Northern NY Agricultural Development Program
2019 Project Report

Advancing Vegetable and New Fruit Crops Production in NNY

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Introduction:

Fresh market vegetable production continues to increase throughout Northern NY (NNY) as evidenced by 1) the St. Lawrence Valley Produce Auction start-up in Franklin County, 2) the Hub on the Hill serving as a distribution center in Essex County, 3) the North Star Food Hub being developed in western NNY, 4) an increase in high tunnels in NNY in recent years; and 5) the many farmers markets, roadside stands, shops, and food coops selling locally-grown produce in the NNY six-county region. As new information, better crop production, marketing methods, and new NNY-adapted crop varieties continue to be developed, we proposed to focus on three key areas for NNY growers for the 2019 edition of the NNYADP Advancing Vegetable Production in NNY project:

1) Researching Integrated Pest Management (IPM) strategies to reduce cucumber beetle damage with new protective materials;
2) Continuing our study of nitrogen uptake in winter high tunnel spinach when fertilized at different rates and the effect on yield; and
3) Testing training methods to simplify the production of novel fruit crops such as ground cherries and goldenberries in high tunnels.

The results of our work with each of these objectives in 2019 follows in individualized sections; all figures and tables are seen in the appendix following the main report.

REDUCING CUCUMBER BEETLE DAMAGE IN HIGH TUNNEL-GROWN CUCUMBERS

Background:

Striped cucumber beetles (*Acalymma vittatum*) are an annual problem for growers of any cucurbit: melons, summer and winter squash, pumpkins, and especially cucumbers. The beetles can quickly destroy young seedlings and transplants and transmit bacterial wilt to older plants through feeding injuries that can kill large, productive plants. There are a limited number of effective chemical controls, and growers are in need of effective control strategies, such as the use of newer insect exclusion materials now on the market. Using low tunnels in field trials, we tested for differences in durability, cost effectiveness, and ability to exclude striped cucumber beetles between lower cost spunbond row cover and higher cost insect exclusion netting.

Methods: Cucumber Beetle Trials

We direct seeded ‘Diva’ cucumbers (Johnny’s Selected Seeds) in a raised bed covered with black plastic mulch on 7 June 2019 at the Cornell Willsboro Research Farm in Willsboro, NY. We chose the variety ‘Diva’ because it is highly susceptible to damage from cucumber beetles. The raised bed was fertilized using compost and Pro Gro fertilizer (North Country Organics; 5-3-4) at a rate of 1000 lbs/ac prior to forming the beds.

Using a randomized complete block design, we installed individual low tunnels over the row of cucumbers to create plots to test the following treatments:

1) Novagryl 0.6 oz. lightweight spunbond row cover ($0.12 per row ft);
2) Proteknet 70g insect exclusion netting ($0.98 per row ft); and
3) Uncovered control.

Each low tunnel was 6 ft long by 5.3 ft wide. Three aluminum conduit wickets (hoops) held the row cover approximately 2 ft above the bed within each plot, and covers were secured by soil at the edges (Fig. 1). Due to poor germination, we replaced plants in the plots with seedlings on 8 Jul. Each tunnel contained three cucumber plants spaced 24 in apart. The covers remained on the low tunnels for the duration of the season. After fruit set, we fertigated twice per week using a soluble 5-12-26 fertilizer to deliver a total of 5 lbs/ac of Nitrogen (N) per week.

From June until September, we tracked cucumber beetle populations, cucumber yields, and environmental conditions within the low tunnel treatments. To measure cucumber beetle populations, we counted the total numbers of beetles (striped and spotted cucumber beetles) in each plot weekly. At each harvest (approximately three times per week), we picked and weighed all cucumbers in each plot and divided the yield between marketable cucumbers, unmarketable cucumbers due to beetle damage, and unmarketable cucumbers due to other causes. Twice during the season, in August and September, we measured light levels, temperature, and relative humidity.

To analyze the effects of treatment on total marketable yield, total beetle abundance, light, temperature, and relative humidity, we performed a series of one-way Analysis of Variance (ANOVA) tests. When a significant treatment effect was found, we performed Tukey *post hoc* tests to differentiate the treatments.

Results: Cucumber Beetle Trials

We experienced uncharacteristically low striped cucumber beetle populations and did not find beetles until early August, after the cucumbers had been growing for nearly two months. To supplement the beetle populations at the research farm, we introduced to the plots a total of ~100 striped cucumber beetles collected from a local farm during the first week of August.

Despite releasing beetles, the highest average number of beetles we found per plot was very low—less than three beetles per plot in mid-August (Fig. 2). When analyzing the total numbers of beetles found per plot over the season, we did not find any significant differences between mean numbers of beetles by treatment ($F=3.08$, $df=2, 9$, $p=0.100$; Fig. 3):

Uncovered control plots:	5 beetles/plot
Plots with insect exclusion netting:	4 beetles/plot
Row cover:	2 beetles/plot

Although we found more beetles on average in the uncovered plots, we harvested significantly more marketable cucumbers from the plots without low tunnels ($F=8.72$, $df=2, 9$, $p=0.008$; Fig. 4). We harvested twice as many marketable cucumbers in the uncovered plots as the row cover plots, and five times as many cucumbers in the untreated as the insect exclusion netting plots.

The environments under the low tunnels seemed to cause stress to the cucumber plants. The covered plants produced dense vines with few fruit. Light levels were lower ($F=16.61$, $df=2, 9$, $p<0.001$; Fig. 5) and humidity was higher ($F=5.79$, $df=2, 9$, $p=0.02$; Fig. 6) under the covers, and temperature was higher under the row cover on a sunny day ($F=11.8$, $df=2, 9$, $p=0.003$; Fig. 7). We also observed high numbers of male flowers under the row covers, a sign of plant stress in parthenocarpic varieties that do not require pollination to set fruit.

Conclusions: Cucumber Beetle Trials

Due to unusually low cucumber beetle populations, we were not able to sufficiently test for differences in efficacy between row cover treatments. We found that the cucumbers fared poorly under the low tunnels in the long term, and would recommend removing them permanently when the plants begin producing fruit.

While the Proteknet was approximately eight times more expensive than the row cover, we found it to be much more durable. It could easily be used for more than one season. The row cover began ripping mid-season, enabling pests to invade the tunnels. In high tunnel situations, we have heard from growers in our region that they have had success fitting Proteknet along sidewalls and vents. The netting is secured with wiggle wire along the sides, and rolled up after cucumbers are removed from the tunnel. When the next crop of cucumbers are planted in the tunnel, the netting can be rolled down for use again.

As part of our high tunnel field trip (see Outreach), we viewed a commercial high tunnel fitted with netting for beetle management. We were unable to conduct a replicated test of this system due to only having one high tunnel available for our cucumber project at the Cornell Willsboro Research Farm.

NITROGEN UPTAKE IN WINTER SPINACH

Background:

For the past two years, we have researched nitrogen uptake in cold soils by winter crops of high tunnel spinach. Spinach can be grown in NNY high tunnels without any supplemental heat and will not only survive the winter, but produce fall, late winter, and early spring harvests, and the associated cash flow when most tunnels would be standing idle. Additionally, winter crops can still allow a grower to produce a full summer crop of tomatoes.

Growers continue to question the ideal rate of N for a leafy crop like spinach grown in unheated high tunnels; current recommendations and practices range widely. In the winter of 2017-2018 we looked at N levels in spinach using three different sources of N at the same rate. In winter 2018-2019, we looked at yields under different rates of N all from the same source, from spinach planted at two planting dates. In calendar year 2019, we completed our 2018-2019 spinach experiment (from our 2018 grant) and began our 2019-2020 experiment.

Our 2019-2020 experiment tests four rates of N fertilization using two fertilizer types. Here, we report the final results from 2018-2019 and the 2019-2020 crop in individual sections by year.

2018-2019 N Uptake in Winter Spinach Experiment

Methods:

For our 2018-2019 experiment, we used an unheated, moveable 20 ft x 48 ft high tunnel with a single layer of polyethylene at the Cornell Willsboro Research Farm. The site was sod prior to moving our high tunnel into its place. The soil type within our high tunnel is Stafford Fine Sandy Loam. Our soil test in the tunnel just prior to planting indicated that the soil pH was 6.7, organic matter was 3.1%, and that calcium levels were high at 2743 lbs/ac.

Within the tunnel, we examined differences in spinach yield and foliar nutrients across two planting dates with four N fertility treatments, for a total of eight treatment combinations. We replicated each treatment four times, for a total of 32 plots (Fig. 8). Using Pro Booster (10-0-0, North Country Organics) as our N fertility source, we applied N in rates of either 0, 65, 130, or 200 lbs N/ac to our research plots within the tunnel approximately one week prior to transplanting our spinach. Nitrogen in Pro Booster is derived from a combination of plant and animal-based protein meal, including alfalfa, cocoa, cotton, kelp, peanut, soybean, blood, crab, feather, and fish.

We seeded 'Space' spinach (Johnny's Selected Seeds) at a rate of three seeds per cell in 72-cell trays filled with compost-based potting mix (Fort Vee, Vermont Compost Company) on 27 August (early planting) and 10 September (late planting). Seeds received a hot water treatment prior to planting to kill seedborne pathogens. After thinning the seedlings to two plants per cell, we transplanted the spinach in the tunnel on 21 September and 9 October 2018, respectively. Each plot consisted of 3 ft-wide beds with two 10-ft rows, each with 40 spinach plants spaced at 6 in within row and 6 in between rows. The spinach remained uncovered with row cover throughout the experiment and received overhead irrigation as needed.

To measure N levels in the plants, we collected foliar samples (whole spinach leaves) and pooled the sample by treatment at five dates throughout the season. We sent the samples to Waters Agricultural Laboratories (Camilla, GA) for foliar nutrient testing.

To measure yield, we harvested spinach plants at baby-medium leaf stage at four dates, 15 October, 5 November 2018, 1 March, and 2 April, and weighed the harvested spinach by plot. To analyze the effects of the treatment on total yield, we ran a generalized linear mixed model with N rate and planting date as fixed effects. We also ran two-way ANOVA tests, with N rate and planting date as factors, on yields from each individual harvest. Yields were analyzed and presented as yields per plant to adjust for different levels of rodent damage (missing or unharvested plants) between plots.

We also used a generalized linear mixed model to analyze the effects of treatment on foliar N levels, with N rate and N source as fixed effects, and sample date and block as random effects We also ran two-way ANOVA tests, with N rate and N source as factors, on yields from each individual sampling date. Tukey HSD tests were used to separate means when one treatment was found to be significant. Results from the Oct harvest were excluded from analyses, as they were collected as pooled samples from each treatment, rather than as replicated samples.

Results: N Uptake in Winter Spinach 2018-2019

Overall, nitrogen rates did not significantly affect yield (F=0.734, df=3, 120, 0=0.533; Table 1). Control plots with no added nitrogen yielded as much spinach as plots treated with 200 lbs/acre N (Table 1; Fig. 9). This was consistent within both planting dates, and across harvest dates.

Planting date did affect yield in the fall and winter, with the earlier planting producing significantly greater yields than spinach planted two weeks later ($F=99.6$, $df=1, 120$, $p<0.0001$). However, the later planting caught up to produce similar yields to the early planting at our April harvest date (Fig. 9).

Foliar N levels were similar among treatments in fall (Fig. 10). Plants receiving higher N treatments had slightly higher foliar N in spring, though all treatments remained within sufficient N ranges throughout the season. We were unable to perform statistical analysis for foliar N, since samples were pooled by treatment.

Conclusions: N Uptake in Winter Spinach 2018-2019

Our results indicate that spinach crops may require significantly less pre-plant N fertilizer than what is commonly applied in the NNY region. We found no significant yield benefit to supplying spinach with any N fertilizer at any of our harvests. Therefore, growers may consider the savings on input costs by forgoing or reducing fall fertilizer application. The data in this report reflects a single year of research. Our results may have been influenced by soil nutrients from the previous sod within the tunnel space. Additional research is needed to determine whether N source impacts the response of spinach to N rates.

Although we did not find any significant differences in spinach yield across N fertilizer rates, we did find that the earlier planting of spinach produced significantly higher yields than the later planting. Thus, we recommend that growers seed spinach in late August for transplanting in September, rather than transplanting into October.

2019-2020 N Uptake in Winter Spinach Experiment

Methods:

Following our 2018-2019 spinach experiment, we moved our 20x48' high tunnel to an adjacent site to avoid carryover effects from our fertilizer treatments. We turned under the sod and sent a soil sample to Agro-One for basic testing. 100 lbs/ac potassium and calcium were broadcast within the tunnel to compensate for low levels of these nutrients revealed in the soil test.

On 30 August, we seeded 'Gazelle' spinach (Johnny's Selected Seeds) into 72-cell trays filled with Fort Vee compost-based potting mix. The seeds underwent a hot water treatment prior to seeding to kill seedborne pathogens. We transplanted the spinach into our high tunnel on 24 September. Using a similar design to our previous projects, we used a randomized complete block design for plots fertilized with either feather meal (13-0-0; North Country Organics) or Pro-Booster (10-0-0, North Country Organics) to achieve rates of either 0, 65, 130, or 200 lbs N/acre. We replicated each treatment four times for a total of 32 plots (Fig. 8). Each plot contained 45 spinach "plants" (groups of two plants each) in three rows of 15 plants spaced 6 in between rows and 5 in within rows. This planting density was more dense that our previous years' experiments, and is reflective of spacing in commercial high tunnels in our region. The spinach received overhead irrigation until November.

On 21 October, 25 November 2019 and 16 March and 22 April 2020, we harvested the spinach when it was mid-sized (between baby and full-sized leaves). We measured yield by weighing the spinach leaves per plot. Additionally, we submitted foliar samples for analysis at Waters Agricultural Laboratories, and independent samples were submitted from each plot.

To analyze the effects of the treatment on total yield, we ran a generalized linear mixed model with N rate and N source as fixed effects, and harvest date and block as random effects. We also ran two-way ANOVA tests, with N rate and N source as factors, on yields from each individual harvest. Yields were analyzed and presented as yields per plant to adjust for different levels of rodent damage (missing or unharvested plants) between plots.

Results: N Uptake in Winter Spinach 2019-2020

Overall, N source significantly affected yield ($F=5.44$, $df=1, 117$, $p=0.02$), with plots treated with Pro Booster producing greater yields than plots treated with feather meal (Table 2; Fig. 11). This was due to significantly higher yields in the October harvest ($F=9.59$, $df=1, 24$, $p=0.005$). In all other harvests, N source did not significantly affect yield ($p>0.05$). Additionally, yields did not differ significantly across N rate treatments ($F=2.21$, $df=3, 117$, $p=0.09$).

Contrary to our yield results, amount of N applied to soil significantly affected foliar N levels ($F=4.42$, $df=3, 86$, $p=0.006$), while N source did not affect foliar N ($F=0.82$, $df=1, 86$, $p=0.37$). This was due to significant differences in November ($F=9.33$, $df=1, 24$, $p=0.0003$), where spinach treated with 130 or 200 lbs N/acre had greater foliar N than spinach treated with 0 or 65 lbs N/ac (Fig. 12). In March and April, spinach foliar N did not differ between treatments ($p>0.05$).

Conclusions: N Uptake in Winter Spinach 2019-2020

Similarly to our previous spinach experiments, we did not find that increasing nitrogen fertilizer rates increased yield. Fertilizer source (feather meal versus Pro Booster) impacted yield. Perhaps the nitrogen sources in Pro Booster, a variety of plant and animal meals, were more available to plants to support growth after transplanting, in September and October, versus feather meal. Curiously, N rate influenced foliar N levels in the fall, despite not having an impact on yield. Despite differences in foliar N, N levels remained within the optimal range during a majority of the season. As with our previous experiments, it is possible that decomposing sod provided some background nitrogen that reduced the impact of our fertilizer treatments on plant growth.

Little or no N fertilizer may be needed for overwintered spinach. If growers choose to apply N fertilizer, Pro Booster appears to increase fall spinach yields in comparison to feather meal. We plan to repeat this experiment in 2020-2021 under a New York Specialty Crop Block Grant (PI Jud Reid) to further explore the impact of N rate and source on overwintered spinach growth.

GROUND CHERRY AND GOLDENBERRY TRAINING METHODS

Background:

Ground cherries (*Physalis pruinosa*) and goldenberries (*Physalis peruviana*) are annual fruit crops receiving a lot of attention recently due to their great flavor and high nutritional content. They can be eaten fresh, blended into smoothies, made into jams, and dried for long-term sales and consumption. Fruits and berries are the first to sell out at farmers markets across the region and these berries can fill a niche and attract customers.

Most fruits are perennial, requiring considerable time and investment to establish, but ground cherries are an annual, low risk crop that NNY growers are interested in trying and can fit well into annual crop rotations. As a warm season crop they benefit from the added protection of a high tunnel. Ground cherries are prolific and begin to ripen in mid-July. However, NNY growers need a system to efficiently manage and harvest them. Goldenberries ripen later, grow taller, and are said to be easily trained to the double leader system we have studied in earlier cherry tomato trials.

Methods: Ground Cherry and Goldenberry Trials

We started the ground cherries and goldenberries in a commercial greenhouse in Essex, NY in March in seedling trays, transplanted them into 4 in pots in April, and planted them into our

30x96' high tunnel (unheated with single layer of plastic) on 23 May. We obtained our seeds from the Boyce Thompson Institute, a Cornell organization currently researching the potential of *Physalis* species as viable crops in NY. The tunnel received 20 lbs/1000 ft^2 Pro Gro (5-3-4). The ground was covered with landscape fabric within the tunnel for weed control, and plants were transplanted into holes within the plastic (Fig. 13). The plants were fertigated starting at fruit set twice weekly using the same rate as our cucumbers.

To demonstrate a new harvesting method for ground cherries, we planted two plots:

1) Ground cherries with a novel harvesting support frame; and
2) Ground cherries grown without additional support.

Each plot consisted of one row of five ground cherry plants spaced 24 in apart. We built our harvesting frame from aluminum conduit pipe with cut flower support netting. We demonstrated our harvest at outreach events and for a video posted to the Eastern NY Commercial Horticulture Program's YouTube page (see Outreach section). We did not measure yield, labor, or cost for our ground cherry treatments; they were for demonstration only.

Within the high tunnel, we tested the following goldenberry treatments:

1) Single leader;
2) Double leader; and
3) Stake-and-weave (Fig. 14)

Additionally, we included an untrellised plot for demonstration purposes.

We set up four 7 ft long plots of goldenberries for each treatment. For the single leader treatment, each plot contained five plants spaced 18 in apart. The double leader and stake-and-weave plots contained four plants each, spaced 24 in apart. We removed lateral stems from the main stem (single leader) or two main stems (double leader) throughout the season, clipping the plants to string so that the plants remained upright, similar to tomato pruning and trellising techniques. Plastic tomato clips secured the plants to the string.

For the stake-and-weave treatments, we installed four wooden stakes per plot and wove string between the stakes to create a wall of plants. We did not prune any branches from the stake-and-weave treatment. We strung and clipped the plants as necessary from June until September. Two applications of Entrust in July-August were necessary to manage three-lined potato beetle and tobacco hornworm in the tunnel. At the end of the season, we released parasitoid wasps (*Aphidius ervi* and *A. colemani*) and predatory midges (*Aphidoletes aphidimyza*) to manage potato and green peach aphids.

To determine whether the trellising systems were worth the added materials and labor expenses, we tracked the costs of our string, clips, stakes, and time spent on each trellising system. Labor costs were determined by multiplying the average time to harvest, trellis, and remove each plant over the season by the 2019 New York State minimum wage of $11.80/hr. We harvested the goldenberries five times, on 12 and 27 August, 16 September, and 1 and 30 October. The berries are ripe when the husks around the fruits turn yellow-brown. At each harvest, we removed the berry husks and sorted the fruit into marketable and unmarketable categories, measuring the yield in pints. Unmarketable fruit included berries that were split, moldy, and/or had pest damage. To analyze the effect of trellising system on total yield, we performed a one-way ANOVA, followed by a Tukey *post hoc* test to differentiate each system.

Results: Ground Cherry and Goldenberry Trials

Overall, yields were low across our goldenberry treatments, though goldenberries trained to the stake-and-weave system had significantly higher yields than the other two treatments ($F=22.6$, $df=2, 9$, $p=0.0003$; Fig. 15). Average marketable yields per plant were all less than one pint (Fig. 16). Goldenberry plants trained using the stake and weave system yielded on average 0.45 pints of marketable berries per plant, compared with 0.04 and 0.1 pints per plant in the single and double leader treatments, respectively. Despite an early start in the greenhouse in March, first harvest was not until August.

The costs of trellising the plants was quite high compared with the yields in return. Removing the lateral branches in the single and double leader systems significantly reduced fruit production. Unlike tomatoes, goldenberries produce single fruits from each petiole, rather than clusters of fruits on trusses (Fig. 17).

Costs of labor for trellising were:

$3.85 per plant for single leader,
$6.54 per plant for double leader, and
$5.89 per plant for stake-and-weave (Fig. 18).

Serious pest pressure contributed to low yields. Three-lined potato beetles, potato aphids, tobacco hornworms, *Heliothis* moths, and an unidentified Hemipteran bug fed on the leaves and fruit husks. Beetles and hornworms defoliated the plants. Aphid honeydew caused husks and fruits to mold, and moths pupated within the fruits. A large proportion of the fruits had moth pupae inside, which was not visible until the fruits were husked.

Conclusions: Ground Cherry and Goldenberry Trials

Low yields due to late ripening and pest pressure rendered the goldenberry crop unprofitable in our study. We calculated that we would have needed to receive $91/pint for single leader, $67 for double leader, and $13/pint for stake-and-weave to recuperate the costs of trellising alone. Such high prices are extremely unrealistic. For example, the single leader plants produced 0.04 pints of marketable fruit per plant, requiring ~23 plants to produce one pint of fruit. At a cost of $3.85 per plant for trellising alone, a price of $91/pint of goldenberries would be necessary to recover the costs. For the stake and weave treatment, which yielded the most, a pint of berries would need to cost $13, which is much less, yet also unrealistic. These estimates are conservative, as they do not factor in time it takes to husk and sort goldenberries. We also did not take into consideration costs of seeds, potting soil, greenhouse space, or time to husk the berries to determine marketability.

Stake-and-weave, or no trellising at all may be the most effective method for maximizing yields of goldenberries. Additionally, for the crop to be viable in New York, more research and development will be necessary to identify shorter season varieties and to improve pest management options for the *Heliothis* moth, which burrows into the fruit, protected from foliar insecticides (Fig. 19). It is likely that commercial growers would not have the time to remove the husks from each berry to check for moths before sending them to market.

Outreach

In 2019, growers had three opportunities to tour our high tunnels and learn about this research in-person at the Willsboro Farm:

- Willsboro Farm Open House: On 10 July, 2019, 46 growers, Extension staff, and members of the general public toured the farm and listened to Judson Reid, Mike Davis, and Elisabeth Hodgdon discuss research findings from the NNYADP projects
- Willsboro Farm Twilight Meeting: project leaders presented research results and general information about high tunnel production to 5 growers and Extension staff on 27 August 2019 (Fig. 20) and distributed research reports on cucumber, goldenberry, and spinach trials.
- Winter High Tunnel Tour: 4 growers and Extension staff toured overwintered spinach trial at the Cornell Willsboro Research Farm, and carpooled to Intervale Community Farm (ICF), Burlington, VT, on 13 November where Andy Jones of ICF discussed his farm's winter vegetable production practices (Fig. 21).

In addition to our Willsboro Farm meetings, we presented our 2018 and 2019 NNYADP project results at the following events and outlets:

- Small Farms Veterans in Ag program: "High Tunnel Growing", Equicenter, Mendon, NY. Judson Reid shared data from the NNYADP Willsboro high tunnel research on March 26, 2019, and January 7, 2020, with 12 military veterans interested in farming.
- "Introduction to Winter Growing" webinar: Judson Reid and Elisabeth Hodgdon gave an overview of winter growing practices in high tunnels, including suitable crops, recommended planting dates, soil fertility, and pest management. Spinach research results were discussed. Eight participated in the live webinar, and, thus far, 138 have viewed the recording. (https://www.youtube.com/watch?v=qbAg4fovYL8&t=83s).
- "What's Bugging Your Vegetables?": On 3 January 2020 at the Lewis County Cornell Cooperative Extension office, Judson Reid and Elisabeth Hodgdon discussed management of common pests and diseases of vegetables in NNY, mentioning NNYADP cucumber beetle and spinach research trials. 11 growers attended.
- Eastern NY Commercial Horticulture Program (ENYCHP) Veg News Podcast: 5 September, Elisabeth Hodgdon discussed the results of the NNYADP 2018-2019 spinach experiment with 91 listeners (https://soundcloud.com/easternnewyorkvegnews), as advertised via the ENYCHP's listserv and social media.

Other outreach materials:

- Demonstration video of ground cherry harvesting frame: (https://www.youtube.com/watch?v=YCaitW_8XTA), 144 views, as well as Elisabeth Hodgdon's professional Instagram page: 96 views.

- Research reports created by project leaders for each of the three projects were distributed at the August 2019 twilight meeting and November 2019 high tunnel tour

Acknowledgements:
We thank Adam Reed of Tangleroot Farm in Essex, NY for growing goldenberry and ground cherry seedlings used in the experiment. We also thank Delvin Meseck, Adam Sayward, and Edward Nesbitt at the Willsboro Research Farm for technical assistance.

APPENDIX

Figure 1. Proteknet (left) and row cover (right) low tunnel treatments. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photo by Andy Galimberti.

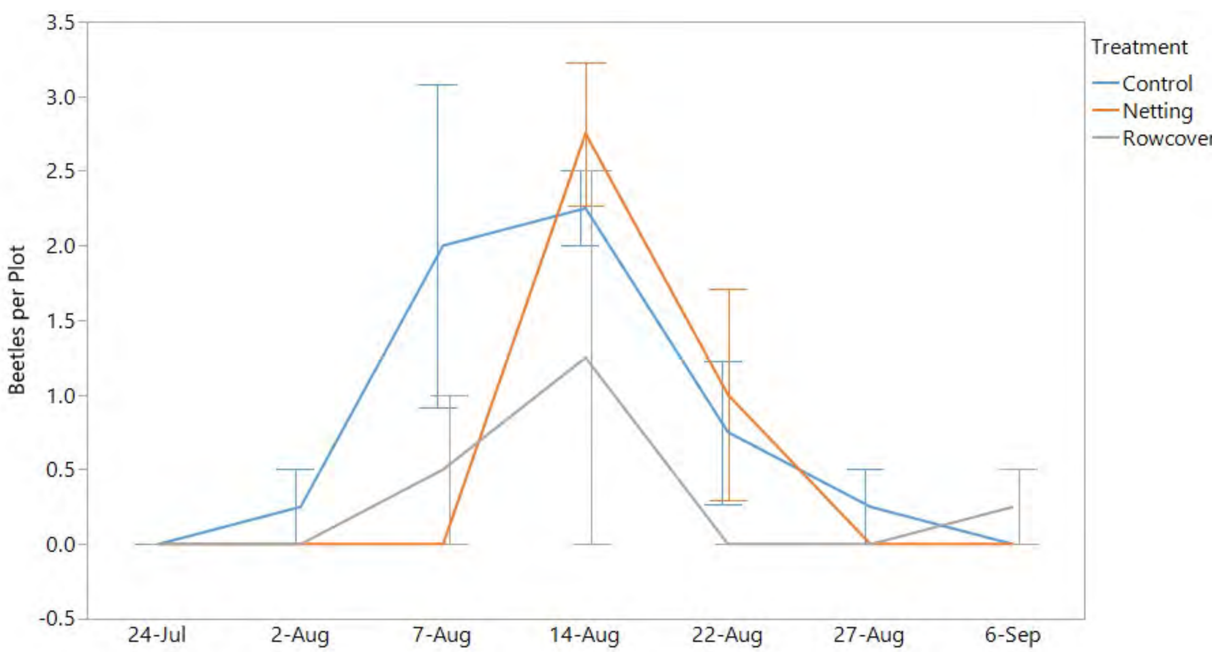

Figure 2. Mean numbers of cucumber beetles per plot. Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

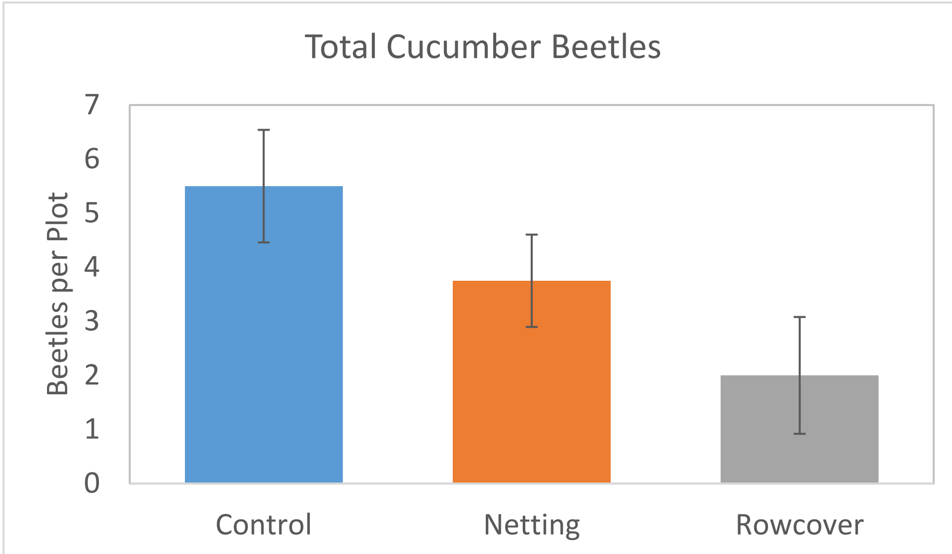

Figure 3. Total numbers of cucumber beetles found in plots over 2019 season. Mean numbers of beetles did not significantly differ across row cover treatments ($p>0.05$). Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

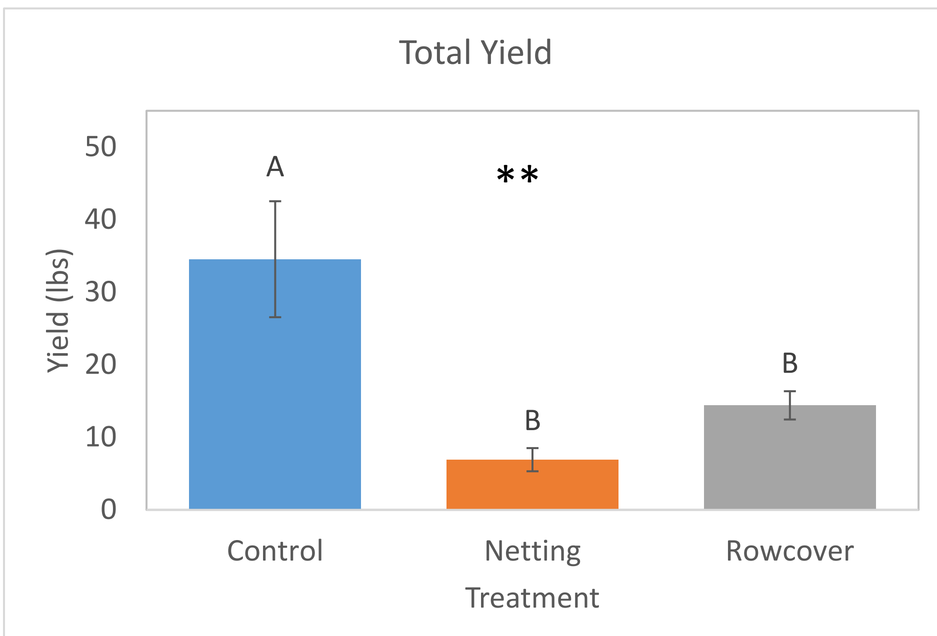

Figure 4. Total marketable cucumber yield between row cover treatments. Asterisks indicate significance level of overall model, where ** = $p<0.01$. Treatments labeled with different letters are significantly different ($p<0.05$) according to Tukey *post hoc* pairwise comparison tests. Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

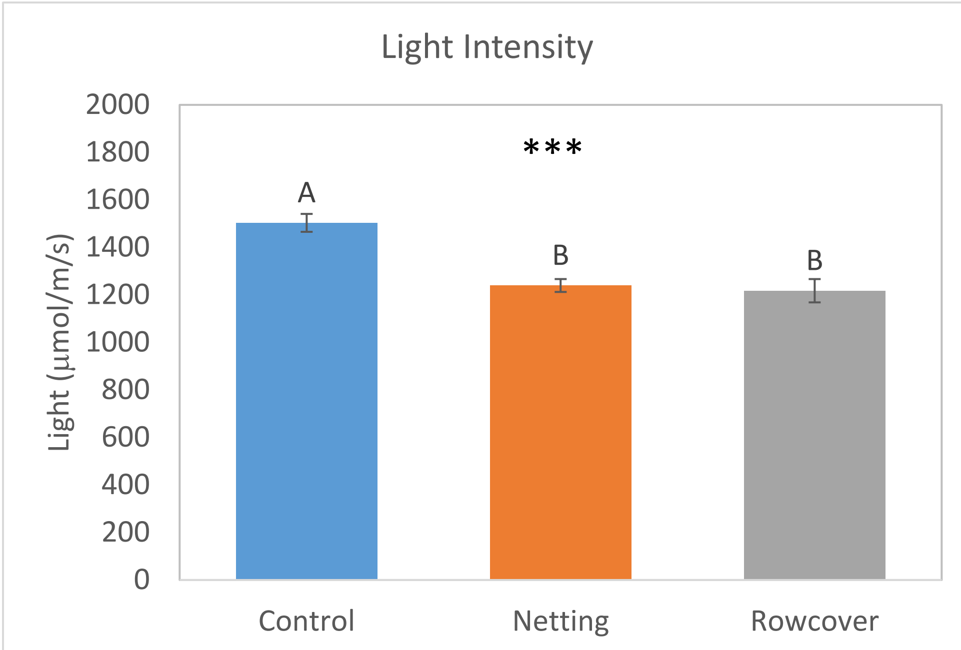

Figure 5. Light intensity across cucumber row cover treatments. Asterisks indicate significance level of overall model, where *** = p<0.001 Treatments labeled with different letters are significantly different (p<0.05) according to Tukey *post hoc* pairwise comparison tests. Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

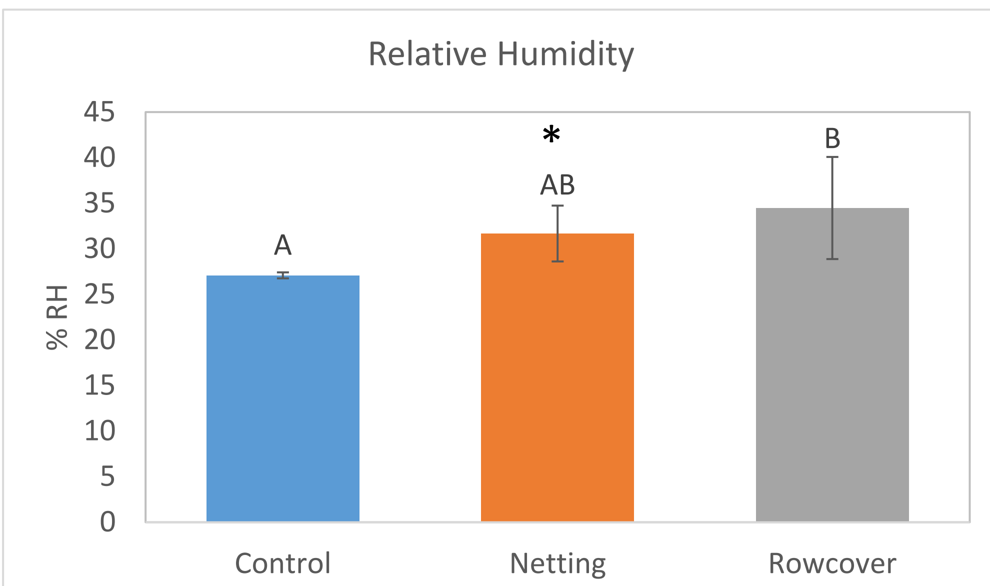

Figure 6. Percent relative humidity (RH) across cucumber row cover treatments. Asterisk indicates significance level of overall model; where * = p<0.05. Treatments labeled with different letters are significantly different (p<0.05) according to Tukey *post hoc* pairwise comparison tests. Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

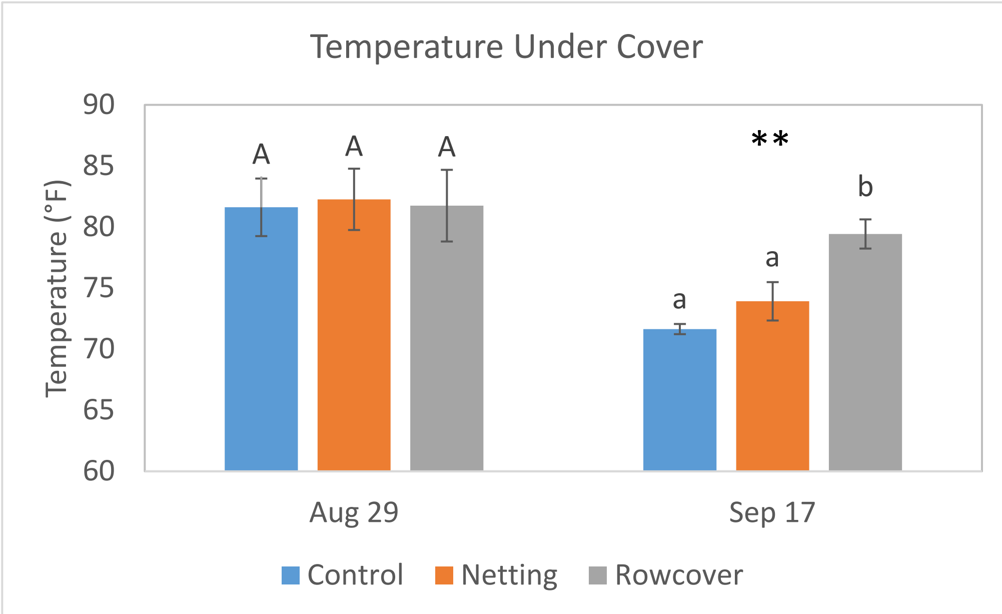

Figure 7. Temperature across cucumber row cover treatments on two dates. On 29 August 2019, the weather was partly cloudy, whereas on 17 September it was full sun. Asterisks indicate significance level of overall model within date, where ** = $p<0.01$. Treatments labeled with different letters are significantly different ($p<0.05$) according to Tukey *post hoc* pairwise comparison tests. Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.


Figure 8. Spinach plots in Willsboro Farm high tunnel in February 2019. 2018 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photo by Andy Galimberti.

Table 1. Total spinach yield from high tunnel plots in 2018-2019 experiment. 2018 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

Treatment		Spinach yield (lbs per 2 x 10' rows)
Seeding Date	Nitrogen (lbs/ac)	
Aug. 27 ("early")	0	2.6
	65	2.4
	130	2.6
	200	3.3
Sept. 10 ("late")	0	1.5
	65	1.3
	130	2.2
	200	1.7

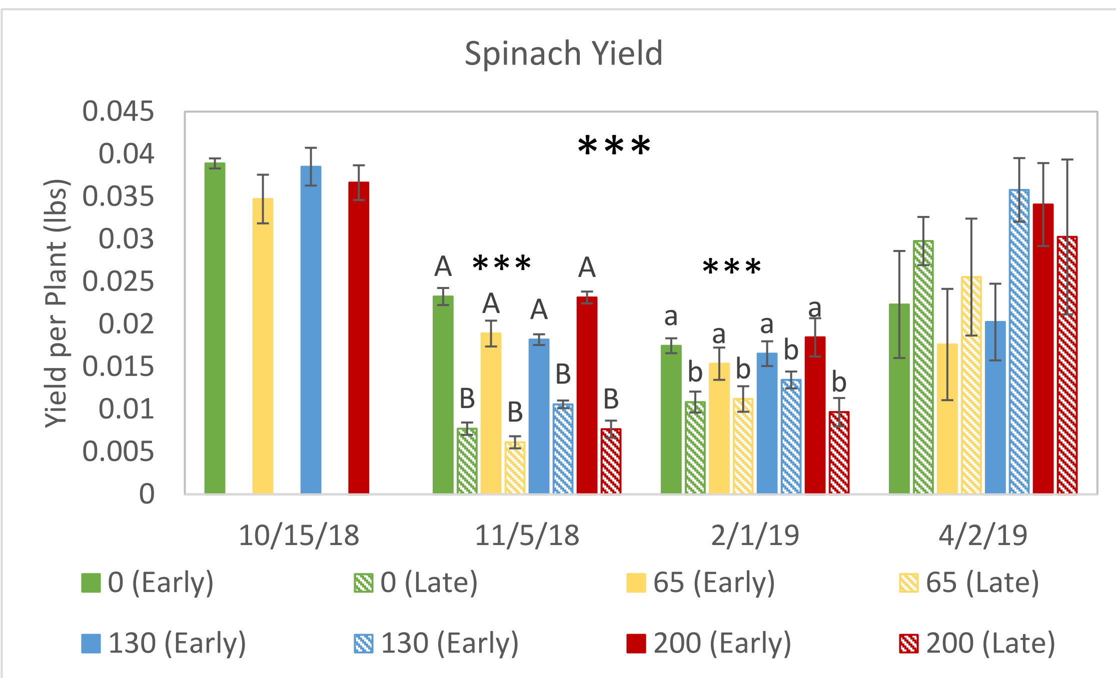

Figure 9. Spinach yield per plant across early and late planting dates and fertilizer treatments (lbs N/ac) in 2018-2019 experiment. Asterisks indicate significance level of overall model and yields within sampling dates; where *** = $p<0.001$. Treatments labeled with different letters are significantly different ($p<0.05$) according to Tukey *post hoc* pairwise comparison tests. Data presented as mean ± standard error. 2018 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

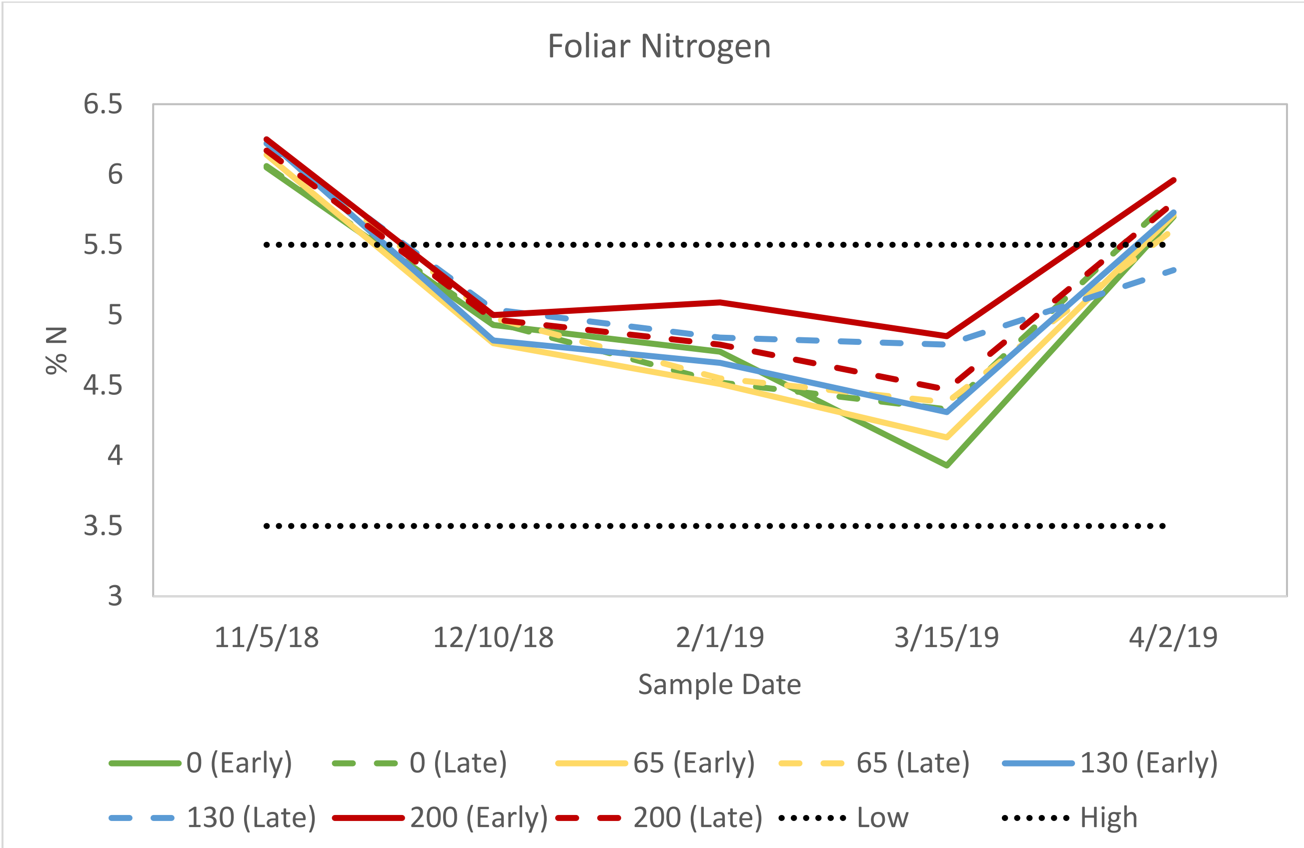

Figure 10. Foliar nitrogen in spinach leaves across early and late planting dates and N fertilizer treatments (lbs N/ac) in 2018-2019 experiment. Dotted black lines indicate range of %N deemed sufficient (Waters Agricultural Laboratories). Values above the line are considered excessive. 2018 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

Table 2. Total spinach yield from high tunnel plots in 2019-2020 experiment. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

Treatment		Total spinach yield
Fertilizer	Nitrogen (lbs/ac)	(lbs per 3 x 6.25' rows)
Feather meal (13-0-0)	0	22.9
	65	20.3
	130	23.3
	200	22.0
Pro Booster (10-0-0)	0	21.5
	65	23.7
	130	28.4
	200	26.6

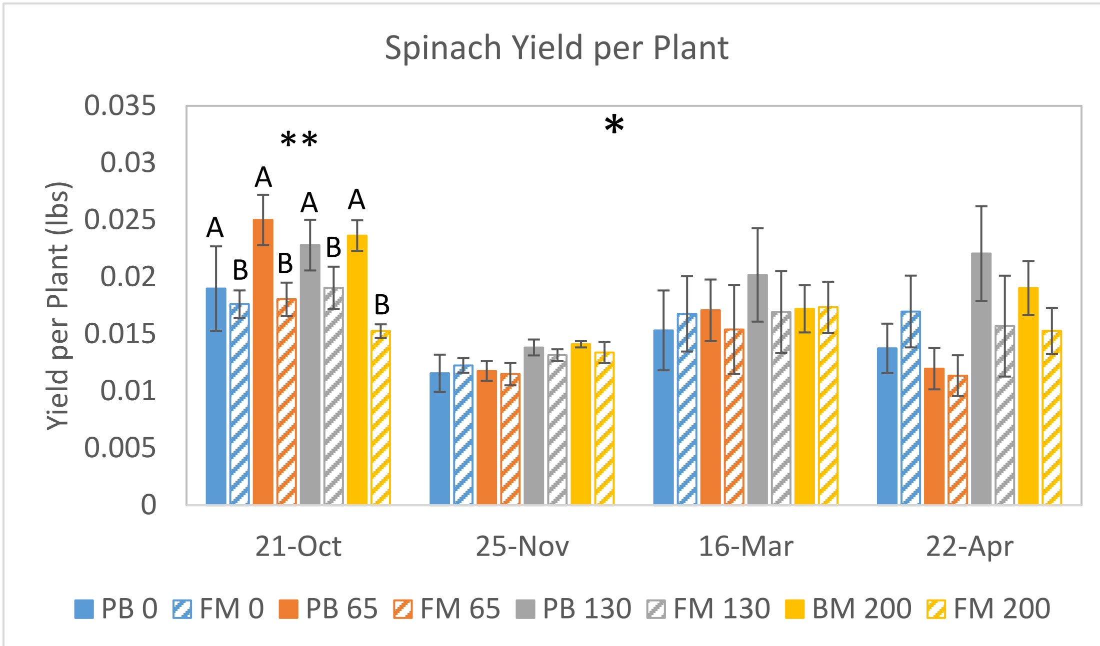

Figure 11. Spinach yield per plant across N fertilizer source and rate treatments in 2019-2020 experiment. Asterisks indicate significance level of overall model and yields within sampling dates, where * = p<0.05 and ** = p<0.01. Fertilizer treatments are represented as PB = Pro Booster, and FM = feather meal, followed by application rate (lbs N/ac). Treatments labeled with different letters are significantly different (p<0.05) according to Tukey *post hoc* pairwise comparison tests. Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

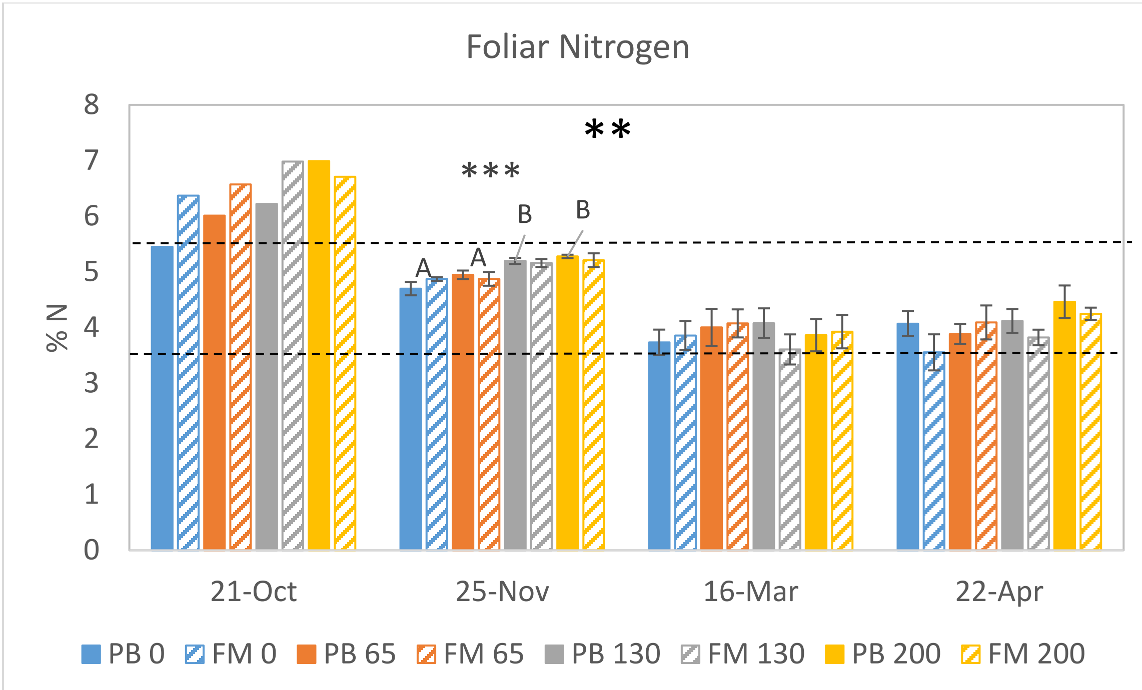

Figure 12. Foliar nitrogen in spinach leaves in 2019-2020 experiment. Asterisks indicate significance level of overall model and values within sampling dates, where ** = p<0.01 and *** = p<0.001. Fertilizer treatments are represented as PB = Pro Booster, and FM = feather meal, followed by application rate (lbs N/ac). Treatments labeled with different letters are significantly different (p<0.05). Data presented as mean ± standard error. For the Oct sampling date, samples for each treatment were pooled together, so the %N for each treatment across replicates is shown. Dotted black lines indicate range of %N deemed sufficient (Waters Agricultural Laboratories). 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

Figure 13. Goldenberries in high tunnel at Cornell Willsboro Research Farm in May 2019. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photo by Andy Galimberti.

Fig. 14. Goldenberries trained to single leader (left), double leader (center), and stake and weave (right) trellising systems at Cornell Willsboro Research Farm. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photos by Andy Galimberti.

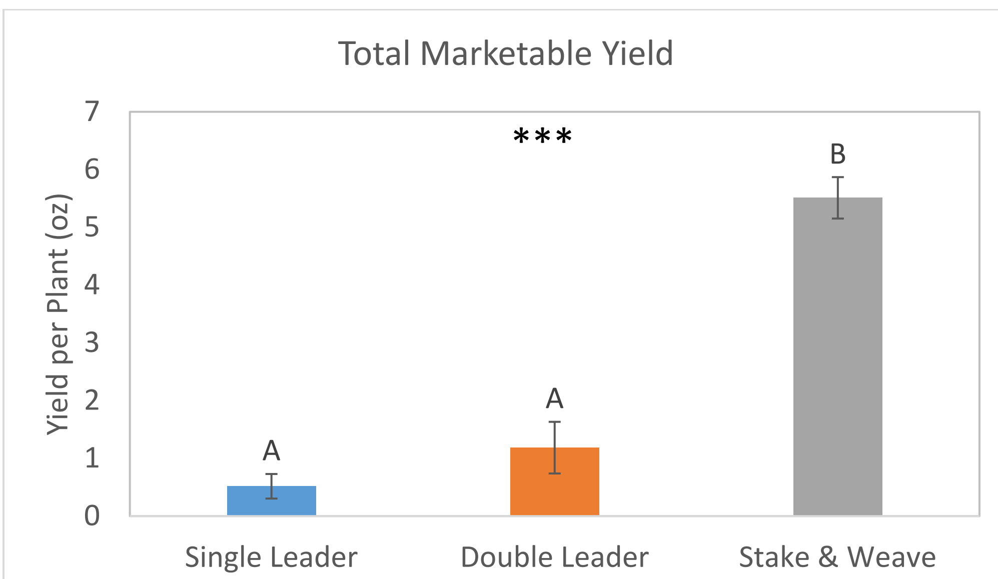

Figure 15. Marketable goldenberry yield for each training system. Asterisks indicate significance level of overall model, where *** = $p<0.001$. Treatments labeled with different letters are significantly different ($p<0.05$) according to Tukey *post hoc* pairwise comparison tests. Data presented as mean ± standard error. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

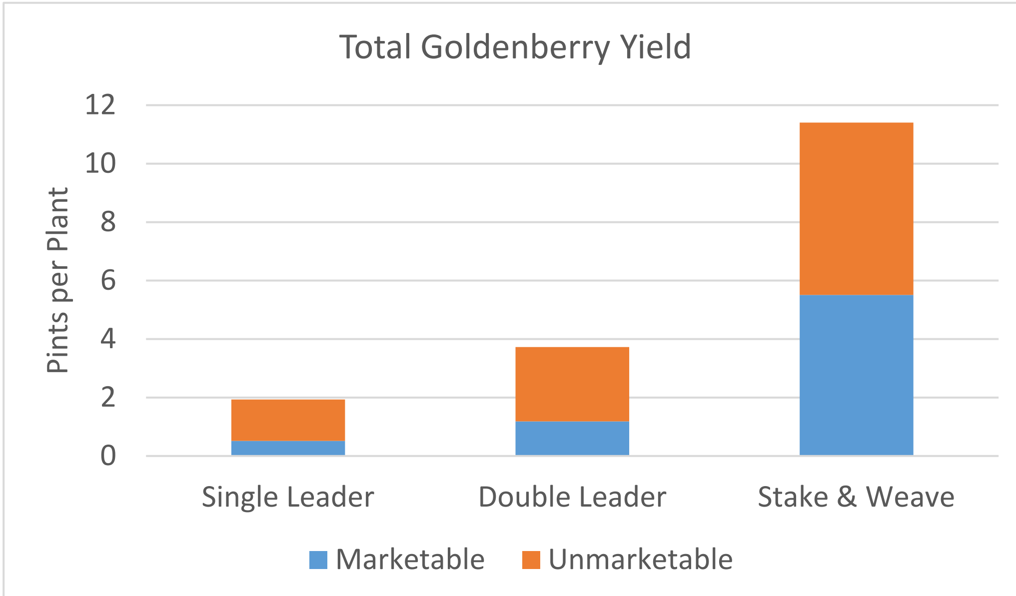

Figure 16. Marketable and unmarketable goldenberry yield across trellising treatments. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.


Figure 17. Ripe goldenberry on pruned single leader stem at Cornell Willsboro Research Farm. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photo by Andy Galimberti.

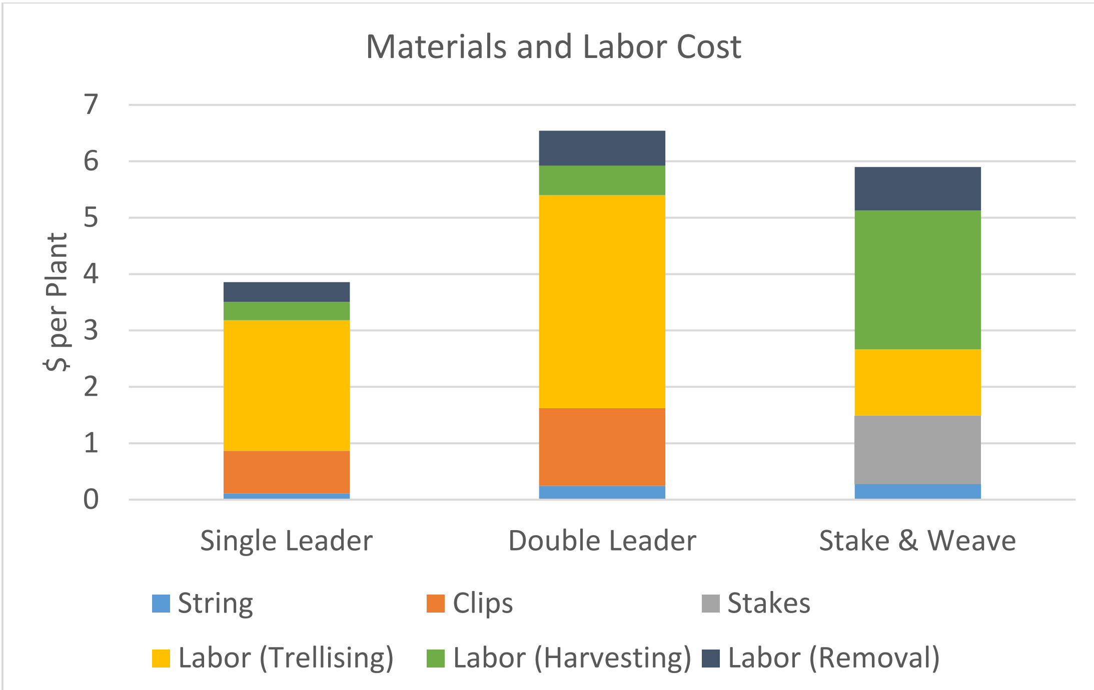

Figure 18. Trellising materials and labor costs for goldenberry trellising treatments. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project.

Figure 19. Heliothis moth entry hole (left) and pupa inside fruit (right), rendering goldenberries unmarketable. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photos by Elisabeth Hodgdon.

Figure 20. Elisabeth Hodgdon and Mike Davis discuss the goldenberry and ground cherry trials at the Willsboro Farm Twilight Meeting on 27 August 2019. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photo by Andy Galimberti.

Figure 21. Andy Jones at Intervale Community Farm, Burlington, VT, shares his winter growing practices at the Winter Greens High Tunnel Tour on 13 November, 2019. 2019 NNYADP Advancing Vegetable and New Fruit Crops Production in NNY project. Photo by Andy Galimberti.