Sheep & Goat Research Journal
Volume 30, 2015 - June

Use of Annual Forage Crops as a Late-Season Forage for Pregnant Ewes, Insect Habitat and to Improve Soil Health

J.W. Stackhouse[1,2], C.S. Schauer[1], and B.A. Geaumont[1,3]

[1] *Hettinger Research Extension Center, North Dakota State University, 102 Hwy 12 W, Hettinger, ND 58639*

[2] *Present Address: University of California Coopertive Extension, 5630 South Broadway, Eureka, CA 95503*

[3] *Corresponding author: benjamin.geaumont@ndsu.edu*

Acknowledgements

Partial support for the research was provided by the National Research Initiative of the USDA Cooperative State Research, Education, and Extension Service, grant # 2005-55618-15754 and by a USDA Five State Ruminant Consortium Grant. The authors would like to thank Don Stecher, Don Drolc, Dave Pearson, and Megan VanEmon for their assistance in data collection.

Summary

Incorporating annual forages into an integrated livestock-crop management system may help prolong the grazing season for most livestock-management systems in the Upper Great Plains. The objectives of this study were to determine (1) the differences in sheep performance ADG (average daily gain) among two mixtures of annual forages and mixed-grass pasture grazed during the dormant season, (2) if differences exist in insect biomass among annual forage mixtures and mixed grass, and (3) to document changes in soil chemical and nutrient status under grazed annual-forage production and grazed mixed-grass pastures. One hundred and eight pregnant Rambouillet ewes were stratified by weight and randomly allotted to one of nine paddocks with two treatments and a control (n = 3) for three consecutive years. Treatments include two spring annual forage plantings (**AF1** and **AF2**), and an introduced mixed-grass and forb mixture that served as the control (**CON**). Grazing occurred continuously for 21d to 22-d during October. Ewe weight gain was increased ($P \leq 0.02$) in the annual forage treatments compared to CON, but was similar between annual forage treatments ($P \geq 0.05$). Similarly, crude protein was greater ($P < 0.01$) in **annual forage treatments** relative to the **CON**; 11.84, 12.04, and 5.90, respectively. The higher crude protein in annual forage treatments was likely responsible for the observed response in weight gain. Insect biomass was greatest for AF2, intermediate for AF1 and lowest for CON ($P \leq 0.05$). Soils analysis generally revealed no treatment differences during the three-year study period ($P \geq 0.05$). Our research indicates that annual forages can provide feed with adequate nutritional value to pregnant ewes and may be an option to lengthen the grazing season and delay the onset of supplemental feeding. Insect biomass differed among treatments (P = 0.02), which could have ecological impacts to the surrounding environment due to the important role that insects play in transferring energy within trophic levels. Additional research is needed to further quantify changes occurring in soil nutrients as a result of long-term propagation and grazing of annual forages within an integrated, crop-livestock system in the Northern Great Plains.

Key Words: Annual Forage, Cover Crop, Insects, Grazing, Sheep, Soil

Introduction

A growing group of livestock producers have recognized the benefits of integrating crop production into livestock enterprises. Crop production can generate revenue from grain sales and supply forage for livestock. In addition, integrated systems can provide greater environmental benefits over conventional farming systems (Tracy and Zhang, 2008).

The integration of forages into crop rotations has recently received greater attention as a means to diversify cropping systems, reduce weed populations, reduce agronomic inputs, and provide both wildlife habitat and forage for livestock (Entz et al., 2002; McCartney et al., 2008; Lenssen et al., 2010). The use of forages to increase the length of the grazing season has become particularly intriguing to producers, who continuously seek ways to reduce costs and increase efficiencies (McCartney et al., 2008). Oats, barley, and corn have been important forage crops sown in the Northern Great Plains (NGP). These crops are typically harvested for grain with livestock grazing the residual. However, economic and environmental concerns have led producers and scientists to evaluate other species (McCartney et al., 2008). Neville et al. (2008) reported that annual forage mixtures, including turnips, radishes and other forage species, provided high-quality feed for cattle and helped extend the grazing season. Similarly, Sheaffer et al. (1992) reported high daily gains for sheep grazing soy beans and cowpea planted as a cover crop following barley harvest.

In addition to providing a food source for livestock, forage crops sown for late-season grazing may provide environmental benefits (SAN, 2007; Maughan et al. 2009). Legumes can incorporate additional N into the system, while cool-season-grass species may help prevent nutrient leaching (SAN, 2007; Unkovich and Pate, 2000). Schoofs and Entz (2000) reported that forage crops reduced populations of wild oats as effectively as a sprayed control.

Livestock grazing of annual-forage crops may influence the environmental benefits received from annual forages, particularly as it pertains to the soil (Haynes and Williams, 1993; Maughan et al., 2009). Soil compaction as a result of livestock grazing may reduce crop yields (Krenzer et al., 1989) and can be magnified if soggy conditions prevail (Maughan et al., 2009). However, not all findings have been negative; Tracy and Zhang (2008) reported no negative effect on corn yield due to the presence of cattle prior to planting.

In addition to providing forage for livestock and potential benefits to the soil, annual forage crops may attract insects. Insects are important to the ecosystem and play a critical role in the transfer of energy from plants to animals (Wilson, 1987; Losey and Vaughan, 2006). Some insects, such as pollinators, fulfill vital roles for society, while others are agricultural pests (Meffe, 1998; Altieri and Nicholls, 2004; Klein et al., 2007). Klein et al., (2007) determined that pollination is important for roughly 35 percent of global crop production.

Sheep producers in the NGP are in search of high-quality feed that can be used to extend the grazing season. In areas of the NGP, limited pasture-land, economics and other issues have led sheep producers to integrate crop production into their operations. Some producers have diversified the crops used in recent years by incorporating mixtures of annual forages into rotations. Annual forage crops can be used as hay or grazed. While some data exist concerning annual forages and cattle in the NGP, little information is available regarding sheep performance, while grazing annual forages planted as a main crop (Neville, 2008). The purpose of this study was to evaluate the potential to incorporate annual forage crops into a 12-month integrated, sheep-cropping system to extend the grazing season. The objectives of this study were to determine (1) differences in sheep performance AGD (average daily gain) among two mixtures of annual-forage crops and mixed-grass pasture grazed during the dormant season, (2) if differences exist in insect biomass among annual-forage mixtures and mixed grass, and (3) to document changes in soil-chemical and nutrient status under grazed, annual-forage production and grazed, mixed-grass pastures. Dormant season was defined for this study as the period of plant dormancy or death brought on by cooler temperatures (Warren et al., 1986).

Materials and Methods

All procedures were approved by the North Dakota State University (NDSU) Institutional Animal Care and Use Committee (Protocol # A10057). The study was conducted at the Hettinger Research Extension Center near Hettinger, North Dakota, in Adams County. The 12-month integrated system used at the station requires sheep to graze native and non-native pasture from mid-April to mid-August or September. Sheep are then moved to graze oat or barley stubble. From September to November/December sheep graze native and non-native pasture and are supplemented with other feeds. Sheep typically lamb in January as part of this system. Oats and barley are the primary small-grain crops sown for both forage and cash. The research was done on nine, 0.81-ha paddocks. Six paddocks are contiguous and ±410 m from the three remaining contiguous paddocks. The research site is in an area mapped as Stady loam (0 percent to 2 percent slope) and Manning Fine Sandy loam (0 percent to 6 percent slope). Both are derived from sedimentary rock (Soil Survey Staff, 2014). Previous land use was small grains or idled pasture. The study area averages 40 cm of precipitation annually, with average summer temperature (June through August) of 19°C (NDAWN, 2012).

Grazing Treatments

The study was done using a completely randomized design with three replicates each of two annual forage crops and one of mixed grass and forb control. Treatments were assigned randomly to paddocks during year 1 and remained in the same paddock throughout the trial. Annual forage crop 1 (**AF1**) was a mixture of oats (18 kg/ha), forage soybean (10 kg/ha), proso millet (2.2 kg/ha), sorghum (2.2 kg/ha), purple-top turnip (1.8 kg/ha), yellow sweet clover (1.1 kg/ha), and forage radish (0.67 kg/ha). Annual forage crop 2 (**AF2**) was a mixture of purple-top turnip (4.0 kg/ha), proso millet (3.4 kg/ha) and forage radish (1.8 kg/ha). The control (**CON**) was pasture dominated by crested wheatgrass (55 percent canopy cover; *Agropyron cristatum*) and alfalfa (25 percent canopy cover; *Medicago sativa*). **AF1** is more diverse, and the species were chosen based on their ability to grow in the NGP, forage potential, phenology, environmental benefits and functional group (SAN, 2007). **AF2** consisted of species selected based on their ability to produce forage for livestock and to add functional group diversity (Smart et al., 2004; SAN, 2007). **CON** consisted of mixed grasses and forbs that had been established for > 20 years. The **CON** replicates had been left idle and not used for > 5 years.

A tank-mixed application of glyphosate (2.34 l/ha) was applied as a pre-planting herbicide on all annual-forage-crop paddocks to control weeds. Annual-forage crops and fertilizer were planted/applied using a 2.4 m Truax™ Flex II no-till drill (Truax Company, Inc, New Hope, Minn.). Planting occurred in mid-June, with fertilizer (11-52-0) applied to annual forage crops at 56 kg/ha during the time of planting. A minimal amount of starter fertilizer was used to reduce costs. No additional fertilizer was applied to the annual forage crops and the **CON** was not fertilized during the experiment.

Forage data were collected annually at the onset of sheep grazing in late-September. Forage production was determined in late-September on a dry matter basis. A 0.25 m^2 frame was used to sample vegetation. All vegetation was clipped to ground level and sorted by species. Nine frames per paddock were clipped. Vegetation was dried using a forced-air oven (55º C) for 48 h and weighed. Dry weights were used to calculate the average total $kg \cdot ha^{-1} \cdot species^{-1}$ for each treatment. Dried samples were sent to Midwest Laboratories Inc. for nutrient analysis of DM (method 930.15: AOAC Int., 2009), N (method 990.03; AOAC Int., 2009), NDF (Van Soest et al. 1991) as modified by Ankom Technology (Fairport, N.Y.) using an Ankom 200 Fiber Analyzer without sodium sulfide, with amylase and without ash corrections as sequentials, ADF (Goering and Van Soest, 1970), and minerals (inductively coupled atomic plasma and wet digest procedure) including sulfur, potassium, calcium, and others.

Livestock

One hundred and eight, 1- to 5-year-old (average 2 years old) Rambouillet ewes bred to lamb approximately on January 15 were used to evaluate livestock performance. Two-day weights were taken at the beginning and end of the grazing period to determine average daily gain (ADG). Ewes were stratified by weight (63 kg ± 0.93 kg initial BW) and sorted to have similar average weights among treatments and randomly assigned to one of nine paddocks (12 ewes per paddock; n = 3). Each of nine paddocks was grazed simultaneously and continuously for 21 to 22 days in October during 2010, 2011, and 2012. Grazing occurred for no greater than 22 days to ensure sustained forage availability for sheep and to maintain residual cover. Forage availability was monitored visually.

Insects

Insects were sampled with 40 cm canvas hoop nets along three, 25-m transects randomly located in each paddock. Insects were collected between 1000 h and 1600 h during dry conditions as suggested by Whipple et al. (2010). Insects were sampled annually in late-July or early-August. Insects were sampled during this time period to coincide with the brooding period of ring-necked pheasants (Mazza, 2013), which actively consume insects during this life stage (Hill, 1985). Furthermore, by late-July AF1 and AF2 were well established. Researchers swept insects while walking along each side of the 25 m tape. Captured insects were transferred to a plastic storage bag, frozen, and later dried and weighed. Insects were dried at 55°C for 48 hours. In 2012, insects were sorted into groups by taxonomic order.

Soils

Soil was sampled annually (mid-May) to a depth of 15.24 cm with a hand-held soil probe. Three samples were taken per paddock and hand mixed together to form one representative sample. Soil samples were sent to the North Dakota State University Soil Testing Laboratory for analysis of nitrogen, phosphorus, potassium, and organic matter.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc, Cary, N.C.). Paddock served as the experimental unit (n = 3). The covariance structure was Autoregressive. The fixed effect included in the model was treatment. Treatment, year, and treatment x year interactions were evaluated. When a significant F-test was observed ($P < 0.05$) for treatment, preplanned orthogonal contrasts were performed to assess differences only if a treatment x year interaction did not exist. Preplanned orthogonal contrasts include 1) AF1 versus AF2 and 2) AF1 + AF2 versus CON. When a significant F-test was observed ($P < 0.05$) for year or treatment x year interaction, LS Means with a Tukey's adjustment were used to partition effects. Significance was determined at $P < 0.05$. When treatment x year interactions were observed ($P < 0.05$), interactions are presented in bold in Table 2. However, the associated treatment and year effects are presented to allow the reader to determine their relative importance, but only the highest order of significance is discussed. Significant year interactions ($P < 0.05$) are discussed only within the text because they are assumed to be associated with environmental factors and averages were not reported within the tables. All interactions that were not significant ($P < 0.05$) were removed from the model.

Results and Discussion

Climate

Precipitation was 10 mm above normal in 2010 and >30 mm below normal in 2011 and 2012 (Table 1). Air temperature, like precipitation, was variable. Sixty-eight percent of normal precipitation fell in June and 162 percent of normal precipitation fell in July in 2012. In addition, July temperatures were warmer than average, which may have given warm-season species a competitive advantage over cool-season species, such as turnips that are not drought tolerant. Turnips are however somewhat frost tolerant and fall regrowth may have been unaffected by the first killing frost of the year, which occurred on September 18, 2010; September 4, 2011; and September 13, 2012.

Livestock and Forage Production

Average daily gain of pregnant Rambouillet ewes was affected

Table 1. Monthly and annual precipitation and average temperature from 2010-2012 at the experimental site in Hettinger, ND.[1]

	Precipitation (mm)				Temperature (°C)			
Month	**2010**	**2011**	**2012**	**30-yr avg.**	**2010**	**2011**	**2012**	**30-yr avg.**
April	30	55	72	38	7	4	8	6
May	85	106	58	62	10	10	12	12
June	77	82	55	81	16	16	19	17
July	92	34	94	58	20	22	24	21
August	56	53	49	49	20	20	20	21
September	75	10	1	37	13	14	15	14
October	6	18	18	35	9	9	6	7
Total	443	398	375	434				

[1] Data are from National Oceanic and Atmospheric Administration (www.nws.noaa.gov) and North Dakota Agricultural Weather Network (www.ndawn.ndsu.nodak.edu).

(P = 0.02) by treatment and year (P < 0.01), with no treatment-by-year interactions (P = 0.91). Average daily gain did not differ between AF1 and AF2 (P = 0.75), but was greater for annual forage treatments than CON (P < .001; 0.12 kg/d ±0.09 kg/d, 0.14 kg/d ± 0.10 kg/d, and -0.01 kg/d ± 0.12 kg/d, respectively) across all years. Year effects within the ADG dataset were largely the result of the reduced ADG in 2011. While many factors may have affected ADG, it was likely the result of internal parasites (data not reported). Forage quantity did not appear to be the reason for the difference in performance between AF1 (2478 ± 139 kg/ha), AF2 (2371 ± 123 kg/ha), and CON 2180 kg/ha ± 58 kg/ha), as no effects were observed for treatment, year, or treatment x year interactions (P > 0.76). The lowest observed biomass at the beginning of each grazing season in all three years was 2066 kg/ha, which provided 1782 kg/paddock. Based on the NRC for Small Ruminants (2007), DM intake requirements for each ewe were 1.31 kg/d. Therefore, the intake requirements for 12 ewes and a maximum of 22 days of grazing was 346 kg, indicating that forage production appeared adequate for all treatments in all years.

Forage Nutrient Analysis

Treatment x year interactions for CP and TDN (Table 2) were observed (P < 0.02). While variable across years, AF1 and AF2 tended to have greater CP concentrations relative to CON (11.84 percent and 12.04 percent, vs. 5.9 percent, respectively). This effect largely explains differences in weight gains across treatments, as energy (expressed as TDN) was not affected by treatment (P = 0.21). Additionally, the CP requirement for 60 kg ewes in early gestation is approximately 8 percent (NRC, 2007), which was exceeded by AF1 and AF2 treatments, but deficient in the CON. Furthermore, ADF was greater (P < 0.01) for CON (44.97 percent ± 1.26 percent) compared to AF1 and AF2 (30.94 percent ± 3.41 percent and 27.99 percent ± 2.60 percent, respectively), further explaining differences in performance. There was no year effect or treatment by year interaction for ADF. The combined CP deficiency and simultaneous increase in ADF concentration for the CON treatment explain the differences in performance. However, the calculated TDN results appear to conflict with the ADF concentrations observed. We have no explanation for these differences. Finally, there was no difference in crude fat among AF1 (2.22 percent ± 0.18 percent), AF2 (1.70 percent ± 0.08 percent) and CON (1.97 percent ± 0.25 percent).

Forage Mineral Analysis

Treatment x year interactions for Ca and Cu were observed (P < 0.02). Similar to nutrient concentrations, variability existed between years, especially for the annual forage treatments (Table 2). CON had consistently lower Ca and Cu concentrations than AF1 orAF2. This trend of increased concentrations of minerals in annual forage treatments also was present for S, P, K, Mg, and Zn, which exhibited a treatment effect (P < 0.03). However, two minerals, Fe and Mn, exhibited a treatment effect (P < 0.03) in which AF1 was different from AF2 (P ≤ 0.003) but when combined were similar to the CON (P ≤ 0.20). While it is impossible to provide all possible comparisons to grain-type annual forages, we compared the mineral concentrations of the average of AF1 and AF2 to oats, a common, annual forage in this region (NRC, 2000). Concentrations of the minerals S, P, Na, Cu, and Zn all fell within the general range of oats. However, K, Mg, Ca, Fe, and Mn were generally greater than expected in oats (4.4, 2.5, 18, 2.3, and 1.5 times greater, respectively). When designing mineral supplementation programs for ewes consuming mixtures of annual forages, these minerals should be considered minerals of interest, as mineral programs may need to be adjusted to avoid potential negative interactions. Year interactions were present for P, K, and Fe in forage analyses (Table 2). Phosphorus concentration was similar during the first two years of the study (P = 0.15 percent; 0.27 percent and 0.24 percent, respectively), but significantly decreased in 2012 to 0.19 percent across treatments (P ≤ 0.04). Similarities were seen between 2011 and 2012 for percent K (P ≤ 0.06) with average K of 1.43 and 1.14 percent, respectively. Percent K was different in 2010 (P < 0.001), with an average of 1.98 percent K. Concentrations of Na did not differ among treatments for AF1 (0.02 percent ± 0.01 per-

Table 2.Sheep production, vegetative biomass production, and feed nutritional analysis from a sheep cover crop grazing trial in southwest North Dakota (October 2010, 2011, and 2012)[1]

	Annual Forage 1[2]				Annual Forage 2[3]				Mixed-Grass Prairie[4]					P-value		
Items	2010	2011	2012	Avg	2010	2011	2012	Avg	2010	2011	2012	Avg	SEM^{Trt}	Trt	Yr	Trt*Yr
Nutrient Analysis																
CP, %	**14.72**^{de}	**10.33**^{bc}	**10.49**^{bcd}	11.84	**15.17**^{e}	**7.97**^{ab}	**13.00**^{cde}	12.04	**6.22**^{ab}	**5.59**^{a}	**5.89**^{a}	5.90	**0.84**	<0.01	0.13	**0.02**
TDN, %	**63.07**^{ab}	**65.07**^{cd}	**66.33**^{de}	64.82	**62.23**^{a}	**66.83**^{e}	**64.03**^{abc}	64.37	**64.07**^{bc}	**65.90**^{cde}	**65.07**^{cde}	65.01	**0.37**	0.21	0.02	**<0.01**
Mineral Analysis																
S, %	0.343	0.313	0.143	**0.27**	0.483	0.247	0.447	**0.39**	0.113	0.103	0.090	**0.10**	0.064	**0.02**	0.58	0.50
P, %	0.310	0.247	0.217	**0.26**	0.357	0.340	0.260	**0.32**	0.150	0.130	0.080	**0.12**	0.016	**<0.01**	0.01	0.86
K, %	2.71	1.98	1.55	**2.08**	2.70	1.77	1.65	**2.04**	0.52	0.54	0.22	**0.43**	0.11	**<0.01**	<0.01	0.15
Mg, %	0.420	0.350	0.333	**0.37**	0.523	0.313	0.393	**0.41**	0.117	0.157	0.093	**0.12**	0.040	**<0.01**	0.51	0.20
Ca, %	**2.26**^{b}	**0.76**^{a}	**0.54**^{a}	1.19	**2.87**^{b}	**0.58**^{a}	**0.97**^{a}	1.48	**0.47**^{a}	**0.61**^{a}	**0.39**^{a}	0.49	**0.15**	<0.01	<0.01	**<0.01**
Fe, ppm	101.3	85.67	196.7	**127.9**	195.0	140.3	375.3	**236.9**	135.7	107.0	249.3	**164.0**	22.33	**0.01**	0.01	0.54
Mn, ppm	47.7	51.7	50.0	**49.78**	104.3	52.0	90.7	**82.33**	87.3	63.0	91.7	**80.0**	9.84	**0.03**	0.38	0.31
Cu, ppm	**3.00**^{abc}	**3.67**^{bcd}	**6.00**^{f}	4.22	**4.33**^{cde}	**4.67**^{def}	**5.67**^{ef}	4.89	**2.67**^{ab}	**3.00**^{abc}	**2.00**^{a}	2.56	**0.28**	<0.01	0.03	**0.02**
Zn, ppm	28.0	24.0	27.3	**26.44**	37.33	43.00	34.33	**38.22**	23.33	20.00	26.67	**23.33**	3.10	**0.03**	0.99	0.77

Contrasts[5]	AF1 vs AF2	AFs vs CON
S, %	0.17	0.01
P, %	0.02	<0.001
K, %	0.83	<0.001
Mg, %	0.32	<0.001
Fe, ppm	0.003	0.49
Mn, ppm	0.009	0.20
Zn, ppm	0.04	0.04

[1] Bolded items indicate main and interaction effects with highest order of significance.
[2] Annual forage mix with greater diversity (**AF1**).
[3] Annual forage mix with less diversity (**AF2**).
[4] Mixed-grass prairie consisting mostly of crested wheatgrass, and alfalfa (**CON**).
[5] P-values for preplanned contrasts for items with a significant Trt effect in a Repeated Measures ANOVA ($P \leq 0.05$)
[a,b,c,d,e] Means within a row, with a significant Trt x Yr interaction, without a common superscript differ ($P \leq 0.05$).

cent), AF2 (0.06 percent ± 0.02 percent), and CON (0.05 percent ± 0.0 percent) nor were there any year or treatment by year interactions ($P > 0.05$).

Insect Abundance

Insect abundance was quantified as biomass (g) per transect. Year or treatment by year interactions did not occur in insect abundance ($P > 0.05$); however, insect abundance differed among treatments ($P < 0.02$). AF1 and AF2 were similar ($P = 0.32$), but differed from CON ($P = 0.01$) at 4.49 ± 1.33, 5.91 ± 3.46, and 1.38 ± 0.53 g/transect; respectively. In 2012, when insects were sorted by order, Orthoptera (grasshopper) comprised approximately 93 percent of the total biomass of dried insects. While unclear which insect orders made the majority of biomass in 2010 and 2011, grasshoppers were observed frequently during all years. Many of the plant species within the CON had reached maturity by the time insects were sampled (personal observation) and grasshoppers may have been attracted to the newer lush growth associated with forage treatments (Rogers and Uresk, 1974; Pfadt, 1994). Grasshoppers may compete with livestock for forage (Hewitt and Onsager, 1983), but that was not evaluated. In addition to grasshoppers, other insects of different orders may have been attracted to flowers associated with annual forage treatments, leading to increased insect biomass (Carreck and Williams, 2002). Along with grasshoppers, 6 percent of the total insect biomass for 2012 was attributed to the order Hemiptera and the remaining 1 percent consisted primarily of Coleoptera (beetles). Limited inferences should be made from a single, point-in-time sampling of insects such as this, however, these data may illuminate the point that integrating annual crops into a rotation will impact the environment in a multitude of ways.

Soils Analysis

Soil phosphorus differed among years ($P \leq 0.01$: Table 3). Years 2010 and 2011 were similar ($P \geq 0.09$), while phosphorus was greater in 2012 ($P \leq 0.04$ and $P < 0.01$, respectively; Table 3). Average P was 11 ppm, 7 ppm, and 17 ppm for 2010, 2011, and 2012, respectively. Mechanisms driving increased soil phosphorus during 2012 are unknown. Above average temperatures and precipitation in April of 2012 may have led to increased soil temperatures enhancing release of P from recalcitrant P pools in the soils (Peverill et al., 1999). Additionally, increased soil P may be attributed to

Table 3.Soil characteristics and analysis from a sheep cover crop grazing trial in southwest North Dakota (October 2010, 2011, 2012)

	Annual Forage 1[1]				Annual Forage 2[2]				Mixed-Grass Prairie[3]					P-value		
Items	2010	2011	2012	Avg	2010	2011	2012	Avg	2010	2011	2012	Avg	SEM^{Trt}	Trt	Yr	Trt*Yr
Soils Analysis																
N, kg/ha	13.81	17.92	10.08	13.93	18.29	19.41	22.40	20.03	13.07	21.65	6.72	13.81	3.37	0.23	0.53	0.50
P, ppm	8.67	6.67	18.67	11.33	11.33	9.33	19.00	13.22	14.33	6.33	12.00	10.89	1.51	0.57	0.01	0.24
K, ppm	303.33	323.33	386.67	337.78	283.33	302.00	411.67	332.33	336.67	358.33	401.67	365.56	16.55	0.15	0.07	0.37
OM, %	2.97	3.17	3.57	3.23	2.90	3.00	2.97	2.96	2.57	2.90	3.57	3.01	0.22	0.29	0.53	0.22

[1] Annual forage mix with greater diversity (**AF1**).
[2] Annual forage mix with less diversity (**AF2**).
[3] Mixed-grass prairie consisting mostly of crested wheatgrass, and alfalfa (**CON**).

P recycling through increased abundance of residue and litter (Bowman and Halvorson, 1997), although soil OM was not affected by treatment, year, or the treatment x year interaction ($P \geq 0.09$). We hypothesize that OM would increase over time in annual forage paddocks if forage crops were continued.

A minimal amount of fertilizer was used during this trial to reduce costs, which have been an expressed concern of producers. As such, N was below recommended values for all species included in annual forage treatments, had they been planted as a sole crop (Franzen, 2010). Applying additional N would likely increase productivity of forage crops and in return provide greater forage for livestock. Additional research is required over longer time-intervals to assess costs and benefits to the soil associated with incorporating annual forage crops into a rotation, as changes in soil characteristics may not occur quickly (Werner, 1997; Clark et al., 1998).

Conclusion and Implications

Annual forages resulted in ADG in pregnant ewes that were significantly greater than ADG for ewes that grazed mixed-grass prairie in the early fall. These results indicate that annual forages have the potential to provide dormant season forage and in return, prolong the grazing season. Further research should be conducted to determine if an optimal forage mixture and or timing of grazing exists to maximize forage and livestock production. The use of annual forages in an integrated system may impact the local insect community although future research should focus on which insect orders are selecting annual forages and further, strive to evaluate how the insect community is changing over time and which factors may be responsible. Finally, if benefits to the soil can occur from incorporating annual forages into an integrated system, more time may be required for these benefits to be recognized.

Literature Cited

Altieri, M.A., and C.I. Nicholls. 2004. Biodiversity and pest management in agroecosystems. No. 2. Food Products Press.

AOAC Int. 2009. Official methods of analysis. 18th ed. AOAC Int., Arlington, VA.

Bowman, R.A. and A.D. Halvorson. 1997. Crop rotation and tillage effects on phosphorus distribution in the central Great Plains. Soil Sci. Soc. Am. J. 61:1418-1422.

Carreck, N.L., and I.H. Williams. 2002. Food for insect pollinators on farmland: insect visits to flowers of annual seed mixtures. J. Insect Cons. 6:13-23.

Clark, M.S., W.R. Horwath, C. Shennan, and K.M. Scow. 1998. Changes in soil chemical properties resulting from organic and low-input farming practices. Agron. J. 90:662-671.

Entz, M.H., V.S. Baron, P.M. Carr, D.W. Meyer, S.R. Smith. Jr., and W.P. McCaughey. 2002. Potential of forages to diversify cropping systems in the Northern Great Plains. Agron. J. 94:240-250.

Franzen, D.W. 2010. North Dakota fertilizer recommendations tables and equations. North Dakota State University Extension Service. Fargo, North Dakota. SF-882 (Revised).

Goering, H.K., and P.J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents procedures, and some applications). Agric. Handbook No. 379.ARS-USDA, Washington, DC.

Haynes, R.J., and P.H. Williams. 1993. Nutrient cycling and soil fertility in the grazed pasture ecosystem. Adv. in Agron. 49:119-199.

Hewitt, G.B., and J.A. Onsager. 1983. Control of grasshoppers on rangeland in the United States-A perspective. J. Range Management 36:202-207.

Hill, D.A. 1985. The feeding ecology and survival of pheasant chicks on arable farmland. J. Appl. Ecol. 22:645-654.

Klein, A.M., B.E. Vaissiere, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen, T. Tscharntke. 2007. Importance of pollinators in changing landscapes for world crops. Proc. Royal Soc. B: Bio. Sci. 274:303-313.

Krentzer, E.G., C.F. Chee, and J.F. Stone. 1989. Effects of animal traffic on soil compaction in wheat pastures. J. Prod. Agric. 2:246-249.

Lenssen, A.W., S.D. Cash, P.G. Hatfield, U.M. Sainju, W.R. Grey, S.L. Blodgett, H.B. Goosey, D.A. Griffith, and G.D. Johnson. 2010. Yield, quality, and water and nitrogen use of durum and annual forages in two-year rotations. Agron. J. 102:1261-1268.

Losey, J.E., and M. Vaughan. 2006. The economic value of ecological services provided by insects. BioSci. 56:311-323.

Maughan, M.W., J.P.C. Flores, I. Anghinoni, G. Bollero, F.G. Fernandez, and B.F. Tracy. 2009. Soil quality and corn yield under crop-livestock integration in Illinois. Agron. J. 101:1503-1510.

Mazza, M.E. II. 2013. Evaluation of ring-necked pheasant brood habitat and survival on Post-Conservation Reserve Program grasslands in southwest North Dakota. NDSU, M.S. Thesis, Fargo, ND.pp. 136.

McCartney, D., J. Fraser, and A. Ohama. 2008. Annual cool season crops for grazing by beef cattle. A Canadian Review. Can. J. Anim. Sci. 88:517-533.

Meffe, G.K. 1998. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Con. Bio. 12:8-17.

NDAWN. 2012. North Dakota Agricultural Weather Network, North Dakota State Univ. http://ndawn.ndsu.nodak.edu. Accessed 23 February, 2012.

Neville, B.W., G.P. Lardy, D.L. Whitted, and K.K. Sedivec. 2008. Cost-effective alternative forages for fall and winter grazing. 2008 NDSU Beef Cattle and Range Research Report. p. 7-9.

NRC. 2007. Nutrient requirements of small ruminants. Natl. Acad. Press, Washington, DC

NRC. 2000. Nutrient requirements of beef cattle. Natl. Acad. Press. Washington, DC.

Pfadt, R.E. 1994. Field guide to common western grasshoppers. Wyoming Ag. Exp. Stat. Vol. 912.

Peverill, K.I., L.A. Sparrow, and D.J. Reuter.1999. Soil analysis. CSIRO Publishing, Collingwood, Victoria. p. 188.

Rogers, L.E., and D.W. Uresk. 1974. Food plant selection by the migratory grasshopper (*Melanoplussanguinipes*) within a cheatgrass community. Northwest Sci. 48:230-234.

Schoofs, A., and M.H. Entz. 2000. Influence of annual forages on weed dynamics in a cropping systems. Can. J. Plant Sci. 80:187-198.

Sheaffer, C.C., G.C. Marten, R.M. Jordan, and E.A. Ristau. 1992. Sheep performance during grazing of annual forages in a double cropping system. J. Prod. Agric. 5:33-37.

Smart, A., P. Jeranyama, and V. Owens. 2004. The use of turnips for extending the grazing season. SDSU, Cooperative Extension Service. ExEx 2043.

Sustainable Agriculture Network (SAN). 2007. Managing cover crops profitably. Project manager and editor. Andy Clark. 3rd edition.p. 244.

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

Unkovich, M.J., and J.S. Pate. 2000. An appraisal of recent field measurements of symbiotic N2 fixation by annual legumes. Field Crops Res. 65:211-228.

Van Soest, P.J., J.B. Robertson, and B.A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Warren, S.D., W.H. Blackburn, and C.A. Taylor, Jr. 1986. The influence of livestock trampling under intensive rotation grazing on soil hydrologic characteristics. J. Range Management 39:491-495.

Werner, M.W. 1997. Soil quality characteristics during conversion to organic orchard management. Appl. Soil Ecol. 5:151-167.

Whipple, S.D., M.L. Brust, W.W. Hoback, and K.M. Farnsworth-Hoback. 2010. Sweep sampling capture rates for rangeland grasshoppers (Orthoptera: Acridea) vary during morning hours. J. Orthoptera Research. 19:75-80.

Wilson, E.O. 1987. The little things that run the world: the importance and conservation of invertebrates. Con. Bio. 1:344-346.