**NE-SARE Partner Grant Report: Evaluation of biological fungicides to control diseases of spinach in winter high tunnels**

Across the Northeast, high-tunnels are being used with increasing frequency to lengthen the season of spinach and other greens to have produce to sell all winter long. In these systems, high tunnels are usually planted to crops like tomatoes or cucumbers in the summer and then turned over and planted to spinach in the fall, and this cycle is repeated year after year. In this high intensity, year-round system, insect and disease pests build up over time and can become difficult to control. A disease of particular importance is damping-off of spinach, which can cause poor germination and stand, sometimes to the extent that the crop needs to be re-seeded and the narrow window for successful establishment may be missed, drastically reducing yields. Damping off (*Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp.), seedling blight (*Rhizoctonia solani*), and leaf spots such as *Cercospora* and *Cladosporium* build up in tunnels where spinach is grown year after year, reducing marketable yield and quality. In this study, UMass Extension partnered with Queen's Greens—a commercial vegetable farm with a focus on year-round production of organic greens—to evaluate efficacy of biopesticides to improve germination, reduce disease severity, and improve yields in winter-grown spinach.

We conducted lab and field trials to: a) determine if certain biocontrol organisms are more cold tolerant than others and would thus be better suited for use in winter production systems; and b) if any of the products evaluated can significantly increase crop yield and quality.

**Field Experiment Methods:** The field experiment was conducted at Queen's Greens in Amherst, MA in a 200 x 300 ft Rimol Nor'Easter (Rimol Greenhouses, Hooksett, NH) high tunnel. No supplemental heating or covers were used. 'Raccoon' spinach seeds (Johnny's Selected Seeds, ME) were direct-seeded with a Jang push seeder on 02 Oct 2015 at approximately 0.5 in. in-row spacing and 11 rows approximately 2 in. apart per bed. A randomized complete block design was used with six treatments plus an untreated control, each replicated four times, in plots consisting of 20-ft of bed with 5-ft buffers between plots.

All treatments were applied as a soil drench over the row at seeding, with follow-up applications made as soil drenches over the row according to rates and intervals specified by the manufacturers (see Table 1). All drench applications were made using a $CO_2$ pressurized backpack sprayer delivering 200 gal/A at 50 psi through one TeeJet Floodjet nozzle (TK-7.5). Germination was first observed on 09 Oct and by 13 Oct most plots had germinated and plant stand was rated by estimating percent of plot area germinated (0-100%). Weekly ratings of plant stand and plot vigor and follow-up treatment applications were made all winter, through 03 Mar 2016. Marketable yield was assessedby measuring wet weight of the crop harvested from the whole plot at the first cutting. Replicates A and B were harvested on 17 January and the remaining two replicates were harvested on 24 January, in order to harvest only what the grower could sell during the following week. The growers determined what was marketable and not, leaving unmarketable spinach unharvested in the tunnel. Environmental data including air temperature, light intensity and soil temperature (2 in. depth) were recorded every 2 hr by Hobo Weather Stations and/or data loggers (Onset Computer, Bourne, MA) from 03 Oct to 03 Mar. All data were analyzed using SAS 9.4 and means were compared using Fisher's LSD ($\alpha = 0.05$).

**Field Experiment Results**: Germination and plant stand was very patchy throughout the tunnel (see Figure 1). This is likely due at least in part to pre- and post-emergence damping off, as signs and symptoms of damping off were observed on 13 Oct and *Rhizoctonia solani* and *Fusarium oxysporum* were isolated from affected plant tissue. The winter of 2015-16 was fairly mild; soil (2 in. depth) temperature in the high tunnel plots 03 Oct 2015 to 03 Mar 2016 averaged minimum of 42.2 and maximum of 56.5°F, and air temperature averaged minimum of 32.8 and maximum of 59.9°F. The absolute minimum temperature of soil and air recorded was 30.8 and 8.7°F, respectively. Unfortunately, we were not able to distinguish any consistent, significant differences in germination, stand, vigor, or yield across treatments. Plant number and vigor decreased at the second and third time-points and then rebounded—this may have been due to post-emergence damping off. Plant number at the third time-point (20 Oct) was significant, with all treatments except Rootshield Plus performing better than the untreated control and Mycostop G performing the best. We did not see any *Cercospora* or *Cladosporium* leaf spots in any of the treatment plots, including the untreated plots.

**Lab Assay:** In the lab assay, we isolated biocontrol organisms from commercial biopesticides and then grew them at different temperatures (75, 50, and 42°F). All of the organisms grew very quickly at 75°F. At 50°F, which was close to the average soil temperature in the tunnel and is also the temperature at which many fungal pathogens become active, most of the organisms were able to grow very slowly, but Mycostop grew fairly well and outperformed all other bacterial organisms in both replications of the experiment. The two *Trichoderma* spp. present in Rootshield Plus grew at 50°F and also were able to grow, albeit slowly, at 42°F.

**Conclusions:** While none of the treatments made consistent, significant differences in overall stand, vigor, or yield, all products performed better than the untreated control during the early stages of germination and growth, and may be worthwhile for growers with soil-borne diseases in tunnels. Mycostop and Rootshield Plus may be better choices in cold conditions such as the winter tunnel environment. Furthermore, there was a really big range in cost depending on the material and the number of applications recommended (see Table 1), so that would be another thing to consider when choosing biopesticides and determining how often to spray. In the case of Mycostop, we feel a much lower rate could be used to bring down the cost per application. With other fungicides, information from the manufacturers was available to advise on the best rate to use, but in the case of Mycostop, we were not able to get more specific guidance from the company and so we used the highest labeled rate. Based on our findings, we feel that applications are most effective when soil is at or above 50°F, when beneficial microbes (and pathogens) are more active, so the number of applications made during the colder winter months can be reduced, further lowering costs.

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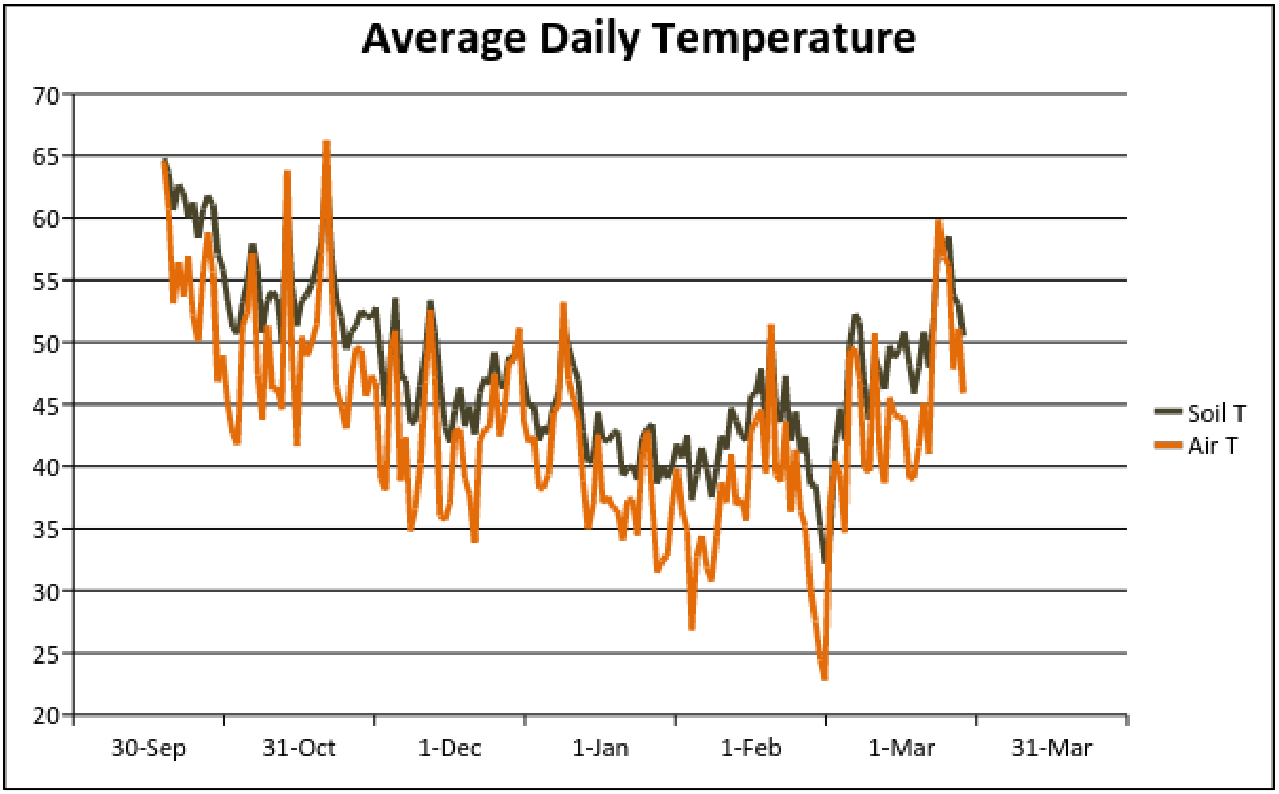
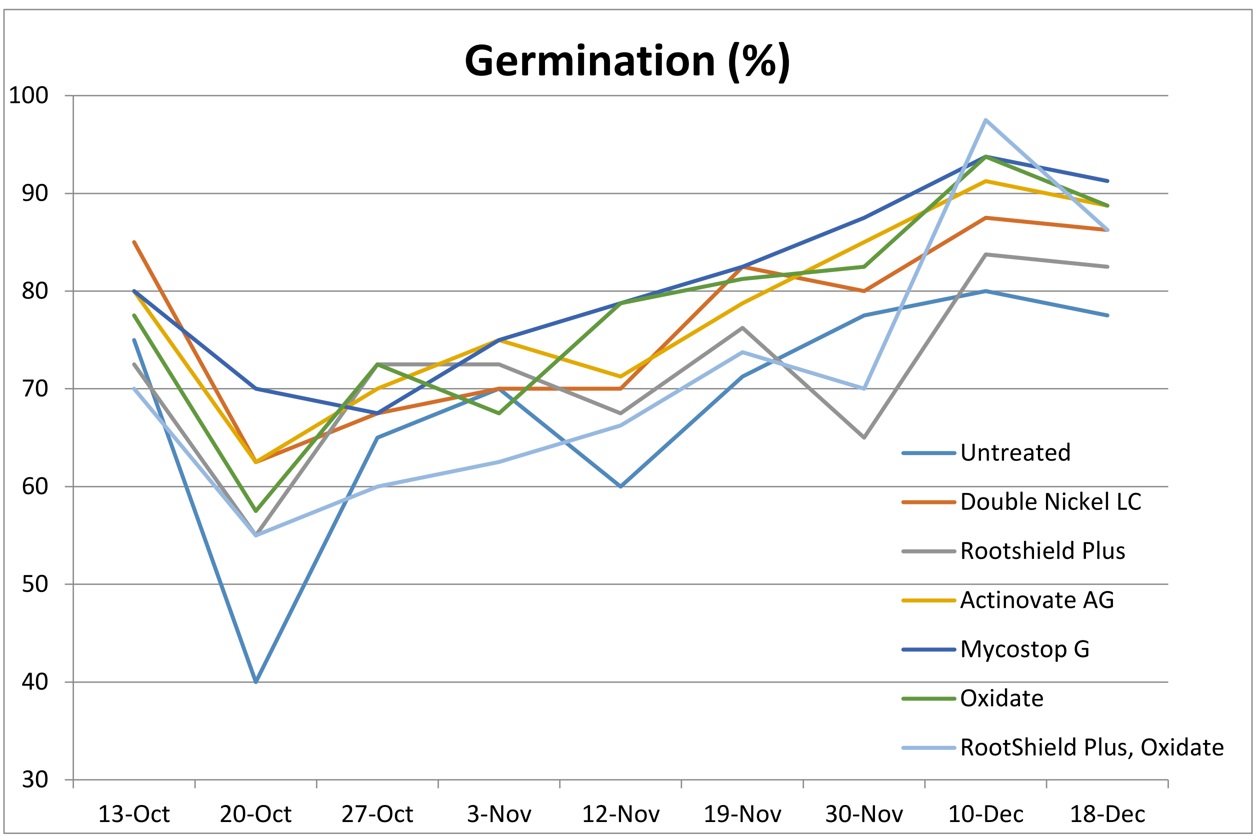
| | Product | Active Ingredient | Interval | Rate | Cost ($) / Tunnel/Season | Cost ($) / Tunnel/Application |
|---|---|---|---|---|---|---|
| 1 | Untreated | n/a | | | | |
| 2 | Double Nickel LC | *Bacillus amyloliquefaciens* Strain D747 | 2 wks | 1.5 qt/ 100 gall | 114.13 | 9.51 |
| 3 | Rootshield Plus | *Trichoderma harzianum* Rifai strain T-22 (1.15%); *Trichoderma virens* strain G-41 (0.61%) | 6 wks | 8 oz/ 100 gall | 74.82 | 18.71 |
| 4 | Actinovate AG | *Streptomyces lydicus* WYEC 108 (0.0371%) | 2 wks | 9 oz/100 gall | 245.39 | 20.45 |
| 5 | Mycostop G | *Streptomyces griseoviridis* Strain K61 (35%) | 4 wks | 2 g/ 100 sq ft | 2073.60 | 345.60 |
| 6 | Oxidate | Hydrogen dioxide | 1 wks | 1:300 | 753.21 | 31.38 |
| 7 | RootShield Plus, Oxidate | *Trichoderma harzianum* Rifai strain T-22 (1.15%), *Trichoderma virens* strain G-41 (0.61%); Hydrogen Dioxide | 6 wks; 1 wks | 8 oz/ 100 Gall; 1:300 | 828.03 | 50.09 |


Average Daily Temperature
70
65
60
55
50
45
40
35
30
25
20
30-Sep
31-Oct
1-Dec
1-Jan
1-Feb
1-Mar
31-Mar
Soil T
Air T


Germination (%)
100
90
80
70
60
50
40
30
13-Oct
20-Oct
27-Oct
3-Nov
12-Nov
19-Nov
30-Nov
10-Dec
18-Dec
Untreated
Double Nickel LC
Rootshield Plus
Actinovate AG
Mycostop G
Oxidate
RootShield Plus, Oxidate