Published January, 1973

Role of Pensacola Bahiagrass Stolon-Root Systems in Fertilizer Nitrogen Utilization on Leon Fine Sand[1]

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ABSTRACT

An experiment was conducted with Pensacola bahiagrass (*Paspalum notatum* Flugge) on Leon fine sand near Gainesville, Fla. for 6 years to determine residual effects of applied N on forage N uptake, and changes in stolons, roots, and soil N. Nitrogen was applied at 0, 112, 224, and 448 kg/ha/year. Except for the control, paired plots were used at each N rate. Nitrogen fertilization was discontinued on one of each treatment pairs in 1969 and 1970 to determine the residual effect of N. These treatments were resumed in 1971. The residual effect of N was small for all treatments, amounting to 8, 41, and 95 kg/ha total N in harvested forage above the control for the 2-year period for the 112, 224, and 448 kg N rates, respectively. Unrecovered N through 1968 was approximately 200, 350, and 770 kg/ha for the three treatments, respectively. Nitrogen lost from the stolon-root systems during 1969 and 1970 through decrease in mass and N concentrations was 60, 100, and 190 kg/ha for the three N treatments, respectively. Little of the unrecovered N could be accounted for by analysis of the surface soil. Lack of residual effect on plant growth confirmed that little available N was in the soil profile to rooting depth. Based on previous studies, leaching appears to have limited importance when N is applied to well-established perennial grass pastures during the growing season. Conditions imposed in this soil by high water table, large amounts of plant residues, and rapid decomposition during the summer season could make denitrification a significant factor.

Additional key words: Forage N, N recovery.

NITROGEN is probably the most deficient nutrient in Florida's mineral soils. Its accumulation in soils occurs slowly and its rate of availability is inadequate for optimum crop production. Nitrogen uptake in perennial grass forage from Leon fine sand without N applied ranged from about 30 to 50 kg/ha in contrast to quantities in excess of 200 kg/ha, where high rates of N were used. Oven-dry forage yields were 3 to 4 tons/ha without applied N and 12 tons/ha or more for high rates of N (3). Residual effects of N applied to harvested plots beyond the season of application have been small (4).

It was demonstrated recently (3) that over a relatively long period, apparent recovery of currently applied N in harvested Pensacola behiagrass (*Paspalum notatum* Flugge) forage gradually increased. During the 7th year it exceeded 70% of the annual application. The stolon-root mass and N concentrations were increased by fertilization. Total N in the stolon-root systems was 105, 182, and 245 kg/ha for N rates of 0, 112, and 224 kg/ha, respectively. There is obviously the potential for a large amount of N to be utilized and immobilized in the development and maintenance of the stolon-root systems. The high recovery efficiency of applied N in the latter years of this study was attributed to development of a static condition in stolon-root system development. Beaty, Brown, and Morris (1) in Georgia have also shown the effect of fertilization on stolon-root weights. They emphasized the importance of this large reservoir for storage materials.

Because of the large quantity of N necessary for intensive production and its relatively high cost, the potential utilization of N immobilized in the stolon-root system in the production of forage and recycling of N in soil-plant-animal systems is of interest. Mott, Quinn, and Bisschoff (6) showed substantial residual N effect for grazed *Panicum maximum* in Brazil. The grass had been fertilized with 200 kg N/ha annually for 8 years. Estimated total digestible nutrient production gradually declined when N fertilization was discontinued. Four years after fertilization was discontinued, however, production was calculated to be approximately 30% above the control. Nitrogen utilized after discontinuance of fertilization undoubtedly came from the soil and stolon-root system as well as recycling from animal excretions.

Henzell, Martin, and Ross (5) using Rhodesgrass (*Chloris gayana*) in Australia, showed 57% recovery of applied N in plant tops and 13% in soil and roots to a depth of 30 cm from an N application of 448 kg/ha. Thirty percent was apparently lost from the system. They suggested that losses under grazing might be higher than from harvested plots and that the slow accumulation of N in the soil probably eliminated appreciable benefits from recycling soil N.

The purpose of this study was to measure the residual effects of fertilizer N in terms of forage N uptake under a clipping system and changes in the stolon-root mass, N contents, and soil N.

MATERIALS AND METHODS

The experiment was initiated in 1966 with a Pensacola bahiagrass sod established in 1962 on Leon fine sand, a spodosol, at the Beef Research Unit near Gainesville. A randomized block design with four N rates and four replications was used. Rates were 0, 112, 224, and 448 kg N/ha from ammonium nitrate. Except for the control (no N), paired plots were established for each N rate to permit later measurement of applied N residuals. Phosphorus and K were applied to all plots as ordinary superphosphate and KCl to give an N-P-K ratio of approximately 9-1-4 (N-P_2O_5-K_2O ratio of 4-1-2). The control treatment received the same P-K fertilizer as the 112 kg/ha N treatment. Soil pH was maintained between 6.0 and 6.5 by combined use of high calcic and dolomitic limestones. Forage harvests were made on approximately May 15, July 1, August 10, and October 4 of each year. The complete fertilizer was applied four times per year in equal increments. Applications were made the last week of March and immediately after each of the first three harvests. However, N fertilization was discontinued on one of each of the treatment pairs during 1969 and 1970. All plots were fertilized with N in 1971 according to the treatments originally established. Plot size was 2 by 5 m and the area harvested was 1 by 5 m.

Forage was cut at a height of 2.5 cm. Stolon-root samples were collected immediately after the last forage harvest in October by taking 30 cm square blocks to a depth of 15 cm in 1967 and 1968 from the edge of each plot. In subsequent years two cores from randomly distributed parts of each plot were taken at the

[1] Florida Agricultural Experiment Station Journal Series No. 4434. Received May 8, 1972.

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same date with a 12.5-cm diameter core sampler to a depth of 15 cm. Samples were washed thoroughly to remove as much soil and debris as possible. Stolons and roots were separated. Only living stolons and attached roots were retained.

Forage, stolons, and roots were dried at 70 C. Nitrogen was determined by a micro-Kjeldahl procedure. Sample weights were adjusted for acid-insoluble residue as a partial correction for soil contamination.

Soil samples were obtained by taking 10 2.5-cm-diameter cores from each plot. These samples were air-dried, passed through a 2-mm sieve, subdivided with a sample splitter, and the subsamples were ground to a powder. Organic matter, by the Walkley-Black wet digestion method (8), and total N, by a micro-Kjeldahl procedure, were determined.

RESULTS AND DISCUSSION

Forage yields increased significantly through 1968 as applied N was increased (Table 1). Yields for N treatment pairs did not differ. When N fertilization was discontinued on one each of the duplicate treatments in 1969, forage yields declined sharply compared to treatments where N fertilization was continuous. The forage yield from the discontinued 112-kg N treatment was not different from the control. Yields from the other discontinued N treatments were significantly larger than that from the control but less than from comparable continuous treatments. In 1970 the residual N effect was extremely small. None of the discontinued N treatments produced yields that differed from the control. When N fertilization was resumed on these duplicate plots in 1971, forage yields recovered quickly. Yields were not significantly different between the continuous and discontinuous 112 kg N rate. Yield was higher for the continuous 224-kg rate than for the same discontinuous rate and was lower for the continuous 448-kg rate than for the same discontinuous treatment. The 448 kg/ha N rate adversely affected forage plant stands after several years of continuous fertilization. The stand of bahiagrass at the highest N rate recovered substantially during the 2 years without fertilization and apparently permitted better utilization of N when fertilization was resumed in 1971.

Forage N concentrations and total contents followed trends similar to forage yields (Table 1). Total forage N did not differ significantly between duplicate treatments through 1968 except for the 448 kg/ha N rate in 1968. When N fertilization was discontinued on duplicate treatments in 1969, forage N declined markedly. For the 112-kg N rate, it was not significantly more than the control treatment. Nitrogen uptake in excess of the control for 1969 was 5, 39, and 79 kg/ha for 112, 224, and 448 kg/ha discontinued N treatments, respectively. For 1970, forage N was not significantly higher from the discontinued N treatments than from the control. When N was reapplied in 1971, forage N from all treatments exceeded the control. It did not differ between the two 112 kg N treatments but was higher from the continuously fertilized 224 kg treatment than from its discontinuous duplicate. Forage N from the discontinuous 448 kg N treatment exceeded that from the continuously fertilized treatment, probably because of differential plant stands.

The percentages of applied N recovered in the harvested forage (Table 2) were similar to values previously reported (3). Recovery by duplicate treatments through the first 3 years was similar. Most efficient utilization occurred at the 224-kg N rate. Values initially were low, probably due in large part to accumulation of N in the stolon-root system. Maximum recovery of 72.1% occurred during the 4th year of fertilization at the 224 kg/ha N rate. During the subsequent 2 years recovery percentages declined. Accumulated quantities of applied N not recovered in the harvested forage are also recorded in Table 2. The maximum quantity at the highest N rate exceeded 1,500 kg/ha after the 6th year. Since initial total soil N levels averaged only 1,122 kg/ha, appreciable accumulation in the surface soil should have been readily detectable following the 6th year of fertilization.

Organic matter in the surface soil (0 to 15 cm) was 2.6% in October 1967 and 2.85% in October 1971. This difference was not statistically significant nor was the effect of N treatments or N treatment $\times$ time interaction.

Total soil N averaged 1,122 kg/ha in 1967 and 1,378 kg/ha in October 1971. This difference was highly significant. There were also differences among N treatments, but the N treatment $\times$ time interaction

Table 1. Pensacola bahiagrass response to levels of applied and residual nitrogen in Leon fine sand.

N applied	Year					
	1966	1967	1968	1969	1970	1971
kg/ha	Oven-dry forage, tons/ha					
0	3.6 a	2.9 a	2.9 a	3.5 a	3.3 a	2.9 a
112	6.5 b	6.3 b	7.3 b	8.3 c	7.2 b	6.3 b
112**				4.0 a	3.3 a	5.9 b
224	9.3 c	10.8 c	11.6 c	13.6 e	12.7 c	10.8 d
224**				6.2 b	3.5 a	9.3 c
448	12.3 d	15.3 d	15.1 d	16.0 f	13.9 d	11.0 d
448**				9.5 d	4.3 a	14.2 e
	Oven-dry forage N, %					
0	0.95 a	1.13 a	1.09 a	1.16 ab	1.08 a	1.21 a
112	1.05 a	1.22 b	1.14 a	1.26 bc	1.19 a	1.25 ab
112**				1.14 a	1.19 a	1.23 ab
224	1.21 b	1.39 c	1.27 b	1.49 d	1.37 b	1.42 b
224**				1.30 c	1.10 a	1.35 b
448	1.54 c	1.64 d	1.47 c	1.77 e	1.59 c	1.76 d
448**				1.26 bc	1.27 a	1.54 e
	Forage N, kg/ha					
0	34 a	32 a	30 a	41 a	36 a	35 a
112	68 b	77 b	84 b	104 c	86 b	79 b
112**				46 a	39 a	73 b
224	113 c	149 c	147 c	208 d	174 c	154 d
224**				80 b	38 a	127 c
448	194 d	250 d	222 d	283 e	221 d	193 e
448**				120 c	52 a	218 f

* Treatment means for each year followed by the same letter are not significantly different at the 0.05 probability level as determined by Duncan's Multiple Range Test.
** Nitrogen was not applied to these treatments in 1969 and 1970. Data for 1966, 1967, and 1968 are averages of the undifferentiated treatment pairs.

Table 2. Disposition of nitrogen applied to Pensacola bahiagrass sod on Leon fine sand.

N applied	Year					
	1966	1967	1968	1969	1970	1971
kg/ha	Applied N recovered, %					
0	-	-	-	-	-	-
112	30	40	48	57	45	39
112*				-	-	34
224	35	52	52	72	62	53
224*				-	-	41
448	33	48	43	54	41	35
448*				-	-	41
	Applied N not recovered in forage, kg/ha					
0	-	-	-	-	-	-
112	78	146	204	249	311	379
112*				202	199	273
224	146	253	360	436	521	626
224*				308	306	439
448	289	522	778	973	1,236	1,525
448*				708	693	957

* Nitrogen was not applied to these treatments in 1969 and 1970.

Table 3. Pensacola bahiagrass stolon-root weights and nitrogen contents at several levels of applied nitrogen on Leon fine sand.

N applied	Year 1967	1968	1969	1970	1971
kg/ha			Oven-dry stolon-root systems, tons/ha		
0	14.9 a	11.7 a	8.6 a	9.5 a	7.8 ab
112	20.7 b	19.0 b	16.9 c	16.6 c	13.4 c
112**			13.9 b	10.3 a	10.0 ab
224	23.1 b	22.1 c	19.6 d	15.2 bc	16.9 d
224**			18.6 cd	13.6 b	10.4 b
448	19.5 b	18.1 b	17.5 cd	15.4 bc	7.4 a
448**			14.4 b	13.4 b	9.4 ab
			Oven-dry stolon-root N, %		
0	0.89 a	--	0.62 ab	0.51 ab	0.50 a
112	0.77 a	--	0.64 ab	0.53 ab	0.53 a
112**			0.56 a	0.46 a	0.55 a
224	1.03 b	--	0.86 c	0.77 c	0.77 b
224**			0.65 ab	0.47 a	0.66 ab
448	1.51 c	--	1.54 d	1.57 d	1.85 d
448*			0.74 bc	0.60 b	1.39 c
			Stolon-root N, kg/ha		
0	132 a	--	54 a	49 a	39 a
112	159 a	--	108 b	88 b	71 a
112**			78 a	47 a	55 a
224	238 b	--	167 c	117 bc	129 b
224**			121 b	64 ab	68 a
448	295 b	--	271 d	243 d	139 b
448**			106 b	81 ab	130 b

* Treatment means for each year followed by the same letter are not significantly different at the 0.05 probability level as determined by Duncan's Multiple Range Test.
** Nitrogen was not applied to these treatments in 1969 and 1970. Data for 1967 and 1968 are averages of undifferentiated treatment pairs.

was not significant. Lack of interaction was surprising when one considers the large differential in quantities of applied N not recovered in the harvested forage.

Stolon-root weights (Table 3) were higher in 1967 and 1968 than in subsequent years. This was particularly true for the control treatment and may have been due in part to border effect from plots treated with N, since samples were collected near the plot edges to avoid interference with forage yield evaluation. Differences due to treatments were primarily between the control and those that received N. When N fertilization was discontinued in 1969 for one treatment at each N rate, stolon-root weights declined. With reinstatement of N fertilization in 1971, they remained significantly less for the discontinuous N treatment than for the continuous at the 112 and 224 kg/ha N rates. They were very low for the 448 kg/ha N rate due to the detrimental effect of this rate on the Pensacola bahiagrass stand.

Stolon-root N concentrations (Table 3) were significantly higher in 1967 as N rates were increased. Concentrations in stolon-root systems from duplicate treatments at each N rate were not different. With the elimination of N fertilization from one each of the duplicate treatments in 1969, stolon-root N concentrations decreased except at the 112-kg N treatment. Nitrogen concentrations decreased additionally in 1970 for treatments where N was not applied. In 1971, when N fertilization was resumed, N concentrations increased but remained significantly different at the 448-kg N treatment.

Total stolon-root N (Table 3) declined as the experiment progressed. Although stolon-root samples were not obtained prior to the experiment, the differentials in stolon-root N contents in 1967 must have occurred as a result of the N treatments made during the two previous growing seasons. When N fertilization was discontinued on one each of the duplicate N treatments in 1969, total N contents declined markedly,

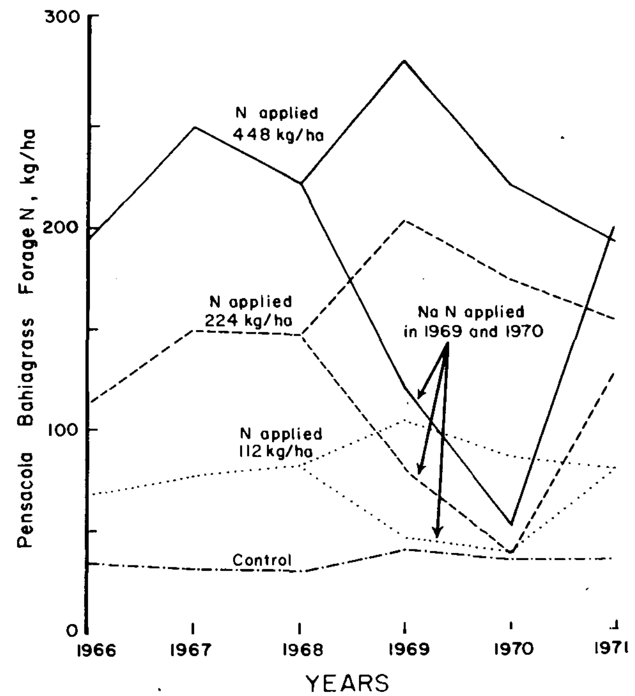

Fig. 1. Nitrogen uptake by Pensacola bahiagrass from Leon fine sand at several nitrogen fertilization rates and their residual effects.

with the magnitude of loss in direct proportion to N rates. Nitrogen contents declined further in 1970. When N treatments were resumed in 1971, total stolon-root N increased relatively little over the previous year, except for the 448-kg N treatment. Nitrogen concentrations increased in 1971, but the stolon-root mass continued to decrease, resulting in little increase in total N.

The residual effect of N not removed in harvested forage was relatively small (Fig. 1). Total forage N for 1969 and 1970, when N fertilization was discontinued on duplicate treatments at each N rate, was 8, 41, and 95 kg/ha for the 112-, 224-, and 448-kg N rates. Nitrogen reductions in stolon-root systems during this 2-year period were approximately 60, 100, and 190 kg/ha from the 112-, 224-, and 448-kg N treatments, respectively. It appears that the stolon-root system is the major source of residual N, but not more than 50% of the N reduction in the stolon-root system was accounted for in the harvested forage. For the 112-kg N rate it was little more than 10%. The decline in stolon-root weights was obviously the result of death and partial decomposition of some stolons and roots. Part of the stolon-root N would have been immobilized in these processes as shown by total N in the surface soil, which increased by an average of 228 kg/ha during this period. The change in soil organic matter was relatively small, however, between 1967 and 1971. According to the recovery of N from soil, forage, and stolon-root systems, a large portion of the applied N was accounted for at the 112 kg/ha N rate. At the 224 and 448 kg/ha rates, however, a substantial part was lost. The limited residual effect of applied N indicated that little available N was present in the soil profile within the rooting zone. Extensive N losses by leaching do not appear likely in light of previous studies with this soil. They showed that multiple applications of N during the growing season (as many as 16 totalling 224 kg N/ha) were not superior to two applications in terms of N uptake in forage (2). Moreover, Volk (7) showed N losses from leaching of less than 2% of a 400 kg/ha N rate applied in several increments to Lakeland fine sand planted to perennial, warm-season grasses in large lysimeters. Denitrification is suspected as a major mechanism of N loss from soils under conditions of this study. This process normally is not considered to be important in sandy soils, but in Leon fine sand the water table is high during the summer rainy season and plant residue decomposition is rapid. Anerobic conditions that could enhance denitrification probably develop.

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