Nitrogen release and decomposition by cover crops in organic no-till systems

by

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INTRODUCTION

Cover crops provide environmental and economic benefits to agricultural systems-reducing soil erosion, increasing soil organic matter, managing soil moisture, controlling weeds, increasing biodiversity, cycling nutrients, and increasing water infiltration (Dabney et al., 2001; USDA, 2010). Cover crops increase nitrogen availability to cash crops through nutrient scavenging and reducing leaching of nitrate (Paustian et al., 1992; McCracken et al., 1994; Sainju et al., 1998; O'Reilly et al., 2012). Leguminous cover crops fix nitrogen, further increasing soil nutrients supplied to cash crops. Providing increased organic matter in low productivity and disturbed soils can result in increased yields (Hargreaves, 2008). Hill et al. (2016) noted that soil characteristics, cover crop characteristics, environment, and management influence soil inorganic nitrogen release. This delicate balance of environmental variables, management practices, and crop characteristics (both cover and cash crop) determine the effects of cover crops on nitrogen cycling, particularly in organic and reduced-till systems.

A grower's selection of cover crop variety is dependent on many factors including the purpose of growing the cover crop, economics, cover crop biology and physiology, environment and season, and cultural practices (Snapp et al., 2005). Some growers may grow a cover crop for its ability to fix nitrogen, while others may choose cover crops to prevent erosion and withstand harsh winters. While grass cover crops reduce nitrate leaching, leguminous crops are chosen for their ability to fix nitrogen (Smith et al., 1987; Meisinger et al., 1991; Ruffo and Bollero, 2003). Cover crops range from leguminous clovers (*Trifolium* L.), field peas (*Pisum sativum* L.), and vetches (*Vicia* L.), to grasses such as cereal rye *(Secale cereal* L.), ryegrass *(Lolium perenne* L.), and spring oats *(Avena* L.). Hairy vetch (*Vicia villosa* R.) is a widely adapted leguminous cover crop that provides high yields (Curran et al., 2006). Hairy vetch easily germinates in cool weather (35 to 40 days before killing frost), making it a good fall cover cropping choice for growers. Additionally, leguminous cover crops, such as hairy vetch, accumulate nitrogen longer than non-leguminous cover crop species (Dabney et al., 2001). Leguminous cover crops also require a longer growth period than non-leguminous cover crops prior to termination to maximize nutrient release (Dabney et al., 2001). Non-leguminous rye as a cover crop can produce double the biomass without using additional nitrogen (Vaughan and Evanylo, 1998; Dabney et al., 2001). Rye effectively suppresses weed growth for up to six-weeks after termination and, therefore, reduces the need for herbicide applications, a key asset in no-till organic systems (Putnam et al, 1983; Dabney et al., 2001). Also, rye is easy to establish, cold hardy, and one of the earliest temperate region cover crops to flower (Dabney et al., 2001). Studies have shown that rye has a greater potential to scavenge residual soil nitrate than legumes, partially due to its quick developing root systems (Meisinger et al., 1991; Wagger et al., 1998; Dabney et al., 2001). A study conducted by Ruffo and Bollero (2003) showed that hairy vetch was nearly completely decomposed at the end of the growing season, while rye had about 5% residue remaining. The expedited decomposition of vetch may aid soil temperatures while the ability of rye to decompose more slowly may suppress weeds. Decomposition, nitrogen availability or scavenging, crop variety root development, biomass, and weed suppression are all factors that influence a grower's choice of cover crop.

Decomposition rates of cover crops and subsequent nutrient availability is influenced by microbial activity. Previous studies indicate that no-till does not increase soil organic matter or moisture in the surface layer (Granatstein et al., 1987; Carter, 1992; Jackson, 2004). The rate of decomposition of cover crops and subsequent release of biomass nutrients, however, is reliant on microbial activity. Microbial activity is influenced by moisture: occurring more rapidly with more moisture and at a slower, constant rate with less moisture (Wagger, 1989). Long-term studies of cover crops with low C:N (i.e., <20:1), indicate a sustained increase in microbial biomass C versus non-cover cropped soils (Sainju et al., 2002). In no-till systems, residual surface residue leads to lower net N-mineralization and nitrate accumulation as well as higher water content, lower bulk density, and lower soil temperatures (Dao, 1998). As a result of soils being minimally disturbed in no-till systems, there may be a greater effect on soil activity and N pools compared to conventional tillage (Paustian et al., 1997).

The benefits of cover crops may be mitigated by their drawbacks, which include intense management requirements, potential for nitrogen immobilization, chances of increased weed or pest incidence, marginal short-term economic benefit, and non-quantifiable long-term benefits. Cover crops require additional labor management, which may deter some growers. A uniform stand of cover crop, which ultimately limits weed growth, may be difficult to establish. If a stand is not uniform or not effectively terminated, cover crops can compete with the cash crop and become weed nuisances or harbor pests (Curran et al., 2006). Termination timing is critical in order to maximize nitrogen release. If terminated too late, the C:N ratio in the soil will be too high (25:1) and nitrogen can be immobilized (Wagger, 1989; Hoorman, 2009). Immobilization is much more likely in grass cover crops with higher C:N ratios than a leguminous cover crop or a younger grass cover crop. Although cover crops are proven to improve cash crop yields, these improvements often require several years before they are substantial enough to justify their costs (USDA, 2006). Multi-year studies of cover crops indicate that cover crops do improve yields, however, short-term benefits of cover crops are more limited (O'Dea et al., 2013). The indirect costs of cover crops (i.e., those costs beyond seed, material, and establishment) can vary greatly and can negate the overall effectiveness and benefits of cover crops (Clark, 2007). Indirect costs can include environmental conditions that delay soil warming and subsequently delay seeding and growth of cash crops (Clark, 2007; Hoorman, 2009). Although long-term benefits of cover crops are proven, they do not easily translate into economic value for the grower. The additional inputs required, the requirements for monitoring of weeds and pests, and potential additional inputs of herbicides or management may discourage growers from establishing cover crops. As a result, growers (particularly those on rented lands) may be less likely to adopt cover crop practices.

Management of cover crops is complex, especially in organic, no-till systems limited by few methods used to terminate cover crops. In non-organic cover cropping systems, producers may use synthetic herbicides as well as mechanical methods to expedite decomposition of cover crops. In organic systems, however, termination methods of cover crops are more limited. This is particularly true in organic, no-tillage situations, where cover crop residue remains on the soil surface. In these systems, cover crops may be mechanically terminated using a roller/crimper or flail mowing. Roller-crimpers (Image 1, Image 2) are hollow steel drums, with metal blades, often in a chevron pattern, that crimp and flatten the stems of a cover crop into a flat mat on the soil surface (Ashford and Reeves, 2003). The drums of roller-crimpers can be filled with water to add weight and ensure flattening of the cover crop.

Image 1. Example of roller-crimper. Source:
https://www.uvm.edu/vtvegandberry/factsheets/winterrye.htm

Image 2. Roller-crimper rolling rye at WSU Puyallup, 2013.

The flailing termination method (Image 3 and Image 4) involves a drum with attached flails (blades) that mow the cover crop down in a more evenly dispersed pattern than a rotary mower.

Image 3. Flail mowing rye at WSU Puyallup, 2013.

Image 4. Flail mowed rye on soil surface at WSU Puyallup, 2013.

Both roller-crimping and flailing leave residue on soil surface. After termination, mechanical plant aids - coulter followed by a shank - (Image 5 and Image 6) prepare a narrow, deep slot of loosened soil for planting vegetables (Schonbeck, 2015).

Image 5. Plant aid used in no-till fields.

Image 6. Rolled rye following plant aid at WSU Puyallup, 2013.

Depending on the type of tillage, the soil bed is prepared. Plant aids ease planting in no-till by limiting the amount of soil and cover crop disturbance. Plant aids utilize a coulter to push aside a

Image 7. Full-till (rotary spader) in terminated rye fields at WSU Puyallup, 2011.

small amount of cover crop to subsequently plant a cash crop. The coulter is followed by a shank that creates a shallow trough in the exposed soil to ease planting. Rotary spading is a full-tillage method that mixes residue into the soil (Image 7). Although there are clear benefits to cover cropping, organic producers, particularly those in no-till systems, need cover crops that efficiently cycle nutrients and decompose effectively as well as mechanical methods that allow for effective decomposition of cover crops without tillage.

Studies of decomposition and nitrogen cycling are numerous (Wagger, 1989; Hargrove, 1986; Ranells and Wagger, 1996; Wagger, et al., 1998). While the number of studies investigating the effects of cover crops within organic systems is increasing, research using cover crops within organic, no-till systems is limited. This study, completed in collaboration with Washington State University Puyallup Extension, investigated the nitrogen contribution and nutrient cycling of rye and hairy vetch cover crops in organic systems with till and no- till practices. Research focused on nitrogen release by cover crops as well as decomposition rates following termination (flail and roller/crimper) and planting (no-till/plant aid and full till) treatments in an organic agriculture system. Our objective was to determine the influence of cover crop species, cover termination, and tillage on the rate of decomposition of the cover crop residue.

MATERIALS and METHODS

Site description and soil characteristics. The research site was at the Washington State University (WSU) Research and Extension Center, Puyallup, Washington. The site is maintained as an experimental organic farm and all research was completed in collaboration with WSU. Soil at the site is classified as a Puyallup fine sandy loam (coarse-loamy over sandy or sandy-skeletal, isotic over mixed, mesic Fluventic Haploxerolls).

The seedbed was prepared 17 September 2012 with a rotary spader (Imants Spader, Ruesel, Netherlands) and seeded with a John Deere planter (model FB B, setting 14) with 15-cm row spacing on 4 October 2012. Seeding rate for rye (cv. 'Aroostook') was 106 lb/acre and 84 lb/acre for hairy vetch (cv. 'Lana'). Each plot was 9 m x 3 m. To account for field variance a randomized block design with four replications was used. Treatments utilized flailing or roller/crimper; plant aid (no-till method) or rotary spader (full tillage method) for planting the cash crop; and rye or vetch cover crop (Table 1). Due to previous difficulty in terminating vetch with a roller, this treatment was not implemented within vetch plots. Each plot was divided between a "west" and "east" subsample.

Following termination, all rye plots were planted with a squash (*Curcurbia pepo* L. cv. table ace acorn) cash crop on 19 June 2013. All vetch plots were planted with broccoli (*Brassica oleracea* L. var. *italica* cv. Everest) cash crop on 12 and 13 June 2013. Prior to planting of cash crop, the soil surface was fertilized by hand with a 12-0-0 feather meal-based fertilizer- in no-till plots this meant fertilizer was applied on top of residue. Nitrogen availability from fertilizer product was assumed to be 75%, with application rates adjusted accordingly. Squash was fertilized at a rate of 160 lb N/acre or 1333 lb product/acre. Broccoli was fertilized at a rate of 133 lb N/acre or 1108 lb product/acre.

Table 1. Treatments identified for termination method, tillage method, cover crop type, and crop.

Treatment	Termination Method	Tillage Method	Cover Crop	Cash Crop
1	Roller/crimper	Plant aid (No-till)	Rye	Squash
2	Flail	Plant aid (No-till)	Vetch	Broccoli
3	Flail	Plant aid(No-till)	Rye	Squash
4	Flail	Spader	Vetch	Broccoli
5	Flail	Spader	Rye	Squash

Residue bags

Decomposition and nitrogen cycling were analyzed using a litterbag method (Harmon et al, 1999; Ranells and Wagger, 1996). Two hundred, 12 in. x 6 in., 3-mm mesh polyester bags were sewn and numbered for easy retrieval. The biomass used for study was obtained by cutting three, 5 in. x 12 in. quadrants in the freshly terminated residue (flailed or rolled). The residue was placed into a bin and mixed. In order to have uniform residue in each bag, random handfuls of the mixed residue were grabbed, weighed, and placed in each bag (97.7 g dry rye residue/bag, +/- 10%; 39.2 g dry vetch residue/bag +/-10%). Subsequently, a 5 in. x 12 in. square was cut in the residue and then 10 bags per plot were filled with residue and stapled.

To simulate surface decomposition, bags in the plant aid treatment (Treatments 1, 2, and 3) were left on soil surface following termination (Image 8). To simulate below-surface decomposition, bags in the rotary spader, full tillage treatment (Treatments 4 and 5) were buried horizontally 4 in. deep in a row approximately 4 in. from the dripline (Image 9).

Image 8. Reduced tillage treatment bags on soil surface, denoted by purple flags.

Image 9. Full tillage treatment bags prior to burial below surface.

Bags were retrieved from each plot at weeks 1, 3, 4, 8, 12 (date A, date B, date C, date D, date E, respectively) (Table 2). After retrieval, soil was lightly brushed from bags while in the field. Bags were placed in bins and transported to the laboratory. Bags were opened in the laboratory and dried in Blue M Batch Ovens (Models 966, DC 966SG, and DC-606SG). Recognizing that buried bags contained not only decomposing plant material, but also soil, material was subsequently oven-dried and then combusted to eliminate any remaining moisture and carbon. Contents were ground using a Wiley Mill screen size 2mm. Organic matter of the ground residue was determined through the Soil Organic Matter Loss on Ignition Method (Gavlak et al., 1994) by combusting in a Thermolyne 30400 Furnace.

Image 10. Rye following grinding in Wiley Mill.

Soil Sampling

At each bag retrieval (weeks 1, 3, 4, 8, 12), 12 soil samples at six-inch depth were taken from each plot, combined, and dried. Soil samples were sieved, ground and analyzed for NO_3-N. No soil samples were taken at dates pre-A (rye only), date A (rye and vetch), or date B (rye) (Table 2).

Rye

Rye was terminated on 15 May 2013. Due to wet weather conditions, tillage and residual bag burial of rye biomass was delayed until 5 June 2013. In order to account for decomposition between termination and tillage, residue bags were filled with residue and placed on the soil surface (labeled "pre-A"). A target mass of rye biomass placed in the residual bags remaining on surface prior to spading (date pre-A), was obtained by cutting three, 5 in. x 12 in. quadrants of residue from the soil surface and averaging the weight of each quadrant in-field. This average weight of 97.7 g biomass/bag +/- 10% was used for filling each pre-A biomass residual bag that was placed on the surface in the rye plots. Pre-A bags remained on soil surface until tillage on 4 June 2013. All rye residual bags were stuffed one week following termination. Bags were buried on 5 June 2013, i.e. one day following tillage.

Vetch

Vetch was terminated and either buried or placed on soil surface 10 June 2013. Because weather did not delay burial, vetch sample data does not include pre-A bags (Table 2). Similar to rye sampling, a target mass of vetch biomass was obtained by grabbing three handfuls of residue from the soil surface within each quadrant and averaging the weight. This average weight of 39.2 g biomass/bag +/-10% was used as a target mass for each bag. All bags were buried on the same date as termination.

Table 2. Termination and sample dates, 2013.

	Rye	Vetch
Cover Crop Planting Date	4 October 2012	4 October 2012
Termination Date	15 May	10 June
Pre-A (bags left on surface)	15 May to 5 June	n/a
Full Tillage (select plots)	4 June	10 June
Bag Burial (Date 0)	5 June	10 June
Cash Crop Planting Date	19 June 2013 (Squash)	12 June and 13 June (Broccoli)
Bag Retrieval Dates	12 June (Date A) 19 June (Date B) 3 July (Date C) 31 July (Date D) 28 August (Date E)	19 June (Date A) 27 June (Date B) 10 July (Date C) 7 August (Date D) 5 September (Date E)
Soil Sampling Dates	5 June (burial) 3 July (Date C) 31 July (Date D) 28 August (Date E)	10 June (burial) 27 June (Date B) 10 July (Date C) 7 August (Date D) 5 September (Date E)

Cash Crops

Broccoli. Broccoli was planted 12 and 13 June 2013. All plots were watered on a frequent interval during the dry summer as needed. Weeds were persistent within the plots, and competition between weeds and the starts was a problem. Weeding was by hand, to be consistent with no-till practices. One nitrogen application was applied by hand as described above. At harvest, broccoli heads were cut from the plant, desiccated, dried, and subsequently sent to Iowa State University for analysis of nitrogen and total carbon.

Squash. Squash was planted 19 June 2013. Similar to broccoli, nitrogen was fertilized by hand. Watering was frequent and weeds were persistent. Data from squash harvest was not included within this study.

STATISTICAL ANALYSIS

Decomposition. All data sets were analyzed in R Project for Statistical Computing (R Core Team, 2015). Upon combustion, a correction factor (*Fli)*, as defined by Harmon et al., 1999, was applied to all buried bags:

$$Fli = (SaAFDM – SlAFDM)/LiAFDM – SlAFDM)$$

Fli = correction factor
SaAFM = percent of ash-free dry matter of the entire litterbag sample
SlAFDM = percent of ash-free dry matter of the soil from which the litterbag was retrieved
LiAFDM = percent of ash-free dry matter of the initial litter

The correction factor accounted for any remaining moisture or carbon within the buried bags.

The percent moisture remaining was multiplied by the Fli factor:

$$\text{Percent residue remaining} = [\text{residue}_{final}*\text{Fli}]/[\text{residue}_{initial}]*100$$

Subsequently, this data was graphed by date and cover crop. An asymptotic 2-parameter non-linear regression model was fit to the data:

$$Y = a(1-e^{-cx})$$

P values for a and c were poor for roll plant aid rye, with some points above 100 percent biomass. Values above 100% were excluded to better fit the non-linear regression line (Figure 1, Table 3).

Soil Nitrate-N. Soil nitrate-N data were fit with a linear mixed model with the lmer function in R (R Core Team, 2015). Treatment was modeled as a fixed variable, replication was a random variable, and day was a repeated variable. The best covariance structure was determineed by inspecting the Akaike Information Criterian and choosing the smallest value. All models were tested for date, treatment, and date x treatment interaction. The first soil nitrate-N date was not included in the linear mixed model because visual inspection indicated that nitrate increased after first sampling date (day -3 for vetch and day 21 for rye) and then decreased linearly for the rest of the season.

RESULTS and DISCUSSION

Residue Decomposition

Figure 1. Percent residue remaining (%) by date of bag retrieval as effected by treatment for rye and vetch each. Any data that was greater than 100% residue remaining was excluded.

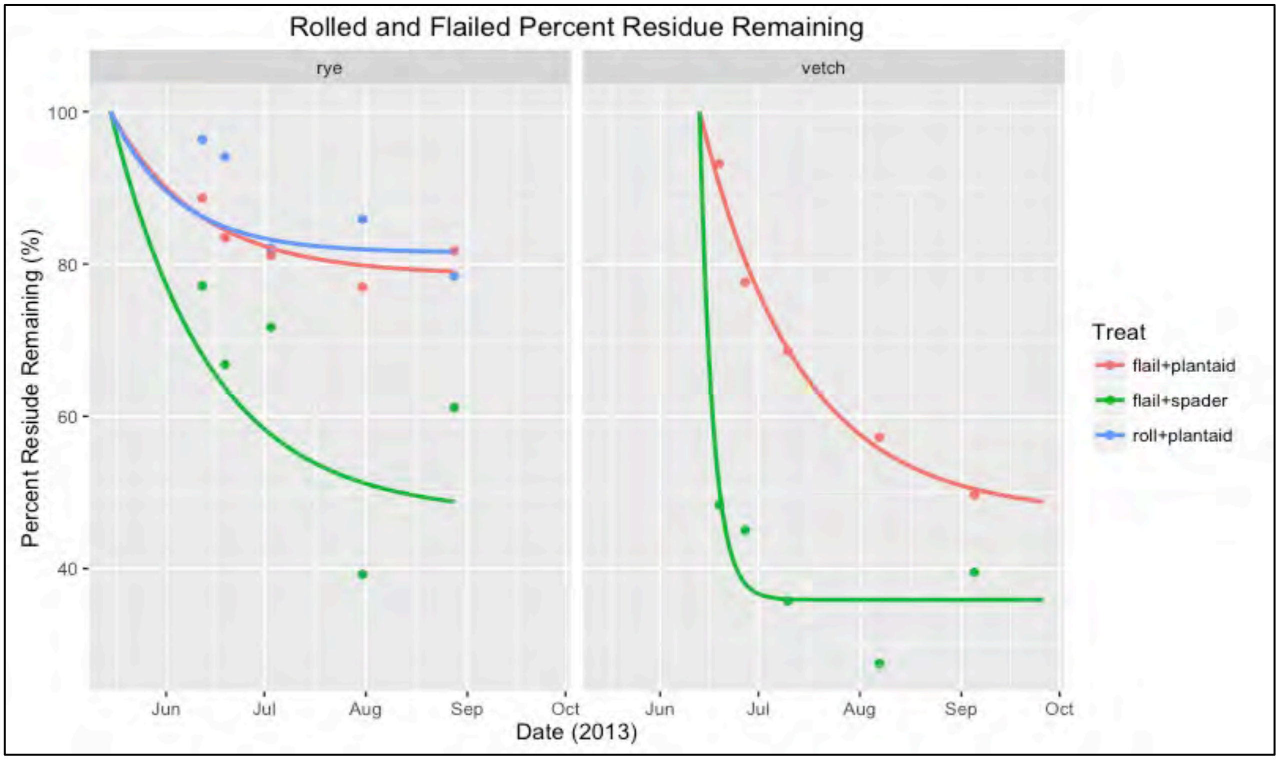

Table 3. Parameter estimates and fit statistics for percent residue as affected by treatment. Excludes rolled data above 100%.						
Cover Crop	Treatment	a estimate (%)	c estimate (% / date)	Std. Error	t value	Pr>t
Vetch	Flail + Plant aid (No-till)	47.15477	0.03308	8.02519	5.876	1.17e-05
Vetch	Flail + Spader	32.6586	0.1313	5.2192	6.257	5.22e-06
Rye	Flail + Plant aid (No-till)	78.56329	0.03689	5.75977	13.640	2.89e-11
Rye	Flail + Spader	48.03235	0.02471	10.77353	4.458	0.000269
Rye	Roll + Plant aid (No-till)	81.47940	0.04867	3.68551	22.108	2.03e-13

In general after a 3.5-month period and regardless of the treatment, all treatments of vetch cover crop residue decomposed more completely than the rye residue (Figure 1). For example, 52.9% of no-till, flailed vetch crops decomposed after 3.5 months and 67.3% of full-till vetch decomposed. Comparatively, at the end of 3.5 months only 21.4% of no-till, flailed rye decomposed, 18.5% of no-till, rolled rye decomposed, and 52.0% of flailed, full-till rye decomposed. The significant effect of cover crop species on relative decomposition rate is supported by prior research by Wagger (1989), Rannells and Wagger (1996), and Ruffo and Bollero (2003), who showed greater decomposition rates of hairy vetch when compared to rye *in situ*.

The type of treatment (i.e. flail+plant aid (no-till); flail+spader; roll+plant aid (no-till)) significantly affected rate of decomposition. Flailed, full till treatments (bags buried below-ground) for both rye and vetch had higher decomposition rates than the flailed, plant aid/no-till (bags on soil surface) (Figure 1). Again, rolled treatments were not implemented within vetch due to difficulty to terminate. Slower surface residue decomposition (i.e., those treatments that used a plant aid) versus buried decomposition was expected. It is widely acknowledged that soil temperatures of tilled soils are higher than those of no-tilled soils, which leads to higher microbial activity and subsequent decomposition rates. It is difficult, however, to compare these results to other decomposition studies, since few focus on no-till systems. Of the no-till studies reviewed, none included a tillage treatment for comparison.

No-till treatments, where cover crop residue was left on the soil surface, had lower decomposition rates than full-till treatments. These results were expected—no-till residues typically increase moisture, lower soil surface temperatures, lower bulk density, and increase the rate of microbial activity within the soil (Granastein et al., 1987; Dao, 1998; Jackson et al., 2004). Although the no-till soils had increased microbial activity, there is less residue in direct contact with soil microbes to decompose. Comparatively, residues within full-till treatments were fully distributed within the soil, allowing for faster rates of decomposition.

When comparing the no-till, flailed versus rolled treatments in rye, the residue from the flailed treatment decomposed slightly more rapidly (2.9% more rapidly) than the residue that was rolled. The slower decomposition in the rolled treatments may be due to the physical size of the rye particles. Following treatment, rolled rye plants remained fairly intact with small bends in each rye plant, as if pressed. In flailed treatments, the rye was chopped into smaller units. Decomposition may have been more efficient based on the size of the terminated rye. If a no-till grower is growing the cover crop for the purpose of decomposition and the release of nutrients, then flailed treatments of rye are more efficient. On the other hand, no-till growers desiring ground coverage to reduce weed establishment may find rolling the cover crop to be beneficial (Wayman et al., 2014; Wayman et al., 2015).

In this study, termination implies the killing of the cover crop. However, it should be noted that not all rye was killed following the termination treatments. During the study, it was not uncommon to see small stands of the cover crop continue growing following treatment. This seemed particularly true for the rolled treatments of rye. This concern is of note in consideration of the term "termination" as well as understanding that some decomposition may have been delayed because the cover crop was not effectively killed and continued to grow. Additionally, weed growth was persistent within the study. Although plots were weeded by hand, weed competition may have disrupted decomposition and competed for soil nutrients.

Soil Nitrate-N Analysis and Discussion

Soil nitrate-N values generally peaked at 4 weeks following treatment for both rye and vetch (Figure 2 and Figure 3, respectively). The peaks of soil nitrate-N values correlate to rising decomposition rates and are supported by previous studies of nitrogen release (Wagger, 1989; Ranells and Wagger, 1996). The exception to this was the rye that was terminated with a flail mower and then fully tilled. The rye residue in the flailed, full till (spader) sample bags did decompose (Figure 1), however, in early July we did not observe a soil nitrate increase. The reason for this discrepancy could not be because the residue decreased rapidly. The vetch decomposed more rapidly than rye and we still observed a soil nitrate-N increase. It could be possible that some rye, not terminated, was scavenging nitrogen. Or, it could be that nitrogen was immobilized due to the incorporation of rye. Also, it could be possible that the amount of nitrogen available from decomposition of rye, a non-leguminous crop, was negligible in the early stages of decomposition.

The autoregressive covariance structure was the best fit for both vetch and rye. The ANOVA of vetch soil nitrate-N values indicates that the date was the only significant effect on soil nitrate-N; neither the treatment nor the interaction between treatment and date were significant (Table 4).

The ANOVA of soil nitrate-N values of decomposing rye showed that date, treatment (roll, spader/till, flail), and the interaction between date and treatment were all significant (Table 5). This significance makes sense given that the soil nitrate increased for the two no-till treatments and not for the full till treatment. Soil nitrate levels in the full till treatment remained essentially unchanged over the decomposition period. Analyzing the interaction of date x treatment, data was sliced by date and tested for treatment effect (Table 6). The treatment factor was significant on 3 July (day 49) (Table 6). Flail full till treatments of rye resulted in very little increase in soil nitrate values in comparison to no till treatments (fail and rolled).

Figure 2. Soil nitrate values of decomposing rye by date.

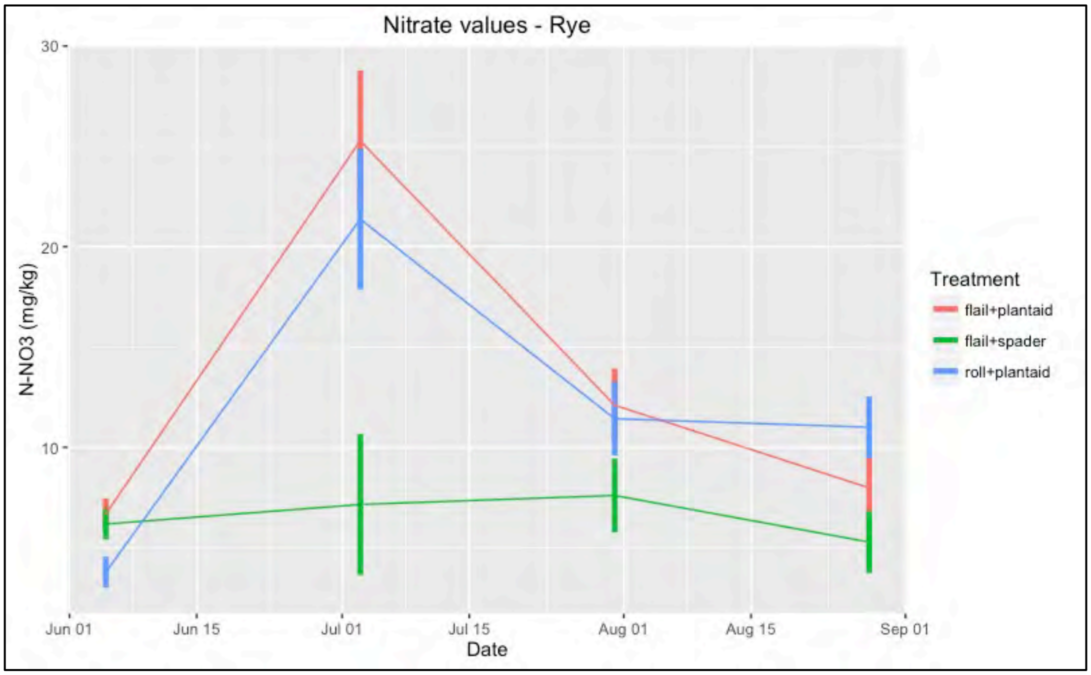

Figure 3. Soil nitrate values of decomposing vetch by date.

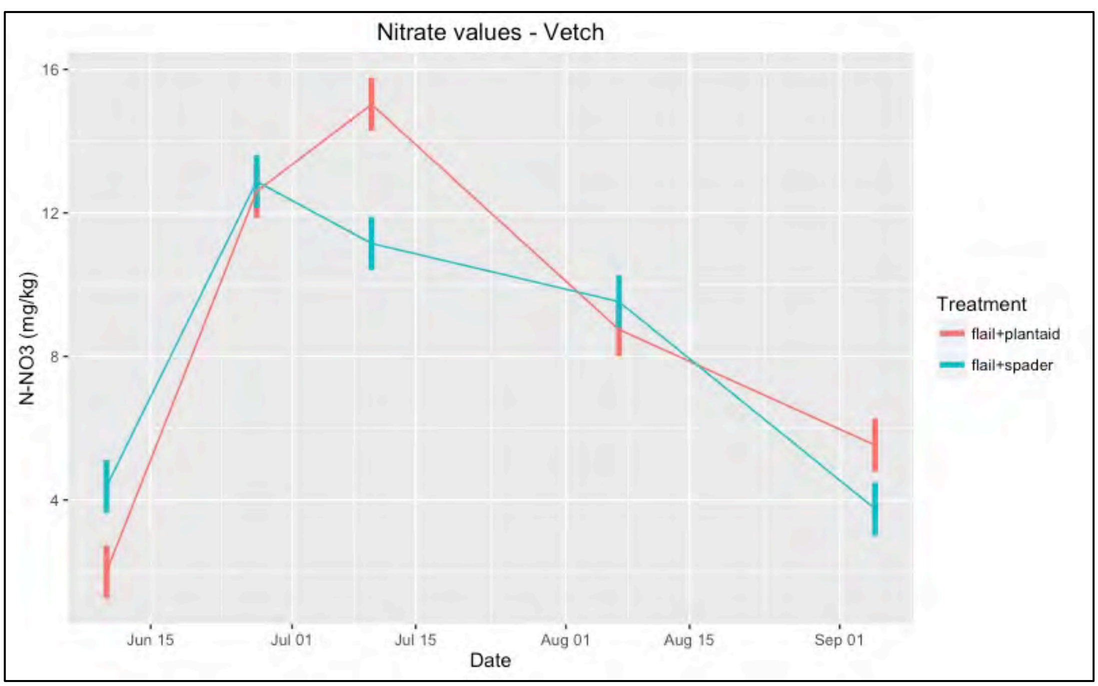

Table 4. ANOVA analysis of variance for soil nitrate-N values in vetch for 2013.

Interaction	d.f.	F value	Pr(>F)
Date	1	35.942	0.00018***
Treatment	1	0.169	0.692
Date x Treatment	1	0.000	0.998

Significance codes: *** = *p*<0.0001

Table 5. ANOVA analysis of variance for soil nitrate-N values in rye, 2013.

Interaction	d.f.	F value	Pr(>F)
Date	1	22.504	0.0003894***
Treatment	2	5.739	0.01762*
Date x Treatment	2	4.615	0.03072*

Significance codes: *** = *p*<0.0001 ** = *p*<0.01 * = *p*<0.05

Table 6. Mean Square for Error (MSE) for soil nitrate values in rye for each date, 2013.

Interaction	MSE	Pr(>F)
3 July 2013	59.4	0.021*
31 July 2013	21.30	0.372
28 August 2013	10.95	0.101

Significance codes: * = *p*<0.05

CONCLUSION

For no-till growers, timing of termination is critical to ensure effective decomposition and nitrogen release for the subsequent cash crop. Decisions about the species of cover crop and the timing of termination are also influenced by the purpose for growing a cover crop. This study demonstrates that full-tillage results in rapid decomposition. The treatment also effects the rate of decomposition. However, slower decomposition rates with no-till may result in slow nitrogen release rates and nitrogen deficiency. Based on this study, soil nitrate levels peaked about four weeks following termination. For growers desiring nitrogen utilization from the cover crop, flailing vetch and allowing for four weeks of decomposition is sufficient to maximize nitrogen release. For growers desiring reduced weed incidence and reduced soil loss/erosion, rolling/crimping rye with slower decomposition rates would be ideal. It should be noted that high biomass, late phenological rolled rye potentially immobilizes nitrogen, which may influence consideration of its use as a cover crop. Potential immobilization of nitrogen was indicated by the significance of date, treatment, and the interaction between date and treatment of soil nitrate-N. This study also included a study of C:N ratios in broccoli. Originally, the intent of collecting this data was to demonstrate nitrogen uptake and the cycling of nitrogen in an organic, no-till system. However, upon review, the data was incomplete and would not allow for any decisive conclusions.

Further research should include nitrogen uptake by cash crops to provide more data about the nitrogen contribution from cover crops in different treatments. As is, this study provided the basis for further research at Washington State University. Researchers at WSU Puyallup Research and Extension Center are completing a three-year study of organic, no-till cover crops (vetch). This study demonstrates the need for research of fertility in no-till organic systems.

Organic, no-till growers need detailed, well-researched recommendations to improve soil health and cash crop production as well as manage weeds.

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