HYDROLOGIC AND WATER QUALITY IMPLICATIONS OF MANAGEMENT OF TALL FESCUE PASTURES IN A SOUTHERN PIEDMONT ENVIRONMENT

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Abstract. Runoff and nutrient losses were monitored over two and half years from different fescue management systems that are used by producers in the Georgia Piedmont. A randomized complete block arrangement of 14 paddocks under combinations of a grazing (grazed or hayed), fertilization (poultry litters or inorganic fertilizer) and tall fescue type (high endophyte high alkaloid, high endophyte low alkaloid, and endophyte free) treatments was used. The study was located at the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center, near Watkinsville, GA. Treatments did not influence amount of runoff. Mean concentrations of ammonium-nitrogen (NH_4-N) and nitrate-nitrogen (NO_3-N) in runoff were low (< 1 ppm). However, concentrations of dissolved reactive phosphorus (DRP) were elevated in the grazing treatments, and were higher with poultry litter (mean: 1.2 to 3.3 ppm) compared to hayed treatments (mean 0.5 ppm). The study suggests that management practices that reduce DRP losses from grazing lands fertilized with poultry litter or inorganic fertilizer are needed to protect water resources.

INTRODUCTION

Pastures have replaced row-crop agriculture in many parts of the Southern Piedmont, in response to soil and water conservation needs. However, nutrient losses from livestock manure and/or poultry litter fertilization can contribute to eutophication of surface waters (Edwards and Daniel, 1992 and 1993). Georgia, the top broiler producer in the US, generates about 1.5 million tons of litter annually, about 40 percent of which is directly applied to fields, usually pastures, around production facilities (Starkey, 2003). The remaining 60 percent is sold or traded to second parties.

Tall fescue (*Festuca arundinacea* Schreb) is a common grass source for pastures in the Southern Piedmont. Most tall fescue is infected with a fungal endophyte, *Neotyphodium coenophialum* (Shelby and Dalrymple, 1987), which produces alkaloids that are toxic to grazing animals (Stuedemann and Hoveland, 1988) with losses of revenue to farmers. Researchers have developed tall fescue with the endophyte removed and one with an endophyte that produces low levels of alkaloids. These types of tall fescue improve animal performance. The endophyte/fescue mutualistic association, however, has broader ecological implications. Franzluebbers et al. (1999) found that soil organic carbon under tall fescue with high endophyte infection was 18% greater at a depth of 0-1 in. than under tall fescue with low endophyte infection. This appears to be true for soil nitrogen also (Franzluebbers, personal communication). The greater C and N sequestration potential of tall fescue with endophyte infection could influence soil characteristics, with impact on runoff and/or water quality.

United States Environmental Protection Agency has recently developed recommendations for numerically-based national nutrient strategy with regard to N and P using "Level III Ecoregions" (EPA, 2002). One such region is the Southern Piedmont. These criteria are intended as starting points for states and other entities to develop more refined criteria based on designated uses. Assessment of the efficacy of existing water quality policies and the need for and likely consequences of new policies need to be based on reliable information. We need to establish if water quality problems are isolated to a particular land use or ubiquitous, whether they show regional associations, or whether they are static or dynamic. Acquiring such information is challenging.

The objective of this research was to determine hydrologic and water quality response of pastures in the Georgia Piedmont under three important management variables that producers have control over: 1) three fescue types expressing different endophyte infection and alkaloid production levels, 2) poultry litter versus inorganic fertilizer, and 3) grazing of cattle versus haying.

MATERIALS AND METHODS

Site

The experimental site, referred to as Dawson Field, is a 50-acre parcel of land near Watkinsville, GA (33^o 62' N, 83 ^{o} 25' W) owned and operated by the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center

(JPC). The soil is predominantly Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludults). Cecil and related soils occupy over 50% of the Southern Piedmont (Radcliffe and West, 2000). They are deep, unless located on eroded landscape, well drained, and moderately permeable. The surface texture is sandy loam to sandy clay loam and the subsoil clay. Dawson Field was in conventional tillage cropping until 1992 when it was fallowed. The site was developed between 1999 and 2002 by laying out all necessary infrastructures for 14 paddocks and establishing the fescue treatments. Paddocks were designed as stand-alone catchments with berms around the perimeter, approximately 2.4 acres each. Average slope of paddocks is 4.1% varying from 2.3 to 6.0%.

Experimental Design

The experiment was laid out as a randomized block design. Three tall fescue types and two different sources of fertilization make up six of the grazing treatments. With duplication this takes up 12 paddocks. A duplicated hayed treatment used as control fills the remaining 2 paddocks.

The three tall fescue types were:

1) High endophyte Jesup with high alkaloid E+ Wild (referred to as Wild henceforth)
2) High endophyte Jesup with low alkaloid E+ Max Q (referred to as Max henceforth); and
3) Endophyte free Jesup E- Free (referred to as Free henceforth).

The two fertilizer sources and rates were:

1) Inorganic fertilizer: 180-36-90 lb N-P_2O_5-K_2O acre^{-1} yr^{-1} - typical for the region; and
2) Poultry litter: 3 tons acre^{-1} yr^{-1} providing ~240-90-125 lb N-P_2O_5-K_2O acre^{-1} yr^{-1}

The higher N rate from broiler litter accounted for a mineralization rate of ~60%. The control paddocks were planted to Max with inorganic fertilizer application. Fertilization is done in split application made in Feb/Mar and in Sep/Oct.

Grazing Strategy

Starting in 2002, a total of about 60 yearling heifers were introduced into the paddocks each October at a density to maintain 900-1800 lb acre^{-1} of available forage per paddock. They were maintained through September of the following year and then taken off paddocks and sold.

Runoff Measurement, Sampling and Analysis

Runoff was routed by gravity to the paddock outlets where the flow rate was measured with a calibrated 1.5ft H flume (L.H. Leathers, Inc., Athens, GA). Rainfall was measured at outlet of four of the paddocks with tipping bucket rain gauges (Model TR-525M, Texas Electronics, Dallas, TX). All measurements were automated through integration with CR10X data loggers (Campbell Scientific Inc., Logan, Utah). A 1-inch diameter PVC pipe with tiny holes was securely placed at the outlet of each flume to continuously intercept and direct part of the runoff to a collecting trough. Runoff following storm events was transferred into labeled polyethylene bottles and brought into the JPC laboratory (two miles away) and stored in refrigerators (4^{o}C). After runoff collection, the sampling devices were cleaned and made ready for the next event. Sub-samples of the stored samples were filtered (0.45 µm) for determination of NO_3-N, NH_4-N and DRP concentrations using a continuous flow analyzer and standard EPA methods.

Statistics

Runoff data were analyzed as a randomized complete block experiment with paddock as the experimental unit and by using mixed model procedures. The fixed main effects were grazing treatment (grazed or hayed), fertilization treatment (poultry litter or inorganic), and fescue treatment (Free, Max, or Wild) and the fertilizer*fescue interaction. Block was considered a random variable. Statistical analyses were conducted using PROC MIXED of SAS (Littell, et al., 1996). Nutrient content of runoff (NO_3-N, NH_4-N, and DRP) was also analyzed by mixed model procedures with similar models. Treatment averages were used to compare grazing treatments with hayed treatments using PROC TTEST of SAS.

RESULTS AND DISCUSSION

Runoff

Runoff measuring sensors malfunctioned in three of 14 paddocks. Occasional sensor malfunction made records incomplete in some others as well. Not all paddocks produced runoff at the same time. Nevertheless, 16 to 28 significant runoff events were recorded. Mean rainfall during these events was 1.81 in. with a range of 0.67 to 3.64 in. Mean runoff from paddocks varied from 0.04 to 0.33 in. Mean runoff as percent of rainfall varied from 2 to 17 percent. Tests for fixed effects of treatments or interaction did not show influence on runoff partly because of runoff variability leading to very high standard errors. There was some consistency in runoff variability among some paddocks, probably attributable to topographical and soil characteristic variations, which need further detailed investigation.

Nutrient Losses

The sampling system generally worked well and the

Table 1. Statistical summary of nutrient concentration from runoff events at Dawson Field Between 5/4/2002 and 9/27/2004

	Paddock number and treatment designation and statistical values*						
Statistics	1, 9 GOM	4, 10 GOW	5, 12 GOF	6, 11 GIM	2, 8 GIW	3, 7 GIF	13, 14 HIM
			NH_4-N concentration - ppm				
Mean	0.39	0.99	0.80	0.36	0.60	0.36	0.38
Median	0.11	0.20	0.23	0.18	0.14	0.15	0.06
STDV	0.90	1.81	2.04	0.55	1.41	0.62	1.27
Minimum	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Maximum	6.20	9.40	11.53	2.83	7.43	2.57	7.40
Samples	56	54	46	48	54	54	54
			NO_3-N concentration - ppm				
Mean	0.23	0.53	0.55	0.42	0.91	0.45	0.85
Median	0.12	0.18	0.17	0.15	0.17	0.12	0.08
STDV	0.33	0.69	0.90	0.61	2.90	1.00	3.39
Minimum	0.00	0.00	0.03	0.01	0.01	0.02	0.00
Maximum	1.76	2.63	3.74	2.66	20.36	5.47	22.97
Samples	56	54	46	48	54	54	54
			DRP concentration - ppm				
Mean	2.84	3.26	2.45	1.20	1.16	1.82	0.49
Median	2.71	2.95	1.85	0.97	1.02	1.58	0.30
STDV	2.48	1.88	2.01	0.90	0.92	1.42	0.59
Minimum	0.46	0.40	0.34	0.10	0.02	0.21	0.00
Maximum	16.74	7.50	9.3	3.39	4.88	7.65	3.43
Samples	56	52	46	48	52	52	54

*Treatment designation: G-grazed, H-hayed; O-organic fertilizer (poultry litter), I-inorganic fertilizer; F-Free, M-Max, W-Wild fescue.

values missing were much less than those of the runoff events. Paddocks 5, 7, and 14 had no runoff data but nutrient samples were collected. A summary of descriptive statistics for nutrient concentrations with paddock numbers and treatments are given in Tables 1. Analysis of variance showed no treatment effect for NH_4-N concentration (P>0.2). Mean and median concentrations were less than 1 and 0.25 ppm, respectively. Concentrations for NO_3-N were generally very low. Means were less than 1.0 while medians were less than 0.2 ppm. Nevertheless analysis of variance showed fixed effects (P<0.1) for all three treatments and the interaction between fertilizer and fescue type: hayed > grazed; inorganic > poultry litter; Wild > Max or Free; and inorganic-Wild > remaining fertilizer-fescue combinations.

Concentrations of DRP were highest in the grazed treatments with means varying 2.5 to 3.3 ppm in the grazed-poutry litter, and 1.2 and 1.8 ppm in the grazed-inorganic treatments. The hayed treatment had a mean of 0.5 ppm. Analysis of variance for DRP showed fixed effect for fertilizer treatment only (P=0.003). Comparison between hayed and grazed treatments is confounded by two fertilizer treatments for grazed with only one fertilizer treatment for hayed. T-Tests were ran between the hayed and each of the fertilizer*fescue grazing treatments showing the hayed treatment had significantly less DRP concentration in each case (P<0.001).

Concentrations for all three nutrients reached maximum values when runoff occurred soon after fertilization. Nutrient mass losses were calculated by multiplying the nutrient concentrations from each event (composite samples collected) by the corresponding runoff amount when available. Nutrient mass losses were very low. Means were: 0.03 lb $acre^{-1}$ or less for NH_4-N, 0.06 lb $acre^{-1}$ or less for NO_3-N, and 0.14 lb $acre^{-1}$ or less for DRP.

CONCLUSIONS

The environmental implications of pastures in the Southern Piedmont managed in tall fescue expressing different levels of endophyte infection and alkaloid production are not understood, especially when the management includes such variables as poultry litter versus inorganic fertilization and grazing versus haying. Localized data are required to refine recent numerically-based ‘Ecoregional Nutrient Criteria’ recommendations by EPA.

After two and half years of experimentation, the treatments have yet to affected runoff amount. Nevertheless, there appear to be consistent runoff variations between some paddocks that exhibit topographical and soil characteristic differences, which need further investigation to elucidate.

Under the imposed treatments of this experiment, the total mass of the nutrients leaving the paddocks was very small. Concentrations of both NH_4-N and NO_3-N in runoff were low. However, runoff DRP concentration was elevated in the grazed paddocks, with values even greater under grazed-poultry litter fertilization compared to hayed paddocks. The grazed poultry litter paddocks had about 2.5 times more P applied. Concentrations of DRP seem to reflect that ratio. The literature indicates that in situations where runoff carries little sediment, as was the case for these paddocks, soluble phosphorus constitutes a large part of the total P leaving a site. Management practices that could reduce this off-site loss of P, such as amount and timing of fertilizer application and perhaps buffers of different grass species, are needed to protect water resources.

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