Cornell CALS

College of Agriculture and Life Sciences

Diseases of garlic

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Main diseases of garlic

- **Diseases associated with catastrophic losses**
  - White rot (*Sclerotium cepivorum*)
  - Bloat nematode/Stem and bulb nematode (*Ditylenchus dipsaci*)
- **Diseases often present and some years of high importance**
  - Fusarium basal rot
  - Fungal bulb rots (Fusarium, Botrytis, Penicillium, Rhizopus)
  - Eriophyid mite
- **Diseases usually of minor importance**
  - Rust
  - *Embellisia allii* (now *Alternaria embellisia*)
  - Anthracnose ‘Orange Fuzzy’
  - Stemphylium leaf blight/Alternaria purple blotch?

White rot (*Sclerotium cepivorum*)
Image courtesy C. Stewart CCE

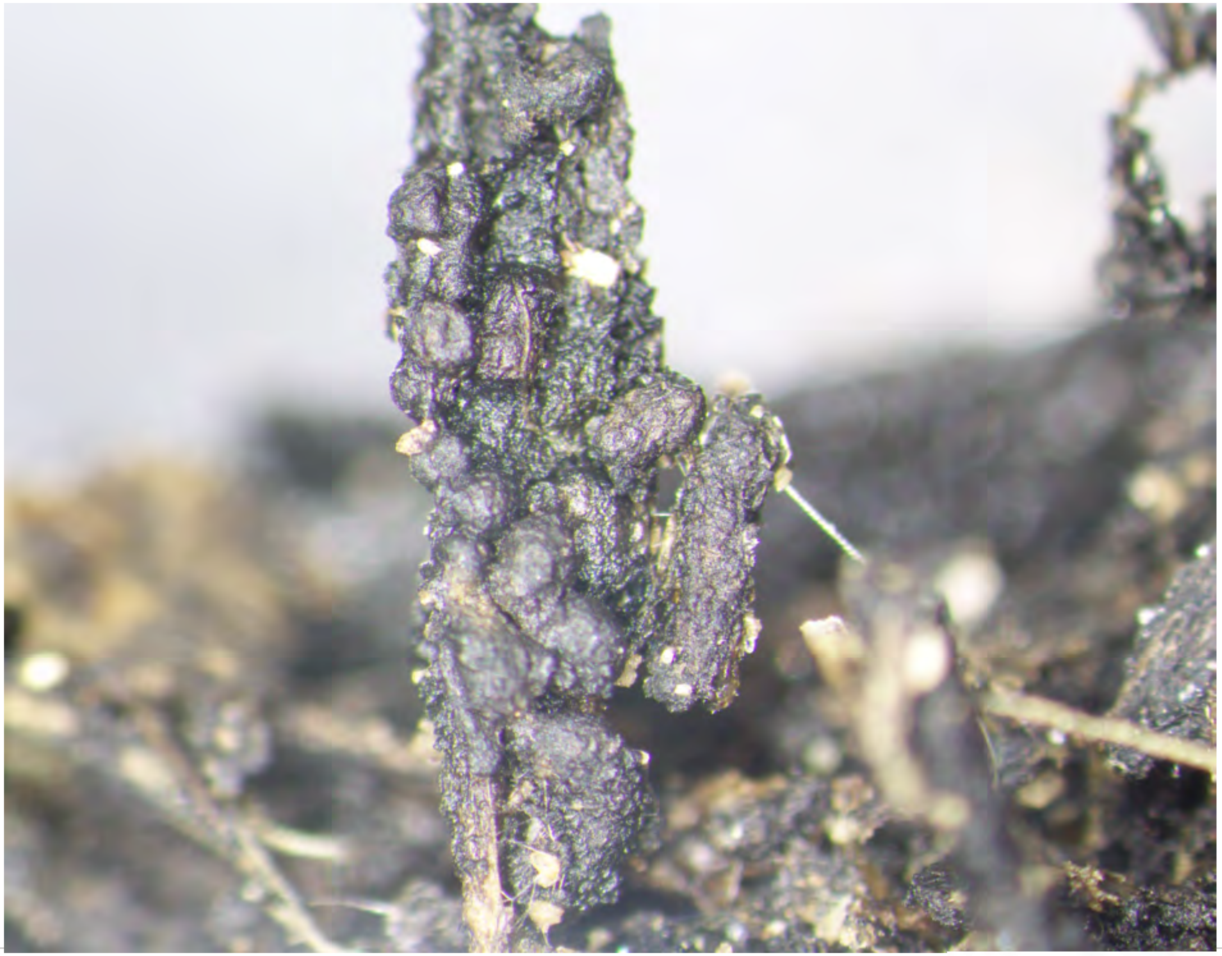
White rot (*Sclerotium cepivorum*)

- Only affects Allium species.
- Aggressive disease of Allium worldwide.
- Survives as sclerotia in soil for > 20 years.
- Eradication is almost impossible – involving 20+ yr rotations.
- No good means of control.

- **White rot has led to farms and regions going out of Allium production.**

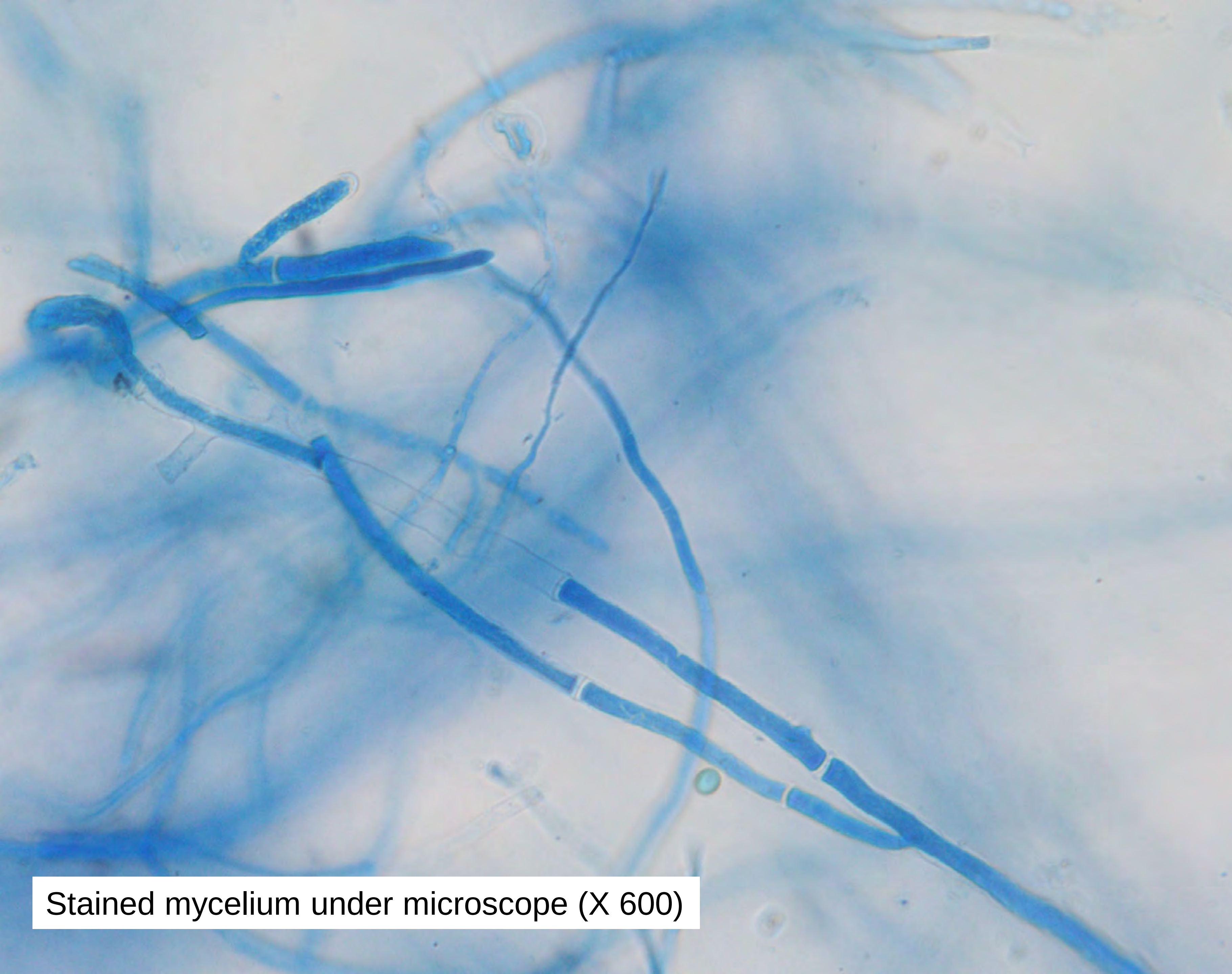
Round poppy seed sized sclerotia (< 0.5 mm)

Can also form larger or aggregated sclerotia.



White mycelium advancing between outer skins of bulb.

‘Mats’ of sclerotia forming underneath outer skins



Stained mycelium under microscope (X 600)

Low numbers of sclerotia can cause high disease incidence

Crowe, F.J., et al. 1980

https://www.apsnet.org/publications/phytopathology/backissues/Documents/1980Abstracts/Phyto70_64.htm

Density of sclerotia per kg (2.2 lb) of soil	Diseased plants (%)
< 1	≤10 %
1-10	10-85%
10-100	85-100%

- "In the western United States, except for a few areas where the growing season occurs at elevated soil temperatures restrictive to *S. cepivorum*, disease incidence in full-season Allium species is unacceptably high if inoculum density at planting is greater than 0.1 sclerotia/liter soil" (Crowe, F.J.; Carlson H.)

http://oregonstate.edu/dept/coarc/sites/default/files/publication/04_flooding_white_rot.pdf

White rot situation in NY garlic

- Not seen in NY for many years.
- Suspect samples sent in by CCE from 13 farms in July/A
  2016.
- Laboratory analysis determined:
  - 4/13 farms were identified as *Botrytis porri.*
  - 9/13 were identified as *Sclerotium cepivorum* (2 of these farms also had *Botrytis porri*).
  - ITS region of DNA of 37 isolates of Sclerotium from garlic was sequenced and were closely related to reference strains of *S. cepivorum* FJ231403: (98.5-99.8 % similar)

- *Sclerotium cepivorum* was obtained from garlic farms in Eastern, Central and Western NY.

Environmental conditions

- Sclerotia lie dormant until Alliums are planted.
- As roots grow through the soil they ‘leak’ organic sulfur compounds which stimulate sclerotial germination under the following conditions:
    - Temperature range approx. 9–22^{o}C (50-72^{o}F).
    - Optimum range approx. 15-18^{o}C (59-65^{o}F).
    - Adequate soil moisture.
    - **Infection terminates at temperatures above approx. 72^{o}F (22^{o}C)**
- Early infection leads to yellowing of young plants, which are easy to dislodge from the ground, often having white mycelium around the base.

Crowe, F.J. and Hall, D. H. (1980) Phytopathology 70: 74-78

Potential sources of white rot

- **Garlic seed**
  - Severely diseased bulbs are obvious and should be disposed of appropriately. However, possibility of non-detectable infection.
- **Soil**
  - Movement of soil, e.g. sharing of implements between infested and non-infested fields/farms, run-off water.
- **Animals**
  - Sclerotia could be carried externally (e.g. hooves). Sclerotia of other fungi survive passage internally through livestock.
  - Role of birds?
- **Compost**
  - Use of infested compost which includes infested garlic/onion residue.
- **Historical on-farm sources**
  - Sclerotia survive 20 years or more in soil. Allium weeds (e.g. *Allium vineale* and *Allium canadense*) might act as a bridge between Allium crops?

Options if white rot diagnosed on farm

- **Keep growing Alliums in the field?**
  - **No! Likely to lead to an exponential increase in disease each year as more sclerotia are produced and spread through the field, and spread to other fields with cultivation equipment.**
- **Take field out of Allium production and plant perennial crop (e.g. pasture, orchard).**
  - Removing field from cultivation and stabilizing soil will reduce potential for transfer of sclerotia to new fields (e.g. on cultivation equipment, or run-off water)

Options if white rot diagnosed (cont.)

- **If continuing to grow non-Allium crops requiring cultivation.**
  - Need to quarantine infested area as much as possible.
  - Schedule field operations in order from non infested first, to infested fields last.
  - Wash down equipment thoroughly between fields (in an area that is not going to allow wash onto cultivated fields, or picked up by tractor wheels and transported)
  - Contour area to prevent soil washing from infested to non-infested areas through rain/irrigation
  - Ensure affected area does not drain onto non-infested land, or into irrigation ponds etc.

Possible options if white rot diagnosed (cont.)

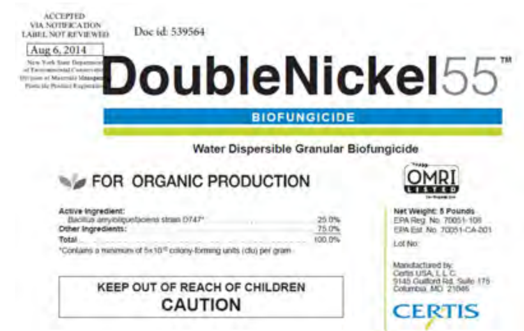
- Institute a fallow period between Allium crops and trial various treatments e.g.:
  - Sclerotial germination stimulants
  - Solarization
  - Biofumigant crop or mustard meal
  - Flooding http://oregonstate.edu/dept/coarc/sites/default/files/publication/94_white_rot_flooding.pdf
  - Biological control (Trichoderma products, Contans®)
  - Composts, chicken manure.

- Each will only be partially effective.
- Most will only affect sclerotia in the top few inches of soil.

When returning to Allium production after an Allium-free period

- **Continual vigilance** to remove, bag and dispose of any suspect plants and surrounding soil, prior to sclerotia formation.

- **Fungicides - OMRI-listed**
  Probably only effective
  once sclerotia germinate, and
  the fungus is present as mycelium.



– **Use of Trichoderma or VAM (mycorrhizal) fungi?**
http://pnva.org/files/files/WhiterotPNWV.pdf

Note: Trichoderma/VAM are living fungi and need to be integrated with other practices.

Germination stimulants

- Diallyl disulphide (DADS) – **effective but now not available**
    - Mimics naturally occurring compounds. Commercially produced as distillate of petroleum industry. Now not available.
    - >5 L/ha (1.9 gallons/acre) led to >98% germination of sclerotia in the absence of Allium crop (Crowe et al. 1994). Sclerotia germinate and die.
- Garlic powder may be of some use?
    - e.g. Garlic powder applied at 125-135 lb/A incorporated to 6 inches reduced sclerotial viability by >95% (Crowe et al. 2000). http://oregonstate.edu/dept/coarc/sites/default/files/publication/00_sclerotium_garlic_powder.pdf

Germination stimulants (cont.)

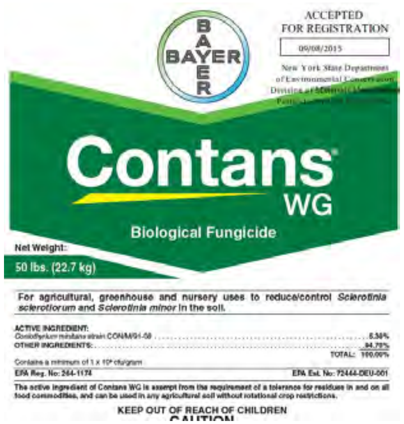
- Garlic powder
  - 100 lb/ac reduced sclerotia from 50.7 to 7.3 per quart of soil at 3 months after treatment.

  From: Dung, J et. al. 2017.
  http://ucanr.edu/sites/Vegetable_Crops/files/256997.pdf

- Regular applications of dilute garlic juice
  - E.g. Commercial food-grade garlic juice applied at 2-weekly intervals from mid-April at 1000 ppm in 2 inches of irrigation water reduced number of viable sclerotia recovered from 131 per core sample (non-treated) to 55 (with garlic juice) by mid-July. From: Crowe, F.J. et. al.

  http://oregonstate.edu/dept/coarc/sites/default/files/publication/07_germination_stimulants_white_rot.pdf

Contans® OMRI-listed



- Soil applied formulation of the fungus *Coniothyrium minitans* which colonizes and destroys sclerotia of *Sclerotinia sclerotiorum* and *Sclerotinia minor*.
- In brochure - ‘**Contans® may also be effective against *Sclerotium cepivorum***’
- Degrades sclerotia over time if incorporated into soil.

Note *Coniothyrium minitans* is a living fungus and is likely to be susceptible to other practices (e.g. soil solarization or biofumigation), so needs to be integrated carefully with your white rot control tactics.

Botrytis porri

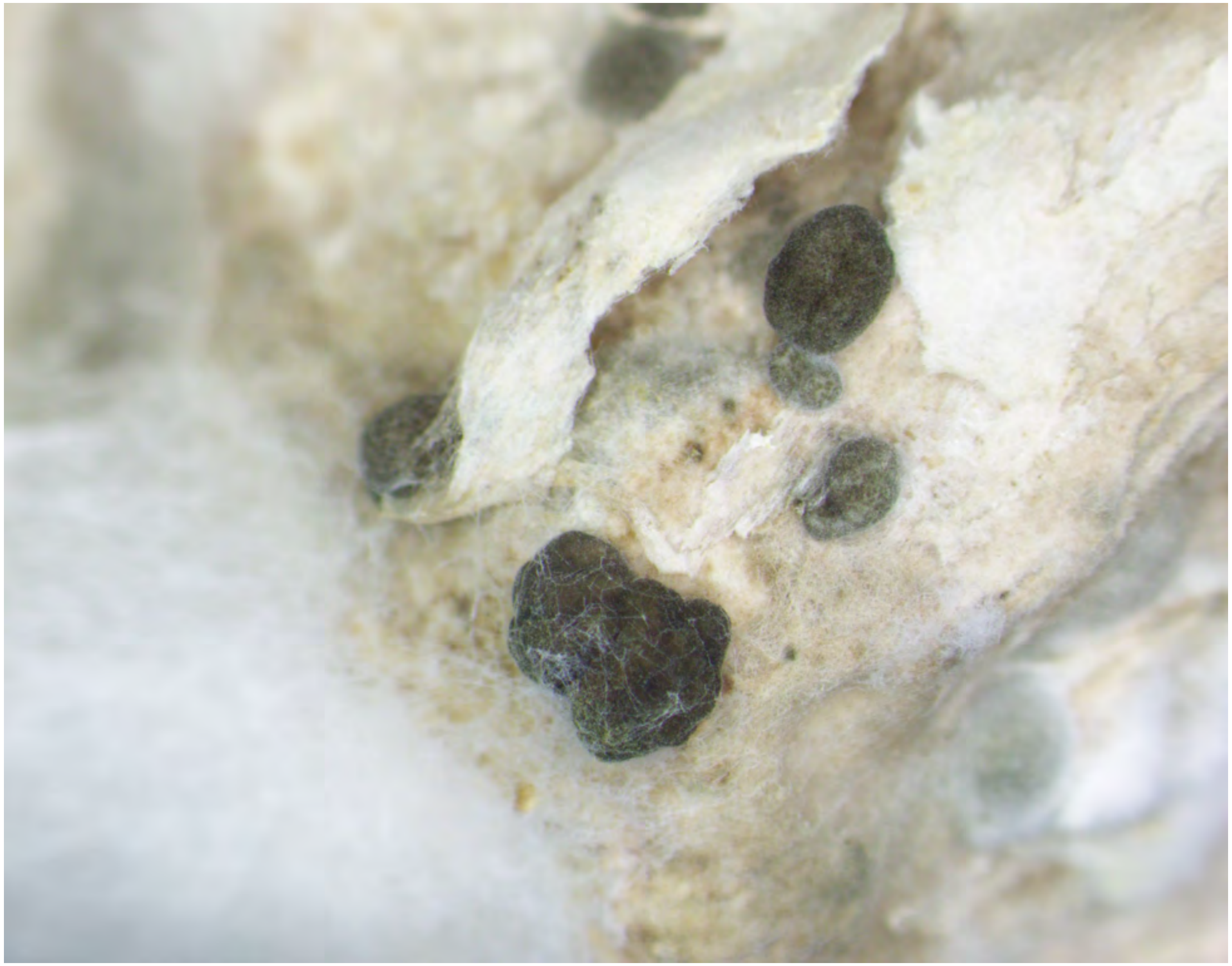
Botrytis porri also produces sclerotia and can be confused with white rot.

Botrytis generally produces larger (0.5-2.0 cm), brain-like sclerotia than *Sclerotium cepivorum*

Fungal growth (mycelium) of Botrytis is grey in color while that of Sclerotium is cream/white.

Botrytis produces tree-like conidiophores amongst mycelium which bear spores.

Botrytis sclerotia (1-2 cm long)

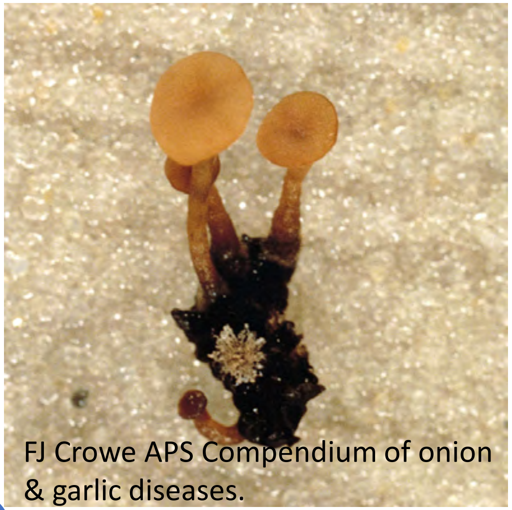


Botrytis mycelium and tree-like conidiophores on rotting clove

Garlic infected with *Botrytis porri* (left) and not infected (right). Note lesions, reddening and leaf flagging on infected plants.

Image courtesy FJ Crowe APS Compendium of onion & garlic diseases.

Life cycle of *Botrytis porri*



FJ Crowe APS Compendium of onion & garlic diseases.

Sclerotia germinate in spring to produce conidiospores or produce small brown mushrooms which release airborne ascospores

Spores infect neck region of garlic causing neck rot. Fungus grows down into bulb.

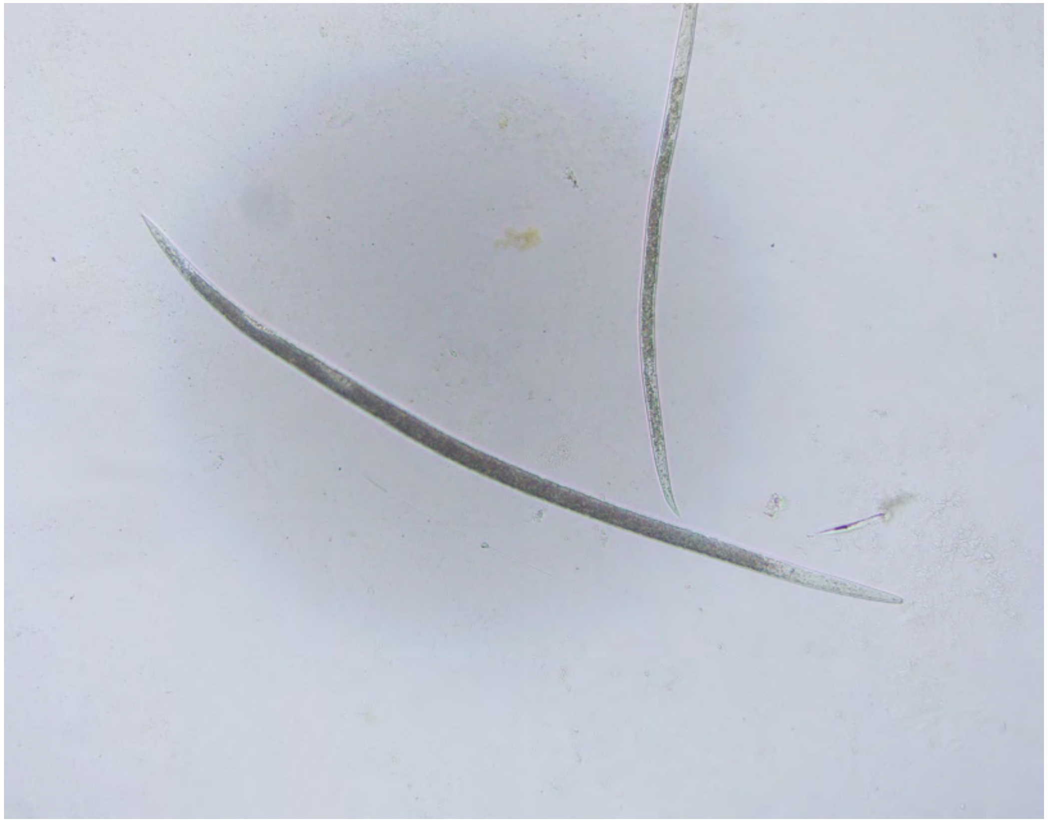
Fungal growth on bulb produces conidiospores which are spread to, and infect other plants

Sclerotia are produced on garlic bulbs and often fall into the soil to act as inoculum for the next season.

Something to watch out for!
Sclerotium rolfsii found on beet in NY (reported to infect garlic)

Round, golden-brown sclerotia

Ditylenchus dipsaci (bloat nematode, stem & bulb nematode)



Damage by *D. dipsaci*

Images courtesy EA Kurtz APS Compendium of Onion & Garlic Diseases

Fusarium basal and bulb rot

Fusarium infection may be associated with reddening (but not always)

Image courtesy FJ Crowe APS Compendium of onion & garlic diseases & pests)

Tamburini et al., Sensors **2016**, 16, 1099; doi:10.3390/s16071099

(a)

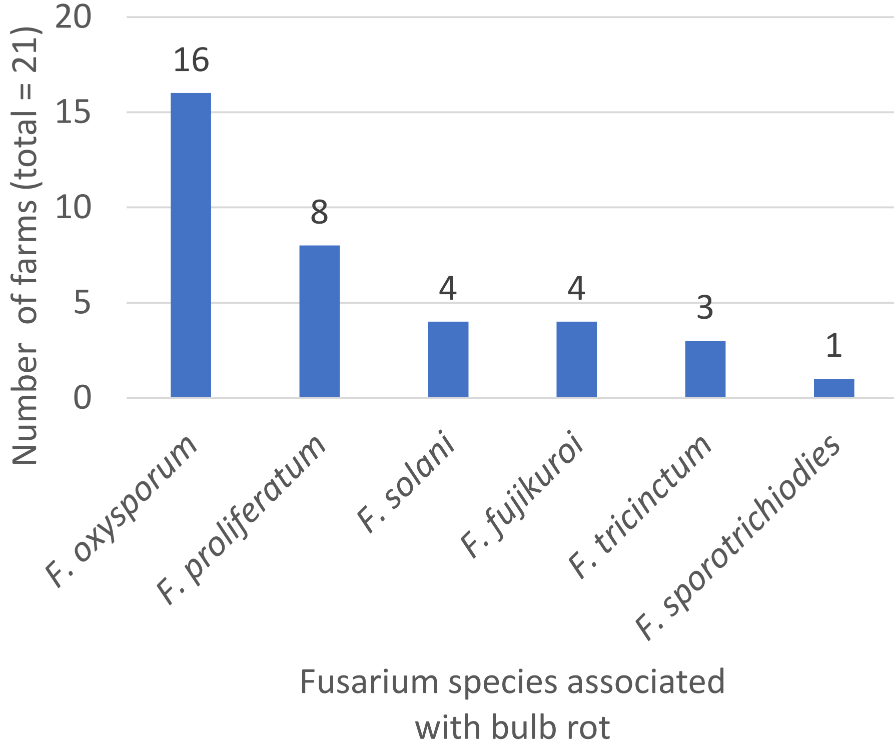
(b)

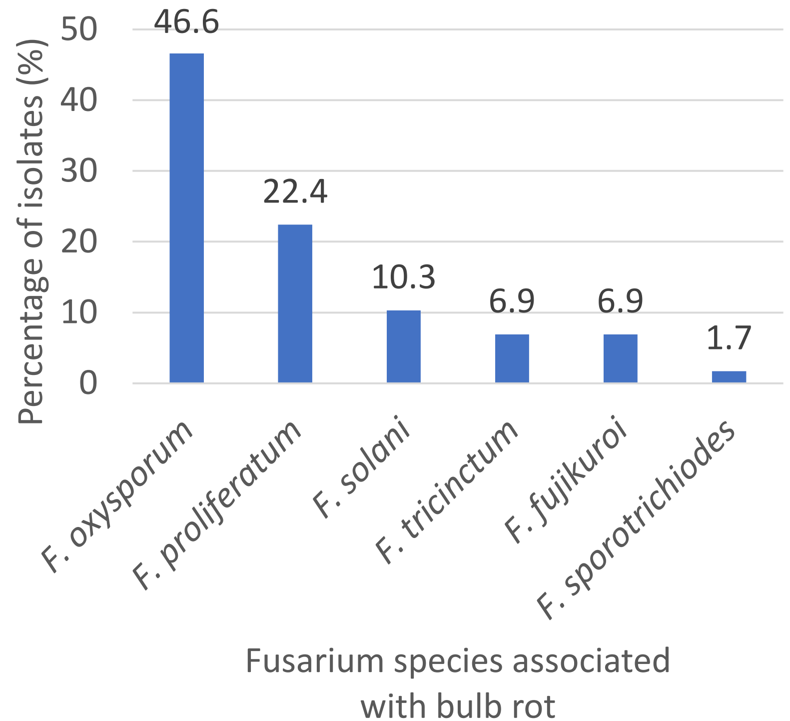
(c)

(d)

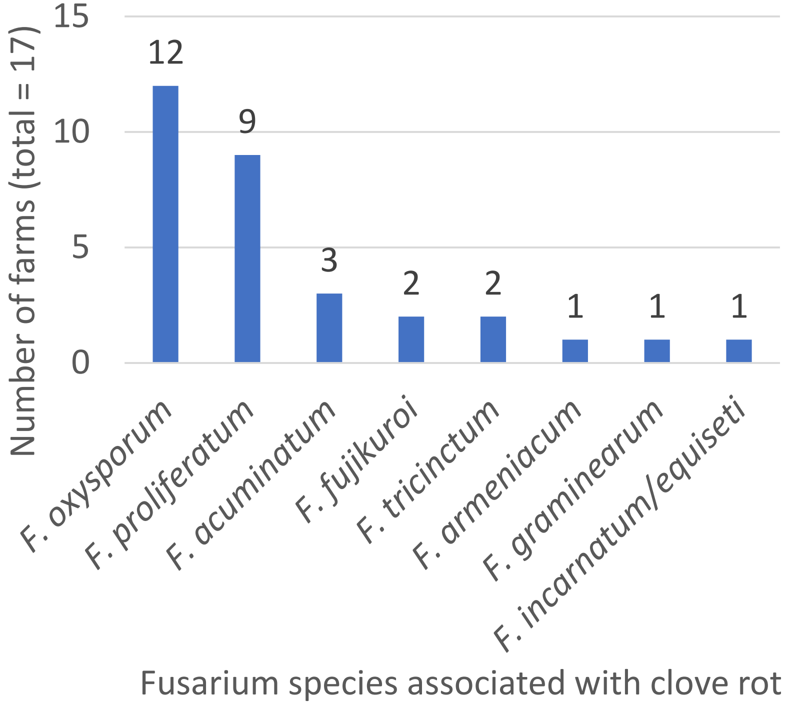
(e)

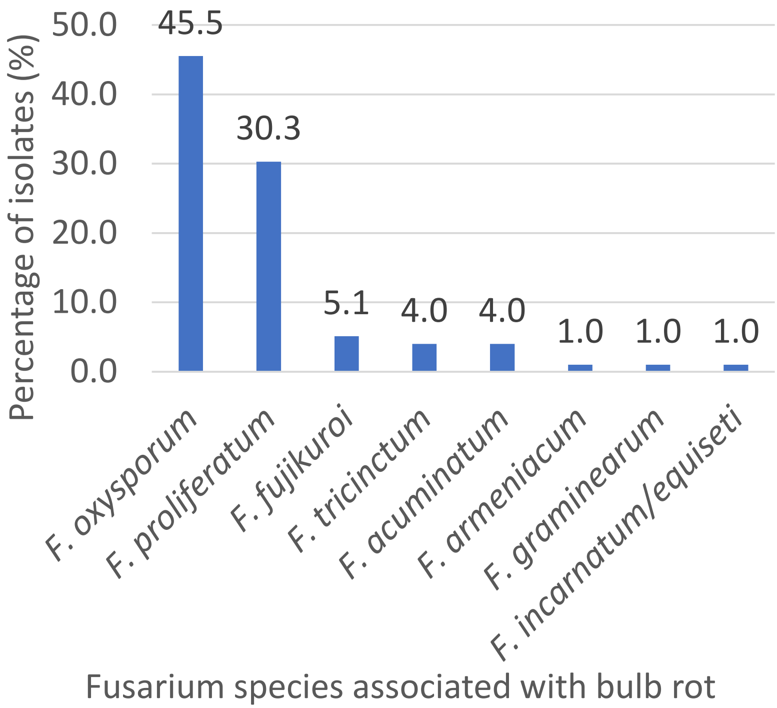

Fusarium associated with garlic bulb rot in 2016 (21 farms/57 Fusarium isolates)





Fusarium associated with garlic bulb rot in 2017 (17 farms/91 Fusarium isolates)





Fusarium proliferatum

- A cosmopolitan saprophyte and also pathogen of wheat, barley, sorghum and other cereals.
- Reported as pathogen of garlic in many countries:
- Produces various mycotoxins in infected garlic (fusaproliferin, fusaric acid, moniliofromin, fumonisin B_1 and beauvericin). Garlic likely to be a lower risk than some other crops.
- Mycotoxins often not broken down during cooking.

Fusarium disease of garlic

- Occurs with warm temperatures 68-86ºC (20-30ºC) and high humidity.
- Late season rains may favor disease.
- Symptoms in the field:
  - Reduced emergence.
  - Yellowing/browning of leaf tips progressing downward with eventual death of whole leaf.
  - Poorly developed root system (sometimes with white mycelium).
  - Stem plate and outer scales may crack open.
  - Purplish red discoloration on stems and bulbs.

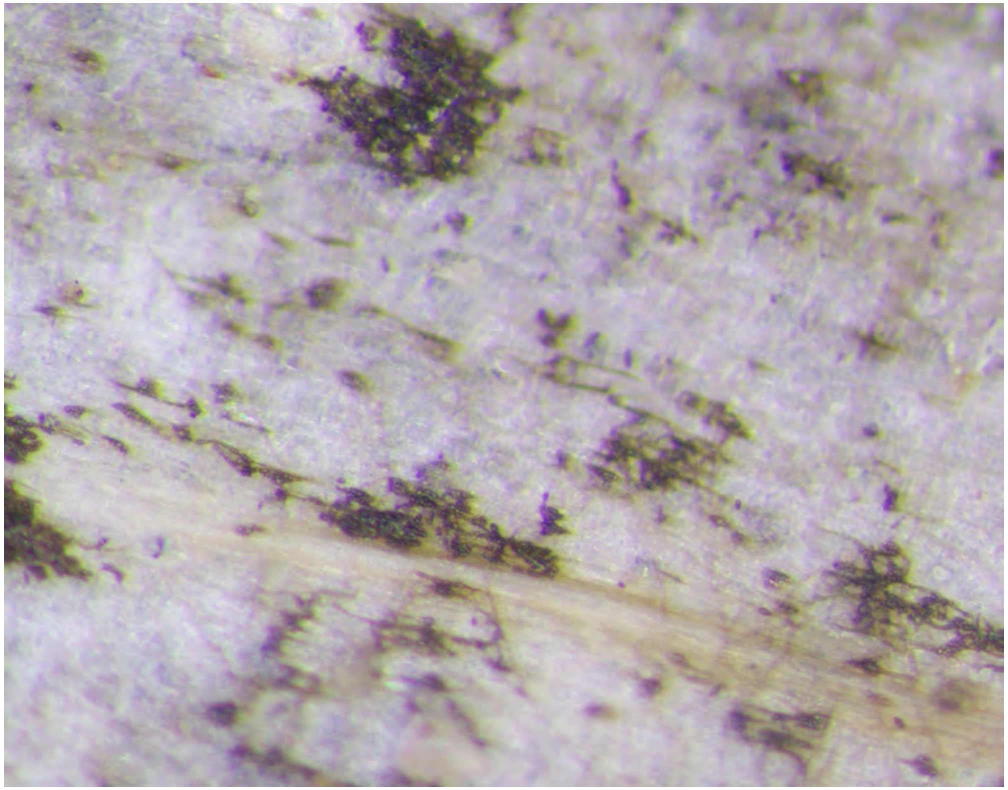
Symptoms in storage

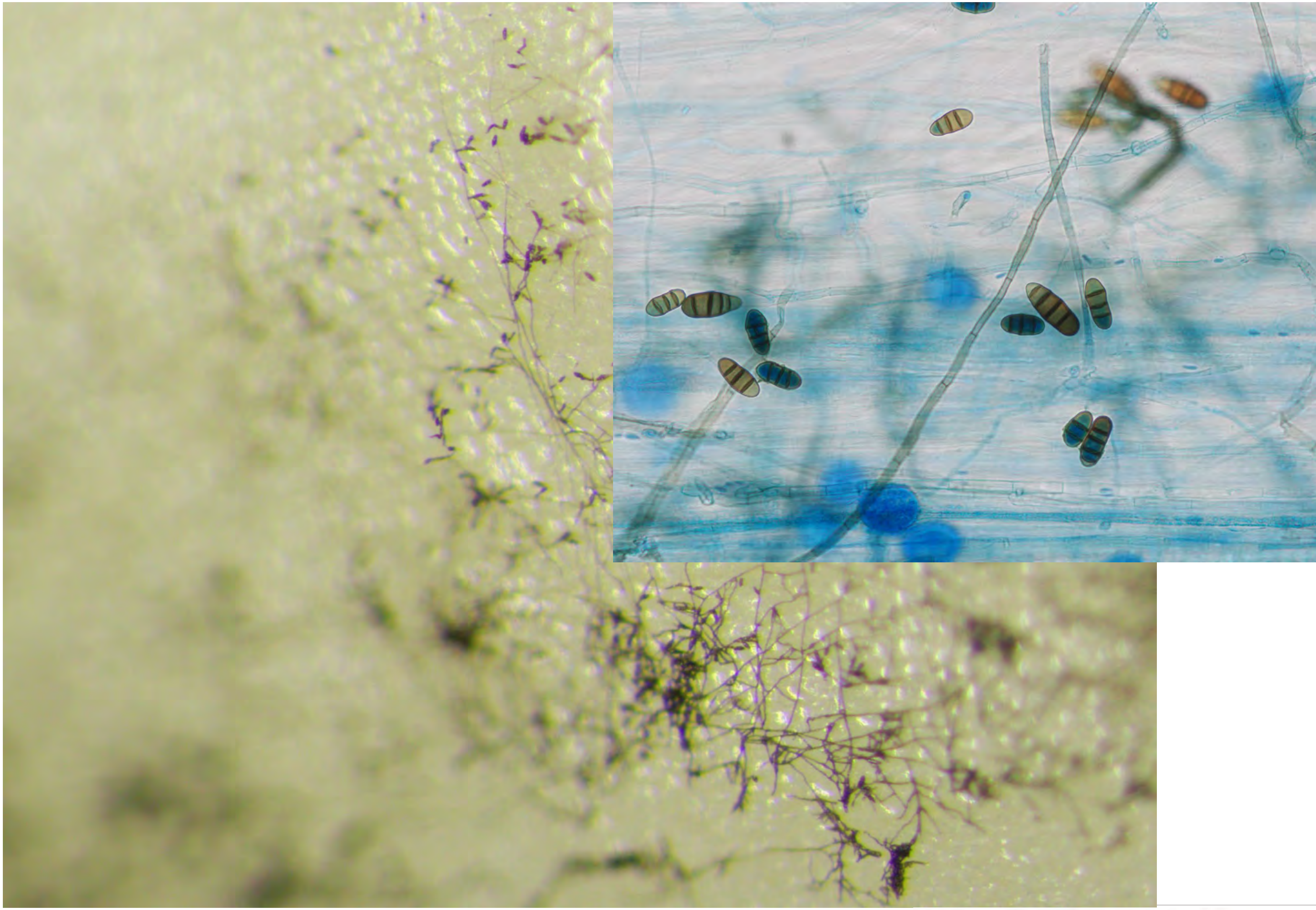
- Sunken brown/yellow rotting lesions.
- Bulbs can be soft, brown and watery when cut open.
- Fungal growth may be present on the cloves or in the lesions - often white or light pink to reddish in color.
- Cracks form in cloves, cloves dry, become crinkled and shrunken.

Control strategies

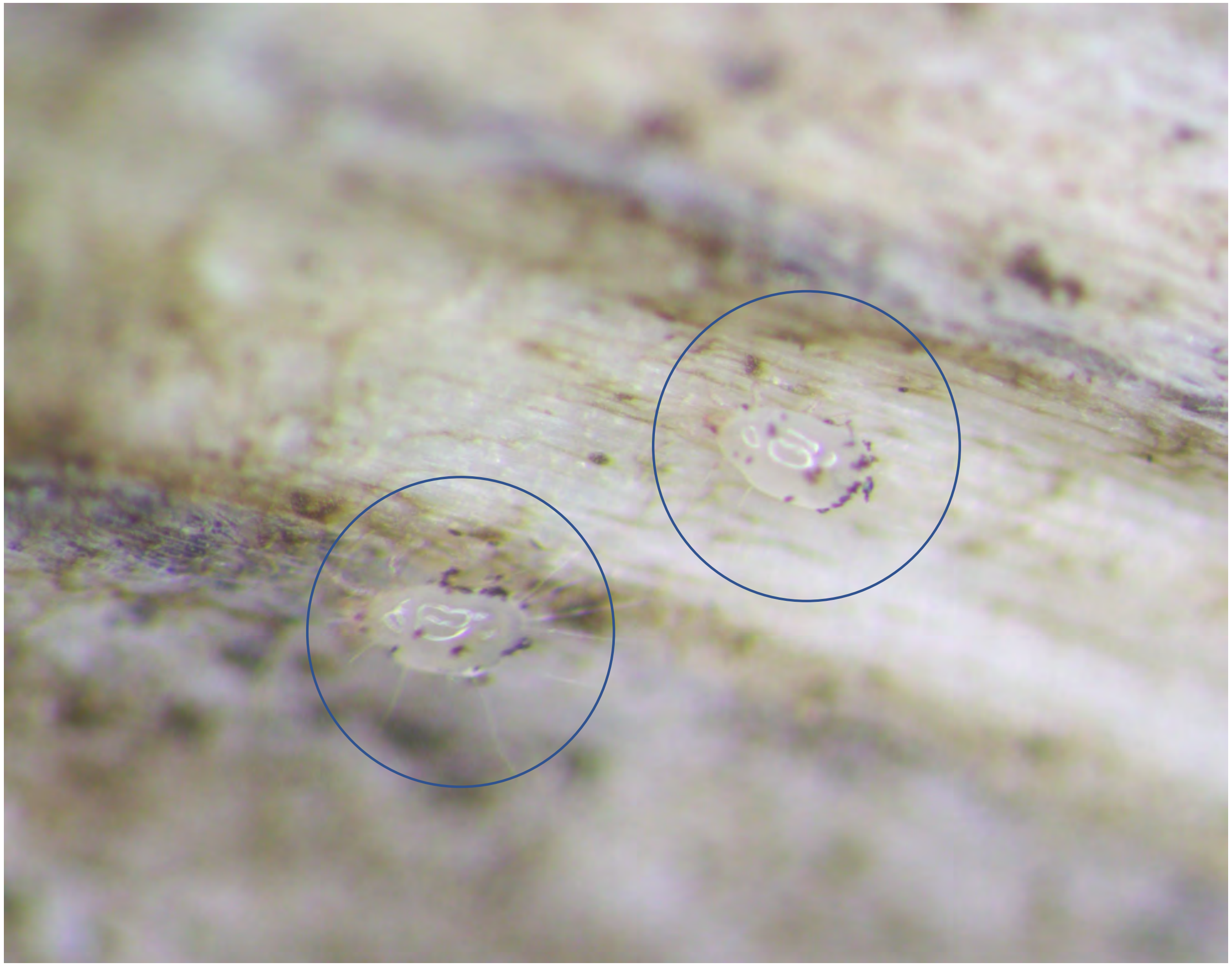
- Avoid planting diseased seed.
- Remove infected plants during the season
- Crop rotation away from Allium (3-4 yr)
  - Solarization?
  - Biofumigation should have some efficacy.
- Avoid storing diseased bulbs.
- Store bulbs at cool temperatures with low humidity and good ventilation.

Alternaria embellisia (63 x) usually causes only superficial damage to outer skins.

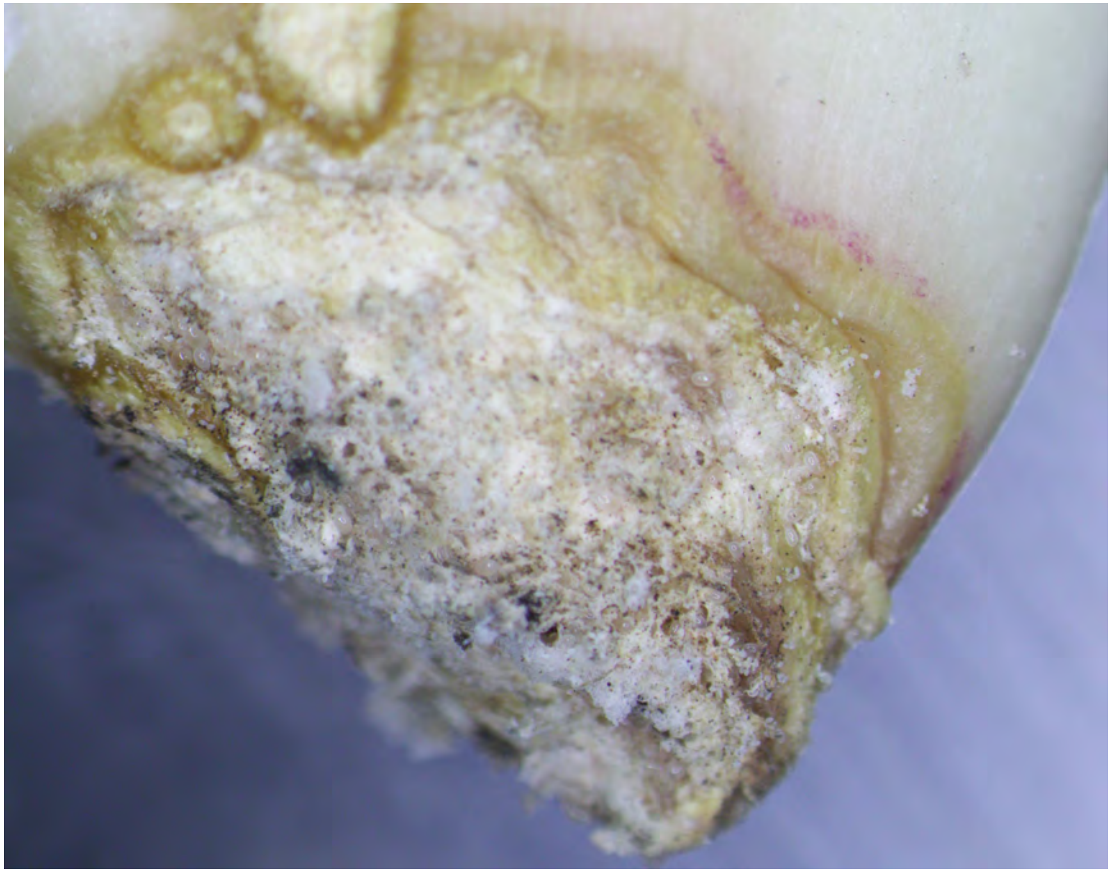




Spores of *A. embellisia* being carried by bulb mites.

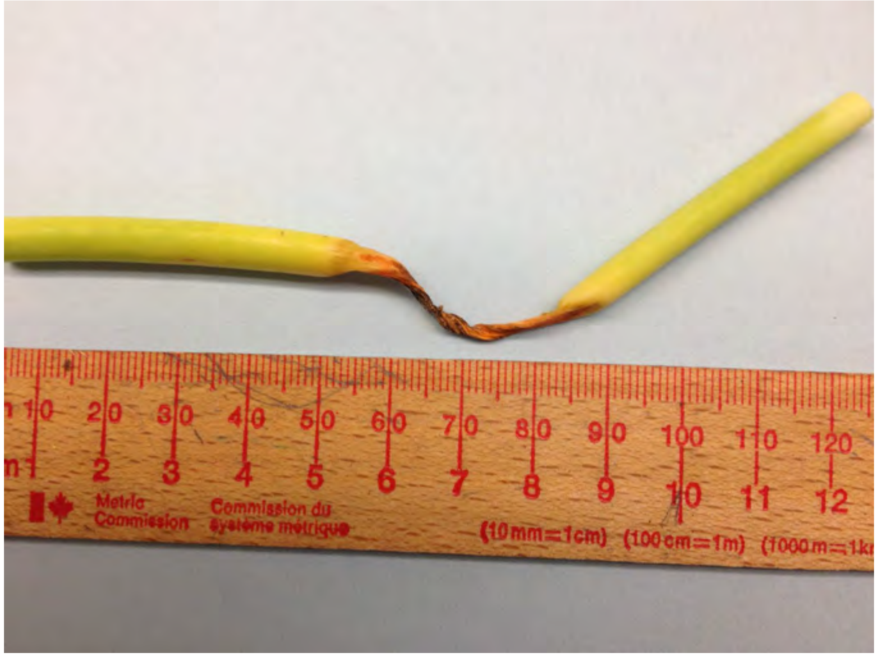


Sometimes *A. embellisia* can be associated with more serious clove rot.

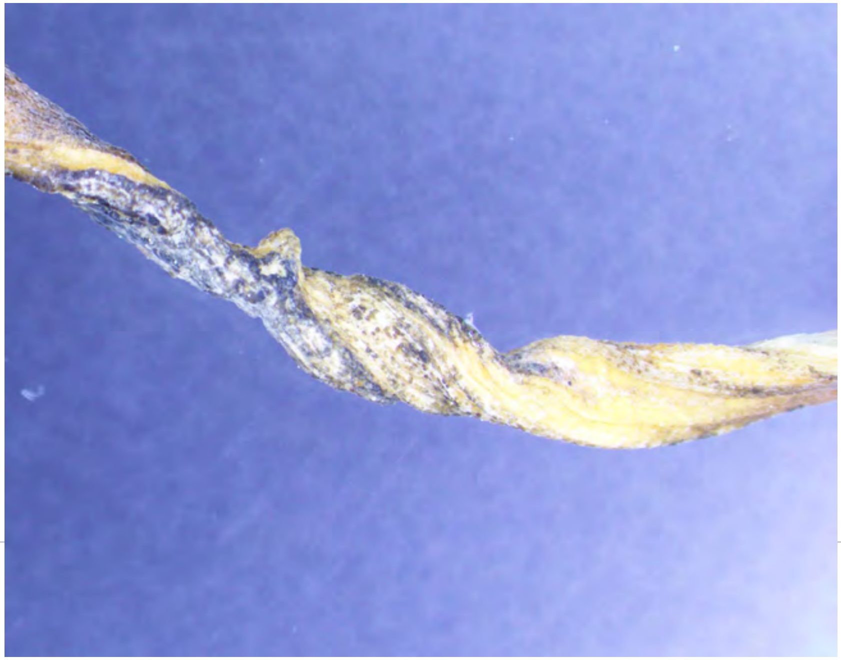


Anthracnose of garlic
‘Orange fuzzy scape!’

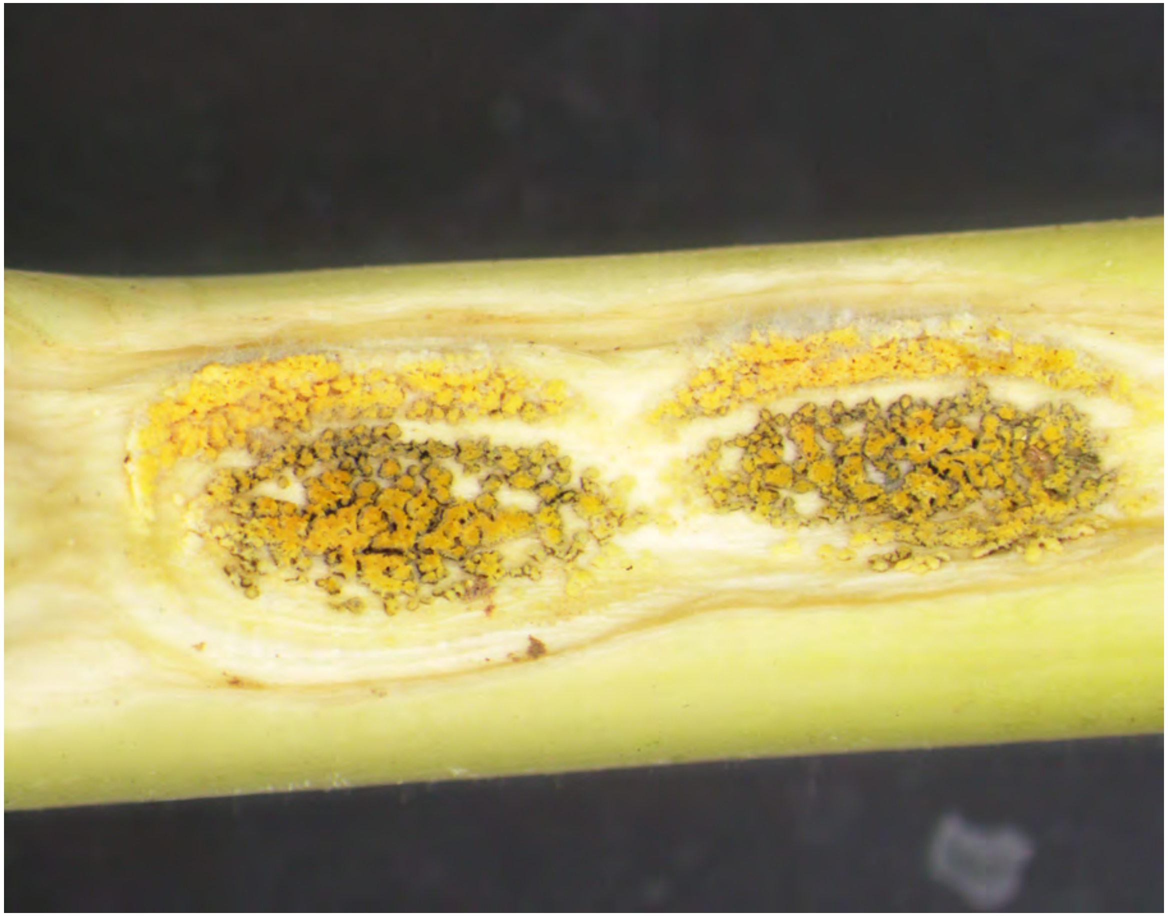
- First noted on elephant garlic scape (*Allium ampeloprasum*)



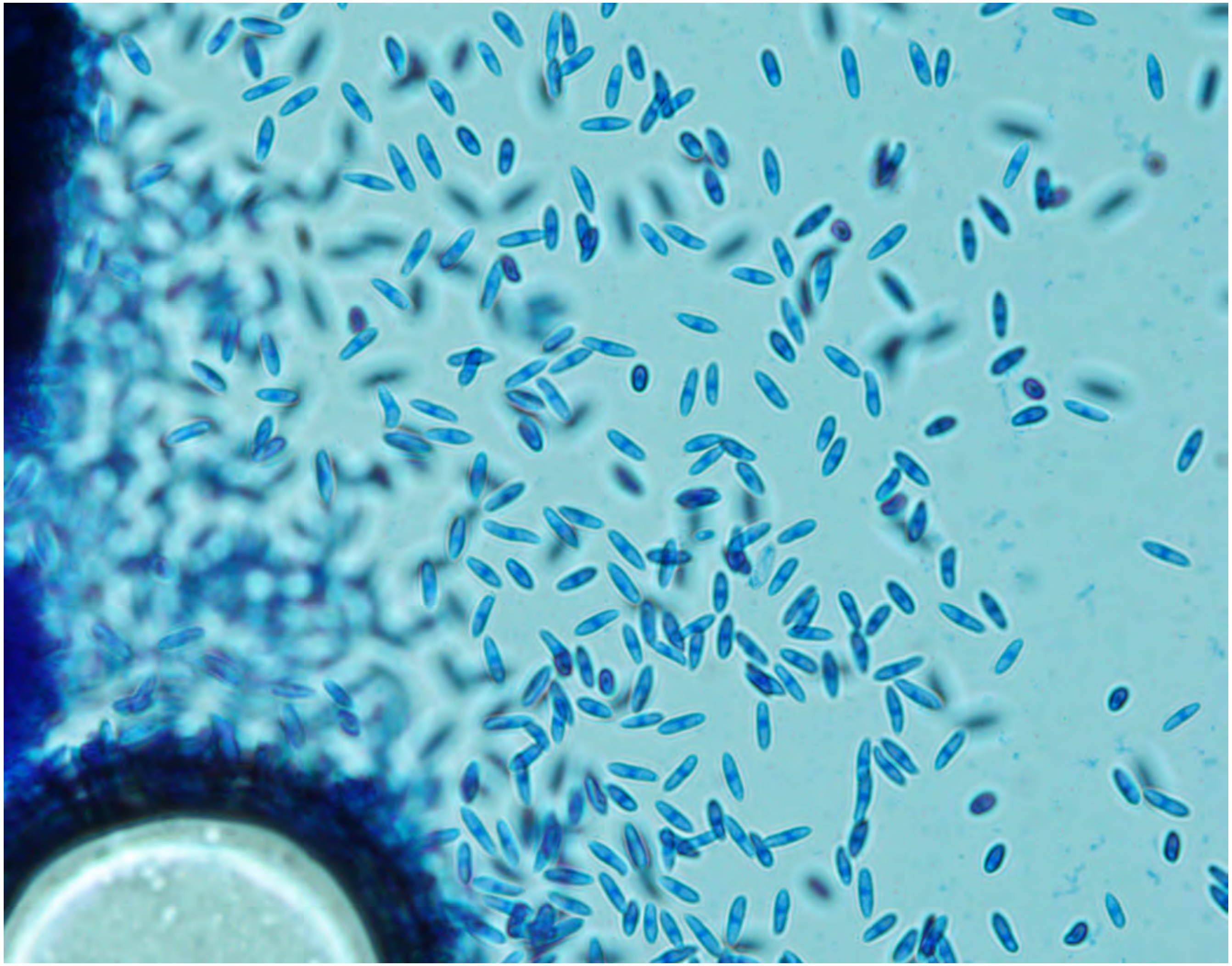
Twisting and girdling at intervals along scape.



Fungus produces masses of spores in brightly colored structures (acervuli) within lesions.



Masses of conidia are produced which can be splash dispersed to adjacent plants.



Cause of anthracnose

- Identified fungus as *Colletotrichum fioriniae*

- This fungus is also associated with rots in fruit
  - E.g. Apple bitter rot, Strawberry anthracnose.

- Disease has been noted on scapes of *Allium sativum* and *Allium ampeloprasum* in farms around NY.

- In garlic the disease appears to be confined to the scape?

***Rhizopus stolonifer* on garlic from New York.**

University of Maine "Mushy Rot" of garlic. https://extension.umaine.edu/ipm/ipddl/plant-disease-images/garlic-mushy-rot-ss/

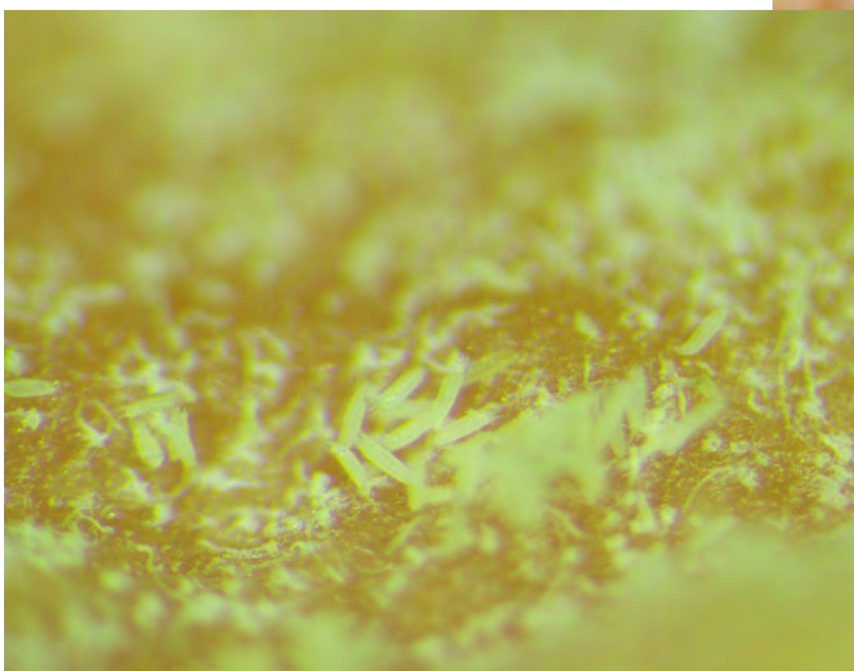
Same fungus causes black bread mold

Eriophyid mites

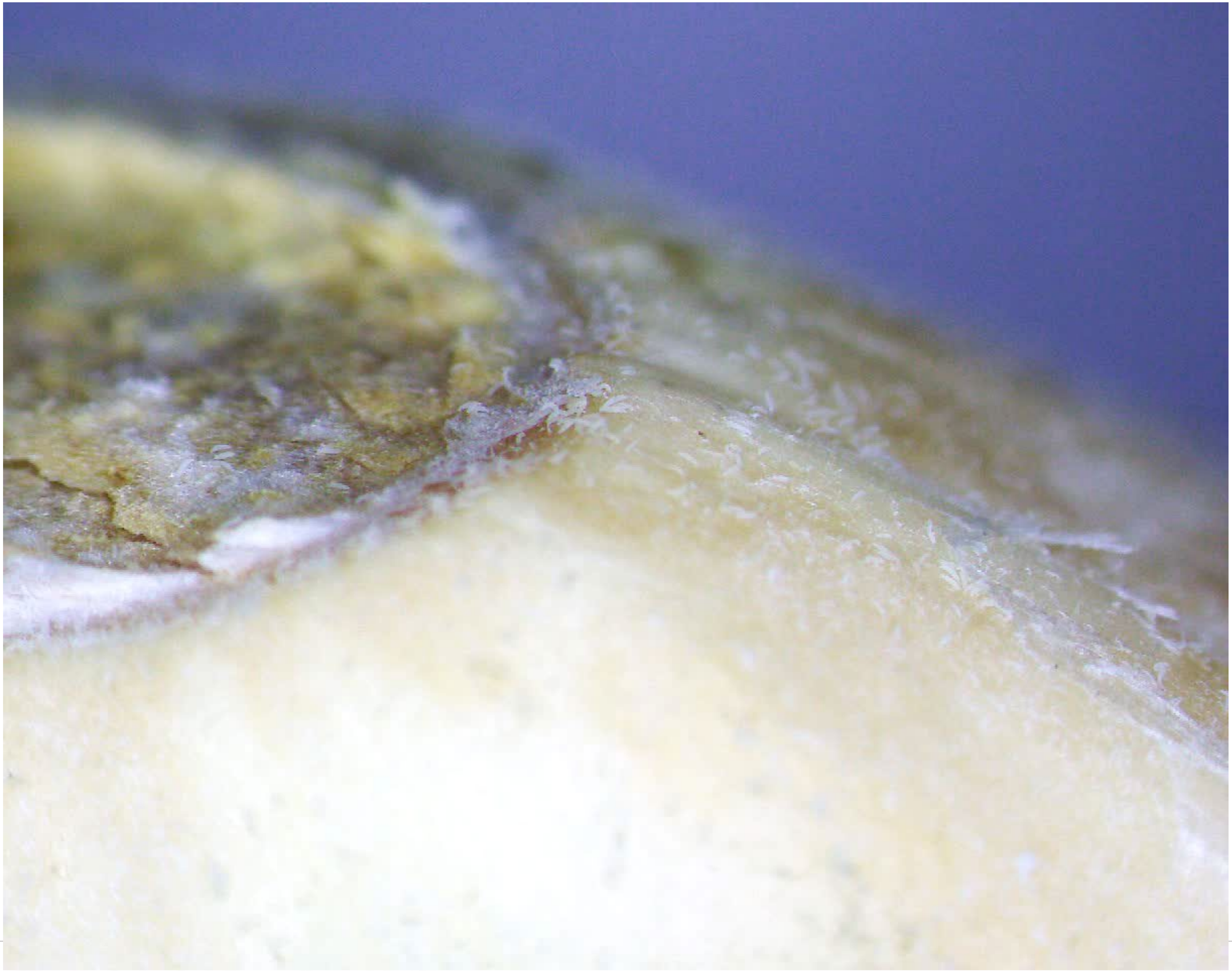
What mite that be?

Clove discolored (tan) and shrunken.

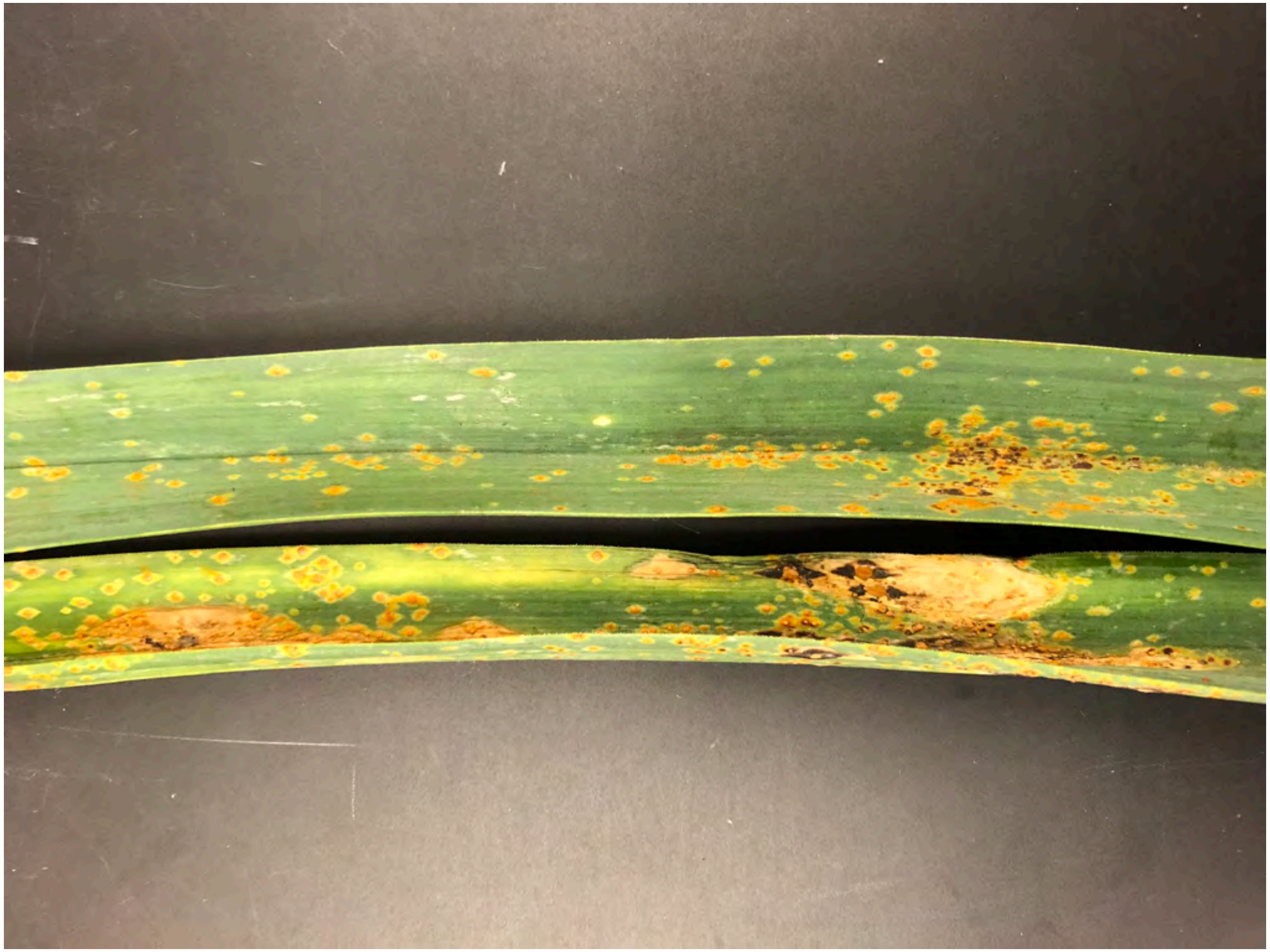
Surface appears covered in dusty or wax-like deposits which are bodies of eriophyid mites.



Eriophyid mite (approx. 0.2 mm long)

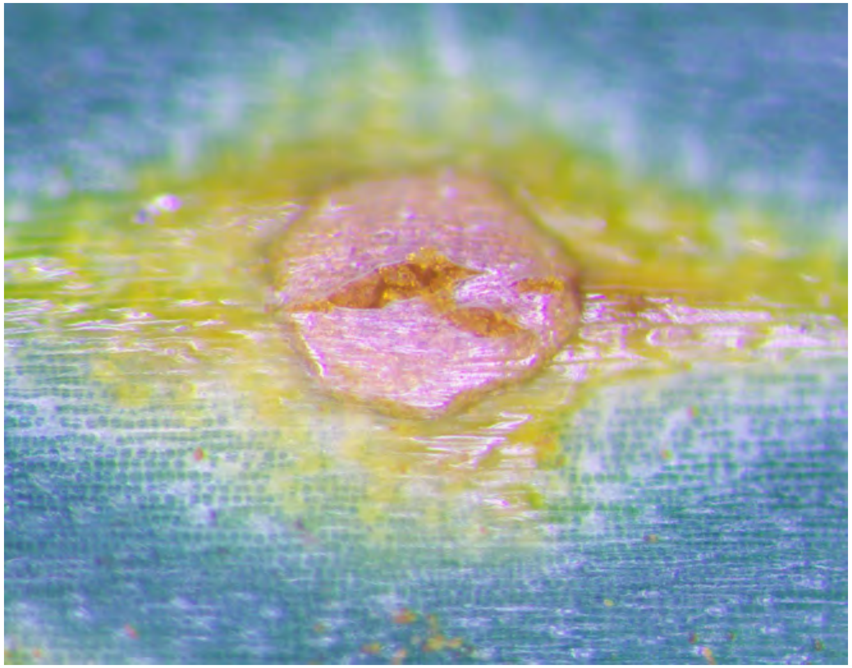


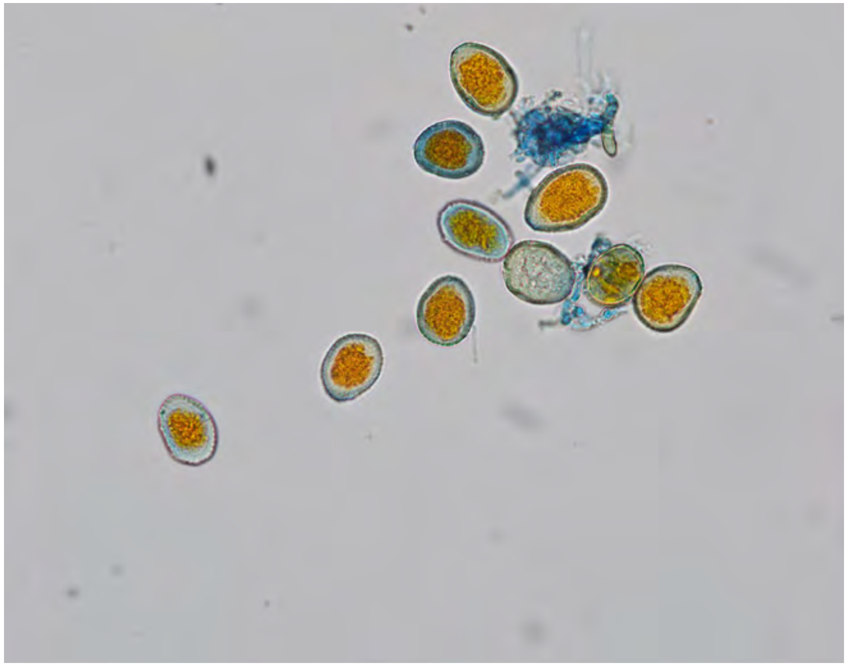
Garlic Rust



Rust fungus produces blister like uredinia with orange urediniospores and brown spots with teliospores.

Blister-like uredinia containing orange urediniospores.





Rust

- Initial sources of rust are (i) infected planting material and (ii) wind-borne spores from other fields.
- Once established will overwinter in crop debris.
- Infection promoted by high plant density, excessive N-nutrition.
- Infection occurs between 41-77° F (54-70° F optimum) and RH >97% for 4 hr.
- Pustules form 9 days after infection.
- If plants are severely affected bulb size may be reduced and bulbs can lack dry outer protective skins.

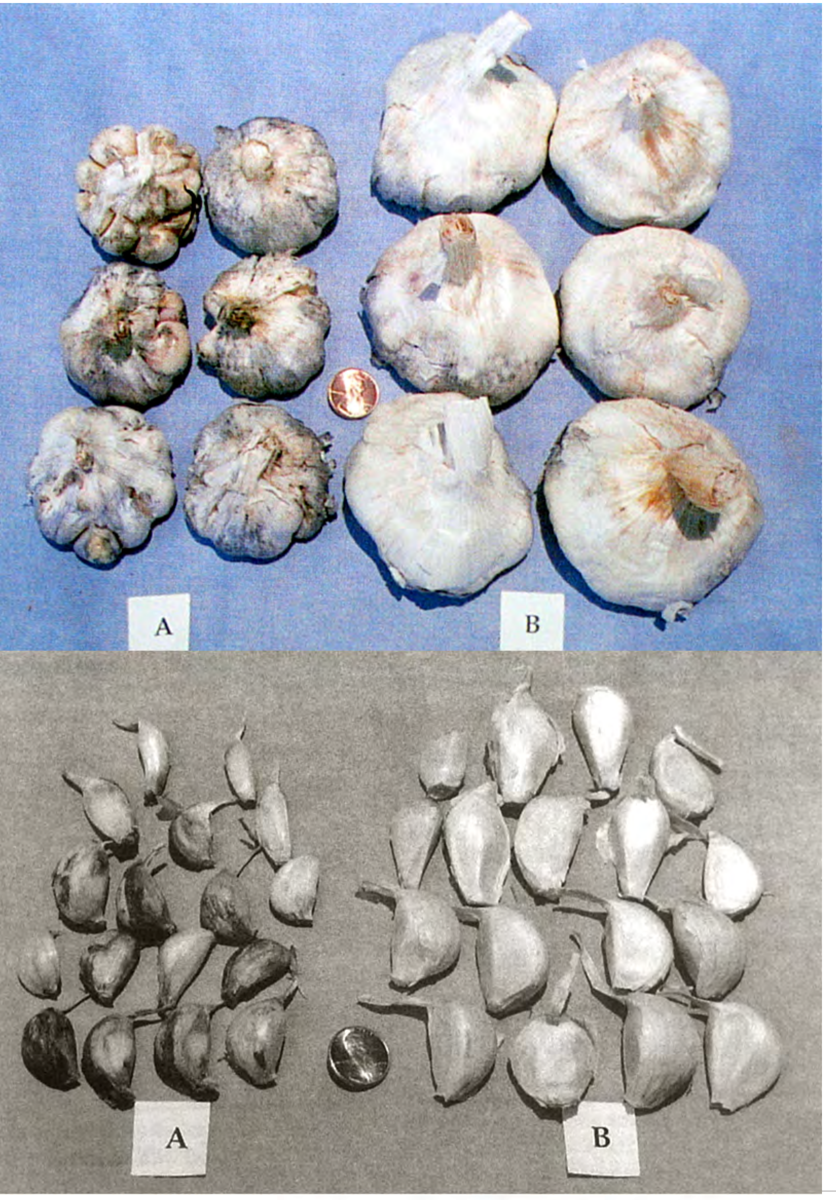
- Meg McGrath (Cornell LIHREC) provides more information at:

http://blogs.cornell.edu/livegpath/gallery/garlic/garlic-rust/

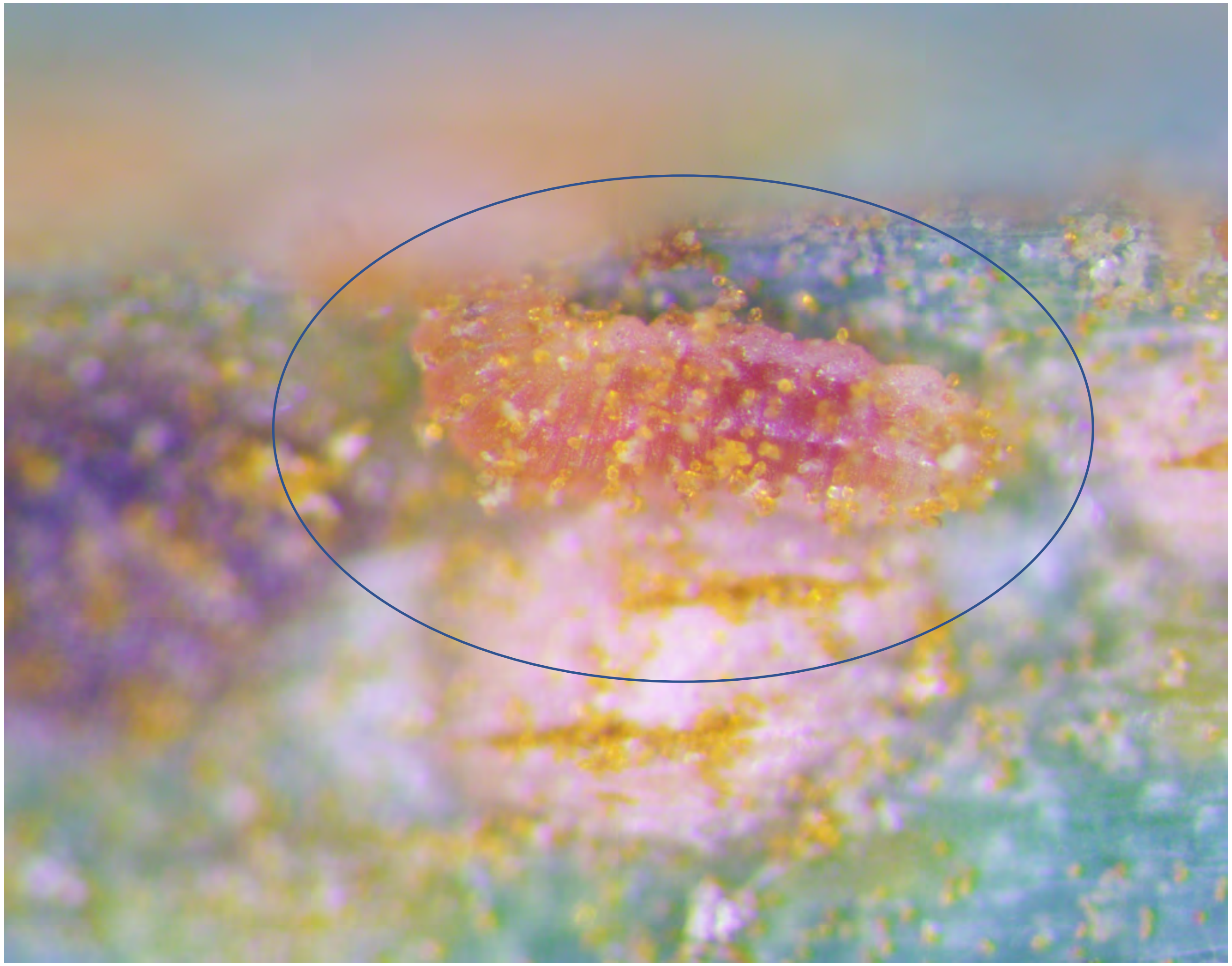
Effect of rust on yield.

Bulbs and cloves from
a) diseased plants, and b) healthy plants.

Image: ST Koike APS Compendium of Onion & Garlic Diseases & Pests



Maggot transporting urediniospores



Sap/picnic beetle (Nitidulidae)

Image: Ken Gray Oregon State University
http://entomology.ifas.ufl.edu/creatures/field/corn/sap_beetles.htm

Sap beetles are attracted to decaying plant material so are considered a secondary issue


Frass of sap beetle
larvae

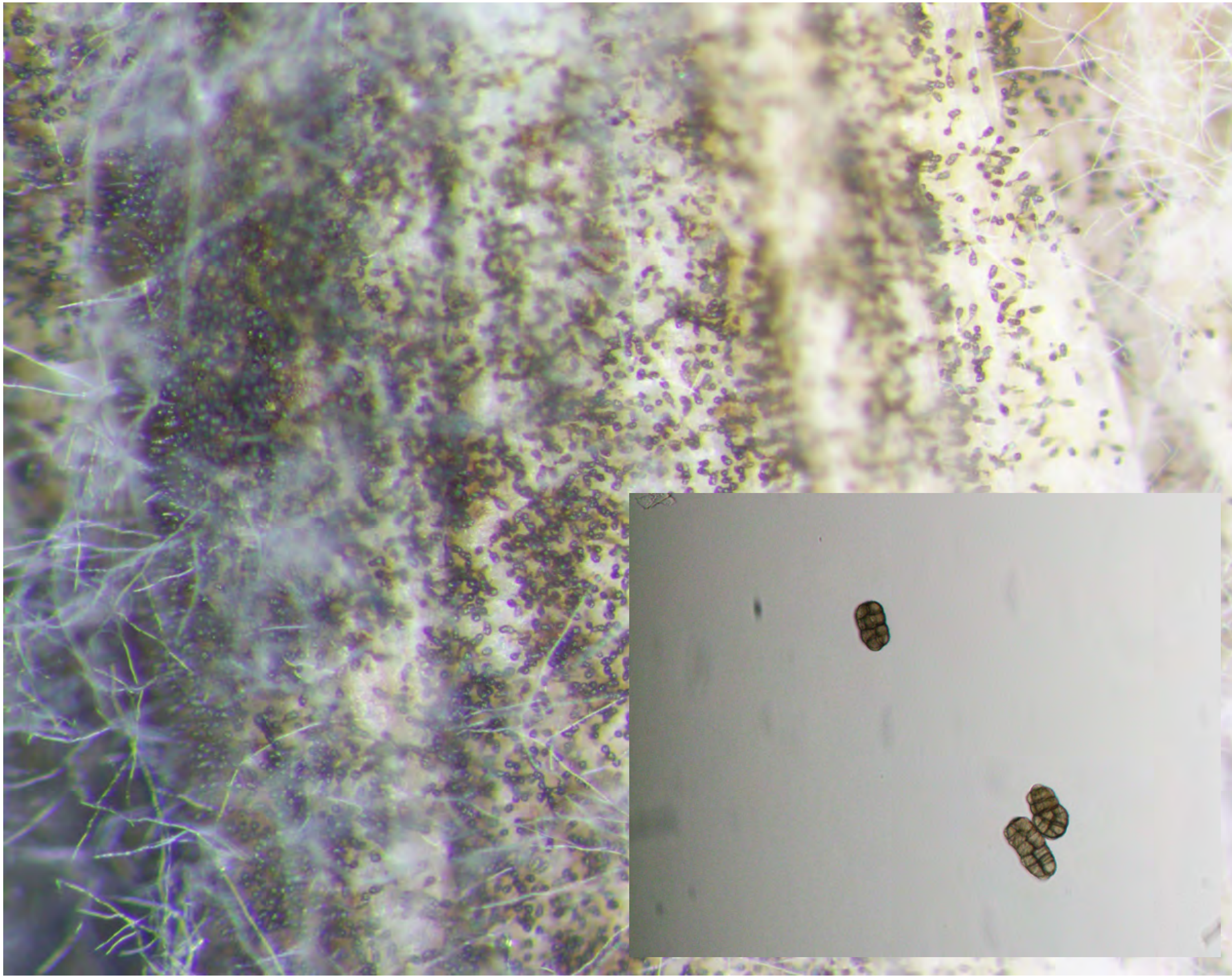
Stemphylium leaf blight (*Stemphylium vesicarium*) on onion
Causing premature senescence of onion
(onions dying standing up rather than lodging properly)

Image: C. Hoepting Cornell Cooperative Extension.

Cornell AgriTech
New York State Agricultural Experiment Station

Symptoms of Stemphylium leaf blight

Photo: C. Hoepting Cornell Cooperative Extension.



Purple blotch (*Alternaria porri*)

APS Compendium (HF Schwartz)

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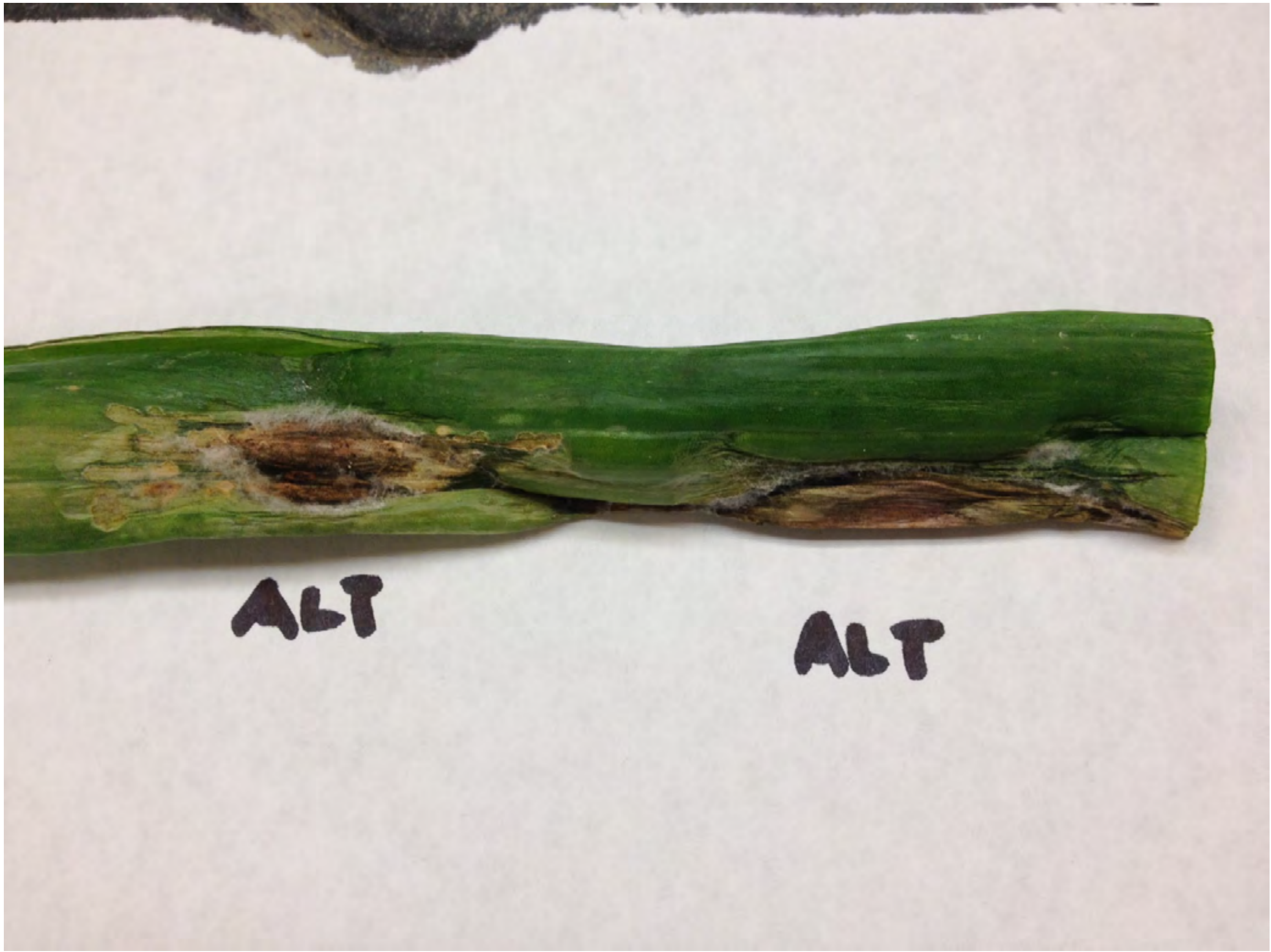
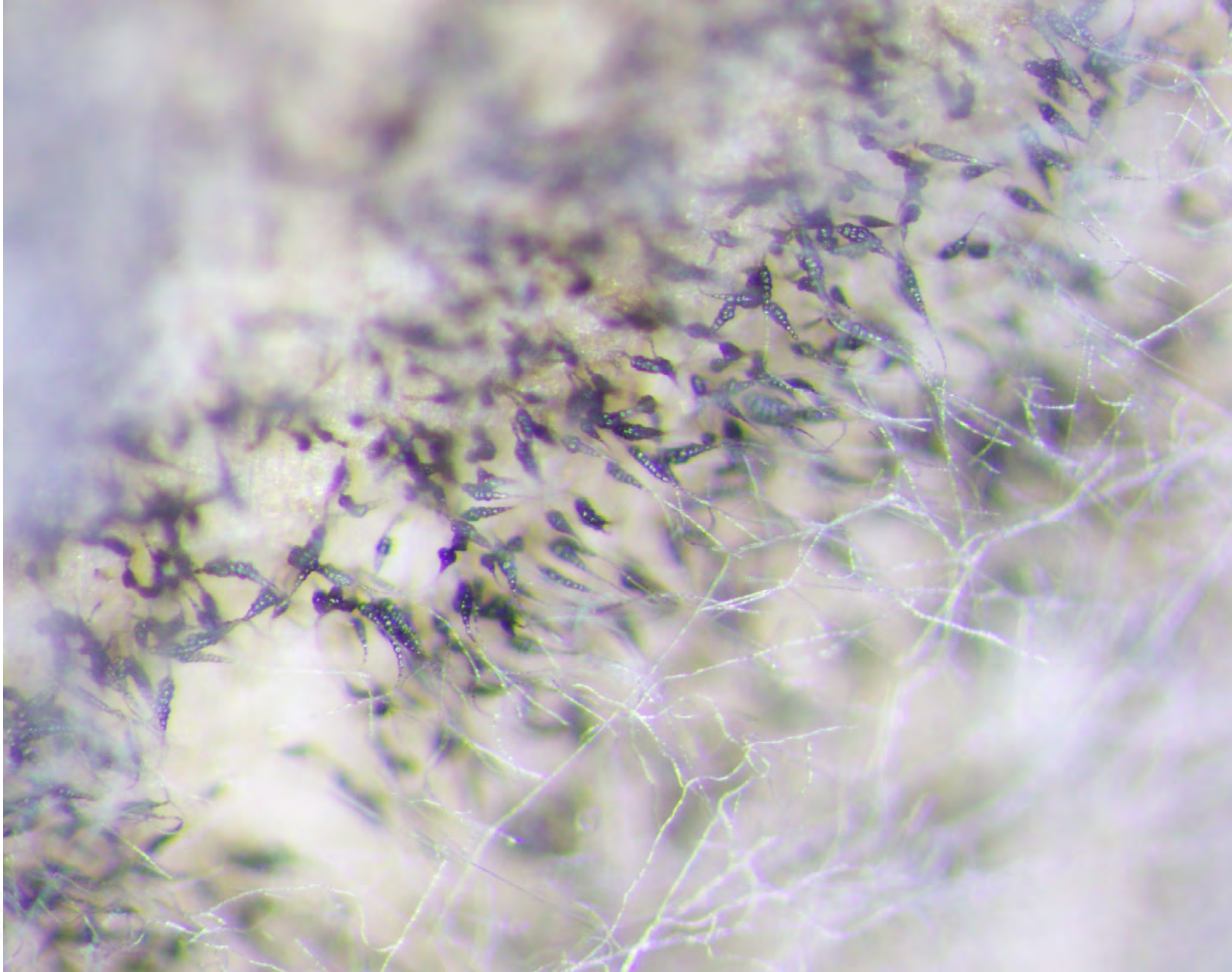
Purple blotch (*Alternaria porri*)





Tenor.com

Diagnostic services

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http://plantclinic.cornell.edu/
kls13@cornell.edu

Project Proposal (pending)

Hay, F.S. Hadad, R., Hoepting, C., Stewart, C. 2018. **Putting the heat on seed-borne pathogens of garlic.** NYFVI.

This project aims to:

- Develop best management practice for garlic storage.
- Re-examine the Lear-Johnson heat treatment protocol for control of bloat nematode and adapt to other pests/pathogens.
  - Pre-heat 38°C/30 min → treat 49°C/20 minutes in 0.75% formaldehyde → cooling in 0.06% benomyl at 18°C/10 min
  - Can we improve seed safety by size grading seed cloves and tailoring heat treatments to specific size grades?
  - Can heating control pathogens/pests other than bloat nematode e.g. Fusarium, mites.
  - Can we find alternatives to formaldehyde and benomyl (now disused) which are just as effective or which expand the range of pests/pathogens controlled.

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- CCE Educators esp. Crystal Stewart, Christy Hoepting, Robert Haddad, Sandy Menasha.
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USDA
United States Department of Agriculture
National Institute of Food and Agriculture

NY farm viability INSTITUTE