Improving Sustainability Utilizing Cover Crop Grazing to Improve Soil Health While Increasing Grain and Livestock Production

K. P. Ewing[1], P. A. Gunter[2], A. M. P. Netthisinghe[2], F. DeGraves[2], and H. O. Galloway[3]

[1]Department of Animal Sciences, University of Illinois, Champaign-Urbana, IL

[2]Department of Animal Sciences, Western Kentucky University, Bowling Green, KY

[3]Hampton Meats, Hopkinsville, KY

Objective

The first objective of this study was to measure soil health properties and cash crop production characteristics of a grazed cover crop field and an un-grazed cover crop field. The second objective was to identify effects of utilizing cover crop forage for grazing by livestock and evaluate strategies to identify whether cover crop grazing is an adequate approach that will increase available forages without harming soil health or grain production.

Introduction

Agronomic and environmental concerns about erosion and overall soil health during periods of rest between crops has generated interest in cover crop utilization. Erosion of soil can limit the capacity for growing crops due to reduced supply of adequate nutrients for crops and failure to maintain soil microorganism biodiversity (Magdoff and Van Es, 2009). This is due to a variety of factors including reduced water infiltration, percolation, aeration and root growth (Magdoff and Van Es, 2009). Soil degradation can also have environmental effects beyond the loss of crop production. It can lead to increased pollution and sedimentation in waterways (Poesen et al., 2003) as well as air pollution (Piper, 1989). Degraded soils have decreased water-holding capacity which can lead to increased damage from flooding (Poesen et al., 2003). Cover crops are used to improve production of subsequent crops by enhancing physical, chemical and biological soil properties as well as improving many other environmental and agronomic components (Weil and Kremen, 2007; Fageria et al., 2005). A study by Franzluebber (2007) showed that usage of cover crops has the potential to aid in soil management, crop production, and increasing long-term economic benefits however, the practice of using cover crops has yet to be widely applied due to the lack of immediate economic benefit. Cover crops can be utilized to help reduce issues with soil health and the negative environmental impact associated with erosion. One of the greatest concerns with using cover crops are the direct costs associated with cover crop seed, labor, fuel, fertilizer, and herbicide or tillage to terminate the cover crop (Snapp et al., 2005). There are strategies that can be utilized that will aid in more efficient use of the forage with a relatively immediate economic benefit. One such strategy is the usage of cover crops as grazing fodder for livestock. Grazing species of animals have the ability to convert cellulose, the predominant carbohydrate source in the world, into products for human use (Oltjen and Beckett, 1996). Utilization of livestock grazing on cover crops allows for an immediate economic benefit while reducing input costs (Franzluebber, 2007; Magdoff and Van Es, 2009). Extending grazing into fall-winter period reduces feed costs increasing efficiency of forage utilization and profitability (Penrose et al., 1996). In comparison to native grass pastures, cover crops generally provide higher quality forage for grazing animals (Franzluebber, 2007; Magdoff and Van Es, 2009). This was demonstrated by Choet et al. (2003) who reported increased average daily gains from steers grazing winter wheat compared to native-pasture grazed steers. Redmon et al. (1995) noted a positive effect on grazed winter wheat with increased grain yield when wheat cultivars were grazed until the joint stage compared to un-grazed winter wheat. Studies have shown that total soil carbon concentration increases in grazed cover crop systems resulting in an overall positive effect on soil organic matter despite potential compaction caused by livestock grazing (Tracy and Zhang, 2008).

Materials and Methods

This study was conducted from 2017 to 2019 at the Western Kentucky University Research and Education Complex located in Bowling Green, Kentucky. Three adjacent fields at 3.6 hectare each were established for data sampling with a comparison of soil physical and chemical parameters, and soybean and corn characteristics between an un-grazed cover crop field, in this case wheat (*Triticum aestivum*; W), grazed cover crop field (WGR), and grazed endophyte-infected tall fescue field (TF). The primary soil type of the three sites is Crider silt loam. Crider silt loam soil is characterized by being well-drained, moderately permeable, high water holding capacity, and neutral to strong acid pH (USDA, NRCS, 2004). Cover crops used in this study include: a soft red winter wheat cultivator (cv. Branson) seeded in November 2016 and 2017; annual ryegrass (*Lolium multiflorum*) established December 2018; and red clover (*Trifolium pratense*) and turnip (*Brassica rapa*) mixture seeded November 2019. Wheat cultivars were harvested in June 2017 and 2018 while annual ryegrass was terminated May 2019. Following harvest or termination of cover crop, the two cash crop fields were planted to either soybeans (*Glycine max*), 3.9 maturity group Syngenta variety, (2017 and 2018) or corn (*Zea mays*), 112-day maturity LG variety, (2019) and harvested. Subsequently, the selected cover crop was then sowed into crop stubble. Cash crop fields were managed and maintained in a no-tillage system. For grazing, tall fescue was stockpiled starting in September and maintained by mowing two times a year. To meet fertilizer requirements, 54 and 32 kg ha^{-1} urea nitrogen was applied to wheat grazed and wheat fields respectively in February or March of each year of the study. Tall fescue was fertilized with urea nitrogen, phosphorus, and potassium (N-P-K) as required by soil test in February and with 43-43-32 kg ha^{-1} N-P-K in September of each year. Different sets of 16 Angus cow/calf pairs of similar body weights were used each year in this study, allocated randomly to grazing winter cover crop or endophyte-infected tall fescue. Cattle grazed for three weeks in 2017 (March 21-April 12), two weeks in 2018 (March 14-March 28), and were unable to graze in spring 2019 or spring 2020. Grazing during spring 2019 was inhibited by excessive rain and polar vortex winter conditions while grazing in spring 2020 was prevented due to late soybean harvest which delayed cover crop planting thus resulting in inadequate stand establishment for grazing. The grazing period length was determined by available forage and weather conditions. Cattle body weights were established at day 0 of grazing and taken again once each week of grazing. Cattle were supplemented with an 11.7% crude protein concentrate and mineral. Initial soil sampling occurred prior to experimental start date in fall 2016 to determine baseline analysis of each field. Soil samples was taken at a depth of 101.6 mm using a 19 mm diameter soil probe (Oakfield Apparatus Co., Fond du Lac, Wisconsin). Bulk density samples were taken using a 173.4 cm^3 compact slide hammer corer (AMS-Samplers, American Falls, Idaho). Soil core samples and bulk density samples were taken in all plots March, June, and October 2017-2019.

Soybean and corn grain was hand-harvested from a sample area of 1 m^2 at six geo referenced locations in each cash crop field and yield was measured as weight threshed. Four replicates of each of the cash crop fields were measured to determine yield. Soybean plants were cleaned and measured for various plant, pod, and seed characteristics. Grain moisture content was determined by a grain moisture meter (Dickie John, Minneapolis, MN). Twelve soil core samples and one bulk density sample were taken from 1 m^2 areas at 12 geo referenced locations within each field. Extractable nutrient samples were then air-dried at room temperature to a constant weight and kept in bags until they were processed. Before analysis, soil was ground to pass through a 2-mm screen. Nitrate and ammonia samples were separated and stored in a freezer until arrival at laboratory for analysis. Soil samples were then analyzed for pH, P, K, Ca, Mg, Fe, Cu, and Zn using Mehlich-3 (M-3). Emission spectroscopy on an inductively coupled spectrophotometer (Vista Pro Varian Analytical Instruments, Walnut Creek, California) was used to determine Mehlich-3 (Mehlich, 1984) extractable nutrient concentrations. A 2-gram soil sample in high-temperature combustion in a Vario MAX C-N analyzer (Elementar America Inc.) was used to measure total soil carbon and nitrogen contents. Sample analysis was conducted by the Waters Agricultural Laboratory in Owensboro, Kentucky. Cattle body weights were recorded weekly by a 9’ weighbridge (For-Most 30, Hawarden, Iowa; Netthisinghe, 2019).

Results

Nitrogen (N; Table 1) in spring sampling differed between W and WGR treatments with greatest content seen in W, intermediate content in TF, and lowest content in WGR. TF did not differ from W or WGR. N level was different between all three years of the study with highest N level seen in 2018 followed by intermediate level in 2019 and lowest level in 2017. Nitrogen from fall sampling was lowest in WGR which varied from TF and W. TF and W were not different. Between years, N was greater in 2019 in comparison to both 2017 and 2018. 2017 had greater N level than 2018.

Nitrate (NO_3^-; Table 2) concentration from spring sampling differed between TF and WGR treatments with TF containing lower NO_3^- levels than WGR. Between years, 2018 was greater in NO_3 than both 2017 and 2019 which did not differ. Nitrate concentration was different in fall sampling. NO_3^- in TF was lower than both W and WGR which did not differ from one another. NO_3^- varied between all three years of the study. 2019 had the highest NO_3 content followed by 2017 and subsequently, 2018.

Ammonia (NH_4^+; Table 3) concentration in fall sampling differed between year but not between treatments. During 2017 NH_4 was greater than both 2018 and 2019. 2018 had lower NH_4 content than 2019.

Within treatments in fall sampling, organic matter (OM; Table 4) in WGR had the lowest OM value and differed from TF and W. TF and W did not differ. 2017 was approximately 19.76 g/kg greater in OM than both 2018 and 2019 which did not differ.

Bulk density (Table 5), often used to quantify compaction, had lower bulk density in TF than W and WGR which did not differ. Bulk density varied between each year of the study with greatest value in 2019, intermediate value in 2017, and lowest value in 2018.

No soybean characteristics were impacted by grazing treatment. Neither corn yield nor moisture were impacted by grazing treatment.

Summary

Soil nitrogen and nitrate levels were all impacted by treatment x year interaction, treatment, and year. OM tended to decrease from spring to fall sampling, potentially due to increased microbial activity during the summer which would have increased breakdown of OM. Although, significant treatment and year effects were observed in soil nutrient parameter analyses, in general, these effects had minor impacts on biological levels. Soybean and corn production characteristics were not impacted by treatment.

Implications

Overall, due to minimal interaction effects, there was little impact of cattle grazing winter wheat for two grazing periods on overall soil health. This implies that grazing cattle on certain cover crops may be an effective method of increasing available forage without negatively impacting soil health or cash crop production. Further research is required to fully determine effects of cover crop grazing by cattle on soil physical and chemical parameters and subsequent cash crop production in the south-central Kentucky region.

Acknowledgements

We thank the United States Department of Agriculture-Agricultural Research Service for providing funding for this project.

Literature Review

Choat, W.T, C.R. Krehbiel, G.C. Duff, R.E. Kirksey, L.M. Lauriault, J.D. Rivera, B.M. Capitan, D.A. Walker, G.B. Donart, C.L. Goad. 2003. Influence of grazing dormant native range or winter wheat pasture on subsequent finishing cattle performance, carcass characteristics, and ruminal metabolism. Journal of Animal Science. 81, 12:3191-3201.

Fageria, N., V. Baligar, and B. Bailey. 2005. Role of cover crops in improving soil and row crop productivity. Commun. Soil Sci. Plant Anal. 36:2733-2757.

Franzluebber, A. J. 2007. Integrated crop-livestock systems in the southeastern U.S.A. Agron. J. 99:361-372.

Magdoff, F. and H. Van Es. 2009. Building soils for better crops: sustainable soil management. Sustainable Agriculture Research and Education Program. Brentwood, MD. p. 101-114.

Oltjen, J. W. and J. L. Beckett. 1996. Role of ruminant livestock in sustainable agricultural systems. Journal of Animal Science 74:1406-1409.

Penrose, C., H. Bartholomew, R. Sulc, S. Schumacher, and R. Duff. 1996. Performance of brassica cultivars from New Zealand and United States seed sources in Southeast Ohio, USA. Proc. of the New Zealand Grassland Assoc. 57:111-113.

Piper, S. 1989. Measuring particulate pollution damage from wind erosion in the western United States. J. Soil Water Conservation. 44:70-75.

Poesen, J., J. Nachtergaele, G. Verstraeten, and C. Valentin. 2003. Gully erosion and environmental change: importance and research needs. Catena. 50:91-133.

Redmon, L. A., G. W. Horn, E. G. Krenzer, Jr., and D. J. Bernardo. 1995. A review of livestock grazing and wheat grain yield: Boom or bust?. Agronomy Journal. 87:137-147.

Snapp, S., S. Swinton, R. Labarta, D. Mutch, J. Black, R. Leep, J. Nyiraneza, and K. O'Neil. 2005. Evaluating cover crops for benefits, costs and performance within cropping system niches. Agron. J. 97:322-332.

Tracy, B.F. and Y. Zhang. 2008. Soil compaction, yield response, and soil nutrient pool dynamics within an integrated crop-livestock system in Illinois. Crop Science. 48: 1211-1218.

Weil, R., and A. Kremen. 2007. Thinking across and beyond disciplines to make cover crops pay. J. Sci. Food Agric. 87:551-557.

Table 1. Total soil nitrogen (g kg^{-1}) from spring and fall sampling as impacted by forage management and year

Item	Year			
Treatment[1]	2017	2018	2019	Mean
Spring Sampling				
TF	2.37	3.68	3.51	3.18
W	2.35	4.46	3.35	3.38
WGR	1.93	4.19	2.91	3.01
Mean	2.21	4.11	3.25	
Fall Sampling				
TF	3.45	2.59	7.07	4.37
W	2.93	2.59	7.22	4.25
WGR	2.83	2.22	3.81	2.95
Mean	3.07	2.47	6.03	

[1] TF=tall fescue, W=wheat un-grazed, WGR=wheat grazed

Table 2. Nitrate (ppm) from spring and fall sampling as impacted by forage management and year

Item	Year			
Treatment[1]	2017	2018	2019	Mean
Spring Sampling				
TF	5.79	5.77	3.39	4.99
W	3.33	10.35	3.92	5.87
WGR	4.07	11.51	4.88	6.82
Mean	4.40	9.21	4.06	
Fall Sampling				
TF	8.50	6.56	3.81	6.29
W	9.48	4.18	15.08	9.58
WGR	8.75	4.73	14.73	9.40
Mean	8.91	5.16	11.21	

[1]TF=tall fescue, W=wheat un-grazed, WGR=wheat grazed

Table 3. Ammonia (ppm) from fall sampling as impacted by forage management and year

Item	Year			
Treatment[1]	2017	2018	2019	Mean
TF	10.24	3.59	5.81	6.55
W	12.90	3.21	3.83	6.64
WGR	10.56	2.96	3.54	5.69
Mean	11.23	3.25	4.39	

[1] TF=tall fescue, W=wheat un-grazed, WGR=wheat grazed

Table 4. OM (g kg^{-1}) from fall sampling as impacted by forage management and year

Item	Year			
Treatment[1]	2017	2018	2019	Mean
TF	24.78	3.35	3.54	10.56
W	23.33	3.03	3.07	9.81
WGR	20.31	2.71	2.83	8.62
Mean	22.81	3.03	3.14	

[1] TF=tall fescue, W=wheat un-grazed, WGR=wheat grazed

Table 5. Bulk density (g cm^{-3}) as impacted by forage management and year

Item	Year			
Treatment[1]	2017	2018	2019	Mean
TF	1.31	1.13	1.51	1.32
W	1.38	1.31	1.56	1.42
WGR	1.44	1.35	1.55	1.45
Mean	1.38	1.26	1.54	

[1] TF=tall fescue, W=wheat un-grazed, WGR=wheat grazed