# The Ceres Trust Final Project Report: 2012-2013

Aaron Yoder, Graduate Student
Mathieu Ngouajio, PhD
Michigan State University- Department of Horticulture

**Project Title:** Exploring the combination of biofumigation and anaerobic soil disinfestation for soil quality enhancement in organic vegetable cropping systems

## Project Rationale:

Organic farmers are often restricted in their abilities to respond to disease pressures that persist through commonly utilized rotational and other non-chemical, preventative measures. Biofumigation (BF) and anaerobic soil disinfestation (ASD) represent management strategies that not only have the potential to alleviate such disease pressures, but to also address another critical issue in organic production- the management of soil fertility. Soil fertility is particularly important in organic cropping systems, where nitrogen can be a seriously limiting mineral nutrient. As fertilizer costs continue to increase, this aspect of cover cropping will become increasingly attractive for conventional growers as well. The multi-functional, dynamic nature of these practices stand to contribute significantly to sustainable agriculture, however the reliance on such a practice requires a heightened understanding of the biological and physical processes to ultimately provide desired outcomes.

## Project Objectives:

Objectives for this project were to:

1. Evaluate the N scavenging potential and release of N following spring brassica cover cropping under bare ground and black plastic mulch.
2. Evaluating the impact of BF and ASD treatments on microbial activity.
3. Determining the effects of BF and ASD treatments on yields of cucumber and tomatoes.

## Project Activities 2012-2013:

*Field setup and data collection methods*

An experiment was designed and conducted at the Horticulture Teaching and Research Center (Holt, MI) in 2012 and 2013 to address these objectives. In 2012, four cover crops were seeded in 8.5 x 13.4 m plots within a randomized complete block design. These treatments were replicated 4 times across the field and each block included a no cover crop control plot. Cover crops included: oriental mustard (*Brassica juncea* 'Pacific Gold') (PG), yellow mustard (*Sinapis alba* 'Ida Gold') (IG), oilseed radish (*Raphanus sativus* 'Defender') (OSR) and oats (*Avena sativa* 'Excel') (OAT). Standard seeding rates of 8,8,11 and 134 kg/ha were used for PG, IG, OSR and OAT respectively. Prior to cover crop seeding, the field was fertilized at the rate of 112 kg N/ ha (Mcgeary's Organic Fertilizer, 8-2-2) using an oscillating spreader. Cover crops were then evenly broadcast by hand in each plot and incorporated using a rolling-basket implement. Due to poor stand establishment in 2012, seeding methods were modified in 2013 by using a multi-row push seeder to better distribute the seeds over the surface and improve seed depth placement. Poor stand establishment among IG plots in 2012 also required altering the seeding rate to 18 kg/ha for 2013. At approximately 50% flowering, cover crops were sampled for above and below ground biomass using four 25 x 50cm quadrats from each plot. Plant residue was then dried at 90°C for two weeks, weighed, and submitted for N analysis (Midwest laboratories, Omaha, NE) Following biomass sampling, cover crops were mowed using a flail mower and immediately incorporated to the soil using a roto-vator. Following incorporation, sub-plot mulch treatments were immediately applied using a mechanical plastic mulch layer, including bare ground (BG), standard low-density black polyurethane (BP) and black virtually impermeable film (VIF). In 2013, an additional mulching treatment (VIF+M) was applied to all main plot treatments; this included the application of molasses at the within bed rate of 19.9 Mg/ha as a standard ASD treatment comparison. After observing a two-week ASD period, fresh-market tomato 'Big beef' and slicing cucumber 'Cortez' (Osborne International Seed co., Mt. Vernon, WA) transplants were planted at 61 cm centers within plots. Soil samples were collected at transplanting and analyzed for microbial biomass. Ion exchange resin strips were installed following plastic mulch application and were exchanged with fresh, charged strips every two weeks during the growing season to evaluate plant available N. Temperature sensors

(HOBO®, Onset computer corp., Bourne, MA) were also installed 10 cm beneath the soil surface in the mulch treatments. As crops matured, yields were collected and sorted into marketable and unmarketable categories.

*Results*

Brassica cover crops displayed differential abilities to accumulate biomass and subsequently scavenge residual nitrogen from the soil in both years. Oilseed radish consistently accumulated the highest levels of biomass

| Cover Crop/ variety | Seeding rate (lbs/ac) | Cover crop biomass (kg/ha) | Weed biomass (kg/ha) | [2]Accumulated N (kg/ha) from cover crop biomass |
|---|---|---|---|---|
| **2012** | | | | |
| Control (no cover) | - | - | 819 ± 99 | 0 |
| Oilseed radish/ 'Defender' | 10 | 2291 ± 301 | 148 ± 27 | 44.3 ± 7.2 |
| Oat /'Excel' | 120 | 2418 ± 431 | 136 ± 24 | 36.9 ± 4.2 |
| Yellow mustard / 'Ida gold' | 7 | 1133 ± 165 | 388 ± 103 | 28.9 ± 4.5 |
| Oriental mustard / 'Pacific gold' | 7 | 1235 ± 216 | 311 ± 19 | 26.8 ± 4.6 |
| **2013** | | | | |
| Control (no cover) | - | - | 732 ± 114 | 0 |
| Oilseed radish/ 'Defender' | 10 | 2097 ± 408 | 133 ± 31 | 51.3 ± 8.2 |
| Oat /'Excel' | 120 | 1459 ± 968 | 122 ± 28 | 27.3 ± 5.8 |
| Yellow mustard / 'Ida gold' | 10 | 1002 ± 183 | 347 ± 119 | 24.6 ± 2.8 |
| Oriental mustard / 'Pacific gold' | 7 | 1246 ± 348 | 278 ± 22 | 28.3 ± 7.4 |

followed by oats and the other mustards (Table 1.1)

Table 1.1- Cover crop treatments, seeding rates, biomass and accumulated N during the 2012 and 2013 season.

Despite these differences, cover crops had no significant effect on plant available nitrogen sampled from resin strips during the growing season in 2012. Plastic mulching caused significantly higher $NO_3^-$ to be available during the early part of the growing season in 2012 and 2013, while the molasses amended plots caused dramatic reductions during the weeks following transplanting (Figure 1.1). Soil temperatures under the black plastic mulches were substantially higher than the bare ground treatments and are believed to be responsible for accelerating mineralization and ultimately the higher $NO_3^-$ observed in the earlier parts of the growing season (Figure 1.2).

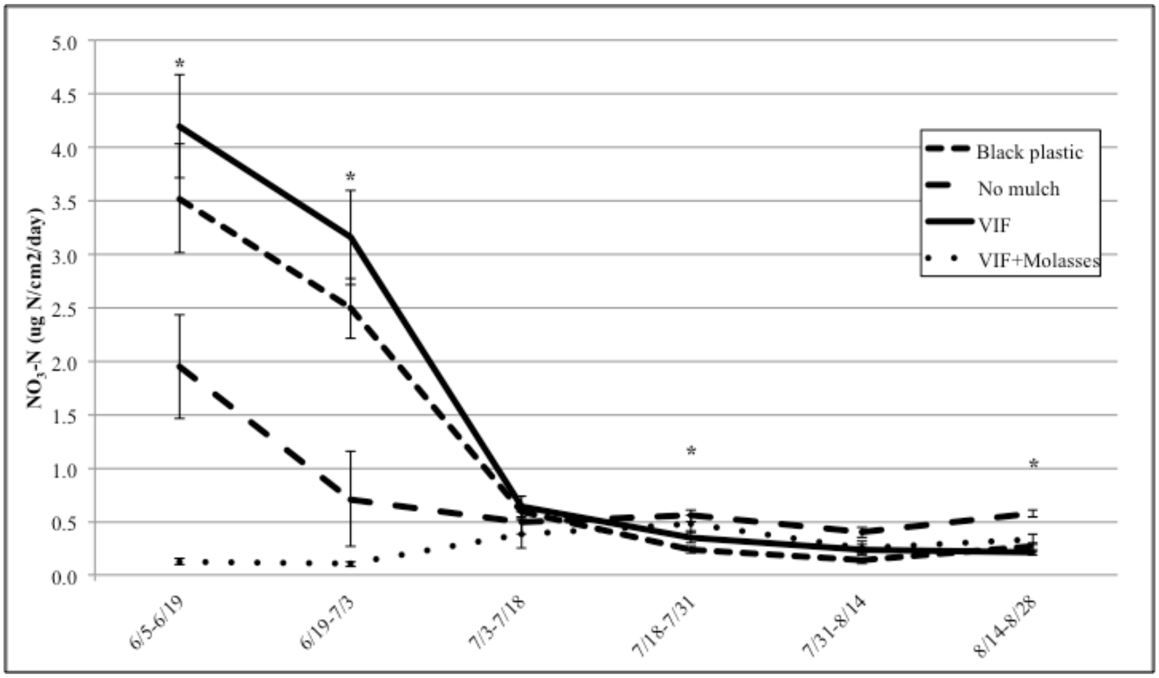


Figure 1.1- Nitrate availability following ASD under mulching treatments in 2013. Cover crop effects were not significant ($\alpha$=0.05)

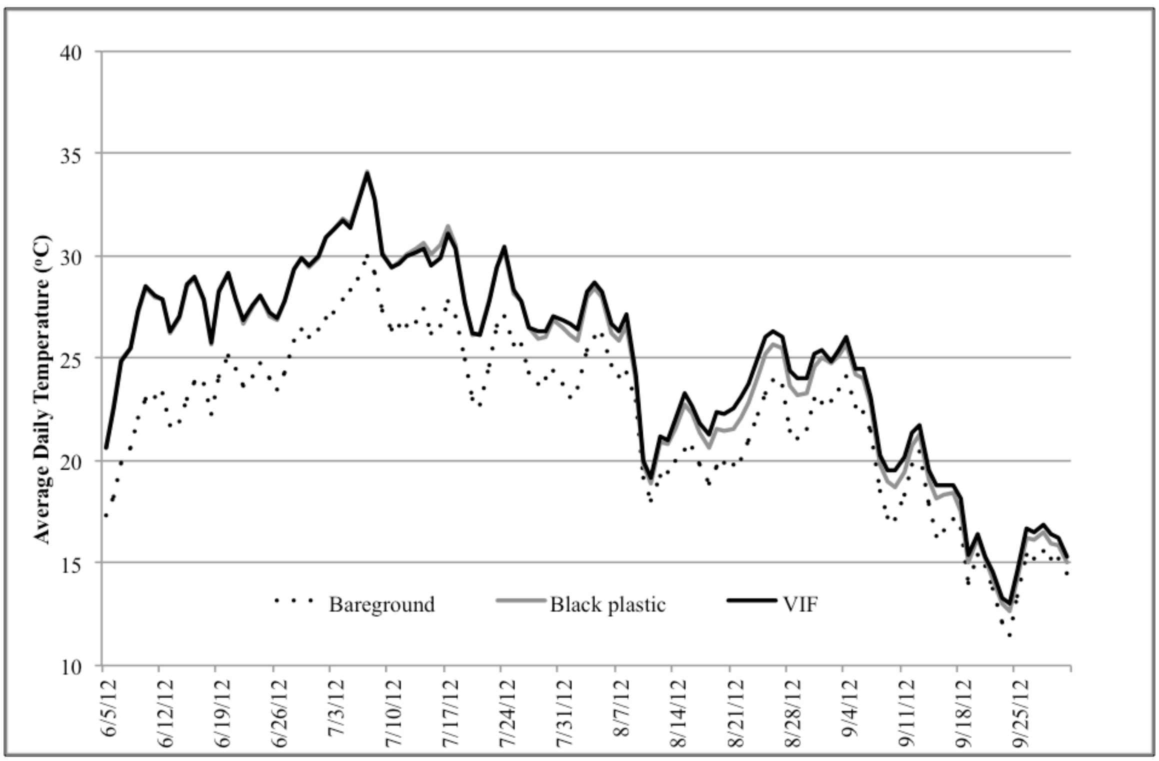


Figure 1.2- Soil temperatures at 10 cm depth during the 2013 growing season under plastic mulch treatments.

The dramatic early reduction in $NO_3^-$ in the molasses amended plots was likely the result of microbial immobilization. Microbial biomass was highest in the molasses amended plots as shown in Figure 1.3. Tomato plants in these plots were observed to be severely nutrient deficient in the first month of growth, although they did eventually resume growth later in the season.

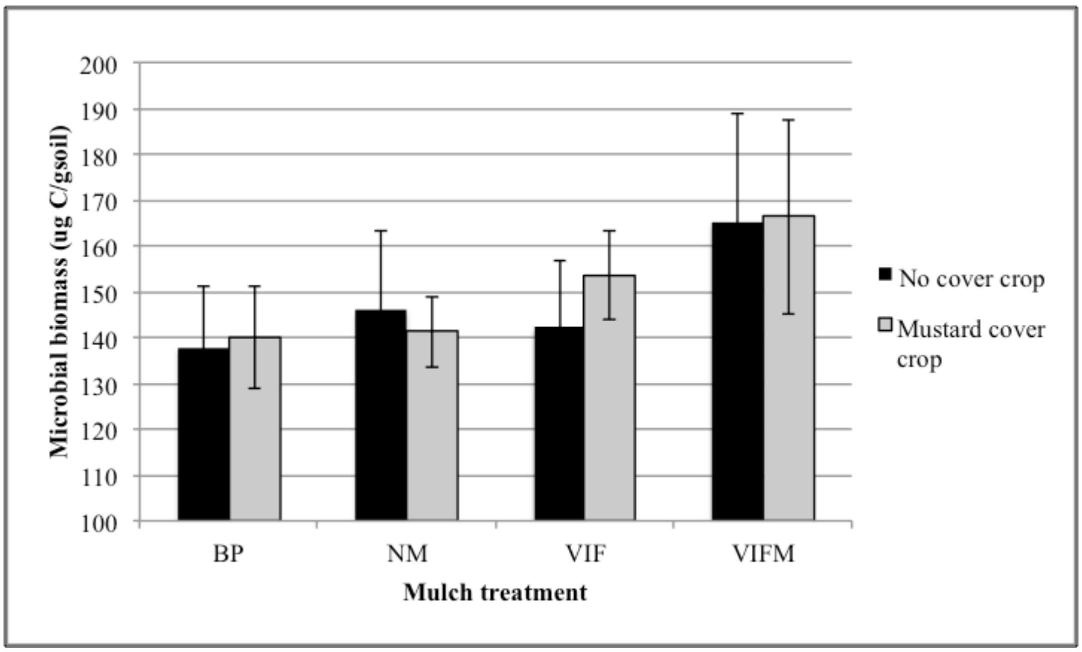


Figure 1.3 (Above)- Microbial biomass carbon following ASD in 2013
Figure 1.4 (Below)- Tomato transplants following in VIF (bottom left) and VIF+ molasses plots (bottom right).

Cover crops did not have significant effects on tomato or cucumber yields in both years, although mulching treatments had dramatic effects in both years. Early yields were higher under black plastic mulching treatments (except for those with molasses added), while later yields were much greater in bare ground treatments, differences which led to the bare ground treatments having the highest cumulative marketable yields in both years (Table 1.2). Extreme temperatures under the black plastic may have been responsible for this outcome, where soil temperatures reached upwards of 105°C during the growing season.

Table 1.2- Tomato yields under plastic mulching treatments in 2012

| Mulch Treatment | [1]Early yields (Mg/ha) | | [2]Late yields (Mg/ha) | | [3]Cumulative yields (Mg/ha) | |
|---|---|---|---|---|---|---|
| | Marketable | Cull | Marketable | Cull | Marketable | Cull |
| **2012** | | | | | | |
| **No Mulch** | [4]3.7 **C** | 1.6 **B** | 41.9 **A** | 29.5 **A** | 55.5 **A** | 31.9 **A** |
| **Black Plastic** | 6.9 **A** | 4.4 **A** | 31.5 **B** | 18.0 **B** | 47.5 **B** | 23.7 **C** |
| **VIF** | 4.3 **B** | 3.7 **A** | 30.9 **B** | 22.7 **C** | 45.9 **B** | 28.0 **B** |
| *Pr > F* | *<0.0001* | *<0.0001* | *<0.0001* | *0.0003* | *0.0014* | *0.0041* |
| **2013** | | | | | | |
| **No Mulch** | 9.4 **B** | 1.6 **B** | 51.1 **A** | 27.8 **A** | 60.5 **A** | 29.4 **A** |
| **Black Plastic** | 21.9 **A** | 3.5 **A** | 33.1 **B** | 15.2 **B** | 55.0 **A** | 18.8 **B** |
| **VIF** | 18.8 **A** | 2.8 **A** | 39.6 **B** | 17.6 **B** | 58.5 **A** | 20.4 **B** |
| **VIF+molasses** | 10.6 **B** | 1.6 **B** | 33.5 **B** | 18.7 **B** | 44.2 **B** | 20.3 **B** |
| *Pr > F* | *<0.0001* | *0.0002* | *<0.0001* | *<0.0001* | *0.0002* | *<0.0001* |

[1]Early yields included the first four harvests in 2012 and the first three harvests in 2013
[2]Late yields included the last four harvests from 2012 and the last three harvests from 2013
[3]Yields were collected weekly for a total of 9 harvests in 2012 (Aug. 13-Oct. 3) and 6 harvests in 2013 (Sept. 4
[4]Means followed by different letters within columns are significantly different ($\alpha$=0.05)

(above) and 2013 (below). Cover crop treatments had no significant effect on crop yields in either year ($\alpha$=0.05).

## On-farm involvement and outreach:

An experiment was designed and conducted at Cinzori's farm (Ceresco, MI) to evaluate combinations of biofumigation and ASD in an organic tomato production system. Cover crops were seeded in early April in 2013 and emerged soon after. Due to heavy infestations of flea beetles, cover crop biomass was almost entirely lost and plants were only sporadically observed in the plots (Figure 1.5).

Figure 1.5- Flea beetle on mustard cover crop (left) and plot overview (right) at Cinzori's farm in May 2013. Note the lack of brassica cover crops and high presence of weeds in picture to the right.

Successfully establishing spring sown brassica cover crops in diverse vegetable production systems has been shown to be challenging and adverse impacts on subsequently planted brassica family cash crops has been shown to occur as well. These cover crops can harbor mobile pests like flea beetles that can move from infested hosts to cash crops. This represents a challenge when considering the utilization of these cover crop species for diversified growers with a lot of brassica cash crops in their rotation.

The results of this study were presented at various grower and scientific meetings including:

- The American Society for Horticulture Science (oral and poster); Palm Desert, CA, 2013.
- The Great Lakes Fruit and Vegetable Grower's Exposition (poster); Grand Rapids, MI, 2012 and 2013.
- The Midwest Organic and Sustainable Education Service annual conference (poster); LaCrosse, WI, 2013 and 2014.