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Evaluation of Cover Crop Productivity for Integrated Crop-livestock Systems in the Intermountain West

Abstract

A multi-year cover crop trial was conducted at three sites to evaluate productivity by comparing the dry matter (DM) yield and reporting forage quality for five seed mixes. The treatments varied in species diversity from n=1 to n=11 when compared to sorghum-sudangrass (*Sorghum x drummondii*) solo. Plots were in Sanpete Co., UT, Cache Co., UT, and Davis Co., UT. Five treatments were replicated four times in a randomized complete block design at each site. Productivity and forage quality were evaluated 45 and 81 days after planting. Cover crop biomass 45 and 81 days after planting ranged 2.15 to 3.86 and 3.01 to 4.91 tons per acre, respectively. Forage quality was determined by the percent of protein, acid detergent fiber, and total digestible nutrient present. Biomass production was only affected by species diversity at one site 45 days after planting. There was not a significant divergence between biomass and species diversity at any site 81 days after planting. Cover crops may provide additional grazing opportunities when added to existing integrated crop-livestock production systems in the western U.S.

Introduction

The utilization of cover crops (CC) to improve soil sustainability has become a topic of interest among agriculture producers across the nation. The bulk of CC research has happened in the midwest and further eastward. Snapp et al. (2005) reviewed the benefits, costs, and overall performance of CC in cropping systems. According to Snapp et al. (2005), adding CC into a cropping system has the potential of reducing income, increasing production expenses, and could possibly interfere with other crops in the cropping system. However, farmers and researchers who used CC also found benefits such as: increased pest-suppression, better soil and water quality, more efficient nutrient cycling, and increased cash crop productivity (Snapp et al., 2005). Furthermore, it is unknown if the reported benefits are relevant in the western U.S., as these soils exhibit slower rates of organic matter accumulation and nutrient cycling than humid soils elsewhere (Aanderud et al., 2010). Although some progress has been made, data for CC in the western U.S. is incomplete (Finkelburg et al., 2016).

Regardless, the adoption of CC by farmers has been slow (Singer et al., 2007; Drost et al., 1996; Curran et al., 2018). Singer et al. (2007) also found that approximately 56% of farmers would be more willing to adopt CC practices if cost-sharing programs were available. Since 2007, many cost-sharing programs have been created by Federal and State agricultural agencies. With adoption, many producers hope to improve soil and cash crop productivity while using the CC as an annual forage. Consequentially, there is a need to understand CC when incorporated into western integrated crop-livestock systems. In this system, CC can be implemented during the period between silage corn or small grain harvest and fall or spring tillage. The CC and cash crop stubble are then removed by grazing livestock. This work evaluates the productivity of CC during these periods of time by comparing the dry matter (DM) yield and forage quality for five seed mixes. The seed mixes utilize replacement to increase species diversity from $n=1$ to $n=11$ when compared to sorghum-sudangrass (*Sorghum x drummondii*) solo. We grouped each species in the mix by the ecosystem services they provide as described by Magdoff and van Es (2021). Our intention was to add an additional group with each successive mix to encourage additional ecosystem services as diversity increased.

Materials & Methods

Research Sites

Three CC research sites were established across the State of Utah in Sanpete, Davis, and Cache counties. Each site represented a different climate within the State of Utah. In Sanpete County, plots were located at the Sustainable Ag Extension (SAGE) Center (39.369106, -111.586920). The Cache County plots were planted at the Intermountain Irrigated Pasture Project site (41.948284, -111.871566). The third site was located at the USU Botanical Center and research farm (41.022620, -111.934756) in Davis County, Utah. Elevation, season length and precipitation for each site is reported in Table 1. It is important to note that most of the research sites precipitation occurs in winter. Summer precipitation is infrequent and is of limited value to crop growth.

Table 1. Site Climate Information

Site	Elevation	Grazing Season Length (Days)	Annual Precipitation
Sanpete	5520'	120 (May 24 th – Sep 25 th)	12 inches
Cache	4500'	112 (May 26 th – Sep 15 th)	18 inches
Davis	4300'	172 (April 26 th – Oct 28 th)	18 inches

Treatments, design, and planting

Treatments consisted of five seed mixes. Species and their respective densities for each mix are found in Table 2. The five treatments were replicated four times in a randomized complete block design for a total of 20 plots at each site. Treatments were planted in May 2020 and 2021 with conventional tillage equipment. Seed drills were calibrated to plant at a rate of 40 lbs. per acre. Plots in Sanpete and Davis counties were 10' by 70' and the Cache plots were 12' by 70'. The difference in width was due to a difference in planting equipment. Drills were vacuumed thoroughly after the planting of each treatment. Because of the wide variety of plants and seed sizes within each mix, the drill was set to ¼ inch deep to avoid planting small seeds too deep. Irrigation was applied by handline within six hours of planting to ensure seed germination.

Table 2. Species density as a percentage by seed mix.

Species	Type	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
		-----%-----				
Sorghum-Sudangrass (<i>Sorghum x drummondii</i>)	Grass	100	75	55	30	12
Hairy Vetch (<i>Vicia villosa</i>)	Legume		25	35	45	12
Buckwheat (<i>Fagopyrum esculentum</i>)	Forb			10	15	3.5
Radish (<i>Raphanus sativus</i>)	Root crop				10	3.5
Faba Bean (<i>Vicia faba</i>)	Legume					35
Mung Bean (<i>Vigna radiata</i>)	Legume					7.5
Triticale (x <i>Triticosecale</i>)	Grass					7.5
Millet (<i>Pennisetum glaucum</i>)	Grass					10
Collards (<i>Brassica oleracea</i>)	Forb					3.5
Turnip (<i>Brassica rapa</i>)	Root crop					3.5
Canola (<i>Brassica napus</i>)	Forb					2

Crop Management

In the Intermountain west, irrigation is a standard practice for row crop and forage production. Plots were provided irrigation every two weeks for 8-12 hours throughout the growing season depending on location. Research plots in Sanpete were not fertilized prior to the growing season. In Cache and Kaysville in 2021, plots were fertilized with a low rate of ammonium nitrate (21-0-0) in 2020 and 2021, respectively, to increase litter decomposition from the previous crop. Prior to planting, the plots were disked and harrowed. Pesticides were not applied during the study period due to the species diversity in several treatments.

Harvesting & Sample Collection

Sample collection took place at 45 and 81 days after planting (DAP). Harvesting was accomplished using a BCS two-wheel tractor with a 48" sickle bar mower attachment to collect a single sample (40-80 sq ft) from the center of each plot. After mowing, CC biomass was weighed to determine yield from each plot. Subsamples were collected from each plot to determine dry matter yield. Subsamples were composited by treatment to analyze for crude protein (CP), acid detergent fiber (ADF), and total digestible nutrients (TDN). West chemistry analysis was provided by Utah State University Analytical Lab (USUAL).

Statistical Analysis

Each research site was analyzed individually, as conditions varied strongly among research sites. CC treatments were considered fixed effects and block was considered random. CC nutritional quality was not analyzed for differences because composite samples were analyzed by USUAL. Data were analyzed using the MIXED procedure of SAS. Mean separations were conducted utilizing the PDIFF option. A p-value of ≤ 0.05 was utilized to identify significant differences among CC treatments.

Results

Forage Yield

Species diversity or CC treatment had no effect ($p > 0.05$) on CC forage yield across all three sites when harvested 81 DAP (Table 3). No effect ($p = 0.9856$) on yield was observed between treatments 45 DAP in Cache (Table 3). In contrast, yield in Davis was affected ($p < 0.01$) by species diversity 45 DAP (Table 3). Mix 1 and mix 2 had significantly higher forage yield than all other seed treatments ($p < 0.05$). Seed mixes 1 and 2 yielded 3.17 and 2.94 tons per acre, respectively. Whereas Seed mixes 3, 4, and 5 yielded 2.49, 2.23, 2.15 tons per acre, respectively (Table 3). Sanpete plots were not harvested at 45 DAP.

Table 3. CC yield at three sites for 45 DAP and 81 DAP (2020 and 2021).*

Treatment	Davis County		Cache County		Sanpete County**
	45 DAP	81 DAP	45 DAP	81 DAP	81 DAP
----- tons/acre (DM) -----					
Mix 1	3.17 a	3.83 a	3.86 a	4.91 a	4.83 a
Mix 2	2.94 a	3.78 a	3.67 a	4.69 a	4.13 a
Mix 3	2.49 b	3.52 a	3.60 a	4.59 a	4.08 a
Mix 4	2.23 b	3.32 a	3.47 a	4.17 a	3.98 a
Mix 5	2.15 b	3.01 a	3.47 a	3.57 a	3.28 a

* Results followed by the same letter in each column were not significantly different.

** Results represent 2020 because the 2021 crop failed due to drought.

Nutritional Quality

CC nutritional quality was not analyzed statistically, but samples were taken to provide preliminary information for DM, CP, ADF, and TDN in a grazing setting at 45 (Table 4) and 81 DAP (Table 5).

Table 4. Forage quality at two sites for 45 DAP (2020).

Treatment	Davis County			Cache County		
	Protein	ADF	TDN	Protein	ADF	TDN
Mix 1	7.9	36.4	60.6	17.0	33.6	64.9
Mix 2	7.7	38.2	58.5	18.2	32.0	66.2
Mix 3	6.7	37.6	58.6	17.9	32.1	65.7
Mix 4	8.8	46.2	49.4	19.8	34.6	62.5
Mix 5	9.4	38.7	57.3	24.9	28.5	68.9

Table 5. Forage quality at three sites for 81 DAP (2020).

Treatment	Davis County			Cache County			Sanpete County		
	Protein	ADF	TDN	Protein	ADF	TDN	Protein	ADF	TDN
Mix 1	5.9	44.0	52.5	9.4	41.4	55.2	8.5	41.3	54.8
Mix 2	6.2	42.8	53.7	11.3	42.3	54.2	8.1	40.2	56.1
Mix 3	5.6	42.4	53.8	10.3	41.7	55.0	9.8	39.6	56.7
Mix 4	7.2	41.8	55.0	10.6	45.6	51.3	9.9	37.3	59.2
Mix 5	6.9	43.8	52.9	15.2	45.6	51.7	10.9	37.0	59.7

Discussion and Implications

Forage and Adoption

CC grown during summer may be a viable option for producers desiring to use alternative forages in integrated livestock crops systems of the western U.S. To facilitate positive producer attitudes for CC adoption, it is important to present CC production data so that producers can understand the degree of CC compatibility with their current production system (Lavoie, 2021). Alfalfa (*Medicago sativa*) is a major crop in each of the 11 western states (AZ, CA, CO, ID, MT, NM, NV, OR, UT, WY; Yost et al., 2020). Productivity and forage quality of alfalfa are used in this work to provide context to CC as forage in the western U.S. Late harvested CC DM of 3.01 to 3.83, 3.57 to 4.91, and 3.28 to 4.83 ton/acre from Davis, Cache, and Sanpete respectively, were similar to the Utah average for alfalfa of 3.7 ton/acre (USDA-NASS, 2017). Though less productive than late CC, early harvested CC from Cache contained similar amounts of CP 17.0 to 24.9% as alfalfa in early to mid-bloom, but CP content of 6.7 to 9.4% from early CC in Davis illustrates that CP may be highly variable and difficult to explain because forage quality analysis was not replicated (Cassida, 2000). Regardless, CC forage quality is acceptable for grazing and can provide valuable livestock forage in the fall when livestock are returning from summer pastures. However, similarly to alfalfa, grazing should be done with care. Alfalfa may cause bloat in livestock and prussic acid levels can be dangerously high in sorghum-sudangrass under certain conditions (Pitcher, 2022; Slade, 1903). Sorghum-sudangrass dominant CC may exhibit higher prussic acid

when plants are immature, drought stressed, exposed to high rates of nitrogen fertilizer, or experience frost damage. Therefore, monitoring toxicity with lab analysis, reducing plant stress, grazing mature plants, and waiting 5-7 days following a killing frost can mitigate the risk of livestock poisoning.

Species Diversity

Globally, biomass productivity is highly variable and dependent on adaptability of CC to growing region due to temperature, humidity, days of growth, and other factors (Ruis et al., 2019). Results indicate that species diversity may influence the productivity of CC under irrigation when grown for less than eight weeks in comparison to sorghum-sudangrass alone. However, results did not indicate a significant difference in DM with increased species diversity in comparison to sorghum-sudangrass alone when irrigated and after at least eight weeks of growth prior to termination. In contrast, Ruis et al. (2019) reported that globally, sorghum monocultures are more productive than two-species and complex mixes. The differences between the results and global averages could be explained by water availability limiting productivity. Irrigation for establishment increases biomass of single species and mixed CC by 42% (Ruis et al., 2019). When irrigated at establishment, mixed CC productivity increased 76% and 115% in humid and semiarid regions respectively (Ruis et al., 2019). Furthermore, when CC are grown in water-limited semiarid environments they deplete soil water, reduce biomass, weed cover, and subsequent cash crop yield (Rosa et al., 2021). This suggests that irrigation has a negative effect on interspecific competition allowing for the result observed in this experiment. However, it is important to stress that more work is needed to elucidate whether irrigation caused this observation.

Future work

Soil health and sustainability has created great interest in cover crops across the Intermountain west. Although this project did not measure soil health parameters, or many of the services provided by CC they should be evaluated in this environment. More work is also needed to explain why biodiversity had little effect on DM in this study. Research may focus on irrigation, time of termination, or other factors.

Furthermore, additional analysis of CC forage quality and DM at shorter termination timings for monocultures and mixes may increase applicability for those desiring to adopt CC.

Another component of CC that should be considered are the economics behind planting and grazing different mixes of cover crops in the western U.S. This study planted CC at 40 lbs./acre and seed prices at this rate may be exceptionally high. However, the value of cover crops as grazing forages cannot be forgotten. In future years, the economics may be able to be tied to soil health and services provided by CC.

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