# Evaluation of Summer Cover Crops for Fall Vegetable Production

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## Introduction

Nutrient and soil management of organic vegetable crops must use National Organic Program (NOP) compliant materials. Allowable inputs include animal manure, compost, legume cover crops, green manures, and commercially produced fertilizer. The practice of rotation with cover crops is a requirement of organic production, but can be a challenge, especially when it comes to finding a planting window between cash crops. This challenge is increased on diversified vegetable operations, where multiple crops are grown in a season.

Planting cover crops in the fall following spring and summer cash crops and in the spring prior to cultivation are excellent opportunities, although the latter method is not common in Iowa due to cold, wet springs. Less common is the use of short duration summer cover crops grown prior to the production of late-summer planted, fall-harvested crops. Short duration summer cover crops have the potential to provide benefits to the subsequent cash crop, especially in the areas of weed suppression and additions of nitrogen and organic matter.

Weed management is highly ranked by organic growers as the top constraint to production. Measuring soil nutrient concentrations after cover crop incorporation can be a challenge due to the variability in biomass and nutrient accumulation capabilities of cover crops, which depends on stage of growth, species, and environment. This project aims to evaluate several short duration cover crops and examine the benefits provided to a following fall vegetable crop in the areas of weed suppression, soil nutrient concentration, vegetable yield, and quality.

## Materials and Methods

This two-year project started in summer of 2019 at the Iowa State University Horticulture Research Station, Ames, Iowa, on certified organic land. Soil type is Clarion loam. Prior to establishment of the study, the plot was cover cropped by growing a summer cover crop mixture of sunn hemp, cowpea, and sorghum sudangrass. This study is a randomized complete block design with nine treatments and four replications. Treatments consisted of eight short duration cover crops and a no-cover-crop control. Cabbage was planted following cover crop termination. Cover crop treatments included brown top millet (BTM), buckwheat (BW), teff grass (TEF), sorghum sudangrass (SS), sunn hemp (SH), mung bean (MB), cowpea (CP), and golden flax (GF).

On June 6, 2019, a baseline soil sample was collected from the field by collecting and homogenizing 10 soil cores to create a composite sample. Soil was sent to Solum Ag, Ames, Iowa, for analysis of macronutrients, pH, CEC, and percent organic matter (Table 1). On June 13, 2019, the field was tilled using a Terraforce rototiller (Terra Force, Carrollton, TX). Following tillage, a cultipacker was used to firm the seedbed. Treatment plots comprised of 20 x 20 ft plots. Each cover crop was chosen based on its ability to reach maturity in eight weeks or less and its tolerance for summer growth. On June

14, 2019, all cover crops except mung bean were seeded with a Gandy drop spreader (Gandy Company, Owatanna, MN). Seeding rates are presented in Table 2. Cover crop seed was incorporated using a drag harrow. Overhead irrigation was immediately installed to apply 1 in. of water. All cover crops emerged within a week after seeding. Aboveground cover crop and weed biomass was collected August 9 from each treatment. A 50 x 50 cm quadrat was randomly placed within each treatment plot and all above ground biomass was cut at the soil level. Plants were sorted by cover crop and grass or broadleaf weeds. Plant material was placed in brown paper bags and dried at 158ºF for 72 hours and later weighed.

Cabbage Red Express was seeded July 5, 2019, in the Iowa State University Horticulture Hall Greenhouses in 50-cell plug trays using Beautiful Land Products organic growing mix (Beautiful Land Products, West Branch, IA). On August 12, cover crops were terminated using a flail mower. On August 13, six soil cores were collected and homogenized from each cover crop treatment plot to create a composite sample and were handled using methods previously described. On August 14, compost from the Iowa State University Compost Facility was applied with a manure spreader at a rate of 20 tons/acre. After mowing and compost application, both the compost and cover crop residue were incorporated.

On August 15, cabbage seedlings were transplanted using a water wheel transplanter on raised black plastic mulch beds spaced 5 ft apart. Each bed comprised of two cabbage rows spaced 12 in. within and between rows. Soon after transplanting, cabbage transplants were hand watered.

Cabbage loopers and imported cabbage worms were managed by spraying *Bacillus thuringiensis* (Dipel DF®) as needed starting August 26. On September 18, cabbage plant height and width were measured. Six plants from each treatment were measured from the base of the plant at soil level to the tip of the newest leaf, and by taking two measurements from tip to tip of the longest leaves in two directions. Cabbage was harvested October 18 and 25. Only firm heads were harvested. All treatments except BW and TEF had harvestable heads. Cabbage heads were weighed for total yield and graded for marketable yield based on size and firmness. Three marketable cabbage heads/replication were selected for measurement of head length, width, and internal core length and width. A final soil sample was collected November 1 and handled as previously described. Data were analyzed using PROC GLM (SAS Institute, Cary, NC).

## Results and Discussion

*Soil test results.* Ammonium ($NH_4^+$) at both sampling dates was highest for SS treatment (Table 3). CP plots were significantly lower in ammonium than SS plots. The GF and CP treatments were significantly lower in ammonium at the end of the season compared with SS treatment. At cover crop termination, nitrate ($NO_3^-$) was higher for SH, MB, and CP plots compared with all other treatments. The GF and TEF treatment were significantly lower in nitrate. There were no differences among treatments in nitrate at the end of the season. Total nitrogen (N) followed the same pattern as nitrate at cover crop termination, but at the end of the season there were no differences among treatments. There were no differences among treatments in phosphorus (P) at cover crop termination. At the end of the season, P concentration was highest for SS when compared with SH and TEF treatments. Potassium (K) was highest for GF and lowest for TEF at cover crop termination.

Soil test results at the time of cover crop termination showed no differences in percent organic matter (OM) between treatments (Table 3). At the end of the season, GF had the highest OM compared with TEF and the no-cover-crop control. All other treatments were not significantly different. There were no differences in CEC among treatments at either sampling date. At cover crop termination and at the end of the season, pH was highest for the no-cover-crop control. The pH was lowest for SH treatment at cover crop termination. At the end of the season SH and SS treatments were lower in pH than the no-cover-crop control.

*Cover crop and weed biomass.* Cover crop biomass, dry weight basis, was highest for TEF, SH, BW, SS, and BTM cover crop plots compared with MB, GF, and CP plots (Table 4). The TEF also had significantly higher dry weight than SS and BTM. Dry weight of broadleaf weeds was higher for MB and the no cover crop control treatment. SS, SH, and BTM treatments had significantly lower broadleaf weeds than the no-cover-crop control and MB treatment. The TEF and BW treatments had the lowest broadleaf dry weight compared with all treatments except GF, SH, SS, or BTM. Dry weight of grass weeds was highest for CP treatment compared with all cover crops except MB and the no-cover-crop control. GF treatment had significantly lower dry weight for grasses than CP but not significantly different than the no-cover-crop control or MB cover crop treatment. The TEF had the lowest grass dry weight than all other cover crops except BW, BTM, SS, and SH.

*Height and width of cabbage plants.* Cabbage plant height four weeks after transplanting was highest for SH followed by CP and MB treatments (Table 5). The BW, TEF, and SS had the smallest plants when compared with SH, CP, MB, and GF treatments. The CP plots produced cabbage plants with the widest spread. There was no significant difference in plant width between GF, SH, and MB treatments. The TEF and SS plots had the smallest plants. Cabbage plants from BW and BTM plots also were significantly smaller than cabbage plants from the CP treatment.

*Cabbage yield and quality.* Number of marketable heads were higher in CP, GF, MB, and SH treatments compared with TEF and BW treatments (Table 5). The CP, GF, MB, and SH treatments had a lower number of nonmarketable heads compared with all other treatments. Total head weight was lower in TEF, SS, BW, BTM, and control treatment compared with all other treatments. Average weight of marketable heads from both harvests combined was lowest in SS treatment compared with control, MB, and SH treatments (Table 5).

Cabbage head length was highest for SH and smallest for TEF treatment (Table 6). Similar trend was found for head width. Internal core length was lowest for TEF and BW treatment with SH, MB, and CP treatments having longer cores. Number of loose cabbage heads were higher in TEF compared with Control, CP, GF, MB, and SH treatments (Table 6). There were no differences in the number of bolted heads among treatments. The BTM and TEF treatment had the fewest number of small heads.

*Discussion.* This study demonstrates summer cover crops can be successfully grown under Iowa growing conditions. The amount of biomass these could produce will depend on seeding date and how long these are grown. Growers should plant their summer cover crops mid-June to late-June to generate adequate biomass and utilize their weed-suppressing attributes. Summer cover crops also should be terminated in a timely manner allowing time for cash crop growth in the fall.

Overall, grass cover crops generated more biomass than legume cover crops. Within legumes, sunn hemp produced large amounts of biomass and resulted in more weed suppression compared with no cover crop or cowpea and mung bean treatment. The combination of high biomass production, weed suppression, and potential N contribution makes sunn hemp a useful summer cover crop for fall vegetable production. Among non-legumes, teff grass produces large amounts of biomass and provides significant grass and broadleaf weed suppression and could serve as a useful weed management tool in organic production. Sorghum sudangrass and brown top millet also yielded high amounts of biomass and resulted in excellent weed suppression.

The disadvantage of grass cover crops was the significant yield reductions in cabbage. Future studies should examine timing of fall vegetable planting following grass cover crops, such as teff and sorghum sudangrass, to determine if planting time has an effect on yield reductions. Golden flax has the potential to be used as a soil building summer cover crop for fall vegetable production. Although golden flax did not provide comparable weed suppression, it did not result in the same yield reductions as the grasses. Additionally, OM was higher in the golden flax treatment compared with the no cover crop and teff grass treatments at the end of the season soil sampling. Future research efforts should focus on optimum summer cover crop mixtures that can provide high biomass for weed suppression as well as nitrogen fixing and soil building benefits without compromising yield.

**Table 1. Baseline soil tests results collected June 6, 2019, prior to cover crop seeding at the ISU Horticulture Research Station Ames, Iowa. Soil samples were collected from a 6-in. depth.**

| Soil test parameter | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $NH_4$ (ppm) | $NO_3$ (ppm) | Total N (ppm) | P (ppm) | K (ppm) | OM (%) | pH | CEC (meq/100 g) | EC (dS/m) |
| 1.0 | 5.9 | 6.9 | 23.6 | 71.2 | 3.4 | 6.8 | 14.9 | 0.2 |

**Table 2. Seeding rates of eight short duration summer cover crops seeded June 14, 2019 at the ISU Horticulture Research Station, Ames, Iowa.**

| | Treatment[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control | BTM | BW | CP | GF | MB | SH | SS | TEF |
| Seeding rate (lb/acre) | 0 | 33 | 110 | 110 | 77 | 44 | 38.5 | 55 | 8.8 |

[1]Treatments are No cover crop control (Control), Brown Top Millet (BTM), Buckwheat (BW), Cowpea (CP), Golden Flax (GF), Mung Bean (MB), Sunn hemp (SH), Sorghum Sudangrass (SS), and Teff grass (TEF).

**Table 3. Soil test results at cover crop termination August 13 and at the end of the season November 1, 2019, at the ISU Horticulture Research Station Ames, Iowa. Soil samples were collected at 0-6 in.**

| Treatment[1] | $NH_4^+$ (ppm) | $NO_3^-$ (ppm) | Total N (ppm) | P (ppm) | K (ppm) | OM (%) | pH | CEC (meq/100 g) |
|---|---|---|---|---|---|---|---|---|
| | August | | | | | | | |
| Control | 1.2 ab[*] | 5.3 bc | 6.5 bc | 28.4 | 88.3 abc | 3.0 | 7.1 a | 16.9 |
| BTM | 1.4 ab | 3.4 bc | 5.4 bc | 25.6 | 76.4 bc | 3.4 | 6.8 abc | 16.8 |
| BW | 1.2 ab | 4.7 bc | 5.9 bc | 26.7 | 79.6 abc | 3.1 | 6.5 bc | 15.9 |
| CP | 1.1 b | 15.9 a | 17.0 a | 21.6 | 82.4 abc | 3.2 | 6.5 bc | 17.0 |
| GF | 1.7 ab | 8.4 b | 10.1 b | 19.2 | 96.0 a | 3.7 | 6.5 bc | 18.8 |
| MB | 1.4 ab | 18.9 a | 20.3 a | 29.1 | 94.5 ab | 3.2 | 6.5 bc | 16.5 |
| SH | 1.6 ab | 19.5 a | 21.1 a | 20.1 | 78.1 abc | 3.2 | 6.3 c | 17.0 |
| SS | 2.0 a | 5.5 bc | 7.5 bc | 25.4 | 79.7 abc | 3.3 | 6.5 bc | 15.7 |
| TEF | 1.5 ab | 2.4 c | 3.9 c | 26.5 | 69.5 c | 3.0 | 7.0 ab | 16.5 |
| | November | | | | | | | |
| Control | 1.4 ab | 22.5 | 23.8 | 66.5 a | 270.0 ab | 3.1 b | 7.3 a | 18.9 |
| BTM | 1.4 ab | 18.4 | 19.8 | 55.1 ab | 256.8 ab | 3.5 ab | 7.2 ab | 18.4 |
| BW | 1.7 ab | 16.4 | 18.1 | 50.3 ab | 224.8 ab | 3.2 ab | 7.1 ab | 15.7 |
| CP | 1.3 b | 21.2 | 22.4 | 57.0 ab | 242.5 ab | 3.4 ab | 7.2 ab | 18.1 |
| GF | 1.3 b | 19.8 | 21.1 | 55.1 ab | 265.1 ab | 3.9 a | 7.1 ab | 19.9 |
| MB | 1.5 ab | 22.9 | 24.3 | 62.4 a | 265.4 ab | 3.3 ab | 7.1 ab | 16.6 |
| SH | 1.3 ab | 20.4 | 21.7 | 40.5 b | 2.7.2 b | 3.3 ab | 7.0 b | 16.4 |
| SS | 2.3 a | 22.3 | 24.5 | 64.1 a | 307.1 a | 3.5 ab | 7.0 b | 17.6 |
| TEF | 1.6 ab | 17.8 | 19.4 | 48.8 ab | 189.7 b | 3.0 b | 7.2 ab | 16.7 |

[1]Treatments are No cover crop (Control), Brown Top Millet (BTM), Buckwheat (BW), Cowpea (CP), Golden Flax (GF), Mung Bean (MB), Sunn hemp (SH), Sorghum Sudangrass (SS), and Teff grass (TEF).
[*]Values with the same letters are not significantly different at $P < 0.05$.

**Table 4. Dry weight biomass of cover crops and weeds (broadleaves and grasses) collected at cover crop termination August 9, 2019 at the ISU Horticulture Research Station, Ames, Iowa.**

| Treatment | Cover biomass (g) | Weed biomass (g) Broadleaf | Weed biomass (g) Grass |
|---|---|---|---|
| Control | NA | 77.7 a | 74.7 ab |
| BTM | 290.8 b[*] | 4.8 bc | 16.4 d |
| BW | 320.9 ab | 1.4 c | 13.6 d |
| CP | 100.4 c | 51.0 ab | 101.1 a |
| GF | 124.1 c | 45.4 abc | 49.6 bc |
| MB | 137.9 c | 78.3 a | 69.8 ab |
| SH | 325.1 ab | 15.0 bc | 32.1 cd |
| SS | 301.8 b | 13.8 bc | 23.9 cd |
| TEF | 377.1 a | 1.4 c | 4.0 d |

[1]Treatments include no cover crop (Control), Brown Top Millet (BTM), Buckwheat (BW), Cowpea (CP), Golden Flax (GF), Mung Bean (MB), Sunn hemp (SH), Sorghum Sudangrass (SS), and Teff grass (TEF).
[*]Values with the same letters are not significantly different at $P < 0.05$.

**Table 5. Cabbage plant height and width measured September 18, 2019 in (cm) at the ISU Horticulture Research Station, Ames, Iowa.**

| Treatment[1] | Plant height (cm) | Plant width (cm) | Number of marketable heads[2] | Number of nonmarketable heads[2] | Total head weight (kg)[2] | Average weight of marketable head (kg)[2] |
|---|---|---|---|---|---|---|
| Control | 15.7 bcd* | 24.3 abc | 6.0 bc | 16.0 a | 6.2 b | 0.41 ab |
| BTM | 15.3 cd | 23.0 bc | 5.0 bc | 16.0 a | 5.2 bc | 0.37 abc |
| BW | 14.2 d | 23.1 bc | 4.0 c | 17.0 a | 4.5 bc | 0.29 bc |
| CP | 17.8 b | 30.0 a | 14.0 a | 6.0 b | 10.0 a | 0.37 abc |
| GF | 17.5 bc | 28.9 ab | 9.0 ab | 11.0 b | 8.9 a | 0.37 abc |
| MB | 17.6 b | 27.6 ab | 1.0 ab | 9.0 b | 9.2 a | 0.43 ab |
| SH | 20.2 a | 28.7 ab | 13.0 a | 7.0 b | 10.1 a | 0.45 a |
| SS | 13.8 d | 21.3 c | 5.0 bc | 16.0 a | 4.0 bc | 0.23 c |
| TEF | 14.1d | 21.2 c | 4.0 c | 16.0 a | 3.1 c | 0.27 bc |

[1]Treatments are No cover crop (Control), Brown Top Millet (BTM), Buckwheat (BW), Cowpea (CP), Golden Flax (GF), Mung Bean (MB), Sunn hemp (SH), Sorghum Sudangrass (SS), and Teff grass (TEF).
[2]Number of marketable and nonmarketable heads, total yield (kg), and average weight of marketable heads (kg) from combined harvest of cabbage.
*Values with the same letters are not significantly different at $P < 0.05$.

**Table 6. Effect of cover crop treatments on cabbage head quality and disorders. ISU Horticulture Research Station, Ames, Iowa.**

| Treatment[1] | Head quality[2] | | | | Number of heads with disorders[3] | | |
|---|---|---|---|---|---|---|---|
| | Head length (cm) | Head width (cm) | Internal core length (cm) | Internal core width (cm) | Loose head | Bolting | Small |
| Control | 12.0 bcd* | 9.0 ab | 7.0 ab | 2.4 b | 10 b | 1 | 6 a |
| BTM | 12.3 abc | 8.3 ab | 7.5 ab | 2.7 b | 12 ab | 2 | 2 b |
| BW | 10.5 cd | 7.6 b | 5.5 b | 2.7 b | 12 ab | 1 | 5 a |
| CP | 12.9 ab | 9.4 a | 7.8 a | 3.0 b | 1 c | 1 | 4 ab |
| GF | 12.9 ab | 8.8 ab | 7.4 ab | 2.8 b | 5 c | 1 | 5 a |
| MB | 13.7 a | 9.5 a | 8.1 a | 2.9 b | 4 c | 1 | 5 a |
| SH | 14.0 a | 9.6 a | 8.5 a | 3.6 a | 2 c | 1 | 4 ab |
| SS | 12.1 abcd | 7.9 ab | 8.5 a | 3.0 ab | 14 ab | 1 | 4 ab |
| TEF | 8.9 d | 7.2 b | 4.9 b | 2.2 b | 16 a | 1 | 2 b |

[1]Treatments are No cover crop (Control), Brown Top Millet (BTM), Buckwheat (BW), Cowpea (CP), Golden Flax (GF), Mung Bean (MB), Sunn hemp (SH), Sorghum Sudangrass (SS), and Teff grass (TEF).
[2]Head quality data collected from three randomly selected marketable heads from each treatment per replication.
[3]Head disorder data from 10-ft-long row from the middle of each treatment plot.
*Values with the same letters are not significantly different at $P < 0.05$.