Strip Tillage and Cover Cropping Effects on Field Water Use Efficiency

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Introduction

Tillage is an important tool in organic systems for weed management, residue management, seedbed preparation, and regulation of spring soil temperature. A balanced approach towards tillage in organic systems is needed to reduce the negative effects of soil disturbance: increased erosion, degraded soil structure, loss of soil organic matter, and diminished microbial communities (1). Using cover crop mulches paired with strip tillage (Figure 1b) reduces the negative impacts of tillage while still allowing farm managers to achieve the necessary soil conditions required for crop establishment and cultivation (2). Flail-terminated rye establishes a mulch layer to enhance moisture retention while suppressing weed germination for organic systems. Cover cropped strip tillage systems have been shown to increase soil moisture when compared to conventional tillage systems (3,4). Flail-terminated cover crops have a high potential to retain moisture due to the thatched nature of the resulting mulch layer in comparison to other methods (5).

Washington's agricultural water resources are projected to be in higher demand with climate change, causing higher drought risk and competition for scarce water resources, and WSDA has set priority on adoption of best practices in water conservation methods to improve water use efficiencies in Washington's agricultural production (6). Field water use efficiency (WUE) to determine potential water savings has not yet been evaluated in strip tillage systems in the Pacific Northwest as previous research has applied irrigation equally between treatments. This project investigates if cover cropping and strip tillage can improve field WUE by investigating the water dynamics of the flailed rye mulch layer (Figure 2b) in comparison to a bare ground full tillage system (Figure 2a) where the rye cover crop as been incorporated into the soil profile.

Objective

Compare field water use efficiency of organic winter squash produced with strip tillage and full tillage following cereal rye cover crop.

Site and Methods

Location — WSU Puyallup Research and Extension Center, Puyallup, WA

Climate — Maritime climate with cool, wet winters and mild, dry summers.

Soil — Puyallup fine sandy loam; coarse-loamy over sandy, isotic over mixed, mesic vitrandic haploxerolls.

Experimental Design — Randomized complete block design with 4 replications and two cropping systems (Full Till and Strip Till as treatment levels). Plots size: 3.05 by 15.24 meters.

Cover Crop — Fall seeded cereal rye, variety 'Aroostook' seeded at (173 kg ha^{-1}). Biomass for both treatments: 9.9 dry Mg ha^{-1}

Rye Termination

	Rye maturity rating	Zadoks[7] scale
Full Till: 4/27/2016	boots swollen	45
Strip Till: 5/10/2016	late anthesis	67

Tillage — **Full Till**: Low rotational speed Imants spader (Figure 1a). **Strip Till**: Modified Maschio multivator (Figure 1b) with row cleaners and subsoil shank

Crop Production — Squash transplants (*Cucurbita pepo* var. turbinata, 'Table ace F1') were mechanically transplanted May 26th. Plots were fertilized with organic feather meal (12-0-0) at 183.2 kg N ha^{-1}. Plots were hand weeded at equal intervals and time spent weeding was recorded.

Irrigation Scheduling — Daily applied irrigation (per treatment) was calculated via WSU AgWeatherNet's irrigation scheduler program using mean volumetric soil moisture data (5TM probes, Decagon, Pullman, WA; Figure 3a). A value of 28.3% was used for water content at field capacity and 15% for available water holding capacity. Management allowable depletion was set at 50% of field capacity. Treatments received similar irrigation for initial two weeks to ensure proper soil moisture requirement for newly transplanted squash root development. Nine days after transplant, separate irrigation scheduling was followed for each tillage treatment.

Measurements — Bulk density measurements were taken in the plant row with three subsamples per plot. Early-season soil nitrate was sampled on June 20th at 0-30.5cm. Penetrometer resistance was measured from 0-40.5cm with five subsamples per plot using a Rimik recording penetrometer (ICT International, Armidale, NSW, Australia). Cover crop biomass was collected at termination date with two randomly selected 0.5 X 0.5m subsamples harvested for above ground biomass, dried, and averaged to obtain dry weight. Hourly soil temperature and volumetric moisture content was recorded (5TM probes, Decagon, Pullman, WA) at 10.2 and 20.3cm depths both at 9cm and 25cm away from the crop (Figure 3b). Initial sensor depth was increased to 26.6cm and 77.5cm on June 30th.

Analysis — The *aov* function was used to test significance of treatment effects for all response variables except applied irrigation where *t.test* was used (R V. 3.0.2).

Figure 1: Imants rotary spader used in full till treatment (a) and modified Maschio powered strip tiller and strip tilled rye residue (b) prior to mechanical transplanting.

Figure 2: Winter Squash 32 days after transplanting in cover crop Full Till (a) and Strip Till (b) plots. Note rye residue in strip till plots has been wind-blown into the plant row.

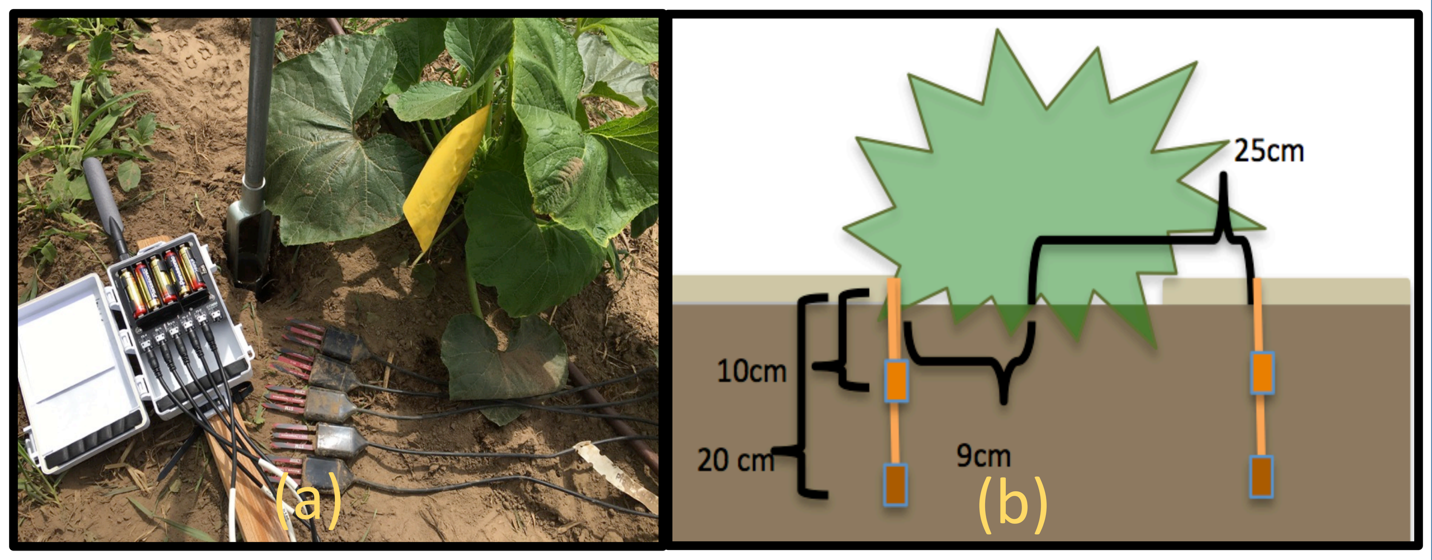

Figure 3: Decagon Devices 5TM volumetric moisture content/temperature sensors (a) placed at both the middle and bottom of crop root zone both within and out of the crop row (b).

Results and Discussion

Cumulative Applied Irrigation

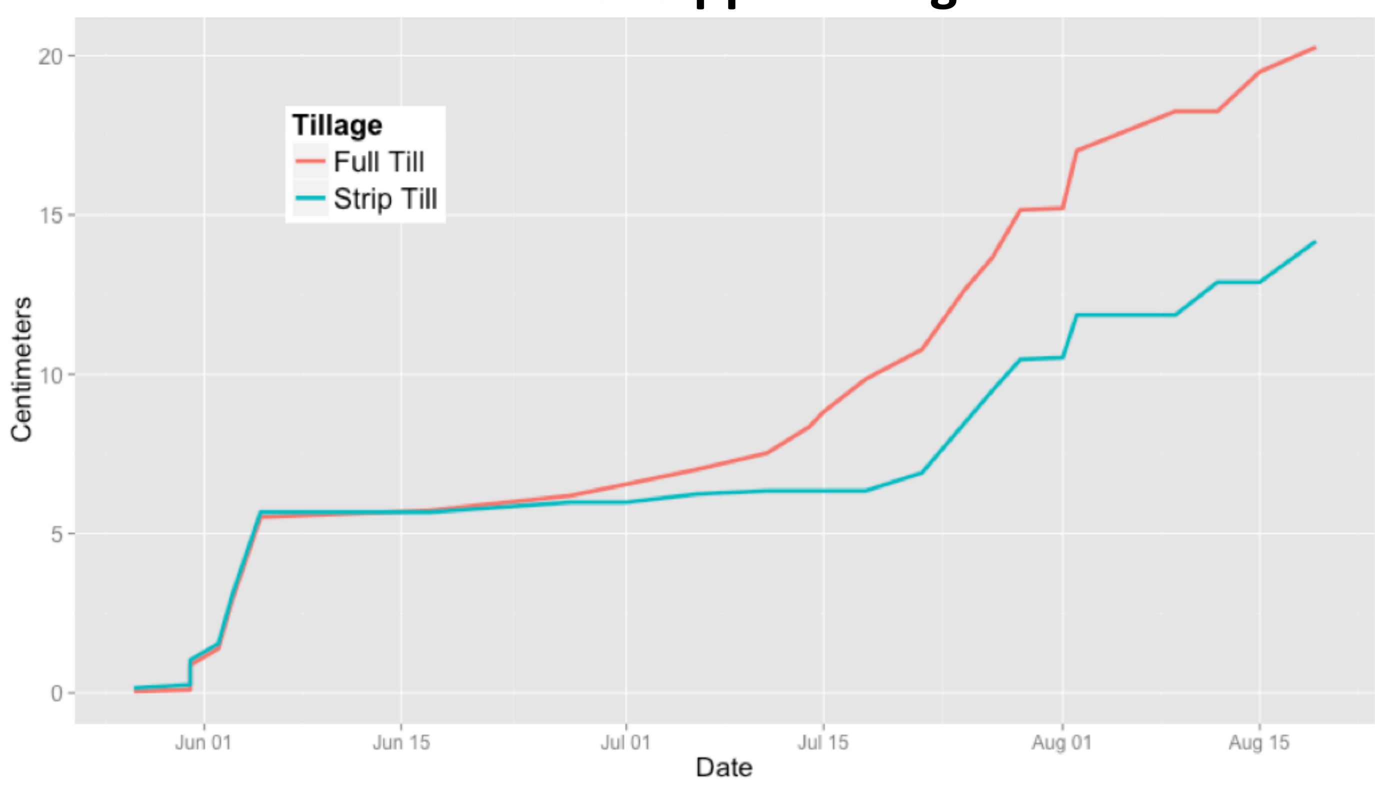

Figure 4: Cumulative water use between treatments

- Full Till required increasingly greater irrigation with crop development, resulting in 42.6% more applied irrigation than Strip Till by the end of the season ($p<0.01$).

Root Zone Soil Temperature

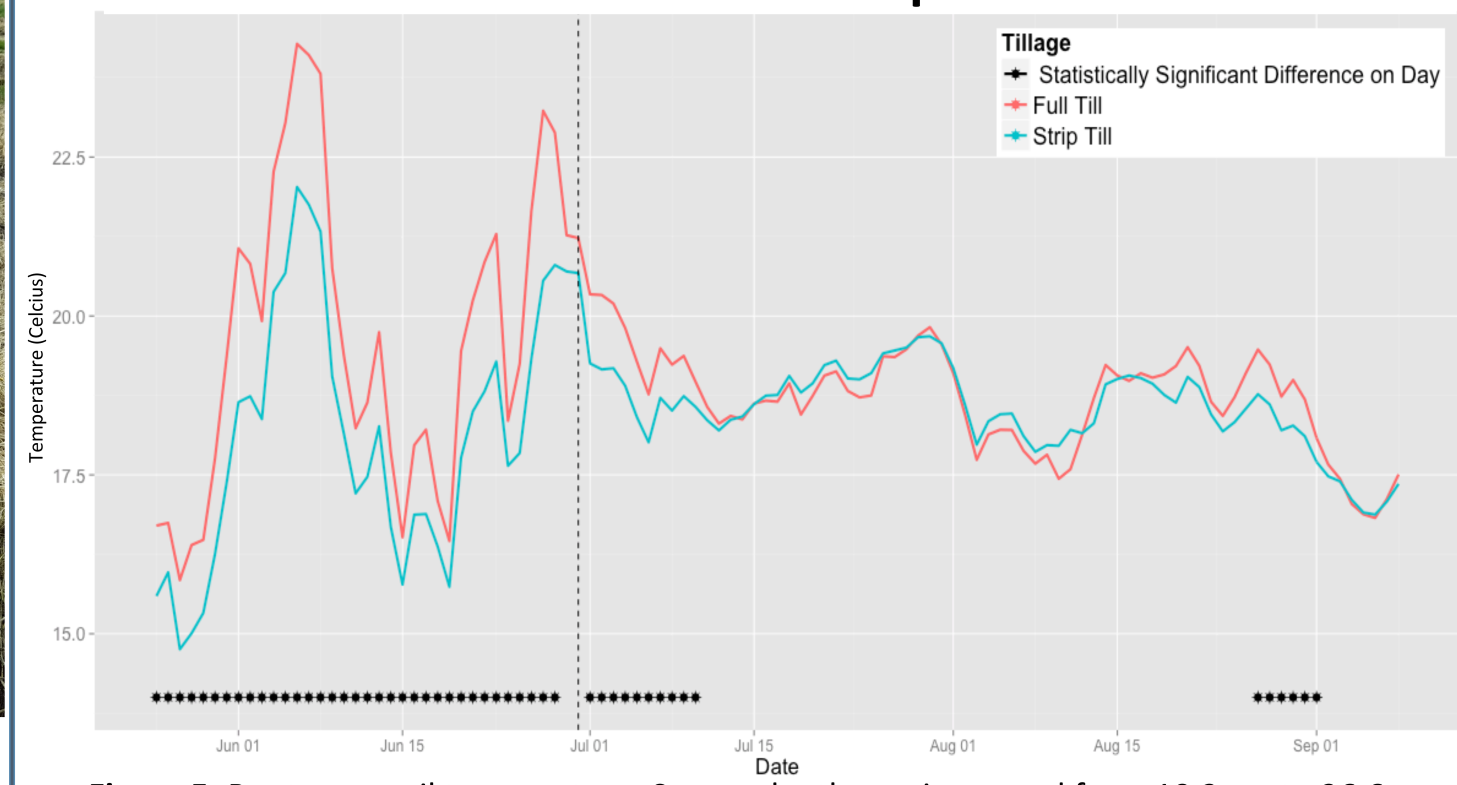

Figure 5: Root zone soil temperature. Sensor depth was increased from 10.2 cm to 26.6 cm on June 30th (indicated by dotted line). Black stars indicate statistically significant difference on day at p<0.05 .

- Mean root zone soil temperature at both the 10.2cm and 26.6cm depth was higher in Full Till plots during early stages of crop growth ($p<0.05$). This difference became less pronounced with crop canopy development.

Plant, Soil, and Irrigation Parameters

	Strip Till	Full Till	P value
Water use efficiency (kg L^{-1})^{a}	0.029	0.031	0.40
Irrigation (cm)	12.9	18.4	0.02
Yield (Mg ha^{-1})	19.7	30.1	<0.01
Bulk density (g cm^{-3})	0.97	1.04	0.03
Soil nitrate, midseason (kg ha^{-1})^{b}	193.4	130.9	<0.001
Average resistance top 10cm (Kpa)	710.8	485.7	0.02

Table 1: Calculated water use efficiency, total applied irrigation, squash yield, bulk density, midseason soil nitrate, and penetrometer resistance in strip tillage and full tillage treatments at Puyallup, WA 2016 . ^{a} kg squash L^{-1} applied irrigation water, ^{b} 0 - 30.5 cm depth 25 days after transplant

- Decreased water use in Strip Till paired with the higher yields in Full Till resulted in no significant difference between the systems in total field water use efficiency.
- There was a 46.3% increase in average penetrometer resistance at the 0 to 10 cm depth, and no other significant differences were found down to depths of 40.5cm.
- Bulk density was slightly lower in Strip Till possibly due to the aggressive tillage within the planting strip versus the lower speed rotary spader used in Full Till.
- Early-season (25 days after transplant) soil nitrate levels between tillage systems was significantly different (p value <0.001). This is most likely due to incorporation of flailed rye residue in Full Till whereas Strip Till cleaned the majority of rye residue from the planting zone prior to soil disturbance. Full till plots exhibited faster crop growth, and differences in soil nitrate could also be attributed to difference in crop utilization.
- Lower root zone soil temperature in Strip Till combined with the increased soil compaction in the top 10cm could have resulted in delayed and overall slower root development throughout the soil profile leading to lower yields.
- There was no significant difference in volumetric soil moisture in the inter-row zone (25cm off of the plant row; data not shown). This could be attributed to lower than normal spring precipitation.

The powered strip tiller was designed to increase soil exposure in the strip for high residue conditions compared to ground-driven strip till implements. Residue was successfully moved from the strip (Figure 1b), but the 23 cm strips were somewhat concave, which reduced solar radiation and may have encouraged collection of wind-blown residue. Increasing strip width as well as creating a convex strip could provide additional solar exposure and increased root zone temperatures.

References

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