THE FATE OF FERTILIZER NITROGEN APPLIED TO THREE WARM-SEASON GRASSES ON A SPODOSOL IN FLORIDA AS INDICATED BY NITROGEN-15

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ABSTRACT

The field experiment with ^{15}N-enriched fertilizer (12.4687 atom % of ^{15}N) was superimposed in March 1977 on a nontracer N experiment with UF-4 *(Cynodon nlemfuemsis* Vanderyst), Transvala digitgrass *(Digitaria decumbens* Stent), and Pensacola bahiagrass *(Paspalum notatum* Flugge) grass sods previovsly established on EauGallie fine sand (sandy, siliceous, hyperthermic Alfic Haplaquod) at the Agricultural Research Center, Ona, Florida. The experiment was established to compare the effect of N rates, and seasonal N applications on forage yields, N uptake efficiency, residual fertilizer N, and distribution of fertilizer N in soil and components of the three warm-season grass species for two-year period. Treatments were arranged in a split-split-plot experimental design with two replications.The three warm-season grass species were the main plots, two N rates (100 and 200 kg/ha) were the subplots, and three seasonal N applications (1, 2 and 3) were the sub-subplots. Wooden frames, 1 m^2 and 15 cm deep, were placed into the soil to a depth of 12 cm to delineate sub-subplots. Fertilizer N was observed in oven-dry forages, stolon-root masses, soils, and soil solutions.

In 1977, total N in forage was not different among grass species, but total N in the stolon-root mass from Pensacola bahiagrass was the largest. Recovery of fertilizer N in forage was 35, 40 and 35% of that applied from UF-4, Transvala digitgrass, and Pensacola bahiagrass; 13, 9 and 20% of that applied in stolon-root mass; and 26, 19 and 21% of that applied to the soil. Recovery of fertilizer N in forage was not different among grass species. Approximately 50% of the forage N came from fertilizer and 50% from non-fertilizer sources. Recovery of fertilizer N in the stolon-root mass from Pensacola bahiagrass was larger than from UF-4 and Transvala digitgrass. Soil solution samples collected from depth of 60 cm showed no evidence of N leaching. Recoveries of fertilizer N in soil-plant systems were 74, 68 and 76% of that applied from UF-4, Transvala digitgrass, and Pensacola bahiagrass, respectively. In 1978, fertilizer N storaged in stolon-root masses at the end of the 1977 were translocated into forage regrowth in 1978 and some were released into the soil. The sum of fertilizer N in forage from 1977 and 1978 plus fertilizer N in the stolon-root mass and soil at the end of 1978 were 72, 69 and 68% of that applied from UF-4, Transvala digitgrass, and Pensacola bahiagrass, respectively.

Three important conclusions from this experiment were the large amount of

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non-fertilizer N in forage, the essentially equal accountability of applied N in the three soil-warm season grass systems, and the relatively large retention of fertilizer N in these sandy soils.

INTRODUCTION

Mineral soil in Florida have developed from highly weathered materials. Usually low in essential elements such as N. The relatively small amount of available native soil N is not sufficient for optimum yields of the introduced perennial warm-season grasses. Forage yields of Pensacola bahiagrass (*Paspalum notatum* Flugge) responsed linearly to applied fertilizer N to at least 224 kg/ha with additional response through 448 kg/ha (Wallace et al., 1955; Blue, 1971). However recovery of fertilizer N in forage and soil at the end of the growing season by tracer method were 32 and 17% of that applied, respectively (Impithuksa and Blue, 1978). Usually fertilizer N use efficiency by plants depends on soil, plant, and rainfall condition. Under sandy soils and high rainfall in Florida, ultilization of fertilizer N by grasses on these soils may be affected by leaching losses from well-drained soils and denitrification from poorly drained soil (Blue and Graetz, 1977).

The efficiency of N absorption following N applications may also be related to growth characteristics of grasses. Pensacola Bahiagrass has been show to absorb N relativtely quicky and in large quantity from both Spodosols and Entisols following fertilization because this grass has a large stolon-root system (Blue, 1970; Impithuksa and Blue 1978). In contrast with some introduced species such as UF-4 (*Cynodon nlemfuemsis* Vanderyst) and Transvala digitgrass (*Digitaria decumbens* Stent) have relatively small and less stolon-root systems (Bogdan, 1977). Blue (personal communication) reported that forage production from Transvala digitgrass and UF-4 were greater than Pensacola bahiagrass but stolon-root mass and total biomass at the end of the growth season were highest from Pensacola bahiagrass. Percentages of apparent N recovery during two-year of study 64, 51 and 56 for UF-4, Transvala digitrass, and Pensacola bahiagrass, respectively. Lowest N recovery from Transvala digitgrass might due to small stolon-root system of this grass which provides a limited reservoir for absoption and storage of N. However, this method does not distinguish between non-fertilizer and fertilizer N in soil-plant system. This can be accomplished by the tracer method which employ fertilizer labeled with the stable N isotope(^{15}N). The tracer method, which permits measurement of the amounts of fertilizer N ultilization by grasses and residual fertilizer N in the soil under various cultural practices, this tracer method is necessary in order to conduct research which may lead to increased fertilizer N efficiency (Leg and Allison, 1967; Hauck and Bystrom, 1970; Westerman et al., 1972; Hauck and Bremner, 1976; Impithuksa et al., 1979; Impithuksa and Blue 1979; Impithuksa, 1979).

The objectives of this field experiment

was to determine the distribution, efficiency of fertilizer N, and residual of fertilizer N in three warm-season grasses (UF-4, Transvala digitgrass, and Pensacola bahiagrass) and EauGallie soil as affected by N rate and seasonal N applications.

MATERIALS AND METHODS

The tracer experiment was superimposed in March 1977 on the non-tracer field experiment with UF-4, Transvala digitgrass, and Pensacola bahiagrass sods established in 1974 on EauGallie fine sand at the Agricultural Research Center, Ona, Florida. This soil had a pH of 5.1 and organic matter content 2.93%. Treatments were arranged in a split-split-plot experimental design with two replications. Three warm-season grass species were the main plots, two N rates (100 and 200 kg/ha) were the subplots, and three seasonal N applications (1, 2 and 3) were the sub-subplots. Wooden frames, 1 m^2 and 15 cm deep, were placed into the soil to a depth of 12 cm to delineate sub-subplots. One soil solution tube was installed at the center of each wooden frame enclosing seasonal N application 1 at the 200 kg/ha rate at a depth of 60 cm to monitor NH_4^+- and NO_3^- - N in soil solutions.

In 1977, seasonal N application 1 consisted of N as $^{15}NH_4\,^{15}NO_3$ (12.4687 atom % of ^{15}N) applied one time on 25 March. For seasonal N application 2, one-half of the N was applied on 25 March as $^{15}NH_4\,^{15}NO_3$ and one-half on 23 June as $^{14}NH_4\,^{14}NO_3$, while for seasonal N application 3, one-half of the N was applied on 25 March as $^{14}NH_4\,^{14}NO_3$ and one-half on 23 June as $^{15}NH_4\,^{15}NO_3$. Nitrogen, P, and K were applied in a ratio of 20: 0.4:1.7. Ammonium nitrate, both tagged and untagged, was carefully applied in solution within appropriate wooden frames; P and K were applied as solid KCI and triple superphosphate, Forage harvests were made on 12 May, 23 June, 4 August, and 26 September. Stolon-root mass and soil samples were collected after the fourth harvest (27 September). Soil solutions were collected after each major rainfall on 22 June, 12 August, and 22 August. This tracer experiment was continued through 1978 to study residual effect of fertilizer N. Nitrogen and other nutrients in 1978 were applied in the same amounts as in 1977 except that only $^{14}NH_4\,^{14}NO_3$ was used. Fertilizers were applied on 27 March and 22 June. Forage harvests were made on 11 May, 22 June, 10 August, and 28 September. Soil solutions were collected on 16 May, 22 May, 14 July, 21 July, 1 August, and 8 August.

Details of experimental methods, analysis of total N and isotopic technique for this experiment were identical to those used in experiments discussed previously (Impithuksa and Blue, 1978) and additional details are given in the Ph.D. dissertation by Impithuksa (1979).

RESULTS AND DISCUSSION

Plant Response to Fertilizer Nitrogen

Oven-dry forage yield response to fertilizer N from each grass species was almost the same in both the 1977 and 1978 growing seasons (Table 1). Oven-dry forage yield increased with increasing N rates but yield were not affected by seasonal N application. The yield from Trans vala digitgrass was higher than those from UF-4 and Pensacola bahiagrass; this was a consequence of the higher growth rate of Transvala digitgrass during the wet, mid-summer period. Furthermore, a higher forage growth rate at each harvest was also obtained for transvala digitgrass.

Stolon-root masses of UF-4 and

Transvala digitgrass tended to decreased when fertilizer N was increased but the opposite was obtained from Pensacola bahiagrass. Stolon-root masses of the three grasses were not affected by seasonal N application. Stolon-root mass from Pensacola bahiagrass was larger than from UF-4 and Transvala digitgrass. Furthermore, stolon-root mass was overestimated for the UF-4 because this grass did not maintain a uniform sod over the plot and sample were taken only from areas where grass was present.

Total biomass of UF-4 and Pensacola bahiagrass tended to increase when fertilizer N was increased but total biomass of the three species were not affected by seasonal N application. The largest biomass was measured for Pensacola bahiagrass.

Nitrogen in Soil-Plant Systems

Total N in forage from all three species increased with N rates but was not different among species (Table 1). Total N in forage was not affected by seasonal N application. This result agreed with that of Blue and Graetz (1977) who reported that split applications of N did not increase uptake of N by Pensacola bahiagrass. The capacities for N uptake by these three grasses were almost the same even though

Table 1. UF-4, Transvala Digitgrass, and Pensacola Bahiagrass Forage, Stolon-Root Mass, and Biomass Responses to Nitrogen Rates on EauGallie Fine Sand in 1977 and 1978.

N rates	Grass species: UF-4			Transvala digitgrass			Pensacola bahiagrass		
	1977	**1978**	**Avg**	**1977**	**1978**	**Avg**	**1977**	**1978**	**Avg**
kg/ha				**Oven-dry forage, kg/ha**					
100	6,360	5,380	5,870	8,930	8,640	8,790	5,560	5,980	5,770
200	10,070	9,010	9,540	12,940	13,910	13,430	10,330	9,700	10,020
Avg	8,220	7,160	7,690	10,940	11,280	11,110	7,950	7,840	7,900
				Total N in forage, kg/ha					
100	79.8	57.1	68.8	81.0	72.5	76.8	66.6	64.5	65.6
200	149.1	112.0	130.6	144.0	134.6	139.3	137.0	116.5	126.8
Avg	114.5	84.6	99.6	112.5	103.6	108.1	101.8	90.5	96.2
				Stolon-root mass, kg/ha					
100	11,430	15,700	13,570	8,440	9,500	8,970	18,540	16,520	17,530
200	10,460	11,060	10,760	7,280	10,370	8,830	24,010	21,520	22,770
Avg	10,950	13,380	12,170	7,860	9,940	8,900	21,280	19,020	20,150
				Total N in stolon-root mass, kg/ha					
100	69.8	88.7	79.3	41.3	47.6	44.5	67.7	62.1	64.9
200	79.3	69.4	74.7	44.4	56.6	50.5	114.1	91.7	102.9
Avg	74.6	79.1	76.9	42.9	52.1	47.5	90.9	76.9	83.9
				Total biomass, kg/ha					
100	17,790	21,000	19,400	17,370	18,140	17,760	24,100	22,490	23,300
200	20,530	20,070	20,300	20,220	24,280	22,250	34,340	31,220	32,780
Avg	19,170	41,070	30,120	18,800	42,420	30,610	29,220	53,710	41,470
				Total N in biomass, kg/ha					
100	149.6	145.8	147.7	122.3	120.1	121.2	134.3	126.5	130.4
200	228.4	181.4	204.9	188.4	191.2	189.8	251.1	208.2	229.7
Avg	189.1	163.6	176.4	155.4	155.7	155.6	192.7	167.4	180.1

growth rates and total forage yield were different. Total N in stolon-root mass of Pensacola bahiagrass increased with N rates but were not affected by N rates from UF-4, and Transvala digitgrass. Total N in stolon-root mass of Pensacola bahiagrass and UF-4 was larger than Transvala digitgrass. Total N in biomass tended to increase with increasing N rates and higher total N was found in UF-4 and Pensacola Bahiagrass.

Fertilizer N in forage from UF-4 and Transvala digitgrass in 1977 tended to increase with N rates (Table 2). In 1977, the 100 kg/ha N rate, fertilizer N uptake in forage from seasonal N application 3 was superior to seasonal N application 2 for all grasses (Table 3). At the 200 kg/ha N rate, fertilizer N uptake in forage from seasonal N application 3 was superior to seasonal N seasonal N application 2 only for Transvala digitgrass. For the 100 kg/ha N rate, application of N in July gave higher efficiency than that applied in March for all grass species but at the 200 kg/ha N rate, July application gave higher effeciency for Transvala digitgrass. This result might due to high growth rate of this grass. No doubt rainfall distribution contributed to this efficiency; low rainfall during the March-May perior (132 mm) resulted in low growth rates of these grasses and applied N probably remained in the soil for a longer period than normal while the July-August period invariably has relatively high rainfall (564 mm). In 1978, residual fertilizer N uptake in UF-4 and Transvala digitgrass forage from season N application 3 at both the 100 and 200 kg/ha N rate was not larger than from seasonal N application 2 (Table 3). But residual fertilizer N content of Pensacola bahiagrass forage from seasonal N application 3 from both rates was larger than from seasonal N application 2. This indicated that the uptake of residual fertilizer N in forage depend on characteristic of grass species, number of harvest, and time after the application. This result agreed with those reported by Westerman and Kurtz (1972). Total fertilizer N uptake in forage during the 2-year period was approximately 37, 43 and 40% of fertilizer N applied to UF-4, Transvala digitgrass, and Pensacola bahiagrass, respectively (Table 2).

Fertilizer N in stolon-root mass tended to decrease when N rate was increased for UF-4, and Transvala digitgrass but reverse was obtained from Persacola bahiagrass from both years (Table 2). Fertilizer N in stolon-root mass was not affected by seasonal N application. Fertilizer N in Pensacola bahiagrass stolon-root mass at the end of 1977 was higher than in UF-4 and Transvala digitgrass, almost twice as much fertilizer N was stored in the Pensacola bahiagrass stolon-root mass as in the other grass. But fertilizer N in stolon-root mass was not different among grass species in 1978.

Fertilizer N in biomass were almost the same among grass species in each year but only slightly higher were observed from Pensacola bahiagrass.

In 1977, fertilizer N in surface soil from both N rates were the same from UF-4 and Transvala digitgrass, but was larger from the 100 kg/ha N rate than from the 200 kg/ha rate from Pensacola bahiagrass (Table 2). Average of fertilizer N in surface soil at the end of 1977 growing season was not different among the three grass species. In 1978, residusl fertilizer N in the surface soils were less at the 200 kg/ha N rate than at the 100 kg/ha N rate, but were not affected by grass species and seasonal N application, Residual fertilizer N in surface soils in 1978 were slightly higher than in 1977 from all of the three species.

Table 2. Fertilizer Nitrogen Distribution in Forage, Stolon-Root Mass, Biomass, and Soil at the End of 1977 and 1978 from EauGallie Fine Sand.

N rates	Grass species: UF-4 1977	UF-4 1978	UF-4 Total	Transvala digitgrass 1977	Transvala digitgrass 1978	Transvala digitgrass Total	Pensacola bahiagrass 1977	Pensacola bahiagrass 1978	Pensacola bahiagrass Total
kg/ha	**Fertilizer N in forage, % of applied**								
100	32.4	2.2		39.1	2.4		30.9	4.0	
200	37.7	2.2		41.7	2.5		29.7	5.5	
Avg	35.1	2.2	37.3	40.4	2.5	42.9	35.3	4.8	40.1
	Fertilizer N in stolon-root mass, % of applied								
100	14.9	8.5		10.4	3.9		18.9	5.7	
200	10.2	3.7		3.3	3.0		20.8	6.4	
Avg	12.6	6.1		9.4	3.5		19.6	6.1	
	Fertilizer N in biomass, % of applied								
100	47.3	10.7		49.5	6.3		49.8	9.7	
200	47.9	5.9		50.0	5.4		60.5	11.9	
Avg	47.4	8.3		49.8	5.9		54.9	10.8	
	Fertilizer N in soil, % of applied								
100	21.9	34.2		17.0	27.0		25.8	28.9	
200	21.5	23.0		17.2	16.8		13.3	15.0	
Avg	21.7	28.6		17.1	21.9		19.6	22.0	

Table 3. Fertilizer Nitrogen in Forage from UF-4, Transvala Digitgrass, and Pensacola Bahiagrass as Affected by Nitrogen Rates and Seasonal Nitrogen Applications in 1977 and 1978.

Seasonal N applications	Grass species: UF-4, N rates, kg/ha: 100	UF-4: 200	Transvala digitgrass, N rates, kg/ha: 100	Transvala digitgrass: 200	Pensacola bahiagrass, N rates, kg/ha: 100	Pensacola bahiagrass: 200
	Fertilizer N in forage in 1977, % of applied+					
1	33.3 a	38.4 a	37.8 b	39.4 b	33.5 a	38.0 a
2	24.7 b	37.5 a	26.0 c	34.8 b	25.9 b	42.4 a
3	39.0 a	37.2 a	53.3 a	50.7 a	33.3 a	38.6 a
	Residual fertilizer N in forage in 1978, % of applied+					
1	1.5 b	1.9 a	2.2 a	2.2 b	3.0 c	4.5 b
2	2.5 a	2.3 a	2.4 a	2.3 ab	3.9 b	4.2 b
3	2.5 a	2.4 a	2.8 a	3.0 a	5.2 a	7.7 a

+Average values within columns followed by the same letter are not significantly different at the 0.05 probability level according to Duncan's new multiple range test.

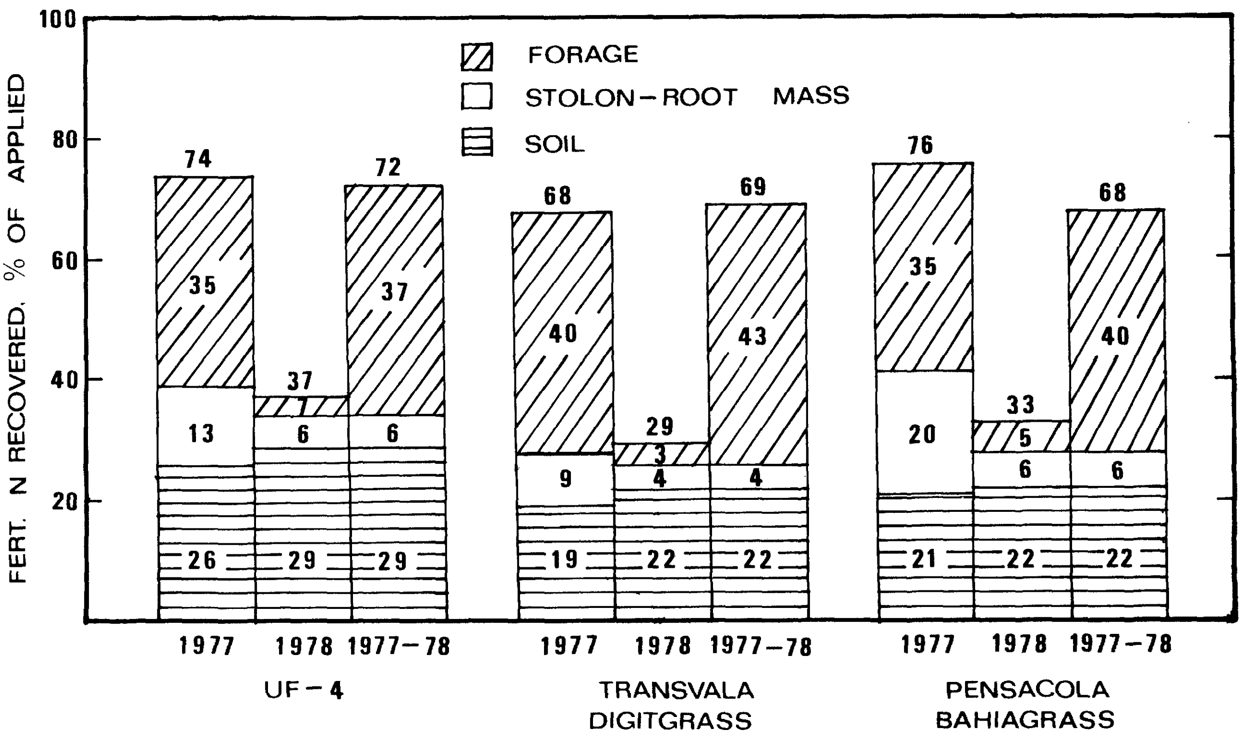
Recovery of fertilizer Nitrogen in the soil-plant systems.

Accountability of fertilizer N applied in 1977 to UF-4 was 26, 13, and 35% in soil, stolon-root mass, and forage, respectively (Fig. 1). Total recovery was 74% of that applied. The amount of fertilizer N in soil was slightly higher in 1978 than 1977. Fertilizer N in the stolon-root mass at the end of 1977 (13%) was translocated in 1978 for forage regrowth and released into the soil. The sum of fertilizer N in forage from 1977 and 1978, and the stolon-root mass and soil at the end of 1978 accounted for 72% of that applied. There was no evidence of fertilizer N loss during the second year.

Accountability of fertilizer N applied to Transvala digitgrass in 1977 was 19, 9 and 40% in soil, stolon-root mass, and forage, respectively (Fig.1). Total recovery was 68% of that applied. The sum of fertilizer N in forage from 1977 and 1978 plus fertilizer N in stolon-root mass and soil at the end of 1978 was 69% of that applied. Fertilizer N retained in the stolon-root mass at the end of 1977 was greater than in 1978 and was apparently translocated for forage regrowth and released into the soil.

Accountability of fertilizer N applied to Pencacola bahiagrass in 1977 was 21, 20 and 35% in soil, stolon-root mass, and forage, respectively (Fig.1). The total recovery was 76% of that applied. The sum of fertilizer N in forage from 1977 and 1978 plus fertilizer N in the stolon-root mass and soil at the end of 1978 was 68% of that applied. Slightly loss of fertilizer N from the system was occured from this system.

Equal accountabilites of applied fertilizer N were obtained from these soil-warm season grass systems.



Fiqure 1. Accountability of fertilizer nitrogen in UF-4, Transvala digitgrass, and Pensacola bahiagrass at the end of 1977, 1978, and summation of the 2 years.

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