COVER CROPS IN SEMI-ARID DRYLAND WINTER WHEAT (*Triticum aestivum*, L.) FALLOW ROTATION

E. Moore and U. Norton
University of Wyoming, Laramie, WY
Emoore24@uwyo.edu (307)766-3111

ABSTRACT

Winter wheat (*Triticum aestivum*, L.) (WW) is a primary dryland crop in the semi-arid part of the US Great Plains. Local producers have been interested in incorporating cover crops (CC) to a WW-fallow rotation, but information on the CC impacts on soil moisture, plant available nitrogen (N) and competition with weeds in a low precipitation region is limited. In this collaborative study, a producer designed and planted two CC mixes: (1) legume-dominated three species mix (**69-17**-14) (3S legume dominated): forage pea (*Pisum sativum* L.), red clover (*Trifolium pratense* L.), daikon radish (*Raphanus sativus* L.) and (2) grass-dominated four species mix (**55**-35-7-3) (4S grass dominated): oat (*Avena sativa* L.), forage pea (*Pisum sativum* L.), daikon radish (*Raphanus sativus* L.) purple top turnip (*Brassica rapa* L.). Soil and vegetation sampling occurred at eleven weeks and a second soil sampling at twenty-six weeks to determine CC impact on soil moisture, soil inorganic nitrogen (IN) and weed competition. Soil moisture was not compromised by either CC mix treatment. The 4S grass dominated outperformed 3S legume dominated by suppressing weedy species and increasing soil IN. A twelve-week laboratory incubation showed that, under optimum soil moisture levels (23%), ammonium (NH_4) and dissolved organic carbon (DOC) was significantly higher in both CC treatments and was highest in 3S legume-dominated. In areas of low precipitation, legume dominated mixes do not perform as well as grass dominated mixes. At optimum soil moisture however, when plant biomass is incorporated into the soil, legume dominated mixes return more N and C to the soil. Fallow could benefit from incorporation of carefully-designed CC mixes but further testing needs to be conducted to establish the most suitable CC mixes for semi-arid areas of very low precipitation.

INTRODUCTION

In semi-arid regions, WW production typically involves a 24-month wheat-fallow rotation where the fallow period lasts 14 months (Bista et al., 2017). During the fallow period of organically certified production, weed management primarily consists of frequent tillage leading to soil organic matter (SOM) mineralization and loss of soil carbon (C) and nitrogen (N) (Ghimire et al., 2018). A possible solution to overcome these challenges is designing agronomic systems that incorporate cover crops (CC).

Cover crop mixtures with diverse plant families offer more benefits than a CC monoculture (Murrell et al., 2017). Grasses offer fast germination with fibrous roots that aid in weed smothering, N scavenging and C sequestration (Finney et al., 2016). Brassicas can germinate under low water conditions, grow deep taproots, and produce large amounts of biomass and legumes fix atmospheric N (Bowman et al., 2012). Broadleaf plants, like Phacelia (*Phacelia tanacetifolia* Benth L.) offer quick germination, high biomass, and drought tolerance (Smither-Kopperl, 2018). The main objective of this research was to evaluate two producer designed CC mixes from the perspective of soil health benefits and weed competition in SE Wyoming.

MATERIALS AND METHODS

This study took place in Pine Bluffs, Wyoming (41.18°N LAT, 104.07°W LONG, 1539 meters above sea level). Soils are loamy with pH of 7.3. Average precipitation was 44.5 cm with 157.48 cm of snowfall. Average high and low temperatures were 16.3°C and -9.0°C respectively (*U.S. Climate Data*, 2022). The site was under an organic certified dryland WW-fallow with CC inclusion. Two CC mixes were planted on April 7, 2020; (1) three species and legume-dominated (**69-17**-14) (3S legume dominated): forage pea (*Pisum sativum* L.), red clover (*Trifolium pratense* L.), and daikon radish (*Raphanus sativus* L.) and (2) four species and grass-dominated (**55**-35-7-3) (4S grass dominated): oat (*Avena sativa* L.), forage pea (*Pisum sativum* L.), daikon radish (*Raphanus sativus* L.), and purple top turnip (*Brassica rapa* L.) (Table 1). Additional treatments included a weedy fallow (WF) where the ground was tilled once and then allowed to fallow without any weed control and a cultivated fallow (CF) treatment where the ground was tilled five times for weed control throughout the fallow period.

Table 1. Cover crop mix breakdown of common name, scientific name, life form, planting rate and percent of mix.

3 Species Legume Dominated Cover Crop Mix (40 Kg ha^{-1})				
	Scientific Name	Lifeform	Kg ha^{-1}	% Mix
Daikon Radish	*Raphanus sativus*	Broadleaf	6	14
Forage Pea	*Pisum sativum*	Legume	28	69
Red Clover	*Trifolium pratense*	Legume	7	17

4 Species Grass Dominated Cover Crop Mix (81 Kg ha^{-1})				
	Scientific Name	Lifeform	Kg ha^{-1}	% Mix
Oats	*Avena sativa*	Grass	45	55
Daikon Radish	*Raphanus sativus*	Broadleaf	6	7
Purple top Turnip	*Brassica rapa*	Broadleaf	2	3
Forage Peas	*Pisum sativum*	Legume	28	35

Sampling took place during a fallow phase. The timing of samplings provided an examination of soil parameters and plant populations during the growing season while cover crops were actively growing. Vegetation sampling took place during the June (summer) sampling only. Two quadrats (one square foot surface area) were placed randomly in each treatment. Plants were cut at soil level, separated into CC and weeds, and placed into paper bags. The quadrat was then flipped horizontally, and the same collection steps were taken. Plant bags were oven dried at 60°C for 48 hours to establish percent moisture and overall dry biomass.

Soil samples were collected in June and September (fall). Four soil cores (0-15 cm depth) were collected using a step-down auger probe. Samples were homogenized, stored in a plastic zipper bag, placed in a cooler with ice until processing within 48 hours of collection. In the lab, soils were sieved through a 2 mm sieve and analyzed for: (1)

gravimetric soil water content (Gardner, 1986); (2) electrical conductivity (EC) and soil pH on a 1:2 soil-to-water ratio; (3) inorganic N (sum of NH_4-N and NO_3-N) on an extract obtained from placing 10 g of fresh soil to 25 ml of two molar potassium chloride (2 *M* KCl) and analyzed (Doane & Horwáth, 2003) on a spectrophotometer microplate reader (UV-VIS Biotek Instruments, Highland park, USA).

A twelve-week lab incubation was conducted to observe potential C and N mineralization at soil field moisture capacity (23%). Field samples were collected by placing a quadrat (same size as above) at random in each block. Aboveground biomass was clipped at soil level and stored in a plastic zipper bag. The top 15cm of soil was collected (belowground root biomass included) homogenized and placed in a plastic zipper bag. At time of processing, plant biomass was cut into 2.5 cm long segments and homogenized with the soil to imitate tillage practices. Samples were placed in a 50 ml Falcon centrifuge VWR tube. Tubes from each treatment were labeled: month 1, month 2, and month 3 and all were placed in a wide-mouth quart mason jar fitted with a lid containing a septum. To ensure soil 23% moisture level, gravimetric water content was determined and needed amount of DI water was added to each tube. At the end of each month one tube was removed, soil was sieved and processed for gravimetric water content, NH_4, and DOC in the same methods as mentioned above.

All statistical analyses were performed in R version 3.6.2 (Team, 2021). The effects of cover crop treatment and time in growing season, on soil and plant properties were assessed using two-way Analysis of Variance (ANOVA) ($P \leq 0.05$). Data were tested for normality using the Shapiro–Wilk test. Transformations were used to achieve normality. Tukey HSD was used to determine treatment significance at a minimum of $P \leq 0.05$. For non-normal data, a Kruskall-Wallis rank sum test was used, followed by the Dunn test to determine significance. Regression analyses was performed on soil moisture and plant biomass data to assess weed suppression by cover crop treatment (Kutner, M. , Nachtsheim, C., Neter, 2004)**.**

RESULTS AND DISCUSSION

The 4S grass dominated mix produced the highest amount of CC biomass, and weedy species biomass was 27 g m^{-2} less than WF (Figure 1). There was a smothering effect of CC on weedy species at a rate of y = 27.32 – 0.08(4S grass dominated Biomass), $R^2 = 0.60$. Weedy species biomass in WF and 3S legume dominated were comparable however (Figure 1). The 4S grass dominated effectively reduced weedy species and outperformed 3S legume dominated. Planting CC increased total plant biomass by 147% in 3S legume dominated and 165% in 4S grass dominated.

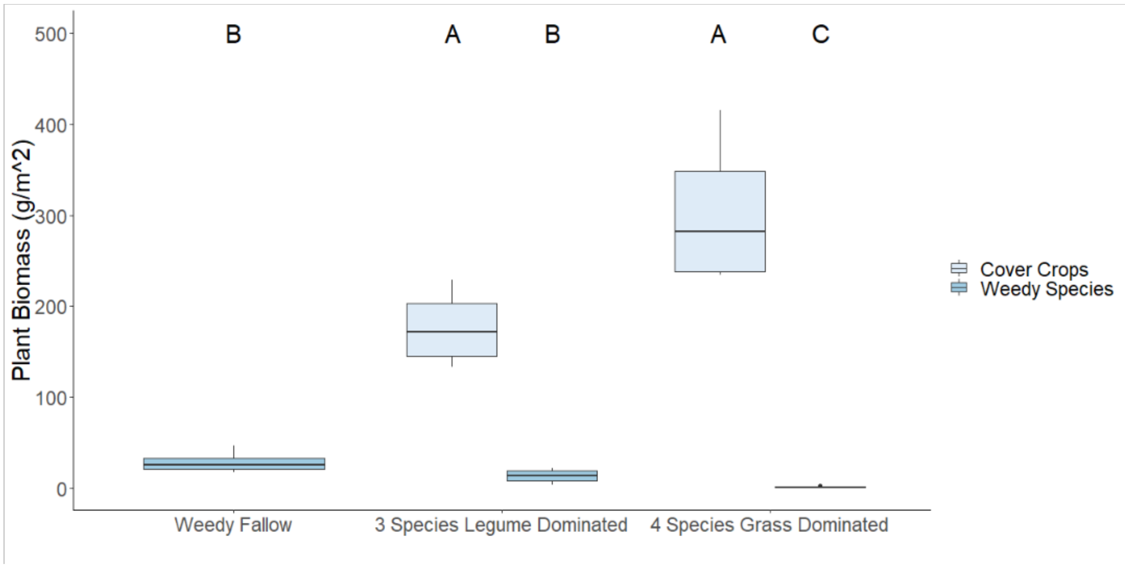


Figure 1. Plant biomass of cover crops and weeds in weedy fallow and cover crop treatments. Different uppercase letters demonstrate treatment differences at p ≤ .05.

Summer sampling demonstrated that soil moisture beneath the two CC mixes did not significantly differ from that of WF or CF, but WF had the lowest soil moisture overall while CF had the highest (Table 2). At fall sampling, where timing corresponded with WW planting, soil moisture was comparable among all treatments (Table 2). Overall, CF had the highest decline in soil moisture between summer and fall, while changes to soil moisture under CC mixes were negligeable. This is consistent with other findings where good soil coverage from CC biomass helped conserve soil moisture (Wortman et al., 2012, 2013).

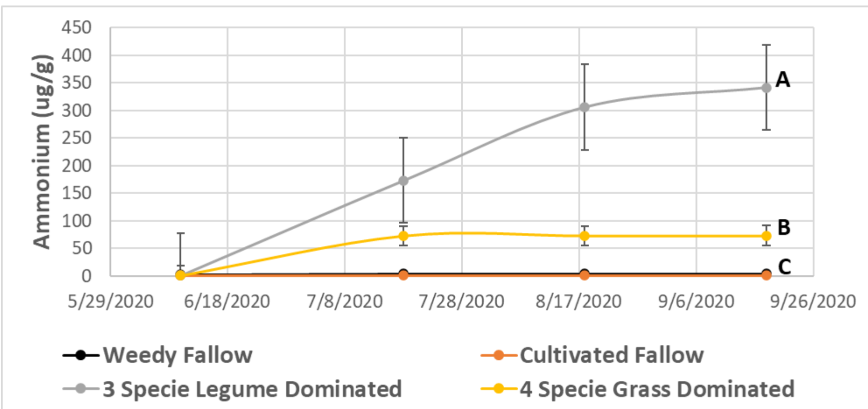
Summer sampling showed that WF had the highest IN concentrations of all treatments, while 4S grass dominated had the lowest (Table 2). In contrast, fall sampling showed that IN concentrations beneath 4S grass dominated were the highest of all. Over time, both fallows demonstrated a decrease in IN concentrations with CF having the largest decrease (Table 2), while the most IN concentration gain was observed beneath 4S grass dominated. The beneficial traits of the grass in 4S grass dominated were seen in soil N accrual.

Table 2. Seasonal changes for soil moisture, soil inorganic N and soil labile N in weedy fallow, cultivated fallow and cover crop treatments. Different uppercase letters demonstrate treatment differences at p ≤ .05.

FARM 2	TRT	Summer	Fall	% Difference
Soil Moisture (g g^{-1} OD Soil)	Weedy Fallow	0.01 (.001) B	0.02 (.13) A	100.00
	Cultivated Fallow	0.20 (.07) A	0.09 (.04) A	-55.00
	3 Species Legume Dominated CC	0.10 (0.09) AB	0.12 (0.08) A	20.00
	4 Species Grass Dominated CC	0.11 (0.07) AB	0.09 (0.03) A	-18.18
	Weedy Fallow	40.43 (13.07) A	27.63 (1.99) B	-37.61

Soil Inorganic Nitrogen (µg g^{-1})	Cultivated Fallow	27.43 (5.17) AB	2.66 (0.99) D	-164.64
	3 Species Legume Dominated CC	11.95 (6.93) BC	12.63 (3.97) C	5.53
	4 Species Grass Dominated CC	5.57 (1.99) C	79.47 (13.67) A	173.80

Laboratory incubation showed that NH_4 and DOC accumulation was the highest in 3S legume dominated, followed by 4S grass dominated and the lowest between CF and WF which were comparable (Figure 2A and 2B).This was likely caused by low C:N ratio of 3S legume dominated leading to quick mineralization of organic residues.

A.


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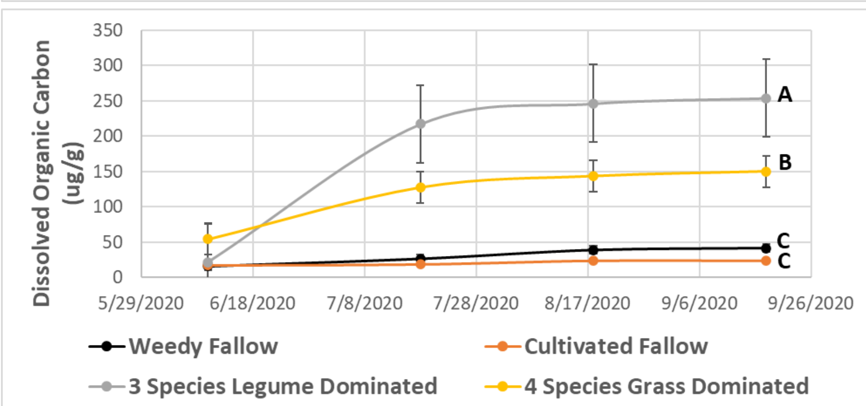

Figure 2. Twelve-week soil incubation for ammonium (A) and dissolved organic carbon (B) in weedy fallow, cultivated fallow, and cover crop treatments. Different uppercase letters demonstrate treatment differences at $p \leq .05$.

CONCLUSIONS

4S grass dominated successfully competed with weeds and significantly increased IN concentrations. The two CC mixes did not compromise soil moisture by the time for WW planting. Cover crop mixtures accumulated more NH_4 and DOC with 3S legume dominated accumulating the most while the two fallows accumulated very low amounts of NH_4 and DOC. In semi-arid, dryland WW production, when producers evaluate the needs of their land and carefully design CC mixes, adequate CC biomass production is possible, resulting in agroecosystem benefits.

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