USDA NRCS Conservation Innovation Grant

Final Report

Innovative Cropping Systems Using Diverse Cover Crops & Manure Injection

October 25, 2017

Grantee Name:	Virginia No-Till Alliance, Inc. (VANTAGE)
Project Title:	Innovative Cropping Systems Using Diverse Cover Crops & Manure Injection
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Period covered by report:	August 2012 to February 2017

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Introduction

Overview

The Virginia No-Till Alliance (VANTAGE) exists to maximize farm productivity and profitability by promoting the successful implementation of continuous no-till systems through shared ideas, technology, conservation and education. The Conservation Innovation Grant (CIG) presented an avenue to investigate topics of interest to the VANTAGE members and farmers in the Shenandoah Valley. The use of cover crops is a logical step in the progression of no-till crop production. Multi-species cover crops have been reported to provide greater soil health benefits than single species. Manure injection had been investigated in the Valley but had limited acceptance. Identifying equipment compatible to no-till systems and operable in rocky soils was necessary for manure injection in the Valley. The appeal of manure injection includes the capture of up to 50% of the available nitrogen reportedly lost with surface applications, reduced odor following application and the reduced potential for runoff of nutrients.

VANTAGE relied upon the technical expertise of the Virginia Cooperative Extension Agent members on the Board to direct the projects. Matt Yancey, former Rockingham County Agent, initiated the cover crop studies in August 2012 and continued work until his resignation in March 2014. His replacement, Doug Horn, was not appointed until late July 2014. The personnel change caused a lapse in the execution of the CIG so a time extension was granted in August 2015. Richard Fitzgerald, currently an independent consulting agronomist with Equity Ag, oversaw all aspects of the manure injection phase of this project in his former role as the Natural Resources Conservation Service (NRCS) Shenandoah Valley Area Agronomist.

Several farm producers were instrumental to the success of the CIG studies. They donated their land, time, resources and equipment to investigate the objectives of the project. The farmers involved have increased their knowledge of cover crops and manure injection which they readily shared as testimonials to other producers.

The farms used in the demonstration projects were located in Rockingham and Augusta counties in the Shenandoah Valley region of Virginia. The initial cover crop studies and the manure injection studies were conducted from August 2012 until March 2014. No CIG field trials were conducted in 2014 due to personnel changes. The final cover crop demonstrations were initiated in July 2015 and concluded in February 2017.

Objectives

1. Investigate and demonstrate the pros and cons of replacing small grain cover crops in the Shenandoah Valley with alternative species and diverse mixes.

2. Focus on farmer-planted strip trials in order to allow Valley growers to gain direct experience with alternative cover crops and to promote farmer-to-farmer information sharing.

3. Evaluate the performance of cover crops planted following wheat grain harvest.

4. Compare the effectiveness of summer versus winter cover crop mixtures planted after wheat.

5. Determine the impact of cover crop mixtures on the subsequent corn grain yields.

6. Demonstrate and compare the impact of injection vs. traditional manure broadcasting on corn silage yield, quality, and production economics.

7. Conduct on farm manure injection trials to encourage farmer perspective and promote peer information sharing.

Scope

The focus of the project was on field scale demonstrations to illustrate the feasibility of the concepts. The manure injection trials used three replications of two treatments. The same treatments were repeated at two locations. Some of the cover crop studies were replicated on the same farm but most studies were simply strip plots on different farms. The idea was to document the acceptability of alternative and multi-species cover crops over a wide range of conditions and management practices. The cover crop after wheat demonstrations used the same three treatments as strip plots on four different farms.

Relationships

Local agribusinesses were very supportive of the projects both financially and through the donation of time and resources (See Table 1 for listing.). Several local businesses provided monetary donations toward the VANTAGE matching funds portion of the grant. Other businesses provided labor and equipment toward the sampling and harvesting procedures which are included in the in-kind portion of the grant.

Table 1. Agribusiness Contributions for the CIG.

Cash	In-Kind	Source
	$21,840.00	Virginia Cooperative Extension
$3,000.00		Pioneer Hi-Bred International
$1,500.00		Houff's Feed and Fertilizer
$750.00		Rockingham Cooperative
$750.00		Augusta Cooperative Farm Bureau
$750.00		Helena Chemical Company
$750.00		Syngenta
$3,000.00		Binkley and Hurst
$510.63		Environmental Defense Fund
$11,010.63	$21,840.00	**TOTAL**

Virginia Cooperative Extension was instrumental in the execution of the grant. Besides the two agents who oversaw the projects, several other agents assisted with field activities including sampling and harvesting. Dr. Rory Maquire from Va Tech shared his experiences with manure injection and provided technical review of the fact sheet and economic analysis.

Funding

The original CIG proposal funding is compared to the actual expenses in the following funding breakdown.

Table 2. Allocation of expenses for the CIG.

Funding Source	Original Amount	Actual Expenditures	Variance
NRCS Contribution	$39,515	$34,897	- $4,618
VANTAGE + Partners	$41,850	$44,560	+ $2,710
Total	$81,365	$79,457	

The actual NRCS expenditures came in below budget. The change in the project leader position caused some discontinuity in the proposed projects and budgeting for the CIG. The budgeted expenses for sample analysis and the video were less than projected.

Background

Manure injection and the use of cover crops can both greatly improve soil health. Manure injection has been shown to increase the amount of crop available nitrogen and add to soil organic matter in no-till and reduced tillage settings.

Cover crops provide a similar benefit by trapping and cycling nutrients, and acting as nitrogen producers for subsequent crops. Furthermore, cover crops reduce runoff and soil erosion, enhance soil health by diversifying cropping systems, and can serve as a valuable forage resource.

The value of cover crop mixes has been documented throughout the world. However, central Shenandoah Valley farmers do not realize their full benefits. Many do not plant cover crops at all, even though state and federal assistance is available through cost share programs. Some farmers believe that the potential benefits are not worth the effort and expense or that cover crops do not fit into their particular cropping system. Most farmers in the area who do use cover crops do not utilize multiple species mixes. Bin run rye is the cover crop of choice, being the cheapest small grain available. Even some who utilize rye cover crops do so with skepticism, citing subsequent crop establishment problems and other issues. Others will rely on their cover crop for cheap feed production, but are again using single species small grain cover crops and are not achieving the forage value that is possible with multiple species. Finally, cover crops with increased diversity, including three or more functional groups, are being evaluated to improve soil quality over time to a much greater degree than single species cover crops.

Manure injection has been researched in this area by Dr. Rory Maguire and others. Board members of VANTAGE have been directly involved in this effort and are currently utilizing the technology. Other farmers have expressed interest after seeing the injector work and learning about injection through the efforts of NRCS, VANTAGE, and Virginia Cooperative Extension.

Part I: Alternative Winter Cover Crops

Review of Methods

Nine cooperating farmers planted a total of 11 fall-seeded cover crop strip trials between 2012 and 2013. Most trials compared one or more alternative cover crop species (see Table 3) to one or more standard small grains. Alternative covers were typically grown in mixes of three or more species (see examples in Table 4). The species grown differed from farm to farm, depending on the cooperator's interests. The number of treatments in each trial at each site ranged from three to twelve. Emphasis was on demonstration, not data collection. However, representative data on cover crop yield, forage quality, and/or soil nutrient status were collected at some locations.
At each site, each treatment was planted only once. In some cases, the same treatments were replicated across two or three locations to allow for more meaningful conclusions.

Table 3. Alternative Cover Crop Species Demonstrated in Strip Trials

Grasses	Legumes	Brassicas
Triticale	Crimson clover	Forage radish
Spring oats	Hairy vetch	Forage turnip
	Austrian winter pea	Canola/rapeseed
		Brassica hybrids

Table 4. Examples of Treatments from a Cover Crop Strip Trial

Strip	**Species and Seeding Rates** *(numbers are rates in pounds per acre)*
1	*Barley (72)*
2	*Barley (48) + Crimson clover (5) + Hairy vetch (10)*
3	*Triticale (10) + Hairy vetch (15) + Forage radish (6)*
4	*Barley (10) + Spring oat (10) + Triticale (10) + Crimson clover (2) + Hairy vetch (10) + Austrian winter pea (10) + Forage radish (2) + Forage turnip (2) + Rape-turnip forage hybrid (2)*

Figure 1. Alternative cover crop mix with vetch, clover and small grain.

Cooperators represented a wide range of enterprises including dairy, beef, cash grains, and sweet corn. Augusta County cooperators were Gerald Garber, Charles & Chuck Horn, Kyle Leonard, and Carroll Swartz. Rockingham County cooperators were Wilson Burkholder, Dennis Koogler, Mike Phillips, Matt Rohrer, and Buff Showalter.

The number of forage radish brands has increased dramatically, causing farmers to ask if there are differences between varieties. A comparison of radish cover crops from five different companies was replicated across three farms. All seed was purchased in 2012 and ranged in price from $15.60 to $21.90 per acre (at 6 pounds/acre (lb/ac)). Each radish variety was planted in strips with 10 pounds of triticale and 15 pounds of hairy vetch in mid-September 2012 on three farms west of Harrisonburg, Virginia. Established radish plots were sampled in late-December prior to winter-kill. The length and girth of each radish bulb were measured. Above and below ground biomass was separated and analyzed at Virginia Tech for accumulation of carbon, nitrogen, and other nutrients.

Findings

Daikon Radish Comparison

Five different brands or varieties of Daikon radishes were evaluated. The varieties compared were: 'Eco-Till', 'Groundhog', 'Nitro' and 'Tillage'. 'Soil Buster' (a blend of WS 10-11 and Kaiwari) was included at the final site, but data is not reported here.

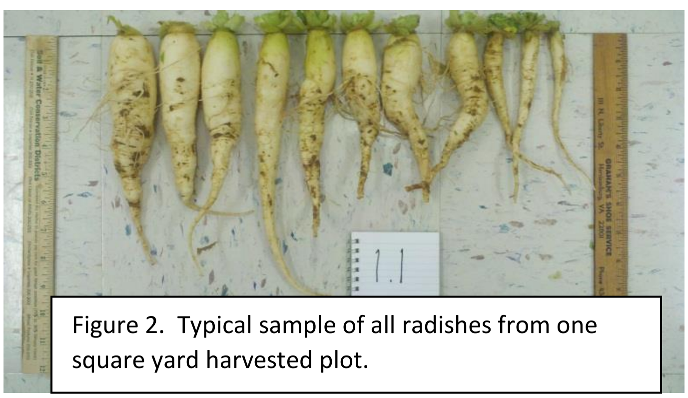


Figure 2. Typical sample of all radishes from one square yard harvested plot.

The data showed minimal differences among radish varieties. Field variability may have had the most impact in this test as sample size was relatively small. Relative data and summary data are presented in Table 5. It is important to note that all varieties produced both large and small radishes, regardless of proximity to neighboring radishes.

Table 5. Daikon radish measurements of selected parameters, relative numbers*						
	Stand Counts	Foliage Dry Weight	Tuber Dry Weight	Total Dry Weight	Length	Girth/ circumference
Eco-Till	0.94	1.17	1.19	1.18	1.07	1.00
Groundhog	1.04	0.83	0.75	0.79	0.87	0.90
Nitro	0.96	1.01	1.08	1.05	1.04	1.03
Tillage	1.06	1.11	1.11	1.11	0.98	1.02
Soil Buster	*N/A*					
AVERAGES	106,000 plants/acre				5.2 inches	3.3 inches
				Maximum (inches)	10.1	6.1

*Rather than actual numbers produced, relative numbers are shown to present yield relative to one another. A response of 1 would be average, and so anything above 1 is above average and anything below 1 is below average.

The nitrogen (N) uptake and carbon to nitrogen (C:N) ratio of the radishes are important figures to recognize. A ratio of 24:1 is ideal to expedite residue decomposition and nitrogen release. A high C:N lacks the nitrogen required to decompose a high-carbon residue, which may result in temporary nitrogen tie-up. In this situation microorganisms pull nitrogen from other sources which can cause yellowing of desirable crops. A lower C:N ratio allows for rapid plant breakdown and release of excess nitrogen. The C:N ratios found in our radish study are very favorable and radishes overall scavenged about 26 pounds of nitrogen/acre.

Table 6. Biomass, carbon and nitrogen accumulation by forage radish.

Average Biomass Produced across all Varieties (lbs/ac)		
	Dry (lbs/ac)	Wet (tons/ac)
Aboveground	421	2.6
Belowground	472	3.7
Total	893	6.3

Average Accumulation in Radishes				
	Percent Nitrogen	Percent Carbon	C:N Ratio	Pounds N/ac
Aboveground	3.5	39	13	15
Belowground	2.3	36.6	16.2	11
			TOTAL	26

Figure 3. Harvesting radishes from triticale, radish, hairy vetch plots.

Figure 4. Twenty-nine inch radish taproot pulled from cover crop plot. It appeared to break off, indicating the root went deeper still.

Alternative Winter Cover Crops

Multispecies cover crop mixes and monoculture small grain cover crops were planted in the fall of 2012. Forage yields were collected in the late fall. In this group of plots, high diversity cover crops in some cases doubled the yields of single species cover crops commonly planted (Table 7). These cover crop mixtures could be grazed in the fall after establishment and allowed to grow throughout the winter and spring to cycle nutrients and limit erosion.

Table 7. Fall yields of cover crop plots, 2012.

Cover crop treatments	% moisture	DM yield lbs./acre
1.5 bu barley	84.2	**1,589**
1 bu rye+ 1 bu oat+2# clover+ 2# rape+ 2# turnip	86.1	**2,305**
1 bu oat+ 2# clover+ 2# rape+ 2# turnip	85.1	**1,942**
1.5 bu rye	82.0	**1,115**
1 bu barley+ 5# clover+ 10# hairy vetch+ 2# radish	89.1	**1,787**
1.5 bu rye + 1 bu oat	83.1	**1,924**
1 bu oat	82.9	**1,447**

It is generally recognized that mixing legumes with small grains can increase the crude protein (CP) content of spring-harvested forage with no drop in dry matter (DM) yield. Spring forage testing on a number of plots in this project was consistent with this trend.

Table 8. Spring production and quality from cover crop mixes vs. single species cereal crops

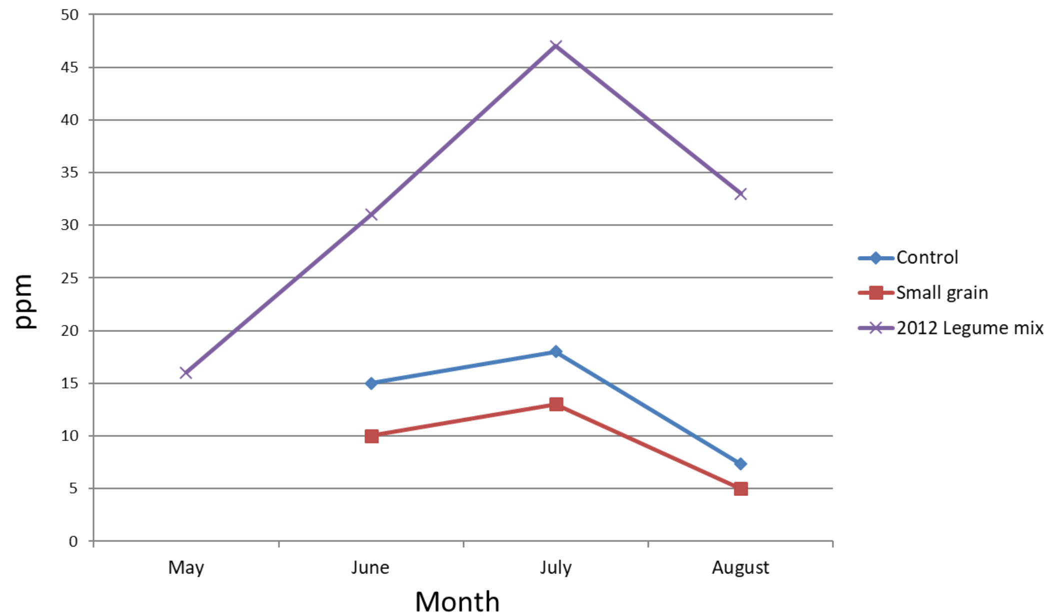
	DM (tons/acre)		CP (%)	
Cover crop forage mixes, BOOT STAGE	**Overall**	**Legume only**	**Overall**	**Legume only**
1 bu small grain, 5# clover, 10# vetch	2.4	0.7	20	**26**
6# radish, 10# small grain, 15# vetch	1.6	1.4	27	**30**
Virginia small grain forage variety tests, 2013 - BOOT STAGE				
barley	1.7		14	
forage rye	1.7		13	
triticale	2.1		11	
wheat	2.1		11	

Killing "high C:N ratio" small grain cover crops and returning those residues to the soil can temporarily tie up or immobilize soil N. Corn planted into those residues is more likely to be N-deficient than corn planted into ground with no cover crop. Adding legumes to the small grain cover crop can eliminate this N immobilization. This was demonstrated in a strip trial replicated across three farms. Soil nitrate levels were measured in July ahead of peak corn N need. Soil nitrate levels were higher following mixed cover crops or no cover crop, and lower following small grain cover (see Figure 7). These results were obvious to farmers visiting the plots who saw yellower corn following small grain and greener corn following mixes (Figure 5).

Figure 5. The lighter green corn in the center of the photo is growing in the cover crop plot that was a monostand of barley. Killing the non-legume cover crop at heading resulted in a high C:N ratio which tied up soil nitrogen.

Figure 6. Mulching down high C:N ratio cover crops like this headed out small grain can lead to immobilization of soil N. Adding legumes to the mix can eliminate this effect.

Figure 7. Soil Nitrate Levels Under Corn After Different Winter Covers (Summer 2013)



45 ppm at 12" deep = 180 lbs of nitrogen

Figure 8. Typical cover crop strip trial from this project. Photo taken in spring. Three strips from left to right show brassica mix (yellow flowers), small grain monoculture and legume mix.

Part II: Dairy Manure Injection

Review of Methods

Three replicated on-farm strip trials compared corn silage performance following two manure treatments: (1) traditional surface broadcasting plus sidedress N fertilizer vs. (2) shallow subsurface injection with no sidedress N fertilizer. Two cooperators conducted a total of three trials between 2012 and 2013.

A high slurry application rate of 9,000 gallons/acre was selected in order to test the idea that injection could completely replace sidedress N fertilizer for corn. The goal was to apply similar amounts of predicted first-year plant available nitrogen (PAN) to each treatment. The target PAN rate was 170 pounds/acre, the amount recommended in Virginia for a 23 ton/acre corn silage yield goal. See Table 9 for details.

Table 9. Average Manure Treatment Nutrient Application Rates ***(all values in lb/acre)***

Treatment	*Material applied*	*Application method*	*Total N applied*	*Total PAN applied**	*Total P_2O_5 applied*	*Total K_2O applied*
Broadcast manure	*Dairy slurry (9,000 gal/ac)*	*Broadcast*	*170*	*63*	*50*	*185*
	N fertilizer	*Starter*	*40*	*40*	*0*	*0*
	N fertilizer	*Sidedress*	*70*	*70*	*0*	*0*
	Total		***280***	***173***	***50***	***185***
Injected manure	*Dairy slurry (9,000 gal/ac)*	*Injected*	*170*	*126*	*50*	*185*
	N fertilizer	*Starter*	*40*	*40*	*0*	*0*
	Total		***210***	***166***	***50***	***185***

**PAN = predicted 1st year plant available N based on manure tests and VA nutrient management guidelines*

As Table 9 shows, a significant portion of the broadcast manure N was expected to volatilize after spreading. The 70 lb/ac sidedress following broadcasting was designed to replace this lost manure N and equalize PAN rates between the two treatments. Each treatment was replicated three times in each trial, resulting in a total of six strips per trial. Strips were sized to match the farmers' field equipment. Manure was injected using a demonstration tanker with Yetter coulter injectors provided by Dr. Rory Maguire of VA Tech (see Figure 9). All other field equipment was provided by cooperating farmers and manure haulers.

Soil samples were taken before and after manure application. The following two soil sampling protocols were compared in some of the injected strips: (a) standard soil sampling, in which cores were pulled randomly throughout the treated area and (b) targeted soil sampling, in which cores were pulled only from the injection zone in the treated area.

Figure 9. Va Tech's shallow, coulter-type slurry injector used in this demo project.

Corn was harvested for silage. Yield for each strip was collected by weighing wagons or with a chopper-mounted yield monitor. Yields were adjusted to account for differences in silage moisture. Silage samples from each strip were sent to a lab for nutritional analysis.

The two cooperators operate dairy farms in Augusta County. Mr. Kyle Leonard owns and operates Colebelle Dairy, a 150-cow operation. Mr. Kevin Phillips owns and operates Northpoint Farms, Inc. with his three brothers. The Phillips family milks 900 cows at three facilities. The two farmer collaborators contributed significant time and crop production resources to the project. Mr. Leonard's willingness to transport the VA Tech injection unit on the highway between sites was especially crucial. Other cooperators included two custom manure haulers. Mr. Lewis Horst of Shen Valley Customs conducted the manure injection at Northpoint. Mr. Linden Heatwole used his tanker to nurse (transfer manure to) the injector at Colebelle.

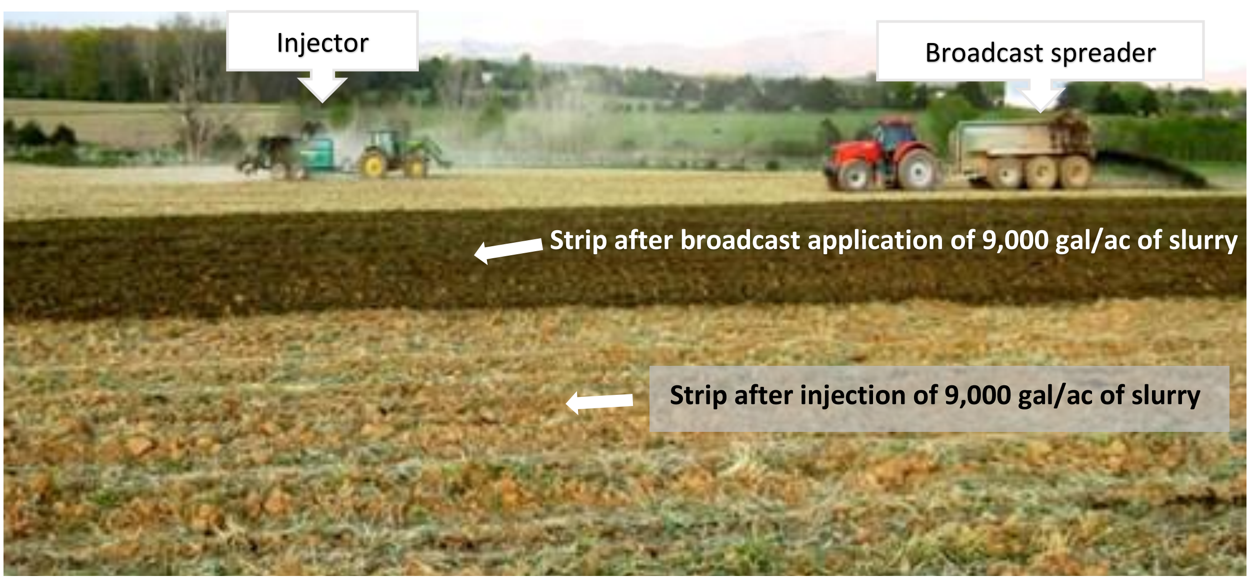
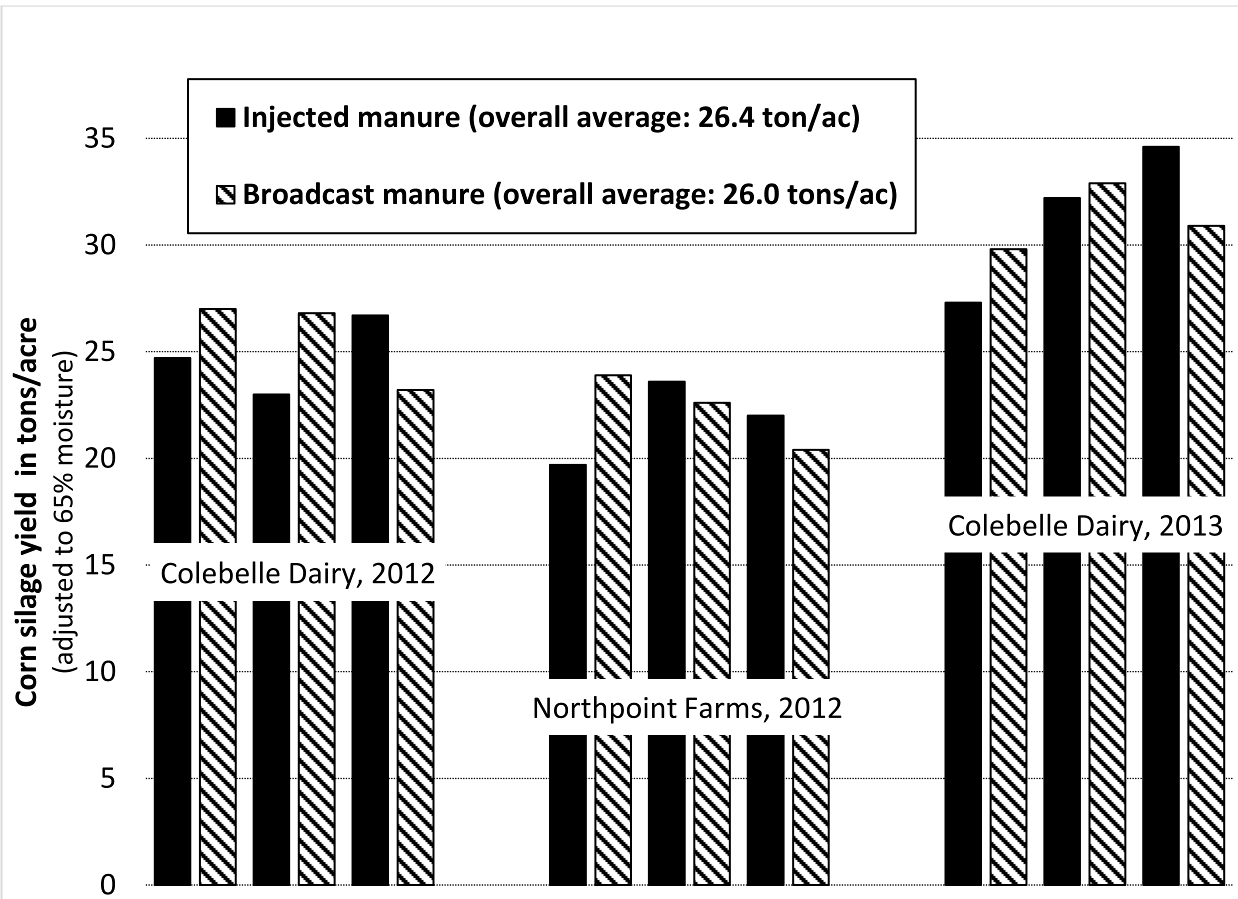


Figure 10. Application of manure treatments in alternating strips at Northpoint Farms.

Findings

Above average corn silage yields were achieved in all trials. Three replicated plots over two years showed no significant yield differences between injecting 9,000 gallons of dairy slurry when compared to broadcasting the same rate (Figure 11). High quality corn silage was achieved in all trials. No difference in silage quality was observed between the treatments. Corn following injection generally had a more uniform green appearance compared to corn following broadcasting, indicating more consistent N supply.

Figure 11. Corn Silage Yields for All Replications of All Trials for the Manure Injection Studies.



The fact that injected manure is concentrated in a narrow band every 30 inches across the field has posed no problem for corn nutrition. Corn roots quickly find the injection slots, proliferate in them, and take up nutrients through the season. Planter-applied starter helps corn grow until roots reach injection slots. Corn roots were observed growing toward the injection zone.

Adequate plant available nitrogen was present in the soil as indicated by the Pre-Sidedress Nitrate Test (PSNT). This same test is correlated for fall crops and indicated the need to add starter nitrogen for the cover crop. Cover crops planted after the corn showed no visual growth differences, either in the fall or spring.

A rate of 9,000 gallons per acre of injected slurry appears to be the upper limit of volume in no-till conditions and still maintain adequate coverage of the injection slot. Mr. Leonard has fields near houses that he does not broadcast manure to avoid odor complaints. He tried injecting 6,000 gal/ac of slurry across one such field and observed no odors or complaints.

Figure 12. Field view after application of manure treatments to a standing cover crop prior to corn planting at Colebelle Dairy. The coulter injector was remarkably good at placing manure into the soil under large amounts of residue and vegetation.

The cost of slurry injection in this project was estimated at $65/ac, compared to $25/ac for broadcasting. Nursing the injector with a second tanker brought estimated injection costs to $75/ac. In summary, the added cost of injection compared to broadcasting was estimated at $40 to $50/ac per acre for this project. The farmer cooperators estimated that the total savings associated with the injection treatment, including 70 lb/ac less N fertilizer, no sidedress pass, and associated reduction in damage to corn, totaled at least $50 to $60 per acre. **The conclusion: higher injection costs were roughly offset by savings on sidedress N fertilizer.**

When soil testing after injection, it is important to sample only the injection slots. A sample taken randomly across the field will likely under-represent the fertility provided by injection. Soil tests had to be collected directly over and in the injection zone to measure the increased nutrient concentration.

Table 10. Effect of soil sample location on nutrient concentrations.

Soil Sample Location	N03 (ppm)	P205 (lbs./ac.)	K20 (lbs./ac.)
Random Pattern	15	93	223
Injection Zone 6 inch	113	360	559
Injection Zone 12 inch	39	257	385
Random Pattern (fall)	13	211	256

Nitrogen removal rates by corn silage were calculated based on forage analysis of samples collected during harvest. Nitrogen removals were significantly greater than the applied target nitrogen rate at 170 pounds. Calculated nitrogen removal rates were 50 to 80 pounds greater than the applied nitrogen.

Part III: Cover Crops After Wheat

Review of Methods

The cover crop following wheat studies were conducted on four farms in 2015 and 2016. The following tables lists the sites and characteristics.

Table 11. Listing of cooperators, management factors and available nitrogen for the four sites used in the cover crop after wheat demonstrations.

Cooperator	Location	Land Management	Initial PSNT* (#N/acre)
Jimmy Crosby	Staunton	No-Till, Glyphosate	24
Barry Koogler	Mt. Crawford	Vertical Tillage, No Herbicide	20
Aaron Showalter	Dayton	No-Till, No Herbicide	119
Frank Swope	Churchville	No-Till, Glyphosate	130

* PSNT = Pre Sidedress Nitrogen Test

No manure was used recently on the Crosby farm. All of the other farms had received manure. The Showalter and Swope farms used cattle manure and the Koogler farm used turkey manure. The manure applications were limited by the soil phosphorus at the Koogler farm, so the manure only supplied a small portion of the nitrogen.

The wheat harvest in 2015 was slightly later than normal and was not conducive to double crop soybeans. Double crop soybeans were decimated by deer on the Crosby farm. Double crop soybeans were actually planted and harvested on the Swope farm.

Three cover crop mixtures were developed for the on-farm demonstrations. The Summer Mix was designed to grow during the warm summer months and fall then completely die during the winter. The Winter Mix targeted species that develop under the cooler weather of fall with most species able to survive a normal winter. The Combination Mix was a 50/50 mixture of the other two mixes. Each mixture contained grasses, legumes and forbs. Forage radish and spring oats were included in the summer mix with the idea that they would provide some additional fall growth after the warm season species frost killed. These same two species, forage radish and spring oats, were included in the winter mix to provide early growth and soil stabilization even though they are known to winter kill. The Combination Mix was intended to be an “insurance package” in case the growing conditions were adverse to some of the species. Hopefully some of the species would grow at some point regardless of the stresses. Triticale was observed in the Summer Mix plots in the spring of 2016. Apparently the seed supplier used triticale instead of spring oats in the summer mix.

Table 12. Composition of the Three Cover Crop Mixtures Examined

Summer Mix	Winter Mix	Combination Mix	
Spring Oats	Spring Oats	Spring Oats	Buckwheat
Forage Radish	Forage Radish	Forage Radish	Sunflower
Sudan/Sorghum	Triticale	Sudan/Sorghum	Cowpea
Pearl Millet	T-Raptor	Pearl Millet	Sunn Hemp
Buckwheat	Austrian Winter Pea	Triticale	Hairy Vetch
Sunflower	Hairy Vetch	T-Raptor	Crimson Clover
Cowpea	Crimson Clover	Austrian Winter Pea	
Sunn Hemp			

One week to three weeks lapsed between the wheat harvest and planting the cover crop demonstrations. All of the cover crop demonstrations were seeded with agricultural grain drills. Each drill was calibrated with the three seed mixtures prior to planting. To simplify the field procedure, the seed mixes were pre-inoculated during the mixing process by the supplier. All three mixtures were seeded on the same day at the Showalter and Koogler farms. Only the Summer Mix and Combination Mix were seeded immediately after wheat at the Crosby and Swope farms. Since these two sites were seeded earlier in July, the seeding of the Winter Mix was delayed in an attempt to optimize the recommended seeding date. A commercially available mix, Ray's Crazy Mix, was planted as a temporary cover crop on the Winter Mix plot at the Crosby farm due to the slope of the field and the length of time being fallow. The Winter Mix was drilled directly into the green cover. Glyphosate was used to terminate the Ray's Crazy Mix the day after drilling the Winter Mix.

Weed suppression varied between the sites. The Showalter farm received no tillage or herbicide applications. The Koogler farm experienced heavy annual grass pressures. The site was rotary mowed and received two passes with a vertical tillage unit. Glyphosate was used at planting on the Crosby and Swope farms.

Management of the cover crops varied between sites. The Summer Mix and Combination Mix were harvested for baleage on the Swope farm. Half of the plot area was fall grazed by beef calves at the Koogler farm. The other half of the plot area was left to provide plant biomass. The cover crop was undisturbed at the Crosby farm until preparation for corn planting. The cover crop studies were observed throughout the season. Data collection included forage yield and forage quality analysis.

Corn for grain was planted at each site in the spring of 2016. Plant tissue samples and Pre Sidedress Nitrogen Test (PSNT) samples were collected during the growing season. Corn grain yields were collected at harvest. At the conclusion of the study soil sampling was conducted for nutrient analysis and PSNT.

Findings

The summer of 2015 was characterized by abundant moisture. All of the July and early August cover crop plantings received rainfall soon after planting and emerged in 4 to 7 days. All species were noted at all locations throughout the fields. The cool season species could be found under the Combination Mix canopy up to five weeks after planting. By 9 weeks only the brassicas, some triticale and volunteer wheat were observed under the canopy. The crimson clover, hairy vetch and Austrian winter pea were outcompeted by the warm season species.

Figure 13. All species had germinated in the Combination mix and were present at 3 weeks after seeding. The cool season species except the brassicas were eventually smothered out by the warm season species.

With good nitrogen fertility and adequate rainfall the brassicas dominated the winter mix. The combined seeding rate of forage radish and T-Raptor was only 2.2 pounds per acre. Rapid succulent growth of the brassicas at the Swope site choked out the remaining 5 species in the winter mix. Upon the death of the brassicas in early January, no other vegetation was observed under the canopy (Figure 14).

November 13, 2015 February 26, 2016

Figure 14. The Winter mix contained 7 cover crop species. At the high nitrogen site the brassicas dominated the stand and smothered the other 5 species. The mix was planted 8/15/15.

The Showalter site had to be abandoned because of the heavy populations and rapid growth of weedy summer annual grasses (primarily foxtail and barnyardgrass). The weeds were so thick and lush that they were baled for hay 6 weeks after seeding the cover crops. Very few of the desirable cover crops survived after mowing. The owner decided to plant wheat as a cover crop in November so the soil would not be exposed during the winter. The site continued to be observed through the fall and early spring. Some forage radish and T-raptor survived. The forage radish foliage smothered all plants under its canopy leaving a circle of bare soil the following spring (Figure 15).

Figure 15. The forage radish smothered all plants under its canopy leaving a circle of bare soil the following spring. The plot area was drilled with wheat in November. Photo was taken March 10th.

Weed suppression enhanced the establishment of the cover crops in July and August. Where no herbicide or tillage was utilized (Showalter site) the cover crops were overtaken by summer annual grassy weeds. The Koogler site was vertical tilled which helped with the establishment of the cover crops. Considerable competition from wheat and summer annual grassy weeds still limited the growth of the cover crops. The use of glyphosate at the Crosby and Swope sites allowed a good stand of cover crops to establish.

The PSNT at planting was a good indicator of the cover crop need for nitrogen. The PSNT soil samples were taken to a 12 inch depth. The Crosby and Koogler sites had low initial PSNT values and the cover crops were lighter green with less overall growth. The competition from weeds and volunteer wheat further stressed the cover crops at the Koogler site. The cover crops at the Swope site yielded 8.3 to 9 tons dry matter (DM) per acre followed by 4 to 7.2 tons DM per acre at the Crosby site and 1.6 to 3.3 tons DM per acre at the Koogler site.

Figure 16. Harvest technique for cover crops. Samples collected for yield and forage quality.

Half of the plot area was grazed in November at the Koogler site. The lack of rainfall in late August and September prevented much growth of the sudan/sorghum hybrids. Grazing was delayed until after a heavy frost since the sudan/sorghum hybrids were only 18 to 20 inches tall. The plots were grazed for about 7 days by 500 pound calves. The calves grazed on the volunteer wheat, grasses and legumes while avoiding the brassicas for the first 3 days. When the supply of grasses and legumes diminished the calves discovered they could eat the brassicas and cleaned up the field (Figure 18). **The composition of the stand and stand density in the spring did not seem to be damaged by grazing in the fall.**

Figure 17. Grazing in November was not detrimental to the stand composition or spring regrowth of the Winter mix.

Figure 18. Young calves grazed around the brassicas in the Winter mix for the first 3 days then realized they could eat them.

The summer mix and combination mix were harvested as baleage at the Swope site. Due to wet weather in late September and early October the forage could not be harvested until October 15. The baleage was more mature than desired but yielded well. The quality of the baleage was considerably less than the fresh sampling done in mid-September (relative feed value of 81 versus 105, respectively). No regrowth of the cover crops was observed after the October harvest and the plots were essentially fallow over the winter.

Figure 19. Essentially no regrowth occurred after the mid-October harvest of the Summer mix on right. The Winter mix is on the left. Photo taken 11/13/15.

Corn was planted on all sites in the spring of 2016. Wet conditions caused the corn to be planted a little later than the producers desired. Good moisture and growing conditions prevailed through July and the corn yields were above the county average for all sites. No consistent yield trends were observed between the treatments.   The Winter mix plot in the south rep of the Koogler site had a much lower yield than the other two treatments. The east end of the plot had a much reduced stand of corn due to wet conditions at planting and heavy feeding by deer.

Corn yields were collected by hand and with a combine at the Crosby site and the north rep of the Koogler site. Only a hand yield sample was collected at the Swope site. Only a combine sample was obtained for the south rep of the Koogler site. The hand sampled yields gave higher results than the combine collected yield data except for two plots (Table 13). The hand sampled yields tended to be about 10% greater than the combine collected yields. The ranking of the yields was different when comparing the hand yields to the combine yields. The corn yield data suggests that the correlation between collection techniques is poor.

Table 13. Corn Yield Data Comparison Between Hand Harvest and Combine Harvest. Data presented as bushels/acre @ 15.5% moisture

	Crosby			**Koogler - North**			**Average**		
Mix ID	Hand Harvest	Combine	% diff	Hand Harvest	Combine	% diff	Mean-Hand	Mean-Combine	% diff
Winter	214	192	10.5%	198	210	-6.1%	206	201	2.5%
Combination	208	210	-0.8%	214	189	11.8%	211	199	5.6%
Summer	220	194	12.0%	248	199	19.9%	234	196	16.2%
Medley Mix*				238	200	16.1%	238	200	16.1%
Mean-Site	214	198	7.3%	225	199	11.3%	222	199	10.5%

* Medley Mix is a commercial mix from Homestead Nutrition, Inc.

Figure 20. Corn yield data was collected by hand sampling and combine harvest at two sites. Combine data was collected from 12 rows in the center of the plots and weighed in a grain weigh wagon. The correlation between the two techniques was poor.

Figure 21. Comparison of growth habits of the Winter mix versus the Summer mix. The seeding of the Winter mix was delayed 3 weeks to optimize the recommended planting date. Photo was taken 9/23/15 which was 6 weeks after seeding the Winter mix on the left and 9 weeks after seeding the Summer mix on the right.

Figure 22. Most summer annual species were blooming 9 weeks after planting. Grazing or harvesting should occur at 7 to 9 weeks for best forage quality. Photo of Combination mix taken 9 weeks after seeding.

Figure 23. Good nodulation of the legumes was observed at 5 weeks. Cowpea nodules on the left compared to sunn hemp nodules on the right.

Figure 24. A diversity of pollinators were attracted to the cover crops during bloom.

Figure 25. Planting forage radish early in August allowed for maximum root development and compaction relief. Photo from Winter mix taken 11/13/15, 13 weeks after seeding.

Figure 26. Some brassicas managed to survive under the summer annual canopy in the Combination mix. Photo was taken 10/30/15, 2 weeks after the first killing frost.

Figure 27. Late March comparison of the Winter mix on left and the Combination mix on right illustrating vegetative and residue cover.

Figure 28. Cover crop residue at planting on 5/11/16. Winter mix on left versus the Combination mix on right.

Conclusions and Recommendations

Part I: Alternative Winter Cover Crops

Fall-seeded mixes including legumes and brassicas can produce more forage, more cover, and more benefits compared to small grains alone. Legumes in particular show great promise for increasing forage quality and quantity while capturing atmospheric N to benefit future crops. When planting corn into heavy cover crop residue, it is crucial to understand how the quality of the residue (the "C:N ratio") impacts N nutrition of the corn and plan accordingly.

Brassicas like forage radish need to be planted early in the fall (August or early September). Some legumes like hairy vetch can be planted later, but in order to achieve their full beneficial effect must be allowed to grow longer in the spring (i.e., until early May).

Fall-planted multi-species mixes with a range of seed sizes can be "pre-mixed" and run together through the large seed box of a grain drill. Some minor segregation can occur in the seed box but all species can be found at all locations throughout a field. Calibrate the drill to determine the right setting to deliver the desired rate of mixed seed.

Winter legumes and brassicas need to be evaluated in terms of the total cropping system – they cost more, demand more management, and require an earlier and/or longer growing season than small grain cover crops. Alternative cover crops may require changes to herbicide programs and other adjustments to your cropping system. Talk to your advisors, conduct your own trials, and educate yourself before jumping in on a large scale.

Alternative cover crops and mixes fit well on farms with appropriate openings in existing rotations. This includes farms where summer crops are out of the field by early September. Simple demonstrations such as those conducted here will likely continue to build interest on these operations. For other Valley growers, adopting alternative cover crops may require rethinking rotations in order to open the early fall and late spring "growing windows" which these covers require. More complex demonstrations evaluating modified rotations will be needed to gain the interest of these farmers.

The option to harvest, and especially to graze, alternative cover crops and mixes is part of their appeal and great potential. Promoting more integrated crop-livestock systems could vastly increase adoption of alternative cover crops in Virginia.

Part II: Dairy Manure Injection Trials

Slurry injection works. Several Valley dairymen have used it for multiple years to grow high-yield, high-quality corn silage on plots and whole fields. Slurry injection allows farmers to use the N in their manure pit more efficiently, thereby cutting your corn fertilizer bill. In this project, 70 lb/ac sidedress N was eliminated following injection with no loss of corn silage yield or quality. Injection is most economical when the improved manure N recovery allows for total elimination of a sidedress N fertilizer application. This is most likely when manure rates are in the higher (6,000 to 9,000 gal/ac) range.

Estimates of the added per-acre cost of injecting compared to broadcasting can vary. This project estimated a relatively high added cost of $40 to $50 per acre, in part because a high rate of manure was applied. Other studies (e.g., Reference 1) have assumed a lower per acre cost. If an operator is considering investing in an injection rig, they must develop their own per acre cost estimate. A key variable is the number of acres across which upfront and operating costs of injection will be divided. The fertilizer savings associated with injection usually offsets the added costs. That was the case in this project, despite conservative assumptions and a high estimated injection cost.

On farm equipment evaluation indicated that the time required to inject can compare favorably with the time required for covering the same area with surface broadcasting. If the distance from the manure pit to the application field is more than one mile a second nurse tanker should be used to keep the injector supplied with slurry and minimize injector down time.

Across all Virginia trails to date, the fact that injected manure is concentrated in a narrow band every 30” across the field has posed no problem for corn nutrition. Corn roots quickly find the injection slots, proliferate in them, and take up nutrients through the season. Planter-applied starter helps corn grow until roots reach injection slots. By increasing crop recovery of manure N already on the farm, injection can play an important role in achieving P-based nutrient management and whole-farm nutrient balancing.

Under typical conditions, injection can eliminate the smell and sight of manure during and after application. Manure injection offers the potential to apply manure to fields not currently considered due to their proximity to residential properties or along public roadways.

The majority of dairy manure slurry in the Valley is now spread by custom haulers. In addition, the cost of injection equipment must be spread across significant acres to be cost competitive with broadcasting. For both reasons, increasing adoption of injection will depend heavily on Valley haulers, farmer cooperatives, or similar entities investing in injectors and nurse trucks. New incentives that promote injection should be aimed at these entities.

Part III: Cover Crops Following Wheat

Cover crops following wheat help diversify a crop rotation. The earlier planting date for the cover crops produces more biomass and allows full expression of the cover crop attributes. Components of a cover crop mixture are dependent on the timing of planting, intended use of the cover crop, prevailing weather patterns and subsequent crop. Summer annual grasses can dominate cool season species when seeded in July. Brassicas, even at low seeding rates, can dominate a mixture on high nitrogen sites when seeded in early August.

Weed suppression should be utilized to reduce weed competition and enhance the establishment of the cover crop. Do not plant the cover crop immediately after the wheat harvest. Allow the summer annual weeds and volunteer wheat to germinate before killing the weeds and seeding the cover crop. A modest rate of nitrogen may be required on low nitrogen sites for mixes dominated by grasses and forbs. A PSNT sample prior to seeding provides a good prediction of nitrogen availability for the cover crop.

The option to harvest, and especially to graze, alternative cover crops and mixes is part of their appeal and great potential. Promoting more integrated crop-livestock systems could vastly increase adoption of alternative rotations and cover crops in Virginia. Fall grazing of cool season species can provide supplemental forage without significantly suppressing the cover crop. Stand density and composition are maintained for regrowth in the spring. Grazing of summer annual mixes should be done prior to the flower emergence to maximize the quality of the forage.

Although wheat production for grain is not widely practiced in the Shenandoah Valley, wheat represents an additional cash crop that allows more diversity in a crop rotation system. Following wheat with a cover crop can maximize the beneficial effects on soil health and crop rotation diversity. Additional studies should compare cover crop treatments to no cover cropping to allow an economic analysis. This study did not have a no cover crop control treatment so no definitive economic analysis was possible.

Studies under local conditions are necessary to convince farmers that the results can apply to their operations. The use of cover crops is typically a break even proposition. The increase in cash crop yield essentially offsets the cost of establishing the cover crop. Long term benefits are attributed to cover crops which can assure sustainability. Quantifiable sampling and tests need to be developed to characterize the contributions of cover crops to long term soil health.

References

1. Manure Injection in No-till and Pasture Systems. Virginia Cooperative Extension (VCE), CSES Publication 22P pubs.ext.vt.edu/CSES/CSES-22/CSES-22- PDF.pdf

Summary of Work Done to Achieve Deliverables

1. Conduct over the life of the project a minimum of 12 on-farm demonstrations involving multi-species cover crops. It is recommended, but not required, that demonstrations be established at four different locations during each project year (4 demonstrations x 3 years = 12 total demonstrations).

   Eleven cover crop strip trials were planted by 9 cooperating farmers in 2012 and 2013.
   Six cover crop demonstrations to evaluate cover crops after wheat were planted on four farms in 2015 and 2016.

2. Ensure that at least 8 of the above cover crop demonstrations include high diversity seed mixes containing at least one species from each of the following groups – grass, nitrogen-fixing legume, and non-nitrogen-fixing broadleaf (forb).

   Each cover crop trial contained at least one high diversity seed mix. The earlier studies looked at 3 species mixes and one 9 species mix. The later studies examined multi-species mixtures with 7, 8 or 13 species.

3. Ensure the following minimum elements are included in each cover crop demonstration:

   a) Each demonstration will include at least one comparison designed to show the impact of multi-species cover crops on the performance of the subsequent harvested crop. Examples of possible comparisons include but are not limited to: subsequent crop yield on cover cropped area vs. adjacent non-cover cropped (control) area; subsequent crop response to normal vs. reduced nitrogen (N) fertilizer on cover cropped area; etc. More sophisticated comparisons are recommended whenever possible.

      All of the cover crop studies were followed by corn the following spring. The initial studies examined the benefits of multi-species cover crops compared to traditional small grain cover crops. The later studies compared a summer annual multi-species cover crop mix to a winter annual multi-species cover crop mix.

   b) Whenever possible, demonstrations should be located on the same sites for multiple years in order to evaluate the impact of repeated cover cropping on performance of subsequent crops and soil health and properties.

      Due to the crop rotations of cooperating farmers the project was unable to repeat the field demonstrations on the same site for multiple years.

   c) Whenever possible, cover crop comparisons should be replicated and randomized to increase the statistical validity of any collected data.

The project emphasis was on larger scale field demonstrations as opposed to smaller replicated plots. The same treatments were repeated on different farms to observe the results under a variety of farming systems.

d) Each cover crop demonstration will be designed and managed to facilitate collection of the data listed below.

The demonstrations utilized strip plots across an entire field to allow for machine planting and harvesting of the crops.

4. Collect, analyze, and summarize (when appropriate in map format) the following data for each cover crop demonstration, as feasible for site managers and conditions:

a) Previous crop and soil management history for the demonstration areas.

Cooperators provided cropping history for each site.

b) Cover crop management details (cover crop species, seeding rate, timing of seeding, inoculation at seeding, timing and method of termination, growth stage at termination, etc.).

Data was recorded for each demonstration to document the techniques and key conditions.

c) Qualitative and/or quantitative evaluation of cover crop performance (yield, forage quality, etc.).

Data collected included yield of cover crops, forage analysis and visual observations.

d) Description of harvested crop(s) planted after cover crops in the demonstration and qualitative and/or quantitative evaluation of harvested crop performance (yield, etc.).

Subsequent crops were visually rated and evaluated for yield. Plant tissue samples were taken for analysis.

e) Any and all details pertinent to comparisons showing impact of multi-species cover crops on subsequent crop performance. Examples include differential nitrogen fertilization rates applied to cash crops following cover crops and associated yield responses.

PSNT data clearly illustrated the tie up of nitrogen by conventional small grain cover crops relative to multi-species cover crops.

f) Partial budgets for each demonstration showing estimate of net economic impact of multi-species cover crops on farmer’s bottom line.

Costs for each cover crop mix were calculated. Since minimal differences in yield were observed the multi-species cover crop mixes increased the cost of production in the short term.

5. Conduct over the life of the project a minimum of six (6) annual on-farm demonstrations involving liquid manure injection. It is recommended, but not

required, that demonstrations be established at two different locations during each project year (2 demonstrations x 3 years = 6 total demonstrations).

2012 demonstrations on two farms
2013 demonstration on one farm (repeat cooperator from 2012)

6. Ensure the following minimum elements are included in each manure injection demonstration:

   a) Each demonstration will include at least one comparison designed to show the impact of manure injection vs. traditional manure application methods on the performance of the subsequent harvested crop. Examples of possible comparisons include but are not limited to: subsequent crop yield on injected area vs. adjacent broadcast area; subsequent crop response to differential rates of nitrogen (N) fertilizer rates in the injected area; etc. More sophisticated comparisons are recommended whenever possible.

      Injection was compared to broadcast manure applications. Injected strips did not receive sidedress nitrogen applications but yielded the same.

   b) Whenever possible, demonstrations should be located on the same sites for multiple years in order to evaluate the impact of repeated manure injection on performance of subsequent crops and soil health and properties.

      One study was repeated at the same location in 2012 and 2013.

   c) Whenever possible, manure injection comparisons should be replicated and randomized to increase the statistical validity of any collected data.

      Every study included 3 replications of each treatment at each site.

   d) Each manure injection demonstration will be designed and managed to facilitate collection of the data listed below.

      The manure injection demonstrations were arranged as strip plots across an entire field so data could be collected with farm machinery.

7. Collect, analyze, and summarize (when appropriate in map format) the following data for each manure injection demonstration, as feasible for project managers and conditions:

   a) Previous crop and soil management history for the demonstration area.

      Cooperators provided cropping history for each site.

   b) Manure management details (manure analysis, rate and method of application, expected nutrient availability, etc.).

      Plant available nitrogen based on manure analysis was used to calculate the manure application rates.

   c) Qualitative and/or quantitative evaluation of manure applications (odor, soil nitrate testing results, etc.).

      Observations collected and documented for each study.

d) Description of harvested crop(s) planted after injection and qualitative and/or quantitative evaluation of harvested crop performance (tissue testing, yield, etc.).

Yield data was collected for all plots. Tissue sampling was conducted at some sites.

e) Any and all details pertinent to comparisons showing impact of manure injection on subsequent crop performance. Examples include differential nitrogen fertilization rates applied to cash crops following manure injection and associated yield responses.

The focus of the studies was to document the total nitrogen application rate on corn could be reduced by injecting manure. The data clearly showed that equal corn yields could be obtained by injecting manure and eliminating sidedress nitrogen applications of 70 pounds nitrogen/acre.

f) Partial budgets for each demonstration showing estimate of net economic impact of injection on farmer's bottom line.

An economic analysis which included additional equipment cost, slower application speeds and nitrogen expense was conducted. Even though the initial expense of application is greater manure injection is just as profitable when considering overall management.

8. Ensure that cover cropping and manure injection demonstrations are co-located or integrated whenever possible, in order to evaluate the potential advantages of incorporating both techniques on the same field as well as to increase the value on on-site educational events.

   A November 2012 field day included both cover crops and manure injection.

9. Partner with appropriate Virginia land grant university system and/or Virginia Cooperative Extension (VCE) personnel in planning and designing the above demonstrations and in analyzing and interpreting associated data.

   Local extension agents provided the coordination and oversight of all studies.

10. Conduct qualitative and/or quantitative soil assessment at each demonstration site to investigate impact of multi-species cover cropping and manure injection on soil health and properties. Project managers will collaborate with appropriate Virginia land grant university system and/or VCE personnel in selecting appropriate soil assessment procedures and interpreting results.

    Standard and PSNT soil test data were collected for most studies. The manure injection studies revealed the importance of soil sampling from the injection site to accurately access the nutrient concentrations.

11. Partner directly with a minimum of four different farmers who will host and/or participate in demonstrations.

    Four on farm field tours relating to cover crops were conducted in 2012 and 2013 with an additional three farm field tours conducted in 2015.

    Two farm tours relating to manure injection were conducted in 2012 and 2013.

12. Provide participating farmers, in a timely manner, with data associated with their demonstrations in order to maximize farmer engagement in the project and boost farmer understanding of the costs and benefits of the practices.

    Cooperating farmers were responsible for planting and harvesting plot areas. All data was shared with the cooperators. Farmer's provided input on the economic analysis of the various treatments.

13. Organize at least two on-farm educational events at demonstrations sites during the life of the project.

    Charlie White, Penn State extension specialist, was brought in to speak at the November 2013 on farm field day.

    A National Fish and Wildlife Foundation field tour visited one of the cooperating farms and highlighted the cover crop demonstrations in November 2016.

14. Explain project activities and results to Virginia farmers and/or their advisors at a minimum of at least three (3) additional indoor or outdoor agricultural meetings over the life of the project (in addition to the two field day events described above).

    Results and updates of the studies were presented at the VANTAGE winter conferences during 2013, 2014, 2015 and 2017 in Harrisonburg. The final results of the cover crop studies were also presented at a VANTAGE conference in Franklin County in February 2017. A presentation was made at the 2013 meeting of the VA Chapter of Soil & Water Conservation Society. Results were also presented at a November 2013 educational session sponsored by the Virginia Cooperative Extension and NRCS. The cover crop information was presented at a Shenandoah Valley Professional Crop Advisors meeting in January 2016.

15. Publicize the project through at least five (5) direct mailings to farmers. Mailings should include distribution of details about project results as well as announcements about educational events described above.

    All demonstrations and field tours were publicized through mailings, email, flyers, press releases and radio announcements.

16. Help produce at least one video presentation about the project to be aired on the Virginia Farming television show.

A video about the experience with cover crops after wheat is still under production. A script has been written, photos collected and a sound track recorded.

17. Collect and summarize feedback from farmers collaborating in the cover cropping and manure injection demonstrations. Also collect and summarize if possible feedback from farmers attending educational events, etc.

    Evaluation forms were distributed at each field day. Some farmers provided feedback during open discussion periods.

18. Develop at least one final document summarizing the overall findings and lessons learned from this project in a case study format. This report should include a summary of participating farmer feedback. The primary audience for this document will be farmers and their advisors. It is strongly recommended, but not required, that this final document be developed in partnership with VCE specialists and take the form of an official Virginia land grant university system publication.

    Farmer feedback is highlighted in two NRCS facts sheets. One fact sheet focuses on the cover crop studies of 2012 and 2013. The second fact sheet summarizes the findings of the manure injection studies. A third fact sheet is being developed for the cover crop after wheat studies.

19. Make readily available through websites including the VANTAGE website and one or more VCE sites the above video and final report as well as other updates about the project.

    The two completed fact sheets are posted on the VANTAGE and NRCS websites. Plans are to post the third fact sheet and video once they are finalized.

20. Participate in at least one state CIG showcase or other comparable event in Virginia designed to highlight projects supported by Virginia NRCS CIG (if NRCS organizes such an event).

    An NRCS CIG showcase was held in Staunton on April 12, 2016. The VANTAGE projects were a significant part of the program. The showcase concluded with an on-farm plot tour to review cover crops at one of the cooperating farms.

Appendix A

Growth Stage Comparisons of the Cover Crops Used in the Part III Cover Crops After Wheat Demonstrations

Legumes

Sunn Hemp

4 days

2 weeks

9 weeks

Cowpea

10 days

3 weeks

9 weeks

Hairy Vetch

8 days

3 weeks

12 weeks

Crimson Clover

2 weeks

4 weeks

9 weeks

Austrian Winter Pea

8 days

3 weeks

13 weeks

Brassicas

Daikon Radish

4 days

3 weeks

11 weeks

T Raptor

4 days

3 weeks

15 weeks

Forbs

Buckwheat

10 days

3 weeks

5 weeks

Sunflower

8 days

3 weeks

9 weeks

Grasses

Sudangrass/Sorghum

8 days

3 weeks

9 weeks

Pearl Millet

10 days

3 weeks

9 weeks