Tillage and Cover Residue Affects on Vegetable Yields

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SUMMARY. The availability of various conservation tillage (CT) practices along with a variety of cover residues creates an opportunity for farm managers to create new systems for vegetable production. We established various tillage practices and cover crop residues for CT use to determine which systems would continue to deliver high vegetable productivity. Recommendations for using CT based only on a yield perspective would lead us to conclude that full season crops could be grown with some form of CT and respectable yields would be obtainable. Tomato (*Lycopersicon esculentum* Mill.) production with CT is successfully being practiced in North Carolina in both the mountain valleys and Piedmont region. Because of the cooler soil temperatures with cover residue, summer and especially fall harvested tomatoes produce the least risk in obtaining similar yields as plow/disc production. Our experiments with short season vegetable crops and CT have had mixed results. Cole crops (*Brassica* L.) grown with CT in early spring or late fall experience soil temperatures cool enough to delay growth compared to plow/disc management. Proper selection of a cover crop residue type and the amount of cover residue can increase yield. Growing short season vegetable crops with CT during the warmest season of the year will reduce the risk of delayed plant growth and thus, decrease the time to harvest.

Conservation tillage (CT) has become an accepted cultural practice for many seeded agronomic crops since its introduction in the 1950s. Acceptance can be attributed to a combination of events occurring concurrently, including improved herbicide development and use, concern for soil erosion, and innovative equipment modifications. Horticultural crops have not been studied as thoroughly as agronomic crops in CT experiments (Hoyt et al., 1994).

The introduction of a no-till transplanter has provided a means for planting bare rooted or containerized transplants in undisturbed soil (Morrison et al., 1973). Direct seeded vegetables such as sweet corn (*Zea mays* L.), dry beans (*Phaseolus* L.), and squash (*Cucurbita* L.) can be planted easily by current no-till seeders designed for agronomic row crops [corn and soybeans (*Glycine max* L.)]. Prior no-till experiments with vegetables have resulted in various degrees of success depending on location, year, moisture, and other factors.

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In Kentucky, Knavel et al. (1977) obtained greater sweet corn and pop-corn yields (Knavel et al., 1985) with no-till culture than with conventional tillage. CT improved or maintained yields similar to conventional tillage in tomatoes (Beste, 1973; Hegwood et al., 1978; Morse et al., 1982), field beans and peppers (*Capsicum annuum* L.) (Lugo-Mercando et al., 1984; Morse et al., 1982), potatoes (*Solanum tuberosum* L.) (Hoyt and Monks, 1996; Mundy et al., 1999), cabbage (*Brassica oleracea* L. Capitata Group) and broccoli (*Brassica oleracea* L. Italica Group) (Hoyt et al., 1996; Morse, 1993; Morse and Steward, 1986; Wilhoit et al., 1990), and lima beans (*Phaseolus lunatus* L.) (Beste, 1973). Conversely, lower yields with CT were obtained with cucumber (*Cucumis-tivus* L.), tomato, and peppers (Beste, 1973; Knavel et al., 1977), cabbage (Hoyt and Walgenbach, 1995; Knavel and Herron, 1981, 1985), potatoes (Mundy et al., 1999), snapbeans (*Phaseolus vulgaris* L.) (Bottenberg et al., 1999) and carrot (*Daucus carota* L.) (Cambell and Anderson, 1980).

The benefits of surface residues or mulch in conserving soil moisture in horticultural crops has been known for many years (Emerson, 1903) with materials such as black plastic emulating the benefits of crop residues (Estes et al., 1985). Growing winter cover crops for surface residues in CT provides mulch that may decrease soil temperature and influence vegetable yields, depending on cover residue selection (Coolman and Hoyt, 1993; Hoyt and Konsler, 1988; Knavel and Herron, 1985). Legume residues have increased vegetable yields when compared to grass residues (Hoyt and Hargrove, 1986) and have increased nitrogen (through biological nitrogen fixation), potassium, and phosphorus recycling within the soil horizon (Morse and Steward, 1985; Waggoner, 1993). Winter cover grass residues can produce similar yields as legume cover residues with CT if fertilizer nitrogen is adequately supplied (Hoyt, 1984; Ranells and Waggoner, 1997).

The following experiments integrate both degree of tillage and type of cover crop residue in CT to identify tillage systems that work for specific vegetables. All experiments were conducted at the Mountain Horticultural Crops Research Station, Fletcher, N.C., in the mountain region of the southeastern United States.

Tillage effects on vegetable growth

Four vegetable experiments using snapbeans, winter squash, broccoli, and tomatoes were established in the same field location. All experiments were planted into a Delanco loam soil (fine loamy, mixed, mesic Aquic Hapludults) using a no-till planter (John Deere MaxEmerge; Deere and Company, Moline, Ill.) on all treatments for the snapbean and squash seeded crops. A barley (*Hordeum vulgare* L.) cover crop [6000 lb/acre (6725 kg·ha⁻¹) dry matter] was killed by applying paraquat at 1 qt/acre (2.3 L·ha⁻¹) 2 weeks before planting. The three tillage treatments were plow/disc, strip till, and no till with four replications for each tillage treatment. The plow/disc treatment was established 2 weeks before planting by plowing the entire plot [30 ft (9.1 m) long with 10 ft (3.0 m) end-row border] with a moldboard plow [tillage to 9 inches (23 cm) depth] and then disking twice. The strip-till treatment was prepared by using a Bush Hog (Selma, Ala.) Ro-till [tillage to 12 inches (30 cm) depth] 2 d before planting. The strip-till treatment created an 8- to 12-inch-wide (20 to 30 cm) tilled area on the surface. The no-till treatment used no prior tillage. Fertilizer P, K, and limestone was applied according to North Carolina Agronomic Division soil test recommendations before planting the cover crop. Over

head irrigations of 0.75 inch/acre (1.9 cm·ha⁻¹) were applied 1 h after planting and 1 and 2 weeks after planting. Means were separated with Fisher's least significant difference (LSD) test at the 5% level of significance (SAS Institute, 1988).

SNAP BEANS. 'Blue Lake' snapbeans were planted on 23 May to determine the effect of plow/disc, strip till, and no till on earliness of pod yield. Plots were four rows wide with a between-row spacing of 3 ft (0.9 m) and final (after thinning) in-row spacing of 2 inches (5 cm). Fertilizer nitrogen was broadcast surface applied at a rate of 70 lb/acre N (78.5 kg·ha⁻¹) 1 d before planting and banded on the soil surface at 30 lb/acre N (33.6 kg·ha⁻¹) 2 weeks later. An application of metolachlor [Dual at 1 qt/acre (2.3 L·ha⁻¹)] and dinoseb [Premerge at 1 gal/acre (9.4 L·ha⁻¹)] 1 week after seeding was used for summer weed control.

Snap beans were harvested every 3 d for seven harvests. Cumulative yields increased as follows: plow/disc > strip till > no till (Fig. 1). However, on the fifth harvest strip-till and no-till yields began to increase compared to the plow/disc treatment, and by the final harvest the two CT treatments equaled the plow/disc treatment (no significant differences among treatments at harvest).

WINTER SQUASH. A winter squash experiment was planted near the snap

Fig. 1. Cumulative snap bean yields of plow/disc, strip-till, and no-till culture; 1 lb/acre = 1.12 kg·ha⁻¹.

Fig. 2. Effect of plow/disc, strip-till, and no-till culture on butternut and acorn winter squash yields; 1 ton/acre = 2.24 t·ha⁻¹.

bean experiment in the same soil type. This experiment measured the effect of tillage on a full season vegetable crop where only a single end of season harvest was taken. 'Table Ace' acorn squash and 'Early Butternut' butternut squash were planted on 23 May in separate, but similar locations with a no-till planter (John Deere MaxEmerge) fitted with a feed cup assembly to match the two sizes of seeds. The three tillage practices were plow/disc, strip till, and no till. Plots were four rows wide with a between-row spacing of 5.5 ft (1.7 m) and final (after thinning) in-row spacing of 2 ft (0.6 m). Fertilizer nitrogen was broadcast surface applied at a rate of 50 lb/acre N (56.0 kg·ha⁻¹) 1 d after planting and two surface-banded sidedress applications were applied at a rate of 30 lb/acre N (33.6 kg·ha⁻¹) 2 and 4 weeks after planting. An application of napropamide [Devrinol 50WP at 2 lb/acre (2.2 kg·ha⁻¹)] and chloramben [Amiben at 1.5 gal/acre (14.0 L·ha⁻¹)] was applied 1 week after planting.

Squash yields for both varieties were high with no statistical differences among the three tillage treatments for either variety (Fig. 2).

BROCCOLI. 'Green Duke' broccoli was planted in the same field and soil type as the snap bean and squash trials. This experiment measured the effect of tillage on broccoli yield when transplanted in both a spring and fall planting. Spring broccoli was transplanted

on 7 May and fall broccoli was transplanted on 7 Aug. The three tillage practices were plow/disc, strip till, and no till. All broccoli transplants were planted with a hand trowel into the three tillage treatments. Plots were four rows wide with a between-row spacing of 36 inches (91 cm) and in-row spacing of 1 ft (0.3 m). Fertilizer nitrogen was broadcast surface applied at a rate of 80 lb/acre N (89.7 kg·ha⁻¹) 1 d before planting and 35 lb/acre N (39.2 kg·ha⁻¹) as a banded side dress 2

weeks after transplanting. An application of napropamide [Devrinol 50WP at 4 lb/acre (4.5 kg·ha⁻¹)] broadcast over the entire plot and oxyfluorfen [Goal 1.6E at 0.5 lb/acre (0.6 kg·ha⁻¹)] applied between the rows 1 d after planting was used for summer weed control. The stale barley cover crop that was killed in the spring but left standing was used as cover residue for fall broccoli production (separate location to the spring broccoli experiment). Glyphosate [Roundup at 2 qt/acre (4.7 L·ha⁻¹)] was applied to kill summer weeds and any barley not yet senesced. Napropamide and oxyfluorfen herbicides were applied similar to the spring production methods.

Spring broccoli production produced greater yields than fall broccoli production (Fig. 3). In both experiments, greater broccoli yields were obtained from the plow/disc compared to the strip-till and no-till treatments, with similar yields in the strip-till and no-till treatments.

TOMATO. 'Mountain Pride' fresh market tomatoes were used to determine the effect of tillage on tomato fruit yield. Six tillage practices were established that included two tillage treatments that tilled the entire plot [plow/disc (described above) and rotavate [the entire plot tilled to a depth of 6 inches (15 cm) with a Howard Rotavator (Howard Rotavator Co., Napa, Calif.)], two strip-tillage

Fig. 3. Effect of plow/disc, strip-till, and no-till culture on spring and fall broccoli yields; 1 lb/acre = 1.12 kg·ha⁻¹.

Fig. 4. Tomato yields from plow/disc, rotavated, strip-rototill, strip-till, no-till, and subsoil tillage treatments; 1 ton/acre = 2.24 t·ha⁻¹.

treatments [strip till (described above) and strip rototill [the in-row strip-till area was tilled with a garden rototiller, creating a tilled area 15 inches (38 cm) wide and tilled to a depth of 6 inches (15 cm)], and two nontillage treatments [no till (plants were planted with a hand trowel using no preplant tillage) and subsoil (a subsoil shank tilling to a depth of 8 inches (20 cm) was run in-row below where the tomato transplants were planted)]. Plots were three rows wide with a between-row plant spacing of 5 ft (1.5 m) and in-row spacing of 2 ft (0.6 m). Fertilizer nitrogen was broadcast surface applied at a rate of 100 lb/acre N (112.1 kg·ha⁻¹) 1 d before planting, and two 50 lb/acre N (56.0 kg·ha⁻¹) surface banded side dress applications 2 and 4 weeks after transplanting. An application of metribuzin [Sencor 75DF at 1 lb/acre (1.1 kg·ha⁻¹)] and napropamide [Devrinol 50WP at 2 lb/acre (2.2 kg·ha⁻¹)] between the row at planting was used for summer weed control. Plants were hand transplanted on 20 May.

Tomatoes were harvested once per week for 10 weeks. Total marketable yields of fruit (U.S. no. 1, 2, and 3) from the two surface tilled treatments were lower than yields from the four conservation-tillage treatments (Fig. 4). The plow/disc and rotavate treatments produced 34.6 and 33.4 ton/acre (77.5 and 74.8 t·ha⁻¹), respectively. The remaining four treat-

ments using varying degrees of CT had yields of fruit in the following order: strip rototill < no till < strip till = subsoil [37.5, 38.6, 39.8, and 39.9 ton/acre (84.0, 86.5, 89.2, and 89.4 t·ha⁻¹), respectively].

Cover crop residue effects on strip-till vegetables

The following four strip-tillage experiments were established to compare cover crop residue effect on vegetable yield and soil temperatures. Cover

crops for each experiment were established in the previous fall by disking the field before planting. Cover crops used in the various experiments were seeded at the following rates: rye (*Secale cereale* L.) at 100 lb/acre (112.1 kg·ha⁻¹), wheat (*Triticum aestivum* L.) at 100 lb/acre, ryegrass (*Lolium multiflorum* Lam.) at 25 lb/acre (28.0 kg·ha⁻¹), austrian winter pea [*Pisum sativum* subsp. *arvense* (L.) Poir.] at 45 lb/acre (50.4 kg·ha⁻¹), hairy vetch (*Vicia villosa* Roth) at 35 lb/acre (39.2 kg·ha⁻¹), and crimson clover (*Trifolium incarnatum* L.) at 30 lb/acre (33.6 kg·ha⁻¹). A mulch treatment was included that used wheat straw applied after planting at a rate of 7000 lb/acre (7846 kg·ha⁻¹). We used a Bush Hog Ro-till for strip tillage and plowing and irrigation techniques as described in the tillage section.

TOMATO. A fresh market tomato experiment was established on the same soil type as the tillage experiments. Plots were three rows wide and 30 ft (9.1 m) long with a between-row plant spacing of 5 ft (1.5 m) and in-row spacing of 2 ft (0.6 m). Fertilizer nitrogen was broadcast surface applied at a rate of 100 lb/acre N (112.1 kg·ha⁻¹) 1 d before planting, and two 50 lb/acre N (56.0 kg·ha⁻¹) surface banded side dress applications 2 and 4 weeks after transplanting. An application of metribuzin [Sencor 75DF at 1 lb/acre (1.1 kg·ha⁻¹)] and napropamide [Devrinol 50WP at 2 lb/acre (2.2 kg·ha⁻¹)] between the rows at planting

Fig. 5. Effect of plow/disc and strip-till culture with various types of cover residue on tomato yields; 1 ton/acre = 2.24 t·ha⁻¹.

Fig. 6. Effect of plow/disc and strip-till culture with various mulches of black plastic and cover crop residue on soil temperatures during the 1985 tomato growing season. Soil temperature at 4-inch (10-cm) depth; °C = 5/9 (°F - 32).

was used for summer weed control. Cover crop burn down was performed 2 weeks before planting, using paraquat at 1 qt/acre (2.3 L·ha⁻¹). 'Mountain Pride' tomato plants were hand transplanted on 22 May. Cover crop biomass production was 3471, 4487, 5995, and 6441 lb/acre (3888, 5025, 6714, and 7214 kg·ha⁻¹) for hairy vetch, crimson clover, ryegrass, and rye, respectively, at spring desiccation.

Tomatoes were harvested once per week for 10 weeks. Combination grade (U.S. no. 1 and 2) fruit yield from the plow/disc, soil bare treatment was lowest at 29.5 ton/acre (66.1 t·ha⁻¹) (Fig. 5). The remaining treatments where some type of mulching system was used all had higher yields. The plow/disc, black plastic treatment produced fruit at 39.6 ton/acre (88.7 t·ha⁻¹) and the strip-till treatments with various covers were in the order: ryegrass < hairy vetch < mulch < crimson clover < rye [37.0, 41.1, 41.3, 42.1, and 42.6 ton/acre (82.9, 92.1, 92.5, 94.3, and 95.4 t·ha⁻¹), respectively].

Soil temperature measurements [1 ft (0.3 m) from the plant in the between-row location at a depth of 4 inches (10 cm)] were related to the amount of residue on the soil surface from the various treatments of tillage and cover residue. Both the plow/disc with black plastic and the plow/disc with bare soil treatments were consis-

tently warmer than any strip-till cover residue treatment at the 4-inch (10-cm) soil depth throughout the season (Fig. 6). The mid-July and mid-August temperature measurements from the bare soil were equal to those with black plastic. Soil temperatures under the strip-till legume residues (hairy vetch and crimson clover) were warmer than the grass residue (ryegrass and rye) or mulch treatments, but cooler than either plow/disc treatment.

CABBAGE. The first cabbage 'Rio Verde' experiment was planted in the same field and soil type as the tillage experiments. The second cabbage experiment was planted near the first (same soil series) the following year. These experiments determined the effect of cover crop residue and strip tillage on cabbage yield. Both cabbage experiments were established in early summer on 30 May and 20 May (Expts. 1 and 2, respectively). All cabbage transplants were planted by hand into the strip-till cover crop treatments using a hand trowel. Plots were 30 ft (9.1 m) long and four rows wide with a between-row spacing of 36 inches (91 cm) and in-row spacing of 1 ft (0.3 m). Fertilizer nitrogen was broadcast surface applied at a rate of 80 lb/acre N (89.7 kg·ha⁻¹) 1 d before planting and 35 lb/acre N (39.2 kg·ha⁻¹) as a surface banded side dress 2 weeks after transplanting. An application of napropamide [Devrinol 50WP at 2 lb/acre (2.2 kg·ha⁻¹)] broadcast over the entire plot and oxyfluorfen [Goal 1.6E at 0.5 lb/acre (0.6 kg·ha⁻¹)] applied between the rows 1 d after planting was used for summer weed control for both experiments. Glyphosate [Roundup at 2 qt/acre (4.7 L·ha⁻¹)] was applied to the winter cover crops. Cover crop biomass production was 4007, 4309, 5179, 7769, and 10,772 lb/acre (4488, 4826, 5800, 8701, and 12,065 kg·ha⁻¹) for austrian winter pea, hairy vetch, crimson clover,

Fig. 7. Effect of plow/disc and strip-till culture with various grass and legume cover crop residue on cabbage yields; 1 ton/acre = 2.24 t·ha⁻¹.

Fig. 8. Effect of plow/disc and strip-till culture with various grass and legume cover crop residues on soil temperatures during the 1986 cabbage growing season. Soil temperature at 4-inch (10-cm) depth; °C = 5/9 (°F - 32).

rye, and wheat, respectively at spring desiccation. Soil temperatures were taken at a 4-inch (10-cm) depth in a between-row location.

The first and second harvests of the first cabbage experiment occurred on 15 and 22 Aug., respectively. The plow/disc bare ground treatments produced the greatest yield for both the initial harvest and total harvest (Fig. 7). The strip-till bare soil treatment also produced high yields that were only slightly lower than the plow/disc treatment. These two treatments produced the warmest soils during early summer (Fig. 8). Cabbage yields from the strip-till treatments with cover residue were in the following order: Austrian winter pea > hairy vetch > crimson clover > mulch > rye > wheat. Wheat residue with strip tillage produced the lowest yields of all treatments in the first harvest, but yields increased the following week. Soil temperatures for all treatments with cover residue were lower than soils left bare (Fig. 8). The two legume cover residue treatments were continuously warmer than the mulch or two grass cover residue treatments.

The second cabbage experiment did not have a plow/disc or strip-till mulch treatment. Cover crop biomass production was 3751, 4342, 5001,

5507, and 5715 lb/acre (4201, 4863, 5601, 6168, and 6401 kg·ha⁻¹) for austrian winter pea, hairy vetch, crimson clover, wheat, and rye, respectively, at spring desiccation. Total cabbage yields for this experiment were similar to those of the first cabbage experiment. The strip-till bare soil treatment had the highest yields, and the cover residue treatments were in the following order: hairy vetch > crimson clover > austrian winter pea > wheat > rye (Fig. 9). Similar to Expt. 1, the strip-till treatments with the legume cover residue produced more cabbage than the grass cover residue treatments. In the first harvest (13 Aug.), yields were extremely low in the grass cover residues, and greatest in the crimson clover and hairy vetch residue treatments. The following week, second harvest (20 Aug.) yields continued to improve in all treatments, with the rye residue treatment having the lowest yield. The rye residue treatment yield improved the final week of harvest, but still remained lowest after the third harvest (26 Aug.).

POTATO. 'Atlantic' potato was used to determine the effect of cover crop and tillage on potato tuber yield. This experiment was established on a

Fig. 9. Strip-till cabbage yields as affected by grass and legume cover crop residues; 1 ton/acre = 2.24 t·ha⁻¹.

Fig. 10. The effect of plow/disc and strip-till culture with grass and legume cover crop residues on Irish potato yields; 1 ton/acre = 2.24 t·ha⁻¹.

Hayesville loam soil (clayey, kaolinitic, mesic Typic Kanapludults). Plots were four rows wide and 35 ft (10.7 m) long with a between-row plant spacing of 4 ft (1.2 m) and in-row spacing of 1 ft (0.3 m). Fertilizer nitrogen was broadcast surface applied at a rate of 160 lb/acre N (179.3 kg·ha⁻¹) 5 d before planting. An application of metolachlor [Dual at 2.5 qt/acre (5.8 L·ha⁻¹)] and linuron [Lorox 50DF at 2 lb/acre (2.2 kg·ha⁻¹)] was broadcast over the entire plot for summer weed control. Paraquat at 1 qt/acre (2.3 L·ha⁻¹) was applied to the winter cover crop 2 weeks before planting. Cut pieces were hand planted on 8 May. Cover crop biomass production was 3100, 3125, 2850, 4675, and 7025 lb/acre (3472, 3500, 3192, 5236, and 7868 kg·ha⁻¹) for hairy vetch, crimson clover, ryegrass, wheat, and rye, respectively, at spring desiccation.

Potato yields responded positively to the mulch conditions provided by the strip-till residue (Fig. 10). Potato yields decreased with cover crop residues as follows: rye > mulch > crimson clover > hairy vetch > bare soil > plow/disc > ryegrass. Only the strip-till ryegrass treatment yielded lower than the two treatments with bare soil on the surface.

Discussion

SHORT SEASON VEGETABLE CROPS. These experiments showed a repeated pattern of greater vegetable yields from

short season crops that had a high degree of tillage. In both tillage experiments with broccoli, the plowed/disc treatment produced greater yields than the mulched CT treatments. In the snap bean experiment, early harvest results showed more mature beans on the first harvest from the plowed/disc treatment, and not until the fifth harvest (15 d later) did the weight of beans in the strip-till and no-till treatments increase over the plowed/disc treatment. This lack of earliness from the CT treatments was also seen in the two cabbage experiments with various cover residues with strip tillage. In both of these experiments, higher cabbage yields were produced from treatments that left the surface bare (the strip-till soil bare and the plow/disc treatments) or had legume residues with strip tillage (Figs. 7 and 9).

Soil temperatures were positively correlated with yield, with greater soil temperatures during the growing season occurring in the same treatments with highest yields (Fig. 8). Soil temperatures were lower in strip-till treatments that used a grass residue as a surface mulch. The lowest soil temperature measurements during the growing season occurred in the strip-till mulch treatment, yet this treatment produced cabbage yields similar to the strip-till crimson clover and vetch residue treatments, but lower than the strip-till bare soil treatment. The strip-till mulch treatment did not

have a cover crop grown in the soil during the winter (similar to the strip-till bare soil), but had mulch added at planting. Thus, the lower yields compared to the strip-till bare soil treatment was probably due to the lower soil temperature. The strip-till mulch treatment produced greater cabbage yields than the strip-till rye or wheat residue treatments. This may have been due to the removal of soil nitrogen during the spring by the rye and wheat cover crop (more so than the legume cover crops), leaving soil inorganic nitrogen levels lower at planting in grass cover crop treatments.

FULL-SEASON VEGETABLE CROPS. We selected winter squash, tomatoes, and potatoes as full season crops to compare degree of tillage and surface residue mulch with strip tillage. In our winter squash experiment comparing degree of tillage, we found little difference among the three tillage treatments for both acorn and butternut squash (Fig. 2). Although higher yields were reported with the two forms of CT in butternut squash, the variability was high, and no statistical differences were found. Tomato yields also were high in treatments with various forms of CT that had a barley residue mulch on the soil surface, whereas the two cultivated treatments (plow/disc and surface rototill) had the residue tilled in and produced lower tomato yields. The other tomato experiment with various cover residues with strip till compared to plowed with bare soil or black plastic also produced greater yields with various forms of mulch (added mulch, killed mulch, and black plastic) and lower yields where the soil was left bare. Soil temperature measurements from this experiment produced similar results as the soil temperature measurements in the cabbage experiment, in that the cultivated treatment with black plastic had the highest soil temperatures compared to the strip-till residue treatments and higher early season temperatures compared to the plow/disc bare soil treatment. A similar pattern of warmer soil temperatures with legume residues compared to the mulch or grass cover crops was observed.

Potato yields increased as residue mulch increased, showing a positive response to all forms of mulch (except for ryegrass). Visual observations of the tilled plots late in the season showed early senescence of the potato vines

due to higher soil temperatures and reduction of soil water in these two treatments, possibly reducing the growing season length for these two treatments and favoring the mulch treatments that had greater soil moisture and cooler soil surface temperatures (during the warm part of the summer).

Literature cited

- Beste, C.E. 1973. Evaluation of herbicides in no-till planted cucumbers, tomatoes, and lima beans. N.E. Proc. Weed Sci. Soc. 7:232-239.
- Bottenberg, H., J. Masiunas, and C. Eastman. 1999. Strip tillage reduces yield loss of snapbean planted in rye mulch. HortTechnology 9(2):235-240.
- Cambell, W.F. and J.L. Anderson. 1980. Effects of no-tillage and herbicides on carrot and onion seed production. HortScience 15:662-664.
- Coolman, R.M. and G.D. Hoyt. 1993. The effects of reduced tillage on the soil environment. HortTechnology 3(2):143-145.
- Emerson, R.A. 1903. Experiments in mulching garden vegetables. Nebr. Agr. Expt. Sta. Bul. 80.
- Estes, E.A., W.A. Skroch, T.R. Konsler, P.B. Shoemaker, and K.A. Sorensen. 1985. Net economic values of eight soil management practices used in stake tomato production. J. Amer. Soc. Hort. Sci. 110(6):812-816.
- Hegwood, Jr., C.P., G.R. Tupper, and E.L. Moore. 1978. Minimum tillage for tomatoes. Amer. Veg. Grower 26:16, 18.
- Hoyt, G.D. 1984. The effect of cover crops on strip-till vegetable and tobacco production. Soil Sci. Soc. N.C. Proc. 27:10-20.
- Hoyt, G.D., A.R. Bonanno, and G.C. Parker. 1996. Influence of herbicides and tillage on weed control, yield, and quality of cabbage (*Brassica oleracea* L. var. capitata). Weed Technol. 10:50-54.
- Hoyt, G.D. and W.L. Hargrove. 1986. Legume cover crops for improving crop and soil management in the southern U.S. HortScience 21(3):397-402.
- Hoyt, G.D. and T.R. Konsler. 1988. Soil water and temperature regimes under tillage and cover crop management for vegetable culture, p. 697-702. Proc. 11th Intl. Conf., Intl. Soil Tillage Res. Org., Edinburgh, Scotland.
- Hoyt, G.D. and D.W. Monks. 1996. Weed management in strip-tilled Irish potato and sweetpotato systems. HortTechnology 6:238-240.
- Hoyt, G.D., D.W. Monks, and T.J. Monaco. 1994. Conservation tillage for vegetable production. HortTechnology 4(2):129-135.
- Hoyt, G.D. and J.F. Walgenbach. 1995. Pest evaluation in sustainable cabbage production systems. HortScience 30:1046-1048.
- Knavel, D.E., J. Ellis, and J. Morrison. 1977. The effects of tillage systems on the performance and elemental absorption by selected vegetable crops. J. Amer. Soc. Hort. Sci. 102(3):323-327.
- Knavel, D.E. and J.W. Herron. 1981. Influence of tillage system, plant spacing, and nitrogen on head weight, yield, and nutrient concentration of spring cabbage. J. Amer. Soc. Hort. Sci. 106(5):540-545.
- Knavel, D.E. and J.W. Herron. 1985. Effect of sudan grass on yield and elemental content of cabbage. HortScience 20(4):680-681.
- Knavel, D.E., J.W. Herron, and G.M. White. 1985. No-till popcorn performs as well as conventionally grown popcorn. HortScience 20:136-137.
- Lugo-Mercando, H.M., J. Badillo-Feliciano, and F.H. Ortiz-Alvarado. 1984. Effects of no-tillage and various tillage methods on yields of maize, field beans and pepper grown on a mollisol in southern Puerto Rico. J. Agr. Univ. P.R. 68:349-354.
- Morrison, Jr., J.E., D.C. Milbocker, W.O. Atkinson, and J.H. Smiley. 1973. Transplanter modification and survival of transplants under no-tillage conditions. HortScience 8:483-485.
- Morse, R.D. 1993. Components of sustainable production systems for vegetables—Conserving soil moisture. HortTechnology 3(2):211-214.
- Morse, R.D. and D.L. Steward. 1985. Cover crops for no-tillage production of cabbage and broccoli. Veg. Growers News. 39(3):1, 4.
- Morse, R.D. and D.L. Steward. 1986. No-tillage production of broccoli and cabbage. Appl. Agr. Res. 1(2):96-99.
- Morse, R.D., C.M. Tessore, W.E. Chappell, and C.R. O'Dell. 1982. Use of no-tillage for summer vegetable production. Veg. Growers News. 37(1):1.
- Mundy, C., N.G. Creamer, C.R. Crozier, L.G. Wilson, and R.D. Morse. 1999. Soil physical properties and potato yield in no-till, subsurface-till, and conventional-till systems. HortTechnology 9(2):240-247.
- Ranells, N.N. and M.G. Waggoner. 1997. Nitrogen-15 recovery and release by rye and crimson clover cover crops. Soil Sci. Soc. Amer. J. 61:943-948.
- SAS Institute. 1988. SAS user's guide: Release 6.03 ed. SAS Institute, Cary, N.C.
- Waggoner, M.G. 1993. Role of cover crops in soil water and nitrogen dynamics. Soil Sci. Soc. N.C. Proc. 36:59-60.
- Wilhoit, J.H., R.D. Morse, and D.H. Vaughan. 1990. Strip-tillage production of summer cabbage using high residue levels. Appl. Agr. Res. 5(4):338-342.