

## **2011 Final Report (January 1, 2009 to March 31, 2011)**

### **Project Information**

**Title: Evaluation Low-residue Cover Crops to Reduce Nitrate Leaching, and Nitrogen and Phosphorous Losses from Winter Fallow Vegetable Production Fields in the Salinas Valley**

**CDFA Contract No. 08-0628**

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### **Statement of Objective**

This project evaluated practical cover crop strategies which allow growers maintain access to production fields in the spring and maintain their production schedules. Cover crop strategies evaluated included low-residue, furrow-bottom cover crops that can reduce sediment and nutrient loss during winter storms. Cover crops included the winter dormant triticale, 'Trios 102' and '888' as well as cereal rye varieties 'Merced' and 'AG104' which were killed with an herbicide before becoming a residue problem. The cover crops were compared with the standard winter fallow treatment. Runoff from the plots were measured and samples will be collected and evaluated for sediment and nutrient content. The nitrogen and phosphorus content of the cover crop were evaluated to determine the sequestration of these nutrients in the cover crop biomass. Nitrate leaching in the treatments were evaluated prior to and following storm events by evaluating nitrate content of the soil at one-foot increments down to 5 feet. The economics of the production of low-residue cover crops were evaluated. The results of these studies were demonstrated to growers via field days and written articles.

### **Abstract**

The Salinas Valley is an intensive vegetable production area which supplies over 90% of lettuce and other cool-season vegetables during the summer months. On average >2.0 crops/acre/year are produced. The intensity of the area is partially fueled by the high cost of production and there is little opportunity to include winter cover crop in the rotations because of the high opportunity cost of producing a non-cash crop or the

potential risk of having a winter cover crop disrupt planting schedules in the spring. As a result, only 5-7% of the acreage is cover cropped over the winter in spite of the well known benefits to soil tilth, and nitrogen sequestration and cycling. This project is evaluating the use of low-residue cover crops that are grown in the fall/winter for 55-60 days on peaked winter beds and then killed in order to provide some measure of ground cover to reduce nutrient and sediment loss. Results from the trial conducted in the winter of 2009-2010 demonstrated that the cover crops reduced the quantity of runoff and improved the quality of the water that did leave the field. The highest dry matter in the 2009-2010 trial was in cereal rye which peaked out at 0.83 tons/A. Cover crops were killed with glyphosate at 55 days after germination and continued to grow for approximately 2 weeks after being sprayed; after the peak of growth, the cover crop began to rapidly decompose and there was 0.4 tons of dry matter on March 10. This level of dry matter did not disrupt the subsequent soil preparation operations for broccoli which was planted in late March.

## **Introduction**

Complying with these water quality regulations is an especially difficult challenge for the Salinas Valley, because of the intensive rotations and the nearly, year-round production. Cool season vegetables are high value and fertilizer cost represent a small portion of the production budget (i.e. <5%, Smith et al 2009). As a result, given economics of these crops, there is little incentive to reduce fertilizer rates and there is a tendency for fertilizer rates to exceed the nutrient needs of the crop. In addition, there are other factors that lead to a buildup of nitrate in the soil of production fields: 1) slow adoption of the presidedress nitrate quick test to account for residual nitrate pools that are available in the soil; 2) high levels of nitrogen returned to the soil from previous crops; 3) high mineralization rates of the soil organic matter and previous crop residue. As a result of these factors, soil nitrate levels tend to peak in the fall, just before the beginning of the rainy season (Smith, Schulbach, and Jackson 1997). In addition, soil phosphorus levels are also high in Salinas Valley soils (i.e. mean values of 70 ppm); this is primarily due to little use of soil tests to guide phosphorus fertilization (Johnstone et al, 2005). Winter cover crops absorb excess soil nitrate and maintain it in the plant biomass, thereby reducing the potential for nitrate leaching. Winter cover crops are also an excellent practice for protecting the soil and reducing sediment and nutrient losses during storm events (Smith and Cahn, 2007). However, the use of winter cover crops is severely limited in the Salinas Valley for the following reasons: 1) high land rents discourage tying up ground with a non-cash crop; and 2) winter cover crops increase the risk of getting rained out of the fields in the spring and thereby potentially missing planting dates. Given the benefits that cover crops can provide in reducing nutrient loss from vegetable production fields and the impediments to their use, we are researching an alternative cover crop strategy which uses low-residue cover crops. These cover crops cover during the period of high intensity rainfall but are killed before they fully mature and impede subsequent early-spring soil preparation and planting operations.

## **Work Description**

#### Task 1: Field evaluations.

Trials were conducted in 2008-2009 and 2009-2010 with cooperating growers near Castroville and Salinas, respectively.

#### Task 2: Data Analysis and cost studies conducted.

Evaluations of cover crop dry matter, water runoff and nitrate leaching were collected and analyzed for both trials. All data collection and analysis will be completed by March 31, 2011.

#### Task 3: Outreach activities

Field visits to the plots were conducted in conjunction with the 2009, 2010 and 2011 Irrigation and Nutrient Management Field Day and Cover Crop and Water Quality Field Day. Newsletter articles for *Monterey County Crop Notes* will be published in the fall of 2010. A video was posted on YouTube that described the 2009-10 trial was posted and has been viewed by key Salinas Valley growers, staff at the Central Coast Regional Water Quality Control Board and allied members of the agricultural industry ([http://www.youtube.com/watch?v=k0oVVJ\\_BA7s](http://www.youtube.com/watch?v=k0oVVJ_BA7s)).

#### Task 4: Reports to CDFA-FREP:

The 2009 Interim and Annual reports and the 2010 Interim reports were submitted. This constitutes the final report and a final invoice will be submitted by May 31, 2011.

**2008-2009 Trial:** The winter 2008-2009 trial was conducted in a commercial vegetable production field with a cooperating grower west of Salinas on a site with 1-3% slopes. There were three replications of each treatment and each plot was eight 40-inch beds wide by 1,280 feet long (7.1 acres total). Soils at the site were Antioch sandy loams and Rincon clay loams at the top of the slope with Diablo clays towards the bottom half of the slope. Cereal rye 'AG104' and winter dormant triticale 'Trios 102' were seeded on November 18, lilled into the soil on November 19 and germinated by rain on November 26, 2008. The cover crop was managed to maintain biomass levels that would not disrupt soil preparation and seeding operations of the subsequent broccoli (scheduled for planting mid- March 2009). 'AG 104' grew more rapidly than Trios 102 and was sprayed with 2% glyphosate on January 20, 2009 (55 days after germination) and Trios 102 was sprayed with 2% glyphosate and 1 pt/A of Goal 2XL on February 4, 2009 (70 days after germination). The untreated control was sprayed with 1 pt/A of paraquat on January 20 to control weeds. Cover crop growth was measured by dry matter sampling on six dates; cover crop ground cover was measured by taking photos and estimating percent ground cover using an 80 point grid.

**2009-2010 Trial:** The winter 2009-2010 trial was conducted in a commercial vegetable production field with a cooperating grower east of Salinas on a site with 1% slopes.

There were three replications of each treatment and each plot was eight 40-inch beds wide by 1,100 feet long (6.1 acres total). Soils at the site were Elder and Placental sandy loams. Several days prior to seeding, granular ammonium phosphate was incorporated into the bed tops at a rate of 400 lbs/A of 15-15-15 (60 lbs/A each of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O). Cereal rye 'AG104' and winter dormant triticale '888' were seeded on November 13, lilled into the soil on the same day and germinated by 1" of irrigation water on November 24, 2008. The cover crop was managed to maintain biomass levels that would not disrupt soil preparation and seeding operations of the subsequent broccoli in the spring of 2010. All treatments were treated with 2% glyphosate on January 15, 2010 (52 days after germination). Cover crop growth was measured by dry matter sampling on seven dates; cover crop ground cover was measured by taking photos and estimating percent ground cover using an 80 point grid.

**Evaluations conducted both years:** Runoff from the plots was measured during rain events. Run-off from each plot was channeled through flumes at the base of the slope. The flumes were instrumented to measure the flow rate and total volume of runoff. An automatic sampler collected composite samples of runoff during storm events. Water samples were sent to the DANR Analytical laboratory at UC, Davis for nutrient and sediment analyses. To measure nitrate leaching, one suction lysimeters was installed at two feet deep in each plot. Leachate samples by applying 20-25 cbars of suction with a small vacuum pump and collecting the leachate following the rainfall event. Nitrate leaching was estimated from the concentration of nitrate in leachate samples and by estimating the amount of percolation during storm events from rainfall by calculating changes in soil moisture storage (using neutron probe readings), and evapotranspiration data.

## **Results, Discussion and Conclusion**

**2008-2009 Trial:** Rye 'AG104' initially grew faster than triticale 'Trios 102' and had significantly greater dry matter at 16 and 40 days after germination (Figure 1). 'AG 104' was sprayed with glyphosate at 55 days after germination, but dry matter continued to accumulate for 21 more days and peaked at 0.48 tons/A at 76 days after germination. 'Trios 102' was sprayed with glyphosate at 70 days after germination and its dry matter peaked at 0.34 tons/A at 87 days after germination. After reaching their peak of dry matter, the dry matter levels of both varieties declined. Nitrogen accumulation roughly followed the same pattern as the dry matter accumulation. Both cover crop varieties contained 30 lbs N/A in the tops at 76 days after germination (Figure 2). 'AG 104' maintained higher levels of nitrogen in its dry matter than 'Trios 102' at 87 days after germination, but nitrogen levels in both cover crops declined at 112 days after germination. Percent ground cover followed the same pattern as dry matter accumulation. Both cover crops had about 90% ground cover at 76 days after germination. Percent ground cover of both cover crops declined at 87 days after germination

Run-off events occurred during February and the beginning of March 2009, when a majority of the rainfall occurred (Figure 4). Run-off was measured most frequently in

the fallow plots. Only one run-off event occurred in the 'AG104' treatment, and no run-off occurred in 'Trios 102' (Table 1). Average storm run-off volumes were highest in the bare fallow treatment. Average suspended sediment, total nitrogen, orthophosphate, and total phosphate concentrations in run-off collected from the fallow treatment between March 3 and 4 exceeded regional water quality standards for agricultural run-off (Table 2). Nitrate-N levels in leachate collected from the 'AG 104' and fallow treatments ranged from 130 to 234 mg/L between February 12 and March 5, 2009. Estimated leaching losses of nitrate-nitrogen were 132 and 155 lb of N/acre for the 'AG 104' and fallow plots, respectively.

**2009-2010 Trial:** The winter of 2009-10 was characterized by two intensive periods of rainfall in mid-January and late-February (Figure 5). As a result, we were able to successfully measure differences in the quantity of runoff from the cover cropped and bare treatments. 47.2% of rainfall ran off of the bare plots while 2.3 and 9.2% ran off of the rye and triticale plots respectively (Figure 6). Low residue cover crops reduced sediment loss (Table 4). The difference in levels of runoff between the cover crops was due to their biomass production and planting configuration. Rye was planted on the entire beds and triticale was planted only in the furrow. Rye 'AG104' grew faster than triticale '888' and had significantly greater dry matter throughout the evaluation (Figure 7). Both cover crops were sprayed with glyphosate at 52 days after germination, but dry matter continued to accumulate biomass and peaked at 0.83 tons/A at 65 days after germination. After reaching their peak of dry matter, the dry matter levels of both varieties declined as the cover crops began to decompose. Nitrogen accumulation roughly followed the same pattern as the dry matter accumulation. Rye 'AG104' accumulated 72 lbs N/A in the tops at 65 days after germination and triticale '888' accumulated 22 lbs N/A in the tops at 51 days after germination (Figure 8).

Nitrate-nitrogen concentrations in leachate were measured on 11 dates; concentrations of nitrate in the leachate were significantly lower in both cover crop treatments than the bare on five dates (Table 5 & Figure 9). However, the cover crop treatments greatly increased water infiltration into the soil and a higher load of nitrate was leached from the cover crop treatments was measured on one sampling date (Table 6).

Clearly, the impact of low residue cover crops has two counter balancing impacts on residual soil nitrate during the winter: they absorb nitrate from the soil and sequester it in their plant biomass, but facilitate greater water infiltration which can leach soil nitrate. In addition, after they are killed to manage cover crop biomass levels and the cover crop decomposes, is the nitrogen contained therein also subject to mineralization and subsequent leaching? We measured an increase in microbial biomass in the cover crop treatments (Table 6), which may indicate that some of the nitrogen contained in the plant biomass may be sequestered in the active fraction of soil organic matter. Deep soil samples at the beginning and end of the season indicated less nitrate in the 2-3 foot depth in the rye cover crop treatment at the end of the trial in March, 2010 (figure 10). On the whole, it appears that in situations where there are high levels of available soil nitrate, low residue cover crops will only be able to sequester a small proportion of the

nitrate. Under more moderate levels of fall soil nitrate, they can probably sequester a larger proportion.

Low residue cover crops increase water infiltration and this can have a beneficial impact on leaching accumulated salts during winter storm events. We observed more leaching of magnesium, sodium and chloride in the low residue cover crop plots (Tables 7&8), and although not statistically significant, there was a trend indicating lower EC levels at all three soil depths in the rye cover crop treatment at the end of the trial.

We followed the preparation of the field for planting broccoli. The cover crop residue did not cause a disruption of soil preparation operations (lillistoning and bed shaping – see youtube video: [http://www.youtube.com/watch?v=k0oVVJ\\_BA7s](http://www.youtube.com/watch?v=k0oVVJ_BA7s)). Initial stand counts indicated a significantly lower number of plants per acre in the cover crop treatments (Table 9). However, by harvest there was no statistical difference among the treatments. There was a great deal of variability in the stand and yield data. The grower attributed the stand issues to trouble that they had with planting the broccoli due to rain and it may have affected the effectiveness of the planter. At this point, it is unclear if lower stand in the cover crop plots was due to issues with the planter or due to treatment effects.

The cash costs of low residue cover crops were estimated to be \$101/A for the triticale and \$104/A for the rye (Table 10). These costs were \$84 and \$87 more than the bare fallow which included only one lilliston operation to maintain weed control on the beds.

In conclusion, low residue cover crops have a great impact on reducing sediment loss from winter fallow vegetable production fields during intense storm events. There were higher levels of nitrate in lysimeter samples of the cover crop treatments in the 2009-2010 trial. Low residue cover crops, by increasing water infiltration into the soil, increase the potential for nitrate loss. Therefore, they appear to only be able to sequester moderate amounts of nitrogen in the plant biomass and may only reduce nitrate leaching at sites with moderate amounts of residual soil nitrate in the soil at the onset of the winter fallow period. If allowed to accumulate up to 0.6-0.7 ton/A of dry biomass, low residue cover crops were able to capture moderate amounts of nitrate from the soil and thereby reducing the loss of this nitrogen from due to leaching. However, when the cover crops are treated with glyphosate, they begin to decline in nitrogen content and it is possible that some of the cover crop nitrogen could be lost as nitrate. Low residue cover crops did not impede soil preparation operations in either yield of these trials.

## **Project Evaluation**

Low residue cover crops clearly have dramatic impacts on winter fallow beds by increasing water infiltration, reducing sediment loss and increasing leaching of salts from winter fallow vegetable production fields. Low residue cover crops accumulate only moderate amounts of nitrogen in the biomass before they are killed to keep them from producing too much biomass that would impede preparation of the soil for subsequent crops. After the cover crops are killed they begin to leak the nitrogen contained in the

biomass. Low residue cover crops increased the microbial biomass of the soil and it is possible that some of the leaked nitrogen may be incorporated into the microbial biomass and not leached. The increased infiltration of water due to the cover crops is beneficial for recharging groundwater resources, but also increases leaching losses if high levels of nitrate are available in the soil. As a result, we observed greater nitrate leaching in the cover crop treatments. As a result, it can be concluded that low residue cover crops can absorb only low to moderate amounts of nitrate from the soil and maintain it in the cover crop biomass. In situations with high levels of soil nitrate, low residue cover crops will not be able to reduce nitrate leaching to a significant degree. The cover crops cost an additional \$80-90/A more than it costs to maintain standard winter fallow beds and this additional cost may be justified by greater water infiltration, leaching of salts and cycling of moderate amounts of nitrogen in the soil.

### **Outreach Activities Summary**

The following outreach activities were conducted during the first half of 2010:

#### ***Presentations and Field Days***

- February 24, 2009 Field Day – demonstrated low-residue cover crop research plots to growers, and RCD and NRCS representatives to discuss the benefits and challenges of low-residue cover crops (see attached). 35 attendees. Richard Smith and Michael Cahn.
- November 17, 2009 Presentation entitled “Impact of low-residue cover crops on sediment and nutrient loss” at FREP Conference in Visalia. 140 attendees. Richard Smith. Posted on website at: <http://cemonterey.ucdavis.edu/files/74503.pdf>.
- January 14, 2009. Presentation entitled “Irrigation and fertigation of vegetables and strawberries” at the Canadian Agronomy Association Meeting, Cambridge, Canada. 200 Attendees. Michael Cahn.
- April 14, 2009. Presentation entitled “Use of vegetation and PAM for water quality improvement” at the Scientific Panel for Agricultural Discharge Waiver in Soledad, CA. 40 attendees. Michael Cahn.
- February 23, 2010 Field Day – demonstrated low-residue cover crop research plots to growers, and RCD and NRCS representatives to discuss the benefits and challenges of low-residue cover crops (see attached). 35 attendees. Richard Smith and Michael Cahn.
- December 9, 2010. Showed low residue cover crop video at the Ventura County Vegetable Production meeting. Ventura, CA 28 attendees. Richard Smith.
- January 7, 2011. Showed low residue cover crop video at the Dune Company meeting as part of a discussion on nutrient management in lettuce. San Diego, CA 30 attendees. Richard Smith.

- February 11, 2011. Discussed low residue cover crops in the presentation entitled, “Improving nitrogen use efficiency in lettuce production” given at the Plant and Soil Conference. Fresno, CA 90 attendees. Richard Smith.
- February 23, 2011 2011 Irrigation and Nutrient Management Meeting and Cover Crop and Water Quality Field Day – showed the low residue cover crops at the meeting and discussed low residue cover crops at the field day portion of the meeting. The meeting was attended by a mix of growers, fertilizer company representatives, RCD and NRCS representatives (see attached). 101 attendees. Richard Smith and Michael Cahn.

### **Publications**

- Smith, R.F., M. Cahn, A. Heinrich and B. Farrara. 2010. Low residue cover crops minimize runoff, erosion, and nutrient loss from fallow vegetable fields. *Monterey County Crop Notes*, August/September.
- Smith, R.F., M. Cahn, A. Heinrich and B. Farrara. 2010. Low residue cover crops minimize runoff, erosion, and nutrient loss from fallow vegetable fields. *Vegetables West*, Nov-Dec, p 8-11.
- Smith, R.F. 2010. Fine tuning nitrogen management for vegetable production. *Monterey County Crop Notes*, March/April.
- Smith, R.F. and M. Cahn. 2009. 2009 Low-Residue Winter Cover Crops Impact on Sediment and Nutrient Loss. Posted at: [http://cemonterey.ucdavis.edu/Vegetable\\_Crops/Cultural\\_Practice\\_Reports.htm](http://cemonterey.ucdavis.edu/Vegetable_Crops/Cultural_Practice_Reports.htm)
- Smith, R.F. and M. Cahn. 2009. Impact of low-residue winter cover crops on sediment and nutrient loss. 17<sup>th</sup> annual CDFA Fertilizer Research and Education Program Conference Proceedings. Visalia, CA. Pages 29-33.

### **Video**

- Low residue cover crops for the Salinas Valley  
[http://www.youtube.com/watch?v=k0oVVJ\\_BA7s](http://www.youtube.com/watch?v=k0oVVJ_BA7s)

### **Literature Cited**

- Johnstone, P.R., T.K. Hartz, M.D. Cahn and M.R. Johnstone. 2005. Lettuce response to phosphorus fertilization in high phosphorus soils. *HortScience* 40(5):1499-1503.
- Smith, R.F, K. Schulbach and L. Jackson. 1997. Development and promotion of nitrogen quick tests for determining nitrogen fertilizer needs of vegetables. Proceedings of the Fertilizer Research and Education Program Conference, pages 51-52.
- Smith, R.F. and M. Cahn. 2007. Winter cover crops: strategies for including them in Salinas Valley vegetable rotations. *Monterey County Crop Notes*. September – October.
- Smith R.F., K.M. Klonsky and R.L. DeMoura. 2009. Sample costs to produce iceberg lettuce. University of California Special Publication, LT-CC-09-2.  
<http://coststudies.ucdavis.edu/files/lettuceicecc09.pdf>.





## 2008-2009 Figures and Tables

Figure 1. Dry matter production (ton dry matter/acre) by cover crops on various dates following germination. Error bars represent standard error. Asterisks indicate statistical differences between means (LSD;  $P < 0.05$ ).

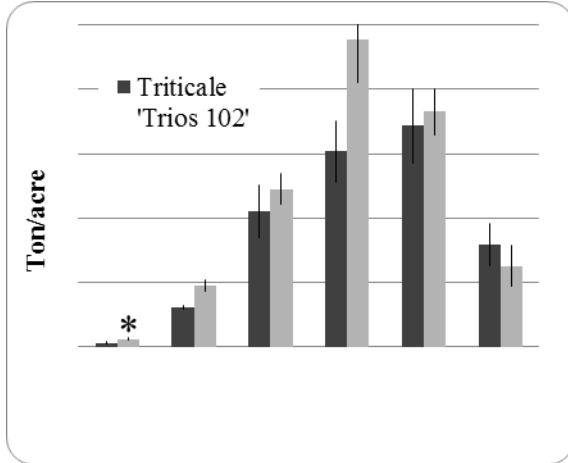


Figure 2. Nitrogen (lb N/acre) in cover crop biomass on various dates following germination. Error bars represent standard error. Asterisks indicate statistical differences between means (LSD;  $P < 0.05$ ).

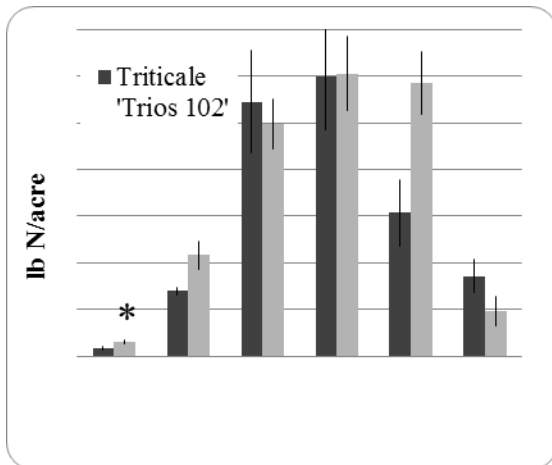


Figure 3. Percent ground cover of cover crops on various dates following germination. Error bars represent standard error. Asterisks indicate statistical differences between means (LSD;  $P < 0.05$ ).

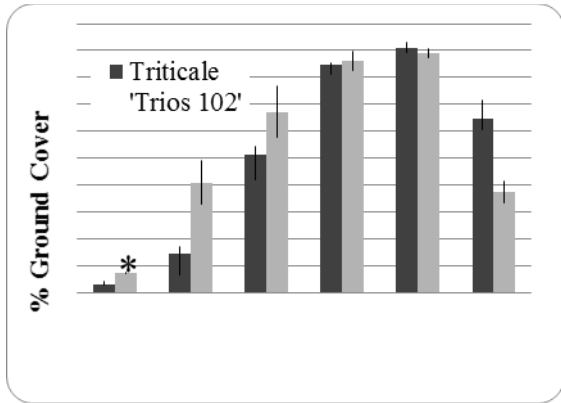


Figure 4. Cumulative and daily rainfall at trial site.

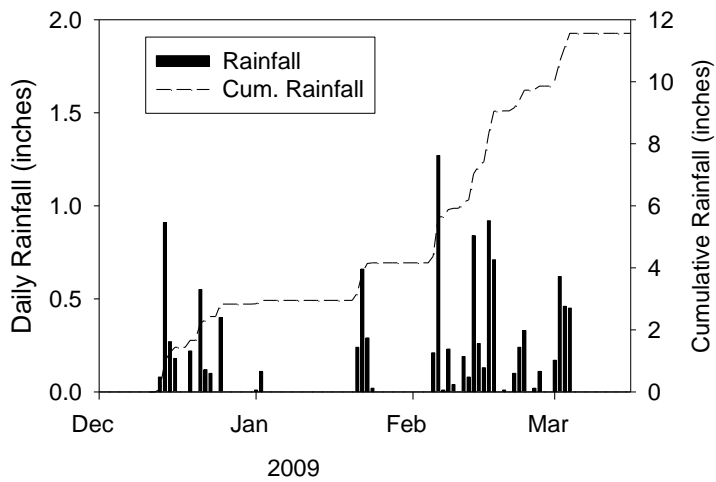


Table 1. Average storm run-off volumes for cover crop treatments

Cover crop treatment	Average run-off volumes during storm events					total
	2/16/2009	2/17/2009	2/27/2009	3/3/2009	3/4/2009	
	----- gallons per plot -----					
Rye	0	0	0	0	1082	1082
Trios	0	0	0	0	0	0
Bare fallow	234	335	263	767	1480	3079

Table 2. Average nutrient and sediment concentrations in storm run-off sampled from fallow plots on March 3-4, 2009.

Constituent	Value	Unit
Total Nitrogen	15.5	mg/L
Ammonium-N	0.1	mg/L
Nitrate-N	0.3	mg/L
Orthophosphate	0.7	mg/L
Total Phosphate	4.7	mg/L
Potassium	1.5	mg/L
Sulfate-S	0.5	mg/L
TDS	160	mg/L
Total Suspended Solids	7023	mg/L
Turbidity	3767	NTU
pH	7.8	
EC	0.1	dS/m

Table 3. Estimated leaching losses of nitrate-nitrogen in individual bare-fallow and rye cover cropped plots between 2/12/09 – 3/5/09. Note that the rye cover crop was killed with glyphosate, sprayed on January 20, 2009.

Cover Crop Treatment	Evapo- transpiration	Rainfall	Soil	Avg nitrate-N concentration of leachate	Nitrogen Loss	
			Moisture Storage			Percolation
		inches		mg/L	lb N/acre	
Fallow	1.6	5.45	0.2	3.7	188	155
Rye	1.6	5.45	0.1	3.8	155	132

**2009-2010 Tables and Figures**

Figure 5. Rainfall during the winter of 2009 to 2010

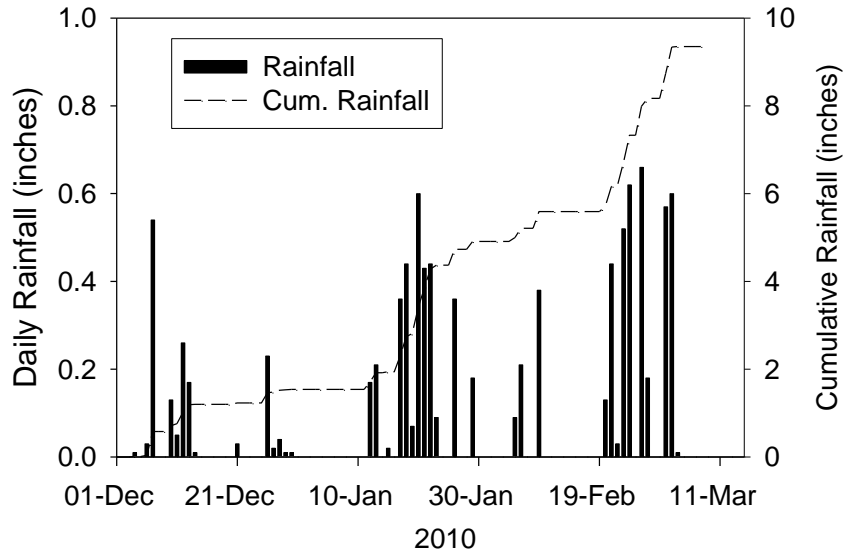


Figure 6. Total runoff in the three cover crop treatments

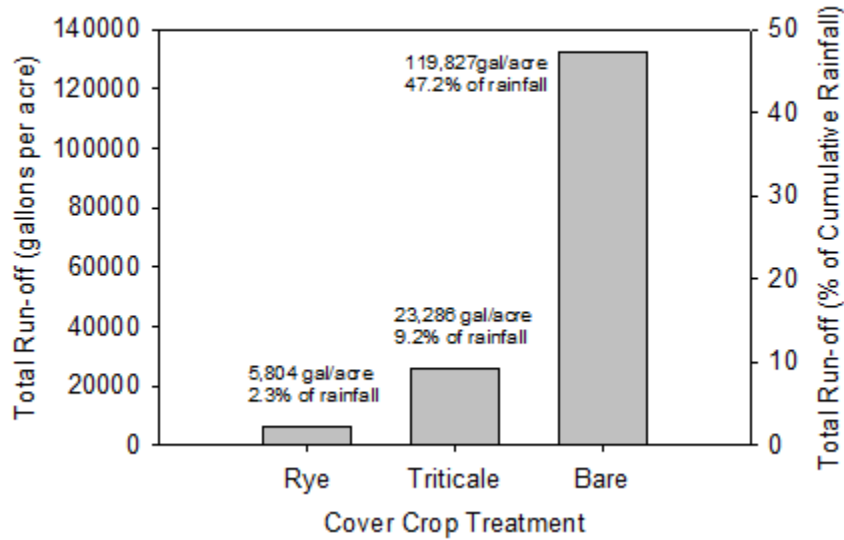


Figure 7. Biomass of cover crop over production cycle

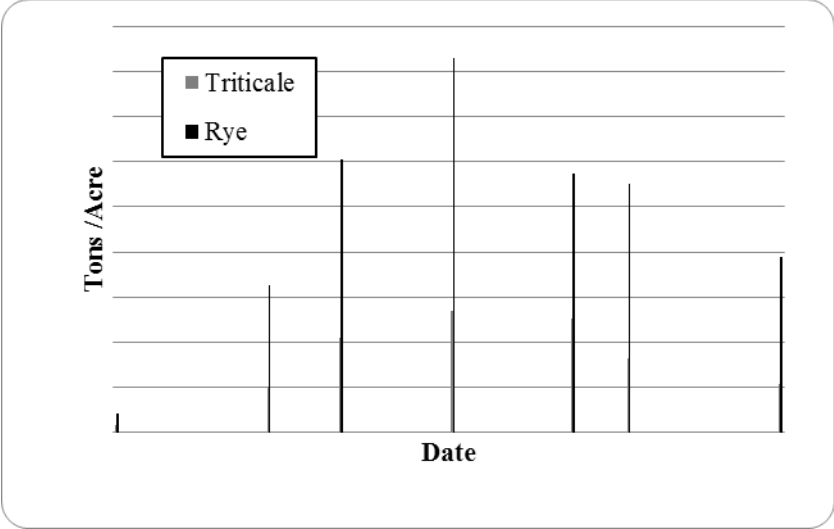


Figure 8. Nitrogen content of cover crop biomass over production cycle

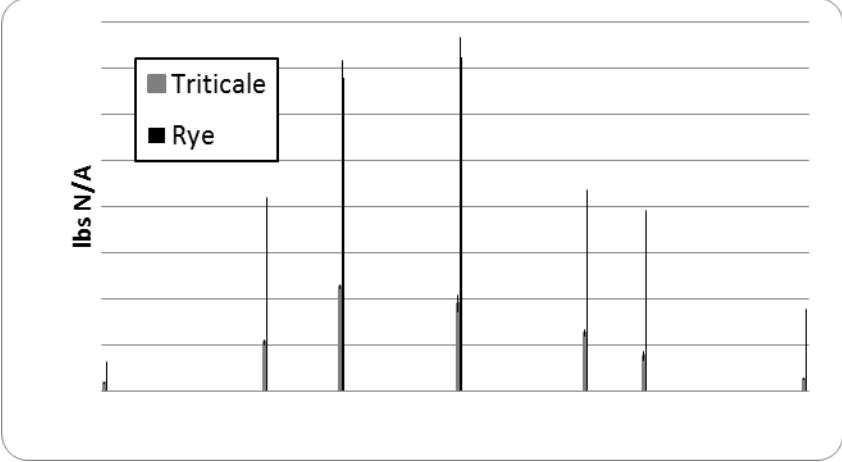


Figure 9. Nitrate concentrations in lysimeter extracts. Error bars represent the SE n=9.

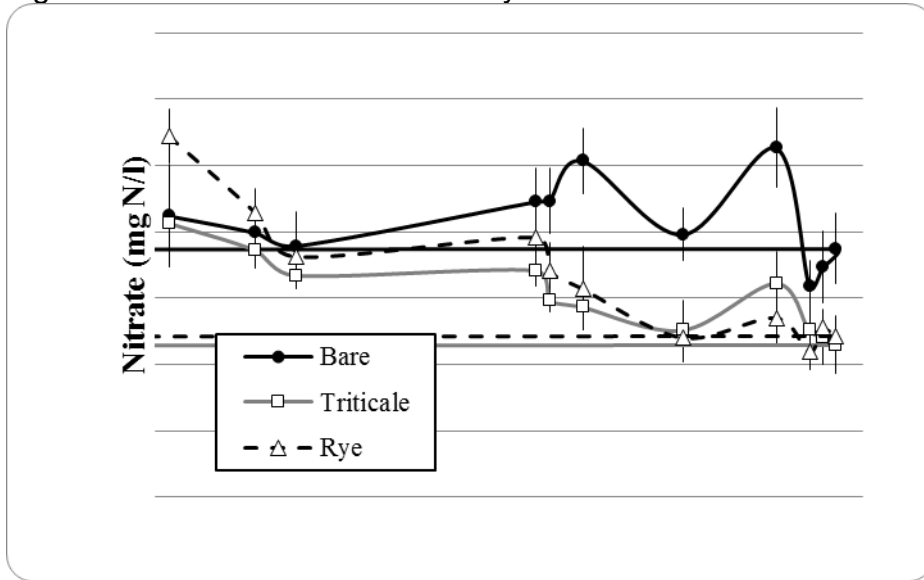


Figure 10. Soil nitrate and ammonium concentrations. Upper graph: 0-1 ft and lower graph: 1-2 ft. Error bars represent the SE n=6.

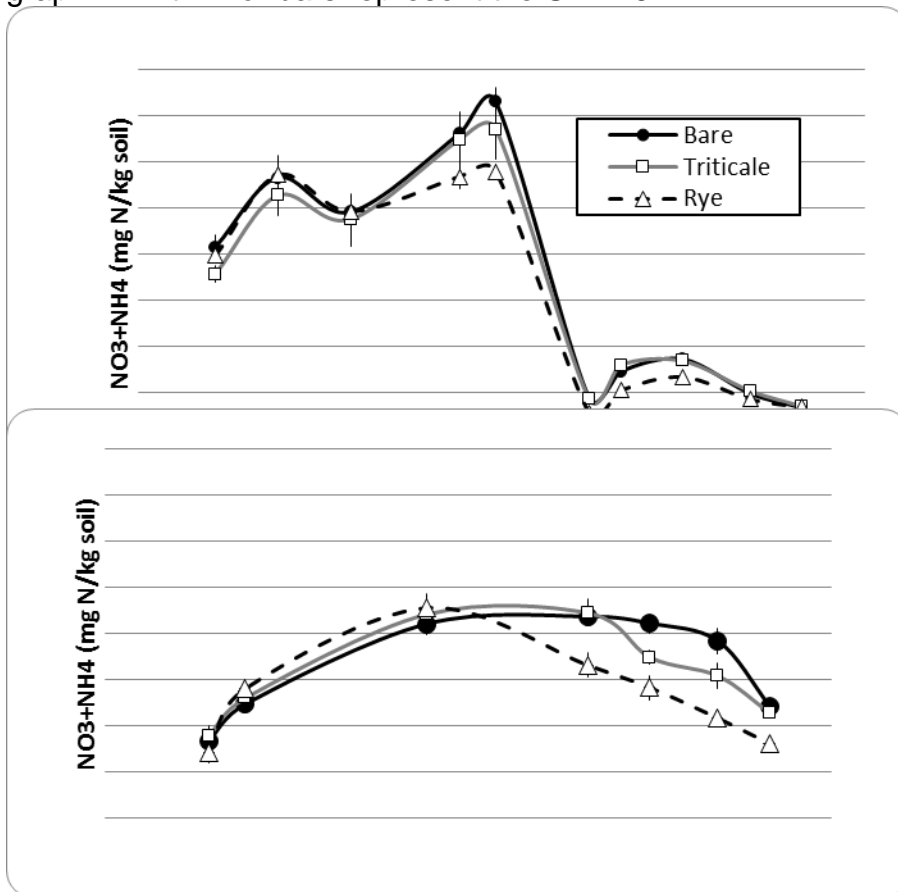


Figure 11. Nitrate and ammonium concentrations in the soil profile. Upper graph: November 23, 2009 prior to cover crop germination and lower graph: March 8, 2010 prior to tillage operations. Error bars represent the SE n=6.

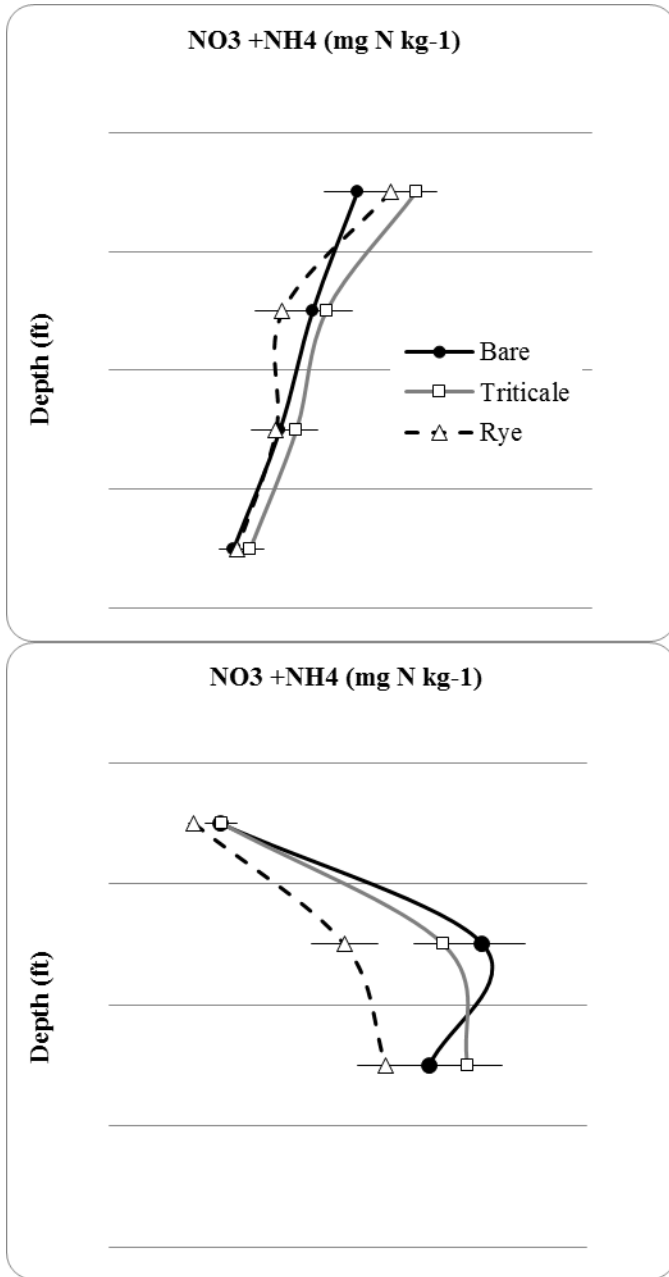




Table 4. Estimated sediment loss for cover crop treatments

Cover Crop Treatment	Suspended sediment concentration (ppm)		
	1000	2000	3000
	----- sediment loss (lb/acre) -----		
Bare-Control	376	753	1129
Rye-Full	9	19	28
Triticale-Furrow bottom:	66	131	197

Table 5. Nitrate concentration in lysimeter samples (mg nitrate-N/L). n=9

Treatment	Nov 25	Dec 08	Dec 14	Jan 19	Jan 21	Jan 26	Feb 10	Feb 24	Mar 01	Mar 03	Mar 05
Bare	162	149	139	173	173	203	148	213	109	124	137
Triticale	157	136	117	121	99	93	76	111	76	71	65
Rye	222	165	132	146	121	107	70	85	59	78	72
Pr>F treat	0.119	0.540	0.734	0.160	0.007	0.009	0.019	0.003	0.148	0.179	0.050
Pr>F block	0.012	0.090	0.533	0.171	0.002	0.077	0.177	0.288	0.391	0.845	0.821
LSD 0.05	NS	NS	NS	NS	45	9	58	72	NS	NS	64

Table 6. Estimates of nitrate leaching (lbs N/A), inches water percolated through soil, percent rainfall that percolated through soil, microbial respiration and net mineralization of N in each treatment.

Treatments	Dec 8	Dec 14	Jan 26	Feb 10	Mar 1	Mar 5	Total	Water percolated through soil (in)	% of rainfall drained past 2'	Microbial Respiration mg CO <sub>2</sub> -C/kg/hr	Net N mineralization mg N/kg soil
Bare	15.1	7.8	18.8	7.5	15.3	3.9	68.5	2.36	24.08	0.36	15.9
Triticale	17.8	3.6	33.8	5.4	36.6	13.0	110.2	5.22	53.19	0.48	22.4
Rye	15.8	4.6	37.4	7.4	30.7	15.7	111.5	5.30	53.94	0.49	20.3
Pr>F treat	0.861	0.411	0.248	0.695	0.245	0.008	0.252	0.015		0.033	0.043
Pr>F block	0.690	0.904	0.407	0.354	0.827	0.184	0.762	0.662		0.859	0.721
LSD 0.05	NS	NS	NS	NS	NS	5.4	NS	1.7		0.11	5.0

Table 7. Soil analysis of three soil depths at end of trial – March 5, 2010.

0 – 1 foot

Treatment	pH	EC dS/m	Ca meq/l	Mg meq/l	Na meq/l	Cl meq/l	X-K ppm	X-K meq/100g	X-Na ppm	X-Na meq/100g	X-Ca meq/100g	X-Mg meq/100g
Bare	7.4	0.69	2.15	1.13	1.94	0.67	306.33	0.79	38.83	0.17	6.36	1.44
Triticale	7.4	0.66	2.06	1.06	1.86	0.65	332.00	0.85	38.33	0.17	6.46	1.42
Rye	7.5	0.58	1.81	0.95	1.60	0.54	317.83	0.81	34.67	0.15	6.41	1.43
Pr>F treat	0.258	0.342	0.420	0.454	0.144	0.439	0.708	0.712	0.217	0.193	0.845	0.887
Pr>F block	0.465	0.859	0.988	0.959	0.898	0.619	0.510	0.520	0.220	0.208	0.169	0.021
LSD 0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1 – 2 foot												
Treatment	pH	EC dS/m	Ca meq/l	Mg meq/l	Na meq/l	Cl meq/l	X-K ppm	X-K meq/100g	X-Na ppm	X-Na meq/100g	X-Ca meq/100g	X-Mg meq/100g
Bare	7.2	1.80	7.53	3.34	4.66	4.15	143.17	0.37	70.50	0.31	6.03	1.37
Triticale	7.3	1.57	6.24	2.70	4.54	3.37	150.83	0.38	69.00	0.30	6.12	1.31
Rye	7.3	1.34	5.07	2.26	4.02	2.78	151.33	0.39	65.33	0.29	5.94	1.33
Pr>F treat	0.116	0.103	0.066	0.050	0.345	0.151	0.893	0.924	0.568	0.581	0.766	0.253
Pr>F block	0.232	0.284	0.347	0.246	0.262	0.144	0.879	0.878	0.256	0.268	0.528	0.101
LSD 0.05	NS	NS	2.05	0.854	NS	NS	NS	NS	NS	NS	NS	NS
2 – 3 foot												
Treatment	pH	EC dS/m	Ca meq/l	Mg meq/l	Na meq/l	Cl meq/l						
Bare	7.1	1.77	7.36	2.79	4.91	5.34						
Triticale	7.1	1.95	8.35	3.06	5.40	5.60						
Rye	7.1	1.56	6.43	2.43	4.49	4.20						
Pr>F treat	0.841	0.328	0.330	0.406	0.297	0.197						
Pr>F block	0.513	0.702	0.666	0.650	0.714	0.785						
LSD 0.05	NS	NS	NS	NS	NS	NS						

Table 8. 2009-2010. Estimate of cations and anions leached

Treatment	Nutrient leached (lbs/A)					
	K	Ca	Mg	Na	Cl	SO4-S
Bare	9	133	32	88	158	36
Triticale	18	216	55	178	275	60
Rye	16	226	63	191	289	69
Pr>F treat	0.260	0.179	0.074	0.008	0.062	0.120
Pr>F block	0.258	0.998	0.991	0.589	0.519	0.812
LSD 0.05	NS	NS	27	50	115	NS

Table 9. Broccoli stand count May 7, and yield evaluations on July 16

Treatment	Stand Count plants/A	First cut heads/A	Second cut heads/A	Second cut tons/A	Total heads/A
Bare	53,556	18,000.0	19,681.2	4.8	37,681.2
Triticale	44,203	22,956.5	95,36.2	2.4	32,492.8
Rye	39,385	19,855.1	10,898.6	2.8	30,753.6
Pr>F treat	<0.001	0.393	0.103	0.116	0.506
Pr>F block	0.487	0.864	0.565	0.595	0.596
LSD 0.05	4130	NS	NS	NS	NS

Table 10. Low residue cover crop costs (costs do not include costs to plant and overhead).

Treatment	Seed costs <sup>1</sup>	Cultivation for weed control <sup>2</sup>	Glyphosate @ 1 gallon/A	Glyphosate application \$/A	Total Cost/A
Bare	0.0	17.0	0.0	0.0	17.0
Triticale '888'	41.0	0.0	40.0	20.0	101.0
Rye 'AG104'	44.1	0.0	40.0	20.0	104.1

1 – Triticale seed @ 100 lbs/A seeding rate and \$0.41/lb seed planted on 50% of the bed; Rye @ 90 lbs/A seeding rate and \$0.49/lb seed planted on 100% of the bed.

2 – cultivation would be a standard practice for bare fallow, but not for low residue cover crops (from Tourte and Smith, 2010, Sample production costs for wrapped iceberg lettuce, [http://coststudies.ucdavis.edu/files/2010Lettuce\\_Wrap\\_CC.pdf](http://coststudies.ucdavis.edu/files/2010Lettuce_Wrap_CC.pdf))