VIRGINIA CORN BOARD

PROJECT REPORT- 2024/2025

TITLE: Utilizing Cover Crops to Offset Fertilizer Inputs for Corn in Virginia

PROJECT LEADER:

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OTHER ENTITIES: We contracted with private laboratories to analyze cover crop, corn, and corn grain biomass for macro- and microelements as private laboratories can conduct the work cheaper than Virginia Tech labs.

INTRODUCTION: Drastic increases in fertilizer costs have greatly impacted the profitability of corn production in Virginia. Cover crops were shown to reduce required fertilizer inputs, especially in regards to nitrogen, when utilizing legume cover crop species like hairy vetch (Finney et al., 2016; Norris et al., 2020). Employing cover crop mixtures of both legume and non-legume species can minimize the inherent tradeoffs between N supply and N retention services these cover crops provide when planted in monocultures (Finney et al., 2016, 2017; White et al., 2017). Furthermore, highly leachable nutrients like potassium [on low cation exchange soils (CEC); i.e. sandy loam and loamy sands of the Coastal Plain] can be mined from deep within the soil profile by cover crops and released from cover crop biomass to the concurrent corn crop that growing season (Sharma et al., 2018).

OBJECTIVE: The overall objective of this project was to research the impact of various cover crop species and crop rotations on corn yield, and cover crops' ability to offset nitrogen and other macro nutrient fertilizer inputs.

MATERIALS AND METHODS: This long-term cover cropping systems study was established in fall 2014 at the Eastern Shore Agricultural Research and Extension Center (ESAREC) to observe the effects of 12 different crop rotations on soil health and cash crop yields. Initially, the study evaluated 12 different crop rotations over a 3-year cycle. In 2023, the study was modified to better align with common crop rotations used by Virginia farmers, shifting to a 2-year repeating crop rotation. The updated design includes 4 replications of each crop rotation treatment.

For the 2023-2024 growing season, cover crops were planted on October 10, 2023, following the corn harvest in treatments 3, 4, 5, 7, 11, and 12 (see Table 3 for cover crop species and seeding rates). In 2024, five treatments were continuous corn, and the remaining seven treatments consisted of either three wheat-double-crop soybean treatments or four full-season soybean treatments. Wheat was planted on October 20, 2023, in treatments 8-10, receiving 30 lb. N/acre (UAN) at planting, followed by 80 lb. N/acre on March 13, 2024.

On April 29, 2024, one day before planting, four 0.125 m^2 aboveground cover crop and weed biomass samples were collected per plot across all treatments. These samples were analyzed for macro- and micronutrient content and total carbon percentage. Corn was planted on April 30, 2024, in the five continuous corn treatments, with 50 lb. N/acre of UAN was broadcast on the corn treatments after planting. Full-season soybeans were also planted on April 30, 2024, in treatments 6, 7, 11, and 12. At the V5-V6 growth stage, corn treatments were sidedressed with 150 lb. N/acre.

Wheat was harvested on June 29, 2024, with yield calculated at 13.5% moisture, and double-crop soybeans were planted immediately following harvest. Corn treatments were harvested on October 9, 2024, with yield calculated at 15.5% moisture, and soybean treatments were harvested on November 25, 2024, with yield calculated at 13% moisture. Grain samples from all treatments will be analyzed for macro- and micronutrients to evaluate the role of cover crops and crop rotations in nutrient cycling and soil health.

RESULTS AND DISCUSSION:

Cover crop biomass/nutrient data

Significant differences were observed in cover crop biomass, weed biomass, and nutrient accumulation ($p < 0.001$); see Table 4. The nine-species Kitchen Sink mix produced the highest dry aboveground biomass (5,132 lb. acre^{-1}) and accumulated the greatest amounts of phosphorus (42 lb. P_2O_5 acre^{-1}), potassium (219 lb. K_2O acre^{-1}), and sulfur (12.2 lb. S acre^{-1}). Despite generating less aboveground biomass (3,991 lb. acre^{-1}), the hairy vetch treatment (treatment 4) accumulated significantly more nitrogen (179 lb. N acre^{-1}) than the Kitchen Sink mix (153 lb. N acre^{-1}) and a statistically similar amount of phosphorus (Table 4). Monoculture cereal rye and cereal rye dominated Residue Maker mix treatments produced significantly lower aboveground biomass, less than 3,000 lb. acre^{-1}. Treatment 3 (continuous corn and cereal rye) produced the lowest aboveground biomass (1,471 lb. acre^{-1}) in 2024. This treatment has shown a steady decline in cover crop biomass production over the last 10 years, starting at over 7,500 lb. acre^{-1} in spring 2015 and decreasing around 600 lb. acre^{-1} annually. This decline highlights the effects of N depletion in the continuous corn and cereal rye CC rotation. Similarly, the poor performance of cereal rye in other treatments also reflects declining biomass trends attributed to

N depletion. This is why corn was fertilized at the highest rate, to help offset the depletion in soil N in these plots.

Corn, Soybean, and Wheat Yields

Significant differences were observed in corn yield ($p = 0.004$), wheat yield ($p = 0.004$), and soybean yield ($p = 0.002$); see Table 5 for yields. Treatment means ranged from 72.1 to 95.0 bu. $acre^{-1}$ for corn yields ($LSD_{0.05}$ = 10.7 bu. $acre^{-1}$), 47.6 to 57.4 bu. $acre^{-1}$ for wheat yields ($LSD_{0.05}$ = 4.4 bu. $acre^{-1}$), and 33.3 to 59.1 bu. $acre^{-1}$ for soybean yields ($LSD_{0.05}$ = 13.4 bu. $acre^{-1}$). The no cover crop controls observed higher corn yields than the cover crop treatments in 2024. The no-till no cover crop control (treatment 2) yields were not significantly different from corn yields following cereal rye or hairy vetch (treatments 3 and 4). Significant drought conditions and volunteer rapeseed negatively impacted the Kitchen Sink treatment corn yields. Additionally, corn treatments were fertilized at 200 lb. N/acre total and data from previous years have shown less cover crop effect on corn yields at high N fertilizer rates (Haymaker, 2024; Wolters, 2019). Despite the significant amount of N accumulated by Vetch and Kitchen Sink cover crop treatments, the drought conditions coupled with the application of 200 lb. N $acre^{-1}$ fertilizer diminished any potential positive impact these cover crops could have had on corn yield. Cover crop effects are more clearly observed during the all-corn year (Table 1) due to the split-plot design and variable N sidedressing rates applied. This design allows for a more nuanced evaluation of how different cover crops and N management strategies interact to influence corn yield.

Wheat yields were significantly higher in treatments with cover crops in the rotation than in the no cover crop control (Table 5). For soybeans, no significant differences were found within double-crop treatments (8-10) or full-season treatments (6, 7, 11, 12), suggesting that cover crop incorporation did not significantly affect soybean yields within these cropping systems. However, soybean yields in the no cover crop control treatments tended to trend lower, indicating a potential benefit of cover crops we have observed in previous years.

Significant drought conditions observed in 2024 negatively affected all cash crop yields. This abnormally dry year underscores the critical importance of conducting long-term research studies, which generate valuable data to assess the enduring effects of cover crop adoption under varying environmental conditions. Additionally, it may take several years to fully observe the long-term impacts of the recent modification to the experimental design. All yield data will inform economic analyses to assess the profitability of integrating cover crops into Virginia row crop production systems.

OUTREACH:

Haymaker, J., & Reiter, M. (2025, Jan. 2). *Nutrient Uptake and Release by Cover Crops.* 2024 Shenandoah Valley Crop Production School. New Market, VA.

Haymaker, J., & Reiter, M. (2024, Nov. 20). *Effects of Long-Term Cover Crop Usage on Crop Yields, Nutrient Cycling, and Soil Quality*. 2024 Mid-Atlantic Crop Management School. Ocean City, MD.

Haymaker, J., Wolters, B., Reiter, M., Mason, J., Stewart, R., & Balkcom, K. (2024, Nov. 13). *Assessing Soil Quality Improvement in Virginia's Coastal Plain through Long-Term Use of Cover Crops and No-Tillage Practices*. [Oral Presentation]. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/157805

Haymaker, J., Reiter, M., Mason, J., Stewart, R., Stephenson, K., & Balkcom, K. (2024, Sept. 24). *Economic and Yield Benefits of Using Cover Crops to Reduce Nitrogen Fertilizer Inputs in Corn Production on U.S. Coastal Plain Soils.* [Oral Presentation]. 22nd International Soil Tillage Research Organisation Conference, Virginia Beach, VA.

Haymaker, J., Reiter, M., Mason, J., Zahed, M.M., Stewart, R., Stephenson, K., & Balkcom, K. (2024, Aug. 1). *Cover crop nutrient accumulation and release*. 2024 Virginia Ag Expo. Champlain, VA

Haymaker, J., & Reiter, M. (2024, Jan. 29). *Fertilizing Corn with Cover Crops: When will cover crop nutrients be available?* 2024 Southeast Virginia Field Crops Conference. Virginia Beach, VA

Haymaker, J., Mason, J., & Reiter, M. (2024, Jan. 25). *Cover Crops: The Fertilizer Recycler*. 2024 Eastern Shore Ag Conference. Belle Haven, VA

Haymaker, J., & Reiter, M. (2024, Jan. 16). *Soil Fertility in 2024: What to Consider?* Virginia Crop Production Association. Richmond, VA

PUBLICATIONS:

Haymaker, J. R. (2024). Cultivating Sustainability: Analyzing Soil Health Dynamics and Economics of Cover Crops in the Mid-Atlantic. https://vtechworks.lib.vt.edu/handle/10919/96592

CONCLUSION:

Results from this study have generated a valuable dataset for evaluating the long-term impacts of cover crops on soil health and cash crop yields, with a particular focus on their effects on corn yields. The recent modification to the experimental design will provide a more accurate assessment of cover crop integration in Virginia corn production over time. The negative impact of cover crops on corn yields in 2024 can be attributed to the significant drought conditions experienced at the research site, as well as the high N fertilizer rates applied to address N depletion in the soils. Results from this study were presented at numerous extension events to Virginia farmers across the state and will continue to be disseminated at multiple winter extension meetings in 2025, as well as through future extension publications and journal manuscripts. These efforts aim to share key findings with Virginia farmers, helping them make informed decisions about integrating cover crops into their production systems.

Table 1. Description of the Eastern Shore AREC long-term cover cropping systems 2-year rotation. In Summer 1 (2023/2025), all treatments were/will be planted in corn and split plot design will be implemented to incorporate variable N sidedressing rates.

Treatment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Description	Baseline A: All corn, tilled, no CC	Baseline A2: All corn, no-till, no CC	All corn, grass CC, High C:N	All corn, legume CC, Low C:N	All corn, diverse CC, Mid-C:N	Baseline B: Corn/FSSB, no CC	Vetch/ Corn, Rye/FSSB	Baseline C: Corn/W/ DCSB, no CC	Vetch/Corn/Wheat /DCSB	Low C:N Mix/Corn/ Wheat/ DCSB	Cover Crop Mixes, Corn/FSSB	VA DCR Cost Share, Cereal Rye Rotation
Winter 1	Fallow	Fallow	Rye	Vetch	9sp Mix	Fallow	Vetch	Fallow	Vetch	High N Fixer 2 Mix	N Cycler 2 Mix	Rye
Summer 1 (2023/2025)	Corn (tilled)	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn
Winter 2	Fallow	Fallow	Rye	Vetch	9sp Mix	Fallow	Rye	Wheat	Wheat	Wheat	Residue Maker 2 Mix	Rye
Summer 2 (2024/2026)	Corn (tilled)	Corn	Corn	Corn	Corn	Full Season Soybean	Full Season Soybean	Double Crop Soybean	Double Crop Soybean	Double Crop Soybean	Full Season Soybean	Full Season Soybean

Table 2. Description of the Eastern Shore AREC long-term cover cropping systems 3-year rotation from the first 9 years of the study.

Treatment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Description	**Baseline A: All corn, conventional tillage, no CC**	**Baseline A2: All corn, no-till, no CC**	**All corn, grass CC, High C:N**	**All corn, legume CC, Low C:N**	**All corn, diverse CC, Mid-C:N**	**Baseline B: Corn/FSSB, no CC**	**Corn/FSSB, Rotating grass/legume CC**	**Baseline C: Corn/Wheat/ DCSB, no CC**	**Corn/Wheat, 1 summer off, rotating CC**	**Corn/FSSB, 1 summer off, rotating CC**	**Corn in long rotation w/ annual CC**	**Corn in long rotation w/ perennial CC**
Investigation/ Demonstration Objectives	Control	Control	Simple cover (Rye)	Simple cover (Vetch)	Kitchen Sink CC Diversity	Control	Simple cover (Vetch/Rye)	Control	Purposeful diversity (mixes with a purpose)	Purposeful diversity (mixes with a purpose)	Purposeful diversity (mixes with a purpose)	Purposeful diversity (mixes with a purpose)
Winter1	Fallow	Fallow	Rye	Vetch	Kitchen Sink 9 species CC Mix	Fallow	Vetch	Fallow	Residue Maker CC Mix	N Fixer CC Mix	Wheat	Alfalfa, Red Clover, Orchardgrass Permanent CC to break rotation cycle.
Summer 1 (2015/2018/ 2021)	Corn (tilled)	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Soybean	Short Summer CC Mix	Tall Summer CC Mix	
Winter2	Fallow	Fallow	Rye	Vetch	Kitchen Sink 9 species CC Mix	Fallow	Rye	Wheat	Wheat	Residue Maker CC Mix	N Fixer CC Mix	
Summer 2 (2016/2019/ 2022)	Corn (tilled)	Corn	Corn	Corn	Corn	Soybean	Soybean	Soybean	Tall Summer CC Mix	Soybean	Short Summer CC Mix	
Winter3	Fallow	Fallow	Rye	Vetch	Kitchen Sink 9 species CC Mix	Fallow	Vetch	Fallow	High N Fixer CC Mix	Late Bloomers CC Mix	N Cycler CC Mix	
Summer 3 (2017/2020/ 2023)	Corn (tilled)	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn

Table 3. Eastern Shore AREC long-term cover cropping systems, cover crop seeding rates.

Cover Crop Treatment Name	Grasses			Brassicas		Legumes			Forbs	Total Seeding Rate
	Black Oats	Triticale	Cereal Rye	Forage Radish	Rapeseed	Austrian Winter Pea	Crimson Clover	Hairy Vetch	Phacelia	
	lb. acre^{-1}									
Rye			112							**112**
Vetch								20		**20**
Kitchen Sink	10	10	10	1	1	10	3	4	1	**50**
Residue Maker 2			55		2	20				**77**
N Cycler 2	15				2		20			**37**
High N Fixer 2			22		2	30		12		**66**

Table 4. Aboveground cover crop and weed dry biomass and nutrient accumulation at termination. Nutrient analysis was conducted on weed biomass in control treatments. Fisher $LSD_{0.05}$ letters separating means by treatment within each column.

Treatment	Cover Crop Species/Mix	Cover Crop Biomass	Weed Biomass	Total Biomass	N	P_2O_5	K_2O	S
		lb. acre^{-1}						
1-CT Corn Control	-	-	1033 a	1033 f	13 e	9 d	29 f	2.2 de
2-NT Corn Control	-	-	1023 a	1023 f	16 de	9 d	28 f	1.6 e
3-Rye/Corn	Cereal Rye	1471 d	211 b	1682 e	20 de	16 c	47 ef	2.7 de
4-Vetch/Corn	Hairy Vetch	3991 b	11 b	4002 b	179 a	45 a	185 b	9.8 b
5-Kitchen Sink/Corn	Kitchen Sink	5132 a	8 b	5140 a	153 b	42 a	219 a	12.2 a
6-C/FSSB Control	-	-	862 a	862 f	11 e	7 d	26 f	1.5 e
7-Vetch/Corn/Rye/FSSB	Cereal Rye	2260 c	136 b	2396 d	22 de	18 c	57 de	2.8 de
8-C/W/DCSB Control	-	-	-	-	-	-	-	-
9-Vetch/Corn/ Wheat/DCSB	-	-	-	-	-	-	-	-
10-Low C:N Mix/Corn/ Wheat/DCSB	-	-	-	-	-	-	-	-
11-Low C:N Mix/Corn/ High C:N Mix/FSSB	Residue Maker 2	2838 c	175 b	3012 c	40 c	25 b	82 c	4.4 c
12- Rye/Corn/Rye/FSSB	Cereal Rye	2964 c	228 b	3193 c	29 cd	23 b	77 cd	3.5 cd
$LSD_{0.05}$		737	247	593	13	5	24	1.4

Table 5. Cash crop yields in 2024. Fisher $LSD_{0.05}$ letters separating means by treatment within each column.

Treatment	Corn	Wheat	Soybean
1-CT Corn Control	95.0 a	-	-
2-NT Corn Control	92.2 ab	-	-
3-Rye/Corn	82.7 bc	-	-
4-Vetch/Corn	82.9 b	-	-
5-Kitchen Sink/Corn	72.1 c	-	-
6-C/FSSB Control	-	-	48.0 ab
7-Vetch/Corn/Rye/FSSB	-	-	51.3 ab
8-C/W/DCSB Control	-	47.6 b	33.3 c
9-Vetch/Corn/Wheat/DCSB	-	57.4 a	40.2 bc
10-Low C:N Mix/Corn/Wheat/DCSB	-	54.1 a	34.2 c
11-Low C:N Mix/Corn/High C:N Mix/FSSB	-	-	59.1 a
12- Rye/Corn/Rye/FSSB	-	-	57.9 a
$LSD_{0.05}$	10.7	4.4	13.4