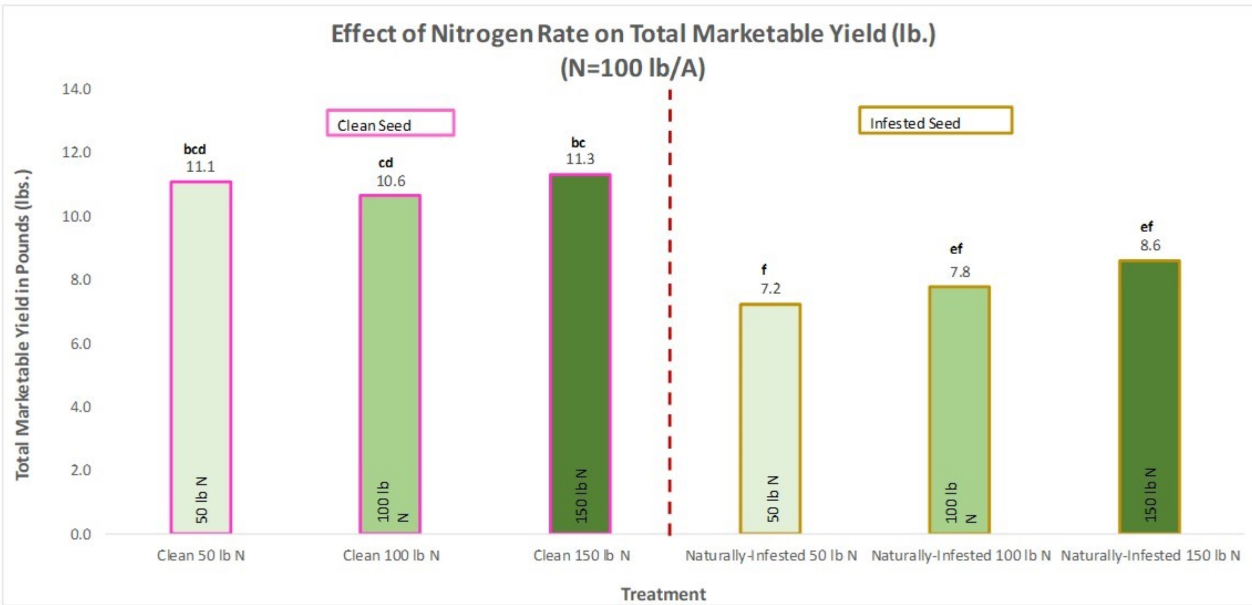
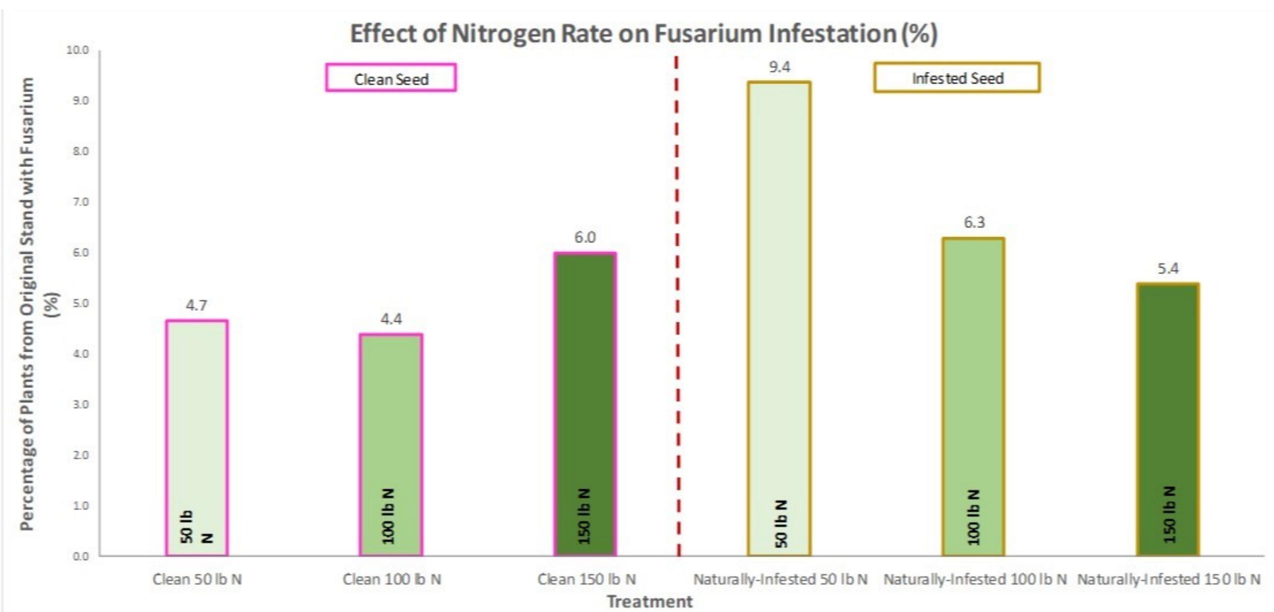
Impact of Fertility Level and Fusarium Infestation of Seed on Garlic Yield: Year One Results

Crystal Stewart, Christy Hoepting, and Sandra Menasha

Garlic growers typically apply 100-150 lbs of nitrogen per acre to garlic in order to ensure adequate sizing. However, there is concern that high nitrogen levels might contribute to higher levels of disease. A trial conducted from fall 2016-summer 2017 looked at the yield and disease levels of garlic planted at three levels of fertility: 50, 100 and 150 lbs of nitrogen per acre. Additionally, both clean (no visible Fusarium lesions) and infested (approximately 30% of the surface covered in lesions) garlic plots were planted in order to determine whether high levels of Fusarium on the seed would contribute to Fusarium levels in the coming growing season. All other nutrients and pH were optimized prior to planting.

This trial was completed in two locations: at the Long Island Horticulture Research Center, in cooperation with Sandra Menasha; and in Batavia, NY, in cooperation with Christy Hoepting.



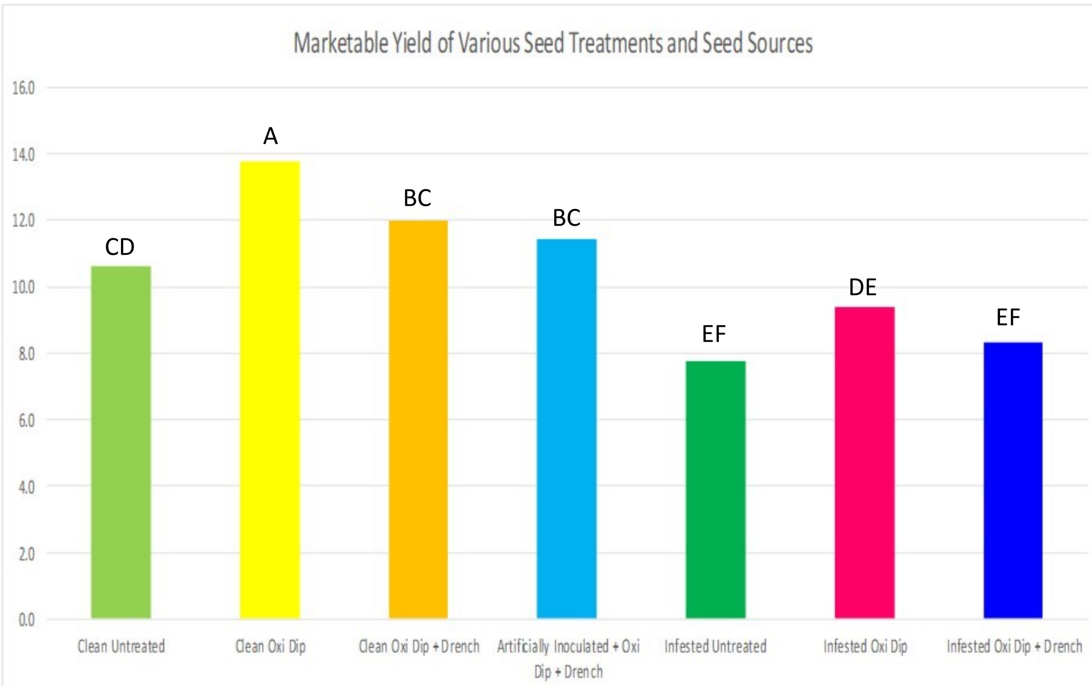


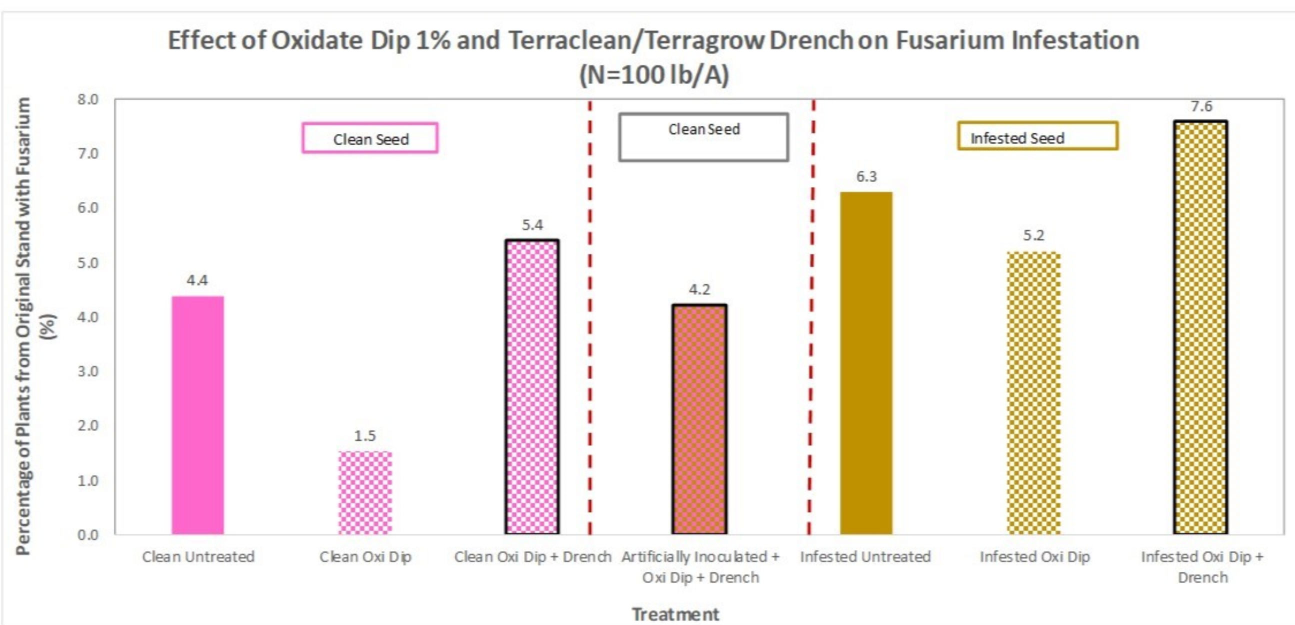
Results from Long Island Show that clean seed shows no statistically significant yield increase from 50-150 lbs of N applied in the spring . Interestingly , Fusarium severity increases with N rate in clean seed, and drops in infested seed. Based on this preliminary work, we suggest planting clean seed at a lower than recommended level of fertility. This work is being repeated for a second season on Long Island and in Western NY.

Effects of Various Pre-Plant Seed Dip and In-Furrow Treatments on Fusarium Infestation Levels in Garlic– Year One Results

Crystal Stewart, Christy Hoepting, and Sandra Menasha

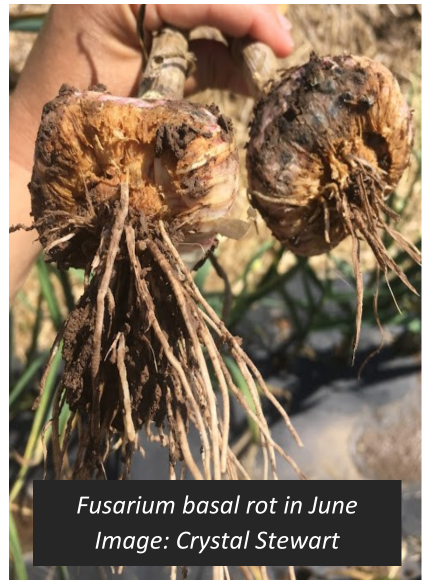
During the fall of 2016 a trial comparing pre-plant dips and in-furrow treatments during the growing season to an untreated control of both clean and Fusarium infested seed. Pre-plant dips were applied immediately before planting, and in-furrow treatments began in the spring at emergence and continued through the season. Initial results suggest that an oxidate dip applied to clean seed results in a significantly higher yield and in reduced Fusarium infestation levels post-harvest. In furrow treatments of soil biologicals did not have a significant positive impact during the 2017 growing season. This trial was repeated in 2018 and the results are currently being analyzed.





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

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



Fusarium basal rot in June
Image: Crystal Stewart

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

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

Fusarium Bulb Rot
Image: Crystal Stewart

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

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

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

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

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

Cornell Cooperative Extension
Eastern NY Commercial Horticulture Program

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

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

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

Raised Bed						
White plastic	Black plastic	Bare ground	Straw mulch	Spring planted bare ground	Spanish Roja	Straw mulch, spring planted
Flat Ground						

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

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

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

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

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

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

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

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

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

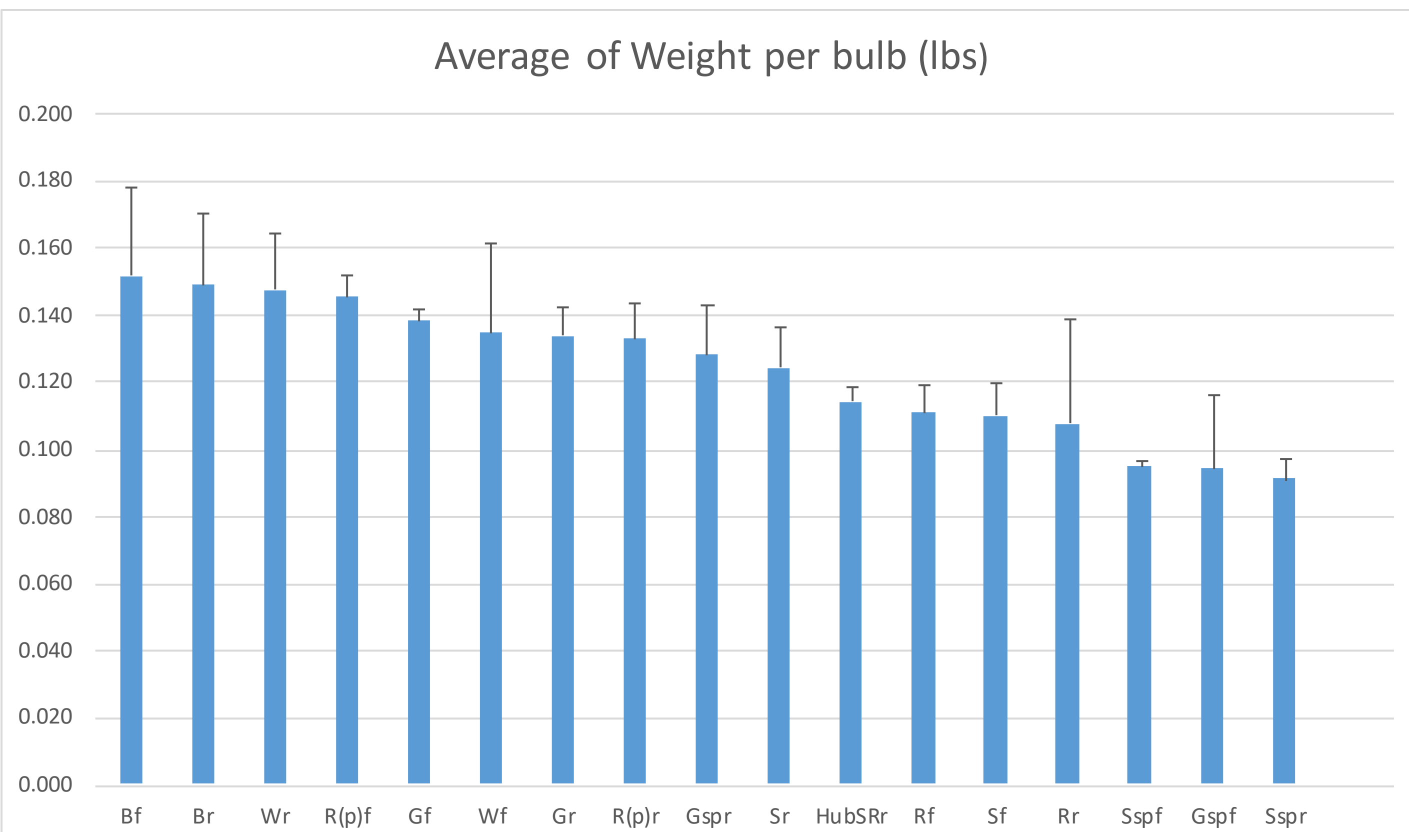
Porcelain varieties are very vigorous and perform well under most growing conditions; Rocambole varieties are often considered to have better flavor but seem more susceptible to disease under many conditions.

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

Cultural Control Trial Results:

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

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



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

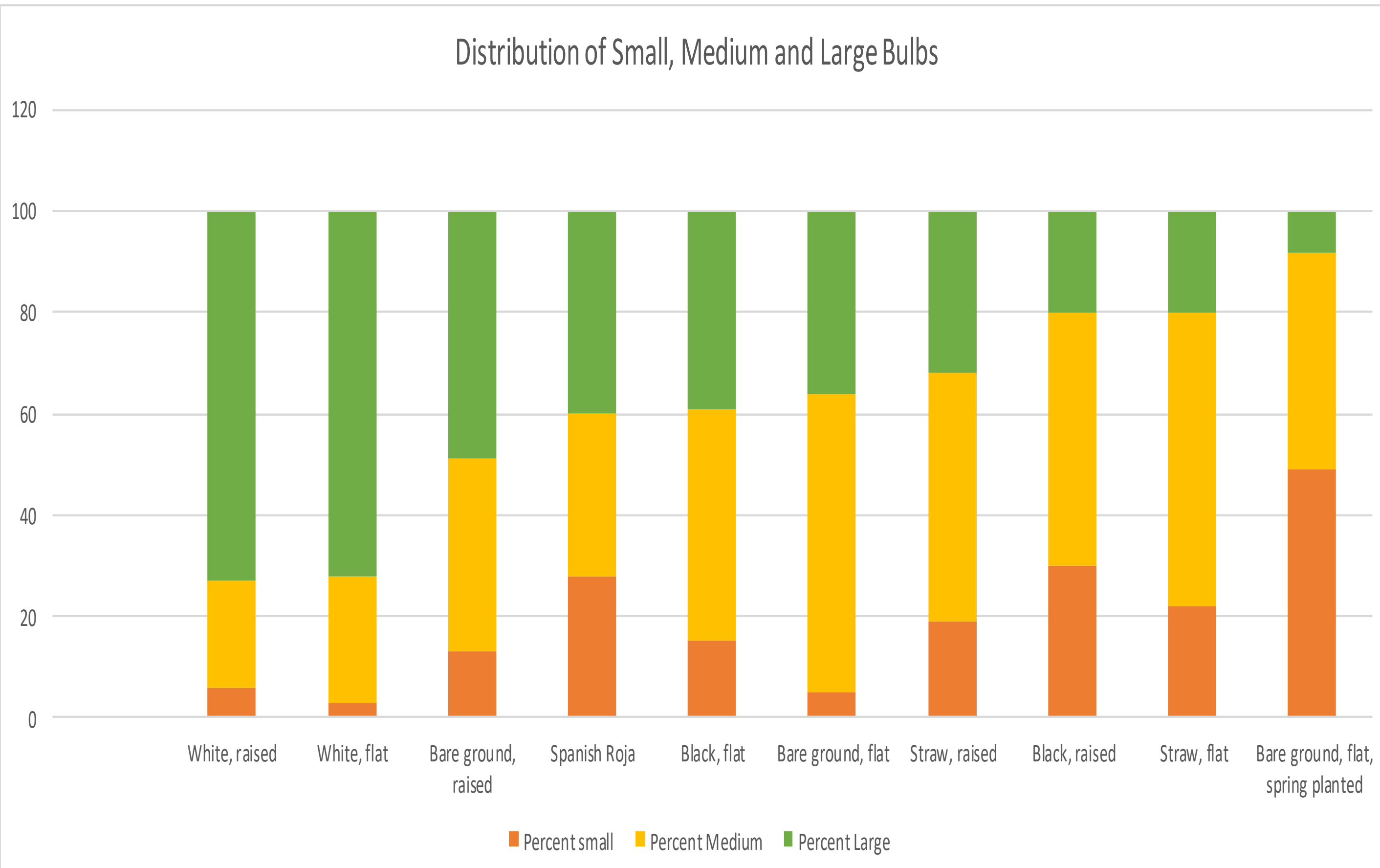
Besides total yield, we also examined the distribution of small, medium and large bulbs.

Small Bulbs: 1.5 inches or smaller

Medium Bulbs: 1.5-2 inches

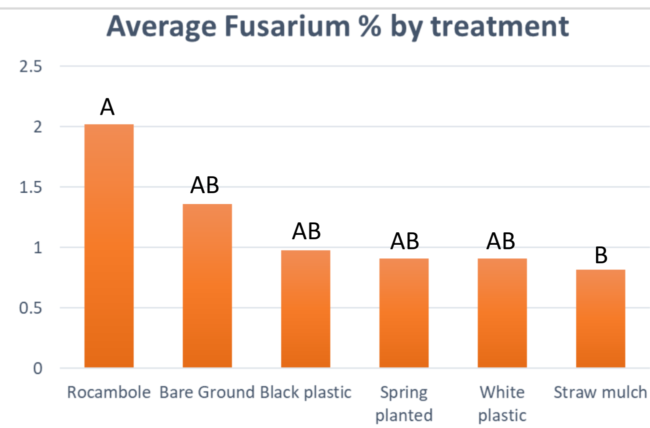
Large Bulbs: 2 inches or larger

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



Fusarium Severity Across Treatments:

To assess Fusarium severity, we selected ten cloves per rep from storage and estimated total percentage coverage with lesions. Across two sites, Fusarium levels were significantly different between the Rocambole variety and straw mulch. Other differences were numerically but not statistically different. There was no effect of raised bed versus flat ground, so during the analysis data were combined to increase the number of plots.



SARE Conference: Our Farms, Our Future

SARE PROJECT LNE16-353 RE12-006

Project Leader: Crystal Stewart
Co-PI's: Christy Hoepting, Robert Hadad, and Sandra Menasha

Development of Disease Management, and Fertility Best Practices for Northeast Garlic Production

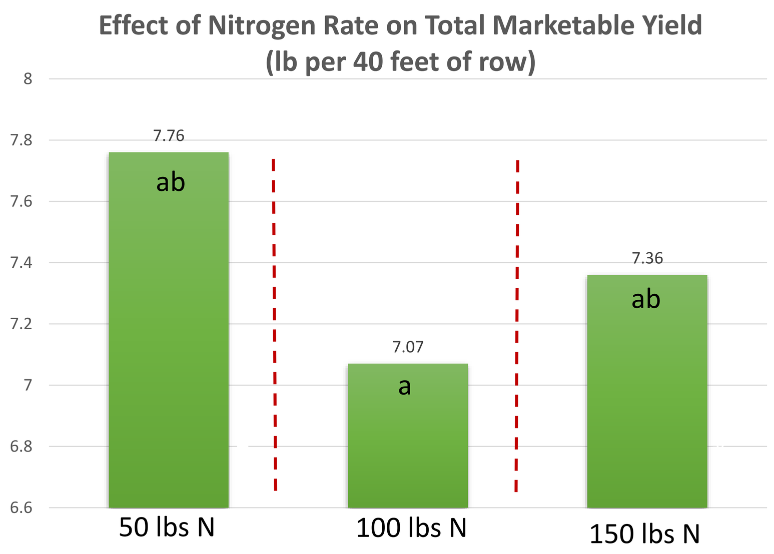
Garlic production in the Northeast:

Garlic is a $20 million industry in New York, and it represents and important and growing niche crop across the Northeast. As the numbers of garlic growers and acreage in garlic have increased, the number of diseases associated with this once trouble-free crop have also increased. Nearly 25% of growers surveyed indicated they have lost 30% or more of their garlic crop at least once in the last five years.

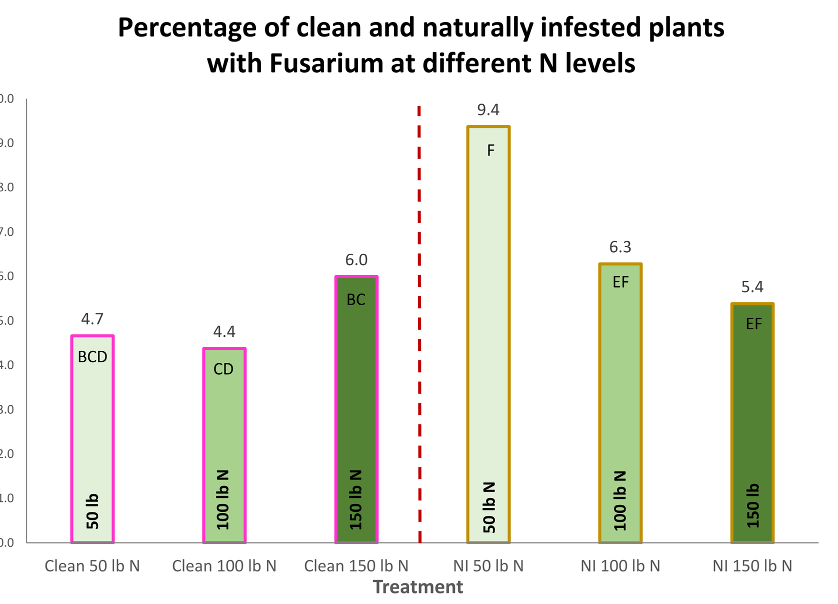
Through two projects funded by Northeast SARE's Research and Education Grants, we were able to examine fertility, disease management, post-harvest handling, and weed control practices currently common in the industry and identify best practices. This poster highlights some aspects of this work including Fusarium management through cultural controls, nitrogen fertility optimization, and post-harvest handling practices which dramatically reduce drying time and storage losses. For complete information on these studies visit https://enych.cce.cornell.edu

Optimizing nitrogen fertility

During both SARE funded projects we examined nitrogen fertilizer rates in order to create a yield response curve for nitrogen and to better understand the effects of nitrogen rates on disease incidence.



2017 trial data showing relationship between spring applied, soluble N level and marketable yield.



Clean garlic (left) responded differently than infested garlic (right)

Phosphorus, potassium and pH were optimized using soil tests pre-planting in all trials. During the 2017 study, soluble nitrogen sources were applied in the spring at emergence. Rates used were 50 lbs, 100lbs, and 150 lbs of N. The 2014-15 study used the same rates and focused on the use of slow-release N sources such as pelletized chicken manure and alfalfa meal, with 25% of total N applied in the spring from quick-release sources.

In the 2014-15 study we also lacked significant differences between the marketable yields at different rates across three trial sites. Our conclusion based on this work was that, if using plant available N sources in the spring, 50 lbs of total N is sufficient, and if using slow-release N sources at planting, 100 lbs of N is sufficient to account for nitrification lagging in cold soils.

Post-harvest handling

In order to determine best practices surrounding post-harvest handling, we compared treatments including cutting tops prior to drying, drying with heat, washing, cutting roots compared to controls of drying whole plants at ambient temperature

High Tunnel vs. Open Air: Across six trials conducted over two years, high tunnels consistently dried an average of 3 days quicker; yielded garlic with less Aspergillus, Botrytis, and Embellisia; and importantly high tunnels never damaged any of the garlic that was dried in them.

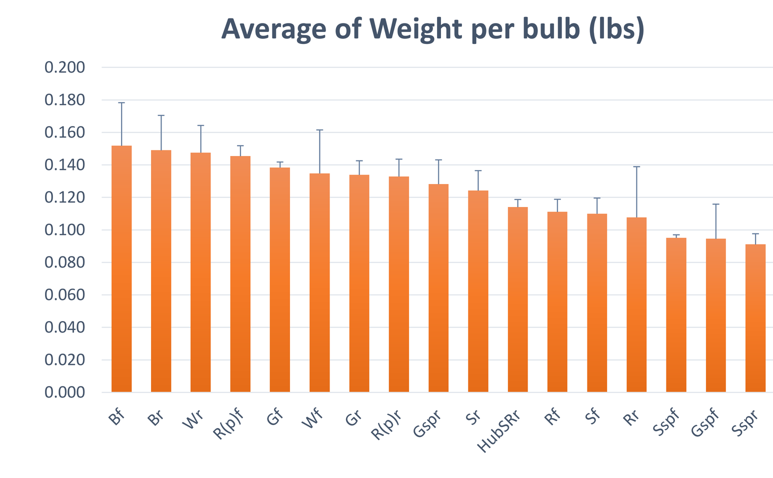
The addition of dehumidifiers at night in closed high tunnels removed an additional 10-15 gallons of water, further speeding the drying process.

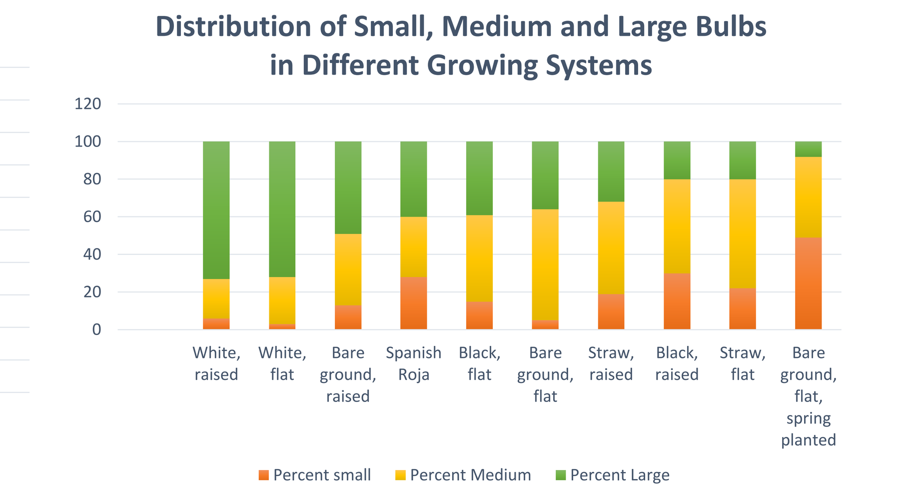
Tops trimmed vs. tops untrimmed: Trimming the tops mechanically in the field greatly increased the speed of harvest and reduced the space needed for drying without increasing disease incidence.

Raised beds, mulches, timing, and variety

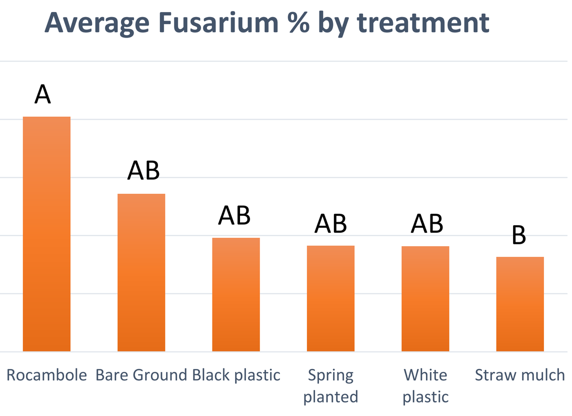
We completed two replicated trials examining the effects of raised beds, flat ground, black and white plastics, straw mulch, bare ground, Porcelain vs. Rocambole varieties, and spring versus fall planting on *Fusarium* incidence, yield, and bulb quality. Seed stock was rated for disease severity prior to planting, and ratings were repeated after curing and storage. Each plot was also graded by size and average weight per bulb was calculated for each treatment.

The largest factor affecting disease incidence in our trials was variety, which suggests that growers should experiment with different varieties to determine what will do best in their environment. Other factors, such as uniformity and size distribution, were affected by growing systems. Overall average size was not significantly different between treatments, aside from in spring planting, which was significantly smaller but otherwise very healthy.





Above (L-R): two row planting systems with drip on black plastic, white plastic, bare ground, and straw.
Below: Planting stock used to evaluate initial disease levels (L) and cloves used to evaluate final disease levels (R).



To assess Fusarium severity, we selected ten cloves per rep from storage and estimated total percentage coverage with lesions. Across two sites, Fusarium levels were significantly different between the Rocambole variety and straw mulch. Other differences were numerically but not statistically different. There was no effect of raised bed versus flat ground, so during the analysis data were combined to increase the number of plots.

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Development of Disease Management, and Fertility Best Practices for Northeast Garlic Production

Crystal Stewart

Eastern NY Commercial Horticulture Program

Fusarium species associated with bulb rot of Garlic in New York.

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Materials and methods

2016

Garlic bulb samples exhibiting signs of *Fusarium* bulb rot from farms around NY were collected and sent into the AgriTech laboratory by Cornell Co-operative Extension educators. Garlic bulbs were cracked, cloves were peeled, and examined for rotting and lesions. Fusarium was isolated by cutting a small portion of diseased tissue from the edge of a lesion and placing onto water agar (1.5%) in Petri plates. Approximately 5 d after isolation, a small portion of agar containing mycelium was excised from the edge of the growing colony using a scalpel, and transferred to potato dextrose agar (PDA). Alternatively, cloves were placed in a humid chamber for 5 d and developing mycelium transferred to PDA, with antibiotics to suppress secondary bacteria. Plugs of mycelium on PDA were transferred to vials containing sterile water for storage.

Due to the difficulty in identifying Fusarium isolates to species on the basis of colony characteristics, a subset of isolates (n = 57) was identified by molecular techniques. Plugs from actively growing cultures on potato dextrose agar (PDA; Difco laboratories, Sparks, MD) medium were transferred to potato dextrose broth (PDB; Difco laboratories) medium amended with 100 μg ml^{-1} ampicillin and incubated at 23 °C on an orbital shaker at 80 rpm. Fungal mycelia were harvested after 5 days and DNA was extracted with the Wizard DNA extraction kit (Promega Corp., Madison, WI). DNA was quantified with the Nanodrop spectrophotometer (Thermo Fisher Scientific, Waltham, MA). PCR was performed on 100 ng of genomic DNA to amplify the internal transcribed spacer (ITS), translation elongation factor 1-α (TEF1), and RNA polymerase beta subunit (RPB2) regions using the standard primer pairs ITS1/ITS4, EF1/EF2, and RPB2 5F/RPB2 7cR respectively. The PCR products were sequenced at the Cornell University Institute of Biotechnology. Raw sequencing reads were analyzed with Geneious software version 11.0.5 (https://www.geneious.com). The reads were trimmed on the ends to remove ambiguous bases. The reads from forward and reverse directions for each locus were aligned to form a consensus sequence. Designation of species to the isolates was done through a BLAST search in the fusarium id database (http://www.fusariumdb.org). For phylogenetic analyses, the sequences were aligned using MAFFT in the Geneious software (https://www.geneious.com). Ambiguously aligned regions were removed with Gblocks (phylogeny.lirmm.fr/phylo_cgi/index.cgi). The resulting sequences from different loci were concatenated, and the data was subjected to phylogenetic analysis using the Maximum Likelihood methods implemented in MEGA X (www.megasoftware.net), with the internal branch evaluated using 1000 replicates.

2017

During 2017, a total of 313 bulbs suspected of Fusarium basal rot were collected by Cornell Co-operative Extension educators and processed at the Cornell AgriTech NYSAES laboratory. Of the known pathogens of garlic, *Fusarium* spp., *Rhizopus* spp., *Penicillium* spp., *Embellisia allii*, and *Botrytis* spp. occurred in 167 (53.4%), 33 (10.5%), 26 (8.3%), 16 (5.1%) and 3 (1.0%) of bulbs respectively. In the remaining 96 bulbs (30.7%), the causal agent of disease could not be confirmed as fungal, often due to the presence of bacteria, maggot and bulb mites which may have masked the fungal infection. Of 41 bulb samples tested, bloat nematode (*Ditylenchus dipsaci*) was detected in 9 (22.0%). Eriopyhid mite was confirmed in one sample of bulbs sent in for Fusarium analysis. Because of the difficulty of identifying Fusarium species by colony characteristics, a subset of fungi (*n* = 91) were subjected to DNA extraction and identification by molecular techniques (as above).

Results

2016

In 2016, *Fusarium* spp. were isolated and identified from a total of 57 bulbs collected from 21 farms. *F. oxysporum*, *F. proliferatum*, *F. solani*, *F. fujikuroi*, *F. tricinctum*, and *F. sporotrichioides* occurred on 16 (76.2%), 8 (38.1%), 4 (19.0%), 4 (19.0%), 3 (14.3%), and 1 (4.8%) farm respectively (Figure 1).

Fusarium oxysporum, *F. proliferatum*, *F. solani*, *F. tricinctum*, *F. fujikuroi* and *F. sporotrichioides* comprised 27 (46.6%), 13 (22.4%), 6 (10.3%), 4 (6.9%), 4 (6.9%) and 1 (1.7%) of 57 isolates respectively. A further two isolates were putatively identified as *F. venenatum* and *F. commune*.

Results indicate that Fusarium garlic bulb rot in NY is associated with a variety of *Fusarium* spp., with *F. oxysporum* and *F. proliferatum* occurring most commonly. Multiple species may be associated with bulb rot at any one site (Figure 1.)

2017

A range of Fusarium species were identified from diseased garlic bulbs. Of the 17 sites from which samples were collected in 2017, *F. oxysporum*, *F. proliferatum*, *F. acuminatum*, *F. fujikuroi*, and *F. tricinctum* were present at 12, 9, 3, 2 and 2 sites respectively, indicating the former two species to be most common in NY garlic (Figure 2). Other species occurred at one site only. Of the 91 isolates identified by molecular techniques, the most common Fusarium species were *F. oxysporum*, *F. proliferatum*, *F. fujikuroi*, *F. tricinctum* and *F. acuminatum* which comprised 45 (45.5%), 30 (30.3%), 5, (5.1%), 4 (4.0%) and 4 (4.0%) respectively. Single isolates (1.0% of fungi were identified as *F. armeniacum*, *F. graminearum* and *F. incarnatum*/*F. equiseti* complex. For sites such as MELE, LIHREC, DRID and CRYST17, where more than 10 isolates of fungi were identified to species (Figure 2), garlic bulb rot was associated with more than one *Fusarium* spp. This indicated that bulb rot on any one farm is likely to be caused by a complex of *Fusarium* spp.

Figure 1. Most common *Fusarium* spp. associated with garlic bulb rot in NY in 2016. Data is the number of isolates identified as a particular *Fusarium* sp. from each of 21 farms.

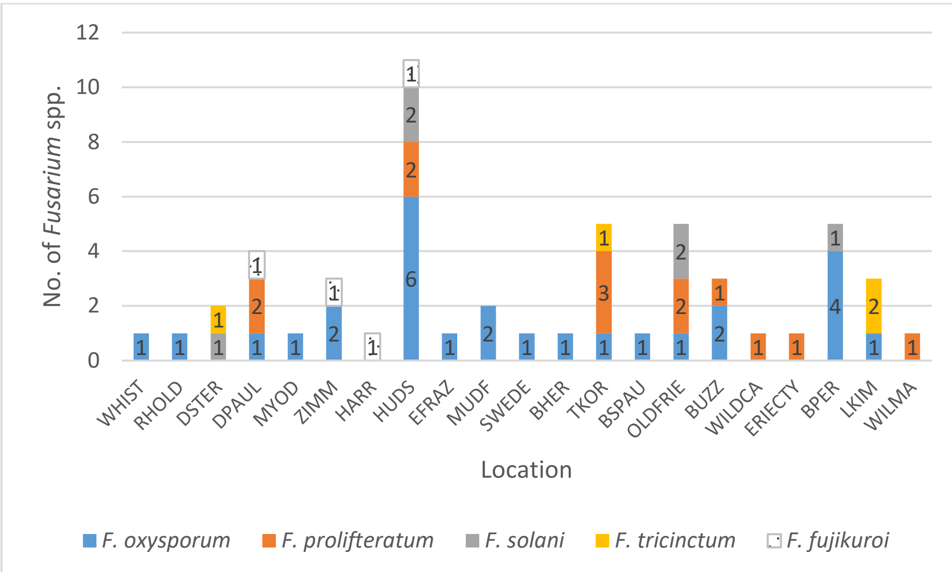
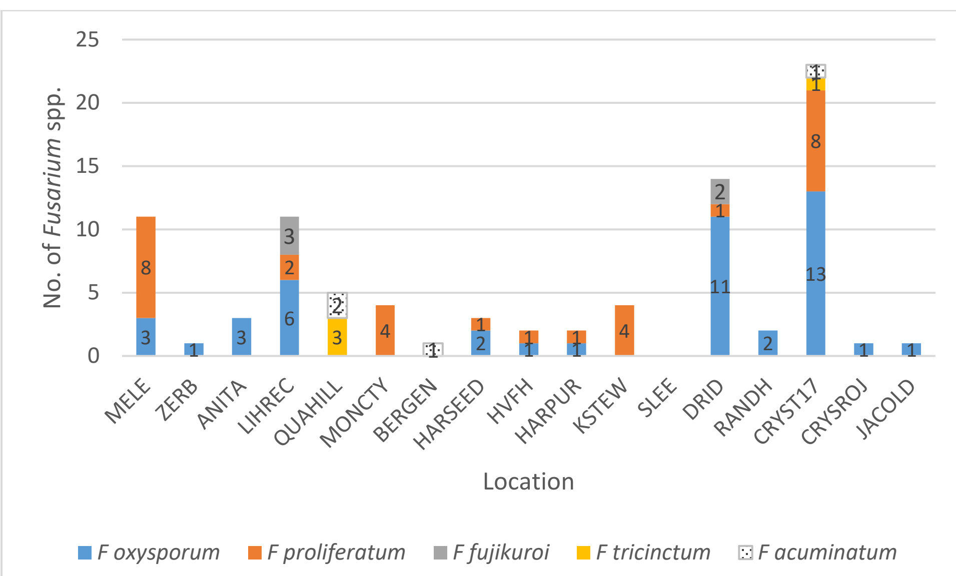


Figure 2. Most common *Fusarium* spp. associated with garlic bulb rot in NY in 2017. Data is the number of isolates identified as a particular *Fusarium* sp. from each of 19 farms.



Discussion

Fusarium oxysporum f.sp. *cepae*, *F. proliferatum* and *F. culmorum* have been identified causing disease of garlic bulbs in North America (Dugan et al. 2003, Jepson 2008). Our study has confirmed *F. oxysporum* and *F. proliferatum* to be the dominant species associated with garlic bulb rot in NY. Although *F. oxysporum* is commonly reported as a cause of bulb rot in garlic, there is surprisingly little literature on this species since the first report of *F. oxysporum* f. sp. *cepae* on garlic in Israel (Koch and Taanami, 1995). By contrast, *Fusarium proliferatum* has been reported from several countries around the world, including USA (Dugan 2003), and has been the subject of much study in recent years. In France *F. proliferatum* is estimated to cause 10% annual loss of pink garlic (Leyronas et al. 2018). *Fusarium proliferatum* has been associated with a range of symptoms in garlic. Ravi Sankar *et al*. (2012) reported water soaked small spots, which progress to small, slightly depressed tan lesions. Leyronas et al. (2018) noted that symptoms generally appeared two months after harvest, with bulbs externally free of symptoms, but underlying cloves softened and brown, with tan lesions, and with white mycelium present at an advanced stage of decay. Other symptoms include internal tan-colored rot of cloves progressing towards the clove apex, with occasional white mycelium in rotted cavities (Palmero et al. 2012). The incidence and severity of clove rot caused by *F. proliferatum* was shown to increase with time in storage and at a faster rate with storage at room temperature in comparison to cool storage (Elshahawy et al. 2017). The severity of rot was higher in white garlic than in purple garlic (Elshahawy et al., 2017, Palmero Llamas et al., 2013). Fusarium infection also impacted upon field performance of seed garlic. In pot trials, inoculation of seed cloves with *Fusarium proliferatum* caused reduced emergence of garlic by 12.5% and 49.5% in each of two cultivars, and caused wilt symptoms in surviving garlic (Elshahawy et al. 2017).

Several Fusarium species other than *F. oxysporum* and *F. proliferatum* have been associated with rot of garlic around the world, including *F. verticillioides*, *F. solani*, *F. acuminatum* (Delgado-Ortiz et al. 2016) and *F. tricinctum* (Ignjatov et al. 2017a). A variety of other species were also detected at low incidence in our study. Some of these have not previously been reported as pathogenic on allium and, given that many *Fusarium* spp., are present in soil, these may represent secondary invaders of diseased tissue. However, three species found at lower incidence in our study (*F. acuminatum*, *F. solani* and *F. tricinctum*) are known pathogens of garlic bulbs. *Fusarium tricinctum* was recently reported causing ‘pink rot’ of stored garlic bulbs in Serbia (Ignjatov et al. 2017a). Bulbs and cloves were described as ‘softened, spongy, or sunken, and covered with white, light pink or reddish fungal growth (mycelium)’. *Fusarium acuminatum* was recently reported as a pathogen of garlic bulbs causing bulb rot of stored garlic on several farms in Serbia in 2016 (Ignjatov et al. 2017b). Infected bulbs were appeared ‘softened, spongy and covered with white or reddish fungal growth’. Deep lesions formed on cloves, which became dry and small over time.

The identification of Fusarium species associated with bulb rot of garlic in NY may be of importance for several reasons. The identification of the most common species associated with garlic in NY might allow management strategies to be formulated to take advantage of knowledge regarding the host range of particular species, to ensure cropping history prior to garlic does not increase inoculum in the soil. It may be important to know which species is present, as *Fusarium* spp. may differ in their aggressiveness to garlic. For example, Delgado-Ortiz et al. (2016) identified *F. oxysporum*, *F. proliferatum*, *F. verticillioides*, *F. solani* and *F. acuminatum* from diseased garlic bulbs in North Central Mexico, and under controlled conditions reported two isolates of *F. oxysporum* and one isolate of *F. acuminatum* to cause more severe disease than other isolates. However, the relative aggressiveness of isolates within and between *Fusarium* spp. has not been widely studied. Further the identification of species is important as some *Fusarium* spp. are able to produce mycotoxins, harmful to human health. Isolates of *F. proliferatum* from garlic in Serbia were able to produce fumonisin B1, beauvericin, fusaric acid, moniliformin and fusaproliferin (Stanković et al. 2007). Similarly, isolates of *F. proliferatum* from garlic in Spain produced fumonisin B1, B2 and B3, moniliformin and beauvericin (Palmero et al. 2017). Fumonisin B1 was detected in garlic bulbs harvested from soil containing *F. proliferatum* (Seefelder et al. 2004), and at low levels in commercial garlic powder (Boonzaaijer et al. 2008). Similarly, *Fusarium tricinctum* is known to produce mycotoxins in other crops, although this has not been confirmed in garlic.

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