Effects of *Carbon-Based Soil Amendment* (*CSA*) on Crop Yield of Irish Potato, Sweet Corn, Tomato and Bell Pepper

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Summary

This research evaluated preplant in-row application of *CSA* on crop yield of Irish potato, sweet corn, tomato and bell pepper at the Kentland Agricultural Research Farm, located near Blacksburg, VA. Overall, our data are encouraging, indicating that beneficial microorganisms (microbes) in *CSA* granules improved productivity of sweet corn (2006 and 2007) and tomato (2007). Based on limited data and observations, enhanced mineralization in the rhizosphere of *CSA*-treated sweet corn and tomato plants is at least partially responsible for increased uptake of nitrogen and improved crop yield. Apparently, placement in near proximity to sweet corn and tomato seed stimulated rapid rhizosphere development of microbial biomass and improved effectiveness of *CSA*. Crop yield of Irish potato and bell pepper was not affected by *CSA*. Distant placement of *CSA* (3-4 inches above the seed pieces in 2007) possibly accounted for lack of crop yield response with Irish potato. Reasons for lack of yield response of *CSA* to bell pepper are not know, since tomato and pepper transplants were treated the same throughout these experiments.

Materials and Methods

Description of field soil and treatments. In 2006 and 2007, all field plots were grown in an organic transition high-quality silt loam soil having a pH of 6.4, with medium to high levels of phosphorus, potassium, calcium and magnesium.

Irish potato and sweet corn. The research field plots both years were divided into four replications (424 ft long and 24 ft wide), consisting of four raised beds (6 ft center to center, and 6 inches high). The top of each bed was approximately 42 inches wide, and the alleyways between beds (bed shoulders and bottoms) were 30 inches. In September preceding each year, two beds in each replication were seeded with forage radish (*Raphanus sativus*) and two beds to crimson clover (*Trifolium incarnatum*). Alleyways in all plots were seeded with cereal rye (*Secale cereale*). Forage radish was frost killed at approximately 20 F and crimson clover and rye over-wintered. In mid April, bed tops were flail mowed and the residues were shallow incorporated (2-3 inches deep) with a rototiller (Table 1).

Biomass produced (and thus mineralizable nitrogen, N) of both cover crops was considerably less in 2006/2007 than 2005/2006. Although actual amounts of cover crop biomass and mineralizable N were not measured, the estimated quantity of plant-available N would be approximately 30 and 15 lb N/acre in 2006, compared to 10 and 5 lb N/acre in 2007, from crimson clover and forage radish, respectively. Because nitrogen availability was a major limiting factor both years, especially in 2007, these relatively small amounts of plant-available N would have contributed relatively little to improved crop yield. In mid April of 2006 (but not in 2007), before seeding Irish potato or sweet corn, all beds were fertilized using 800 lb/acre of Renaissance 8N-1P-5K organic fertilizer (composed of feather meal, bone meal, soybean and potassium sulfate). The organic fertilizer was precision placed in-row and incorporated to a depth of 5-6 inches deep in grow zones located 20-inches apart on top of the raised beds. Grow zones are the designated row areas on raised beds where vegetables were seeded.

Growing Irish potato. Whole seed potatoes (Chieftain in 2006 and Kueka Gold in 2007) were cut into 2-oz seed pieces, treated with *Oxidate* for 5 minutes, stored for 1-2 weeks and planted by hand in 2006 and using a potato seeder in 2007 (Table 1). Seed pieces were set 10-12 inches apart and 5-6 inches deep in the two grow zones on each bed (212 ft long). In 2006, *CSA* granules (30 lb/acre) were applied before planting the seed pieces. *CSA* granules were hand applied to subplots (two beds, 76 ft long) in the grow zones and incorporated to a depth of 3-5 inches with a wheel hoe. In 2007, *CSA* granules (20 lb/acre) were applied (after planting potato seed pieces with the seed planter) in the grow zones and shallow incorporated (only 1-2 inches deep) with a hand hoe. Each year, the remaining row area (136 ft long) of each row was left untreated, of which the middle 60 ft was designated as a buffer zone separating the *CSA*-treated (+CSA, 76 ft) from the untreated (no *CSA*, 76 ft). Plots were irrigated and hand weeded as needed throughout the growing season. Stand counts were made and potato tubers were harvested in late September using a two-row potato digger. In 2007, each subplot was further divided into two equal sub-subplots (one 6-ft bed, 76 ft long, received 2 gallon of fish concentrate/acre and a second adjacent bed received no fish concentrate—i.e., control). Each sub-subplot was further divided into two equal sub-sub-subplots (one bed, 38 ft long) (one-half of each sub-subplot received 80 lb N/acre as a sidedress fertilizer and the other half received no sidedress fertilizer—i.e., control).

Growing sweet corn. Sweet corn seed (Spring Treat in 2006 and Sugar Queen in 2007) was hand planted with and *Earthway Seeder* in the two grow zones (212 ft long and 20 inches apart) of the raised beds. Immediately before seeding in both years, *CSA* granules were applied to subplot in-row grow zones (76 ft long) of each bed. In 2006, *CSA* granules (20 lb/acre) were hand applied and incorporated to 1-2 deep with a wheel hoe. In 2007, *CSA* granules (30 lb/acre) were hand applied using the *Earthway Seeder* to a depth of 1-2 inches. The remaining area (136 ft) of each bed was left untreated, of which the middle 60 ft was designated as a buffer zone, separating the *CSA*-treated (+*CSA*, 76 ft) and the untreated (no *CSA*, 76 ft) sections. Plots were irrigated and hand weeded as needed throughout the growing season. Stand counts were made and sweet corn ears were harvested by hand (Table 1). In 2007, subplots were further divided into sub-subplots and sub-sub-subplots, as described above for Irish potato.

Nitrogen sidedressing (2006). Two weeks after immergence, potato plants in untreated subplots (no *CSA*) were sidedressed by hand at the rate of 60 lb N/acre (20 lb N from sodium nitrate and 40 lb N from feather meal). Plants in the *CSA*-treated (+*CSA*) were not sidedressed. Five weeks after planting, sweet corn plants of both +*CSA* and no-*CSA* subplots were divided into three sub-subplots (25 ft long) and were sidedressed by hand at three rates of nitrogen fertilizer (0, 50 and 100 lb N/acre, from a mixture of sodium nitrate and feather meal).

<u>*Tomato and bell pepper* (2007)</u>. In two separate experiments, tomato (Mountain Fresh) and bell pepper (Aristotle) were grown on small plastic covered plots (24 ft wide and 72 ft long). The experimental design was a randomized split block, with four replications. **Main plots were transplant-growing mixes: McEnroe Lite (ML—an organic potting mix) and Metro Mix 360 (MM—an inorganic potting mix).** Subplots were addition of *CSA* granules to the growing mixes (1 cup *CSA* granules/5 gallons of growing mix): untreated control (no *CSA*) and *CSA*-treated (+*CSA*—granules were thoroughly blended in the growing mixes). Seeds of tomato or bell pepper were placed into 72-cell trays containing either untreated or *CSA*-treated ML or MM growing mixes, and grown to maturity (about 7 weeks for tomato and 9 weeks for bell pepper). At maturity, the tomato and bell pepper transplants were set by hand in previously established raised beds covered with black plastic mulch. A starter solution consisting of hydrolyzed fish concentrate (2 gallons/acre) was applied with water (200 gallon/acre) as a liquid drench around the base of each transplant in all treatments. To avoid contamination, untreated (no *CSA)* and *CSA*-treated subplots were separated by 150 ft.

A cereal rye/hairy vetch (R/HV) cover crop biculture was seeded in the tomato/bell pepper field site in early October of 2006. Before laying off raised beds and applying black plastic mulch, the R/HV cover crop was flail mowed and incorporated using a disk plow. No fertilizer was applied at planting or during the growing season for either tomato or bell pepper; however, the incorporated R/HV residues would have provided approximately 40-60 lb N/acre.

Results and Discussion

<u>**Effects of *CSA* on marketable crop yield**</u>. Marketable crop yield was highest in *CSA*-treated plots for sweet corn (2006 and 2007) and tomato (2007). Application of *CSA* had no crop yield effects for Irish potato and bell pepper (Table 2). Why different yield responses to *CSA* occurred for tomato (17% increased fruit yield) and bell pepper (no response) is unknown, since both crops were treated identically throughout the duration of the experiments. In-row placement of *CSA* granules was distinctly different for Irish potato and sweet corn and could possibly account for different yield responses to application of *CSA*. Granules of *CSA* were placed in close proximity to sweet corn seed in both 2006 and 2007; however, in 2007, shallow incorporation of *CSA* granules and deep placement of potato seed pieces (5-6 inches below the soil surface) resulted in relatively reduced *CSA*-seed contact with potato, compared to sweet corn. In 2006, CSA-seed contact was adequate; however, yield response to application of *CSA* granules was confounded, because the untreated control (no *CSA*) potato plants were sidedressed with 60 lb N/acre, while the *CSA*-treated plants were not sidedressed.

How (what mechanisms) *CSA* improves crop yield is mere speculation. Perhaps, *CSA* microbes (at proper concentration, placement and timing) can improve absorption of plant-available soil moisture, and/or improve rate of mineralization (release of plant-available N). Drip irrigation was applied uniformly across all plots both years; hence, we have no evidence that improved water absorption contributed to improved crop yield in *CSA*-treated plots. On the other hand, enhanced mineralization could have accounted for the increase crop yields, as evidence by the potato data for 2006. Potato tuber yield in 2006 was nearly identical in *CSA*-treated and untreated (no *CSA*) plots, although the untreated plants received 60 lb N/acre as a fertilizer sidedressing, while *CSA*-treated plants were not sidedressed. Since the soils in our experimental sites were nitrogen deficient, these data indicate that more plant-available N was released (mineralized) in *CSA*-treated than untreated plots.

Effect of growing mixes and *CSA* on marketable fruit yield of tomato. An interaction occurred between potting mixes used for growing tomato transplants and application of *CSA* granules. Tomato transplants grown in the inorganic Metro Mix 360 (MM) out yielded plants grown in the organic McEnroe Lite (ML) by 6%; however, when *CSA* granules were added to the potting mixes, tomato transplants grown in MM out yielded ML by 16% (Table 3). Apparently, proliferation of beneficial microbes was uninhibited in the more "sterile" *CSA*-treated MM, while microbial competition possibly reduced buildup of beneficial microbes in *CSA*-treated ML. **The result was a 22% tomato yield increase in *CSA*-treated MM (vs. untreated), compared to only a 12% yield increase in *CSA*-treated ML (Table 3).**

Effect of *CSA* on growth of tomato and bell pepper transplants. Application of *CSA* granules to MM and ML potting mixes (*priming*) enhanced growth rate and size of both tomato and bell pepper. **Although not measured, transplant size at time of field setting was approximately 15-25% larger.** Enhancement in growth response to *CSA priming* appeared to be greater for tomato than bell pepper. The potential of *CSA priming* to shorten the time required to produce marketable transplants and subsequent increased marketable fruit yield merits further research. (Refer to the 2006 report).

Effect of cover crops on marketable yield of Irish potato and sweet corn. There was no yield response to cover crops in 2007 (data not shown). No yield response is highly predictable, since growth of cover crops was severely curtailed because of delayed seeding, drought and poor plant stands. Refer to the 2006 report for discussion of the cover crop effects on crop yield in 2006, when growth of cover crops was excellent.

Effect of N sidedressing and liquid fish concentrate on marketable yield of Irish potato and sweet corn in 2007. In accordance with the agreed-upon protocol, no preplant fertilizer was applied in 2007. Therefore, since the soil at the research sites is relatively low in plant-available N and little cover crop biomass was produced, these unfertilized plots showed a dramatic yield response to N sidedressing (80 lb N/acre) for both Irish potato and sweet corn (Table 4), and even showed a slight response to in-row application of liquid fish concentrate for Irish potato (Table 5).

Table 1. Dates of important cultural practices.

Cultural practice	2006	2007
Seeded cover crops	Sept. 6 (05)	Sept. 18 (06)
Applied preplant fertilizer	Mid April	------
Planted Irish potato	April 19	May 9
Planted Sweet corn	June 13	May 31
Transplanted tomato and bell pepper	------	June 11
Applied nitrogen sidedressing—Irish potato*	May 24	June 13
Applied nitrogen sidedressing—sweet corn	July 18	July 2

*Only untreated (no *CSA*) potato plants were sidedressed (60 lb N/acre) in 2006.

Table 2. Effect of application of *CSA* on marketable organic crop yield.

Vegetable Crop	2006 Yield (cwt/acre) No *CSA*	2006 Yield (cwt/acre) *CSA*	2006 Sign.	2007 Yield (cwt/acre) No *CSA*	2007 Yield (cwt/acre) *CSA*	2007 Sign.
Irish potato	189*	183	ns	88	82	ns
Sweet corn	93	107	.05	61	67	.10
Tomato	----	----	----	634	740	.10
Bell pepper	----	----	----	352	357	ns

*In 2006, untreated (no *CSA*) potato plots received 60 lb N/acre as a sidedressing; *CSA*-treated potato plots were not sidedressed.
Cwt = hundred weight units (100 lb); ns = not statistically significant at p = .10

Table 3. Effect of *priming* growing mixes with *CSA* on marketable organic crop yield, 2007.

Growing mix		Yield (cwt/acre) No *CSA*	Yield (cwt/acre) *CSA*	Avg.	Difference (cwt/acre) *CSA*- no *CSA*	(%)
Tomato						
ML = McEnroe Lite		615	687	651	+72	+12
MM = Metro Mix 360		653	794	724	+141	+22
Avg.		634	740	----	+106	+17
Difference:	MM-ML	+38	+107	+73	----	----
	(%)	+6	+16	+11	----	----
Bell Pepper						
ML = McEnroe Lite		366	368	367	+2	0
MM =Metro Mix 360		339	346	342	+7	+2
Avg.		352	357	----	+5	+1
Difference:	MM-ML	-27	-22	-25	----	----
	(%)	-7	-6	-6	----	----

CSA = Carbon Based Soil Amendment; cwt = hundred weight units (100 lb); Avg. = average; *CSA*-no *CSA* = CSA minus no *CSA*; MM-ML = MM minus ML.

Table 4. Effect of nitrogen fertilizer sidedressing on marketable organic crop yield of Irish potato and sweet corn.

	2006		2007	
Vegetable Crop	N rate (lb/acre)	Yield (cwt/acre)	N rate (lb/acre)	Yield (cwt/acre)
Irish potato	-----	-----	0	73
	-----	-----	80	98
			Sign.	.001
Sweet corn	0	102	0	31
	50	98	80	96
	100	100	Sign.	.001
	Sign.	ns		

Cwt = hundred weight units (100 lb); ns = not statistically significant at p = .05.

Table 5. Effect of liquid fish concentrate applied in row at planting on marketable organic crop yield of Irish potato and sweet corn, 2007.

Liquid fish (Gallons/acre)	Yield (cwt/acre) Irish potato	Sweet corn
0	80	61
2	91	66
Significance	.05	ns

Cwt = hundredweight units (100 lb); ns = not statistically significant at p = .05.