Title: **Development and Evaluation of Minimum-Tillage Vegetable Production Systems for Western Oregon**

Project Leader: Dr. John Luna
Department of Horticulture
Oregon State University
Corvallis, OR 97331

Cooperators

Dan McGrath
Oregon State University
Cooperative Extension Service
Salem, OR

Peter Kenagy
Kenagy Family Farms
Albany, OR

Mark Dickman
Dickman Farms
Silverton, OR

Keith Grover
Grover Farms
Salem, OR

Carl Hendricks
Hendricks Farms
Scio, OR

Dale Lucht
Crestview Farms
Molalla, OR

Bill Chambers
Stahlbush Island Farms
Corvallis, OR

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ABSTRACT

Six on-farm trials were conducted in the Willamette Valley in 1996 to evaluate the potential for rotary strip-tillage in vegetable productions systems. In two sweet corn trials (Grover Farm and Hendricks Farm), yield of sweet corn was reduced approximately 0.5 tons/acre in the strip-tillage treatments, compared to the standard tillage practices used by the growers. In these farms, the number of tillage operations was reduced by 4-5 passes with the strip-tillage system. In two other trials involving sweet corn, (Dickman Farms and Crestview Farms), corn yield was reduced by approx. 2 and 2.5 tons/acre in the strip-till treatments compared to the standard tillage treatments. In a transplanted broccoli trial (Crestview Farm), the strip-tillage and standard tillage treatments performed comparably. In the sixth trial, involving winter squash (Stahlbush Island Farms), the November flood of 1996 carried the squash off the research plots before they could be harvested.

PROJECT GOAL

To develop minimum tillage systems for sweet corn and broccoli production which produce high quality, high yielding vegetable crops, while reducing tillage and weed control costs and improving soil conservation and soil quality.

OBJECTIVES

1. Compare the operational feasibility of a strip-tillage, high-residue cultivation minimum tillage system with a "standard practice" tillage and weed control system.

2. Evaluate effects of these two crop production systems on vegetable crop quality and yield, weed population abundance, pest abundance, and soil moisture.

PROCEDURES

Six on-farm trials were established in the Willamette Valley in 1996, four involving sweet corn, one broccoli and one squash. Each farm represented a unique opportunity to examine the potential of the strip-till system and to explore specific constraints limiting the feasibility of this system. All trials (except the Lucht broccoli trial) involved two treatments, rotary strip tillage and "standard" tillage. Standard tillage represented the particular set of tillage practices used by each grower to prepare a seedbed. This suite of tillage practices varies among the farmers, but also varies within a farm, depending on the specific soil conditions encountered at the time of tillage (soil type, moisture, residue), and the vegetable crops to be planted. Two types of strip-tillage equipment were used in these trials. A modified 4-row Northwest Tillers® strip-tiller was used on the Grover, Hendricks, and Dickman farms. This machine tilled a 6-inch wide strip, approx. 5-inches deep on 30" centers. Modifications included replacing two of the three L-tines with an 60° angled tine and a straight tine. This modification was intended to minimize the potential soil compaction occurring at the bottom of the tillage channel by the L-tines. A second type of strip-tiller, an Italian-made "Multivator" was used on the Lucht and Chambers farms. This machine was a lighter-duty tiller, with smaller tines, tilling an 8-inch wide strip approx. 3-4 inches deep. This machine was used to till strips on 36-inch centers, the row spacing used by these growers.

<u>Yield estimation</u>. Because of excessive variability encountered in previous years' work in small plots, yield were estimated in these trial using the growers' harvesting equipment. For sweet corn, a corn picker was used to pick in-husk corn into a dump truck traveling next to the picker. When the truck was full, the truck was driven to the processing plant were the corn weight was determined. Grade and maturity of the corn was determined by staff at the processing plants. Rather than attempt to harvest entire treatment plots, the area required to fill a truck was determined and per acre yield calculated. For the broccoli trial at Crestview Farm, the broccoli was hand-harvested by the farm crew into totes that were weighed at the

processing plant. The November flood of 1996 carried away the squash in the trial at the Chambers' farm near Corvallis, therefore this project will not be discussed in this report.

Soil Compaction Measurements. A hand-held penetrometer was used on three of the trials to examine soil compaction directly under the crop row. Readings were taken at 5-10 locations in each of the fields during mid-August. Measurements were taken at 3 - inch increments to a depth of 27 inches.

Farming Practices. The following descriptions of the on-farm trials gives a general sequence and dates of major events, with more specific fertilization and pest control details contained in Table 2.

Sweet Corn Trials

Grover Farm. A cover crop of Celia triticale and common vetch was drilled in two adjacent fields near Keizer, OR in early October, 1995. One of these fields was previously cropped (1995) in onions, the other in sweet corn The cover crop was killed with an application of glyphosate (1 qt/A) on March 1, 1996. A randomized block experiment with four replications was established, with two replications in each field. Two treatments, strip tillage and standard tillage, were randomly allocated. Treatment plots were 45 x 1,320 ft. Tillage in the standard tillage plots began on March 20, and included subsoiling, chisel plowing, disking, and harrowing. The fields were rotovated to incorporate fertilizer and herbicide (Dual) on April 10 and sweet corn (Rogers 1861) was planted. The strip till treatments were strip tilled on April 10 and planted immediately. A period of protracted cold, wet weather followed after planting and corn emergence in both tillage treatments was inadequate for an economic stand of corn. The standard tillage treatment was rotovated and the strip-till treatment tilled a second time on April 28. Corn was replanted on April 29.

Dickman Farm. Cover crops planted for this trial in the fall of 1995 were drowned during the excessively rainy fall and winter of 1995-96. This trial was established in a field near Mt. Angel, OR, that contained wheat stubble from a 1995 wheat crop. A non-replicated paired comparison was used, with a 45 x 1,200 foot block on the edge of the field used for the strip-till plot. The remaining portion of the field was prepared using the standard tillage practices. Standard tillage began in mid-April, with a moldboard plowing followed by subsequent disking and harrowing operations. The strip-tillage block was sprayed with glyphosate (1 qt/A) on May 30, flailed on June 3, and strip-tilled on June 4. Both treatments were planted on June 5 with Crookham Crisp N Sweet 710 and a targeted plant population of 27,000 plants per acre.

Hendricks Farm. A cover crop mixture of Cayuse oats, common vetch, and Austrian field pea were planted in early October, 1995 in a field near Stayton. This cover crop was sprayed with glyphosate in mid-May. Cover crop biomass was sampled on June 7 by clipping and removing the cover crop residue in six 0.25 m^2 quadrats randomly selected in the field. Little legume residue was found, and the oat residue was estimated to be 5,640 lbs/acre, with a carbon to nitrogen (C:N) ratio of 55:1. Total nitrogen contained in the above-ground biomass was estimated to be 46 lbs/A. Both tillage blocks were flailed in mid-May. Tillage in the standard treatment blocks began on June 12, and included disk-ripping, 4-5 passes with an offset disk, and one pass with a rotovator. The strip till block (45 x 1800 ft) was tilled on June 13, when both tillage blocks were planted.

Crestview Farm. This trial was conducted near Mollala, OR. A cover crop mixture of Steptoe barley and Austrian field peas was planted in early October, 1995. This cover crop was grazed by sheep during the spring of 1996, which removed most of the above-ground biomass. Glyphosate was applied in late May, prior to tillage. Standard tillage consisted of a single pass with a rotovator. The Multivator strip-till machine was used for the strip-till plots, but due to dry, hard soil, 3 passes were necessary to prepare a seedbed. Sweet corn (Rogers 2684) was planted June 20.

Broccoli Trials

Two trials were established in the fall of 1995, one at the OSU Horticulture Farm, near Corvallis and one on-farm trial at Crestview Farms near Mollala. At the OSU farm, a Steptoe Barley and common vetch cover crop was planted in late October, 1995. This plot was completely submerged by floodwaters for approx. one month following the February flood of 1996, killing the cover crops. Without a cover crop residue, this experiment was discontinued.

Crestview Farm. An experiment was established in the fall of 1995 in field near Mollala. The experimental design involved three tillage treatments in a randomized block design with three replications. Individual treatment plots were approx. 1 acre in size. Tillage treatments included (1) standard, (2) strip-till (ST), and (3) strip-till on ridges (STR). The ridges, or beds, were formed on Nov. 3 using a Buffalo high residue cultivator equipped with ridging wings. Beds were formed on 36 -inch centers. A cover crop mixture of Steptoe barley and common vetch was seeded in the plots on Nov. 6. The cover crop was drilled in the standard and strip-till treatments, but was broadcast applied in the ridge treatments. Due to the late planting and excessively wet fall and winter of 1995-96, cover crop growth was erratic. During late March, 1996, glyphosate was band-applied over the ridges and in the strip-till plots on 36′ centers. These plots were flailed on April 28. In the standard tillage plots, glyphosate was applied on April 6, followed by a series of tillage operations (chisel plow, two diskings, one rotovation). The Mulivator strip till machine was used in the strip till and strip-till with ridges plots on April 29. Two passes of the strip tiller were required to prepare an acceptable seedbed. Broccoli (c.v. - Pacman) was transplanted in all plots on April 30. On May 30, a Buffalo high residue cultivator was used to cultivate the strip-till and strip-till with ridges plots.

RESULTS AND DISCUSSION

Grover Farm. The standard tillage treatment produced approx. 0.5 tons of in-husk corn yield more than the strip-till (statistically significant $\alpha = .05$) (Table 1). Although the intention in this experiment was to band apply herbicide over the corn rows in the strip-till plots, this was performed rather late, and was not very effective in controlling weeds. The regular cultivator was also used in the strip-till plots instead of the intended Buffalo high residue cultivator, which reduced the effectiveness of the between-row cultivation in the untilled soil. There was considerable pigweed present in the strip-till plots at harvest, which may have reduced yield. Although an economic analysis of this project has not yet been completed, a rough estimate of tillage costs at $10-15 per pass per acre suggests that the reduction in tillage costs would offset the yield reduction in corn (valued at approx. $80/ton). There was little or no cover crop residue remaining in the field because of the relatively early March kill date of the cover crop. If the cover crop had been allowed to grow longer, a greater quantity of cover crop residue may have assisted in weed control in the between-row strips. The early April planted date precluded this, however. Soil penetrometer data (Fig. 1) show that the soil was more compacted under the strip-tillage plots than in the standard tillage plots.

Dickman Farm. Corn emergence in the strip-till plots was slower than the standard tillage block, and the stand was reduced by approx. 15%. Plants grew slower and were smaller than in the standard tillage treatments, tasseling was later, and yield was dramatically reduced by approx. 2 ton/A (Table 1). At harvest, 10 corn stalks approx. 6 - in. long were collected from each tillage block and analyzed for nitrate content. Standard tillage stalks contained an average of 7,567 ppm nitrate, whereas the strip-till plots contained an average of 4,444 ppm nitrate. Two possible reasons for the reduced corn growth and yield has been suggested, including: (1) cold, wet soil conditions following planting, (2) nitrogen immobilization following incorporation of the high-fiber wheat straw at planting. The standard tillage plots had been worked for at least a month prior to planting, allowing the soil to warm. The strip-till plots were tilled, then planted immediately. The soil in these plots was cool and moist, compared to the standard tillage plots. With a few days, the weather became cool and rainy, which probably prevented the soil within the tilled strips from reaching an optimum temperature for germination and seedling growth. There is also a well-documented phenomenon of soil nitrogen immobilization following the incorporation of a high carbon-to-nitrogen ratio crop residue such as wheat straw. There is little soil nitrate available following wheat harvest and a season of intense rainfall would have leached away any available N in the soil. Coupled with the immobilization by soil microorganisms consuming any available soil nitrate to break down the wheat residue, the germinating corn seeds could have easily have been N starved. The corn was side-dressed with N approx. 4 weeks later, but by this time the strip-till corn plots were far behind the standard tillage treatments. Soil penetrometer readings under the corn rows indicated that the soil was less compacted under the strip till rows than under the standard tillage rows (Fig. 1)

Hendricks Farm. A severe outbreak of cutworm infested this field within a few weeks after the corn emerged, dramatically reducing the stand. This stand reduction was reflected in the reduced corn yields in this field, although stand counts revealed no apparent differences between the two treatments. Corn yield in the strip-till plots was reduced by approx. 0.5 tons per acre compared to the standard tillage block (Table 1), but as in the situation at Grover Farm, the economic savings in tillage costs would have easily off-set the slight yield decrease. Like the wheat residue at the Dickman Farm trial, this cover crop also had a high C:N ratio (55:1) and could easily have tied up soil nitrogen during early stages of corn growth. Stalk nitrate analysis at harvest, however, revealed slightly higher nitrate levels in the strip-till plots (5,960 ppm) than in the standard tillage plots (5,430 ppm).

Crestview Farm, Corn. Dry, compacted soil conditions at planting time made strip tillage very difficult, with several passes of the tiller required for seedbed preparation. The Multivator strip-tiller was clearly too lightly built to function well in this situation. Irrigation was delayed in this planting for some time, and corn in the strip-till plots were yellow and stunting during the early stages of growth. Digging corn roots when the corn was approx. 24 inches tall revealed that the roots were contained within the narrow tilled trench. Yields were reduced approx. 2.6 tons per acre in the strip-tilled plots compared to the standard tillage (Table 1). A number of factors were hypothesized as contributing to this yield reduction, including inadequate tillage equipment, compacted soil from sheep grazing, inadequate soil moisture during early corn growth, and possibly N immobilization from cover crop roots. Soil compaction was also greater under the strip-tillage plots than under the standard tillage plots (Fig. 1)

Crestview Farm, Broccoli. Broccoli growth in the strip tilled and the strip-tilled with ridges was comparable or better than broccoli growth in the standard tillage blocks. However, adverse weather during the head initiation period caused premature flowering and failure of the heads to mature, resulting in below-normal yields in all tillage treatments (Table 1) This was a common problem in these early planted broccoli fields in this area of the valley in 1996. Broccoli yields were comparable in all three tillage treatments.

GENERAL DISCUSSION AND FUTURE RESEARCH NEEDS

A meeting of all the growers and cooperators involved in this project was held in Salem, OR, on December 18, 1996 to discuss the outcomes of this year's project and to discuss directions for future research. There was a consensus that this project needs to be continued, but with some possible equipment modifications and an increased focus of research in exploring the possible causes of yield decline in the strip-tillage systems. We have developed several hypotheses to examine, including, soil temperature at planting and during early growth, soil moisture depletion in the undisturbed cover crop areas, soil compaction, N immobilization by the cover crop, weed competition, and possible glyphosate microbiological interactions. The owner and manufacturing director of Northwest Tillers, of Yakima, WA, attended this meeting to discuss cooperation in the 1997 project. We are considering a 6-row machine (we now have a 4- row machine that does not match the planter spacings of several of the cooperating growers) equipped with residue clearing coulters in front of the tillers to reduce the amount of residue incorporated. Soil firming baskets following the tillers could also assist in soil firming to reduce loss of soil moisture. Other considerations in the 1997 trials include managing cover crops in the spring to optimize C:N ratios and biomass accumulation. Another question to be examined includes whether there is a need to strip-till the field 1-3 weeks prior to planting to allow time for initial residue decomposition to occur and to allow soil warming prior to planting.

If yield reducing factors can be understood and a predictable, manageable system of strip-till vegetable production developed, there is a potential to dramatically reduce tillage costs and enhance soil quality through conservation of soil organic matter and biological diversity.

Table 1. Summary of crop yields in strip-till vegetable production systems in Western Oregon, 1996.

Year	Location	Cover Crop	Vegetable Crop	Tillage treatment	Crop Yield (tons/A)	Comments
1996	Grover Farm, Salem, OR	Celia triticale + common vetch	Sweet Corn	Conv. till Strip-till	10.47 9. 95	More weeds in strip-till
1996	Hendricks' Farm	Cayuse oat + common vetch	Sweet Corn	Conv. Till Strip-till	7.72 7.20	Extensive cutworm damage in both tillage treatments
1996	Dickman Farm, Mt. Angel, OR	Wheat stubble	Sweet Corn	Conv. till Strip-Till	9. 54 7.58	Poor stand establish-ment and slower growth in strip-till
1996	Crestview Farms, Mollalla OR.	Steptoe barley + common vetch	Sweet Corn	Full-width Rotovation Strip-till	7.70 5.09	Cover crop sheep grazed Hard soil at planting
1996	Crestview Farms, Mollalla, OR	Steptoe barley + common vetch	Broccoli	Conv. till Strip-till Strip-till ridges	1.78 1.62 1.77	Early planting of broccoi and cold weather reduced yields

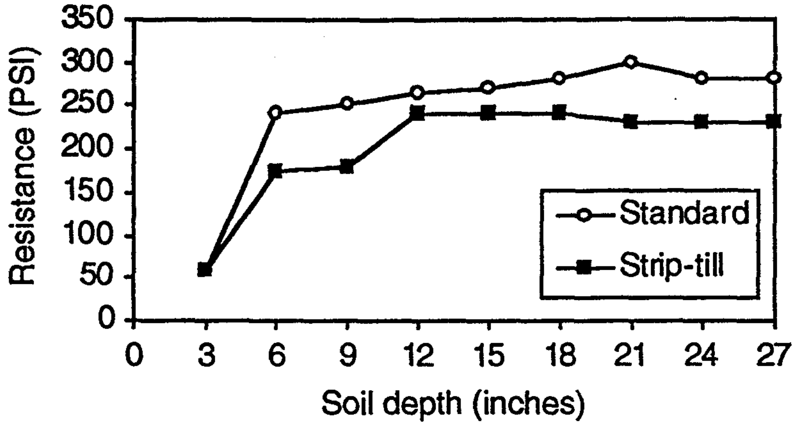
Table 2. 1996 Strip-till Project: Farming Practices

Grower and crop	Cover crop management	Tillage	Planting	Between row spacing	Fertilization Preplant (lbs NPK/acre)	Fertilization At Plant (lbs NPK/acre)	Fertilization Sidedress (lbs N/acre)	Weed and insect control
Mark Dickman Sweet corn	Wheat stubble 5/30/96: glyphosate 1 qt/A 6/3/96: flailed	Conv: 4/96, moldboard plow, 2 passes disc harrow, rototilled S-T: 6/4/96 NW tiller	6/5/96: Crookham CNS 710, 27,000 plants/A	30"	6/3/96: 42-0-54	6/5/96: 38-100-36	7/11/96: 129	Conv: 6/3/96 Lasso 6 pt/A incorporated S-T: no weed control
Keith Grover Sweet corn	Celia triticale + Common vetch 3/1/96: glyphosate 1 qt/A	Conv: 4/28/96*: sub-soiled, chisel plow, disc, heavy harrow, rototilled S-T: 4/28/96* NW tiller	4/29/96*: Rogers #1861 on 8" spacing	30"		4/29/96: 31-61-31	6/17/96: 138	Conv: 5/21 broadcast 1.25 qt/A Laddox, 1 qt/A crop oil, 0.75 pt/A Dual, 6/17 cultivated, 6/29: 2 pt/A Basagran, 2 pt/A atrazine S-T: 5/24 drip sprayed, same as above, 6/17 cultivated, 6/29: 2 pt/A Basagran, 2 pt/A atrazine
Carl Hendricks Sweet corn	9/95: Oats + Austrian peas + Common vetch, 5/21/96: glyphosate 6/8/96: flailed	Conv: 6/13/96 disc ripped, 4-5 disc passes, rotovated S-T: 6/13/96 NW tiller	6/13/96: Jubilee Super Sweet on 8" spacing	30"		6/13/96: 96-170-112 1.5 tons lime/A	8/3/96: 92	6/13/96: broadcast Eradicane 7/11/96: Accent 0.67 oz/A, Atrex 2 pt/A drop nozzle applied
Dale Lucht Sweet corn	9/95: Steptoe barley + Austrian peas 3/96: grazed sheep, glyphosate applied for grow back	Conv: 6/96 rototilled S-T: 6/96 2+ passes with Multivator	6/20/96: Rogers #2684 on 8" spacing	36"		6/20/96: 29-99-0	88.5	Laddok S-12 2.33pt/A 6/20/96: Dyfonate 15G 5lb banded
Dale Lucht Broccoli	11/7/95: Steptoe barley + Common vetch 3/25/95: glyphosate 4/28/96: flailed regrowth	Conv: 4/29/96 chisel, 2 disc passes, rotovator S-T: 4/29/96 2 passes with multivator	4/30/96: Packman transplants	36"		4/30/96: 16-16-8	5/30/96: 45	4/30/96: Goal 0.25 pint/A 5/30/96: Cultivated 5/4/96: Lorsban 50W 0.5 lb/A 5/25/96: Sevin 1 pt/A

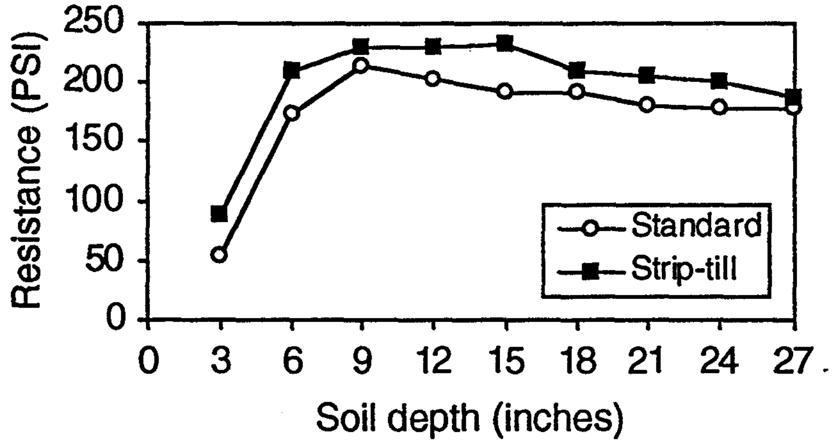
* Grower had to replant because of poor stand establishment in both tillage treatments. First tillage operations occurred on 3/20/96 for conventional tillage and 4/10/96 for strip-till. The initial planting date was 4/10/96, fertilization and weed control included: 62-122-62 NPK/A and 1 1/2 pt/A of Dual, both incorporated.

Figure 1. Strip-till and standard tillage corn penetrometer data taken on August 19, 1996.

Dickman Farm



Grover Farm



Crestview Farm