate onion plants grown from seed and 12 replicate onion plants grown from sets were inoculated with OC5a. Three replicate water controls were tested concurrently for each plant type. All plants were incubated in the greenhouse for up to six weeks. A total of nine set-grown set inoculated plants and 13 seed-grown inoculated plates were removed from the greenhouse and dissected in the laboratory for disease observations during a period of 2, 3, and 5 weeks after inoculation. The rest of the inoculated plants are in 4ºC storage and will be dissected at a later time. Attempts were made to re-isolate bacteria from bulbs that exhibited center rot symptoms using the procedures for isolation described previously. The isolated colonies were identified using PCR.

Results

Isolation of Pantoea ananatis. Bacterial isolations were made from suspect onion bulbs grown in New York during 2006-08. Twelve pathogenic strains of *P. ananatis* were isolated from these onions (Table 1). OC5a was isolated in 2007 from an onion grown during 2006. Strains OC39a, OC53, OC75, OC81, OC85 and OC86 were isolated in 2008 from onions grown during 2007. Strains OC105, OC110, OC113, OC132, and OC134 were isolated in 2008 from onions grown during 2008. All strains were isolated from yellow variety onion bulbs grown in Orange County, New York. All of the strains were pathogenic on onions and reacted indistinguishably from each other.

R. D. Gitiatis and R. R. Walcott donated a total of six strains of *P. ananatis* to be used as references during our experimentation (Table 1). All strains, with the exception of

Walcott's 6366 *P. ananatis*, were pathogenic on onion plants. Strain 97-1 has been the positive control strain used by Gitiatis. OC5a tested indistinguishably from 97-1 in all pathogenicity tests that we conducted.

Identification of Pantoea ananatis

Media. Semi-selective PA 20 and non-selective NA media were the two primary media used when culturing for and isolating *P. ananatis*. PA 20 had an 87.5% growth efficiency compared to NA after examining the growth of *P. ananatis* in both media (Figure 4). Extensive bacterial isolations from onion bulbs on PA 20 have shown that at least four morphologically different bacteria were able to grow on PA 20. The growth characteristics of pathogenic strains of *P. ananatis* on PA 20 are a raised colony, cloudy yellow-white, smooth and irregular margin, and often with a darker middle.

PCR. PCR was used to molecularly identify and confirm the identity of bacteria believed to be *P. ananatis* that grew on PA 20. This reaction amplified a gene sequence specific to *P. ananatis* (ca. 350 base pairs). Results indicated that, although at least four morphologically different bacteria grew on PA 20, only one was amplified during PCR with the selective primers utilized in our study. Bacteria that were able to grow on PA 20 and tested positive in all pathogenicity tests resulted in amplification during PCR. On the other hand, amplified reactions using bacterial strains with characteristic *P. ananatis* colony morphology did not always result in the identification of pathogenic strains of *P. ananatis* following a pathogenicity test, which suggests these were non-pathogenic strains of the bacterium. PCR was used to identify 12 New York strains of pathogenic *P. ananatis* (Table 1).

Biolog® Identification System. The Biolog® database does not include *P. ananatis*, however, there was still value in testing the bacterium in this software. Bacteria from the CU culture collection were tested using Biolog® in order to determine the accuracy of the identification. All bacteria tested were successfully identified using Biolog®. Once the Biolog® software was running effectively, OC5a and 97-1 were tested. The result was that OC5a had visually the same "metabolic fingerprint" as strain 97-1 when compared in the Biolog® Identification software.

Pathogenesis of Pantoea ananatis

Inoculation of Onion Slices. When OC5a and 97-1 inoculum was applied to onion slices and incubated for 24 hours, symptoms showed yellow discoloration and water-soaked tissue near the area of inoculation. Infected tissue was not macerated and a foul odor was not present. Water control slices did not display any sign of infection. PCR and PA 20 growth results confirmed that inoculated bacteria were successfully re-isolated from infected slices.

Inoculation of Onion Bulbs and Sets. P. ananatis strains OC5a and 97-1 reacted indistinguishably when 40-50 µl of inoculum was injected into onion bulbs and sets and incubated for 6-7 days at 28°C. The symptoms included odorless, yellow-brown discoloration of infected scales, drying and/or shrinking of scales, and non-macerated tissue (Figure 5). The symptoms became more severe as incubation time increased. OC5a and 97-1 were pathogenic on all Bejo set varieties. Both strains were successfully re-isolated from onion bulbs and sets. Growth on PA 20 and amplification during PCR confirmed these results. The inoculum dilution endpoint was observed between 10^{-2} and 10^{-3} when an initial OD_{600} = 0.20 was created. This was the point at which no symptoms were observed on

onion set tissue after 6-7 days incubation at 28°C. Dilutions 10^{-1} and 10^{-2} displayed similar infection symptoms on onion sets. No symptoms were observed with 10^{-3} and 10^{-4} dilutions.

Inoculation of Onion Leaves. The symptom caused by either OC5a and 97-1 when inoculated into onion leaves consisted of a gray-white lesion developing after 2-4 days (Figure 6). Within 7-10 days, the lesion extended up and down the leaf creating a necrotic zone behind the disease margin (Figure 7). Inoculation of the seed stalk resulted in a similar symptom. Small leaves became completely necrotic and collapsed after 14 to 20 days. The inoculum dilution endpoint was observed between 10^{-2} and 10^{-3} when an initial OD_{600} = 0.20 was created. This was the point at which symptoms were not observed on leaf tissue after 21 days incubation in the greenhouse. There was a decrease in leaf lesion growth from dilution 10^{-1} to dilution 10^{-2}. Symptoms were not observed with 10^{-3} and 10^{-4} dilutions.

I*noculation of Onion Leaves Leading to Bulb Infection.* Leaf infection was observed in all plants one week after incubation when inoculated with OC5a. Inoculated plants were dissected 2, 3, and 5 weeks after inoculation. Water controls did not exhibit any disease symptoms. Infection was present in the necks of all dissected plants. After bulb dissections were completed, infection was present in 77% of the bulbs grown from seed and in 67% of the bulbs grown from sets. Most common bulb symptoms were mild yellow-brown discoloration in one or two scales near the neck and top of the bulb. Other symptoms in this area included depression of the scale and non-macerated tissue. More advanced bulb symptoms were infection and discoloration in up to ca. 75% of the bulb scale, which resulted in the splitting of the infected scale (Figure 7). OC5a was successfully re-isolated from both infected leaves and scales. Growth on PA 20 and amplification during PCR confirmed the identification.

Discussion

Our studies on an onion bulb disease not encountered in New York prior to the 2006-07 onion storage season has demonstrated that the disease is caused by the bacterium *P. ananatis*. A number of strains of this bacterium were isolated from onion bulbs harvested from plants grown in New York during the 2006-08 growing seasons. Characterization of several New York strains by a semi-selective medium, different pathogenicity tests, and PCR showed that they are essentially identical to the reference strain, 97-1, from Georgia and other strains of the bacterium provided to us by R. D. Gitaitis and R. R. Walcott. One New York grower orally reported that he destroyed a 20-acre field of onions in 2006 with symptoms of the center rot disease prior to harvest. However, the grower may have been mistaken since the consistently present bacterial canker-sourskin disease, caused by *B. cepacia,* may have been the primary culprit. Nevertheless, center rot may have been present prior to the 2006 onion growing season since the symptoms of bacterial canker-sourskin, are likely to overshadow the occurrence of other bacterial pathogens of onion.

In addition to detecting the presence of *P. ananatis* and the center rot disease in New York, we have developed new techniques for inducing typical yellow-brown non-macerated symptoms of center rot in onion bulbs and sets. We used sterile 26 gauge, 0.5 inch hypodermic needles to inject 40-50 µl of bacterial suspensions into various areas of onion bulbs and sets resulting in the typical symptoms as observed on onion bulbs naturally infected only with *P. ananatis*. Typical leaf symptoms of the disease resulted from injecting bacterial suspensions of *P. ananatis* into the sub-epidermal layers of leaves of young onions grown from onion sets. Seed stalks of mature Candy variety onion which were similarly

inoculated in the middle of the seed stalks developed lesions typical of those described previously occurred.

Perhaps the most important results of the study resulted when a hypodermic needle was used to inject 20-40 µl of strain 0C5a inoculum into the sub-epidermal layer of adjacent middle aged leaves of onion plants grown from seeds and sets ca. 3 cm from the top of the neck. After incubation in the greenhouse for up to six weeks, neck tissues of all plants were infected and typical symptoms of center rot (yellow-brown non-macerated discoloration) occurred in the bulb tissues. *P. ananatis* was successfully re-isolated from the infected tissue, completing Koch's postulates. We suspect this is the first report indicating the completion of Koch's postulates for infection of onion bulbs following artificial leaf infection by *P. ananatis*.

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Figure 1. Onion bulbs suspected of center rot infection. The bulbs were grown in New York State during 2008. *P. ananatis* was isolated from the bottom bulb and labeled OC113. Note that only one scale is infected and the condition of this scale was discolored and non-macerated.

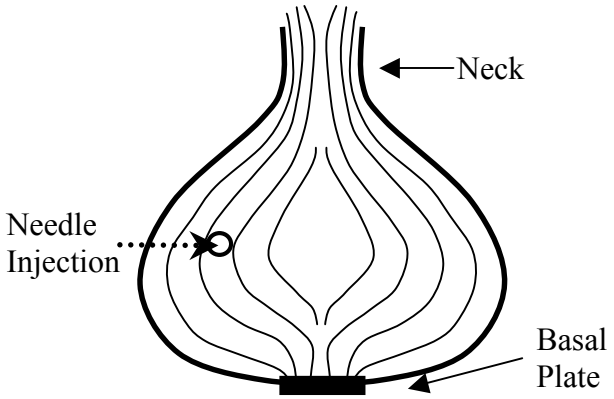

Figure 2. Location of needle injection for onion bulb and set inoculations. Forty to fifty microliters of inoculum was injected into the midsection using a sterile 26 gauge, 0.5 inch hypodermic needle. The inoculated bulbs and sets were incubated at 28°C for 6-7 days.

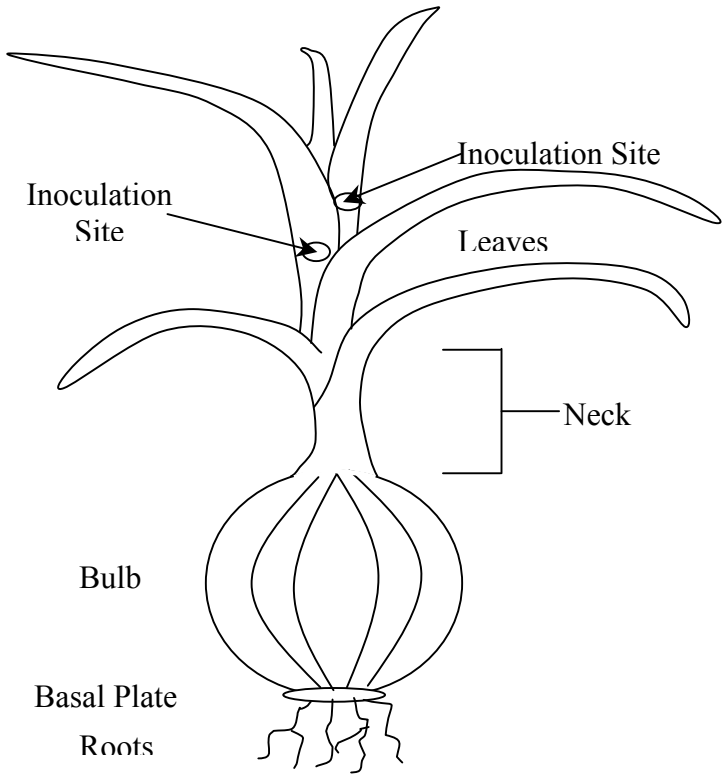

Figure 3. Location of needle injections for onion leaf inoculations. The injection was made into the sub-epidermal layer of two middle- to young-aged leaves with 20-40 µl of inoculum using a sterile 26 gauge, 0.5 inch hypodermic needle.

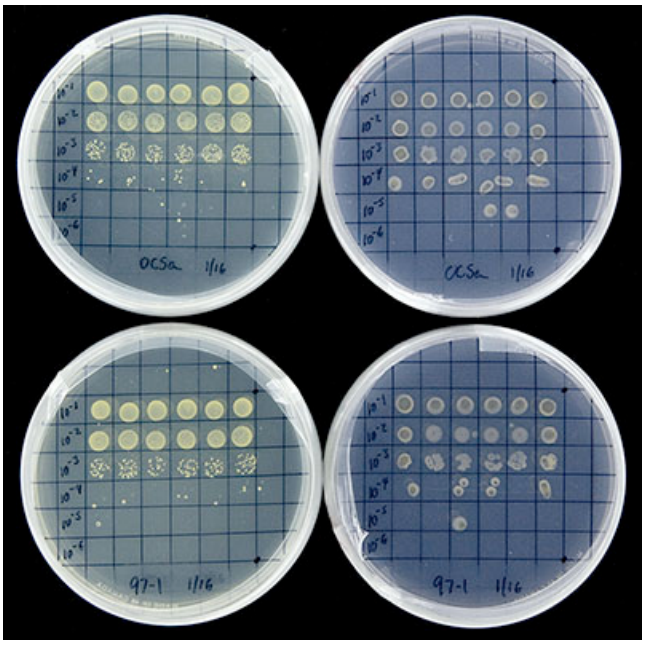

Figure 4. Growth efficiency test results. NA plates are on the left column and PA 20 plates are on the right column. OC5a is on the top row and 97-1 is on the bottom row. Serial dilutions ran from 10^{-1} to 10^{-6} with a starting OD_{600} = 0.20. Six replicates of 5 µl of inoculum were spotted for each dilution.

Figure 5. Infection artificially caused by OC5a when injection was made into yellow onion bulbs and Talon onion sets (left image). Negative control was injected with sterile water (right image). All bulbs and sets were injected with 40-50µl of inoculum using a 26 gauge, 0.5 inch hypodermic needle and incubated at 28°C for 6-7 days.

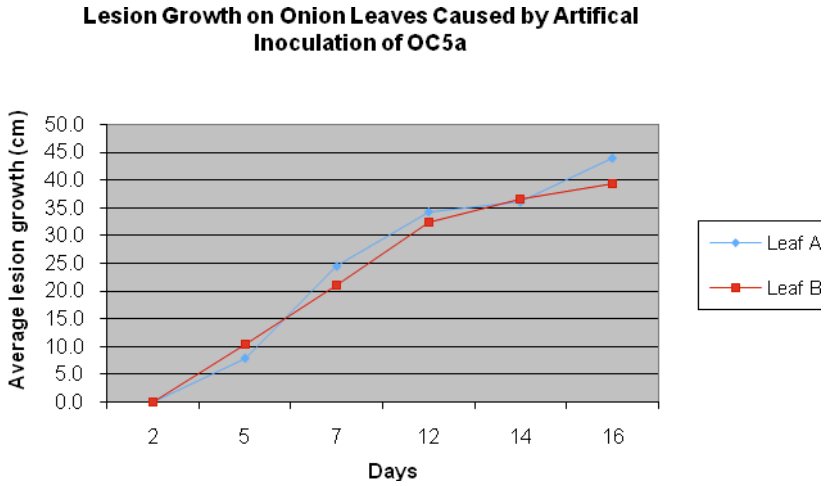

Figure 6. Graph of leaf lesion growth after artificial inoculation. Leaf A represents the younger of the two youngest leaves inoculated and leaf B represents the older of the two leaves. Sixteen plants, two leaves per plant, were inoculated with 20-40 µl of OC5a inoculum into the sub-epidermal layer, ca. 3 cm from the top of the neck. Measurements were taken every 2-3 days after inoculation for 16 days. Measurements were discontinued after leaves had become completely necrotic and collapsed. Sterile water inoculated into onion leaves resulted in no infection.

Figure 7. Bulb symptoms resulting from onion leaves inoculated with OC5a. Two young to middle-aged, adjacent onion leaves were inoculated per plant. A 26 gauge, 0.5 inch hypodermic needle was used to inject 20-40 µl of water or inoculum into the sub-epidermal layer of the onion leaf, ca. 3 cm from the top of the neck. The black circle on the leaves indicates the location of the needle injection. Leaf lesions were observed 2-5 days after inoculation (top left). Bottom left image shows onion leaves injected with sterile water. Bulb scales had become infected after leaf inoculations were made followed by two weeks incubation under greenhouse conditions (top right). Infection greater than 50% of the bulb scale had resulted in "splitting" of the scale (bottom right).

Table 1. *P. ananatis* strains isolated from New York State onions and reference strain information. The origin indicates the year and location where the strain was isolated or donated from. Growth on PA 20 medium is in reference to New York reference strain OC5a and Georgia reference strain 97-1. Positive control used during PCR was Georgia reference strain 97-1. No results indicate that the test was not completed.

Bacterium and strain number	Origin	Growth on PA 20	Amplicon with primers	Pathogenic to onion bulbs and sets	Pathogenic to onion leaves	Pathogenic to onion slices
			P. ananatis			
OC5a	NY-2006	+	+	+	+	+
OC39a	NY-2007	+	+	+		+
OC53	NY-2007	+	+	+		+
OC75	NY-2007	+	+	+	+	+
OC81	NY-2007	+	+	+	+	+
OC85	NY-2007	+	+	+		+
OC86	NY-2007	+	+	+		+
OC105	NY-2008	+	+	+		
OC110	NY-2008	+	+	+		
OC113	NY-2008	+	+	+		
OC132	NY-2008	+	+	+		
OC134	NY-2008	+	+	+		
97-1	GA	+	+	+	+	+
PNA07-1	GA	+	+	+		
PNA07-2	GA	+	+	+		
6313	GA	+	+	+	-	
6314	GA	+	+	+	+	
6366	GA	+	+	-	-	
			Erwinia herbicola			
Eh332	CU	+	+	+	+	+
			Burkholderia cepacia			
PCE	CU	-	-	+		
			Burkholderia gladiola			
PA16	CU	-		+		
PA23	CU	-		+		-

NY = New York State
GA = From R. Gitaitis and R. Walcott culture collection
CU = Cornell University culture collection
PA = Pennsylvania State

POWDERY MILDEW (*LEVEILLULA TAURICA*) INCIDENCE ON ONION CULTIVARS AND SOME NATIVE FLOWERING PLANTS IN THE TREASURE VALLEY REGION OF IDAHO AND OREGON

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Abstract

A powdery mildew disease of onion (*Allium cepa L.*) has been observed annually from 2006 to 2008 in Treasure Valley [southwestern Idaho and eastern Oregon]. Powdery mildew of onion is a relatively new disease in North America caused by *Leveillula taurica* (Lév.) G. Arnaud (= *Oidiopsis taurica* (Lév.) Salmon). Several onion cultivars at mid- to late-bulbing stage in an onion cultivar trial at Oregon State University, Ontario, OR were found to be infected. Foliar symptoms included infrequent, circular to oblong, chlorotic to necrotic dry lesions with effuse, whitish patches consisting mostly of conidiophores. Diagnostic characteristics indicative of *L. taurica* included endophytic mycelium with conidiophores emerging through stomata, and dimorphic conidia (lanceolate and cylindrical to ellipsoid conidia). The teleomorph stage was lacking on onions. Disease was apparent only on mature plants, two to three weeks before harvesting. Iris yellow spot virus (IYSV) disease is endemic in this region and induces straw-colored, dry necrotic lesions on leaves, which are often are similar to those caused by powdery mildew. Incidence of powdery mildew in commercial bulb onion varieties was observed on 3 out of 54 varieties (2006), 21 out of 59 (2007) and 2 out of 46 (2008). Search for sources of primary inoculum in the vicinity revealed the following plants infected with *L. taurica*: *Cleome hassleriana, C. lutea and C. serrulata* (Capparaceae), *Sphaeralcea grossulariifolia, S. parvifolia and S. coccinea (*Malvaceae) and *Astragalus filipes (Fabaceae*). Both anamorphic and teleomorphic states of *L. taurica* were observed on all these hosts. These flowering plants constitute new alternative hosts records for *L. taurica*. Additional research is needed to determine whether these newly recognized hosts play any role in the epidemiology of this recurring onion disease.

Introduction

Onion powdery mildew [OPM] has been reported with increased frequency in recent years from western US. *Leveillula taurica* is thought to have originated in warm, arid regions of the mid-east but currently is spreading in North America. This polyphagous pathogen is known to infect over 1000 species in more than 70 families including onion, cucumber, peppers, tomato, eggplant and several other flowering plants and weeds. In Idaho, this disease first was observed on onion in a breeding nursery in 1994 and on commercial onion bulb crops in 2006. The objectives of our study were to assess disease incidence and severity on onion varieties and to identify possible alternative hosts of L. taurica in the region. With this objective, several crops, weeds and other plant species in the vicinity of onion fields were surveyed for *L. taurica*. Material and Methods: In late August of

2006, 2007and 2008, OPM was observed on a few onion cultivars at mid-bulbing growth stage [10- to 12-leaf stage] in an experimental onion cultivar trial at the Oregon State University, Malheur Experimental Station, Ontario, OR. Surveys were conducted in the summers of 2006. 2007 and 2008 in the vicinity of onion fields to search for possible sources of inoculum of *L. taurica*. Fresh, infected plant materials were examined under a light microscope and identified based on morphological characteristics.

Results and Conclusions

In all the three years, OPM disease was observed on a few onion cultivars with varying disease incidence. In 2006, the disease was found on 3 of 54 varieties at a very low incidence (< 1% plants affected); in 2007, it was found on 21 out of 59 onion varieties, with several showing a maximum disease rating of 4.5 [1-5.0 rating]; and in 2008, it was found on only two cultivars (very low incidence of <1%). Few of the varieties, which did not exhibit disease symptoms in 2006, were affected by the disease in 2007. The causal agent was determined to be Leveillula taurica (Lév.) G. Arnaud based on morphological characters including internal mycelium, conidiophores emerging from stomata, and dimorphic conidia (lanceolate and cylindrical to ellipsoid). The teleomorph was lacking on onion. Typical symptoms on host plants consisted of circular to oblong, chlorotic, necrotic lesions with effuse, whitish growth on mature leaves. Except for the presence of fungal mycelium, these necrotic lesions closely resembled those initiated by Iris yellow spot virus [IYSV] and thrips infestations. IYSV produces straw or tan colored, spindle or diamond-shaped lesions, with or without green centers on leaves and scapes. *L. taurica* was not detected on common weeds but it was found on ornamental plants of *Cleome hassleriana* Chodat (spider-flower) growing in a flower bed near the onion trial [Sampangi et.al. 2006]. Survey of native flowering plants in seed production research plots in the vicinity of onion field found three globemallow species [*Sphaeralcea grossulariifolia*, *S. parvifolia and S. coccinea*] infected with powdery mildews in late July-August 2007. Several wildflowers [Table 1] were cultivated as part of native wildflower seed production trials for range restoration efforts in the Great Basin [Shock, C.C. et.al. 2008]. In 2008, basalt milk vetch, (*Astragalus filipes* Torr. Ex A. Gray), a forb (non woody perennial) native to western North America was found infected with *L. taurica*. Signs included extensive white, superficial powdery mycelial growth and 3

conidia, initially forming on the abaxial leaf surface, later covering both leaf surfaces [Fig.1]. Chasmothecia initially were cream to light yellow in color, turned brown to black at maturity, and were found immersed in dense mycelial masses on both adaxial and abaxial leaf surfaces and stems. Conidia were hyaline and dimorphic, consisting of both primary (initially-formed, lanceolate) and secondary conidia (elongate to cylindrical). The fungus was determined to be L. taurica on the basis of anamorph and teleomorph morphology. Symptoms caused by *L.taurica* on onion and other flowering plants differed markedly. The initial symptoms generally started as minute yellow spots on the leaves, and enlarged rapidly, sometimes covering entire leaves and stems. *Leveillula* species are encountered frequently, in warmer and drier parts of the world, predominantly Asia and Mediterranean Europe. These newly recognized hosts enlarge the range of hosts known to occur in the region. Other hosts known to support development of the teleomorph in the PNW include *Triglochin maritima* L. (Glawe et.al. 2005) and *Cleome hassleriana* (Sampangi et.al 2006), while only the anamorph has been reported from *Gaillardia • grandiflora* Van Houtte. (blanket flower) (Glawe et al., 2006) and *Cicer arietinum* L. (Chickpea) (Attanayake et al., 2008). The anamorph of *L.taurica* was reported earlier on glossy leaf genotypes of onion from Idaho [Mohan et.al. 2005]. Earlier reports from CA and WA suggest the possibility of cultivar-specificity among isolates pathogenic to onion.

Because the ascigerous state provides a means of genetic recombination, there is the potential for races of the pathogen to arise with greater frequency. This has serious implications for managing fungicide resistance and breeding for disease resistance. Genetic resistance of onions to *L. taurica* is not well documented, and no cultivars are recommended for disease management. Irrigation, cropping under cover, diversified crops in this region along with a diversity of alternative hosts provides ample opportunities for this pathogen to become well established in Treasure Valley.

Conclusions

This study reports incidence of *L. taurica* in onion cultivar trials during each of the last 3 years. The disease tended to appear on few cultivars near the end of the growing season on senescing tissues causing apparently no marked effect on yield. Since 1990's IYSV has become pandemic in regions of onion bulb and seed production in Treasure Valley and both these diseases are known to infect onions at mid-bulbing growth stage. Co-infection of IYSV and onion powdery mildew disease might become production constraints. The polyphagous nature of *L.taurica* may increase the potential risk it poses to the onion industry in PNW. With the confirmation of *L. taurica* on diverse hosts in the PNW, some species having been shown to support development of the teleomorph, it is clear that understanding the epidemiology of this onion disease will require consideration of the roles of alternative hosts in providing inoculum. The possible 5 epidemiologic roles of alternative hosts, and the potential for economic losses to be caused by this pathogen warrant, further study

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Table 1. Survey for alternative hosts of *L. taurica*.

Common name	Family	Scientific name	*L.taurica*	Chasmothecia
Hairy nightshade	Solanaceae	*Solanum villosum* (L.) Mill	--	--
Redroot pigweed	Amaranthaceae	*Amaranthus retroflexus* (L.)	--	--
Common purslane	Portulacaceae	*Portulaca oleracea L.*	--	--
Potato	Solanaceae	*Solanum tuberosum L.*	--	--
Spiderflower	Capparaceae	*Cleome hassleriana* Chodat	+	+
yellow spiderflower	Capparaceae	*Cleome lutea* Hook.	+	+
Rocky Mountain beeplant	Capparaceae	*Cleome serrulata* Push	+	+
Scarlet globemallow	Malvaceae	*Sphaeralcea coccinea* (Nutt.) Rid.	+	+
Gooseberry leaf globemallow	Malvaceae	*Sphaeralcea grossulariifolia* (Hook. & Arm.) Rid.	+	+
Small flower globemallow	Malvaceae	*Sphaeralcea parvifolia* A. Nelson	+	+
Biscuitroot	Apiaceae	*Lomatium spp.*	--	--
Sulfur buckwheat	Polygonaceae	*Eriogonum umbellatum Torr*	--	--
Hawksbeard	Asteraceae	*Crepis acuminata* Nutt	--	--
Prairie clover	Fabaceae	*Dalea spp*	--	--
Basalt milkvetch	Fabaceae	*Astragalus filipes* Torr. ex A. Gray	+	+

+ [Present], -- [Absent]

Sphaeralcea coccinea *Sphaeralcea parvifolia* *Sphaeralcea grossulariifolia*

Allium cepa *Cleome hassleriana* *Astragalus filipes*

Fig.1. Symptoms of *L.taurica* on different hosts.

EVALUATION OF NEW MEXICO AUTUMN-SOWN ONION ENTRIES

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Abstract

New Mexico has a long history of growing onions in the U.S. In addition to favorable environment conditions, New Mexico has a market window for onions during the months of June and July. The breeding efforts of the New Mexico State University onion breeding program has led to the release of 27 cultivars that have allowed the New Mexico onion industry to remain competitive in the U.S. market. Continued competitiveness in the years to come is partially dependent on the continued development and release of improved onion cultivars from the NMSU breeding program. The evaluation of promising breeding lines and their comparison with commercial cultivars is crucial to this development effort. Fourteen autumn-sown breeding lines, that varied in their maturity time, were compared with 11 commercial cultivars for maturity date, scape percentage, pink root severity, fusarium basal rot severity and incidence, marketable bulb yield, percentage marketable yield, average bulb weight, and the percentage of single-centered bulbs. Among the early-maturing breeding lines, all were comparable to 'NuMex Camino' and 'NuMex Chaco' and none exceeded the performance of these two cultivars. Among the intermediate-maturing entries, NMSU 05-17 exhibit potential as a replacement for 'Texas Early White' and as an early-maturing, white-scaled cultivar. More breeding work needs to be completed for late-maturing breeding lines before they outperform current commercial cultivars.

Introduction

Onion (*Allium cepa* L.) is the third most important crop of New Mexico after alfalfa (*Medicago sativa* L.) in terms of farm gate value (Anonymous, 2006). New Mexico produced 152,000 t of bulb onions on 2,550 ha and generated $63.4 million in 2007 (USDA, 2008). In terms of productivity, i.e., production per unit of land, New Mexico ranked among top six states nationwide (USDA, 2008). There has been tremendous increase in area and productivity of bulb onion production in last few decades. The production area was approximately 1200 ha in 1970, which increased more than 210%, while the productivity increased from 33.6 $t \bullet ha^{-1}$ to 59.6 $t \bullet ha^{-1}$ (175% increase) in the same time period (Corgan, 2002). The continuous and successful efforts of the onion breeding program at New Mexico State University are one of the major reasons for this increase in onion productivity.

Our onion breeding program is striving towards developing better yielding cultivars that enhance bulb quality and productivity. Several promising breeding lines and the most commonly-grown cultivars are evaluated each year in field trials. The objectives of these field trials are to compare developmental open-pollinated and hybrid breeding lines to current commercial cultivars, to identify the best lines for potential release, and to demonstrate the performance of new lines to New Mexico onion growers.

Several important traits are desirable for any new cultivar. A high bulb yield coupled with a low cull number (a high marketable yield) is a desirable trait for most cultivars. The premature formation of seed stalks, or bolting, can drastically reduce bulb yield, as bulbs that produced seed stalks are unmarketable. Cultivars that are resistant to bolting formation do not exhibit a yield reduction. Another trait, that has become important in the last ten years, is the percentage of bulbs

that possess a single growing point (a single center). Onion ring processors are requiring that a shipment of onion bulbs be at least 85% single-centered. Bulbs from a cultivar, that produces a high percentage of single-centered bulbs, can be sold for onion ring processing or can be sold on the fresh market if prices are higher there. Cultivars possessing this trait allow onion shippers two separate avenues for bulb sales. Commercial onion buyers on the fresh market are requested increasingly, that the onions that they purchase, possess a single center.

As with other crops, onion cultivars possessing disease resistance are highly desirable. Two diseases, that affect onions, are pink root and fusarium basal rot (FBR). Pink root (*Phoma terrestris* Hansen) is the most widely-distributed onion disease in New Mexico (Wall and Corgan, 1993). Although, present cultivars have a high amount of field tolerance to pink root, reducing the disease severity is still desirable. Fusarium basal rot (*Fusarium oxysporum* Schlechtend. W.C. Synder and H.N. Hans, f. sp. *cepae*) destroys the onion basal plate and allows secondary bacterial infections to rot bulbs. FBR is a growing problem in the fields of New Mexico, but still no field resistance is found in current cultivars. Increasing the levels of FBR resistance in new cultivars is an important goal of NMSU onion breeding program.

Materials and Methods

The study was conducted at the Fabian Garcia Science Center in Las Cruces, New Mexico during 2007-2008. For ease of field management and harvesting, entries were grouped into three relative maturity groups: early, intermediate, and late. For this study, twelve entries were placed in the early-maturing group, ten entries were placed in the intermediate-maturing group, and four entries were placed in the late-maturing group (Table 1). In the early-maturing group, 'NuMex Camino' and 'NuMex Chaco' are commercially-grown cultivars that produce yellow-scaled bulbs, mature at different times, and are the standard cultivars for comparing with any promising lines. In the intermediate-maturing group, NM 899, 'NuMex Crispy', 'NuMex Mirage', 'NuMex Radiance', and 'Texas Early White' are commercial cultivars and produce white-scaled bulbs. 'NuMex Mirage' was released from the NMSU onion breeding program in 2007 and has yet to be commercially-available for sale (Cramer and Corgan, 2007). 'NuMex Radiance' was recently released in October, 2008 from the NMSU onion breeding program and is not commercially-available for sale (Cramer, 2008). Results from these cultivar trials were used to justify the release of 'NuMex Radiance'. 'NuMex Crimson', a red-scaled cultivar, and 'NuMex Starlite', a yellow-scaled cultivar, are grown commercially in New Mexico. In the late-maturing group, 'NuMex Luna' is a yellow-scaled cultivar that is grown in New Mexico.

Seeds were sown approximately 1-2 cm deep in two rows 6 cm apart on 17 Sept. 2007 and 20 Sept. 2007 in field 1 and field 2 respectively. Early- and intermediate-maturing entries were sown in both fields, while late-maturing entries were sown only in the field 2. For each two-row plot, 1.5 g of seed was sown and plants were thinned later to 10 cm between plants within the row. Each plot was 2.4 m long and 1 m wide and separated by an alley of 0.6 m from the next plot on the same bed. The study was conducted in randomized complete block design with four replications. Standard cultural practices were followed to produce autumn-sown onions in southern New Mexico (Corgan et al., 2000). Diammonium phosphate (18N-20P-0K; Helena Chemical Co., Collierville, Tenn.) at a rate of 170 $kg \bullet ha^{-1}$ was applied as a band 10 cm below the soil surface prior to seeding. Field 1 was surface irrigated, while field 2 was drip irrigated. Subsurface drip irrigation lines (T Tape, T-Systems International, San Diego, CA), that had emitters every 20 cm, were placed 10 cm deep in the center of each bed. Irrigation and fertilizer (26N-0P-0K-6S; Western Blend, Inc., Las Cruces, NM) were applied as needed.

All plots were harvested when 80 percent of the plant tops were lying down. The harvest date was considered the maturity date, and the days from sowing until harvest was counted for each plot. The number of plants that produced seed stalks was counted for each plot. The seed stalk percentage, a measure of bolting was calculated by dividing the number of plants with seed stalks by the total plant number per plot. These fields have been used for onion production for last few decades and may have higher levels of disease inoculum compared to farmers' fields. Immediately after harvest, the total bulb number was determined and 20 randomly-selected bulbs per plot were rated for pink root severity using a subjective rating of 1 (no pink root) to 9 (heavily infected roots). The percent incidence of pink root disease was calculated by counting bulbs having a rating of more than one, and divided it by 20. Later, bulb tops and roots were clipped, and the basal plate of 20 randomly selected bulbs was cut transversely to observe FBR severity and incidence as described by Lopez (2003).

After harvest, bulbs were placed in mesh sacks and on the same day transferred indoors to an onion shed. Bulbs were cured for three to four days under high temperature and low humidity conditions to reduce storage losses and decay. After curing, the total bulb fresh weight was measured for each plot. Bulbs were graded to remove culls (diseased bulbs, bulbs under 3.8 cm in diameter, split- and double bulbs). The number of culls was subtracted from the total bulb number to obtain the marketable bulb number per plot. After bulbs were graded, they were weighed again to obtain marketable bulb weight per plot. The marketable yield percentage was calculated by dividing the marketable bulb weight per plot by the total weight per plot. The average bulb weight was calculated by dividing marketable bulb weight by marketable bulb number. Later, 25 bulbs were cut transversely at the widest point on the vertical axis, to determine the percent of bulbs possessing a single growing point. If a bulb possessed a single growing point or multiple growing points within 1.3 cm of the bulb center, then the bulb was considered single centered.

Statistical Analysis: Proc Means statement in the General Linear Models (GLM) procedure of the SAS statistical software (SAS Institute, Cary, NC version 9.2) was used for calculating the entry means across four replications. The Proc GLM statement analyzed entry differences for each trait. The mean separation was performed using Fisher's protected least significant difference (LSD) among different entries at five percent level of significance.

Results and Discussion

Early-maturing entries: Among the early-maturing entries, 'NuMex Camino' and 'NuMex Chaco' are commercial cultivars that mature 1-2 weeks apart. The other entries that were tested in this group were compared against these two cultivars. Of the breeding lines tested in this group, NMSU 05-09-1, NMSU 05-10-1, NMSU 05-22-1, and NMSU 05-24-1 were open-pollinated lines, while NMSU 05-03-2, NMSU 05-09-2, NMSU 05-10-2, NMSU 05-15-2, NMSU 05-22-4, and NMSU 05-24-4 were hybrid lines.

The early-maturing entries were harvested between 20 May and 4 June in field 1, and between 20 May and 10 June in field 2 (Table 1). In both fields, 'NuMex Camino' matured earlier than 'NuMex Chaco'. As potential replacements for 'NuMex Camino' and 'NuMex Chaco', breeding lines must matured at a similar time. In both fields, NMSU 05-09-1, NMSU 05-09-2, and NMSU 05-10-1 matured at a similar time as 'NuMex Camino' (Table 1). These breeding lines would show the most promise at maturing the same time as 'NuMex Camino'. NMSU 05-03-2, NMSU 05-10-2, NMSU 05-22-1, NMSU 05-24-1, and NMSU 05-24-4 matured at the same time as 'NuMex Camino' when grown in field 2, but matured later than 'NuMex Camino' when grown in field 1. This inconsistency in maturity date relative to 'NuMex Camino' from field to field is undesirable. When

grown in either field, 'NuMex Chaco' matured later than all other entries except NMSU 05-15-2. This late maturity date for 'NuMex Chaco' is later than in previous years. In addition, this late maturity would prevent one of the tested breeding lines from being a replacement for 'NuMex Chaco'. Of the entries tested, only 'NuMex Camino' matured in the same number of days after sowing when grown in both fields.

Depending upon the sowing date, cultural practices, and environmental conditions during growth, seed stalk percentage can vary greatly year to year and field to field. With the sowing dates of 17 and 20 Sept. for field 1 and 2, respectively, a low amount bolting would be expected for entries that possess a moderate amount of bolting resistance. In both fields, the seed stalk percentage was low ranging from 0 to 5.5% (Table 1). Related to their high level of bolting resistance, 'NuMex Camino' and 'NuMex Chaco' exhibited no bolting in either field. In order for one of the breeding lines tested to replace either of the commercial cultivars tested, the lines must also possess a comparable level of bolting resistance. NMSU 05-03-2, NMSU 05-10-1, NMSU 05-10-2, and NMSU 05-15-2 could be sown at an early date and produce a low bolting percentage comparable to 'NuMex Camino' and 'NuMex Chaco'. While the bolting percentage was quite low, a later sowing date would be recommended for NMSU 05-09-1, NMSU 05-09-2, NMSU 05-22-1, NMSU 05-22-4, NMSU 05-24-1, and NMSU 05-24-4. When sown at a later date in field 2, entries were not different in their bolting percentage. In addition, the average bulb weight was lower in field 2 than in field 1. This bulb size difference would suggest that plant size was smaller in field 2 than field 1 and a smaller plant size would explain a lower bolting percentage observed in field 2.

As mentioned earlier, average bulb weight was greater in field 1 with a range of 285 g to 381 g than in field 2 where a range of 192 g to 303 g was observed (Table 1). Of the breeding lines that matured the same time as 'NuMex Camino', all produced bulbs of a similar weight to those produced by 'NuMex Camino' regardless of field (Table 1). The exception was 'NMSU 05-09-2' that produced larger bulbs than 'NuMex Camino' when both entries were grown in field 1. Most bulbs, produced by breeding lines, were similar in weight to bulbs produced by 'NuMex Chaco'. NMSU 05-22-1, NMSU 05-24-1, and NMSU 05-24-4 produced larger bulbs than 'NuMex Chaco' when all entries were grown in field 1 but not when entries were grown in field 2. The only entry that produced larger bulbs than 'NuMex Chaco' when grown in field 2 was NMSU 05-15-2. This breeding line matured at a similar time as 'NuMex Chaco'. A promising line should at least produce bulbs of a similar size as those of commercial cultivars.

In addition to average bulb weight, marketable bulb yield is important yield characteristic for successful cultivars. Across all entries, marketable yield was greater when entries were grown in field 1 than when they were grown in field 2. The marketable yield in field 1 varied from 64.0 to 82.8 $t \bullet ha^{-1}$, and from 41.5 to 63.3 $t \bullet ha^{-1}$ in the field 2. Of the breeding lines that matured the same time as 'NuMex Camino', all produced a similar marketable yield as 'NuMex Camino' when grown in field 1, and NMSU 05-03-2 and NMSU 05-24-4 produced a greater yield than 'NuMex Camino' when grown in field 2 (Table 1). When grown in field 1, NMSU 05-10-2, NMSU 05-22-1, NMSU 05-24-1, and NMSU 05-24-4 produced a greater marketable yield than 'NuMex Chaco'. This yield difference was not observed when entries were grown in field 2. The percentage marketable yield ranged from 90 to 99% and was similar for all entries when they were grown in either field (data not presented).

The percentage of bulbs that possess a single growing point has become an important traits for onions destined for ring processing. Both 'NuMex Camino' and 'NuMex Chaco' produce a high percentage of single-centered bulbs. For both fields, the percentage of single-centered bulbs ranged from 85-90% for 'NuMex Camino' and 80-86.5% for 'NuMex Chaco' (Table 1). With these high percentages, it is difficult to find breeding lines that outperform either cultivar for the percentage of single-centered bulbs. None of the breeding lines tested produced a higher percentage of single-centered bulbs than 'NuMex Camino' or 'NuMex Chaco'. When grown in field 1, NMSU 05-09-1,

NMSU 05-10-1, and NMSU 05-15-2 produced a comparable percentage of single-centered bulbs as 'NuMex Camino' and 'NuMex Chaco', while all other breeding lines produced a lower percentage of single-centered bulbs. When grown in field 2, all breeding lines, except NMSU 05-09-2, NMSU 05-15-2, and NMSU 05-24-1, produced a comparable percentage of single-centered bulbs as 'NuMex Camino' and 'NuMex Chaco'.

A high pink root severity can drastically reduced bulb size and in turn reduce marketable bulb yield. Many commercial cultivars possess high levels of pink root resistance. When grown in field 1, bulbs of 'NuMex Camino' were rated as 3.2, on an ordinal scale of 1 to 9 (9 being most severe), for pink root severity (Table 1). For the entries that matured at the same time as 'NuMex Camino', only NMSU 05-09-1 exhibited less severe pink root symptoms than 'NuMex Camino'. This reduced amount of pink root symptoms did not translate into larger bulbs as the bulb size of NMSU 05-09-1 to that of 'NuMex Camino'. When grown in field 2, 'NuMex Camino' exhibited more severe pink root symptoms (4.5) than when the cultivar was grown in field 1. When grown in this field, bulbs of NMSU 05-10-1, NMSU 05-10-2, NMSU 05-22-1, NMSU 05-24-1 exhibited less severe pink root symptoms and matured at the same time as bulbs of 'NuMex Camino'. As observed in field 1, the bulbs of these entries were not larger than bulbs of 'NuMex Camino' even though these entries possessed lower disease severity. The pink root resistance of 'NuMex Chaco' is often less than other cultivars. Part of this difference may be attributed to a later maturity and a longer time period for infection to occur. When grown in field 1, all breeding lines exhibited fewer pink root symptoms than 'NuMex Chaco' (Table 1). For the entries that matured at a similar time as 'NuMex Chaco' when grown in field 2, bulbs of NMSU 05-22-4 exhibited few pink root symptoms than bulbs of 'NuMex Chaco'.

Usually the severity and incidence of fusarium basal rot (FBR) symptoms observed in growers' fields are low due to good rotational practices. As the ability to rotate between fields becomes reduced, FBR severity and incidence will increase. 'NuMex Camino' exhibits a low FBR severity and incidence. When grown in either field, no breeding line exhibited a lower FBR severity or incidence than 'NuMex Camino' (Table 1). Bulbs of 'NuMex Chaco' tend to exhibit more FBR symptoms than bulbs of 'NuMex Camino'. Of the entries that matured close to 'NuMex Chaco' when grown in field 1, only NMSU 05-03-2 exhibited a lower FBR severity and incidence than 'NuMex Chaco'. When entries were grown in field 2, no breeding line, that matured at a similar time as 'NuMex Chaco', exhibited a lower FBR severity or incidence (Table 1).

Intermediate-maturing entries: Among the intermediate entries, these entries were further subdivided based upon the scale color of the dry outer scale. The reason for doing this was that a promising breeding line would only replace a commercial cultivar of the same scale color. A yellow breeding line would not replace an established white onion cultivar. The entries in this maturity group possessed yellow, white, or red dry outer scales. Only those entries with white scales were represented by more than two entries in the trial while there were only two entries with yellow or red scales each, respectively. For this reasons, only the results for the white-scaled entries will be presented in table format.

For the white-entries, NM 899 and 'NuMex Radiance' matured at a similar time of the second to third week of June whether either entry was grown in field 1 or 2 (Table 2). 'NuMex Radiance' is a new cultivar that has just been released this year as a replacement cultivar for NM 899. NM 899 was a germplasm release from the NMSU breeding program in 1990 that was adopted as a cultivar by local onion growers, due to the lack of a suitable cultivar that matured at this time. When entries were grown in field 1, NMSU 05-17 matured earlier than 'NuMex Crispy' and 'NuMex Mirage', and matured at a similar time as 'Texas Early White' (Table 2). NMSU 05-17 is being tested as a potential replacement cultivar for 'Texas Early White'. When grown in field 2, NMSU 05-17 matured 8-14 days earlier than other entries within this group. 'NuMex Mirage' was released in 2006

as a replacement cultivar for 'Texas Early White' (Cramer and Corgan, 2007). NMSU 05-17 matures at a time that is earlier than 'NuMex Mirage'. NMSU 05-17 is very consistent in the number of days until maturity when grown in either field. It matured in 260-261 days from sowing whether grown in either field. The other entries required more days to mature when grown in field 1 as compared to being grown in field 2.

One reason for a desired replacement for 'Texas Early White' is its propensity for bolting when growing conditions are favorable. When entries were grown in field 1, 'Texas Early White' produced a bolting percentage of 43.8% while all entries were significantly lower for their bolting percentage (Table 2). When favorable conditions for bolting were not present, there was no difference in bolting percentage as was the case when entries were grown in field 2. When grown in both fields, 'NuMex Radiance' produced a comparable bolting percentage as NM 899 (Table 2).

As mentioned earlier, the percentage of single centers produced by a cultivar is becoming an important desired characteristic. Even though the vast majority of onions processed into onion rings are yellow-scaled cultivars, growers are requesting that white-scaled cultivars also produce a high percentage of single-centered bulbs. When grown in either field, NMSU 05-17 produced a higher percentage of single-centered bulbs than 'NuMex Crispy', 'NuMex Mirage', and 'Texas Early White' (Table 2). This high percentage of single centers would justify the release of NMSU 05-17 as a new cultivar. When grown in either field, 'NuMex Radiance' produced a higher percentage of single-centered bulbs than NM 899. This high single centered percentage was used to justify the release of 'NuMex Radiance'.

Even though emphasis is placed on traits, such as, the percentage of single centers and bolting resistance, marketable bulb yield is just as important of a trait for onion growers. Due to the high prevalence of seed stalks, 'Texas Early White' produced a lower marketable bulb yield than other entries when all were grown in field 1 (Table 2). When a high bolting percentage was absent, as was observed for field 2, all entries produced a comparable marketable yield. In terms of percentage marketable yield and average bulb weight, all entries were similar for these two traits regardless of field (data not shown).

There were few differences between entries with regards to disease symptoms. When grown in field 1, NMSU 05-17 produced bulbs with a higher pink root severity than bulbs of all other entries (Table 2). This difference in pink root severity was not observed when entries were grown in field 2. When entries were grown in field 2, pink root severity was greater than when entries were grown in field 1. When grown in field 1, 'Texas Early White' produced a lower FBR incidence than other entries that matured at a similar time (Table 2). In addition, NM 899 produced a lower FBR incidence than 'NuMex Radiance' (Table 2). There was no difference in FBR incidence between entries when they were grown in field 2. In addition, there was no difference in FBR severity between entries when they were grown in either field.

As mentioned earlier, both yellow-scaled and red-scaled onion entries were also evaluated in this trial. For the yellow-scaled entries, NMSU 06-95 was compared to 'NuMex Starlite'. NMSU 06-95 was the original version of 'NuMex Starlite' when the cultivar was released in 1990. The current version of 'NuMex Starlite' is being compared to its original version to determine if significant changes have been made to the cultivar through our continued breeding efforts. When grown in either field, the current version of 'NuMex Starlite' produced a greater percentage of single-centered bulbs (72.5-83.5%) than the original version, NMSU 06-95 (16.3-21.3%) (data not shown). For all other characters measured, the two versions were similar to each other when grown in either field (data not shown). For the red-scaled entries, NMSU 05-31 was compared to 'NuMex Crimson'. For all characters measured, both entries were similar to each other when grown in either field (data not shown).

Late-maturing entries: As with the intermediate-maturing entries, there were two yellow-scaled entries and two red-scale entries evaluated in this group. For the yellow-scaled entries, 'NuMex Luna' was being compared with NMSU 07-06, as a possible replacement for 'NuMex Luna'. NMSU 07-06 matured on 10 June that was six days later than 'NuMex Luna' (data not shown). Normally, 'NuMex Luna' would mature later than 4 June. 'NuMex Luna' produced a higher marketable bulb yield (60.9 $t \bullet ha^{-1}$) than NMSU 07-06 (51.9 $t \bullet ha^{-1}$); however, average bulb weight was similar between the two entries (245-250 g) (data not shown). Both entries were similar for scape percentage (0.5-1.6%), percentage of single centers (87-89%), percentage marketable yield (91-94%), pink root severity (3.9-4.8), and FBR severity (1.6-2.0) and incidence (15-28%) (data not shown). For red-scaled entries, 'NuMex Crimson' was being compared with NMSU 06-10 as a potential replacement for 'NuMex Crimson'. NMSU 06-10 produced large bulbs (263 g) than 'NuMex Crimson' (182 g); however, the marketable bulb yield was similar for the two entries (45.0-45.4 $t \bullet ha^{-1}$) (data not shown). The percentage of single-centered bulbs was much lower for NMSU 06-10 (29%) than for 'NuMex Crimson' (81.0%) (data not shown). As mentioned earlier for white-scaled cultivars, there is growing interest in red-scaled cultivars that produce a high percentage of single-centered bulbs. 'NuMex Crimson' is particularly attractive for the high percentage of single-centered bulbs that it produces. Both entries were similar in their maturity date (4-10 June), scape percentage (0.0-0.4%), percentage marketable yield (91-93%), pink root severity (5.4-5.7), and FBR severity (2.7-2.8) and incidence (28-44%) (data not shown).

Among the early-maturing entries, all of the breeding lines were comparable to 'NuMex Camino' and 'NuMex Chaco'. Both of these cultivars perform quite well when grown in New Mexico. A new cultivar, that would replace either of these cultivars, may be difficult to develop. Among the white-scaled, intermediate-maturing entries, NMSU 05-17 shows great promise as a potential replacement for 'Texas Early White' and an earlier maturing complementary cultivar to 'NuMex Mirage'. 'NuMex Radiance' may replace NM 899 due to its production of a high percentage of single-centered bulbs. Breeding for improvement of 'NuMex Starlite' has been successful in increasing the percentage of single-centered bulbs. More work needs to be done to late-maturing breeding lines before they are ready to replace established commercial cultivars.

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Table 1. Bulb maturity, scape percentage, average bulb weight, percentage of single centers, marketable bulb yield, pink root disease severity and fusarium basal rot disease severity and incidence of early-maturing, autumn-sown onion entries planted at the Fabian Garcia Science Center in Las Cruces, NM during 2007-2008.

Entry	Maturity date (DAS)[z]	Scapes (%)[y]	Average bulb weight (g)[x]	Single centers (%)[w]	Marketable yield ($t \bullet ha^{-1}$)[v]	Pink root severity[u]	Fusarium basal rot severity[t]	incidence (%)[s]
				Field 1				
NMSU 05-03-2	May 29 (255)	0.0	339	57.0	72.3	2.5	1.2	10
NMSU 05-09-1	May 20 (246)	3.7	320	73.0	70.8	2.8	1.4	21
NMSU 05-09-2	May 20 (246)	3.8	330	52.0	72.0	3.2	1.7	25
NMSU 05-10-1	May 22 (248)	2.0	288	68.0	68.3	3.1	1.3	18
NMSU 05-10-2	May 25 (251)	3.1	334	39.0	81.6	2.8	1.5	29
NMSU 05-15-2	May 29 (255)	1.7	305	71.0	64.0	2.9	2.0	44
NMSU 05-22-1	May 27 (253)	4.9	380	42.0	81.2	2.7	1.9	36
NMSU 05-22-4	May 27 (253)	5.5	341	58.0	73.3	2.7	1.9	39
NMSU 05-24-1	May 27 (253)	5.4	360	53.0	81.5	2.6	1.8	40
NMSU 05-24-4	May 29 (255)	5.5	381	41.0	82.8	2.7	1.7	39
NuMex Camino	May 20 (246)	0.0	285	85.0	70.5	3.2	1.6	30
NuMex Chaco	June 4 (261)	0.0	315	80.0	72.6	4.2	2.1	53
LSD (5 %)	5 days[***]	3.5[**]	36[***]	18.1[***]	8.4[***]	0.4[***]	0.5[*]	20[**]
				Field 2				
NMSU 05-03-2	May 23 (246)	0.4	234	91.0	58.0	4.0	1.1	8
NMSU 05-09-1	May 20 (243)	1.6	193	85.0	44.0	4.2	2.3	37
NMSU 05-09-2	May 25 (248)	0.0	213	66.0	41.5	3.8	2.3	35
NMSU 05-10-1	May 21 (244)	0.4	192	90.0	42.8	3.6	1.7	36
NMSU 05-10-2	May 21 (244)	0.7	208	80.0	47.1	3.7	2.1	38
NMSU 05-15-2	June 10 (264)	0.0	303	64.9	42.9	4.8	2.9	43
NMSU 05-22-1	May 26 (249)	1.7	239	78.8	52.0	3.6	2.9	49
NMSU 05-22-4	June 4	3.8	259	75.3	58.7	3.8	2.6	44

	(258)							
NMSU 05-24-1	May 26	0.0	230	64.0	55.8	3.6	2.4	34
	(249)							
NMSU 05-24-4	May 26	0.4	254	78.3	62.2	3.8	2.1	36
	(249)							
NuMex Camino	May 23	0.0	222	90.0	46.7	4.5	1.6	21
	(246)							
NuMex Chaco	June 10	0.0	256	86.5	63.3	4.8	2.2	35
	(264)							
LSD (5 %)	6 days***	NS	45***	17.3*	10.9***	0.8*	0.9**	19*

$^{NS, *, **, ***}$Nonsignificant at $P = 0.05$, significant at $P = 0.05$, significant at $P = 0.01$, and significant at $P = 0.001$, respectively. Test was conducted at $\alpha = 0.05$.

[z]A plot was considered mature when 80% of the tops were down and harvested at that time. DAS = Days after sowing.

[y]The scape percentage was determined at harvest and calculated by dividing the number of plants with scapes by the total plant per plot.

[x]Average bulb weight was calculated by dividing the marketable bulb weight by the number of marketable bulbs.

[w]The percentage of bulbs with single centers (single growing points) was determined by cutting each bulb transversely at the vertical center and measuring the number of growing points that extended 1.3 cm beyond the bulb's center.

[v]Marketable bulb yield ($t \bullet ha^{-1}$) was calculated by weighing the marketable bulbs per plot and adjusting the plot size to one ha.

[u]Root systems of 20 bulbs per plot were rated based on a scale of 1 (no infected roots) to 9 (completely infected roots).

[t]Transversely cut basal plates of 20 bulbs per plot were rated based on a scale of 1 (no disease tissue) to 9 (70 percent or more of basal plate decayed).

[s]Percentage of bulbs with Fusarium basal plate rot.

Table 2. Bulb maturity, scape production, percentage of single centers, marketable bulb yield, pink root severity, and Fusarium basal rot incidence yield of intermediate-maturing, autumn-sown onion entries planted at Fabian Garcia Science Center in Las Cruces, NM during 2007-08.

Entry	Maturity date (DAS)[z]	Scapes (%)[y]	Single centers (%)[x]	Marketable yield (t●ha^{-1})[w]	Pink root severity[v]	Fusarium basal rot incidence (%)[u]
			Field 1			
NM 899	June 12 (270)	2.3	30.0	49.5	3.0	28
NMSU 05-17	June 2 (260)	4.2	77.0	67.2	3.9	45
NuMex Crispy	June 4 (262)	3.2	59.0	60.3	2.9	45
NuMex Mirage	June 4 (262)	0.8	39.0	62.0	3.4	44
NuMex Radiance	June 12 (270)	0.0	83.0	65.2	2.8	44
Texas Early White	June 1 (261)	43.8	40.2	34.0	3.3	25
LSD (5 %)	2 days***	11.5***	8.8***	10.6***	0.3***	12**
			Field 2			
NM 899	June 18 (273)	0.0	35.6	17.5	4.4	57
NMSU 05-17	June 6 (261)	0.5	89.0	24.9	4.6	55
NuMex Crispy	June 20 (275)	0.0	51.0	25.0	4.6	43
NuMex Mirage	June 15 (270)	0.5	22.0	28.1	4.8	44
NuMex Radiance	June 17 (272)	0.0	65.4	21.0	4.2	50
Texas Early White	June 14 (269)	5.4	40.0	30.6	3.6	25
LSD (5 %)	5 days***	NS	23.8***	NS	NS	NS

$^{NS, **, ***}$Nonsignificant at $P = 0.05$, significant at $P = 0.01$, and significant at $P = 0.001$, respectively. Test was conducted at $\alpha = 0.05$.

[z]A plot was considered mature when 80% of the tops were down and harvested at that time.

[y]The scape percentage was determined at harvest and calculated by dividing the number of plants with scapes by the total plant number per plot.

[x]The percentage of bulbs with single centers (single growing points) was determined by cutting each bulb transversely at the vertical center and measuring the number of growing points that extended 1.3 cm beyond the bulb's center.

[w]Marketable bulb yield (t●ha^{-1}) was calculated by weighing the marketable bulbs per plot and adjusting the plot size to one ha.

[v]Root systems of 20 bulbs per plot were rated based on a scale of 1 (no infected roots) to 9 (completely infected roots).

[u]Percentage of bulbs with Fusarium basal plate rot.

MANAGING INSECTICIDES FOR MAXIMUM EFFICACY AGAINST THRIPS IN DRY BULB ONION IN THE OREGON/IDAHO PRODUCTION REGION

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Objective

Determine the most effective rates and combinations of insecticides to use with Carzol SP to provide season long thrips control in dry bulb onion and reduce the risk of resistance development. **Not all insecticides referred to in this report are registered for use on onions. Always obtain and read the insecticide label to ensure that the product is registered for the crop for which it is intended.**

Introduction

OSU trials in 2005 showed that Carzol SP (formetanate hydrochloride) was effective in controlling thrips and reducing iris yellow spot virus (IYSV) incidence. The EPA granted several states a section 18 registration for Carzol SP use on onions for the 2006 and 2007 growing seasons, but at a lower rate than was considered effective. This project was designed to determine the optimum rate, timing and rotation sequence with other insecticides to maximize thrips control within the parameters of the section 18 label. The thrips makeup in the Treasure Valley onion production region of Oregon and Idaho is about 80% onion thrips and 20% western flower thrips.

Materials and Methods

Trials were established at the OSU Malheur Experiment Station to determine the most effective insecticides to rotate with Carzol SP in a complete thrips control program. The Carzol SP rotation trial consisted of 18 treatments of Carzol SP rotated with other insecticides in 2007 (Table 1) and 26 treatments in 2008 (Table 2). A block of onion 22 feet wide by 648 feet in length was planted to 'Charismatic' (Seminis, Payette, ID) on March 21, 2007, and a similar block planted to 'Vaquero' (Nunhems, Parma, ID) on March 24, 2008. The onions were planted as two double rows on a 44-inch bed. The double rows were spaced two inches apart. The seeding rate was 137,000 seeds per acre. Lorsban 15G was applied at planting in a 6-inch band over each double row at a rate of 3.7 oz. / 1,000 feet of row for onion maggot control.

The plots were 27 feet long by 3.67 feet wide in 2007 and 37 feet long by 3.67 feet wide in 2008. Insecticide applications were made with a CO_2 pressurized back pack sprayer. Materials were applied with water at 41.3 gpa in 2007 and 35 gpa in 2008. Each treatment was replicated four times. Thrips counts were made weekly by visually counting the total number of thrips on fifteen plants in each plot. Iris Yellow Spot Virus severity was evaluated in August, but infection incidence was low both years. Yield and grade evaluation was completed in late September.

Results

The weekly average thrips counts are listed in Table 3. The 2007 growing season had light thrips pressure with little visual damage, while the 2008 season had much higher populations with some treatments showing severe damage. There were significant differences in thrips populations between treatments in 2007, but not in 2008. The 2008 thrips population data is suspect because of errors by the students employed to do the counting. Visual evaluations of thrips damage were done on July 22 and July 31 to determine differences in thrips feeding activity (Table 4).

In 2007, Treatments 1, 4 and 17 had significantly more thrips than the other treatments, with treatment 17 having significantly more thrips than treatments 1 or 4. Treatment 1 is the untreated check, and treatment 4 is an untreated check except for the seed coat application of Regent. Treatment 17 is a synthetic pyrethroid only treatment and illustrates the problem of thrips resistance to this class of insecticides in the Treasure Valley. Synthetic pyrethroid insecticides are not selective and are more harmful to beneficial insect populations than other insecticides. This treatment had the lowest total yield of any of the treatments in 2007 and 2008. As a Comparison, treatment 15 is weekly Lannate applications, and treatment 16 is a combination of Lannate and Warrior. The addition of the synthetic pyrethroid did not improve thrips control over Lannate alone, and tended to decrease super colossal and total yield.

Regent was applied to the onion seed coat of treatments 4, 7, 8 and 9, with non-Regent treatments 1, 5, 11 and 13, respectively, as a comparison. In addition, treatment 9 had straw applied as a mulch on June 15, at a rate of about 1,000 lb/acre. The Regent treatments had higher yields than the non-treated in three of the four treatments, but it was only significant in treatment 8 versus treatment 11, which was the grower standard treatment. The Regent treatments were made with seed treated in the spring of 2006, and may have lost some of its effectiveness during storage. The Regent plus straw mulch was not better than the comparison treatment (treatment 13).

Treatment 2 had four 8.0 oz. treatments of Carzol SP applied at two-week intervals, while all of the other treatments were applied at weekly intervals. It had significantly higher average thrips numbers compared to the best treatments, but provided high total yield in spite of the high thrips counts (Table 5). This data would suggest that three 8.0 oz. applications (legal application rate of Carzol SP is 24.0 oz/acre under 2006 and 2007 section 18 emergency registrations) might be better than the single 20.0 oz. application which growers are currently using. They should be integrated into the grower standard practice of using spinosad insecticides (Success, Radiant) early, followed by Carzol SP, then finish the season with Lannate.

The highest yielding treatments for 2008 were combinations of Lannate, Carzol SP, Movento and Radiant (Table 5). This combination of treatments gave consistently higher colossal, super colossal and total yield than other insecticide combinations, even when two or three of the insecticides were the same.

Conclusions

Synthetic pyrethroid use varied, depending on treatment, from no effect, to significantly less thrips control and lower yields. Growers are urged not to add this class of insecticides to their tank mixes unless they know they have had positive experiences on their farm.

Multiple applications of Carzol SP at the 8.0 oz. rate appear better than a single 20.0 oz. application.

Combinations of Lannate, Carzol SP, Movento and Radiant consistently gave the highest yield of colossal, super colossal and total yield.

Table 1. Rotation trial – insecticide treatments applied during the growing season. Malheur Experiment Station, Oregon State University, Ontario, OR. 2007.

	Application		Application		Application		Application		Application		Application		Application	
	29-May	Rate/a	8-Jun	Rate/a	13-Jun	Rate/a	20-Jun	Rate/a	27-Jun	Rate/a	3-Jul	Rate/a	12-Jul	Rate/a
1	UTC		UTC		UTC		UTC		UTC		UTC		UTC	
2	Carzol	8.0 oz			Carzol	8.0 oz			Carzol	8.0 oz			Carzol	8.0 oz
3	Lannate	3.0 pt	Carzol	16.0 oz	Lannate	3.0 pt	Carzol	16.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
4*	UTC		UTC		UTC		UTC		UTC		UTC		UTC	
5	Diazinon	1.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Diazinon	1.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
	MSR	3.0 pt					MSR	3.0 pt						
6	Diazinon	1.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Diazinon	1.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
	MSR	3.0 pt	Warrior	3.84 oz	Warrior	3.84 oz	MSR	3.0 pt	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz
	Warrior	3.84 oz					Warrior	3.84 oz						
7*	Diazinon	1.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Diazinon	1.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
	MSR	3.0 pt					MSR	3.0 pt						
8*	Success	6.0 oz	Success	6.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Carzol	16.0 oz	Lannate	3.0 pt	Lannate	3.0 pt
	AzaDirect	16.0 oz	AzaDirect	16.0 oz										
9**	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz
	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz
10	Diazinon	1.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Carzol	20.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
	MSR	3.0 pt												
11	Success	6.0 oz	Success	6.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Carzol	16.0 oz	Lannate	3.0 pt	Lannate	3.0 pt
	AzaDirect	16.0 oz	AzaDirect	16.0 oz										
12	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	Lannate	3.0 pt	Carzol	16.0 oz	Lannate	3.0 pt	Lannate	3.0 pt
	MSR	3.0 pt	MSR	3.0 pt	MSR	3.0 pt								
13	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz
	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz
14	Success	6.0 oz	Success	6.0 oz	Success	6.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
	AzaDirect	16.0 oz	AzaDirect	16.0 oz	AzaDirect	16.0 oz	Carzol	8.0 oz	Carzol	8.0 oz	Carzol	8.0 oz	Carzol	8.0 oz
15	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
16	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz
17	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz
18	Lannate	3.0 pt	Carzol	12.0 oz	Lannate	3.0 pt	Carzol	12.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt

*Seed treated with Regent insecticide.

**Seed treated with Regent insecticide, straw mulch applied on June 15.

Table 2. Rotation trial – insecticide treatments applied during the growing season. Malheur Experiment Station, Oregon State University, Ontario, OR. 2008.

	Application		Application		Application		Application		Application		Application		Application		Application	
	5-Jun	Rate/a	12-Jun	Rate/a	19-Jun	Rate/a	25-Jun	Rate/a	2-Jul	Rate/a	11-Jul	Rate/a	21-Jul	Rate/a	28-Jul	Rate/a
1	Radiant	6.0 oz	Radiant	6.0 oz	Radiant	6.0 oz	Radiant	6.0 oz	Lannate	2.0 pt	Lannate	2.0 pt	Lannate	2.0 pt	Carzol	20.0 oz
2	Lannate	2.0 pt	Lannate	2.0 pt	Lannate	2.0 pt	Lannate	2.0 pt	Lannate	2.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	Carzol	20.0 oz
3	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	Lannate	3.0 pt	Radiant	6.0 oz	Carzol	20.0 oz
4	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Carzol	20.0 oz	Lannate	3.0 pt	Radiant	6.0 oz	Radiant	6.0 oz
5	Radiant	6.0 oz	Radiant	6.0 oz	Radiant	6.0 oz	Radiant	6.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Carzol	20.0 oz
6	UTC		UTC		UTC		UTC		UTC		UTC		UTC		UTC	
7	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Batallion	20.0 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz	Warrior	3.84 oz
8	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	MSR Aza Direct	3.0 pt 2.0 pt	Lannate	3.0 pt	Carzol	20.0 oz	Lannate	3.0 pt	Lannate	3.0 pt
9	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	Movento	5.0 oz	Carzol	8.0 oz	Carzol	8.0 oz	Carzol	8.0 oz	Lannate	3.0 pt
10	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	AgriMek	1.0 pt	Carzol	20.0 oz	Lannate	3.0 pt	Radiant	6.0 oz	Lannate	3.0 pt
11	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	Radiant Aza Direct	6.0 oz 2.0 pt	Movento	5.0 oz	Carzol	20.0 oz	Lannate	3.0 pt	Radiant	6.0 oz	Lannate	3.0 pt
12	Radiant Aza Direct	6.0 oz 2.0 pt	Movento	5.0 oz	Movento	5.0 oz	Carzol	20.0 oz	Lannate	3.0 pt	Radiant	6.0 oz	Lannate	3.0 pt	Lannate	3.0 pt
13	Radiant Aza Direct	6.0 oz 2.0 pt	AgriMek	1.0 pt	AgriMek	1.0 pt	Lannate	3.0 pt			Carzol	20.0 oz			Lannate	3.0 pt
14	Movento	5.0 oz	Radiant	6.0 oz	Radiant	6.0 oz	Carzol	20.0 oz	Radiant	6.0 oz	Lannate	3.0 pt	Radiant Movento	6.0 oz 5.0 oz	Lannate	3.0 pt
15	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Carzol	20.0 oz	Lannate	3.0 pt	Radiant	6.0 oz	Radiant	6.0 oz
16	Success Aza Direct	8.0 oz 2.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	Carzol Penncap M	20.0 oz 3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
17	Success Aza Direct	8.0 oz 2.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	Lannate Batallion	3.0 pt 20.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
18	Success Aza Direct	8.0 oz 2.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	Carzol Lannate	20.0 oz 3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Radiant	6.0 oz

19	Success Aza Direct	8.0 oz 2.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	MSR	3.0 pt	Lannate	3.0 pt	Carzol	20.0 oz	Lannate	3.0 pt	Lannate	3.0 pt
20	Success Aza Direct	8.0 oz 2.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	AgriMek	1.0 pt	Lannate	3.0 pt	Carzol	20.0 oz	Lannate	3.0 pit	Lannate	3.0 pt
21	Success Aza Direct	8.0 oz 2.0 pt	Radiant	6.0 oz	Radiant	6.0 oz	Carzol Aza Direct	20.0 oz 2.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
22	Radiant Aza Direct	6.0 oz 2.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Carzol	12.0 oz	Radiant Aza Direct	6.0 oz 2.0 pt	Lannate	3.0 pt	Carzol	12.0 oz	Radiant Aza Direct	6.0 oz 2.0 pt
23							Carzol	20.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
24									Carzol	20.0 oz	Lannate	3.0 pt	Lannate	3.0 pt	Lannate	3.0 pt
25											Carzol	20.0 oz	Lannate	3.0 pt	Lannate	3.0 pt
26													Carzol	20.0 oz	Lannate	3.0 pt

Table 3. Average thrips counts during the 2007 and 2008 growing seasons. Malheur Experiment Station, Oregon State University, Ontario, OR. 2007, 2008.

2007 Season Total		2008 Season Total	
Treatment	Average thrips/plant	Treatment	Average thrips/plant
1	7.1	1	57.8
2	4.3	2	42.9
3	3.0	3	42.7
4	6.2	4	49.4
5	3.5	5	46.2
6	4.0	6	45.6
7	3.3	7	50.7
8	3.1	8	44.8
9	3.4	9	41.6
10	3.4	10	44.7
11	3.1	11	40.5
12	3.8	12	48.0
13	3.2	13	44.0
14	2.9	14	46.5
15	3.2	15	45.9
16	3.3	16	44.6
17	9.1	17	48.9
18	3.2	18	52.7
		19	48.4
		20	48.1
		21	41.3
		22	49.2
		23	48.6
		24	46.2
		25	49.8
		26	46.0
LSD (.05)=	1.2		ns

Table 4. An evaluation of thrips feeding damage to onion foliage averaged over July 22 and July 31. Malheur Experiment Station, Oregon State University, Ontario, OR. 2008.

Treatment #	Rating*
4	0.6
11	0.6
12	0.6
9	0.6
14	0.7
18	0.8
15	0.9
23	0.9
3	0.9
16	0.9
21	0.9
22	0.9
1	1.1
5	1.1
10	1.1
2	1.1
19	1.2
20	1.2
8	1.3
17	1.3
24	1.3
13	1.6
25	1.9
26	2.7
6	3.2
7	3.9
LSD=(.05)	0.4

*Rating:
0 = no visual thrips feeding damage
5 = foliage white from feeding damage

Table 5. Carzol SP rotation trial yield. Malheur Experiment Station, Oregon State University, Ontario, OR. 2007.

Treatment	Medium	Jumbo	Colossal	S. Col	Col + S Col	Total Yield
	-cwt/acre-					
1	9.7	291.5	612.5	295.7	908.2	1209.4
2	12.3	305.3	629.2	357.4	986.6	1304.3
3	14.3	359.9	553.8	192.3	746.1	1120.3
4	28.0	680.8	481.5	76.7	558.2	1267.0
5	13.9	341.0	523.9	205.3	729.2	1084.1
6	5.9	351.8	521.4	152.6	674.0	1031.7
7	26.3	555.2	503.0	62.7	565.7	1147.3
8	32.3	609.9	543.7	142.3	686.1	1328.3
9	29.3	512.3	478.4	162.7	641.1	1182.8
10	6.0	374.6	554.8	261.6	816.4	1197.0
11	10.7	311.9	516.2	309.4	825.6	1148.2
12	13.0	394.7	558.3	221.2	779.4	1187.1
13	14.1	349.3	555.9	299.4	855.3	1218.8
14	19.1	367.5	492.2	380.1	872.3	1259.0
15	8.9	320.5	565.5	281.9	847.4	1176.9
16	13.8	375.9	587.1	154.2	741.3	1131.0
17	20.1	588.7	374.0	48.3	422.3	1031.2
18	5.0	337.7	500.5	293.3	793.8	1136.5
LSD (.05)	12.7	119.4	N.S.	103.6	180.3	152.4

Table 6. Carzol SP rotation trial yield. Malheur Experiment Station, Oregon State University, Ontario, OR. 2008. (Displayed in highest total yield to smallest.)

Treatment	Medium	Jumbo	Colossal	S. Col	Col + S Col	Total Yield
	- cwt/acre -					
11	49.3	854.6	347.2	36.1	383.3	1287.2
14	12.0	861.4	361.2	33.8	395.1	1268.5
9	20.7	853.7	337.7	44.8	382.5	1256.9
12	14.3	819.2	373.4	24.8	398.3	1231.8
15	39.7	902.2	266.1	17.3	283.4	1225.2
3	28.2	874.6	300.3	20.4	320.6	1223.4
10	33.6	919.5	254.0	11.0	265.1	1218.1
20	16.4	902.8	275.2	21.0	296.2	1215.4
18	11.3	880.7	288.7	21.1	309.8	1201.9
23	27.4	913.6	229.3	11.5	240.7	1181.7
4	21.2	841.6	284.1	20.2	304.3	1167.1
17	30.2	925.6	190.5	17.6	208.1	1163.9
21	23.9	896.1	217.4	17.4	234.8	1154.8
22	15.3	928.8	197.2	9.9	207.1	1151.1
24	28.8	875.8	227.7	17.1	244.8	1149.4
19	19.4	883.0	228.2	18.3	246.6	1149.0
1	25.2	920.9	188.4	7.8	196.2	1142.3
16	19.3	875.7	237.9	8.8	246.7	1141.7
5	42.3	882.4	192.6	11.2	203.9	1128.6
8	26.0	902.6	178.7	14.3	193.0	1121.6
2	33.1	832.3	243.0	8.2	251.2	1116.5
13	41.9	866.5	151.6	7.2	158.8	1067.2
25	37.8	892.2	109.5	0.0	109.5	1039.4
26	50.7	889.8	55.7	1.5	57.2	997.6
6	63.2	800.5	39.6	0.0	39.6	903.2
7	125.2	599.3	3.3	0.0	3.3	727.7
LSD (.05)	27.4	84.8	88.8	16.1	94.7	84.4

SOUR SKIN DETECTION IN VIDALIA ONIONS USING A GAS SENSOR ARRAY

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Introduction

Vidalia onions' lack of pungency, along with other factors, makes them susceptible to various fungal and bacterial diseases and have a shorter shelf life (Maw et al., 1989). It is reported that on average, there are roughly 20% losses due to various fungal and bacterial diseases during CA storage in a typical year. However, on occasion undetected pathogens can ruin an entire room of onions in CA storage (Boyhan and Torrance, 2002). Among the various diseases, sour skin is a bacterial disease that can easily infect onion bulbs both in the field and postharvest bulbs. Sour skin is caused by the bacterium *Burkholderia cepacia* (formerly known as *Pseudomonas cepacia*) and it can infect onion plants and bulbs with contaminated soil and water serving as a source of inoculum. In order to reduce postharvest losses, infections must be either prevented in the field or infected onions must be detected and removed prior to being stored in a CA room. Since there are limited measures that can be taken in the field, improved detection and grading procedures offer the most feasible means of reducing disease losses. It is known that compositional changes in organic volatile compounds may occur during fruit and vegetable ripening and vary depending on the presence of diseases and physical damage (Simon et al., 1996). Volatiles emitted by the onions can provide important information on quality, because disease onions are likely to emit different volatile compounds when compared to healthy onions. Indeed, sour skin is always characterized by its unique "sour" smell. Therefore, it is very likely that early development of sour skin could be detected by its volatile profile.

The gas sensor array, usually called the electronic nose (E-nose), is designed to provide a rapid means of differentiating volatile profiles when the identification of individual volatile compounds is not needed. The E-nose consists of an array of electronic chemical sensors which are partially specific to certain chemicals and capable of recognizing volatiles with a pattern-recognition system (Gardner and Bartlett, 1994). An effective pattern recognition model is usually as important as the chemical sensors. Several studies have been done in the past to apply the E-nose for allium research. An AromaScan electronic nose from Osmotech was applied to discriminate different *Allium* species including garlic, leek, shallot, bulb onion and spring onion (Abbey et al., 2001); the same type of the E-nose was used to evaluate onion headspace volatiles and bulb quality as affected by nitrogen, sulphur and soil type by the same group (Abbey et al., 2005). However, little work has been done to use the E-nose for onion postharvest pathogen disease detection. In this research, a commercially available electronic nose, the Cyranose 320, coupled with the support vector machine (SVM), was used to detect sour skin infection in the Vidalia onion bulbs by measuring their volatile profiles. Specifically, the objectives of this research are to:

1. Test the hypothesis that the E-nose responses to healthy onions and sour skin infested onions are significantly different;
2. Develop and validate support vector machine classification models;

Material and Methods

Bulbs of Vidalia onions (cv. Nirvana) were harvested in April 2008 and stored at 4±2°C in a cold room with a relative humidity of 80% at the Vidalia Onion Research Lab (VORL) at the University of Georgia Tifton Campus. Two sets of experiments were conducted independently to investigate whether the gas sensor array could detect sour skin in Vidalia onions. In these experiments, medium-sized onions were selected for the test. Before use, dry skins were removed, basal roots were trimmed and the bulbs were surface-sterilized using a Lysol wipe and then rinsed with sterilized, distilled water to remove chemical residues. A culture of *Burkholderia cepacia* (Bc 98-4) was obtained from the Natural Products Lab at the University of Georgia and was grown on tryptic soy agar. The culture was maintained long-term in 15% glycerol at – 80°C.

To inoculate the onions, a toothpick was used to collect a small dab of bacteria from the surface of the agar medium in a *Barkholderia cepacia* Petri dish. Then, the toothpick was stabbed into the onion to create a wound and introduce the bacteria. Similar physical wounds without pathogen inoculation were created for control onions. Equal number of onions were used for a negative control. Sour skin inoculated onions were put in the incubator at 30°C to promote the growth of *B. cepacia* and development of sour skin; the control onions were stored in an air-conditioned room at 24°C. Prior to each measurement, both inoculated and control onions were held at room temperature for an hour to reach the equilibrium of headspace gas. The samples were analyzed 3-6 days after inoculation (dai).

Onion bulbs were placed in 89 mm wide mouth glass bottles sealed with 100 x 100 mm aluminum foil squares to facilitate the accumulation of headspace gas. The headspace gas was allowed to accrue for 12 h before each sampling. The headspace samples from onions were analyzed by the Cyranose 320 electronic nose (Smith Detection Inc., Pasadena, CA), a gas sensor array consisting of 32 individual thin-film carbon-black polymer composite chemiresistors. The E-nose sampling needle was inserted through the aluminum foil to draw headspace volatiles and the aluminum foil was resealed after each sampling. Sampling periods were ~2 minutes. The sensor chamber was purged with ambient air between each measurement.

The detection of sour skin was divided into two phases. The first phase is the discovery and training phase; and the second phase is the validation phase. In the first phase, a non-blinded analysis of the volatiles of onions was performed to explore possible differences between control and treatment groups. The cross validation within the training group was performed. When it is determined that the treatment onions and control healthy onions emit distinct volatile profiles, the trained model using the training dataset will be tested on the validation datasets which are collected in a totally different samples and not seen in the training phase. By this means, the classification model will be tested on its robustness when a new dataset is tested.

Training datasets and validation datasets for the sour skin detection were collected in two separate experiments with different onion samples. In both experiments, onions were continuously measured using the gas sensor from 3 dai to 6 dai when the bacteria grew rapidly. In the training dataset, 20 onions half inoculated with *Botrytis alli* and half healthy were measured. Each onion was measured twice and the average was calculated from the duplicates, a total of three data samples were collected from each onion sample. In total, 240 samples were collected with equal number of control and sour skin infested onions. In the validation phase, 30 onions were measured and in total 359 data samples were collected for four days with 181 samples as control and 178 samples as sour skin infested. The final sample numbers were shown in table 1.

Principal Component Analysis (PCA) is a multivariate technique used for reducing the dimensionality of the data while preserving the structure. The E-nose multi-dimensional data were compressed using (PCA) prior to processing by discriminant analysis. PCA uses eigenvectors and eigenvalues to define the reduced subspace, which is a representation of the original *N*-dimension space. The principal components are linear combinations of interrelated variables. Coefficients of the linear combinations are the eigenvectors of the covariance or correlation matrix. A correlation matrix was used in this analysis to enhance the influence of small spectral features. The PCA score plot can provide information on the clustering of data, while the PCA loading values can be used to investigate the contribution from each sensor in a multi-dimensional space. Multivariate analysis of variance (MANOVA) was used for statistical test of whether onion volatiles depend on its treatment. SAS software (SAS Institute, Inc., Cary, N.C.) was applied for this purpose.

Support vector machine is a supervised learning method used for classification and regression. The basic idea of the support vector machine is that it simultaneously minimizes the empirical classification error and maximizes the geometric margin between two data sets. The nonlinear kernel function Radial Basis Function (RBF) is usually recommended due to its superior performance over other kernel functions. A preliminary computational experiment confirmed that the RBF indeed performed better and it was used in this study for the SVM model development. Data were scaled to [0, 1] range in order to avoid the dominance of the greater numerical sensor values over those small sensor values. The data classification model was developed by the computation programming software MATLAB (Mathworks, Nortic, MA).

Results and Discussion

The principal component analysis (PCA) score plot was used as an exploratory technique to investigate clustering of datasets within the multi-dimensional space. PCA scores (eigen values) were calculated and the first two principal components were used to create the 2-D PCA score plot. Figure 1 demonstrates discrimination between samples from control and sour skin group on each individual days from 3 dai to 6 dai. The percentage of variance explained by the first two principal components were also shown in the figure. Differences between these two groups showed up starting from 3 dai and they were evident in the following three days. On the first two days of the experiment, the first principal component (PC1) accounts for more than 95% of variance; while the PC1 accounts for less variance on 5 and 6 dai. However, the first two PCs invariably account for more than 98% of total variance.

The statistical test MANOVA (multivariate analysis of variance) was performed using the SAS (SAS Inc., Cary, NC) to test the null hypothesis: there was no overall type effect (control vs. sour skin) in these 240 datasets. The Wilks' Lambda statistic was used and the results were shown in table 2. Based on the calculated F-value and P-value, the null hypothesis was rejected, which means that the E-nose response to control onions and sour skin infested onions were significantly different at the significant level of 0.05 ($P<0.0001$).

Data collected in the first experiment were used for model training and cross validation. Support vector machine (SVM) model was developed to classify the data. Because the SVM has to be trained and then tested, the total dataset (240 vectors) was randomly divided into four folds and each time, 3 folds were used for training and the remaining one fold (60 vectors with 30 control and 30 treatment) was used for testing. The testing was performed in all 4 folds and the average performance across these 4 folds was evaluated in order to avoid any bias caused by certain number

of testing datasets. Only 6 sensors that were most responsive to onion volatiles were selected for classification model development (sensor selection method was presented in another paper). Table 3 shows the SVM model cross validation performance for training data set. Although the SVM model showed slight differences in four different folds, ranging from 91.7% to 98%, on average, correct classification rate of 93.8% was achieved. After this cross validation test, the SVM model was trained using all 240 datasets.

The SVM classification model trained in the previous section was validated by testing on totally different datasets collected from different set of onion samples in order to evaluate the robustness and repeatability of the classification model. Thirty onion samples with 15 healthy and 15 sour skin infested onions were collected in four days from 3 dai to 6 dai. In total, the validation data sets consist of 359 data sets among which 181 were healthy onions and 178 were sour skin infested onions (the disparity of the sample numbers between these two groups was caused by sampling errors during data collection). The SVM model trained by the training datasets achieved 85% classification accuracy for 359 testing data sets. The SVM model performed best when C=32768 and γ=1.

Figure 2. illustrates the SVM classification of 359 datasets. The x-axis represents the sample numbers; the y-axis represents the probability that each sample belongs to either of two classes: positive values indicate this sample belongs to the control group (healthy onions) while the negative values indicate this sample is a member of the sour skin group. The first 181 samples were from healthy onions; the last 178 samples were from sour skin infested onions. In order to better visualize the classification, the lines with open circles in the end were correct classifications; and lines with filled dark circles were misclassifications. It is shown that 54 healthy onions were misclassified as sour skin onions; while only one sour skin onion was misclassified as healthy onions. In summary, 55 samples were misclassified among 359 validation datasets and the total classification accuracy was 85% (304/359).

Table 4 shows the classification confusion table and other accuracy indices for the detection of sour skin. The sensitive is an index describing the model's capability to detect the sour skin when it is present; the specificity is an index describing the capability of a model that can correctly identify healthy onions when they are present; the positive predictive value is an index describing the percentage of correct rate in the predicted sour skin samples; the negative predictive value is to describe the correct rate in the predicted control onions.

Among 55 misclassifications, only one onion bulb with sour skin was misclassified as a healthy onion and the remaining 54 misclassification were all from the control group (i.e., healthy onions were misclassified as onions with sour skin). The sensitivity of the model is excellent with 99.4%; the specificity of the model is 70.2%; the positive predictive value is 76.6% and negative predictive value is 99.2%. These results suggest that the sour skin detection model has the excellent capability to detect sour skin when present; however, the model is also prone to be "over-sensitive": it misclassified roughly 30% of control onions into sour skin onions.

In summary, this research has investigated a new technique for onion postharvest disease detection using a gas sensor array and the support vector machine. Both the PCA score plots and the MANOVA statistical test proved that the responses of the gas sensor array to healthy onion bulbs and sour skin infested onion bulbs are significantly different (P-value<0.0001). The classification model development was undertaken in two phases: training and cross-validation within the training datasets and validation using new datasets. In the training stage, the model achieved 94% correct classification rate, while at validation stage, the model achieved 85% correct classification rate when it was tested on new testing datasets. This study proved the feasibility of

using a gas sensor array for the sour skin detection in the sweet onion bulbs. It will help reduce the postharvest losses of the sweet onions due to sour skin and may pave the way for a non-destructive and automatic sensing approach which will eventually replace the human labor visual inspection in the storage room in the future.

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Table 1. Samples of sour skin detection

Training set			
3 dai	C (30)	S (30)	60
4 dai	C (30)	S (30)	60
5 dai	C(30)	S(30)	60
6 dai	C(30)	S(30)	60
Total	120	120	240
Validation set			
3 dai	C (45)	S (45)	90
4 dai	C (46)	S (45)	91
5 dai	C 45	S (43)	88
6 dai	C 45	S 45	90
Total	181	178	359

Table 2. MANOVA statistic for control and Sour skin infested onions.

	Wilks' Lambda value[a]	F value	Num DF[b]	Den DF[c]	Pr>F
C Vs. S[d]	0.09766655	59.76	32	207	<.0001

[a] Wilks' lambda is s a test statistic used in multivariate analysis of variance (MANOVA) to test whether there are differences between means of different groups.
[b] Num DF refers to numerator degrees of freedom.
[c] Den DF refers to denominator degrees of freedom.
[d] C stands for control group; S stands for sour skin infested onions.

Table 3. Control vs. sour skin cross validation results

	Fold 1	Fold 2	Fold 3	Fold 4	Average
Correct Classification rate	93.3%	91.7%	91.7%	98%	93.8%

Table 4. Classification confusion table and accuracy indices of the sour skin detection using the E-nose

Predicted	Control	Sour skin present	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Control	127	1				
Sour skin	54	177				
Total	181	178	99.4% n=177/178	70.2% n=127/181	76.6% n=177/231	99.2% n=127/128

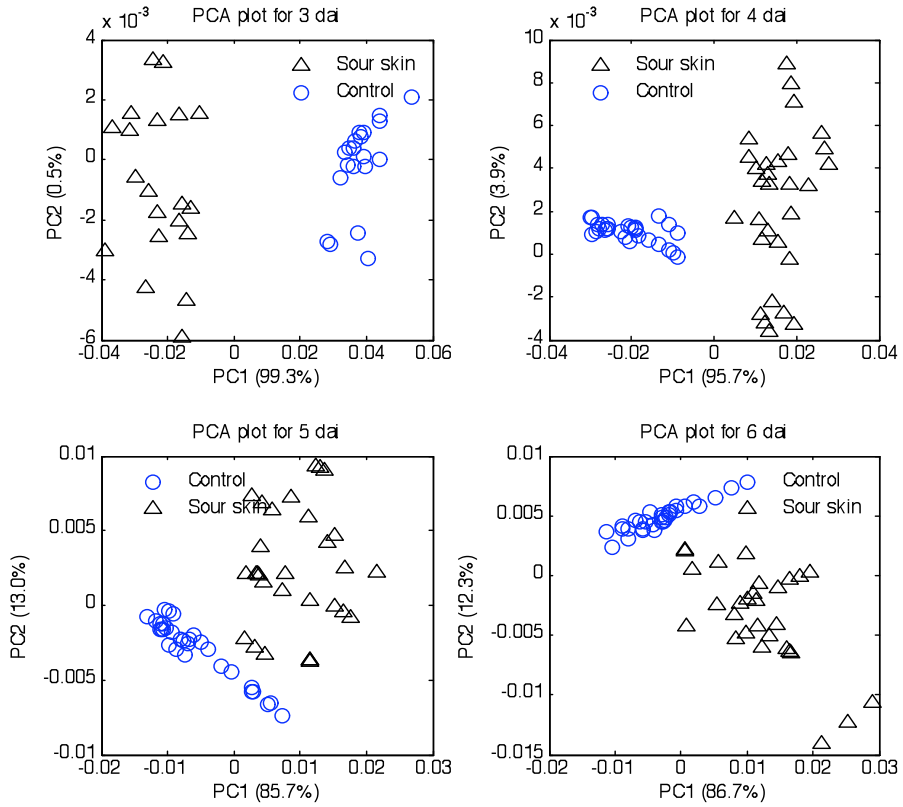

Figure 1. PCA score plot of control and sour skin group from 3 dai to 6 dai.

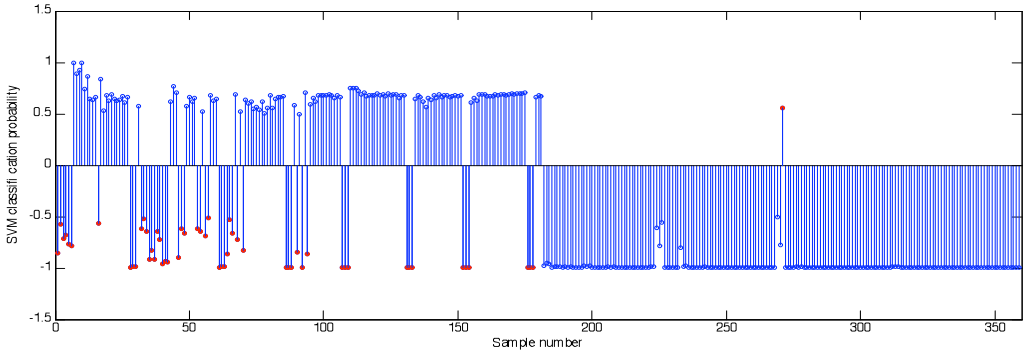

Figure 2. Support vector machine (SVM) validation results in Vidalia onions using 6 sensors.