Spring Application of Winter Rye Grain for Weed Control in Summer Vegetables

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Introduction

Plasticulture production of vegetables has been widely adopted in the Northeast providing farmers with in-row weed control, soil moisture regulation and season extension. However, the bare row middles in this system require herbicide or cultivation which increase environmental impacts; impairing water quality, decreasing soil organic matter levels and increasing labor inputs. In 2012 the Cornell Vegetable Program was awarded a NESARE grant to evaluate a new use of cover crops, by sowing winter rye between plastic-mulched beds of tomatoes and onions on two cooperating farms. Both farms provided cultivation and herbicide treatments to enable us to compare weed control, yield and pest and disease impacts.

MATERIALS AND METHODS:

Two small-plot, on-farm trials were conducted in Penn Yan, NY on two different farms, one growing onions and one growing tomatoes.

ONIONS

Project Design: The trial was set up as a randomized complete block design with 3 treatments (Rye, Cultivation, and Herbicide) and 4 replications. Each treatment replicate was two row middles and a plastic raised bed approximately 10 feet wide by 10 feet long. Onion transplants (*Allium cepa*, var. Candy) were produced on farm and transplanted by hand on April 16. Onions were planted into reflective silver plastic mulch beds, 4 rows per bed, with 6 inch in-row spacing in a Lima fine sandy loam soil, which had received an inch of dairy manure the previous fall and incorporated. The onions received two applications of 10-20-10 fertilizer (Growers Mineral Solutions, Milan, OH), via drip irrigation, prior to bulbing, at 5 gal/A. Herbicide (Prowl H20-pendimethalin) and Rye (3 bu/A) applications were made on either side of the onion beds on April 10. A foliar application of Movento (spirotretamat) at label rate for thrips control was made to all plots in early July.

Plant growth: Ten randomly selected plants per replicate were measured for plant height, of the tallest leaf, and number of leaves per plant on May 22, June 12, July 3 and July 24.

Disease Pressure: Levels of Botrytis Leaf Blight (*Botrytis squamosa*) and Onion Thrips (*Thrips tabaci*) were evaluated on June 12. Five randomly selected plants per replicate were evaluated. Botrytis Leaf Blight was evaluated by counting the number of lesions the on outer three leaves and determining how many lesions per leaf. Onion Thrips were counted per plant.

Tissue Analysis: Leaf samples were collected from the newest fully developed leaf of 20 plants per treatment on July 3rd and 24th. Samples were sent to Waters Agricultural Laboratories, Inc. in Owensboro, KY for foliar nutrient level analysis.

Weed Biomass: Weeds were collected from 4 random 1 square foot sections of row middles per treatment on May 22, June 12, and July 3. Weeds were cut or pulled out at ground level and weighed in grams fresh weight.

Yield and bulb size: Onions were harvested on August 16. All bulbs in 10 feet of bed per block were pulled, topped to 1 inch necks, weighed and sized. Bulb size distribution included colossal (>4"), jumbo (3-4"), medium (2-3"), small (<2"), culls due to rot and culls due to undersize or other.

Statistics: Statistical differences among treatments was determined by General Analysis of Variance (ANOVA) with mean separation by an LSD test with a $p \leq 0.05$.

TOMATOES

Project Design: The trial was set up as an in-row complete block design with 3 treatments (Rye, Cultivation, and Herbicide) and 4 replications. Each treatment replicate was two row middles and a plactic raised bed approximately 10 feet wide by by 20 feet long. Tomato transplants (*Solanum lycopersicum*, var. Primo Red) were produced on farm and transplanted by hand on May 15. Tomatoes were transplanted into black plastic mulch beds, 1 row per bed, with 24 inch in-row spacing, the soil a Lima Silt Loam. Rye treatments were seeded between the plastic rows on May 7 (3 bu/A) followed by the herbicide treatment, at labeled rates on May 8. The herbicide treatment consisted of a tank mix of Sandea, Dual, Prowl, and Roundup (active ingredients: halosulfuron, metolachlor, pendimethalin, and glyphosate, respectively). An application of Admire Pro (imidicloprid) was made on June 18 at label rates for tomato to control common armyworm.

Fertility was maintained by the grower, as their standard. The field received 400 pounds/acre 15-15-15 fertilizer on March 15 as well as 2.5 tons/acre chicken manure on March 21. On March 23, Potash (0-0-61) and Phosphorus (11-52-0) were applied to the field at 25 and 30 pounds/acre, respectively. Prior to transplanting plants received 15 oz. of 20-20-20 fertilizer per 100 gallons of water (Miller Chemical, Hanover PA). At transplant each plant received 2 cups of starter fertilizer solution (8 oz 12-48-8 per 5 gallons of water). Tomatoes received 20-20-20 (9-15-30 was used on July 31 and Aug 16) via drip emitters, weekly, through mid August.

Plant growth: Three randomly selected plants per replicate were measured for plant height, of the tallest leaf, on July 17, Aug 14, Sept 4 and Sept 25.

Disease Pressure: Early Blight (*Alternaria solani*) ratings were taken on July 3, Aug 8, Sept 4 and Sept 13. Ratings were done using an ordinal scale of 0-9, with 0 representing no visible disease and 9 representing plant death or near-death.

Tissue Analysis: Leaf samples were collected from the newest fully developed leaf of 20 plants per treatment on July 3rd and 8th. Samples were sent to Waters Agricultural Laboratories, Inc. in Owensboro, KY for full tissue analysis.

Weed Biomass: Weeds were collected from 4 random 1 square foot sections of row middles per treatment on July 3, Sept 13, and Oct 1. Weeds were cut or pulled out at ground level and weighed in grams of fresh weight. Rye was cut with a string trimmer on June 30 due to manage height. Herbicide plots were hand weeded once, in early August, to remove weed escapes.

Yield: Tomatoes were harvested as they matured from July 19 to Sept 25. All marketable fruit was counted and weighed in pounds.

Statistics: Statistical differences among treatments was determined by General Analysis of Variance (ANOVA) with mean separation an LSD test with $p \leq 0.05$.

Results

The impact of using rye instead of herbicides or cultivation was measured season long through plant growth, disease pressure, foliar nutrient levels, crop yield and labor input under the different weed management methods.

ONIONS

Plant growth: Height and number of leaves was recorded four times throughout the season (**Table 1**). Onions plots with rye middles were significantly the tallest on 3 out of 4 dates. Cultivation was consistently the shortest treatment. Rye treated plots had the fewest number of leaves.

Disease Pressure: The onions had minor infestations of Onion Thrips (*Thrips tabaci*) and Botrytis Leaf Blight (*Botrytis squamosa*). While there were no differences in leaf disease, there was a difference in pest pressure. On June 12, there were significantly less onion thrips in the herbicide plots than in the rye and cultivated plots, with the cultivated plots having the most thrips (***Table 1***).

Table 1. Onion Plant Growth and Pest Pressure.

ONION	**Plant Height (cm)**				**Number of Leaves**				**Pest Pressure.** Jun 12	
	May 22	*June 12*	*July 3*	*July 24*	*May 22*	*June 12*	*July 3*	*July 24*	*No. BLB Lesions/Leaf*	*No. Onion Thrips/Plant*
Rye	21.3 a	57.8	76.6 a	71.9 a	4.1	7.0 b	8.8 b	7.6 b	2.92	4.22 ab
Cultivation	19.3 b	56.4	71.1 b	68.2 b	4.3	7.6 a	9.0 b	8.4 a	2.92	5.07 a
Herbicide	20.5 ab	57.7	73.1 b	72.8 a	4.1	7.4 a	9.6 a	8.5 a	2.42	3.01 b
pValue	*0.0488*	*NS*	*0.0009*	*0.0108*	*NS*	*0.0071*	*0.0124*	*0.0032*	*NS*	*0.0342*

Yield and bulb size: Cultivation and Herbicide plots were significantly the highest yielding for marketable bulbs, with 84.26 and 83.5 pounds per 10 feet of bed, respectively (***Table 2***). These plots had twice as many colossal sized onions than the rye plots ***(Chart 1)***. There was little to no culls from bacterial rot in any plots.

Table 2. Onion Yield in Pounds per 10 feet of bed

ONION	Colossal	Jumbo	Medium	Small	Cull	Cull-Rot	Total Marketable
Rye	29.49 b	34.28 a	2.29 a	0.14	1.71	1.63	66.19 b
Cultivation	60.11 a	23.45 b	0.66 b	0.04	1.15	0.46	84.26 a
Herbicide	64.38 a	18.13 b	0.96 ab	0.04	0.61	0.00	83.50 a
pValue	*0.0008*	*0.0261*	*NS*	*NS*	*NS*	*NS*	*0.0001*

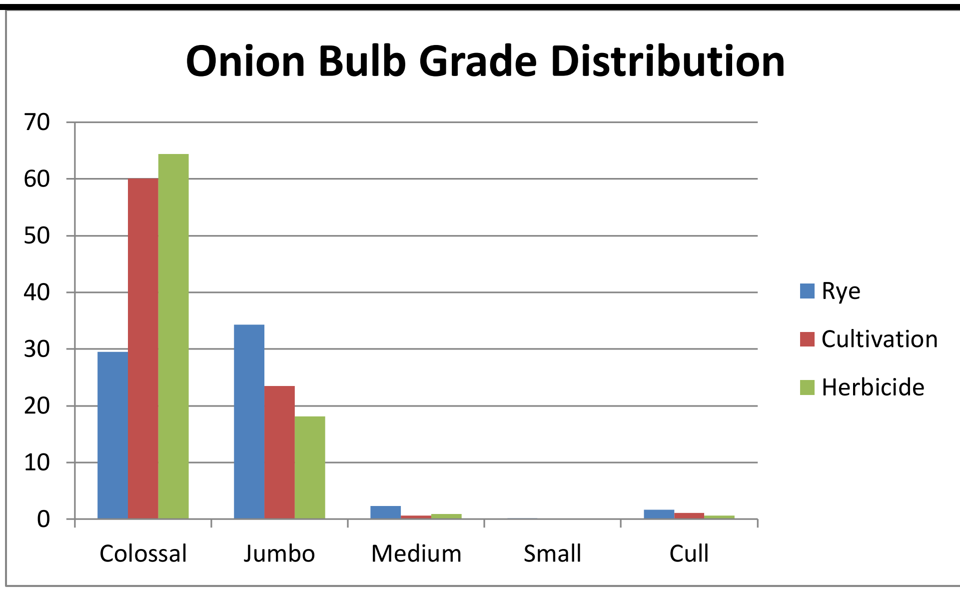

Chart 1. Size of onions as affected by treatment.

Weed Biomass: The rye plots had the lowest amount of weeds as measured by fresh weight (g). There were not statistical significant differences on any of the three collection dates. Cultivated and herbicide plots had similar same weed levels (***Table 3 and Figure 1***).

Table 3. Onions and Tomatoes: Weed Biomass taken from Row Middles in grams.

	Onions			Tomatoes		
	May 22	*June 12*	*July 3*	*July 3*	*Sept 13*	*Oct 1*
Rye	0.03	1.28	0.00	0.00	28.3	83.5
Cultivation	1.75	1.15	3.35	3.35	127.6	86.0
Herbicide	0.68	20.58	1.45	1.45	28.2	40.0
pValue	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*

Figure 1

Tissue Analysis: Foliar nutrient levels did differ between the treatments ***(Table 4).*** Nitrogen and Potassium were lower in rye treated plots on both sample dates than cultivated and herbicide treated.

Table 4. Onion foliar nutrient levels.

	Onions: July 3, 2012			***Onions: July 24, 2012***		
	Rye	**Cultivated**	**Herbicide**	**Rye**	**Cultivated**	**Herbicide**
Nitrogen	2.65%	3.21%	3.29%	2.64%	2.92%	2.75%
Phosphorus	0.47%	0.45%	0.35%	0.35%	0.25%	0.23%
Potassium	3.38%	3.96%	3.82%	3.35%	4.16%	4.09%
Magnesium	0.30%	0.23%	0.29%	0.42%	0.33%	0.33%
Calcium	1.79%	1.22%	1.82%	3.59%	3.30%	3.13%
Sulfur	0.73%	0.97%	0.89%	0.67%	0.85%	0.79%
Boron	27 ppm	27 ppm	25 ppm	31 ppm	33 ppm	32 ppm
Zinc	13 ppm	15 ppm	15 ppm	13 ppm	13 ppm	10 ppm
Manganese	54 ppm	69 ppm	71 ppm	75 ppm	109 ppm	118 ppm
Iron	81 ppm	101 ppm	116 ppm	117 ppm	146 ppm	144 ppm
Copper	6 ppm	6 ppm	6 ppm	15 ppm	7 ppm	6 ppm

KEY:

- *Deficient*
- *Low*
- *Sufficent*
- *High*
- *Excessive*

TOMATOES

Plant growth: Herbicide treated plots were significantly the tallest plants measured on July 17 and Sept 4 (***Table 5***) and not significantly different on the other two measurement dates.

Table 5. Tomato height, disease and yield data.

TOMATO	Plant Height (cm)				Disease Pressure *Early Blight Rating (0-9)*				Harvest Yield		
	July 17	*Aug 14*	*Sept 4*	*Sept 25*	*July 3*	*Aug 8*	*Sept 4*	*Sept 13*	*Mean Fruit per Plant*	*Mean Fruit Weight (lbs)*	*Yield (lbs/plant)*
Rye	94.3 b	74.6	71.5 b	69.7	0.0	0.0	3.9	6.3 b	38.7 b	0.62	23.97 b
Cultivation	103.6 a	76.3	71.4 b	65.3	0.0	0.0	4.9	5.9 b	49.2 a	0.62	30.37 a
Herbicide	105.0 a	81.0	79.3 a	69.5	0.0	0.0	2.8	7.1 a	48.9 a	0.67	32.55 a
pValue	*0.0009*	*NS*	*0.0177*	*NS*	*NS*	*NS*	*NS*	*0.0056*	*0.0354*	*NS*	*0.0018*

Disease and Insect Pressure: Tomato plots were visibly free of disease until early September when Early Blight (*Alternaria solani*) developed. On Sept 13 there were significant differences in disease ratings (Table 5). Herbicide plots had the most amount of disease with an ordinal rating of 7.1, followed by the rye and cultivation plots with 6.3 and 5.9, respectively. Although no qualitative data was collected on pest populations, the grower observed slug (Limax and Deroceras spp.) and armyworm (*Psuedaletia unipuncta*) feeding differences between the treatments. Approximate percentage of fruit grade as affected by pest damage from a single harvest was made on August 30. Culls were the highest in the rye blocks and lowest in the herbicide treatments (***Chart 2***).

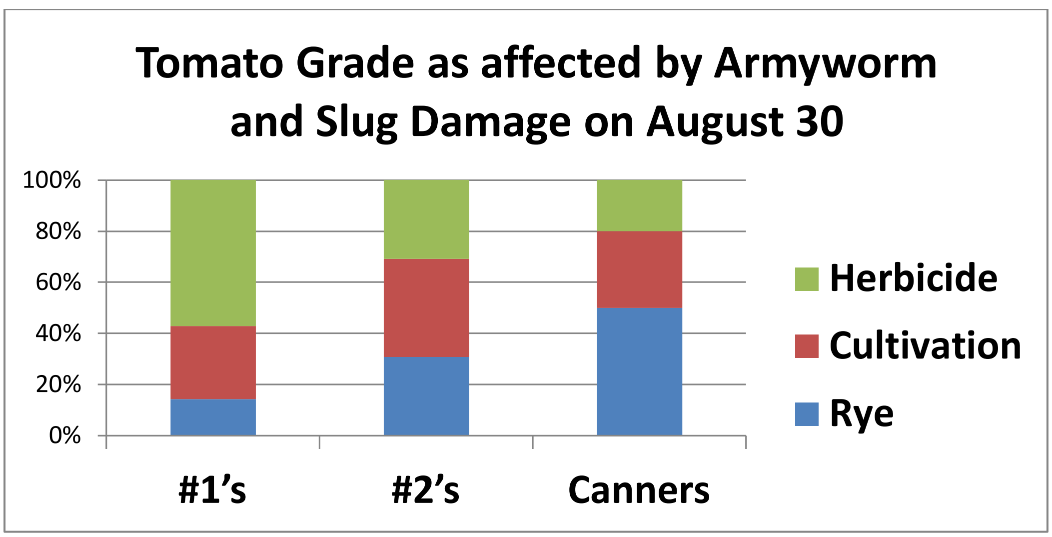

Chart 2. Pest Damage increase culls in rye treatments.

Tissue Analysis: Foliar samples were taken on three dates from each of the treatments (***Table 6***). Potassium was lower in the rye plots on all three dates and highest in the cultivated plots. Calcium was higher in the rye plots on all three dates. No other trends are apparent.

Table 6. Foliar nutrient levels of tomatoes over time.

	Tomatoes: July 3, 2012			*Tomatoes: August 8, 2012*			*Tomatoes: September 4, 2012*		
	Rye	**Cultivated**	**Herbicide**	**Rye**	**Cultivated**	**Herbicide**	**Rye**	**Cultivated**	**Herbicide**
Nitrogen	3.93%	4.41%	4.30%	3.44%	3.65%	3.68%	3.63%	4.04%	3.13%
Phosphorus	0.33%	0.47%	0.39%	0.28%	0.26%	0.24%	0.29%	0.31%	0.29%
Potassium	3.50%	4.54%	3.91%	1.99%	3.13%	2.84%	3.10%	4.09%	4.13%
Magnesium	0.58%	0.46%	0.48%	0.66%	0.48%	0.48%	0.73%	0.64%	0.58%
Calcium	4.01%	2.97%	3.46%	7.15%	5.36%	5.30%	6.23%	5.09%	5.27%
Sulfur	0.82%	0.85%	0.89%	1.43%	1.19%	0.98%	1.37%	1.00%	1.20%
Boron	36 ppm	35 ppm	41 ppm	52 ppm	47 ppm	40 ppm	62 ppm	53 ppm	57 ppm
Zinc	26 ppm	31 ppm	24 ppm	23 ppm	28 ppm	28 ppm	34 ppm	48 ppm	45 ppm
Manganese	47 ppm	55 ppm	41 ppm	61 ppm	61 ppm	62 ppm	80 ppm	89 ppm	85 ppm
Iron	173 ppm	169 ppm	145 ppm	97 ppm	78 ppm	88 ppm	137 ppm	141 ppm	158 ppm
Copper	14 ppm	23 ppm	25 ppm	9 ppm	10 ppm	10 ppm	13 ppm	27 ppm	18 ppm

Weed Biomass: Weed biomass was collected in grams fresh weight three times throughout the growing season (***Table 3***). Rye plot weed biomass was equal to or less than herbicide on the first two dates, with herbicide having the lowest weight late in the season. There were not statistical significant differences between treatments on any date.

Table 7. Onions and Tomatoes: Weed Biomass taken from Row Middles in grams

	Onions			**Tomatoes**		
	May 22	*June 12*	*July 3*	*July 3*	*Sept 13*	*Oct 1*
Rye	0.03	1.28	0.00	0.00	28.3	83.5
Cultivation	1.75	1.15	3.35	3.35	127.6	86.0
Herbicide	0.68	20.58	1.45	1.45	28.2	40.0
pValue	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*

Yield: Yield was calculated by mean fruit per plant, mean fruit weight (in pounds) and pounds fruit per plant. The herbicide plots were significantly the highest yielding with 32.55 pounds per plant, followed by cultivation plots with 30.37, both in the same statistical grouping (Table 5). Rye plots yielded 23.97 pounds per plant. Herbicide plots had the heaviest fruit, 0.67 pound each, while the mean fruit weights in the rye and cultivation plots were the same at 0.62 pounds per fruit; with no significant differences.

Cultivation plots had the highest number of fruit per plant with 49.2, followed by herbicide in the same statistical grouping, with 48.9. Rye plots had significantly less with 38.7 fruit per plant.

Results and discussion

Rye as an inter-row cover crop presented challenges in this project. The primary effect observed was loss of yield, as measured by fresh weight of product. In tomatoes we lost over 8.5 pounds of marketable fruit per plant, a value of nearly $13/plant, assuming an average price of $1.50/lb, compared to the herbicide treatment. In onions the loss was over 18 lbs per 10 linear feet of row when compared to cultivation, the highest yielding treatment. Calculating onion economics is difficult as there are price differentials related to grade (bulb size) and market. However, rye treated plots yielded less than half than number of colossal bulbs ($\geq$ 4" diameter) of herbicide and cultivation plots. The value of these bulbs is often $ 0.40 more than the next class, representing a loss of over $21 per 10 linear feet of bed.

What is causing this yield loss is not completely understood. Mid-summer rainfall at both farms was scarce, and thus water competition is a possibility. Nutrient competition is also possible, with nitrogen and potassium at times lower in the rye plots, although trends are not clear. Allelopathy from the rye has also been suggested, even though rye roots did not extend underneath the plastic mulch when examined. Pest pressure in the tomato crop did negatively affect yield as common armyworm and slug feeding lead to many unmarketable fruit. The armyworm infestation was a regional phenomenon at abnormally high levels in 2012.

Rye provided very good weed control at both farms. At our onion site it performed as well or better than herbicides and cultivation until harvest. At our tomato site late season weed pressure increased in the rye plots. There was an unexpected disease in the rye, leaf rust, caused by *Puccinia recondita tritici* ***(Figure 2)*** at both sites. Although this disease did not impact the vegetable crop it reduced rye stands. For the shorter season crop of onions this did not present a problem. With tomato harvest extending into October the diminished rye stand had diminished capacity to suppress Fall weed growth. Labor associated with managing rye vigor was minimal as both cooperators reported mowing 1 time mid-season.

Figure 2


Rust on rye

A inter-row cover crop of rye successfully reduced the environmental impact of vegetable farming in this study by reducing erosion and replacing herbicides. On the cooperating onion farm eliminating an application of pendamethalin reduces the field Environmental Impact Quotient (EIQ) by 33.9 points per acre. At our tomato farm the replacement of 4 herbicides (pendamethalin, halsulfuron, glyphosate, and metalochlor) resulted in an EIQ reduction of 90 points/acre. However, with the increased pest damage in the rye treated plots, some farms may have applied additional insecticides, reducing or eliminating environmental gains made by replacing herbicides. It should be noted that cultivation would also eliminate the EIQ of the herbicides, but with a higher labor input when compared to rye.

Conclusions

In this study, winter rye as an inter-row cover crop provided weed control comparable to cultivation and herbicides. However the yield loss, particularly as caused by pest feeding in tomatoes, prevents promotion of the system at this time. Given the unique pest population in 2012, these may be less in future seasons.

The mechanism in which rye reduced yield, particularly in onions, warrants further attention. Future work will examine other winter grains as inter-row cover crops and higher fertility/irrigation rates for the vegetable crop to eliminate potential competition.

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