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NUTRIENT SOURCE AFFECTED QUALITY BIOMASS PRODUCTION OF EARLY HARVEST SWITCHGRASS FOR ANIMAL FEED

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ABSTRACT

The main research emphasis on switchgrass (*Panicum virgatum* L.) in the USA is as lignocellulosic bioenergy feedstock. However, early harvest of switchgrass can be used for animal feed leaving the late growth for bioenergy feedstock. However, soil fertility status can affect quality biomass production. The objective of this experiment was to determine the effect of cattle manure (CM), poultry litter (PL), urea, combined NPK chemical fertilizer, inter-seeded crimson clover (*Trifolium incarnatum* L.) and control on biomass and selected qualities of early harvest switchgrass for animal feed. When average over years, the mean dry biomass yield at Lake Carl Blackwell (LCB) was 17% greater than Perkins. But the crude protein concentration at Perkins was 20% higher than LCB perhaps due to dilution effect. Over years and sites, switchgrass biomass yields and qualities were improved with the application of nutrients. The dry biomass and crude protein concentration for the nutrient sources ranged from 6,974 to 10,618 kg ha^{-1} and from 6.2 to 7.7 %, respectively. Application of PL increased dry biomass yield and crude protein concentration by 52 and 24% over the control treatment, respectively. Application of PL and CM produced improved crude protein concentration without biomass yield tradeoff compared with chemical fertilizer applications. This result is promising to enhance quality forage production and promote nutrient re-cycling. However, economic analysis and monitoring of PL and CM application are needed to determine profitability and ensure environmental sustainability, respectively.

Keywords: Animal feed, confined farming, forage, nutrient sources, switchgrass.

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INTRODUCTION

Switchgrass is a perennial warm season grass and can be grown for dual purpose (animal feed and feedstock for bio-fuel). The early growth can be hayed or grazed by livestock and the later growth can be allowed to mature and harvested for feedstock for cellulosic bio-fuel. This manuscript focused on providing findings on early harvest of switchgrass for animal feed. Switchgrass can produce forage yield as high as 5 tons ac^{-1} with crude protein concentration to the extent of 17 percent (McIntosh et al., 2015). Several research results showed that soil fertility level is one of the most important factors determining quality biomass production of switchgrass (Sanderson et al., 1999; Brejda et al., 2000; Muir et al., 2001; Lee et al., 2007). Nitrogen fertilization accounted 80% of the variation in switchgrass biomass yield (Stout et al., 1988). Application of CM and PL to switchgrass fields not only help to re-cycle nutrients but also can enhance quality biomass production of switchgrass for animal feed.

In some parts of the USA, confined animal farming is an important industry producing substantial revenue. However, this industry generates huge amounts of PL and CM over a limited geographic area. Accordingly, these waste management remains an ongoing challenge to the industry (Britton and Bullard, 1998). Wood et al. (1993) showed that application of PL as fertilizer for Bermuda grass to be "an excellent sustainable agricultural practice" with residual effects on yield and crude protein continuing into the second year. Application of PL can provide N to growing crop that can last for three years after application (Zhang et al., 2009). Similarly, several reports showed that the use of PL and CM have long term impact in improving soil fertility compared with inorganic fertilizers (Kingery et al., 1993; Sharpley et al., 1993; Nyakatawa et al., 2001; Mitchell and Tu, 2006). Planting legumes such as crimson clover, between switchgrass rows, can fix atmospheric N and thus can share this fixed available N to growing switchgrass.

To date, information that simultaneously compared application of animal wastes (PL and CM), inter-seeded legume and chemical fertilizers on quality biomass production of switchgrass for animal feed is limited. It was hypothesized that application of PL, CM and inter-seeded legume synchronize switchgrass nutrient demand with nutrient supply thus increase biomass yield and improve forage qualities compared with chemical fertilizer applications. Therefore, the objective of this study was to determine the effect of CM, PL, inter-seeded crimson clover, urea, combined NPK chemical fertilizers and control on biomass and selected forage qualities of switchgrass for animal feed.

MATERIALS AND METHODS

Site description, trial management, data collection and analysis

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The experiment was carried out at LCB (36°08'N 97°17'W) and Perkins (35°99'N and 97°04'W), Oklahoma State University (OSU) experimental sites from 2009 to 2011. The soil at LCB is a Pulaski (coarse-loamy, mixed, superactive, nonacid, thermic Udic Ustifluvents) with pH of 5.8 and 2.33 % organic matter. The available N, P and exchangeable K in the top 0-12 inch soil depth were 1.8, 63 and 297 lb ac^{-1}, respectively. The soil at Perkins consists primarily of Teller (fine-loamy, mixed, active, thermic Udic Argiustolls) loams and sandy loams with pH of 7.3 and 1.31 % organic matter. The available N, P and exchangeable K in the top 0-30 cm soil depth were 5, 118 and 319 kg ha^{-1}, respectively. In-season mean air temperature and precipitation of the sites are shown in Table 1.

Table 1. Mean maximum and minimum air temperature from March to June and total rainfall from January to June at LCB and Perkins, Oklahoma from 2009 to 2011.

Year	Air temperature from March to June (°C)				Total rainfall from January to June (mm)	
	LCB		Perkins			
	Maximum	Minimum	Maximum	Minimum	LCB	Perkins
2009	24	11	24	12	390	373
2010	24	12	24	13	572	488
2011	26	12	26	13	297	304

(Sources; http://www.mesonet.org/index.php/weather/daily_data_retrieval)

The experimental design was randomized complete block in four replications with 1.5 m by 1.5 m plot size. A lowland switchgrass cultivar 'Alamo' was planted at a seed rate of 6 kg ha^{-1} with row spacing of 30 cm. Switchgrass seeds were drilled into a well-prepared seedbed with a conventional drill (3P606NT, Great Plains, KS) to a depth of 1.5 cm. A one-year stand was allowed for both sites to ensure complete plant establishment and then treatments were applied. The treatments were: 1) control, 2) CM, 3) PL, 4) urea (134 lb ac^{-1} N), 5) combined chemical NPK fertilizers (150, 40 and 20 kg ha^{-1} N, P_2O_5 and K_2O, respectively) and 6) inter-seeded crimson clover.

Solid CM and PL were obtained from feedlot operation and poultry research farm of OSU, respectively. The N content of these CM and PL was determined using dry combination with LECO (Truspec, St. Joseph, MI). The phosphorus and potassium concentration of CM and PL were determined on an ICP emission spectroscopy (Spectro Ciros, Mahwah, NJ) after digesting the samples in a digestion block at 115 °C with concentrated nitric acid and hydrogen peroxide, and results are presented in Table 2.

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Table 2. Major nutrient content of CM and PL at the time of application for the different years (results are mean for three samples).

Nutrient type	Year	Nutrient sources and nutrient content (%)	
		CM	PL
Total N	2009	2.3	2.6
	2010	1.4	3.1
	2011	1.9	2.5
Phosphorus (P_2O_5)	2009	1.2	2.6
	2010	1.2	2.9
	2011	0.7	2.7
Potassium (K_2O)	2009	1.6	3.0
	2010	1.2	3.1
	2011	2.3	2.5
Carbon (C)	2009	24.1	17.7
	2010	12.8	23.8
	2011	17.6	22.5

Cattle manure and PL were applied first week of March. Crimson clover was planted this same time. Cattle manure and PL were applied to provide 150 kg of nitrogen ha^{-1} on dry bases considering 65% of nitrogen availability in the first year of application. Crimson clover was planted at seed rate of 20 kg ha^{-1} between switchgrass rows. All phosphorus and potassium from the chemical fertilizers and 1/3 of the N from urea were applied in the first week of April. The remaining 2/3 of the N from urea was applied after harvest to enhance growth for dual purpose. Therefore, actually, only 50 kg ha^{-1} N was applied from urea to enhance first cut of switchgrass for forage biomass. Harvesting was made with hand held sickles from a net plot of three rows and one m long from the center of the plot at 10 cm height above the ground in mid of June. Biomass samples were dried at 70 ^{o}C till constant weight was recorded then dry biomass was calculated and subsamples from each treatment were used for forage quality testing.

The N content of the plant samples was determined using dry combination as explained above. Then, this N percent was multiplied by 6.25 to get crude protein concentration. Forage nitrate content was measured following the cadmium reduction method using flow-injection auto-analyzer after the nitrate has been extracted using a 2% acetic acid. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using Ankom fiber analyzer (Ankom Technology, Macedon, NY). ADF and NDF are residues remaining after the extractions with these solutions and determined gravimetrically. Total digestible nutrient (TDN) was calculated as: TDN = 87.84 - (ADF*0.70).

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Statistical Analysis

The univariate procedure of SAS computer software (SAS, 2001) was used to test normality of data and homogeneity of variance. Analysis of variance and interest of mean comparison using orthogonal contrasts were performed using General Linear Model of SAS computer software (SAS, 2001). Fisher's protected LSD's were used to compare treatment means when appropriate.

RESULTS AND DISCUSSION

Importance of animal waste testing

The nutrient content of CM and PL varied for the different years suggesting the importance of testing these materials every year to avoid over or under fertilization (Table 2).

These differences in nutrient concentration can be due to variation in rations feed to the animal, storage and handling conditions of these material. These nutrient variations recorded in our result is in agreement with previous findings (Sims and Wolf, 1994; Evers, 1998). The PL had the lower C:N ratio due to high N content than CM. The relatively low C:N ratio of PL probably can limit mineralization due to low carbon content as energy source for microbial activities. This can cause the use of soil carbon as energy source and can accelerate soil organic matter depletion. The higher C:N ratio in CM suggest that N can be a limiting factor for mineralization and thus N immobilization by soil microbes can limit N availability for plant N uptake. This may suggest to blend PL with CM but this need long term evaluation to find out the right proportion.

Switchgrass biomass yield and forage quality

The effect of site, year and nutrient sources were significant for most of the recorded and calculated parameters (Table 3). The interaction effect of site by year, and year by nutrient source resulted in significant differences in plant height, nitrate and crude protein concentration. As shown in Table 4, LCB produced greatest fresh biomass yields than Perkins. This might be related to high initial soil organic matter content of LCB than Perkins. However, improved crude protein concentration, ADF and TDN were recorded at Perkins than LCB (Table 4). The higher available soil nitrogen in the top 0 -30 cm soil depth at Perkins, as found at the beginning of the experiment, could have contributed to these forage quality differences.

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Table 3. Analysis of variance table showing the effect of sites, years, nutrient sources and their interaction on switchgrass biomass and selected forage quality for animal feed at LCB and Perkins, Oklahoma from 2009 to 2011.

Factors and interactions	Dry biomass	Fresh biomass	Plant height	Nitrate (ppm)	Crude protein	ADF	NDF	TDN
	(kg ha^{-1})		(cm)		(%)			
Site (S)	NS	*	NS	NS	***	**	NS	***
Year (Y)	***	***	***	***	***	***	***	***
S * Y	NS	NS	*	NS	NS	NS	NS	NS
Nutrient source (NS)	**	**	***	***	***	NS	P<0.1	NS
Y * NS	NS	NS	P < 0.1	***	P<0.1	NS	NS	NS
S * NS	NS	NS	NS	NS	NS	NS	NS	NS
S * Y *NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	9,128	29,792	102	516	6.9	42.9	75.4	55.4
CV (%)	34.30	39.44	11.85	59.16	18.46	3.63	1.92	2.18

ADF = acid detergent fiber, NDF = neutral detergent fiber, TDN = total digestible nutrient, ***, ** and * indicate level of significance at 0.001, 0.01 and 0.05 probability, respectively, and NS = Non-significant.

Both dry and fresh biomass yields were significantly higher in 2010 than the other two years (2009 and 2011) (Tables 3 and 4). The precipitation in 2010 was greater than the remaining two years and may explain these differences (Table 1). In similar studies, we have shown the effect of inter-seasonal precipitation differences on biomass yields (Mohammed et al., 2013; Mohammed et al., 2014; Mohammed et al., 2015) However, improved crude protein concentration, ADF, NDF and TDN were recorded in 2009 than the remaining two years. This revealed the decline of these forage qualities with age of switchgrass establishment. This may suggest to develop improved agronomic management practices to keep the quality in acceptable ranges for animal feed. Nitrogen fertilization may be a key component in this regard. In addition, the lower crude protein content in 2010 and 2011 than 2009 may be explained by dilution effect. Dilution effect is phenomena when low nitrogen in the biomass is recorded due to higher biomass or grain yields. Similar dilution effects have been reported in different studies (Mohammed et al., 2013; Mohammed et al., 2015).

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Table 4. Mean values for sites, years and nutrient sources on switchgrass biomass and selected forage quality for animal feed at LCB and Perkins, Oklahoma from 2009 to 2011.

Factors	Dry biomass	Fresh biomass	Plant height (cm)	Nitrate (ppm)	Crude protein	ADF	NDF	TDN
	(kg ha^{-1})				(%)			
Sites								
LCB	10,024	31,841	106	411	6.0	44.9	76.3	54.0
Perkins	8,546	28,426	102	587	7.2	41.7	74.7	56.4
Year								
2009	4,054 c	12,107 c	94 b	845 a	8.6 a	36.9 c	71.5 c	60.2 a
2010	11,592 a	40,779 a	105 a	353 c	7.2 b	46.5 a	77.5 a	52.7 c
2011	9,218 b	27,642 b	107 a	514 b	5.2 c	42.4 b	75.1 b	55.9 b
Nutrient sources								
Control	6,978 c	21,661 d	93 d	403 c	6.2 b	42.5	74.9	55.8
Cattle manure	9,845 ab	34,686 ab	110 ab	613 ab	7.7 a	43.0	75.7	55.4
Poultry litter	10,606 a	36,411 a	114 a	769 a	7.7 a	42.6	74.9	55.7
Nitrogen (urea)	9,307 ab	28,862 bcd	106 bc	385 c	6.5 b	43.7	75.9	54.9
NPK combined	9,576 ab	29,960 abc	102 c	376 c	6.7 b	43.2	75.8	55.2
Crimson clover	8,490 bc	27,182 d	100 c	554 bc	6.5 b	42.6	74.9	55.7

ADF = acid detergent fiber, NDF = neutral detergent fiber, TDN = total digestible nutrient; Means followed by a common letter in a column for the same main factor are not statistically significant at alpha = 0.05

Mean dry biomass yields and crude protein concentration with the application of different nutrients ranged from 6,977 to 10,606 kg ha^{-1} and from 6.2 to 7.7%, respectively (Table 4). Contrast analysis results showed that nutrient application increased biomass yields and improved forage quality compared to the control treatment (data not shown). This reveal the importance of improving soil nutrient levels for better switchgrass forage production. This result is in agreement with previous similar research results (Stout et al., 1988; Brejda et al., 2000; Lee et al., 2007; John et al., 2011). In this study, application of N fertilizer from urea resulted in 33% more biomass yield compared with the control treatment. But Stout et al. (1988) reported 80% biomass yield difference due to N fertilization. This difference in magnitude of biomass yield response to N application could be due to environmental effects. Based on contrast analysis, application of animal wastes (mean of cattle manure and poultry litter) improved crude protein concentration, ADF, NDF and TDN of forage samples without biomass yields tradeoff compared with chemical fertilizers (mean of urea and NPK) (Table 4). These improved forage qualities are

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good indicators to focus on PL and CM as soil fertility amendments for quality switchgrass biomass production for animal feed than using chemical fertilizers. However, continues application of PL and CM based on N rate can result in buildup of soil phosphorus resulting excess accumulation and also to run off affecting water quality. Therefore, long term monitoring of the system with soil testing and economic analysis are needed to ensure profitability and protect the environment from pollution.

CONCLUSION

As nutrient sources, PL and CM nutrient concentration varied from year to year suggesting the need to test these materials every year for proper nutrient management. The biomass yields at LCB was higher but with low crude protein concentration compared with Perkins. Some forage qualities declined with age of switchgrass establishment requiring agronomic management practices to keep them in acceptable range. Switchgrass biomass yields without nutrient application was low with poor forage qualities. Application of PL and CM increased dry biomass yields of switchgrass by 52 and 41% with improved crude protein concentration compared to the control treatment, respectively. Similarly, fertilization of switchgrass with PL and CM improved crude protein concentration without biomass yields, ADF, NDF and TDN tradeoff compared with chemical fertilizers. This helps to promote nutrient re-cycling and production of quality switchgrass animal feed. When PL and CM applied based on nitrogen requirement, phosphorus could build up beyond crop phosphorus due to repeated applications. Therefore, continuous monitoring of the system and economic analysis of the different nutrient sources are needed to warrant environmental quality and profitability.

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