COVER CROP AND LIVESTOCK INTEGRATION IN A DRYLAND WHEAT-FALLOW PRODUCTION SYSTEM IN THE NORTHERN GREAT PLAINS

Samuel Wyffels, Maryse Bourgault, Julia Dafoe, Peggy Lamb, Darrin Boss[1]

ABSTRACT

The introduction of cover crops as fallow replacement in the traditional cereal-based cropping system of the Northern Great Plains has the potential to decrease soil erosion, increase water infiltration, reduce weed pressure, and improve soil health. However, In the Northern Great Plains, there has been hesitation for the adoption of cover crops in rotation with wheat due to concerns regarding the potential negative effects on the following wheat crop yields. Crop-livestock integration has demonstrated that cover crops can be terminated using livestock grazing with minimal negative impacts on soil health. Therefore, the potential for a reduction in wheat yields following a cover crop may be mitigated by using the cover crop as a forage source for livestock. However, the ability to use cover crops as a livestock forage source in dry-land systems is dependent on the cover crop mixture. A long-term research project conducted at the Northern Agricultural Research Center in Havre, MT evaluated 15 different cover crop mixtures (29 species) and 3 cover crop termination methods in a semi-arid wheat-fallow system in the Northern Great Plains over the course of 8-years. This research suggests that individual mixtures had minimal effect on forage quality and biomass, however, whether the mixture was predominately cool- or warm-season species had a profound impact on the use of cover crops as a potential forage source for livestock. In general, in a dryland cover crop-wheat rotation that requires early-July termination to prevent volunteer cereal grains in the following wheat crop, cool-season cover crop mixtures should provide a suitable forage source for livestock grazing most years. Additionally, the potential for a reduction in wheat yields following a cool-season cover crop may be mitigated using the cool-season cover crop as a forage source for livestock. However, the relatively high and variable nitrate levels of the cover crop mixtures used suggests that forage should be tested for nitrates before grazing/haying.

INTEGRATING COVER CROPS AND LIVESTOCK IN WHEAT-FALLOW SYSTEMS OF THE NORTHERN GREAT PLAINS

Diversifying cropping systems by incorporating a cover crop in wheat-fallow systems, can reduce off-farm inputs while producing similar profits to more conventional systems (Davis et al., 2012). Additionally, the introduction of cover crop systems has been shown to improve soil organic C and N, which leads to retention of organically bound nutrients and improved soil hydrology (Franzluebbers and Stuedemann, 2008b). Moreover, increasing species and functional group diversity of cover crop mixtures can further increase soil organic C compared to a single-species mix due to greater above and below-ground biomass production (Faé et al., 2009; Blanco-Canqui et al., 2015). However, prior to the planting of commodity crops, cover crops must be terminated. Conventional cover crop termination typically includes tillage, herbicide,

Sam Wyffels (samwyffels@montana.edu), Julia Dafoe (jdafoe@montana.edu), Peggy Lamb (plamb@montana.edu), and Darrin Boss (dboss@montana.edu), Northern Agricultural Research Center, Montana State University, Havre, MT. 59501. Maryse Bourgault (maryse.bourgault@usask.ca), College of Agriculture and Bioresources, University of Saskatchewan, Saskatoon SK, S7N 5A8, Canada. In: Proceedings, 2021 Western Alfalfa and Forage Symposium, Reno, NV, Nov 16-18. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616. (See http://alfalfa.ucdavis.edu for this and other alfalfa conference Proceedings.)

crimper roller, or a combination of methods, all of which represents a cost with no immediate return, potentially limiting producer adoption of the practice.

An integrated crop-livestock system approach utilizes livestock grazing and/or haying as a mechanism to terminate cover crops and is proposed as a mutually beneficial alternative for both livestock and crop producers (Franzluebbers and Stuedemann, 2008a; Tobin et al., 2020). Cover crops including annual grasses, small grains, and forage legumes following grain or fiber crops could provide a source of high-quality forage (Franzluebbers and Stuedemann, 2007; Franzluebbers and Stuedemann, 2008b). Livestock grazing of cover crops could provide a low input alternative for beef cattle nutrition requirements while delivering a low-input cover crop termination method. Additionally, integrating crops and livestock allows for a better coupling of nutrient demand and availability (Liebig et al., 2012; Russelle et al., 2007). Furthermore, grazing or selling cover crop hay would provide an economic return that could at least partially offset expenses and therefore encourage producers to adopt the practice, even if soil health benefits are not immediately apparent. Nevertheless, the benefits of incorporating a cover crop rotation in a semi-arid cereal-based system are highly variable compared to the humid environments that the bulk of cover crop research has been performed (Blanco-Canqui et al. 2015).

In general, cover crops are promoted worldwide due to the conservation benefits including reduced soil erosion, greater water infiltration, and enhanced soil biological abundance and activity (Snapp et al., 2005; Myers and Watts, 2015; Sanderson et al., 2018). Although livestock grazing or haying of cover crops could provide a low input alternative for beef cattle nutrition requirements while delivering a low-input cover crop termination method, previous research evaluating the integration of livestock grazing on cover crops focuses mainly on the following crop production and soil attributes and evaluates little metric of the effects of cover crop mixtures on animal nutrition with the exception that grazing cover crops could expose livestock to toxic levels of nitrates (Brummer et al., 2018; Farney et al., 2018; Lenz et al., 2019b). The lack of information integrating the effects of cover crop mixtures on commodity crop yield, cover crop biomass and forage quality for livestock grazing or haying limits our understanding of the long-term sustainability of integrated crop-livestock systems involving cover crops for livestock forage in dryland cereal grain production systems in the Northern Great Plains.

Recently, the Northern Agricultural Research Center in Havre, MT completed a long-term study (8-years) evaluating 15 different cover crop mixtures (29 species) and 3 cover crop termination methods in a semi-arid wheat-fallow system in the Northern Great Plains. Of the 15 cover crop mixtures, 5 of the mixtures were predominately cool-season, warm-season, or a mixture of cool- and warm-season species (mid-season). Cover crop seeding rates and planting dates were based on Montana Natural Resources Conservation Service recommendations to ensure each cover crop was planted at the respective rate and planting window (cool-season, early-April to mid-May; warm-season, mid-May to mid-June; mid-season, May), mimicking general planting rates and dates of the region for each cover crop group (USDA-NRCS, 2021a & b). Cover crop mixtures were typically terminated from late June to early July to avoid volunteer cereal grains in the following wheat crop. Cover crops were either terminated by herbicide, swathing and bailing, or grazing. All crop fields were managed as no-till for over 25-years. Measurements of wheat production (Bourgault et al. 2021), soil bacterial communities (Eberly et al. 2021), and cover crop forage quality (Wyffels et al. 2021) in response to cover crop mixture and termination methods are described in detail in research manuscripts published in "*Renewable Agriculture and Food Systems"*.

THE ROLE OF COVER CROP MIXTURE ON FORAGE QUALITY

The forage quality and quantity research results from the aforementioned study (Wyffels et al. 2021) suggests that individual mixtures within the cool-, warm- and mid-season groups had minimal effect on forage quality and biomass, with the exception that the addition of oat in a cool- or mid-season cover crops can increase overall biomass production, however, oats can reduce crude protein content in cool-season mixtures, most likely linked to maturity of the oats at termination. In general, warm- and mid-season cover crop mixtures were found to produce greater crude protein and total digestible nutrients than cool-season mixtures; however, they produced less biomass at the time of termination. Typically, the forage produced by the cover crops in the study met the nutritional requirements of beef cattle for most stages of production at the time of crop termination (National Research Council, 1996, 2016). However, it should be noted that the cool-season cover crop mixture did not fully meet the crude protein nutritional requirements for cattle one of the years in the study, likely related to below-average precipitation for that growing season.

Although nutrient quality sets the upper limit of individual animal performance, forage quantity determines the proportion of the performance that is attained (Duble et al., 1971; Sollenberger and Vanzant, 2011). Thus, forage quality interacts with forage quantity in determining animal performance, where forages with greater nutrient quality require less forage quantity to reach maximum potential. Therefore, it is generally considered that moderate to high-quality forages require 670- to 890-lbs $\cdot$ ac^{-1} of forage biomass to achieve optimum animal performance while grazing (Duble et al., 1971; Sollenberger and Vanzant, 2011). The cool- and mid-season cover crops produced adequate forage biomass to achieve optimum animal performance the majority of the years of the study. However, the warm-season cover crops never produced over 471 ± 34-lbs $\cdot$ ac^{-1}. Of the years that cool- and mid-season cover crops did not produce adequate forage biomass (2017) was a severe drought, with precipitation during the growing season 4.7-in below average. Although severe drought can reduce overall biomass production, forage quality is often greater under drought stress compared to normal conditions (Grant et al. 2014), as seen in the study. When not limited by the nutritive quality of forage, cattle typically consume 1 – 3% of their body weight daily (Cordova et al., 1978). Thus, assuming an animal consumes 3% of its body weight per day, a 1200-lb cow will consume approximately 36-lbs $\cdot$ d^{-1}. Therefore, based on the assumption of 50% use, the cover crop mixtures used in the trial could support approximately 1.2-ac $\cdot$ animal unit months (AUM)$^{-1}$ for cool-season mixtures, 2.2-ac $\cdot$ AUM^{-1} for mid-season mixtures, and 7.1-ac $\cdot$ AUM^{-1} for warm-season mixtures.

Species composition of the cover crop mixtures used in the study also did not influence nitrate contents. Both mid- and warm-season cover crop mixtures contained greater levels of nitrates than cool-season cover crop mixtures. These results are likely due to the stage of maturity as nitrate levels are negatively associated with plant maturity (Khorasani et al., 1997; Lenz et al., 2019a). It is not recommended for pregnant cattle to graze forages with greater than 1500 ppm nitrates on a dry matter basis; however, 1500 to 5000 ppm on a dry matter basis is generally considered safe for non-pregnant livestock. (Cash et al., 2002). Nitrate levels between 5000 and 10000 ppm on a dry matter basis are not suitable for livestock grazing but could be harvested and fed as hay to non-pregnant livestock, as long as feeding is limited to 25 – 50% of the ration (Cash et al., 2002). All cover crop mixtures used in the study contained between 1500 and 3500 ppm nitrates on a dry matter basis on average. Additionally, each cover crop mixture produced nitrates at unsafe levels for livestock grazing for one year of the study, likely related to drought conditions. Thus, when evaluating the potential for nitrate toxicity associated with grazing cover crops, forages should be tested prior to grazing, especially during drought conditions. If nitrate levels of a cover crop are beyond the limits for livestock grazing, producers should consider postponing grazing till nitrate levels drop to a safe level or harvest the cover crop as hay.

THE ROLE OF COVER CROP MIXTURE AND TERMINATION METHOD ON THE FOLLOWING WHEAT YEILD

The wheat yield research results from the above-mentioned study (Bourgault et al. 2021) suggests that termination methods did not significantly impact the following years grain yield and cover crop biomass was a poor predictor of wheat yields. Although not consistent across years, wheat yields following cover crops as a replacement of fallow were reduced frequently and large enough to raise some concerns about the introduction of cover crops in semi-arid cropping systems in the Northern Great Plains. Maximum reductions were 19-bu $\cdot$ ac^{-1} (60%) for winter-wheat and 15-bu $\cdot$ ac^{-1} (35%) for spring-wheat; such reductions are likely to have important consequences on the economic margin of production. Warm-season cover crops may limit the effect on subsequent wheat yields and be a safer alternative, however, the low biomass accumulation generally, demonstrated a poor performance as cover, let alone as forage (Wyffels et al., 2021). It is also doubtful that such low productivity and the lack of consistent cover would lead to the expected long-term soil health benefits.

BASIC CASH VALUE USING TWO YEAR PRODUCTION CYCLES OF WHEAT-COVER CROP ROTATIONS AND TERMINATION METHODS

Basic cash values were calculated using the above ground biomass plus the subsequent wheat crop value on a cash basis (Table 1). Full economic analysis for the 8-year projects is currently being modeled based on the published data from the above-described research. Cash value of the wheat-cover crop rotation to the enterprise was calculated by valuing the above ground biomass at \$105.88 $\cdot$ t^{-1} if cut then baled or valued as \$30 $\cdot$ AUM^{-1} if the above ground biomass was grazed. The cover crop treatment that was chemically treated as a termination step was valued as \$0. These were added to the subsequent winter- and spring-wheat crop yields based on average price and protein bonus to establish a two-year cash return. Prices we collected from harvest averaged for Portland prices to standardize shipping for all areas of Montana. Data presented are not a full economic analysis with machinery and production costs. This data is presented to represent a value to the farm/ranch in comparison to a wheat-fallow production system, so producers could critically evaluate the value of the cover crop as a forage source. In general, all chemically terminated cover crops and warm-season cover crop mixtures provided no additional cash value compared to the traditional wheat-fallow system. Harvesting cool-season cover crops as hay produced the greatest value compared to all other rotations and terminations methods, producing approximately \$394 · ac^{-1} more than the traditional wheat-fallow system (Table 1). Harvesting mid-season cover crops or grazing cool- and mid-season cover crops also added greater value to the cropping system than the traditional wheat-fallow rotation. However, harvesting cover crops as hay would also likely increase production costs that may offset the differences in cash value between haying and grazing termination methods of cool- and mid-season cover crops.

Table 1. Total 2-year cash value (\$ · ac^{-1}) averaged over 8-years of a wheat-cover crop mix (spring and winter wheat; cool-, mid-, warm-season cover crop mixtures) rotation with 3 cover crop termination methods of a traditional wheat-fallow system at the Northern Agricultural Research Center, Havre, MT.

	Termination Method				
Rotation[1]	Chemical	Hay	Graze	Fallow	SE[2]
Spring-Wheat				1149.24[a]	85.77
Cool-Season	1149.24[ab]	1542.97[d]	1397.15[c]		85.77
Mid-Season[3]	1149.24[ab]	1356.45[c]	1279.71[bc]		85.77
Warm-Season	1149.24[ab]	1212.60[ab]	1189.14[ab]		85.77
Winter-Wheat				1218.90[a]	99.77
Cool-Season	1218.90[ab]	1612.63[d]	1466.81[c]		99.77
Mid-Season	1218.90[ab]	1426.11[c]	1349.36[bc]		99.77
Warm-Season	1218.90[ab]	1282.26[ab]	1258.79[ab]		99.77

[1]Wheat-cover crop rotation (cool-, mid-, warm-season mixtures)
[2]Pooled standard error.
[3]Mixture of cool- and warm-season species
Basic cash values were calculated using the above ground biomass plus the subsequent wheat crop value on a cash basis.
All variables within spring or winter wheat lacking a common superscript differs by $P < 0.05$.

CONCLUSION

Although warm-season cover crop mixtures had greater crude protein levels, total digestible nutrients and less of an impact on wheat yields compared to cool-season mixtures, warm-season species produced the least amount of biomass with the highest levels of nitrates. Additionally, warm-season cover crops added no additional cash value when compared to a wheat-fallow system. An integrated crop-livestock system approach that is mutually beneficial for livestock and crop producers necessitates a cover crop that produces an abundant source of forage that meets livestock nutrient requirements. Therefore, in a dryland cover crop-wheat rotation that requires early-July termination to prevent volunteer cereal grains in the following wheat crop, cool-season cover crop mixtures should provide a suitable forage source for livestock grazing most years. The potential for a reduction in wheat yields following a cool-season cover crop may be mitigated using the cool-season cover crop as a forage source for livestock. However, the relatively high and variable nitrate levels of all cover crop mixtures suggests that forage should be tested for nitrates before grazing/haying. Further economic analyses are required to determine if the integration of livestock is necessary to mitigate the risks associated with the introduction of cover crops in replacement of fallow in the Northern Great Plains.

REFERENCES

Blanco-Canqui, H., T. M. Shaver, J. L. Lindquist, C. A. Shapiro, R. W. Elmore, C. A. Francis, and G. W. Hergert. 2015. Cover crops and ecosystem services: Insights from studies in temperate soils. Agronomy Journal 107(6):2449-2474. https://doi.org/10.2134/agronj15.0086

Brummer, J., S. Johsnon, A. Obour, K. Caswell, A. Moore, J. Holman, M. Schipanski, and K. Harmoney. 2018. Managing Spring Planted Cover Crops for Livestock Grazing under Dryland Conditions in the High Plains Region. Colorado State University Extension Fact Sheet No. 0.309. Fort Collins, CO.

Bourgault, M., S.A. Wyffels, J.M. Dafoe, P.F. Lamb, D.L. Boss. 2021. Introducing cover crops as fallow replacement in the Northern Great Plains: II. Impact on following wheat crops. Renewable Agriculture and Food Systems

Cash, D., R. Funston, M. King, and D. Wichman. 2002. Nitrate toxicity of Montana forages. Montana State University Extension Service MontGuide 200205. Bozeman, MT

Cordova, F., J. D. Wallace, and R. D. Pieper. 1978. Forage intake by grazing livestock: a review. Journal of Range Management, 31(6):430-438. http://dx.doi.org/10.2307/3897201.

Davis, A. S., J. D. Hill, C. A. Chase, A. M. Johanns, and M. Liebman. 2012. Increasing cropping system diversity balances productivity, profitability and environmental health. PloS one 7(10):e47149. https://doi.org/10.1371/journal.pone.0047149

Duble, R., J. Lancaster, and E. Holt. 1971. Forage Characteristics Limiting Animal Performance on Warm-season Perennial Grasses 1. Agronomy Journal 63(5):795-798. https://doi.org/10.2134/agronj1971.00021962006300050042x

Eberly, J., M. Bourgault, J.M. Dafoe, C. Yeoman, S.A. Wyffels, P.F. Lamb, D.L. Boss. 2021. introducing cover crops as fallow replacement in the Northern Great Plains: III. Impact on soil microbial communities. Renewable Agriculture and Food Systems

Faé, G. S., R. M. Sulc, D. J. Barker, R. P. Dick, M. L. Eastridge, and N. Lorenz. 2009. Integrating winter annual forages into a no-till corn silage system. Agronomy journal 101(5):1286-1296. https://doi.org/10.2134/agronj2009.0144

Farney, J., D. Shoup, D. Rethorst, D. Blasi, and J. Holman. 2018. Forage Crops: Grazing Management: Toxic Plants. Manhattan: Kansas State University Agricultural Experiment Station and Cooperative Extension Service MF3244

Franzluebbers, A., and J. Stuedemann. 2007. Crop and cattle responses to tillage systems for integrated crop–livestock production in the Southern Piedmont, USA. Renewable Agriculture and Food Systems 22(3):168-180. https://doi.org/10.1017/s1742170507001706

Franzluebbers, A. J., and J. A. Stuedemann. 2008a. Early response of soil organic fractions to tillage and integrated crop–livestock production. Soil Science Society of America Journal 72(3):613-625. https://doi.org/10.2136/sssaj2007.0121

Franzluebbers, A. J., and J. A. Stuedemann. 2008b. Soil physical responses to cattle grazing cover crops under conventional and no tillage in the Southern Piedmont USA. Soil and Tillage Research 100(1-2):141-153. https://doi.org/10.1016/j.still.2008.05.011

Grant, K. J. Kreyling, L.F.H. Dienstbach, C. Beierkuhnlein, A. Jentsch. 2014. Water stress due to increased intra-annual precipitation variability reduced forage yield but raised forage quality of a temperate grassland. Agriculture, Ecosystems & Environment 186: 11-22. https://doi.org/10.1016/j.agee.2014.01.013.

Khorasani, G., P. Jedel, J. Helm, and J. Kennelly. 1997. Influence of stage of maturity on yield components and chemical composition of cereal grain silages. Canadian Journal of Animal Science 77(2):259-267. https://doi.org/10.4141/a96-034

Lenz, M. E., J. K. Farney, R. J. Kern, C. E. Orvis, and M. E. Drewnoski. 2019a. Nitrate toxicity in annual forages: Survey of beef producer perspectives and samples submitted to a commercial testing laboratory in Nebraska. Applied Animal Science 35(5):455-463. https://doi.org/10.15232/aas.2019-01865

Lenz, M. E., R. J. Kern, C. E. Orvis, and M. E. Drewnoski. 2019b. Nitrate Concentrations of Annual Forages Grown for Grazing in Nebraska. University of Nebraska-Lincoln Nebraska Beef Cattle Reports. 1035. Lincoln, NE. http://digitalcommons.unl.edu/animalscinbcr/1035

Liebig, M.A., Tanaka, D.L., Kronberg, S.L., Scholljegerdes, E.J., & Karn, J.F., 2012. Integrated crop and livestock in central North Dakota, USA: Agroecosystem management to buffer soil change. Renewable Agriculture and Food Systems: 27, 115-124.

Myers, R., and C. Watts. 2015. Progress and perspectives with cover crops: Interpreting three years of farmer surveys on cover crops. J. Soil Water Conserv. 70:125A–129A. http://doi.org/10.2489/jswc.70.6.125A

Russelle, M.P, Entz, M.H., & Franzluebbers, A.J., 2007. Reconsidering integrated crop-livestock systems in North America. Agronomy Journal 99, 325-334.

Sanderson, M., Johnson, H., & Hendrickson, J. (2018). Cover crop mixtures grown for annual forage in a semi-arid environment. Agronomy Journal, 110:2, 525-534.

Snapp, S.S., S.M. Swinton, R. Labarta, D. Mutch, J.R. Black, R. Leep, J. Nyiraneza, and K. O'Neil. 2005. Evaluating cover crops for benefits and costs and performance within cropping system

Sollenberger, L. E., and E. S. Vanzant. 2011. Interrelationships among forage nutritive value and quantity and individual animal performance. Crop Science 51(2):420-432. https://doi.org/10.2135/cropsci2010.07.0408

Tobin, C., S. Singh, S. Kumar, T. Wang, and P. Sexton. 2020. Demonstrating Short-Term Impacts of Grazing and Cover Crops on Soil Health and Economic Benefits in an Integrated Crop-Livestock System in South Dakota. Open Journal of Soil Science 10(03):109-136. https://doi.org/10.4236/ojss.2020.103006

USDA-NRCS. 2021a. Cover Crop (Code 340) Seed Calculator. Electronic Field Office Technical Gude. USDA Natural Resources Conservation Service, Bozeman, Montana. https://efotg.sc.egov.usda.gov/#/state/MT (last accessed: July 26, 2021).

USDA-NRCS. 2021b. Cover Crop (Code 340) Practice Specification. Electronic Field Office Technical Gude. USDA Natural Resources Conservation Service, Bozeman, Montana. https://efotg.sc.egov.usda.gov/#/state/MT (last accessed: July 26, 2021).

Wyffels, S. A., M. Bourgault, J.M. Dafoe, P.F. Lamb, D.L. Boss. 2021. Introducing cover crops as a fallow replacement in the Northern Great Plains: I. Evaluation of cover crop mixes as a forage source for grazing cattle. Renewable Agriculture and Food Systems, 1-11. https://doi.org/10.1017/S1742170521000417