EFFECTS OF IRRIGATION ON BERMUDAGRASS GROWN ON SOIL HEAVILY FERTILIZED WITH POULTRY LITTER FOR 40+ YEARS

D.E. Rowe, G.E. Brink, and K.R. Sistani
Waste Management and Forage Research Unit
USDA-ARS, Mississippi State, MS

INTRODUCTION

It is now understood now that long term land application of animal manures may result in high concentrations of the soil nutrients, nitrogen and phosphorus. As those concentrations increase the potential for pollution of runoff water may also be increased. Remediation is effected on these fields to reduce the concentrations of nutrients through proper management of forages so nutrients are removed from the soil in the harvested hay. The forage yield is optimized using management which also insures that the soil surface is protected from erosion. Some researchers have postulated and some research has indicated that fields long used for waste disposal still respond to supplemental nitrogen applications (Halverson, 1989). This suggests that nitrogen may be limiting, possibly because the nitrogen content of the animal waste is modest in contrast to the phosphorus content. The amounts of nitrogen and phosphorus in the forages be in a ratio near 8:1 while the animal waste used as a fertilizer may have a nutrient concentrations in ratios closer to 4:1 (Sharpley and Halvorson, 1994). Other researchers have found that phosphorus contents of leaves, stems, and other plant parts do vary and have suggested that breeding might be used to increase the amount of phosphorus removed in the harvested hay by simply increasing the quantity of that plant part or the relative percentage of biomass for that plant part (Pederson and Brink, 2000). This approach appears successful for the improvement of alfalfa hay protein with use of multifoliate gene to increase leaf mass relative to the constant stem mass.

Increasing manure application rate generally increases forage yield, but not all of the nutrients in the effluent or litter may be available to the plant. For poultry litter, estimates of N volatilization shortly after field application are 10 to 37% (Kee et al., 1996). Soil storage of P may be near 90% of the total P applied (Scott, et al., 1995). Estimates over four years of field tests suggest 25% of the N and less than 20% of the P in the applied manure were recovered in the harvested forage. The accumulation of nitrogen in the aboveground portion of plants in contrast to total N of the plant is estimated to be 75% for rye (*Secale cereale* L.), 90% for hairy vetch (*Vicia villosa* Roth), and 80% for crimson clover (*Trifolium incarnatum* L.)(Shipley et al., 1992). The uptake of nitrogen may be underestimated because abundant N favors volatilization of NH_3 from the plant (Charpe, et al., 1988). Time of application does affect the rate of apparent uptake or recovery. With early applications of N about 40% of the N is recoved, but with late applications, 90% of the N is recovered (Bigeriego, et al., 1979). Estimates of total plant N which is lost due to volatilization of NH_3 is 23% of the total plant N (Sharpe and Harper, 1997). Nitrogen unaccounted for in nitrogen balance studies are attributed to leaching, denitrification, or sampling errors (Sharpe et al., 1988), but NH_3 loss from the plant may be much more important than previously thought.

Researchers at WM&FRU proposed that irrigation might be an economically reasonable method of reducing the rate of approach to the limits of extractable P in the soil at which application rates are severely curtailed or application is terminated. Researchers are also aware that bermudagrass morphologically changes during periods of severe drought stress. Under drought, the stolons are relatively large and few but with irrigation to alleviate that moisture stress, the leaves are many and stems have small diameters. Thus the effects of irrigation are expected to be increased yields and changes in morphology of the plant. Any interaction of these two factors on the rates of nutrient removal is not predictable for the extraction of the major nutrients from the field.

Bermudagrass was used in this study because it is recognized as an aggressive grass which with its indeterminate growth habit increases in production of biomass as soil fertility is increased. Also, farmers know how to manage this forage and this grass has known nutritive and market value.

MATERIALS AND METHODS

This study of management systems was executed in a field used for litter disposition since about 1955. The soil tests regularly indicate greater than 300 ppm extractable P using Mechilic 3 extraction (Mechlich, 1984). This soil is a Savannah silt loam on which 'Alicia' bermudagrass which is thought to be a triploid hybrid between *Cynodon dactylon* L. Pers and *C. transvaalensis* had been established several years earlier. Litter had been regularly applied and the land was grazed for up to nine months of the year. The plots were 2 x 5 meters with 2 meter aisles between irrigated and unirrigated plots. All of the plots were fertilized in the spring with split applications at 60 da intervals with poultry litter at either 9 Mg/ha (4 tons/acre) or 18 Mg/ha (8 tons/acre). Nitrogen was also applied to half of the plots at a rate of 67.2 kg/ha (60 pounds/acre). Half of the plots were irrigated with 20 cm (0.8 inches) of water on seven day intervals when rain accumulation was less than 15 cm in the previous seven days. In 1998 the irrigation was applied on eight occasions and in 1999 irrigation was applied eleven times. Data reported here includes only the first two years of a continuing study. Harvests were made on 30 day intervals except for the last harvest which could be delayed by slow growth under droughty conditions. Dry weights of harvested forage were tabulated and concentrations of phosphorus and potassium determined after ashing and acid treatment using an ICP (Inductively Coupled Plasma) analyzer and the total nitrogen was estimated using Kjedahl digestion.

RESULTS

Though the test plots and the culture did not change from year to year, the environments for 1998 and 1999 were very different in levels of moisture stress. Because of the large difference, responses are reported separately for each year. Irrigation resulted in yield increases of 12% in 1998 and 45% in 1999 over the unirrigated plots (Table 1). This difference in production increases largely reflected the greater rain and the better spacing of those rains in 1998. The four harvests in 1998 yielded an average of 17.7 Mg/ha (7.9 tons/acre) which was 21% greater than 14.6 Mg/ha (6.5 tons/acre) from five harvests in 1999. In particular, the unirrigated plots of 1999 yielded 30% less than the unirrigated plots of 1998. For the irrigated plots, the 1999 biomass yield was 8% less than that of 1998. Obviously the irrigation applied was not sufficient to compensate for all of the moisture stress.

Irrigation significantly increased the yield of biomass and each nutrient in both years and the differences among harvests were always significant (Table 1). The litter treatment appeared to affect everything except phosphorus yields and the nitrogen treatment affected nearly everything except phosphorus yields. Interactions of harvest and nitrogen application or irrigation were also common. None of the three way interactions were significant. In contrast, the concentrations of nutrients in the plants were little affected by the irrigation (Table 2). All nutrient concentrations were affected by litter applications and nitrogen application had a significant effect on concentrations of nitrogen and phosphorus.

DISCUSSION

Under the often accepted theory of factors limiting growth, plant growth proceeds "normally" until some factor in the environment becomes limiting. When that limit is removed, such as with irrigation, growth is again maximized until some factor again becomes limiting. This phenomena has often been observed as the response to fertilization and other factors, but yield of an element per unit of harvested field area is a function of both the biomass yield and concentration of element in biomass. The prediction of nutrient yield from biomass production can be effective only when the nutrient concentration in the plant is unresponsive to changes in the environment. The veracity of constant nutrient concentration in different environments is an assumption which can not be accepted without verification.

Nutrient Removal

The current research was structured to measure yields as function of litter application rates, nitrogen fertilization, and irrigation. In this design, the effects of nitrogen and irrigation on nutrient concentrations along with biomass yields facilitates verification for this system of bermudagrass production. When nutrient yields are not equivalent to changes in biomass, the responses are obviously complex and generalities are made only with some caution.

With irrigation the yields increased about 12 and 45% while the phosphorus removal increased by 20 and 46% (Table 3). The irrigation did not have any consistent significant effect on nutrient concentrations (Table 2), thus it appears that increases in nitrogen, phosphorus, and potassium removal with irrigation were proportional to changes in biomass production because concentrations did not vary.

The addition of nitrogen in the form of ammonium nitrate increased the biomass in 1998 but not in 1999 and increased the yield of nitrogen in both years but not phosphorus or potassium. These results did not support assumptions that nitrogen was limiting or that nitrogen application increases ether biomass or phosphorus yield in that biomass.

The addition of 18 Mg/ha of poultry litter significantly increased biomass and the extraction of nitrogen and potassium over that found with 9 Mg/ha. In contrast, the yield of phosphorus was unchanged. It is inconsistent that phosphorus removal was linked to substantial biomass increases with irrigation, but increases in biomass attributed to increases in applications of poultry litter did not increase the phosphorus removal.

Table 2 indicates that concentrations of nitrogen, phosphorus, and potassium were all significantly affected by the litter applications and with nitrogen applications the concentrations of nitrogen and phosphorus were significantly affected, but not the potassium concentrations. The incongruency for phosphorus yield not increasing when the biomass production did increase is solved by inspection of the mean concentrations of phosphorus for the different treatments. Application of either nitrogen or an additional 9 Mg/ha of poultry litter resulted in significant decreases in phosphorus concentrations which partially offset the increases in biomass. In 1998 the concentration of phosphorus decreased from 0.35% to 0.33% for both treatments and in 1999 the concentrations of phosphorus decreased from about 0.38 to 0.36 %. In general terms there was an apparent antagonistic relationship between treatments expected to promote growth, other than irrigation, and the concentration of phosphorus in the herbage.

This complex response has been observed in the first two years of a continuing study and has to be applied with caution. The results may be specific for this grass species, or this cultivar, or just for these environments. With those cautions applied, the results do indicate the complex responses can occur when applications of organic or inorganic nutrients on the field are increased. This unexpected antagonistic relationship between increases in soil fertility and the concentration of phosphorus in the plant indicates the linkage between biomass yield and phosphorus yield is dependent on the cause of the increase in biomass yield.

Value of Irrigation

A primary motive of this research was to define the effect of a moderate irrigation for the removal of phosphorus from fields which have been exposed to continued application of poultry litter. The effect of irrigation was to stabilize the phosphorus removal from this field at about 68 kg/ha (57 lbs/acre) while the phosphorus yield on the unirrigated was greatly reduced by drought. Thus an average of 30 or 35% increase in phosphorus removal was effected with this irrigation. With irrigation, the amount of phosphorus removal in ten years would approximate that with 14 years of harvesting on the unirrigated field.

The economics of this operation would be affected by probability of greatly reduced litter application rates or termination of applications on fields which are testing at increasingly higher levels of extractable phosphorus. The difficulties of acquiring additional land for litter applications and the problems of moving the litter to more remote locations or even the potential loss of poultry house due to increased costs of litter handling would all affect the decision to irrigate. Of course the decision would be easier if a substantial pond was in the immediate vicinity of the field. Another factor which may offset costs is that in drought years, the value of the hay may be greatly increased.

To verify the value of irrigation, more comprehensive studies using different bermudagrasses and different rates of irrigation are planned. In any case, the irrigation will likely be a farm specific choice which is influenced by a complex set of financial and logistical conditions.

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Table 1. Summary of tests for significant effects and interactions on biomass production or nutrient yields in 1998 and 1999.

	Yields							
	Biomass		Nitrogen		Phosphorus		Potassium	
Source	1998	1999	1998	1999	1998	1999	1998	1999
Irrigation	*	*	*	*	*	*	*	*
Litter	*	*	*	*			*	*
Nitrogen	*		*	*			*	*
Irrigation*Litter								
Irrigation*Nitrogen								
Litter*Nitrogen								
Irrigation*Litter*Nitrogen								
Harvest (Harv)	*	*	*	*	*	*	*	*
Harv*Irrigation		*		*	*	*		*
Harv*Litter	*		*	*				
Harv*Nitrogen	*	*	*	*		*		*
Harv*Irrigation*Litter								
Harv*Irrigation*Nitrogen								
Harv*Nitrogen*Litter								

* Indicates statistical significant effect at the P=0.05 level of confidence.

Table 2. Summary of tests for significant changes in concentrations of nutrients for each factor and each interaction in 1998 and 1998.

	Nutrient Concentrations					
	Nitrogen		Phosphorus		Potassium	
Source	1998	1999	1998	1999	1998	1999
Irrigation			*			*
Litter	*	*	*	*	*	*
Nitrogen	*	*	*	*		
Irrigation*Litter				*		
Irrigation*Nitrogen	*					
Litter*Nitrogen						
Irrigation*Litter*Nitrogen						
Harvest (Harv)	*	*	*	*	*	*
Harv*Irrigation	*	*	*	*		*
Harv*Litter		*		*		
Harv*Nitrogen		*				
Harv*Irrigation*Litter						
Harv*Irrigation*Nitrogen						
Harv*Nitrogen*Litter						

* Indicates statistical significance at the P = 0.05 level.

Table 3. Changes in yields of herbage and nutrients as affected by either irrigation nitrogen fertilization, or litter applications for years 1998 and 1999.

	Biomass		Nitrogen		Phosphorus		Potassium		
Treatment	1998	1999	1998	1999	1998	1999	1998	1999	
	----Mg/ha----		---------kg/ha---------						
Not Irrigated	16.7	11.8	333	235	53.6	42.3	415	269	
Irrigated	18.7	17.2	368	357	64.3	63.3	468	414	
Change	12%	45%	10%	51%	20%	46%	12%	53%	
Significance of change	*	*	*	*	*	*	*	*	
No Nitrogen Added	16.8	14.1	329	272	57.8	53.0	425	225	
Nitrogen Added		18.4	14.8	373	320	60.1	53.6	589	348
Change	9%	5%	13%	17%	4%	1%	7%	4%	
Significance of change	*		*	*					
4 Tons of Litter	16.8	13.9	327	272	57.8	52.6	425	305	
8 Tons of Litter	18.4	15.2	376	320	60.1	53.9	458	376	
Change	9%	9%	15%	18%	4%	2%	8%	22%	
Significance of change	*	*	*	*			*	*	

* Indicates significant differences shown in Table 1 and reproduced here for clarification.