BIOAg Project Report

Report Type: FINAL

Title: Improving forage quantity and quality through organic fertilizer and no-till seeding in Western Washington

Principal Investigator(s) and Cooperator(s):

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Abstract: Forage production is the largest agricultural land use in western Washington supporting a diverse livestock industry. Poor grazing management and repeated hay removal without amendment contribute to reduced productivity, encroachment of weeds, erosion, and inadequate forage quality to support animal health. This integrated research and extension project addresses the WSU Sustaining Resources Grand Challenge. Its goal is to optimize organic fertilizer and no-till practices in order to reduce cost of pasture renovation, increase regional production of quality forage, conserve soil resources and improve organic weed management.

This project leverages existing funding and partnerships between WSU Extension and Conservation Districts implementing no-till seeding programs. Research will: 1) test the impact of fertilizer and no-till seeding on forage quantity, quality, and species composition; 2) test fall and spring plantings of five legume species to determine appropriate planting time and species for no-till seeding. Extension components will: 1.) facilitate producer to producer information exchange, 2.) training on the use of no-till seed drill and 3.) new literature on forage management in western Washington giving producers access to the information, training, and tools they need to successfully evaluate and implement new practices.

Project Description:

This project is investigating techniques for improving forage quality and quantity of established hay fields through use of no-till seeding and organic fertilizer amendment. This will be achieved through the three primary objectives:

Objective #1: Evaluate impact of organic fertilizer and no-till seeding on forage quantity, quality, and species composition.

Objective #2 Identify optimum legume species and planting time for no-till seeding in established sod.

Objective #3: Conduct outreach to support adoption of forage quality improvement through fertilizer and no-till forage seeding.

Outputs

- **Overview of Work Completed and in Progress:**

Objective #1: Evaluate impact of organic fertilizer and no-till seeding on forage quantity, quality, and species composition.

- Three on-farm trials were established in San Juan County. Three years of data collection have been completed and preliminary results have been presented. Results from forage quality testing in 2022 are pending.

Objective #2 Identify optimum legume species and planting time for no-till seeding in established sod.

- Two on-farm trials were established in fall 2020 to evaluate 5 legume species, one in San Juan County and one in Pierce County. Additionally, 7 on-farm demonstrations were planted in San Juan County and one tilled demonstration plot was planted in Pierce County.
- Spring planted no-till legume trials were planted in 2021 in Pierce and San Juan counties.
- Data collection was completed in spring and fall of 2021 and spring of 2022 in San Juan County. Preliminary results have been presented and results from forage quality testing in 2022 are pending.

Objective #3: Conduct outreach to support adoption of forage quality improvement through fertilizer and no-till forage seeding.

- See outreach and educational activities below.

- **Methods, Results, and Discussion (discussion for final reports only):**

Objective #1: Evaluate impact of organic fertilizer and no-till seeding on forage quantity, quality and species composition.

Field Trials: Three on-farm trials (Coffelt, Beaverton, Dill) were established in San Juan County. At each site four plots (12 ft x 50 ft) were seeded in fall of 2019 with a mixture of Italian ryegrass 'Crusader' and white clover 'Kakariki' using a no-till drill (Land Pride 606NT), adjacent to unplanted control plots. Coffelt and Beaverton locations were mowed prior to seeding, Dill had minimal vegetation so was not mowed. In spring 2020 seeded and control plots were split into five sub plots (12 ft x 10 ft) and amended with a base fertilizer and varying rates of nitrogen using bone meal (4-13-0), K+SOP (0-0-50) and feather meal (11-0-0). Design is split-plot complete block with four replicates of main plot level.

Treatments: Main plot treatments are: 1.) Seeded (Italian ryegrass at 30 lbs/acre and white clover at 6 lbs/acre); and 2.) Unseeded Control. Subplot treatments are: i.) Control (no fertilizer); ii. Base (32 lbs N/acre, 104 lbs P_2O_5/acre, 60 lbs K_2O/acre); iii.) Base + 22 lbs N/acre; iv.) Base + 54 lbs N/acre; and v.) Base + 88 lbs N/acre. Base fertilizer rate was determined from soil tests taken fall 2019. Trial areas were cut for hay by farmer cooperators after forage data was collected.

Figure 1. Laying out plots and applying organic fertilizer at Dill Rd location, April 30, 2020 (credit: B. Brouwer).

Data Collection and Analysis: Forage quantity and quality was determined by harvesting, drying and weighing plant material in from one quadrat (0.5 m x 0.5 m) placed in the center of each sub plot. Forage was cut at a height of 2 inches and wet weight was measured. Samples were sealed, refrigerated, and shipped to Puyallup Research Extension Center where they were oven dried and weighed to determine moisture content in 2020. In 2021 and 2022 samples were air dried in a greenhouse prior to shipping and oven drying. Dry samples were milled and submitted to Soiltest Lab (Moses Lake, WA) to measure forage quality parameters by NIR. Species composition was determined at the time of forage sampling, by placing one quadrat in the center of each plot and estimating percent coverage of species present. In the fall, percentage cover of functional groups (grass, legume, other forbs, and bare ground) was estimated in the center of each plot. Data analysis has been conducted using *R.* Two-way analysis of variance (ANOVAs) were performed with a blocking term to test all statistical hypotheses and determine significance associated with variation among treatment responses to factor levels using fixed effects. All model assumptions were tested using Levene's test of homogeneity of variance and the Shapiro-Wilk test to assess normality of model residuals. Data were transformed when appropriate using Tukey's ladder of powers to meet assumptions. All ANOVA tests were completed using the car package and type II sum of squares, except when interactions between factors were identified, in which case type III sum of squares were calculated. Post-hoc pair-wise comparisons were constructed using Tukey's honestly significant difference test (Tukey's HSD). For models that did not meet assumptions, non-parametric permutational univariate analysis of variance (using PERMANOVA procedures) was completed using the vegan package.

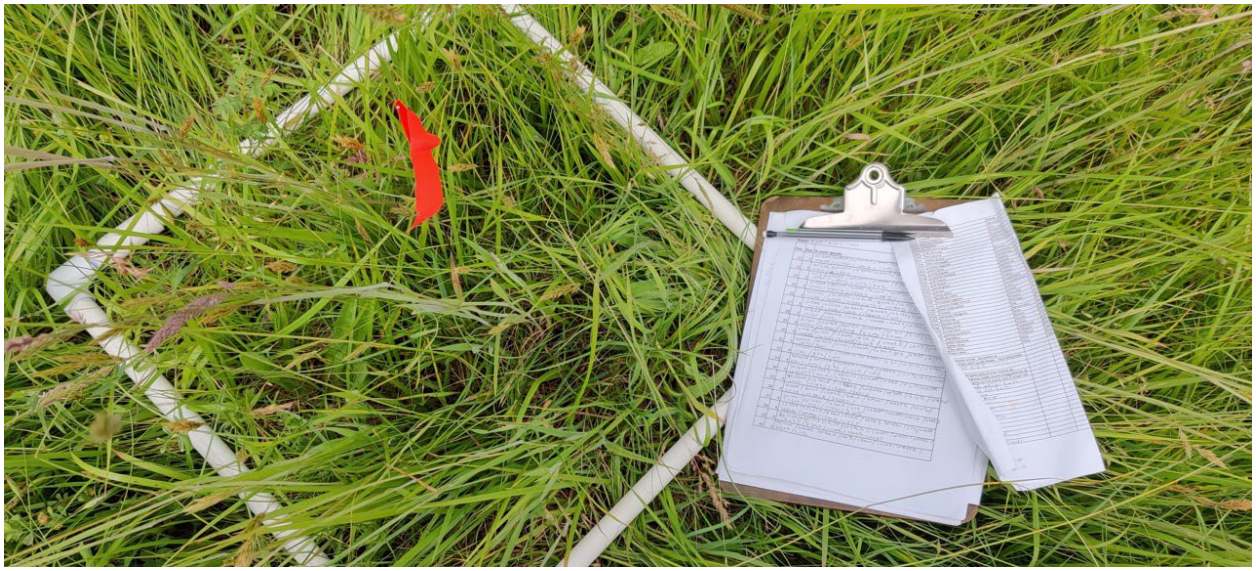

Figure 2. Species composition and percent cover determination at Coffelt trial plots. June 22, 2020 (credit: B. Brouwer).

Objective #2 Identify optimum legume species and planting time for no-till seeding in established sod.

Field Trials: On-farm trials were established in Pierce and San Juan counties to evaluate spring and fall plantings of five legume species: alfalfa (*Medicago sativa*), hairy vetch (*Vicia villosa*), red clover (*Trifolium pretense*), white clover (*Trifolium repens*), birds foot trefoil (*Lotus corniculatus*) and a no-seed control. Legume seed was inoculated with species appropriate Rhizobium spp.. The trial design is split-plot complete block with four replicates of main plot level. Main plot is legume species and sub plot is seeding time (spring or fall). Sub plots are 6 ft x 50 ft. Trial sites are established hay fields and will be harvest according to local practice after forage data collection.

San Juan County: Trial is located at SJC Land Bank Beaverton Marsh Preserve. The field was mowed to approximately 1" stubble height on 9/22/20. Planting was started on 9/29/20 (vetch, birdsfoot, and white clover) and completed 9/30/20 (alfalfa and red clover). Based on soil test collected 9/3/20 from each block, organic fertilizer was applied to reach target of 100 lbs P2O5/acre and 115 lbs K2O/acre using bone meal (4-13-0) and K+SOP (0-0-50). Spring planting was conducted 5/7/21 after mowing the plots on 4/30/21.

Figure 3. Seeding legume trial at Beaverton Marsh Preserve 9/30/20 (credit: B. Brouwer).

Pierce: The field experiment was initiated on 9/29/2020 at a cooperating farmer's pasture in Puyallup, WA. The field was mowed with a flail mower as low as possible without disturbing soil (approximately 1 in). Treatments were planted with a no-till drill (Land Pride 606NT).
In addition to the replicated no-till experiment a tilled demonstration plot was installed adjacent to the no-till experiment. The plot was 30 X 20 ft and plants were seeded at the same rate as the no-till trial. Spring planting was conducted 4/29/21 after flail mowing the plots.

Soils were sampled by taking one sample across the no-till field and a separate sample across the full-till plot. Fertilizer was applied 5/26/21 at a rate of 30 lbs N per acre (Feather meal 12-0-0) and 70 lbs K2O per acre (K+ SOP 0-0-50).

Data Collection and Analysis: Visual observation in fall of 2020 indicated that determining stand establishment would not be possible, due to limited growth of new seedings. Spring forage quantity, quality and species composition was determined using same methods as described above under Objective #1 methods except two sub samples were taken from each subplot. San Juan County was sampled 6/21/21 and 6/16/22 and Puyallup was sampled 6/22/21. Fall percent cover measurements were conducted 11/9/21 in San Juan County and 9/24/21 at Puyallup.

Table 1. No-till pasture legume trial species, variety, germination, target and actual seeding rates for Pierce and San Juan County.

Plant	Species	Variety	Germ	Target Seeding Rate (lbs/acre)	Target (correct for germ) lbs/acre	Actual San Juan (lbs/acre)	Actual Pierce (lbs/acre)
Hairy Vetch	*Vicia villosa*	Namoi	0.92	30	33	33	47
Alfalfa	*Medicago sativa*	Magnum 7	0.85	15	18	18	18
Red Clover	*Trifolium pratense*	Emarwan	0.85	12	14	14	17
White Clover	*Trifolium repens*	Haifa	0.85	5	6	6	8
Birds Foot Trefoil	*Lotus corniculatus*	VNS	0.31	8	26	20	32

Results

Objective #1

Analysis of forage yield, forage quality and species composition data for Objective #1 shows that in 2020 fertilizer affected forage biomass at Coffelt ($p<0.001$) and Dill ($p=0.023$) but not Beaverton (Table 2). In 2021, fertilizer affected forage biomass at Beaverton ($p=0.002$) and Dill ($p<0.001$) and was marginally non-significant at Coffelt ($p = 0.061$, Table 3). High N rate forage yield was significantly higher than the control for pairwise comparisons of dry weight results (Table 2 and Table 3). No-till seeding did not affect forage biomass in 2020 or for most sites in 2021, though dry weight biomass decreased with seeding at Coffelt in 2021 ($p =0.009$). Similarly, fertilizer affected forage crude protein in 2020 at all sites (Table 2). However, in 2021 fertilizer only affected crude protein at Beaverton (marginally in seeded plots $p=0.045$) and Coffelt, ($p=0.002$) but not at Dill (Table 3). No-till seeding again had minimal to no effect in 2021.

Table 2. 2020 biomass and forage quality by amendment. Mean ± standard deviations for fertilizer treatments.

Observation	Fertilizer rate 1	Fertilizer rate 2	Fertilizer rate 3	Fertilizer rate 4	Fertilizer rate 5	p^1
Beaverton Marsh						
Dry weight (lbs/acre)	5197 ± 1005	5685 ± 1044	6205 ± 1161	5973 ± 1301	6594 ± 993	0.167
Crude protein (%)	5.8 ± 0.72^{a}	6.86 ± 0.6^{b}	7.28 ± 0.57^{b}	8.46 ± 1.1^{c}	10.2 ± 0.64^{d}	**0.001**
Relative feed value	87.8 ± 2.87	87.2 ± 2.31	85.2 ± 4.68	87.2 ± 3.54	88.5 ± 3.34	0.468
Acid detergent fiber	37.8 + 1.22	37.6 + 1.25	38.4 + 1.71	37.5 + 1.49	37.1 + 1.22	0.384
Neutral detergent fiber	63.0 + 1.77	63.7 + 1.10	64.6 + 2.35	63.8 + 1.73	63.2 + 1.62	0.925
Coffelt Farm Preserve						
Dry weight (lbs/acre)	3345 ± 833^{a}	5018 ± 755^{bc}	4617 ± 717^{ab}	6193 ± 1339^{c}	6272 ± 1572^{c}	**0.001**
Crude protein (%)	7.79 ± 0.63^{a}	8.57 ± 0.86^{a}	8.89 ± 1.03^{a}	10.3 ± 0.99^{b}	11.3 ± 1.11^{b}	**0.001**
Relative feed value	93.2 ± 6.39^{b}	82.6 ± 4.53^{a}	86.1 ± 3.98^{ab}	85.2 ± 4.59^{a}	85 ± 4.5^{a}	**0.003**
Acid detergent fiber	36.5 ± 1.53^{a}	39.2 ± 1.06^{b}	38.1 ± 1.36^{ab}	38.6 ± 1.29^{b}	38.5 ± 1.32^{b}	**0.006**
Neutral detergent fiber	60.6 ± 3.03^{a}	65.8 ± 2.91^{b}	64.0 ± 2.05^{ab}	64.2 ± 2.44^{ab}	64.6 ± 2.80^{b}	**0.008**
Dill Rd.						
Dry weight (lbs/acre)	1170 ± 130^{a}	1355 ± 571^{ab}	1796 ± 524^{ab}	1694 ± 524^{ab}	1869 ± 572^{b}	**0.023**
Crude protein (%)	9.71 ± 0.55^{a}	11.9 ± 1.78^{ab}	11.6 ± 1.07^{ab}	12.6 ± 1.79^{b}	13.7 ± 1.36^{b}	**0.001**
Relative feed value	113 ± 8.22^{a}	128 ± 16.6^{b}	120 ± 5.55^{ab}	$132 + 12.7^{b}$	$130 + 8.11^{b}$	**0.001**
Acid detergent fiber	36.1 ± 1.86^{a}	32.8 ± 2.68^{b}	34.5 ± 1.02^{ab}	32.4 ± 1.83^{b}	32.7 ± 1.78^{b}	**0.002**
Neutral detergent fiber	50.2 ± 2.93^{b}	46.7 ± 4.48^{ab}	48.1 ± 1.73^{ab}	45.2 ± 4.10^{a}	45.3 ± 2.49^{a}	**0.002**

Table 3. 2021 biomass and forage quality by amendment. Mean ± standard deviations for fertilizer treatments.

Observation	Fertilizer rate 1	Fertilizer rate 2	Fertilizer rate 3	Fertilizer rate 4	Fertilizer rate 5	p^1
Beaverton Marsh						
Dry weight (lbs/acre)	3894 ± 437^a	4379 ± 800^a	3968 ± 1306^a	4375 ± 913^a	5367 ± 627^b	**0.002**
Crude protein (%)	-	-	-	-	-	-
Without seeding	8.02 + 0.97	7.38 + 0.86	7.45 + 0.77	8.05 +1.27	6.88 + 0.35	0.183
With seeding	8.07 + 1.15	10.3 + 2.5	10.1 + 3.48	7.9 + 1.57	7.35 + 0.86	**0.045**
Relative feed value	104 + 6.8^b	102 ± 4.87^b	102 + 6.28^b	99.9 + 5.84^{ab}	92.5 + 4.81^a	**0.007**
Acid detergent fiber	32.4 ± 1.82	32.5 ± 1.09	32.4 ± 1.58	32.7 ± 1.43	34.5 ± 1.43	0.061
Neutral detergent fiber	57.3 ± 2.53^a	57.9 ± 2.03^a	58.1 ± 2.50^a	59.1 ± 2.42^{ab}	62.6 ± 2.15^b	**0.001**
Coffelt Farm Preserve						
Dry weight (lbs/acre)	2005 ± 954	2529 ± 788	2398 ± 1213	2779 ± 934	3090 ± 1420	0.061
Crude protein (%)	8.82 ± 0.92^a	11 ± 2.24^b	9.16 ± 1.26^a	9.14 ± 1.26^a	8.52 ± 0.69^a	**0.002**
Relative feed value	96.8 + 4.83^{ab}	98.5 ± 4.75^b	97.4 ± 4.69^{ab}	92.6 ± 5.21^a	92.4 + 4.44^a	**0.009**
Acid detergent fiber	34.8 ± 0.99	34.6 ± 1.08	34.5 ± 1.21	35.8 ± 1.12	35.8 ± 1.09	**0.034**
Neutral detergent fiber	59.4 ± 2.44^{ab}	58.5 ± 2.22^a	59.5 ± 2.42^{ab}	61.5 ± 2.56^b	61.6 ± 2.59^b	**0.007**
Dill Rd.						
Dry weight (lbs/acre)	995 ± 355^a	1613 ± 442^{ab}	2541 ± 804^{bc}	3030 ± 674^{cd}	3657 ± 903^d	**0.001**
Crude protein (%)	11 ± 0.66	11.2 ± 0.6	10.5 ± 0.92	10.1 ± 1.32	10.1 ± 1.26	0.074
Relative feed value	126 ± 6.59^c	121 ± 6.50^{bc}	115 ± 8.65^{ab}	110 ± 6.28^a	109 ± 8.68^a	**0.001**
Acid detergent fiber	31.5 ± 1.30^a	32.2 ± 0.87^{ab}	33.5 ± 0.98^{ab}	33.8 ± 1.3^b	33.9 ± 2.19^b	**0.012**
Neutral detergent fiber	47.6 ± 1.92^a	49.1 ± 2.24^{ab}	51.0 ± 3.49^{abc}	52.8 ± 2.56^{bc}	53.4 ± 3.24^c	**0.001**

Based on fall functional group assessment, percent cover of grass was higher in fertilized plots at Beaverton ($p<0.001$) and Dill ($p<0.001$) in 2020 and higher at Dill in 2021 ($p=0.047$) and 2022 ($p=0.005$) (data not shown). No-till seeding affected percent cover of white clover at Coffelt ($p=0.002$) in 2020 (Table 4)and at Beaverton ($p=0.028$) and Coffelt ($p=0.011$) in 2021 (Table 5) there were no significant differences in fall 2022 (Table 6).

Table 4. 2020 Fall functional group percent cover by no-till seeding. Mean ± standard deviations for no-till seeding treatments.

Observation	Without seeding	With seeding	p^1
Beaverton Marsh Preserve			
Grasses (% cover)	91.8 ± 7.30	91.5 ± 6.51	0.894
Forbs (% cover)	0 ± 0	0.5 ± 2.24	1.0
Legumes (% cover)	2.95 ± 2.67	1.95 ± 2.65	0.174
Clover (% cover)	0.35 ± 1.14	0.1 ± 0.31	0.684
Coffelt Farm Preserve			
Grasses (% cover)	98.5 ± 2.35	96.2 ± 11.2	0.562
Forbs (% cover)	5.9 ± 5.53	6.65 ± 6.36	0.640
Legumes (% cover)	3.7 ± 4.35	6.8 ± 6.81	0.076
Clover (% cover)	0 ± 0^a	4.65 ± 6.96^b	**0.002**
Dill Rd.			
Grasses (% cover)	24.8 ± 15.3	21.8 ± 19.1	0.184
Forbs (% cover)	59.5 ± 13.0	63.2 ± 16.9	0.483
Legumes (% cover)	4.1 ± 5.83	4.05 ± 6.50	0.644
Clover (% cover)	0.05 ± 0.224	0 ± 0	1

Table 6. 2021 Fall functional group percent cover by no-till seeding. Mean ± standard deviations for no-till seeding treatments.

Observation	Without seeding	With seeding	p^1
Beaverton Marsh			
Grasses (% cover)	87.2 ± 13.3	89 ± 12.2	0.592
Forbs (% cover)	0 ± 0	0.25 ± 1.12	1
Legumes (% cover)	18.0 ± 14.9	16.6 ± 13.5	0.663
Clover (% cover)	0 ± 0	2.8 ± 4.97	**0.028**
Coffelt Farm Preserve			
Grasses (% cover)	94.2 ± 4.06	91.2 ± 7.41	0.154
Forbs (% cover)	5.75 ± 4.67	6.15 ± 5.60	0.188
Legumes (% cover)	3.25 ± 3.19	2.9 ± 2.99	0.316
Clover (% cover)	0 ± 0	1.4 ± 2.70	**0.011**
Dill Rd.			
Grasses (% cover)	14.5 ± 6.86	14.5 ± 7.93	1
Forbs (% cover)	73 ± 14.1	69 ± 12.0	0.283
Legumes (% cover)	4.5 ± 3.03	5.2 ± 3.72	0.344
Clover (% cover)	1.35 ± 3.17	1.4 ± 3.55	0.916

Table 6. 2022 Fall functional group percent cover by no-till seeding. Mean ± standard deviations for no-till seeding treatments.

Observation	Without seeding	With seeding	p^1
Beaverton Marsh			
Grasses (% cover)	94.8 ± 4.13	94 ± 6.41	0.6744
Bare (% cover)	5.25 ± 4.13	6 ± 6.41	0.6744
Coffelt Farm Preserve			
Grasses (% cover)	94.5 ± 7.05	94.8 ± 4.44	0.88944
Forbs (% cover)	0.75 ± 1.52	0.65 ± 1.53	1
Legumes (% cover)	0.55 ± 1.54	0.25 ± 1.12	0.7059
Bare (% cover)	5.25 ± 6.97	5.25 ± 4.44	1
Dill Rd.			
Grasses (% cover)	53.8 ± 12.7	58.5 ± 13.8	0.197
Forbs (% cover)	41.5 ± 13.1	36.2 ± 12.4	0.165
Legumes (% cover)	1.5 ± 3.28	2 ± 2.99	0.412
Clover (% cover)	1.5 ± 3.28	2 ± 2.99	0.412
Bare (% cover)	3.5 ± 5.16	4 ± 6.61	0.738

Plant species composition was shown to vary with fertilizer rate at Dill in 2021 using non-metric multidimensional scaling (Figure 4, MRPP p= 0.001). There was also a significant difference in species composition associated with seeding at Coffelt in 2021 (MRPP p=0.012). No significant differences were found in species composition response to fertilizer or seeding at other sites in 2020, 2021 or 2022 (data not shown). There were significantly higher percent cover of white clover (*Trifolium repens*) with seeding at Coffelt in 2020, 2021 and 2022. There was also significantly higher Italian ryegrass (*Lolium perenne* ssp. *multiflorum*) at Coffelt in 2020 (p=0.006) (data not shown).

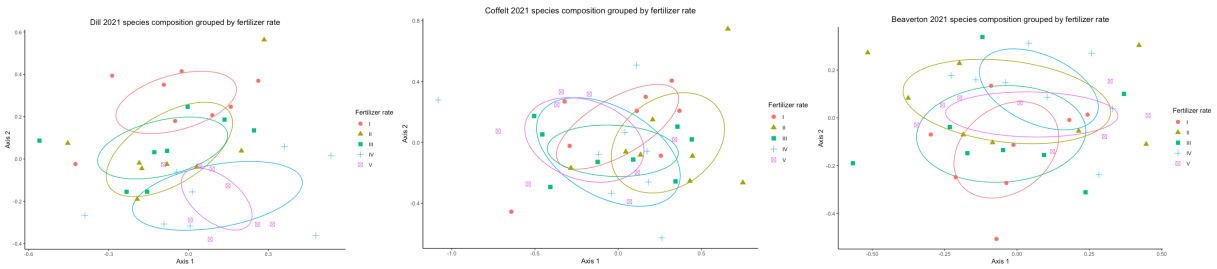

Figure 4. From left to right species composition grouped by fertilizer rate for trials at Dill Rd, Coffelt Farm, and Beaverton Preserve (Credit W. Andrews).

Objective #2

No-till seeding did not affect forage biomass by legume treatment in 2021. Forage biomass did increase overall by season planted for fall-planted legumes at Beaverton ($p < 0.001$). In 2021 percent cover of some legume species increased including fall-planted ($p<0.001$) and spring-planted Hairy Vetch ($p<0.001$) at Puyallup and spring-planted Hairy Vetch at Beaverton ($p<0.001$, Table 7). Fall-planted Red Clover at Puyallup also significantly increased in percent cover in 2021 ($p<0.001$, Table 7). In terms of forage quality, crude protein and relative feed value increased for spring-planted Hairy Vetch at Puyallup (Table 9, $p = 0.005$ and $p = 0.006$ respectively) in 2021. Neutral detergent fiber decreased for this same treatment combination (Table 9, $p = 0.011$). In 2022 no difference was observed in percent cover of planted legume species at Beaverton (Table 8).

Table 7. 2021 legume species percent cover by legume treatment. Mean ± standard deviations for legume treatments.

Observation	Control	White Clover	Trefoil	Red Clover	Alfalfa	Hairy Vetch	*p*[1]
Beaverton							
Hairy Vetch (% cover)	-	-	-	-	-	-	-
Spring	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	4.33 ± 4.54	**0.001**
Fall	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	-
Red Clover (% cover)	0 ± 0	0 ± 0	0 ± 0	0.042 ± 0.204	0 ± 0	0 ± 0	1
White Clover (% cover)	0 ± 0	0.042 ± 0.204	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1
Trefoil (% cover)	0 ± 0	0 ± 0	0.625 ± 3.06	0 ± 0	0 ± 0	0 ± 0	1
Alfalfa (% cover)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	-
Puyallup							
Hairy Vetch (% cover)	-	-	-	-	-	-	-
Spring	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	15 ± 12.6	**0.001**
Fall	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	2.67 ± 4.44	**0.001**
Red Clover (% cover)	-	-	-	-	-	-	-
Spring	0.417 ± 1.44	0.083 ± 0.289	0.417 ± 1.44	1.33 ± 3.08	1.25 ± 2.26	0.083 ± 0.289	0.330
Fall	0.417 ± 1.44	0.167 ± 0.389	1.25 ± 3.11	7.5 ± 6.57	0.417 ± 1.44	0.417 ± 1.44	**0.001**
White Clover (% cover)	0.208 ± 1.02	0.458 ± 1.41	0 ± 0	0.417 ± 2.04	1.08 ± 3.28	0.5 ± 1.41	0.456
Trefoil (% cover)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	-
Alfalfa (% cover)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	-

Table 8. 2022 legume species percent cover by legume treatment. Mean ± standard deviations for legume treatments.

Observation	Control	White Clover	Trefoil	Red Clover	Alfalfa	Hairy Vetch	p^1
Beaverton							
Hairy Vetch (% cover)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	-
Red Clover (% cover)	0 ± 0	0 ± 0	0 ± 0	0.312 ± 1.25	0 ± 0	0 ± 0	1
White Clover (% cover)	0 ± 0	0 ± 0	0.625 ± 2.5	0.312 ± 1.25	0 ± 0	0 ± 0	0.42
Trefoil (% cover)	0 ± 0	0 ± 0	1.56 ± 6.25	0 ± 0	0 ± 0	0 ± 0	1
Alfalfa (% cover)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	-

Table 9. 2021 no-till legume seeding biomass and forage quality by legume treatment. Mean ± standard deviations for legume treatments.

Observation	Control	White Clover	Trefoil	Red Clover	Alfalfa	Hairy Vetch	p^1
Beaverton							
Dry weight (lbs/acre)	1324 ± 121	1183 ± 146	1203 ± 130	1117 ± 125	1156 ± 226	1214 ± 138	0.073
Crude protein (%)	9.16 ± 1.38	8.84 ± 0.57	9.21 ± 1.12	8.62 ± 0.53	9.55 ± 0.85	8.99 ± 0.73	0.491
Relative feed value	112 ± 3.76	114 ± 5.08	113 ± 4.65	110 ± 4.21	117 ± 7.94	113 ± 3.99	0.127
Acid detergent fiber	31.2 ± 0.68	30.8 ± 0.71	31.0 ± 0.80	31.5 ± 1.04	30.2 ± 1.18	31.2 ± 0.87	0.101
Neutral detergent fiber	53.6 ± 1.49	53.1 ± 1.97	53.3 ± 1.76	54.6 ± 1.81	52 ± 2.75	53.4 ± 1.62	0.220
Puyallup							
Dry weight (lbs/acre)	2672 ± 330	2887 ± 567	2562 ± 686	2590 ± 848	2694 ± 852	2589 ± 841	0.837
Crude protein (%)	-	-	-	-	-	-	
Spring	11.2 ± 0.56^a	12.4 ± 1.22^{ab}	10.8 ± 0.85^a	11.2 ± 1.45^a	11.9 ± 1.27^{ab}	14.1 ± 1.33^b	**0.005**
Fall	11.2 ± 0.63	11.2 ± 1.34	10.1 ± 0.62	11.5 ± 0.56	11.5 ± 0.76	10.9 ± 0.70	0.176
Relative feed value	108 ± 8.63^a	112 ± 9.02^{ab}	110 ± 5.45^{ab}	114 ± 6.16^{ab}	113 ± 4.73^{ab}	115 ± 7.65^b	**0.006**
Acid detergent fiber	33.6 ± 1.35	33.7 ± 0.85	33.4 ± 0.67	33.2 ± 0.82	33.3 ± 0.95	32.3 ± 1.20	0.067
Neutral detergent fiber	54.2 ± 3.67^b	52.6 ± 4.12^{ab}	53.6 ± 2.50^{ab}	51.7 ± 2.54^a	52.0 ± 2.47^{ab}	51.7 ± 3.22^a	**0.011**

Discussion

Objective #1 Evaluate impact of organic fertilizer and no-till seeding on forage quantity, quality, and species composition.

In this study we found that fertilizer increased forage biomass, though the effect varied between locations and over time. Forage quality also showed mixed results, fertilizer effect on forage crude protein tended to decline after the first year indicating that the benefit of nitrogen fertilizer application has a relatively short-term impact on forage protein. Relative Feed Values (RFV) were generally lower with higher fertilizer rates. This may be due to the increased biomass resulting in a higher stem to leaf ratio in fertilized plots. Fertilizer also shifted the pasture composition at some locations resulting in a higher grass cover. Fertilizer shifted the species cover at one site in 2021, indicating the potential for nutrient management to change the relative abundance of species, particularly at sites with little grass coverage.

No-till seeding with Italian ryegrass and white clover did not have a significant effect on forage biomass or quality in this study. At one of the sites there was an increase in the percent cover of the species planted, indicating successful establishment. Italian ryegrass is a biannual, so it is likely that it did not persist after the initial year, whereas white clover is a persistent perennial. At the site where

establishment was successful, the planted species had very low percent cover likely due to the high degree of competition for existing vegetation. The limited success indicates a need for additional management strategies to improve the success of no-till seeding into established hay fields.

Objective #2 Identify optimum legume species and planting time for no-till seeding in established sod.

When evaluating different legume species for establishment in spring and fall planting, we found the most success with hairy vetch (*Vicia villosa*), an annual legume. Spring planted vetch resulted in increased forage protein and improved relative feed value at one site, indicating that interseeding this species has the potential to benefit forage quality. However, it was not found to persist past the first year. Further research is needed to determine the factors contributing to successful planting of legumes into established hay fields.

- **Publications, Handouts, Other Text & Web Products:**

Brouwer, B., Andrews, W., Stacey, N. E., Bary, A., & Collins, D. P. (2021) *Impact of Organic Fertilizer and No-till Seeding on Forage Quantity, Quality and Species Composition in Western Washington* [Abstract]. ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT. https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/138957

- **Outreach & Education Activities:**

Brouwer, B., A. Greene, S. Pope, B. Gregory, and A. Borner. June 29 2020. Field Webinar Walk: Improving forage quality and quantity. WSU San Juan County. Online. 25 participants.

On-farm demonstration plots. 2020. Seven farms were engaged to host demonstration plantings on their farms. At each site strips of 5 legume species were planted in fall of 2020.

Brouwer, B., B. Gregory, A. Borner. Feb 26, 2021. No-Till Drill Listening Session. Online. 16 participants.

Borner, A., B. Gregory, K. Mikulak and B. Brouwer. July 10, 2021. No-Till Seed Drill Training. San Juan. 14 participants.

Borner, A., B. Gregory, and K. Mikulak. July 17, 2021. No-Till Seed Drill Training. Orcas. 8 participants.

Borner, A., B. Gregory, K. Mikulak and B. Brouwer. July 24, 2021. No-Till Seed Drill Training. Lopez. 10 participants.

Brouwer, B., D. Collins, R. Skaggs and N. Warren. Sep 24, 2021. Hay Improvement Farm Tour and No-till Drill Training. Puyallup. 7 participants.

Brouwer, B. November 21, 2021. Impact of organic fertilizer and no-till seeding on forage quantity, quality and species composition in western Washington. Tilth Conference. Lynwood, WA. 17+ participants.

Brouwer, B., M. Chaney., B. Gregory., M. Claussen. April 21, 2022. Managing Livestock for Water Quality Workshop. Orcas. 12 participants.

Brouwer, B. May 9, 2022. Local Forage Research Pasture Walk. Lopez. 13 participants.

Brouwer, B. May 16, 2022. Local Forage Research Pasture Walk. San Juan. 11 participants.

Brouwer, B., K. Mikulak. May 23, 2022. Local Forage Research Pasture Walk. Orcas. 6 participants.

Impacts

- **Short-Term:**
  We have had 140+ participants in outreach and educational programs to date and our work has resulted in a change in knowledge regarding utilization of no-till drills, organic fertilizer management, no-till seeding for forage production, and more.

  Ninety percent of the 2020 Field Walk Webinar evaluation respondents reported their knowledge of the impact of fertilizer on forage quality and quantity increased from a moderate amount to a lot, 20% of respondents reported their knowledge of pasture aeration increased from a lot to a great deal, 30% of respondents reported increased knowledge of measuring forage and soil quality by a lot, 60% of respondents reported increased knowledge of no-till seeding into established fields from a lot to a great deal.

  From the 2021 no-till drill trainings with the SJICD, all of the respondents reported increased knowledge of how to operate a no-till seed drill, with 85% reporting their knowledge increased a lot to a great deal, and 100% of respondents reported increased knowledge of successful strategies for no-till pasture seeding, with 60% reporting their knowledge increased a lot to a great deal.

  Half of the participants at the Fall 2021 Hay Improvement Farm Tour and No-till Drill Training in Puyallup reported their knowledge of amending with organic fertilizer was increased to greatly increased, 83% of respondents said their knowledge of no-till drill seeding into hay or pasture fields increased to greatly increased, 33% reported their knowledge of planting more legume forage varieties increased to greatly increased, and 67% reported their knowledge of using no-till equipment increased to greatly increased.

  Seventy- six percent of participants in 2021 Tilth Conference presentation, (*Impact of organic fertilizer and no-till seeding on forage quantity, quality, and species composition in western Washington*) agreed or strongly agreed that their knowledge on the topic had greatly increased.

  All of the evaluation respondents from the Spring 2022 Managing Livestock for Water Quality Workshop reported increased knowledge of managing grazing for production and protecting water quality from a moderate amount to great deal, 100% of respondents reported increased knowledge of soil testing and determining amendment needs from a moderate amount to a lot, 100% of respondents reported increased knowledge of fence system design and set up

from a little to a lot, and 86% of respondents reported a moderate to great deal increase in knowledge of design and use of overwintering areas.

From the Spring 2022 Pasture Walks, all of the evaluation respondents reported increased knowledge of using no-till seed drill to establish new forage plantings from a moderate amount to a great deal, 68% of respondents reported their awareness of no-till planting equipment available in San Juan County increased from a moderate amount to a great deal, and 95% of respondents reported their knowledge of the impact of fertilizer on forage productivity and quality increased from a moderate amount to a great deal.

When averaged across multiple outreach trainings 75% of participants reported an increase in knowledge regarding use and operation of no-till drill. Additionally, 84% of participants reported increase in knowledge relating to soil amendment and use of organic fertilizer. These evaluation outcomes demonstrate a clear impact on knowledge gained among farm operators served through this project.

- **Intermediate-Term:**

In addition to knowledge change, participants in educational programs indicated that they are likely to make changes to production practices based on the information they learned. Participants outreach events managed 3,144 livestock and 3,407 acres of farmland, 3,334 of which is in San Juan County, representing over 18% of farmland in the county.

From the 2020 Field Walk webinar, 70% of respondents reported they are extremely likely to fertilize and amend pasture or hay fields, 30% are somewhat to extremely likely to aerate pasture or hayfields, 50% are extremely likely to use a no-till drill to plant new species into pasture or hay field, and 80% are extremely likely to conduct forage or soil testing.

All of the evaluation respondents from the Fall 2021 Hay Improvement Farm Tour and No-till Drill Training in Puyallup plan on seeding into hay or pasture fields using no-till equipment from a rental program in their county, 80% of respondents plan on amending with organic fertilizer, and 60% of respondents plan on planting more legume forage varieties. When asked what specific changes they plan to make to their forage management practices, participants indicated they plan to implement overseeding, weed removal, and no-till.

All of the respondents from the Spring 2022 Managing Livestock for Water Quality Workshop are likely to highly likely to implement changes to their soil testing, use of amendments, and livestock grazing practices, 67% are likely to implement changes to their fence systems, and 50% likely to implement changes to their use and set up of overwintering areas.

Eighty-four percent of Spring 2022 field walk eval respondents reported they are likely to highly likely to use a no-till drill for planting and 95% of respondents reported they are a likely to highly likely to implement changes to their nutrient management for forage production.

When averaged across multiple outreach events 60% of respondents indicate that they are likely or highly likely to utilize a no-till drill for pasture planting and 86% indicated that they are likely or highly likely to make changes to nutrient amendment or fertilizer practices. Based on fertilizer amendment trial results, adopting a high rate of fertilizer application could increase forage yield by approximately 1 ton/acre/year. If 50% of participants, representing half of the acreage managed by evaluation respondents in outreach programs to date (~1,500 acres) implemented this change it could results in an additional 1,500 tons of forage per year which valued currently at approximately $300/ton (USDA Columbia Basin Direct Hay Report 6/24/22) this would be a gross increase in value of $450,000.

- **Long-Term:**
  Improved forage species following no-till planting will increase productivity of grazing land, reduce erosion, and contribute to soil carbon storage. Similarly, appropriate nutrient management will improve the forage quantity and quality and reduce the need for imported feed. Follow up evaluation of participants is planned for early 2023 to assess implementation of no-till and amendment practices and assess possible barriers to adoption.

Additional funding applied for/secured:

Project leveraged partnerships with the San Juan Islands Conservation District and the Pierce Conservation District to conduct outreach events and additional on-farm demonstrations.

Approximately $6,000 in funding from San Juan County was leverage to complete forage quality testing in 2022.

A pilot study to evaluate the success of interseeding native prairie species into pastures was set up in fall of 2022 looking at a combination of no-till, broadcast seeding and shallow till treatments.

Graduate students funded:

None

Recommendations for future research:

Additional research is needed to improve success of no-till seeding into existing hay production fields using organic methods. What are the pre and post planting management strategies to optimize success of legume plantings? Observations from on-farm plantings indicate that no-till seeding of legumes is most successful in fields where nutrient deficiencies have been managed prior to planting, or where starter fertilizer is banded with the seed. In addition to nutrient management, pre and post planting mowing and grazing regimes may need to be modified to manage for persistence of new seedings.

This project demonstrated an impact from increased nitrogen fertilizer on forage quantity and quality. Future research to help identify the optimum fertilizer rate for other key nutrients, such as phosphorous and potassium, as well as the long-term impact following a single fertilizer application.

Our work found a variation in the success of establishment of different legume species. This indicates further research could be undertaken to identify the optimum species for different forage interseeding applications.