YIELD AND NUTRIENT CONCENTRATION AND CONTENT IN RESPONSE TO NITROGEN FERTILIZATION IN FORAGE AND GRAIN SORGHUM

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ABSTRACT

Dairy farmers are looking for forage crops that can remove large amounts of N from spray fields. With this concern in mind two cultivars of sorghum (Sorghum bicolor), 'Asgrow Chaparral' (Grain Sorghum) and 'DeKalb FS25E' (forage sorghum), were used in a study to determine their response to seven N rates (0. 40, 80, 120, 160, 200, 240 lb N/ac). The third leaf from the flag was sampled at the early bloom stage of maturity and analyzed to determine plant health. Plant concentrations showed that N and K were below sufficiency levels with Mn, Fe and Ca being accumulated at sufficient levels and P, Mg, Cu, and Zn accumulated at levels above sufficiency. Whole plant samples were collected to determine nutrient content and yield. Nitrogen accumulation in the whole plant increased with N fertilization rate from 26.7 to 63.4 lb N/ac for the O and the 160 lb N/ac rate, respectively, while N accumulation decreased with additional N. Dry matter accumulation increased with increasing N fertilization rates and peaked at 160 lb N/ac. Grain samples were also collected to determine grain mineral concentration and yield. Grain yield was highest in the Asgrow Chaparral, however both cultivars showed a response in grain yield to N fertilization up to the 120 lb N/ac level.

INTRODUCTION

Determination of nutrient removal by plants is important for three reasons. First, this information can be used to find the uptake ratios of nutrients by various species of plants so that plant requirements can be met. Secondly, nutrient removal information can be helpful for determination of animal nutrient intake. The third reason, nutrient removal has become a major concern due to the risk of environmental pollution. Dairymen, feedlot operators, and poultry producers have all been faced with new environmental regulations that have forced them to control the nutrients N and P in manure wastes. One method that these producers are using to dispose of excessive nutrients is to recycle them through crops. This is one of the most economical and efficient strategies for nutrient removal because plants take up large quantities of N and other nutrients and the plants can be used for livestock feed.

Florida is unique when compared to other areas of the country because crops can be grown year round. Double or triple cropping is a common practice that is used to take up manure nutrients on dairy spray fields throughout the year. Sorghum (Sorghum bicolor L. Moench) can be used in a double cropping system to remove N by following itself or corn (Zea mays **L.).** Gallaher, et al. (1991) in a double cropping study in Central Florida found that forage sorghum varieties take up 96 to 235 lb N/ac for 2 April planting and 121 to 242 lb N/ac for 20 July plantings. Some sorghum varieties exhibit a large potential to take up nutrients which suggests that sorghum is a good crop to use for excess manure nutrient removal.

Perry and Olson (1975) found that grain N increased with N fertilization rates (0.80, 160, and 240 lb N/ac) in corn and grain sorghum with response in grain yield up to the 80 lb N/ac. Heron, et al. (1963) found that N content of both forage and grain increased for all application rates of N fertilizer (0. 40, 80, and 120 lb N/ac). The greatest accumulation of N occurred between the soft dough and hard dough stages of maturity. Total recovery of N in above ground parts of plant averaged between 37 to 83% with the greatest recovery in the 40 lb N/ac treatment, suggesting diminishing returns with increased N application. Vanderlip (1979) reported that N and dry matter accumulation in the leaves and stalks begins to decrease 50 days after emergence due to diversion for grain production. Nitrogen recovery efficiency of plants will have a large impact on the use of plant varieties in excessive nutrient recovery systems. More research is needed to determine the ability of crop varieties to effectively take up nutrients. This study will look at the effectiveness of two cultivars, grain sorghum and forage sorghum, to take up **N** under varying N levels, as well as the effect of N levels on other essential

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nutrients and plant health. Jones, et al. (1991) published the sufficiency ranges for minerals in the third leaf below the head (diagnostic leaf) during the bloom stage with head visible.

MATERIALS AND METHODS

Two cultivars of sorghum, 'DeKalb FS25E' (forage sorghum) and 'Asgrow Chaparral' (grain sorghum) were planted at the Green Acres agronomy farm in Gainesville, Florida. The cultivars were no-till with subsoil planted on 27 May 1993 into an area of soil type Arredondo fine sand (Sandy siliceous thermic Grossarenic Paleudult) following a crop of 'Wrens Abruzzi' rye (Secale cereale L.) grain. The following day, 2 qtslac of Glyphosate and 12 Ibslac of Corbofuran 15G were applied. The plot was irrigated to ensure germination of seed. A N study was setup using a split plot design laid off in blocks. Three blocks were formed using the two cultivars as the whole plots and seven N rates (0, 40, 80, 120, 160, 200, and 240 lb N/ ac) as the split plots. On 12 June, one half of the split N rates was applied. On 17 June, 1.5 qtslac of Lanate was applied and on 18 June. 2 qtslac Atrazine and 0.75 qtlac of 2-4D were applied. On 1 July, 0.75 qt/ac Gromoxone was postdirected and the second half of the N was applied. Irrigation was used during the growth period to insure adequate moisture for normal growth.

On 4 August (at early anthesis), 5 diagnostic leaves per plot (3rd from the flag) were sampled per plot from the Asgrow Chaparral plots. Samples were dried and ground for analysis. Two 16 ft row samples of Asgrow were collected to determine grain yield and whole plant yield on 18 August. The samples for grain yields were dried, thrashed, weighed to determine yield then ground for analysis. Sub-samples of whole plants were dried for dry matter determination, then chopped and ground for analysis. This same procedure was repeated on the DeKalb FS25E with the diagnostic leaves collected as plant heads emerged and the grain yield and whole plant samples taken on 21 September.

Samples were analyzed for N and mineral concentration. Nitrogen analysis was performed using the procedure developed by Gallaher, et al. (1975) using an aluminum digestion block and an auto analyzer (Agronomy Lab, UF), Mineral concentration was determined for P, K, Ca. Mg. Cu, Fe, Mn. Na and Zn using the procedure described by Gallaher, et al. (1991). Mineral analysis was conducted in the University of Florida Soil Testing Laboratory by using flame emission spectrophotometry for K; colorimetry for P; and atomic absorption spectrophotometry for Ca, Mg, Cu, Mn, Fe, Na and Zn.

Results were placed in a QUATRO-PRO 4.0 (1987) spreadsheet for nutrient content transformations and manipulations. Statistical analysis (MSTAT, 1987) and regression analysis were also performed.

RESULTS AND DISCUSSION

Diagnostic Leaf Nutrient Diagnosis

Evaluation of the results from the analysis of the diagnostic leaf showed many characteristics of crops grown on sandy soils. Nitrogen concentration in the plant material was below the sufficiency level for all levels of N fertilization as defined by Jones, et a1. (1991). However. there was significant differences in N accumulation between N levels (Table 1). Diagnostic leaf N accumulation increased significantly from the 0 to 40 lb N/ac level (increasing 0.19 % N for the grain sorghum, and 0.34 % N for the forage sorghum), and the 80 to 120 lb N/ac level (increasing 0.31 % N for the grain sorghum and 0.16 % N for forage sorghum). The deficiency of N in the diagnostic leaf was assumed to be caused by N-leaching through the sandy soils used in the experiment. Application of N in 3 or 4 splits has aided in preventing N-leaching on sandy soils (Lord, 1991). However, the two applications of N in this study did not correct the problem and suggest that N should be split into 4 or more applications to decrease N-leaching.

Phosphorus concentration levels were high in diagnostic leaves at all levels of N fertilization. There were significant differences in P among the levels of N fertilization (Table 1). There was also a significant difference in the concentration of P between the two cultivars, the grain cultivar had significantly higher concentrations of P compared to the forage cultivar (grain sorghum, 0.67 % P; forage sorghum, 0.46 % P).

Potassium concentration, like N concentration. was low at all levels of N fertilization. There were

Table 1. Nitrogen, P, Mg, K. Ca. Mn, Zn, Cu. and Fe concentrations in the third leaf from the flag at early flowering in two sorghum hybrids.

N	Hybrid			Hybrid			Hybrid		
	Asgrow	DeKalb		Asgrow	DeKalb		Asgrow	DeKalb	
Rate	Chapar	FS25E	Mean	Chapar	FS25E	Mean	Chapar	FS25E	Mean
lb N/ac	---------- % N ----------			---------- % P ----------			---------- % Mg ----------		
0	1.46	1.14	1.30 c	0.72	0.49	0.61 a	0.40	0.25	0.33 c
40	1.65	1.48	1.57 b	0.70	0.43	0.57 abc	0.39	0.31	0.35 bc
80	1.67	1.55	1.61 b	0.71	0.41	0.56 abc	0.48	0.30	0.39 abc
120	1.98	1.71	1.85 a	0.62	0.42	0.52 c	0.47	0.35	0.41 abc
160	2.03	1.68	1.86 a	0.63	0.46	0.55 bc	0.46	0.35	0.41 abc
200	2.03	1.79	1.91 a	0.67	0.50	0.59 ab	0.50	0.37	0.43 ab
240	2.18	1.78	1.98 a	0.68	0.48	0.58 ab	0.52	0.40	0.46 a
LSD =			0.16			0.058			0.089
MEAN	1.86	1.59**		0.67	0.46**		0.46	0.33	
CV =	8.03			8.52			18.7		
	---------- % K ----------			---------- % Ca ----------			-------- ppm Mn --------		
0	1.20	1.30	1.25 a	4.3	2.6	3.5 d	21.0	24.0	22.5 c
40	1.34	1.20	1.27 a	4.7	3.6	4.1 cd	21.3	31.0	26.2 c
80	0.88	1.29	1.09 a	6.0	3.2	4.6 bc	25.0	27.3	26.2 c
120	1.08	1.15	1.12 a	6.8	3.8	5.2 b	26.7	32.0	29.3 bc
160	1.20	1.29	1.24 a	6.7	4.0	5.3 ab	27.7	35.0	31.3 bc
200	0.82	1.05	0.94 a	7.0	3.9	5.4 ab	34.0	37.7	35.8 ab
240	0.70	1.07	0.88 a	7.9	4.4	6.1 a	51.3	36.7	44.0 a
LSD =			NS			0.85			0.91
MEAN	1.03	1.19 NS		6.1	3.6 *		29.6	32.0 NS	
CV =	40.82			14.18			24.8		
	-------- ppm Zn --------			-------- ppm Cu --------			-------- ppm Fe ----------		
0	40.3 b	43.0 a	41.7	10.3	10.7	10.5 a	73.3	50.0	61.7 b
40	39.0 b	35.3 b	37.2	11.0	10.3	10.7 a	76.7	63.3	70.0 a
80	41.3 ab	30.0 c	35.7	10.0	9.7	9.8 a	83.3	53.3	68.3 ab
120	39.3 b	32.0 bc	35.7	10.3	9.7	10.0 a	86.7	53.3	70.0 a
160	41.7 ab	31.3 bc	36.5	11.3	9.7	10.5 a	90.0	56.7	73.3 a
200	41.7 ab	33.0 bc	37.3	11.7	11.0	11.3 a	86.7	63.3	75.0 a
240	45.7 a	31.3 bc	38.5	12.3	9.3	10.8 a	90.0	60.0	75.0 a
LSD =	5.1	5.1				NS			7.9
MEAN	41.3	33.7 *		11.0	10.0 +		83.8	57.1 *	
CV =	8.03			16.89			9.4		

+, *, and ** = Significant at the 0.10. 0.05 and 0.01 levels of P, respectively. NS = not significant. Values in columns among N rates for each element not followed by the same letter are significantly different at the 0.05 level of P according to LSD. Chapar = Chaparral.

no significant differences in the averages of K accumulation between the cultivars or the N levels (Table 1). Low levels of K in the plant material were attributed to the low levels of soil K. Increased K fertilization would be recommended in future studies conducted at this location. Potassium deficiency may have resulted from leaching of fertilizer and the K deficiency may have reduced the yield response to N fertilization. Calcium concentrations in the diagnostic leaf were sufficient at all N rates except the 0 N rate for the forage sorghum. There were significant differences in the Ca concentration at different N rates with Ca increasing with increasing N rate (Table 1). There was 0.25 % higher concentration of Ca in the grain sorghum compared to the forage sorghum.

Magnesium concentrations were high at all N fertilization levels with significant differences between the N levels (p=.10) (Table 1). Manganese concentrations were sufficient at all levels of N fertilization with no significant differences in accumulation due to cultivars or N fertilization rate (Table 1). Zinc concentrations were above sufficiency levels for both cultivars (Table 1). There was no trend in the Zn accumulation in either of the cultivars (Table 1). Copper was also above sufficiency levels at all levels of N fertilization with no significant differences in Cu accumulation among the N fertilization levels (Table 1). Iron accumulation was sufficient at all levels of N fertilization with the grain cultivar having a higher accumulation of Fe than the forage cultivar (Table 1).

There were several common mineral relationships that held true in this study. With increasing N rate, N concentration in the diagnostic leaf increased, while P concentrations decreased showing the inverse relationship between N and P. The relationship between N, K, Mg, and Ca was supported by the results of this study. As the N rate was increased K concentration in the diagnostic leaves decreased while the concentrations of Mg and Ca increased.

Yield and Nutrient Content

Grain sorghum showed a 258% greater propensity to accumulate grain than did forage sorghum (p=.10) (Table 2). However, both Cultivars increased 155% in grain yield from N fertilization to peak at 120 lb N/ac with no further response to increased N rate (Table 2). Forage sorghum accumulated 107% more whole plant dry matter than grain sorghum (p= .10). Both cultivars increased 87% from N fertilization to peak at 160 lb N/ac (Table 2).

Meeting sufficiency levels in this study location has been difficult in the past (Lord, 1991). The low K levels may be the limiting agent of insufficient N concentrations in the diagnostic leaf even though high levels of N fertilization were used. Potassium fertilization (possibly split applications) and more awareness of nutrient availability in the soil will aid with future N studies done in this location. The effects of varying the N rate on N accumulation was studied for yield and grain content and whole plant content (Table 2). There was no statistical difference between cultivars in whole plant N accumulation rate at increasing N rates (p=.05) or in the average N accumulation (p= .10. As N rate was increased in both cultivars, the whole plant N accumulation increased 138% to peak at 160 lb N/ac. Beyond 160 lb N/ac, N content remained constant (Table 2). There was also no statistical difference in N accumulation rate at increasing N rates (p= .05) in the grain between forage sorghum and grain sorghum. However, grain sorghum accumulated an average of 300% (p=0.10) more total N in its grain than forage sorghum. With an increasing N rate, N accumulation increased 275% to peak at 160 lb N/ac (Table 2). There was no significant change in N accumulation beyond 160 lb N/ac.

CONCLUSION

Plant health was defined by sufficiency ranges for the diagnostic leaf (Jones, 1991). At all levels of N fertilization, N and K were below sufficiency ranges; Mn, Fe and Ca were within the sufficiency ranges and P, Mg, Cu and Zn were above the ranges. There were no significant changes in nutrient sufficiency with N fertilization. The results of this project suggest that both cultivars will work equally well in nutrient recycling. However, forage sorghum should better utilize the recycled nutrients as a crop for cattle operations interested in feed production.

The effect of varying N fertilization rate on N accumulation, dry matter production and nutrient concentration and content in forage and grain sorghum was studied. Under conditions of K deficiencies in this study, the data suggests there is no difference between the two cultivars of

Table 2. Grain and total plant dry matter yield and N and K content of two sorghum hybrids: ANOVA and regression analysis.

Hybrid	N Rate 0	40	80	120	160	200	240	Mean
				Grain yield, lb dry matter/acre				
Asgrow Chaparral	949	1649	1433	1785	2001	1825	1678	1617*
DeKalb FS25E	15	298	378	674	601	560	636	452
Average	482 c	974 b	906 b	1230 ab	1301 a	1193 ab	1157 ab	
LSD = 325								
Asgrow Chaparral	$y = 1027.9 + 10.47x - 0.032x^2$			$r^2 = 0.80$				
DeKalb FS25E	$y = 30.5 + 6.58x - 0.017x^2$			$r^2 = 0.92$				
				Grain N content, lb N/acre				
Asgrow Chaparral	12.2	24.2	20.7	28.0	35.9	32.0	33.2	26.6*
DeKalb FS25E	0.3	5.2	6.3	11.8	10.7	11.0	11.0	8.0
Average	6.3 d	14.7 bc	13.5 c	19.9 ab	23.3 a	21.5 a	22.1 a	
LSD = 6.2								
Asgrow Chaparral	$y = 13.28 + 0.182x - 0.00041x^2$			$r^2 = 0.86$				
DeKalb FS25E	$y = 0.04 + 0.117x - 0.00031x^2$			$r^2 = 0.94$				
				Grain K content, lb K/acre				
Asgrow Chaparral	4.3	6.8	6.0	7.0	7.3	8.2	6.2	6.5*
DeKalb FS25E	0.1	1.4	1.8	3.0	2.5	2.6	2.9	2.0
Average	2.2 c	4.1 ab	3.9 b	5.0 ab	4.9 ab	5.4 a	4.5 ab	
LSD = 1.4								
Asgrow Chaparral	$y = 4.57 + 0.0362x - 0.00011x^2$			$r^2 = 0.69$				
DeKalb FS25E	$y = 0.22 + 0.0279x - 0.00001x^2$			$r^2 = 0.92$				
				Whole plant yield, lb dry matter/acre				
Asgrow Chaparral	3231	4904	3880	5589	5821	5215	4984	4803**
DeKalb FS25E	5554	9327	9950	11721	10671	11659	10751	9948
Average	4393 c	7116 ab	6915 b	8655 a	8246 ab	8437 ab	7868 ab	
LSD = 1545								
Asgrow Chaparral	$y = 3347 + 25.5x - 0.077x^2$			$r^2 = 0.67$				
DeKalb FS25E	$y = 6080 + 67.3x - 0.203x^2$			$r^2 = 0.91$				
				Whole plant N content, lb N/acre				
Asgrow Chaparral	23.1	40.8	32.4	48.8	62.6	47.0	56.3	44.4NS
DeKalb FS25E	30.2	41.6	51.8	57.4	64.2	57.1	52.7	40.5
Average	26.7 c	41.2 bc	42.1 bc	53.1 ab	63.4 a	52.1 ab	54.5 ab	
LSD = 8.8								
Asgrow Chaparral	$y = 24.24 + 0.2754x - 0.00062x^2$			$r^2 = 0.73$				
DeKalb FS25E	$y = 29.12 + 0.3903x - 0.00121x^2$			$r^2 = 0.97$				
				Whole plant K content, lb K/acre				
Asgrow Chaparral	26.6	56.2	40.3	74.4	36.7	53.8	40.7	47.0NS
DeKalb FS25E	30.2	48.0	65.2	54.3	62.9	50.0	49.4	51.4
Average	28.4	52.1	52.8	64.4	49.8	51.9	45.1	
LSD = NS								
Asgrow Chaparral	$y = 31.96 + 0.377x - 0.00145x^2$			$r^2 = 0.33$				
DeKalb FS25E	$y = 32.96 + 0.416x - 0.00151x^2$			$r^2 = 0.78$				

ANOVA = analysis of variance; +, *, and ** = Significant at the 0.10, 0.05 and 0.01 levels of P, respectively. NS = not significant. Values in columns among N rates for each element not followed by the same letter are significantly different at the 0.05 level of P according to LSD.

sorghum in their ability to accumulate total N in the whole plant. Forage sorghum was found to have a greater propensity to produce dry matter, however grain sorghum had much higher grain yields. The higher grain yield combined with higher N content in the grain of grain sorghum enabled it to overcome the higher dry matter yield of forage sorghum to give an equal ability to accumulate N for both cultivars. This is contrary to the popular belief, which suggests that forage sorghum will be more effective at total N accumulation as well as dry matter production. For the dairyman interested in recycling nutrients, both cultivars appear equally capable of removing N from agricultural wastes. However, the forage sorghum with its higher dry matter yield would likely be the preferential crop for silage production.

Responses in production to increasing N rate suggest that the optimal N fertilization rate for both cultivars should be 160 lb N/ac at this site. Beyond this 160 lb N/ac, there was no significant change in dry matter accumulation, N content or grain yield. The lack of plant response to fertilization above the 160 lb N/ac suggests that the added N is not being taken up by the plant to the same degree as at lower N rates, possibly due to the K deficiency, and may contribute to environmental pollution.

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