WSU Puyallup Reduced Tillage Organic Agriculture Research Field Day
25 April 2016.

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Please complete the evaluation! Thank you!

This research is supported through grants from the Western Sustainable Agriculture Research and Education program, WSU's Center for Sustaining Agriculture and Natural Resources, Biologically Intensive and Organic Agriculture Program, and G.A. Harris Fellowship (Decagon Devices).

Project Overview

Increasing Adoption of Reduced Tillage Strategies on Organic Vegetable Farms in the Maritime Northwest

Project Directors: Doug Collins, Chris Benedict, Andy Bary, Liz Myhre.
Graduate Students: David Sullivan, Ryan Tarbell, Becky Collier
Farmer Cooperators: Colin Barricklow, Kirsop Farm; Steve Hallstrom, Let Us Farm; Adam McCurdy, Oxbow Farm; Tom Thornton, Cloud Mountain Farm;

Project Goal: Incorporating reduced tillage into organic vegetable cropping systems requires careful integration of cover crops and specific implements. Cover crops for reduced tillage systems must survive winter, produce sufficient biomass to smother weeds, mature early, and preferably add nitrogen to the system. Tools must effectively terminate the cover crop without tillage and also prepare the soil to receive a transplant or seed. Our goal is to increase organic farmer economic and environmental sustainability through soil conservation and reduced tillage.

Specific questions that guide our work include:

1. Which implements and strategies are most effective to manage residue in zone-tilled ground?
2. How does reduced tillage affect nutrient cycling and fertility management?
3. Which cover crops, mixes, and termination strategies perform best?
4. What specific challenges and opportunities do continuous reduced-tillage present?

Additionally, we are committed to providing essential support to western Washington organic producers interested in implementing reduced tillage techniques on their farms.

Experimental designs: In fall 2011 we initiated a long-term reduced tillage cropping systems experiment with three cash crops in rotation and adaptive management to incorporate new cover crops and equipment improvements. This experiment is referred to as "Crimp 4" (see Plot Map). The 6 cropping systems in the trial vary in cover crop termination and ground preparation method. Treatments include:

1. Flailing+NoTill
2. Flailing+StripTill
3. Roll/Crimp+NoTill
4. Roll/Crimp+StripTill
5. Full Till
6. Continuous MinTill+Flailing+StripTill

Treatments 1–4 are rotational reduced tillage treatments; tillage is used in the fall to prepare a seed bed for establishing cover crops. In the spring, cover crops are terminated then ground prepared for transplanting with a reduced-tillage strategy. Treatment 5 utilizes a spader in spring and fall. Treatment 6 is a continuous minimum-till treatment.

In separate experiments between fall 2011 and summer 2015, winter cover crop varieties were evaluated for suitability in organic reduced tillage cropping systems. Cover crops were terminated at different stages based on phenology. Vetches were terminated with flail mowing and grains were terminated with either flail mowing or roller/crimper. Termination of vetches was attempted with the roller/crimper in 2012 and was ineffective irrespective of termination date, so this treatment was not included in future experiments.

We are using adaptive management in our reduced tillage cropping systems experiment (Crimp 4). For example, as we trial new cover crops we are using them in the rotation. Because of our success with flailing vetch in 2012 we incorporated vetch in the systems experiment. Similarly, we changed our grain cover crop from 'Strider' barley to 'Aroostook' rye. The crop rotation within each treatment is:

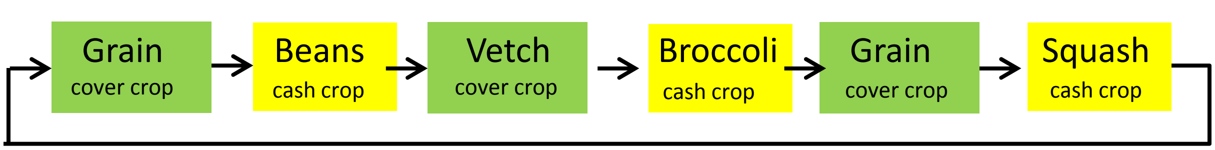


Figure 1. Cash crop and cover crop rotation within each experiment in long-term reduced tillage trial.

Significant Findings 2012-2014

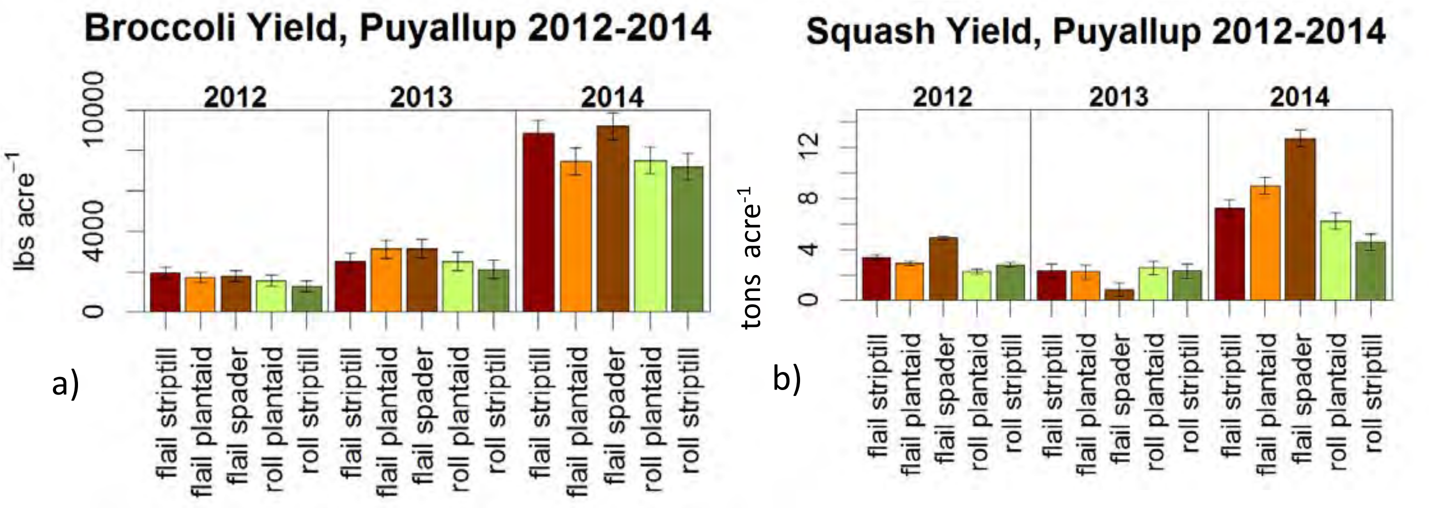


Figure 2. Broccoli (a) and squash (b) yield by treatment at WSU Puyallup in 2012-2014. Treatment was not significant for broccoli and was significant for squash in 2012 and 2014 ($p<0.0001$). Bars represent standard error of the mean.

Key Findings

- Cover crop termination and reduced tillage combinations did not effect broccoli yields during any of the 3 years of the trial (Figure 2a).
- Full tillage (flail spader) bore greater squash yields than reduced tillage treatments in both 2012 and 2014 (Figure 2b).
- Flail mowing produced greater squash yields in 2012 and 2014, among reduced tillage treatments (Figure 3).
- Strip tilling yielded more squash in 2012, but plant aid yielded more in 2014 (data not shown).

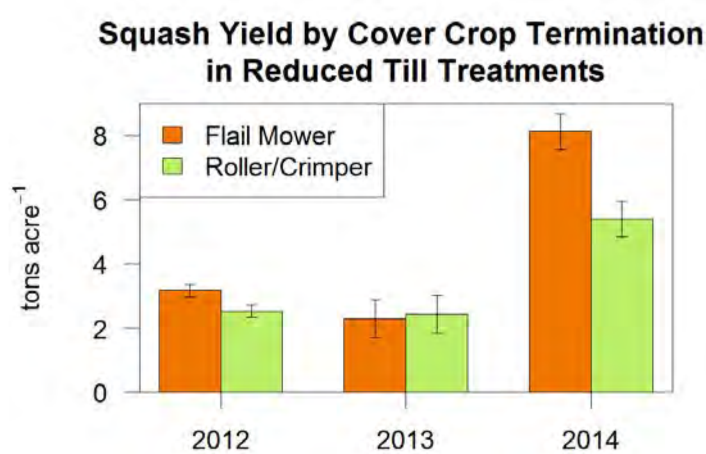


Figure 3. Squash yield at WSU Puyallup by cover crop termination method within reduced tillage treatments in 2012-2014. Termination method was significant in 2012 and 2014 ($p=0.008$, $p<0.001$). Bars are SE.

Significant Findings 2012-2014

Figure 4.

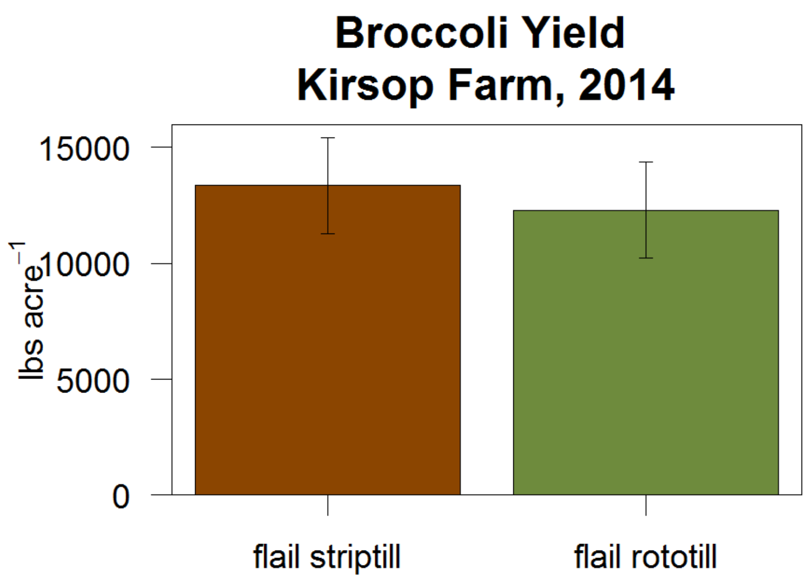


Figure 5.

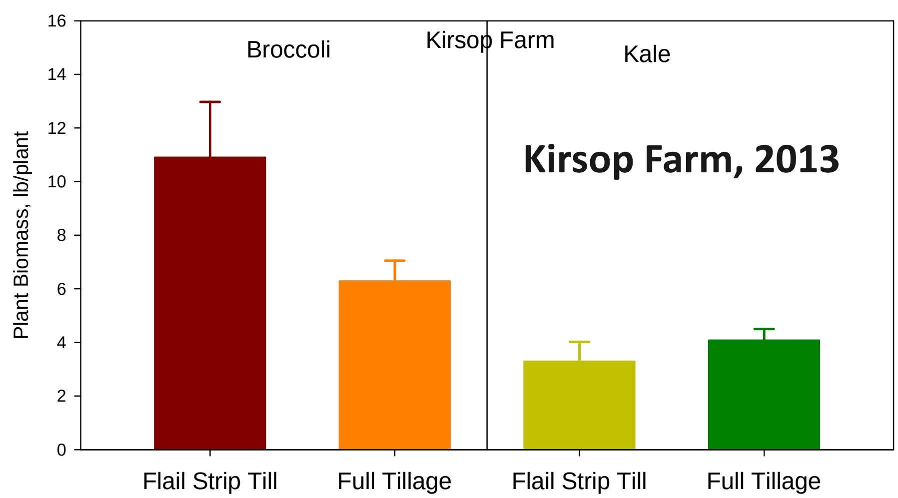
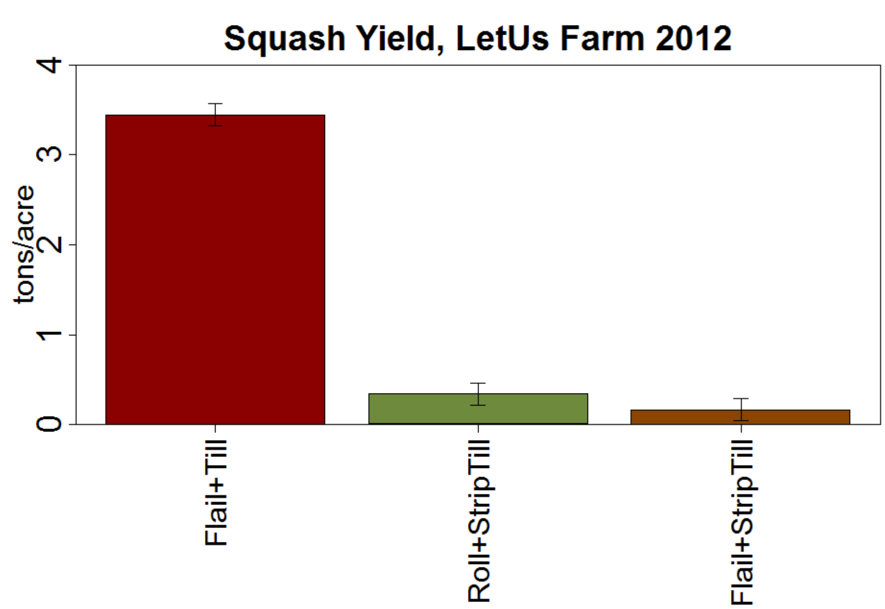


Figure 6.



Significant Findings 2012-2014

Figure 7. Soil Compaction with Different Reduced Tillage Treatments, 25 July 2012, Puyallup

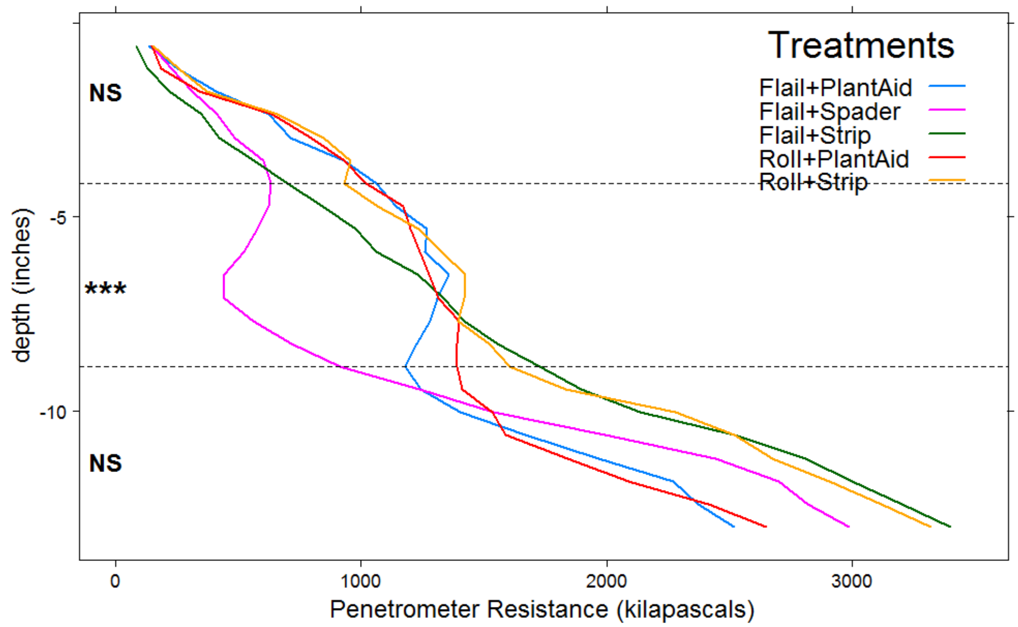


Figure 8. Infiltration with Different Reduced Tillage Treatments, Puyallup 2012-2103

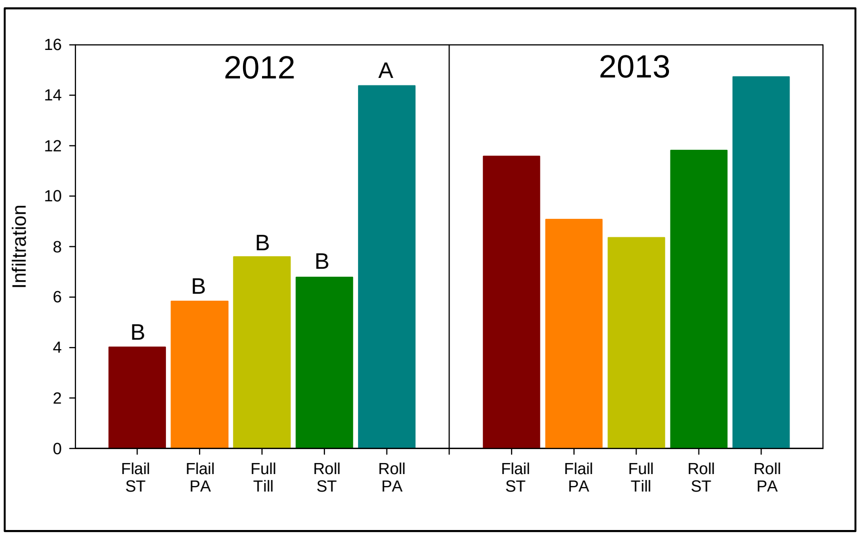
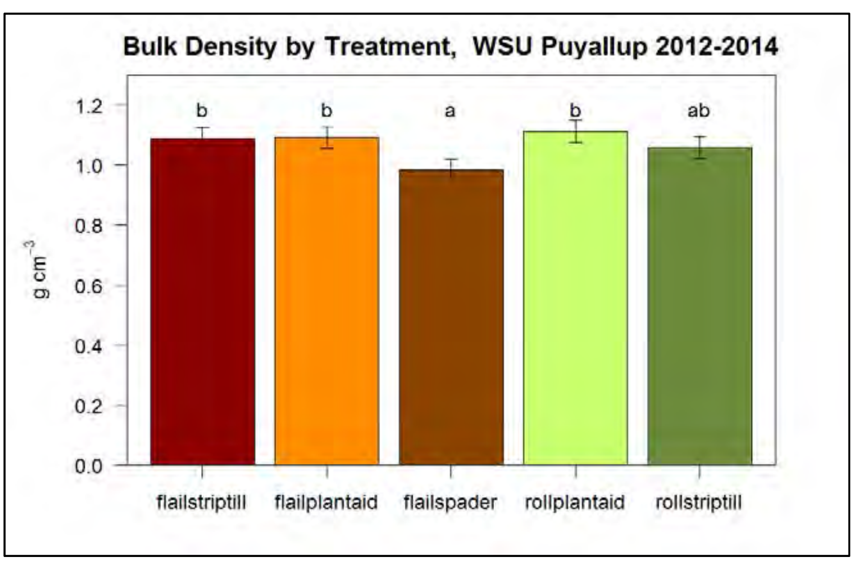


Figure 9.



Significant Findings 2012-2014

Figure 10. Mean Daily Soil Temperature at 10cm by Tillage, 2012

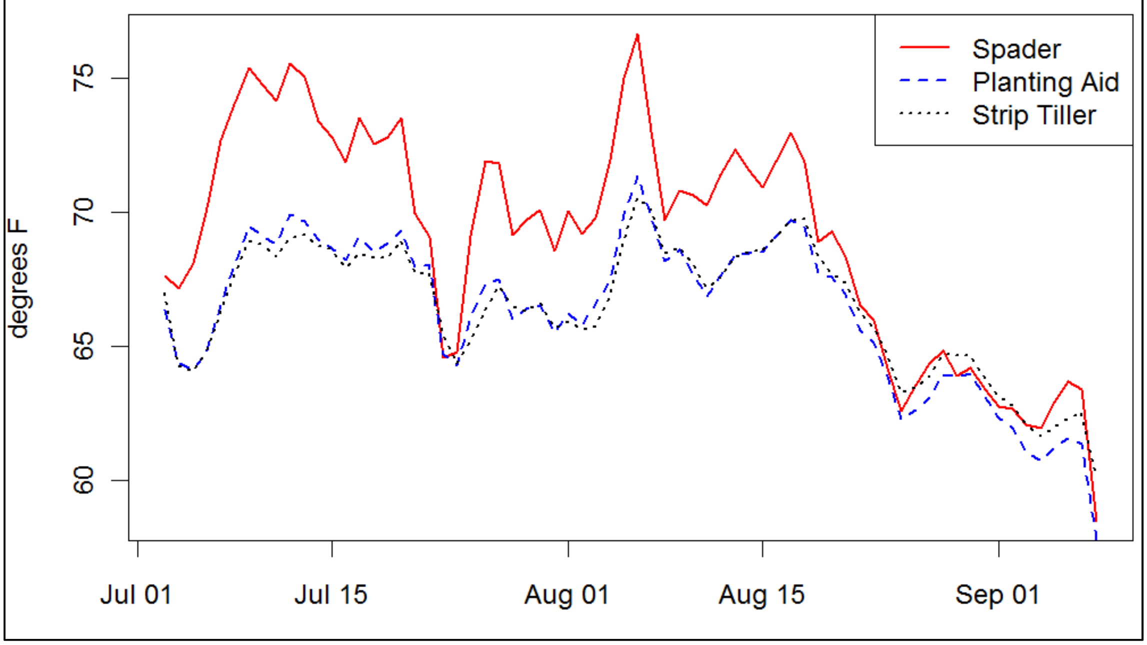
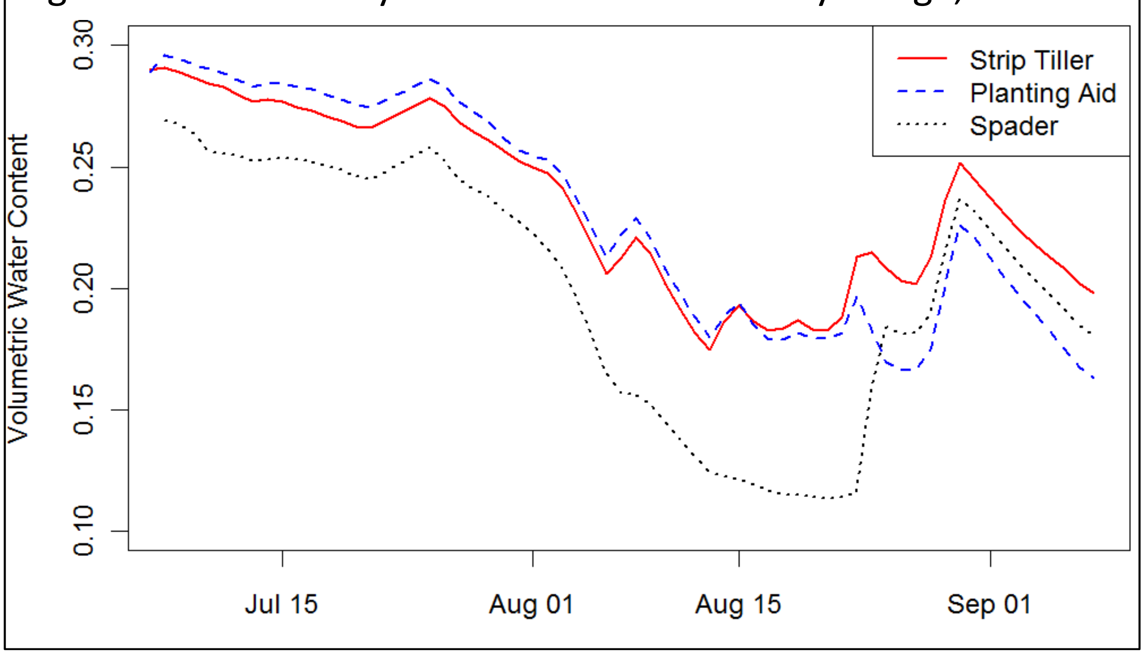
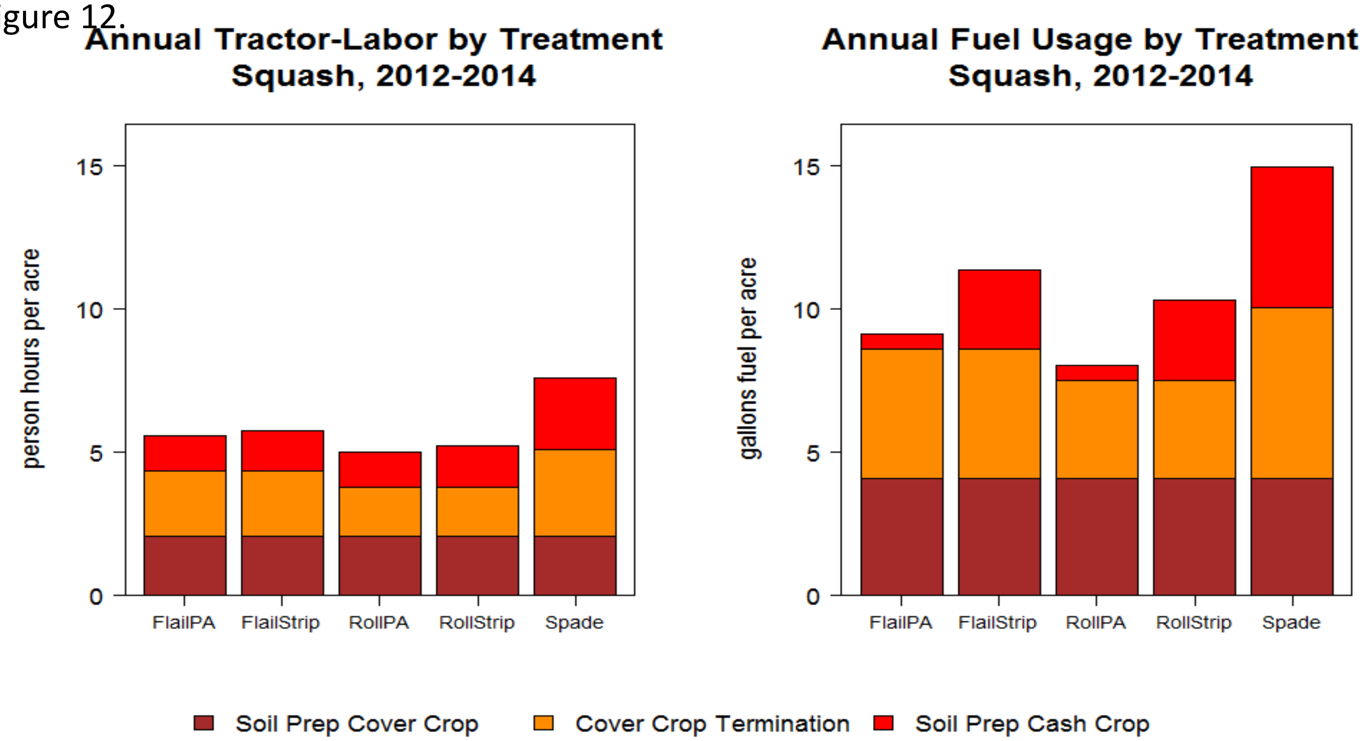


Figure 11. Mean Daily Soil Moisture at 10cm by Tillage, 2012



Significant Findings 2012-2014

Figure 12.



Significant Findings 2012-2014

Figure 13.

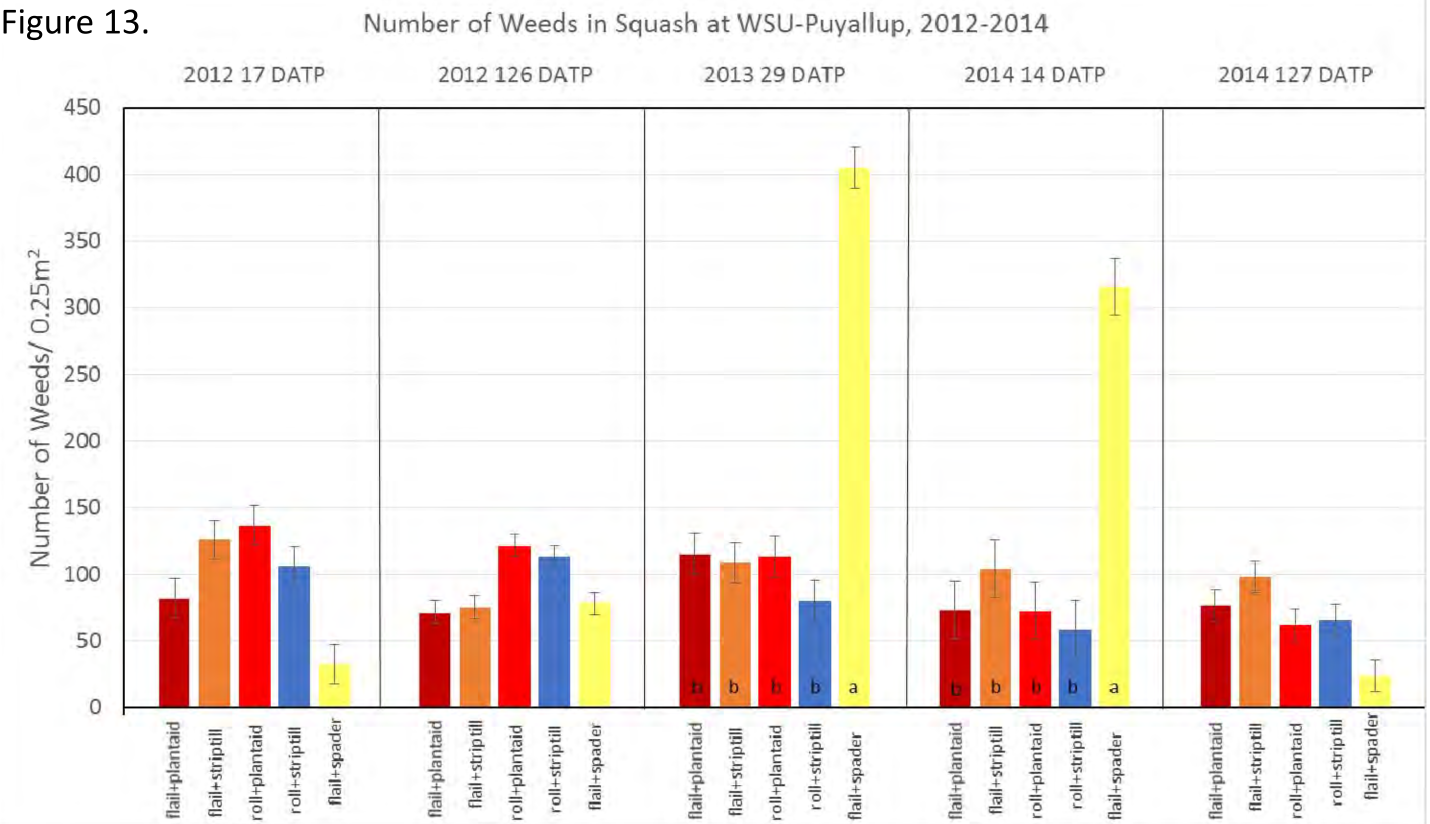
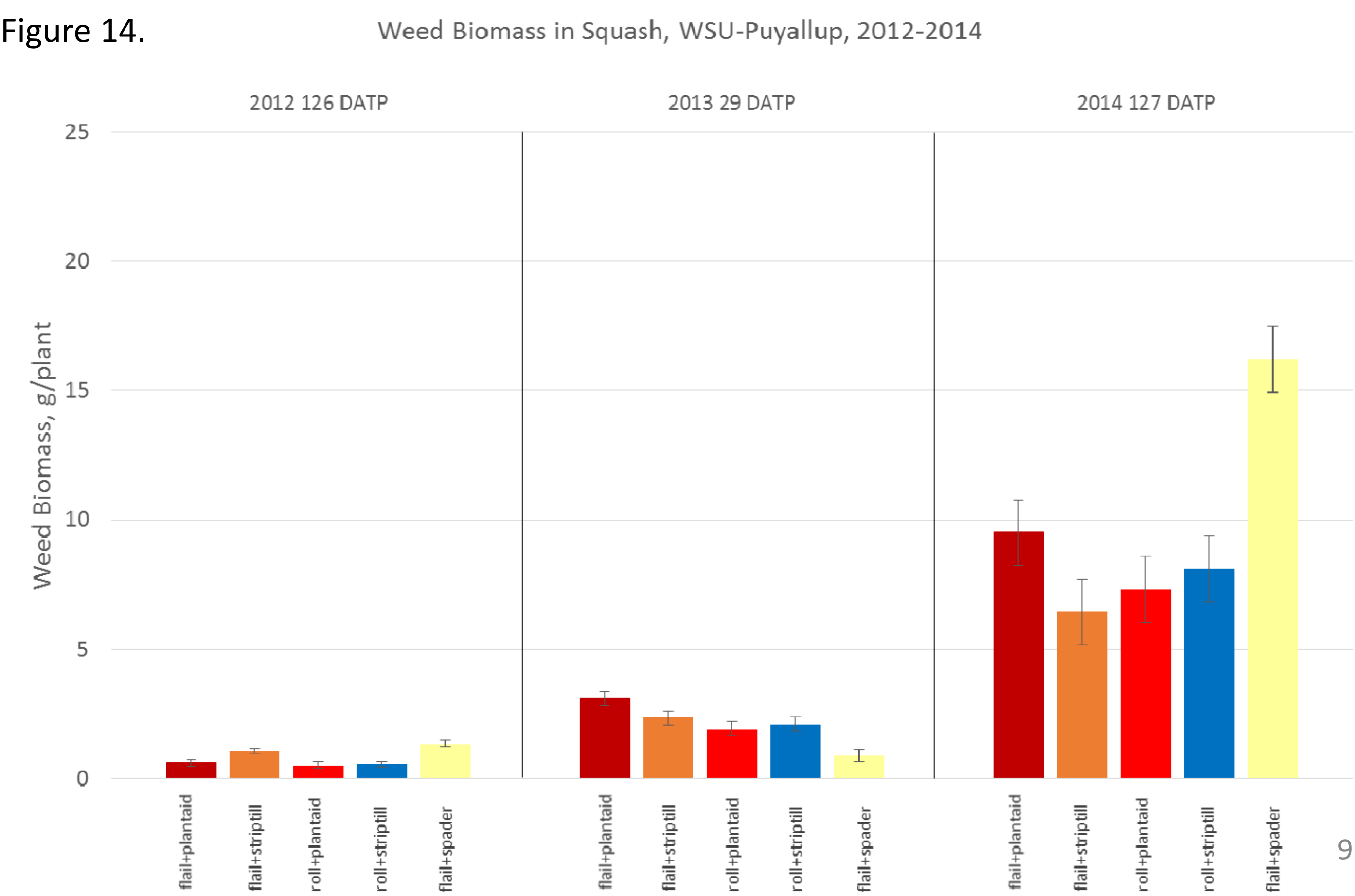


Figure 14.



Significant Findings 2012-2014

Figure 15.

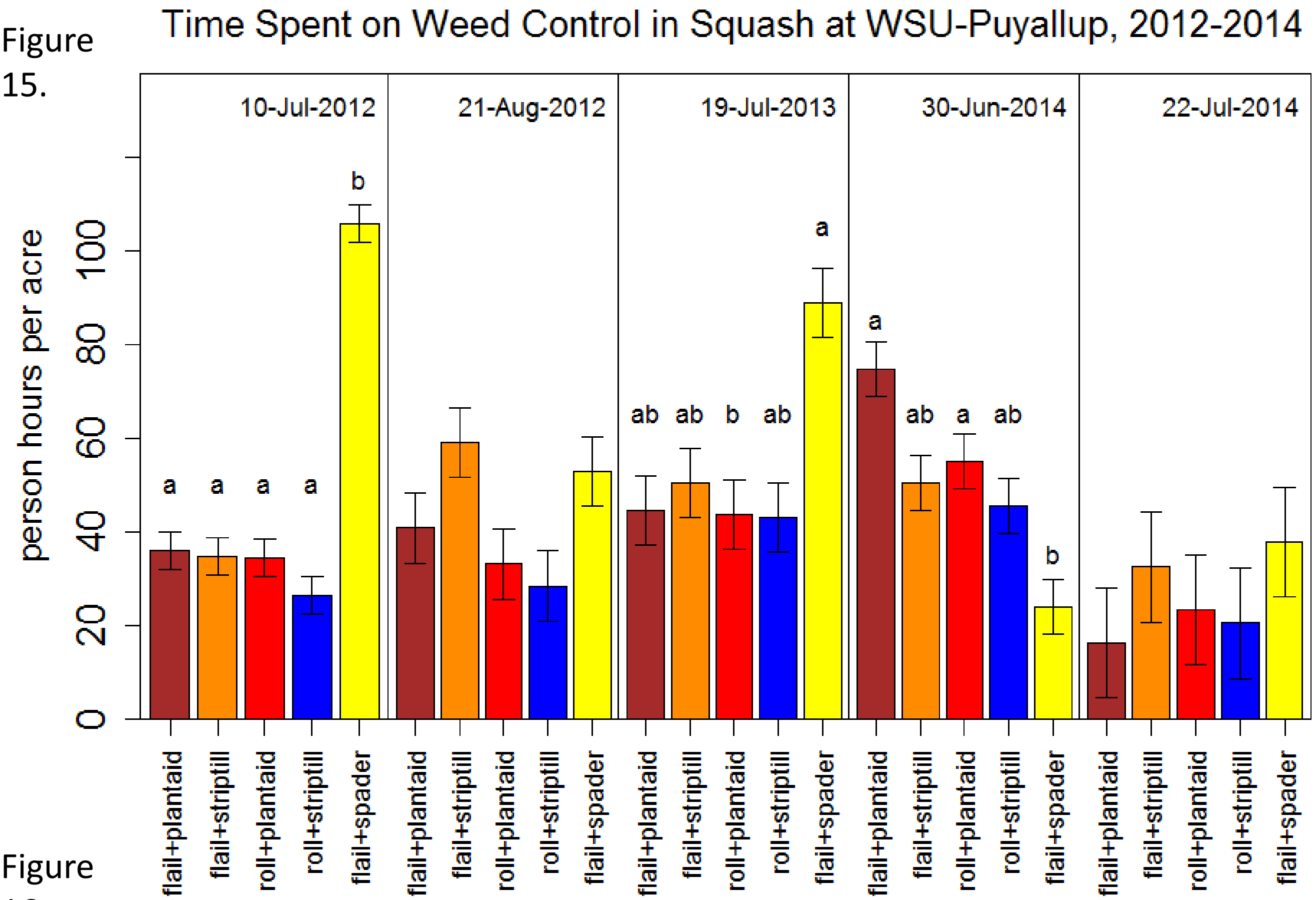
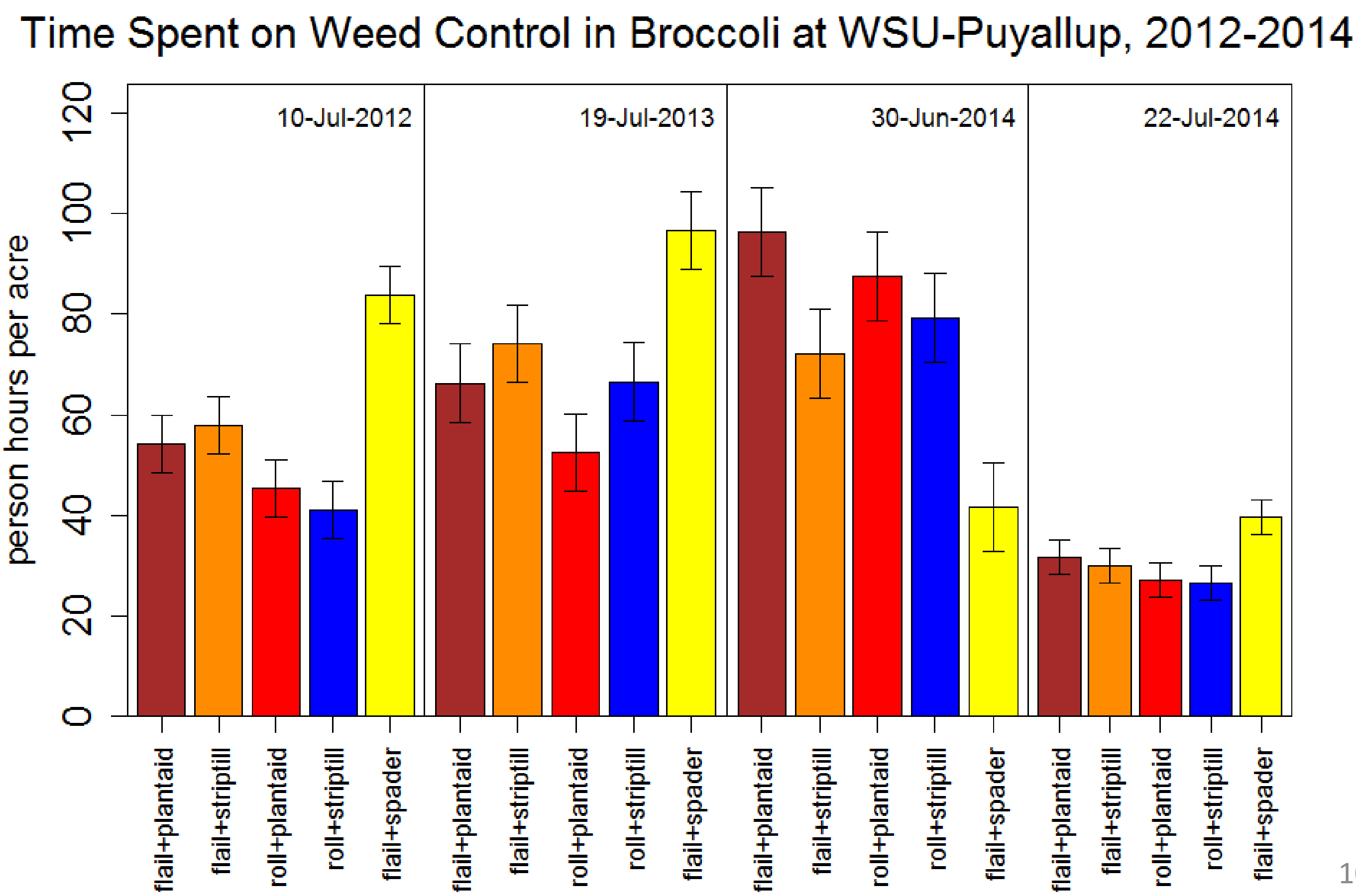


Figure 16.



Significant Findings 2015

Figure 17

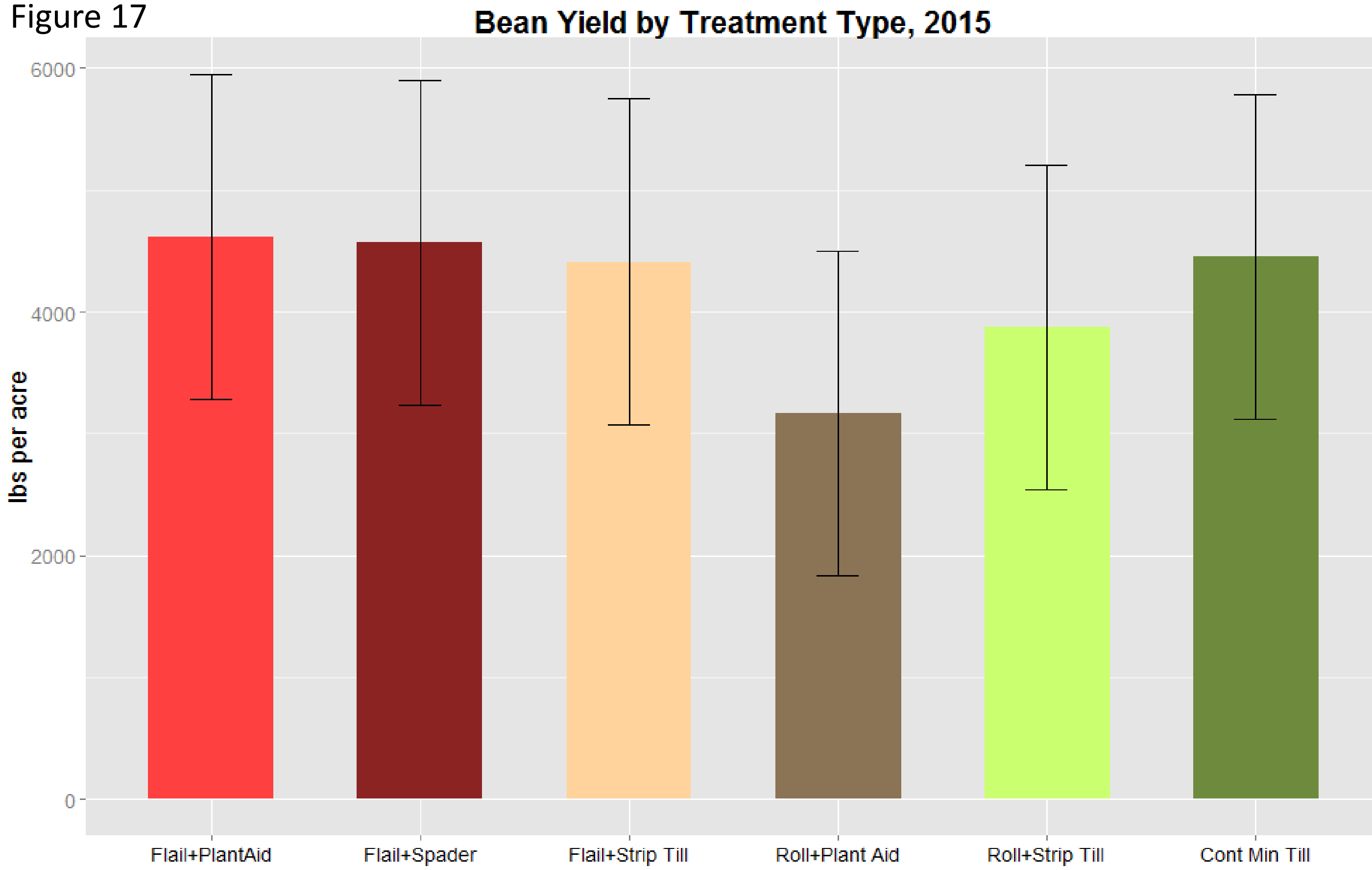
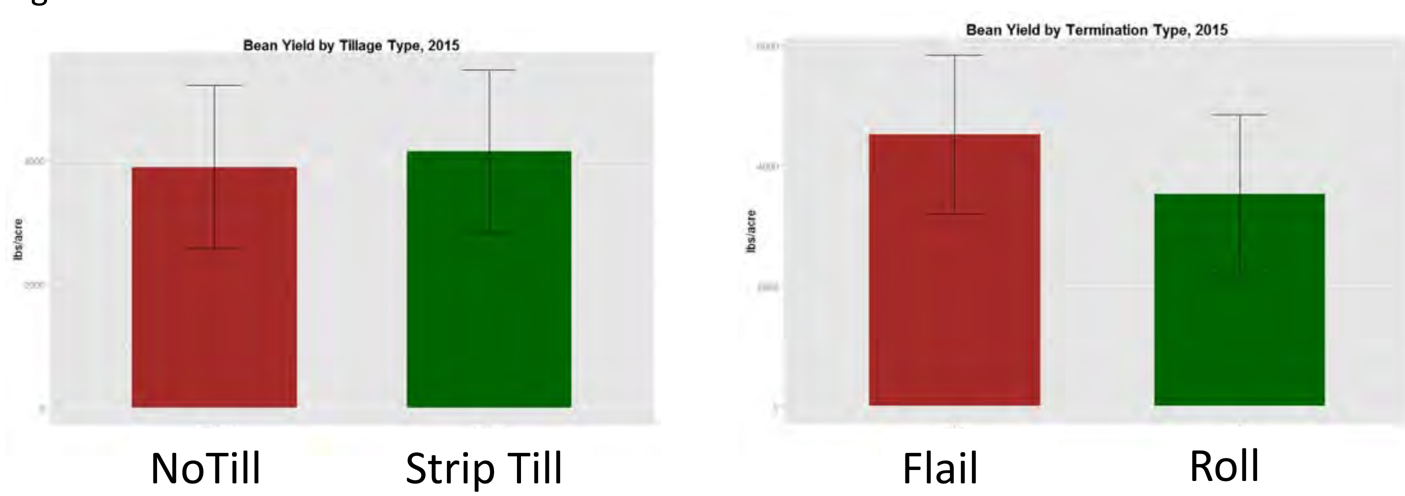


Figure 18



Significant Findings 2015

Figure 19

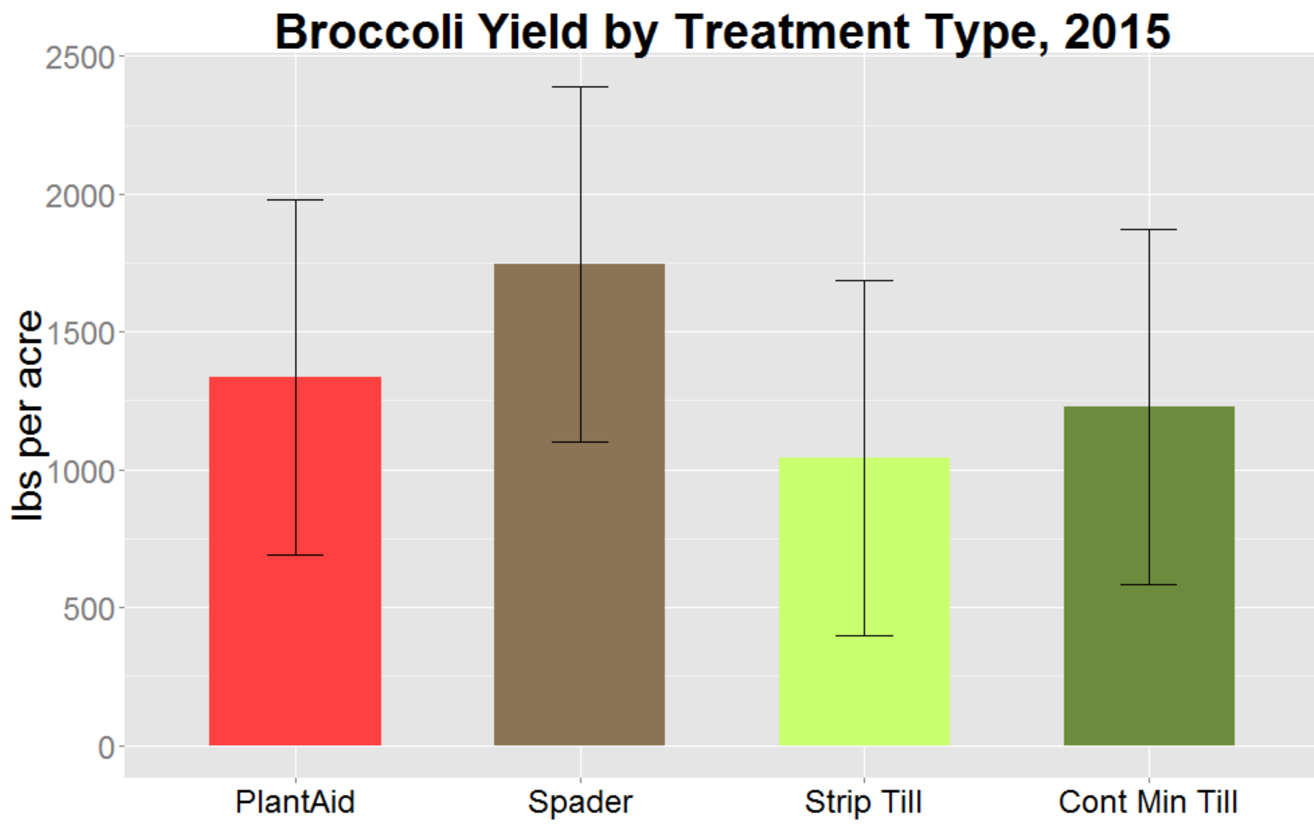
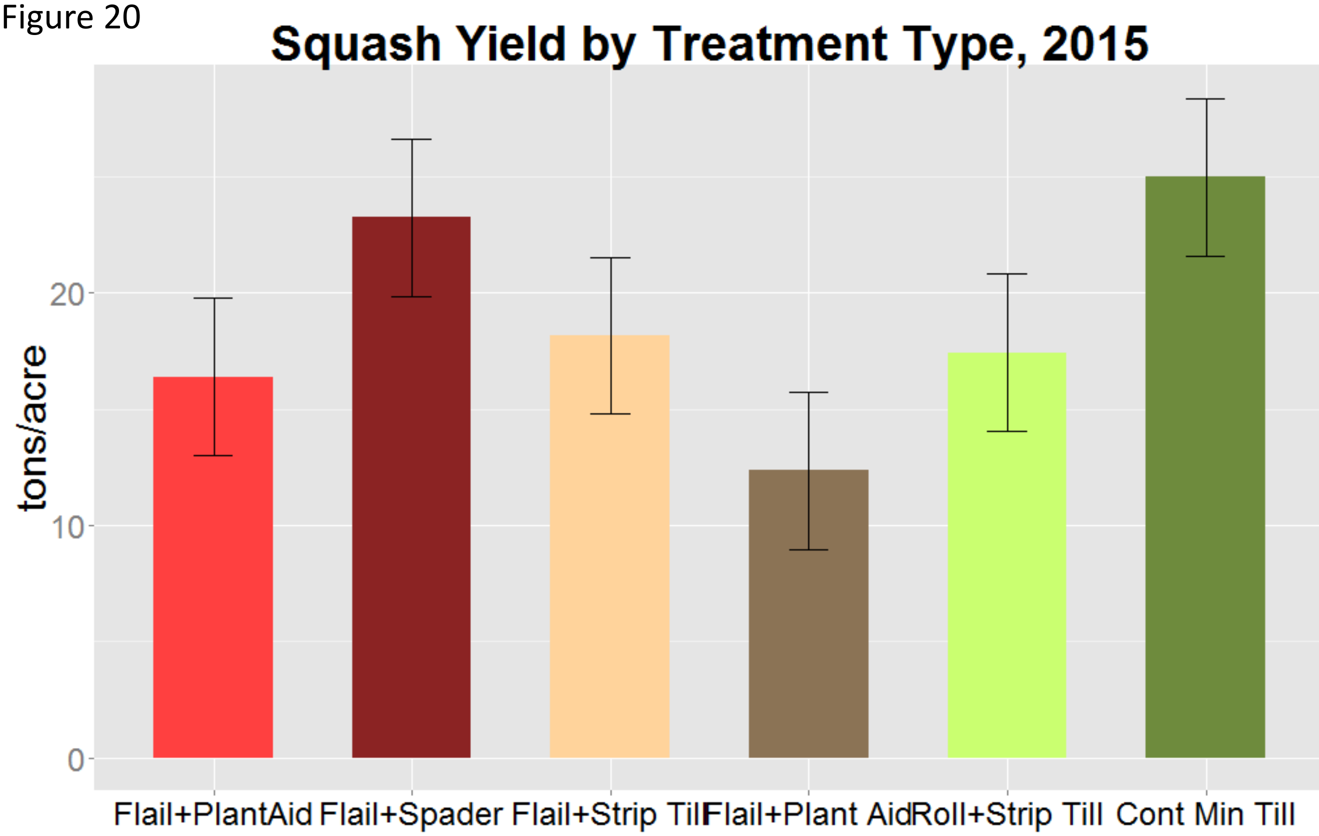


Figure 20



Significant Findings 2015

Figure 21

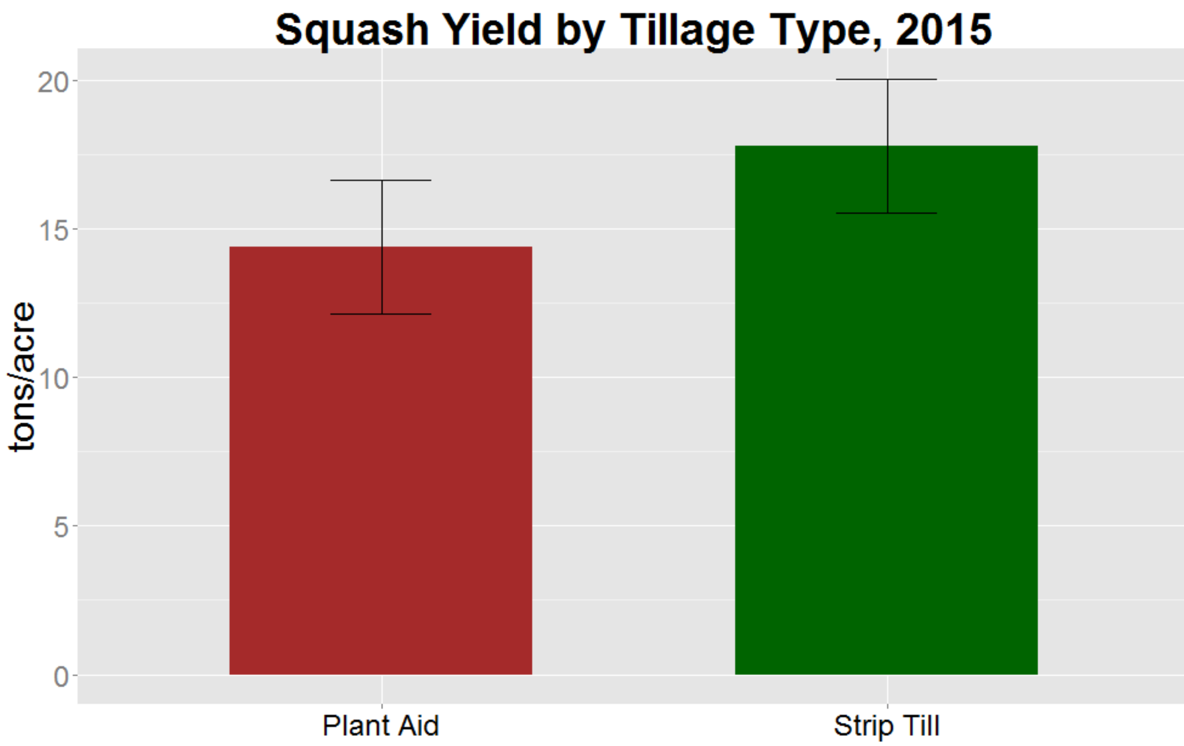
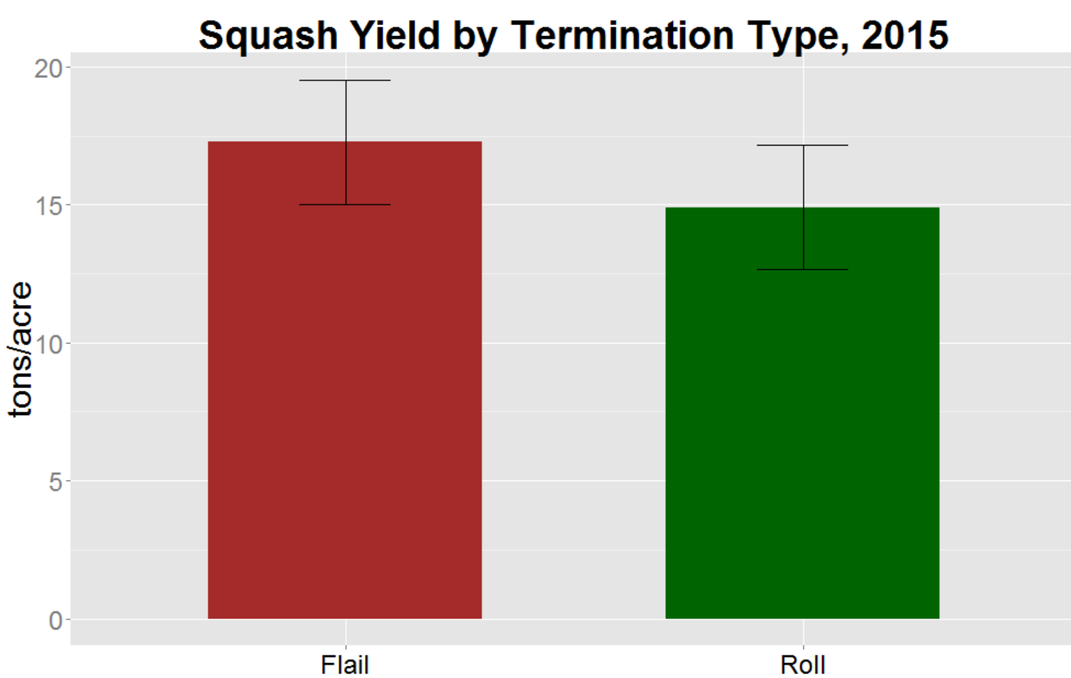
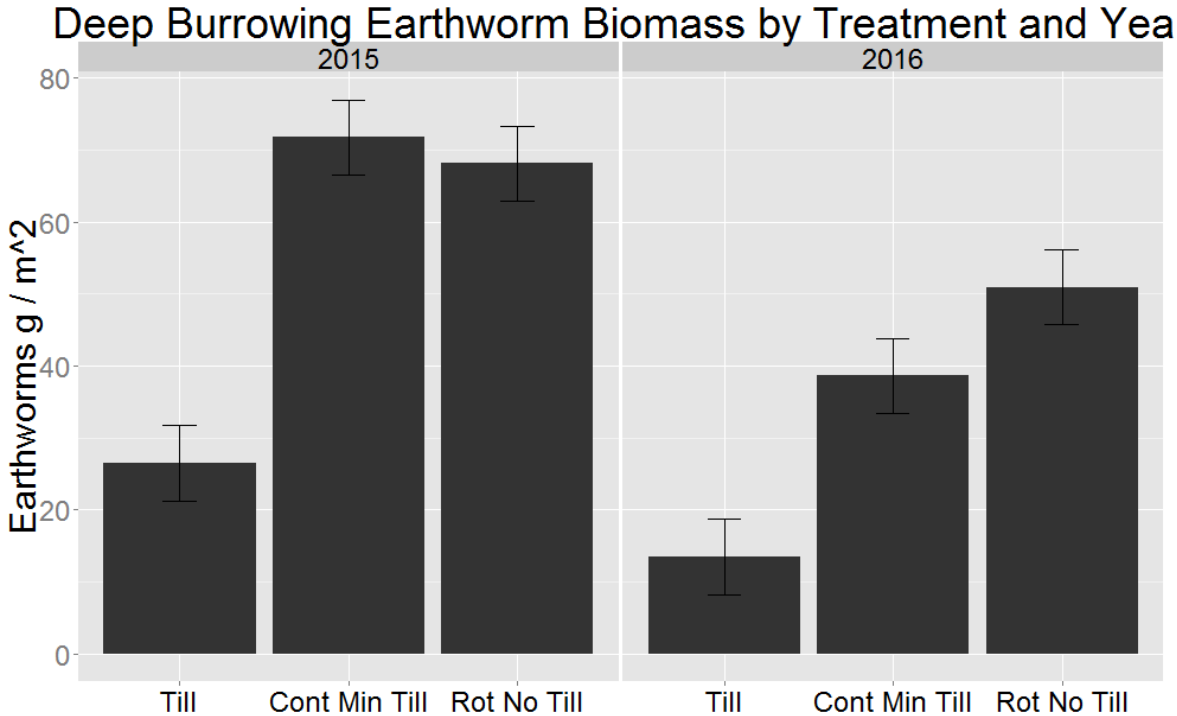


Figure 22



Significant Findings 2015

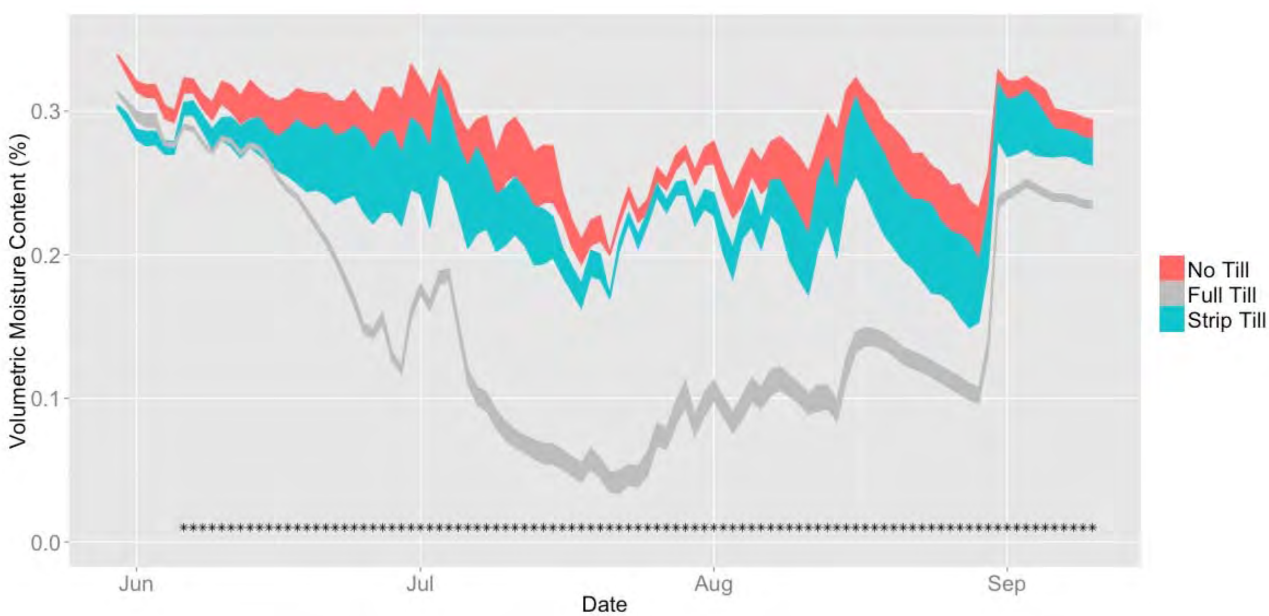
Figure 23



Significant Findings 2015

Figure 24. Mean daily soil temperature at 10cm, Puyallup 2015

Figure 25. Mean daily soil moisture at 10cm, Puyallup 2015



For both figures, thickness of bands represents standard error. Statistical significance of contrasts between treatments on each day is indicated by * for P < 0.05 and + for P < 0.1. Difference is between Full Till and both reduced till treatments (No Till and Strip Till). There was no significant difference among reduced tillage treatments (No Till and Strip Till).

Cover Crop Selection and Biomass

Table 1. Cover Crop Varieties and Dry Matter at Puyallup, 2012-2013

Type	Cover Crop	2012 t/a	2013 t/a	2015 t/a
Grain	Alba barley	3.5	--	
	Aroostook rye	4	3.1	5.4
	Common rye	2.9	3.3	
	Merced rye	1.8	--	
	Strider barley	3.7	3.5	
Mix	Aroostook+Common	--	3.6	
	Aroostook+Purple	--	2.4	
	Merced+Common	--	2.5	
	Merced+Purple	--	2.4	
	Strider+Common	--	3	
	Strider+Lana	2.4	--	
	Strider+Purple	2.9	2.1	
Vetch	Cahaba	--	2.2	
	Common	2.6	2.2	2.1
	Hairy	2.5	3.4	
	Lana	1.5	2.1	
	Purple bounty	2.5	2.6	

Table 2. Cover Crop Varieties and Dry Matter On-Farm, 2012-2013

Site	Type	Cover Crop	2012 ton/ac	2013 ton/ac
Let Us	**Grain**	Strider barley	4.3	
		Aroostook Rye		3.04
Kirsop	**Grain**	Strider barley	2.5	
		Aroostook Rye		4.22
	Vetch	Common		4.42
	Mix	Strider+Crimson	2.5	

Table 3. Cover Crop Varieties and Dry Matter at Mount Vernon, 2012

Type	Cover Crop	2012 ton/ac
Grain	Alba barley	6.33
	Aroostook rye	8.41
	Common rye	7.61
	Strider barley	5.99
Mix	Strider+Lana	5.37
	Strider+Purple	3.83
Vetch	Common	6.29
	Hairy	4.43
	Lana	5.57
	Purple bounty	4.31

Cover Crop Decomposition and Nitrogen Availability

General guidelines from Sullivan and Andrews (2012), "Estimating plant available nitrogen release from cover crops"

- Legume cover crops provide up to 100 lb PAN/a. To maximize PAN contribution from legumes, kill the cover crop at bud stage (early May).
- Cereal cover crops immobilize up to 50 lb PAN/a. To minimize PAN immobilization from cereals, kill the cover crop during the early stem elongation (jointing) growth stage (early April).
- Legume/cereal cover crop mixtures provide a wide range of PAN contributions, depending on legume content. When cover crop dry matter is 75 percent from cereals + 25 percent from legumes, PAN is usually near zero.
- A laboratory analysis for cover crop total N as a percentage in dry matter (DM) is a good predictor of a cover crop's capacity to release PAN for the summer crop.

— When cover crops contain a low N percentage (less than 1.5 percent N in DM), they provide little or no PAN.

—When cover crops contain a high N percentage (3.5 percent N in DM), they provide approximately 35 lb PAN/ton of dry matter.

— PAN release increases linearly, as cover crop N percentage (in DM) increases from 1.5 to 3.5 percent.

- Cover crops decompose rapidly and release or immobilize PAN rapidly. Most PAN is released in 4 to 6 weeks after cover crop kill.

Table 4. Cover crop N concentrations, C:N ratios, and N in kg ha^{-1} and lbs a^{-1}. Grains were terminated at late anthesis or early milk and vetches were terminated at 60% or 100% flower and values are pooled over both termination times. Significance letters indicate difference of means within type groupings. "ns" indicates no significant differences among varieties within type.

Type	Cover crop	% N	C:N ratio	N kg ha^{-1}	N lbs a^{-1}
Grain	StriderB	0.92 a	48 b	76 a	68
	AlbaB	0.73 b	61 b	59 ab	53
	AroostookR	0.53 c	88 a	48 b	43
	CommonR	0.56 c	84 a	35 b	31
Vetch	HairyV	2.9 a	15 b	156 ns	139
	LanaV	3.1 a	14 b	110 ns	98
	CommonV	2.8 ab	15 b	165 ns	147
	PurpleBV	2.4 b	19 a	129 ns	115
Mix	Strider + Purple	2.1 ns	21 ns	133 ns	119
	Strider + Lana	2.2 ns	20 ns	119 ns	106

Figure 26

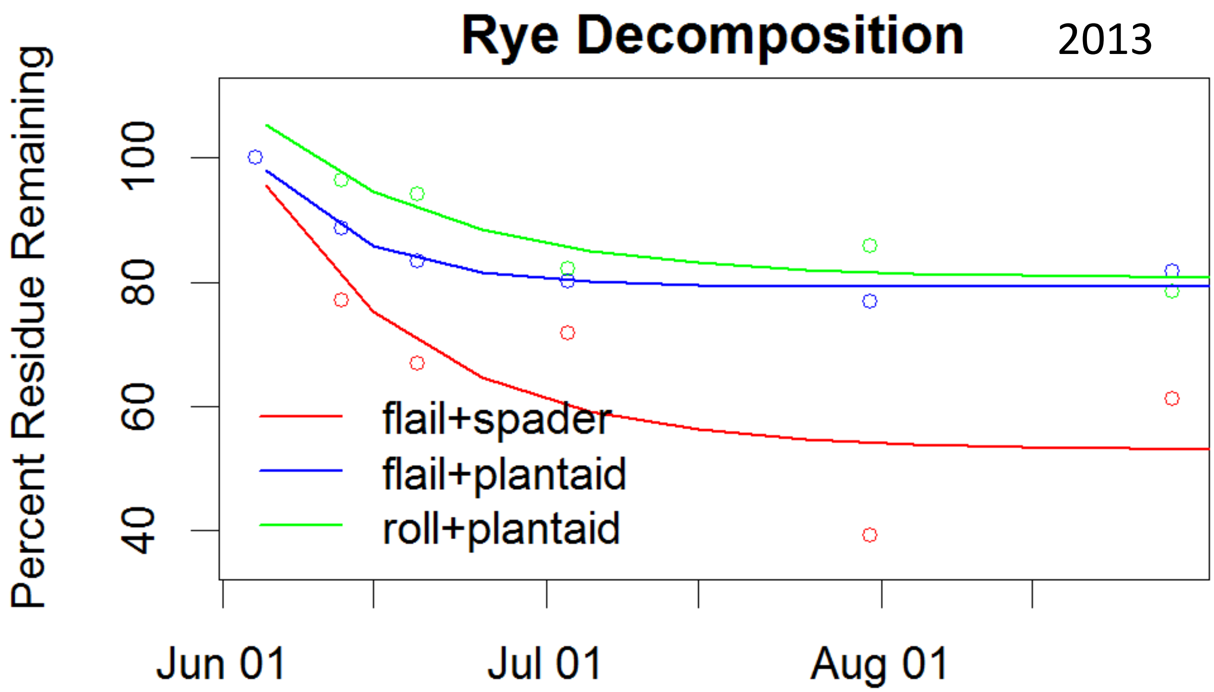
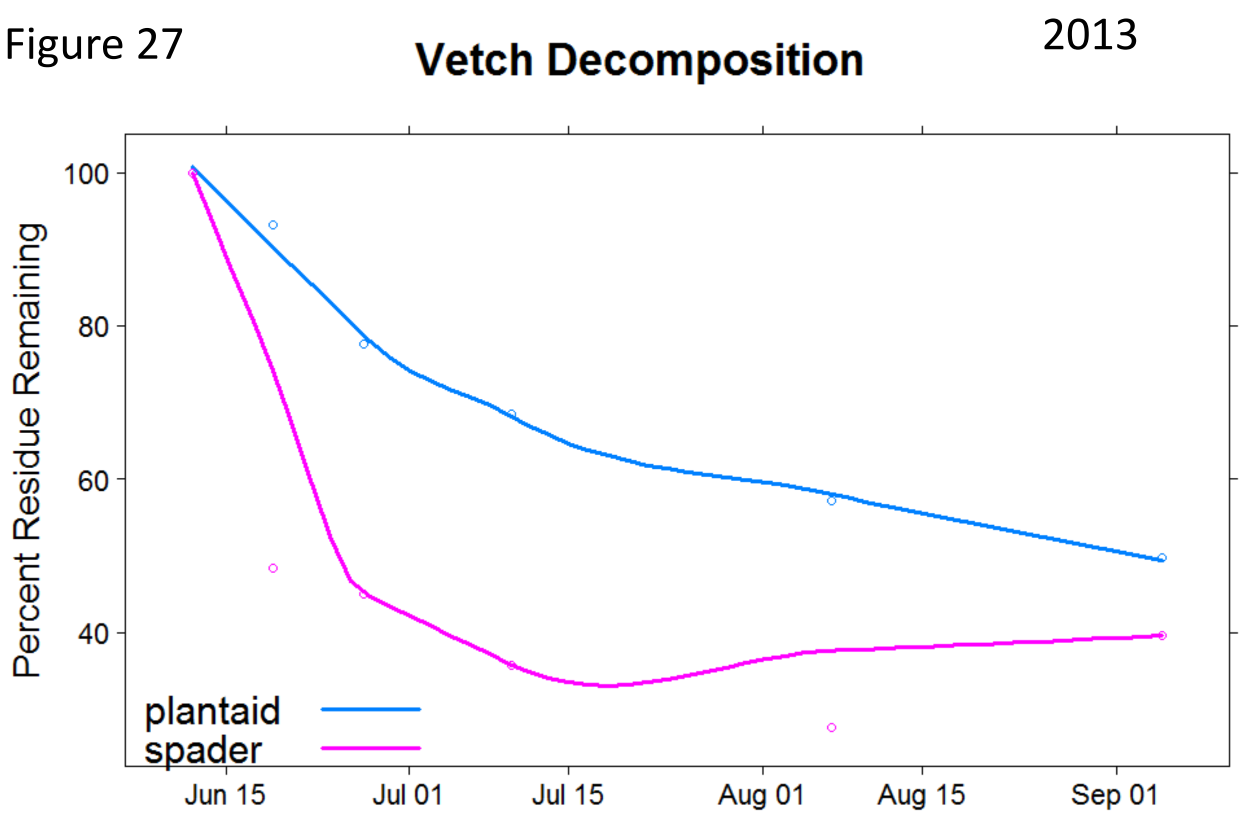


Figure 27



Cover Crop Management

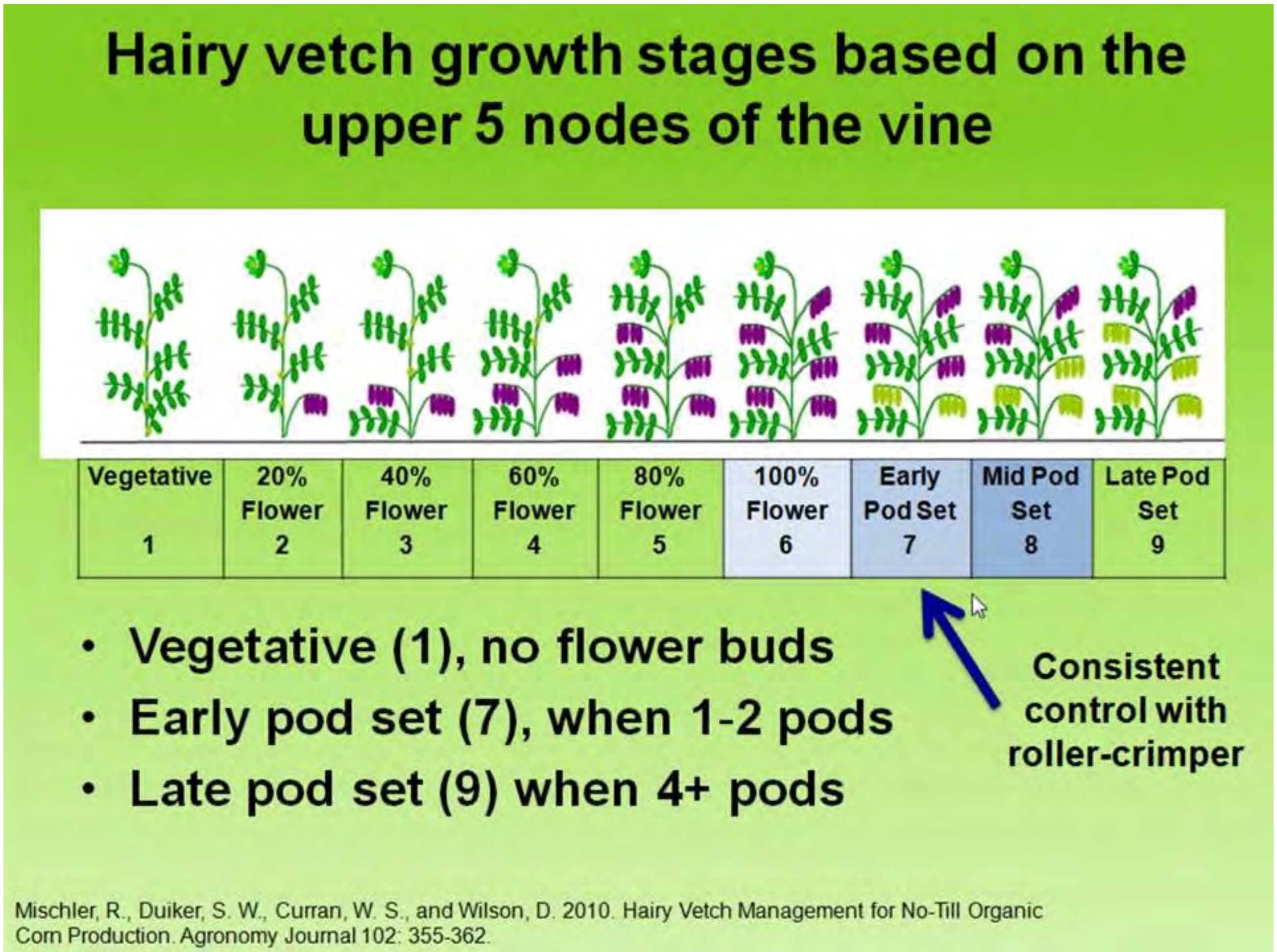
Cereal Grain Development Stages By Zadoks, Feekes And Haun

Zadoks Scale	Feekes Scale	Haun Scale	Description
			Germination
00			Dry seed
01			Start of imbibition
03			Imbibition complete
05			Radicle emerged from seed
07			Coleoptile emerged from seed
09		0.0	Leaf just at coleoptile tip
			Seedling growth
10	1		First leaf through coleoptile
11		1.+	First leaf unfolded
12		1.+	2 leaves unfolded
13		2.+	3 leaves unfolded
14		3.+	4 leaves unfolded
15		4.+	5 leaves unfolded
16		5.+	6 leaves unfolded
17		6.+	7 leaves unfolded
18		7.+	8 leaves unfolded
19			9 or more leaves unfolded
			Tillering
20			Main shoot only
21	2		Main shoot and 1 tiller
22			Main shoot and 2 tillers
23			Main shoot and 3 tillers
24			Main shoot and 4 tillers
25			Main shoot and 5 tillers
26	3		Main shoot and 6 tillers
27			Main shoot and 7 tillers
28			Main shoot and 8 tillers
29			Main shoot and 9 or more tillers
			Stem elongation
30	4-5		Pseudo stem erection
31	6		1st node detectable
32	7		2nd node detectable
33			3rd node detectable
34			4th node detectable
35			5th node detectable
36			6th node detectable
37	8		Flag leaf just visible
39	9		Flag leaf ligule/collar just visible

Zadoks Scale	Feekes Scale	Haun Scale	Description
			Booting
40			—
41		8-9	Flag leaf sheath extending
45	10	9.2	Boots just swollen
47			Flag leaf sheath opening
49		10.1	First awns visible
			Inflorescence Emergence
50	10.1	10.2	First spikelet of inflorescence visible
53	10.2		1/4 of inflorescence emerged
55	10.3	10.5	1/2 of inflorescence emerged
57	10.4	10.7	3/4 of inflorescence emerged
59	10.5	11.0	Emergence of inflorescence completed
			Anthesis
60	10.51	11.4	Beginning of anthesis
65		11.5	Anthesis half-way
69		11.6	Anthesis complete
			Milk development
70			—
71	10.54	12.1	Kernel watery ripe
73		13.0	Early milk
75	11.1		Medium milk
77			Late milk
			Dough development
80			—
83		14.0	Early dough
85	11.2		Soft dough
87		15.0	Hard dough
			Ripening
90			—
91	11.3		Kernel hard (difficult to divide by thumbnail)
92	11.4	16.0	Kernel hard (can no longer be dented by thumbnail)
93			Kernel loosening in daytime
94			Overripe, straw dead and collapsing
95			Seed dormant
96			Viable seed giving 50% germination
97			Seed not dormant
98			Secondary dormancy induced
99			Secondary dormancy lost

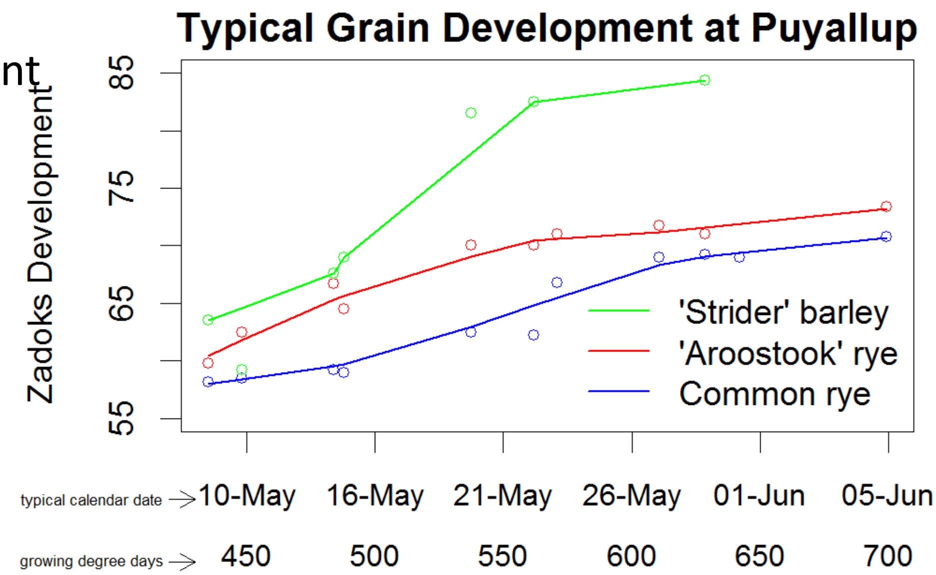
**The Haun scale stages used in this example from boot through ripening are based on a seven-leaf plant.

Late anthesis: Consistent control with rolling rye



To evaluate vetch flowering, at least three stems per subplot are chosen at random and evaluated. Following the method of Mishler et al. (2010), the first five nodes below the apical meristem are counted. Nodes have to be at least 5 cm apart or the next sequential node is counted. Each node is recorded as a bud, flower, or pod to classify the growing stage. Flowers include “any purple color on the raceme.”

Cover Crop Management



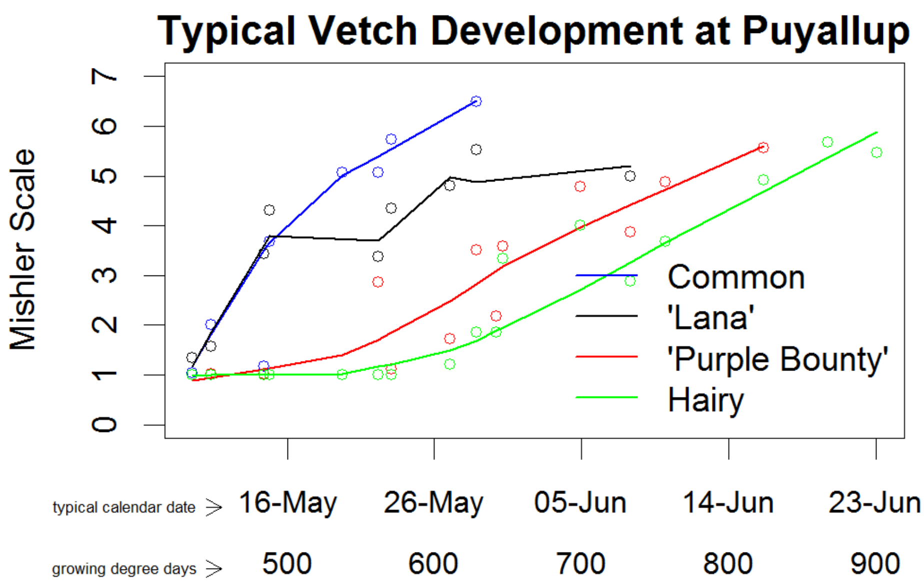


Figure 28. Vetch and grain development May-June 2012/2013 using Zadok's development scale for grains and Mischler's et. al. scale for vetch. Zadok's stages are: 50-60 inflorescence emergence, 60-70 anthesis, 70-80 milk development. Vetch stage are: 4 = 60% flowering, Stage 6 = 100%

	Cover crop		Early	Late
			% of plot upright	
Grain	Alba barley	a	79	59
	Aroostook rye	c	8	0
	Common rye	c	10	2
	Strider barley	ab	68	20

Table 5. Percent of rolled plots with early and late termination, with standing ("the undead") cover crop mulch. "Percent upright" indicates the cover crop did not properly roll. Letters indicate significant difference of the mean by Tukey's HSD test. "Early" = Zadoks 67, "Late" = Zadoks 70. Note: these values are qualitative, derived from visual estimations, so values are approximate.

Cover Crop Management

Table 6. Percent weed cover following rolling and flail mowing

Grain cover crop	-% weed cover -	
	Flail	Roll
Aroostook rye	17	7
Common rye	41	29
Strider barley	24	19
Cover crop average	27	19

Termination type p=0.007

Flail Roll

"Crimp 9" Details

Objectives 1.) Determine the effects of cover crop type and termination timing on total biomass production and weed suppression. 2.) Assess the effectiveness of strip tillage for organic kale production.

Design Split-split plot design with 4 replications. Cover crop were the main plots, tillage was the first split and termination timing was the second split. Plots were 5X30 ft.

Cover Crops Rye, Vetch, and 50/50 mixture

Tillage
FullTill: low-speed rotating Imants spader
StripTill: 22 inch BCS L-tine rototiller modified to till 8 inches, two strip zones per 60" bed

Termination Time

	Rye/Vetch maturity rating	Zadoks/Mischler scale
Early: April 15th	boots swollen/vegetative	45/1
Mid: May 7th	early pollination/20% flowering	60/2
Late: May 21st	late pollination/60%flowering	67/4

Fertilization Each 30' plant row was directly fertilized with 2 lbs organic feather meal (12-0-0), resulting in 139.2 lbs N/acre.

Measurements Weed counts were collected 2 weeks post transplant with sample sites located centrally between each crop row. Two 1.25X0.2m subsamples were collected per plot. Kale was harvested according to wholesale standards. Cover crop biomass collected at termination date with two randomly selected 0.5X0.5m subsamples harvested for above ground biomass, dried, and averaged to obtain dry weight.

Three stages of preparing cover crop for transplanting: (a) standing cover crop, (b) flailed, and (c) flailed and strip-tilled

Figure 29. Cover Crop Biomass Production at Varying Termination Times
Puyallup 2015, "Crimp 9"

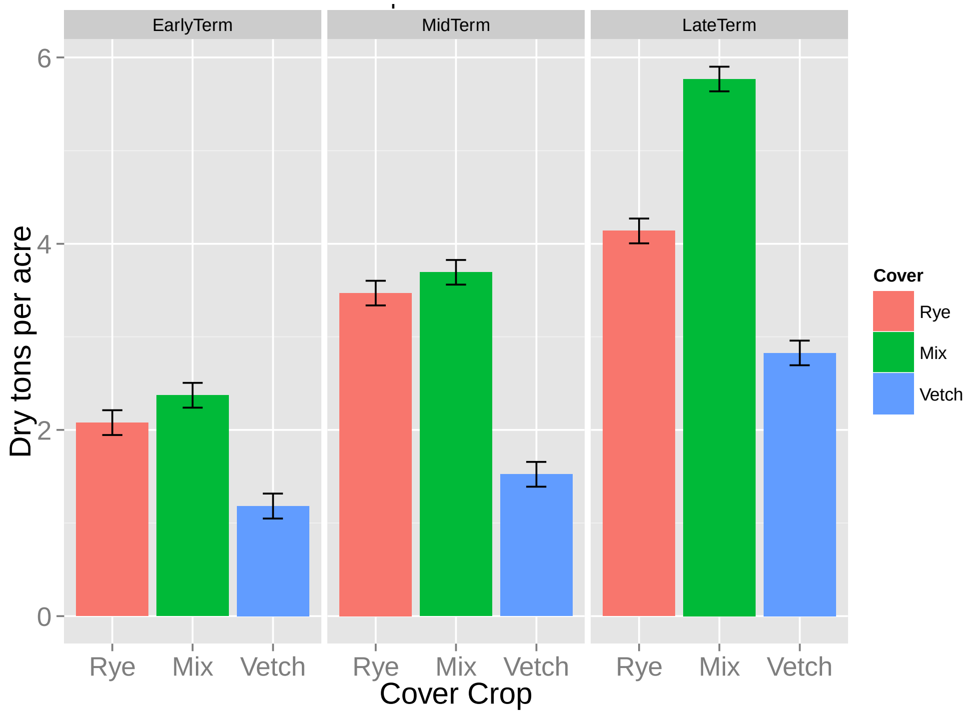


Figure 30. Cover Crop Regrowth Biomass at Kale Harvest
Puyallup 2015, "Crimp 9"

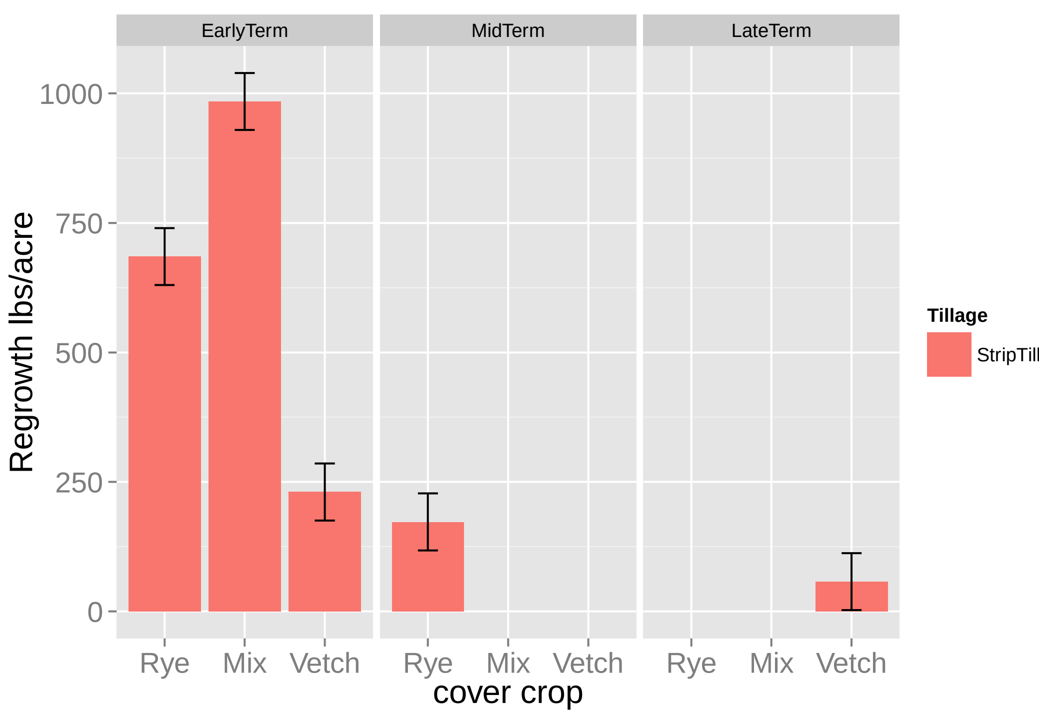


Figure 31. Weed Biomass at Kale Harvest
Puyallup 2015, "Crimp 9"

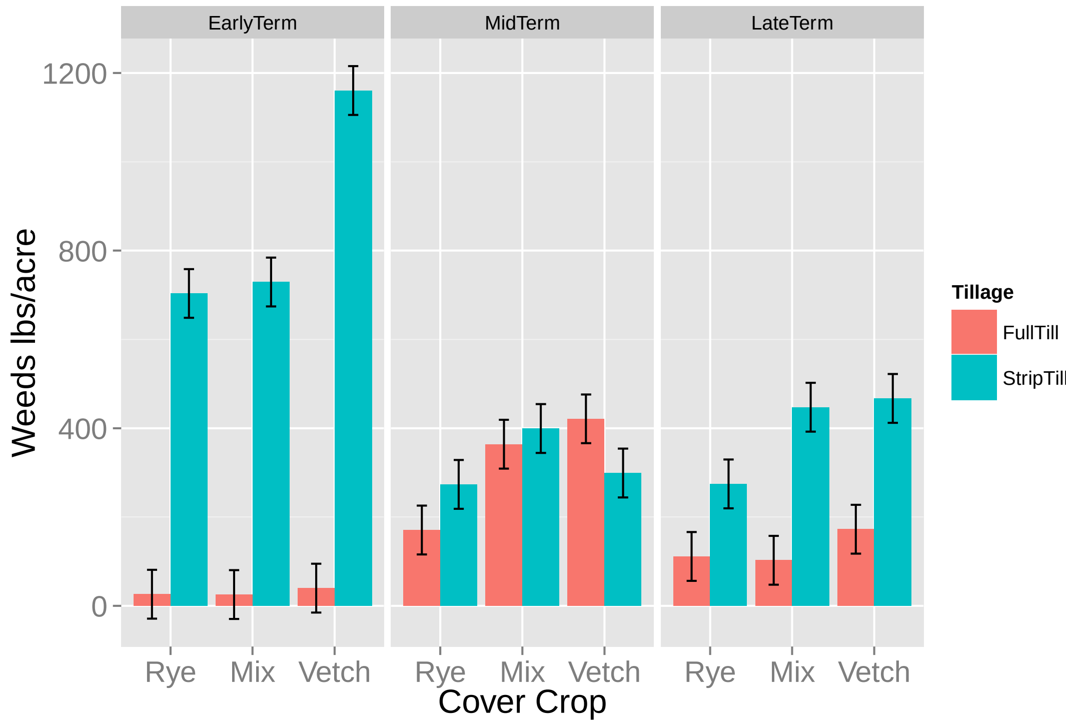
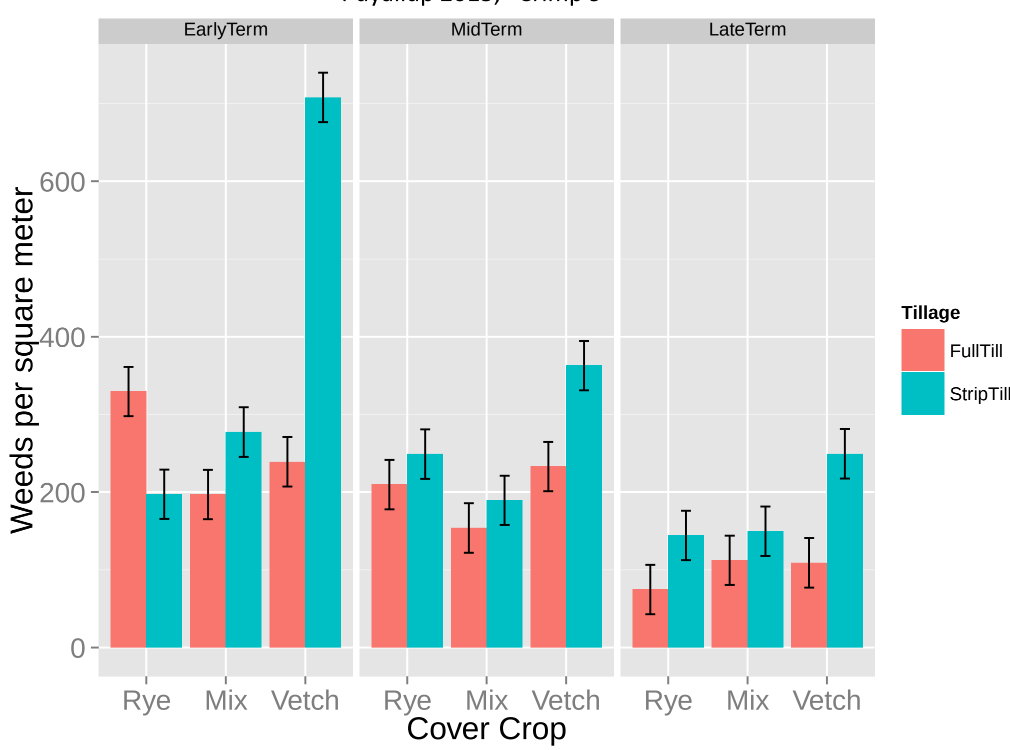
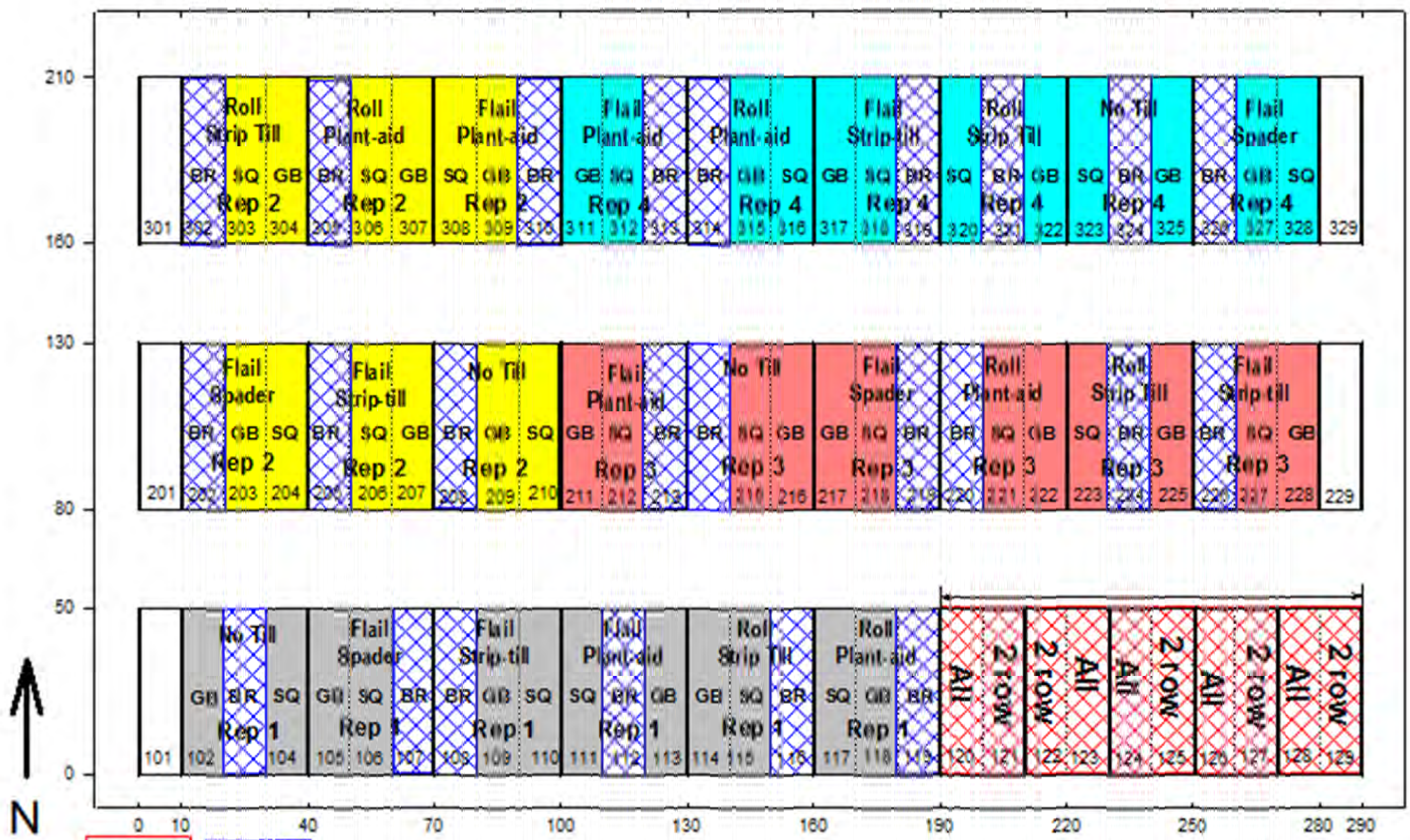


Figure 32. Weed Counts, two weeks after Transplanting Crop
Puyallup 2015, "Crimp 9"

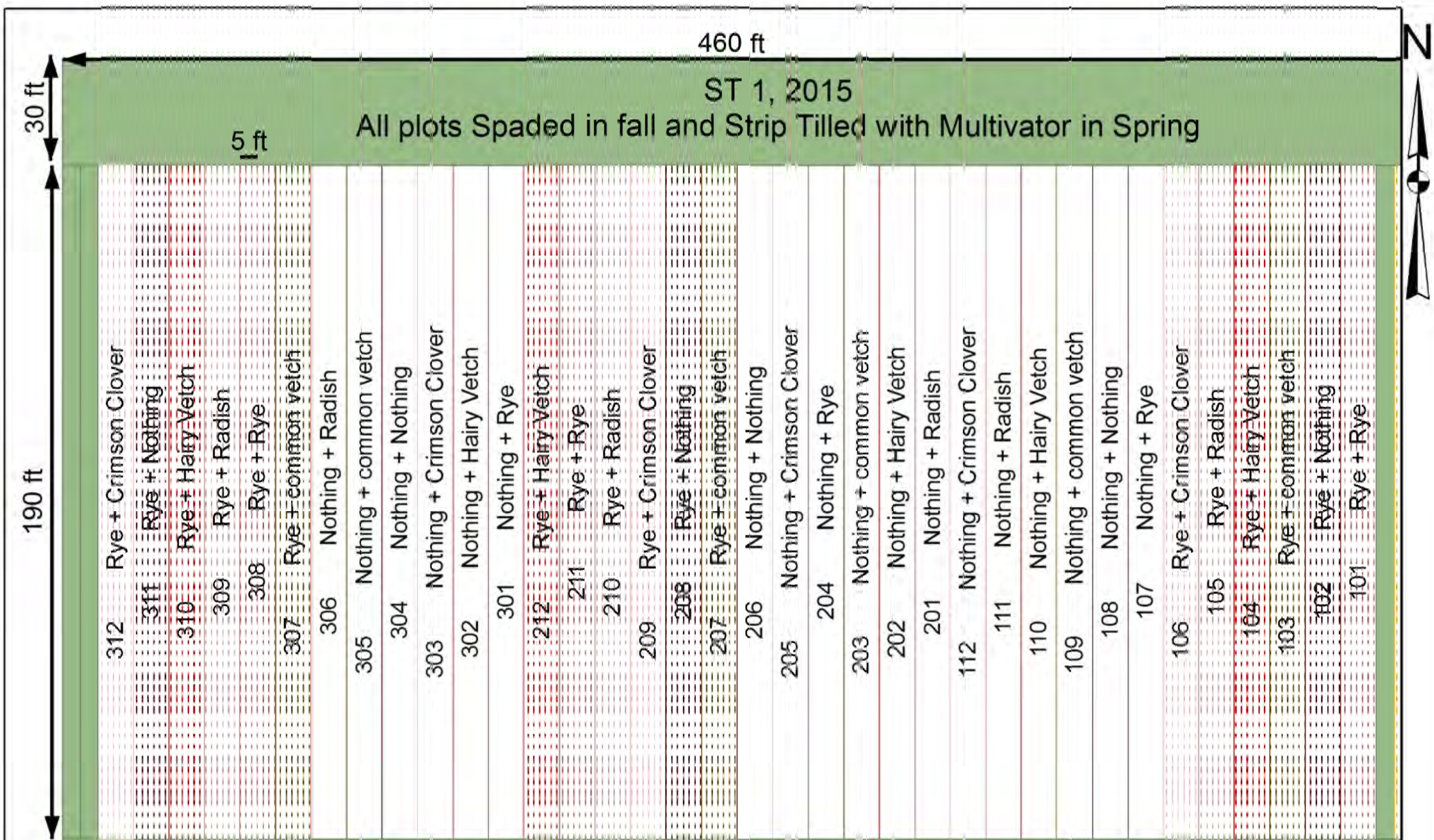


Reduced Tillage Experiment

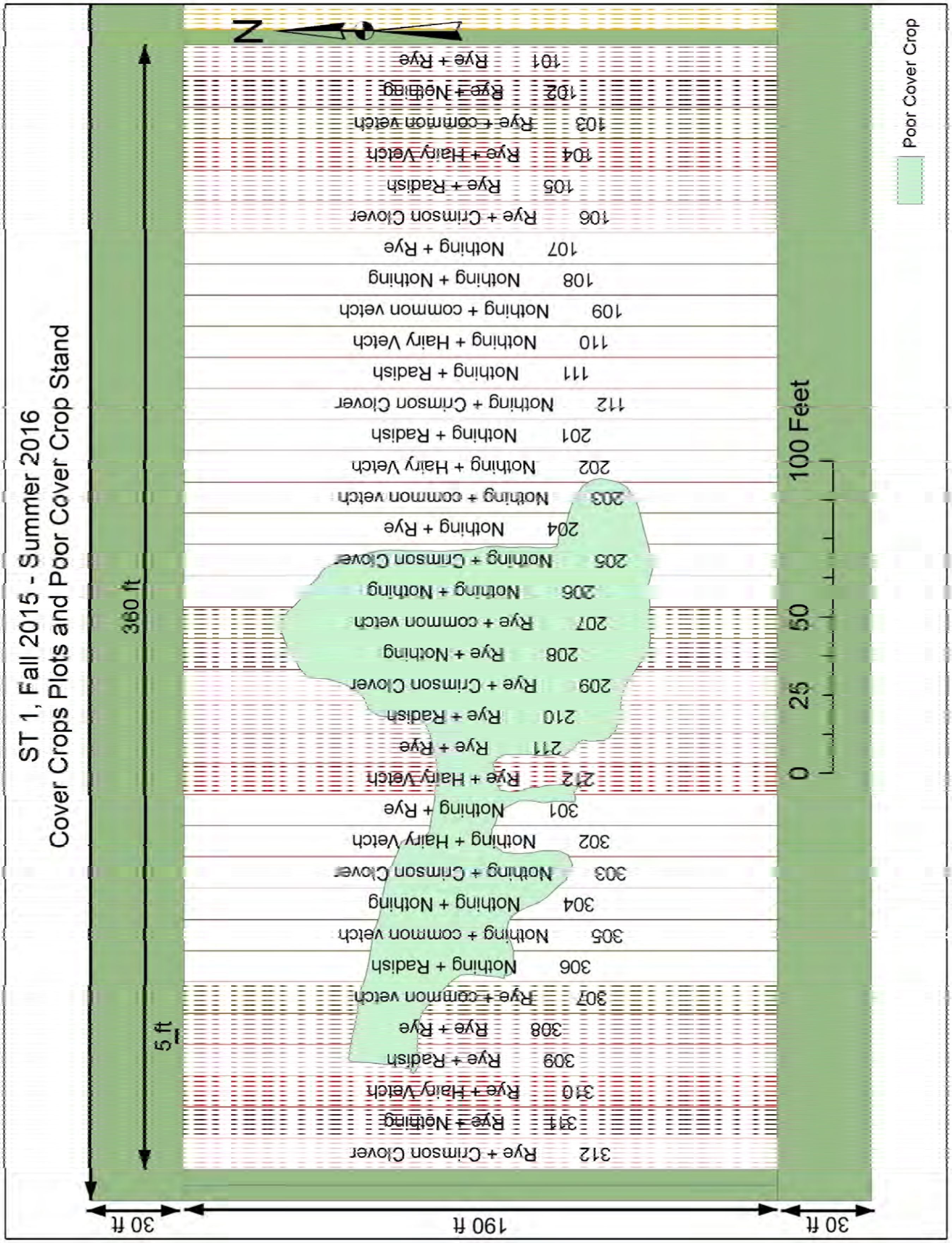
Crimp 4 9Sep15 for **2016** growing season

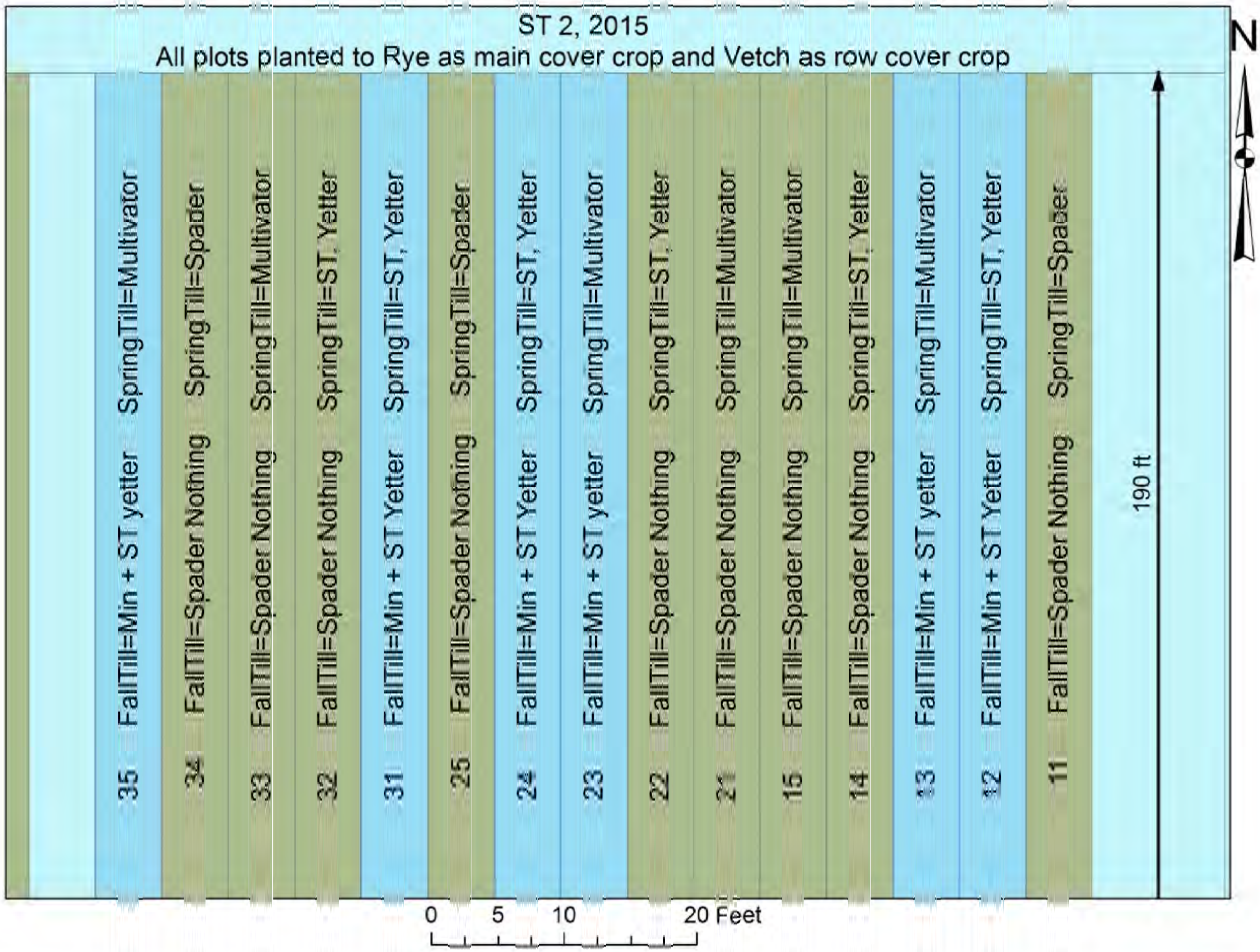


Cover crop	Planting date	Seeding rate (lbs/a)
Aroostook rye	9/23/2015	115
Common vetch	9/24/2015	61



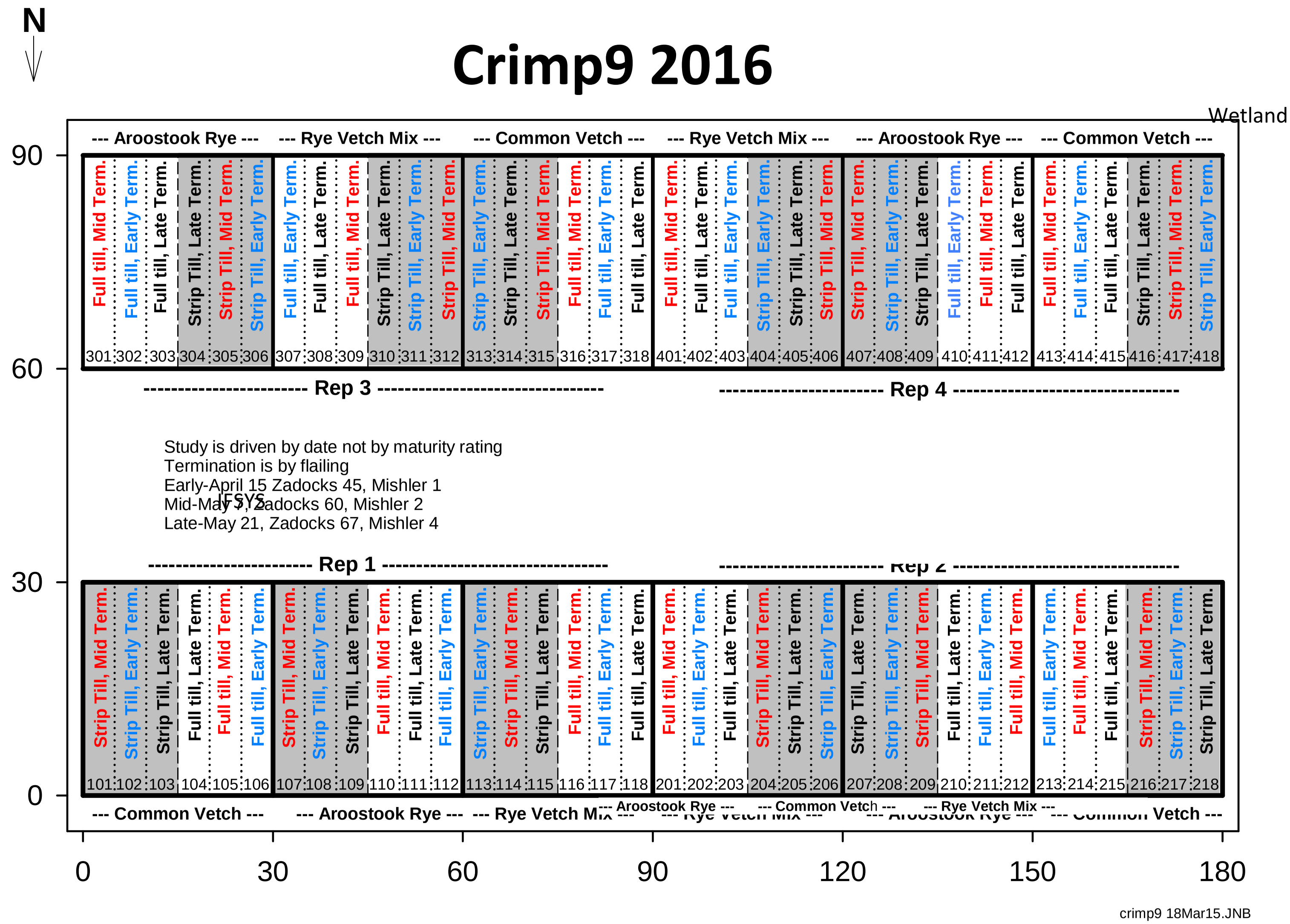
Cover crop	Planting date	Seeding rate (lbs/a)	
		Actual	Target
Aroostook rye	10/1/2015	115	100
Common vetch	10/1/2015	145	60
Hairy vetch	10/1/2015	145	60
Radish	10/1/2015	134	20
Clover	10/1/2015	19	22


ST 1, Fall 2015 - Summer 2016
Cover Crops Plots and Poor Cover Crop Stand
N
101 Rye + Rye
102 Rye + Nothing
103 Rye + common vetch
104 Rye + Hairy Vetch
105 Rye + Radish
106 Rye + Crimson Clover
107 Nothing + Rye
108 Nothing + Nothing
109 Nothing + common vetch
110 Nothing + Hairy Vetch
111 Nothing + Radish
112 Nothing + Crimson Clover
201 Nothing + Radish
202 Nothing + Hairy Vetch
203 Nothing + common vetch
204 Nothing + Rye
205 Nothing + Crimson Clover
206 Nothing + Nothing
207 Rye + common vetch
208 Rye + Nothing
209 Rye + Crimson Clover
210 Rye + Radish
211 Rye + Rye
212 Rye + Hairy Vetch
301 Nothing + Rye
302 Nothing + Hairy Vetch
303 Nothing + Crimson Clover
304 Nothing + Nothing
305 Nothing + common vetch
306 Nothing + Radish
307 Rye + common vetch
308 Rye + Rye
309 Rye + Radish
310 Rye + Hairy Vetch
311 Rye + Nothing
312 Rye + Crimson Clover
360 ft
5 ft
30 ft
190 ft
30 ft
0 25 50 100 Feet
Poor Cover Crop



Cover crop	Planting date	Seeding rate (lbs/a)	
		Actual	Target
Aroostook rye	10/2/2015	73	100
Common vetch	10/2/2015	97	60

Crimp9 2016



Cover crop	Planting date	Seeding rate (lbs/a)	
		Actual	Target
Aroostook rye	9/24/2015	87	100
Common vetch	9/24/2015	79	60
Rye/Vetch Mix (50:50)	9/24/2015	82	100