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Poultry Manure Fertilization of Sudangrass

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Sudangrass (*Sorghum sudanense* (Piper) Stapf.) and sorghum x sudangrass hybrids (*S. bicolor* (L.) Moench) x (*S. sudanense* (Piper) Stapf.) are grown as summer annual forages. They may be used for pasture, hay, or silage.

Sudangrass is of tropical origin (Piper, 1915; deWet, 1977). High yields are seldom attained where the mean temperature in the hottest month is less than 25 C. Washko (1963) and Jung and Reid (1966) have recommended the growing of sudangrass as a means of producing ready forage during hot, dry periods in midsummer when the cool season grasses are semidormant. A special problem with sudangrass is the presence in the forage of a cyanogenic glycoside, dhurrin. Upon ruminant digestion this compound liberates prussic acid, HCN. Thus the forage itself is a potential danger to ruminants unless properly managed to minimize the content of dhurrin (Boyd et al., 1938).

Yields of sudangrass depend on cutting management and the availability of plant nutrients, chiefly nitrogen (Broyles and Fribourg, 1959; Holt and Alston, 1968). The forage quality of sudangrass depends on the stage of growth at harvest as well as the crop's nutrition (Ademosum, Baumgardt, and Scholl, 1968; Farkoomand and Wedin, 1968).

Costs of inorganic nitrogen fertilizers are linked to energy costs and are rising (Hardy and Havelka, 1974). Fresh, litter-free poultry manure frequently contains in excess of 5% nitrogen on a dry matter basis (Bell and Freeman, 1971). Papanos and Brown (1950) used poultry manure containing litter to successfully produce 15 different crops in Connecticut. They characterized poultry manure containing litter to be approximately 2% nitrogen at approximately 40% moisture.

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At the present time, 70-80% of the poultry in Connecticut are raised without bedding (Muller, personal communication).[2] This manure will have a higher nitrogen content than that collected with litter. Rubins and Bear (1942) have demonstrated that the carbon: nitrogen ratios of organic fertilizer materials influence the rate of nitrogen availability to plants.

Accordingly, fresh, litter-free poultry manure was evaluated as a means of supplying the nutrients required to grow sudangrass. Particular attention was placed on assessing the nitrogen response of the crop and the rate of nitrogen availability from the applied manure.

METHODS AND MATERIALS

Field Experiment I

Three sudangrass cultivars: 'Piper,' 'Monarch,' and 'Trudan V' were grown under four fertility treatments: 1120 kg/ha 15-10-10 and 5.6, 8.4, and 11.2 mt/ha fresh, litter-free poultry manure. The experiment employed a split-plot design with four replications. Main-plot treatments were fertility levels. Subplots were cultivars with a plot size of 7 x 2.1 m. The soil was a Paxton fine sandy loam of pH 6.4. Soil samples taken and tested (McIntosh, 1969) prior to the initiation of the experiment indicated phosphorus, potassium, calcium, and magnesium levels of 6, 262, 2493, and 547 kg/ha, respectively.

On 30 May 1974, the manure was spread and incorporated immediately using a tractor rototiller.[3] On 7 June, the three cultivars were drilled at 34 kg/ha. Harvests were taken on 12 August and 20 September.

Following the second harvest, applications of poultry manure at the rates previously stated, were again incorporated in the respective main plots. Five hundred sixty kg/ha of 15-10-10 were applied to those plots which had previously received the inorganic fertilizer. The experimental area was then cover cropped. On 27 May 1975, the cover crops were removed from all plots.

In 1975, the experiment was repeated on the same plots. On 28 May 1975, manure was spread and the inorganic fertilizer was ap-

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[3] *Manure was obtained from the Robert Goodwin farm, Star Route, Chaplin, Connecticut.*

plied, as in the spring of 1974. The three cultivars were again drilled at the same rate on 1 June 1975. Harvests were taken on 5 August and on 29 September.

Field Experiment II

Piper sudangrass was grown using five main fertility levels. Each fertility level was established with or without a supplemental banding of triple superphosphate, at seeding, to supply 84 kg P/ha. The fertility treatments were: 1120 kg/ha 15-10-10 and 0, 8.4, 16.8, and 22.4 mt/ha fresh, litter-free poultry manure. A split-plot design with four replications was used. Main-plot treatments were fertility levels. Subplots were banded phosphorus levels. The soil was a Paxton fine sandy loam of pH 6.4. Soil samples taken and tested prior to the initiation of the experiment indicated phosphorus, potassium, calcium, and magnesium levels of 3, 138, 2300, and 550 kg/ha, respectively.

Manure and inorganic fertilizer were applied on 28 May 1975. On 1 June, all plots were seeded with Piper sudangrass at 34 kg/ha. Harvests were taken on 6 August and 29 September. On 9 June, 16 June, 23 June, 30 June, 7 July, 14 July, 21 July, 28 July, 11 August, 8 September, and 1 October soil samples were taken for determination of exchangeable ammonium, nitrite, and nitrate concentrations. Soil temperature at the 20 cm depth was monitored daily by *in situ* recording soil thermometers.

Greenhouse Experiment

Following the 29 September harvest, soil and ratoons were taken from Field Experiment II and placed in ceramic crocks. Each crock contained approximately 2 kg of soil and four freshly tillering ratoons. Two crocks were filled from each plot sampled. The selected treatments were those plots which had received 1120 kg/ha 15-10-10 and 0, 8.4, and 22.4 mt/ha poultry manure. None of the sampled plots had received supplemental phosphorus.

Ammonium nitrate was applied to one of each pair of crocks to supply 112 kg N/ha. The other crock in each pair received no supplemental fertilization.

Soil samples were taken from the crocks as they were being filled. A ratoon crop was grown from the 24 crocks in the greenhouse until 3 December 1975. On that date, all top growth was harvested and the entire yield oven-dried.

Sampling and Analytical Procedures

All soil samples represent the 0-20 cm depth. The pH values were taken in 1:1 soil/distilled water slurries. Air-dried soil samples were extracted with modified Morgan reagent (McIntosh, 1969) for the determination of soil phosphorus, potassium, calcium, and magnesium. Fresh soil samples were extracted with 1.5 *N* KCl (Bremner, 1965a) for the determination of ammonium, nitrite, and nitrate concentrations. All soil samples were screened to pass a 2-mm sieve prior to extraction. All soil chemical data were corrected to an oven-dry soil basis by drying subsamples at 105 C for 24 hours.

Poultry manure was obtained on a fresh, litter-free basis and transported directly to the field. Manure was weighed out, spread on the plots, and immediately incorporated. While the weighing and spreading were in progress, 1-kg samples of well-mixed manure were scooped from the weighing bucket and retained in sealed plastic bags to prevent ammonia losses. The sealed bags were refrigerated until chemical analyses were made.

Poultry manure samples were dried for 24 hours at 105 C to determine dry matter content. Prolonged drying for 72 hours at 105 C showed no changes in dry matter content. In 1974, nitrogen in the fresh manure was determined by the macro-Kjeldahl procedure (AOAC, 1955) employing the titration procedure of Meeker and Wagner (1933). In 1975, these procedures were augmented to include predigestion with salicylic acid (Bremner, 1965b) prior to the sulfuric acid digestion. Phosphorus, potassium, calcium, and magnesium were determined in the fresh manure by digesting the material using the procedure of Hagstrom and Rubins (1961).

Fresh weights of the sudangrass plots were taken in the field. Representative 5-kg samples were collected, bundled, chopped, and mixed. One-kg samples were then dried at 105 C for 48 hours to determine the dry matter content. The dried samples were ground to pass a 1-mm sieve and tissue analyses were performed on these samples. Chemical analysis of the plant tissue employed the same techniques as those used for the manure.

Nutrients in the soil extracts, manure and plant digests were determined by the following procedures. Phosphorus concentration was determined by the chlorostannous molybdophosphoric blue colorimetric method (Dickman and Bray, 1940). Potassium and calcium were determined by flame photometry. Magnesium was determined by atomic absorption spectrophotometry.

Ammonium, nitrite, and nitrate concentrations in the soil extracts were determined by the procedure of Kamphake, Hannah, and Cohen (1967). The concentrations of all the nitrogen containing ionic species are expressed as nitrogen alone on an oven-dry soil basis. Digestibility of the sudangrass was assessed by the procedure of Tilley and Terry (1963).

RESULTS AND DISCUSSION

Analysis of the Poultry Manure

Analysis of the three collections of fresh, litter-free poultry manure averaged 5.55, 2.29, 1.72, 10.0, and 0.69% nitrogen, phosphorus, potassium, calcium, and magnesium, respectively on a dry matter basis (Table 1). Phosphorus was the most variable of the nutrients determined. Phosphorus contents varied among the collections from 1.50 to 3.38%. Nitrogen and potassium contents varied between 5.25 and 5.70% and 1.60 and 1.80%, respectively.

Table 1. Analysis of the poultry manure used in the field experiments.

Experiment		H_2O	N*	P	K	Ca	Mg
		%					
Experiment I	1974	70.5	5.25	3.38	1.78	13.4	0.86
Experiment I	1975	76.2	5.70	1.50	1.80	8.3	0.60
Experiment II	1975	76.0	5.70	2.00	1.60	8.4	0.60

**Percent nitrogen, phosphorus, potassium, calcium, and magnesium are expressed on a dry matter basis.*

Field Experiment I

The total nitrogen supplied in the three applications of the highest rate of poultry manure, 11.2 mt/ha, was 416 kg/ha. The total nitrogen supplied for three applications of the inorganic fertilizer was 420 kg/ha.

In both 1974 and 1975, the inorganically fertilized sudangrass was greener, taller, and more morphologically advanced at harvest than any of the sudangrass fertilized with any rate of poultry manure. Yield trends were similar for both years. Therefore, averaged data for both growing seasons are presented (Table 2). In both years, yields of the inorganically fertilized sudangrass were significantly ($P < 0.01$) greater at the first cutting, the second cutting, and in the total yield than those fertilized with any rate of poultry manure. All three cultivars responded in a similar manner to the fertility treatments.

Table 2. Dry matter yields for the first and second cuttings and the total yields in Experiment I, averaged over 1974 and 1975.

Fertility treatment	First Cutting	Second Cutting	Total
		mt/ha	
1120 kg/ha 15-10-10*	6.22	2.28	8.50
5.6 mt/ha poultry manure**	5.06	1.32	6.38
8.4 mt/ha poultry manure	5.02	1.27	6.29
11.2 mt/ha poultry manure	5.22	1.67	6.89
Mean	5.38	1.64	7.02

**To convert kg/ha to lb/acre, multiply by 0.892.*
***To convert mt/ha to ton/acre, multiply by 0.446.*

Trends in forage quality were similar for all three cultivars in both years, therefore the data presented are averaged over both growing seasons (Table 3). The differences between the first and second cuttings may be attributed to the relative stages of development at harvest. At the first cutting, plant heights varied from approximately 1.5-2.0 m. At the second cutting, all plants were vegetative and less than 1 m in height. Digestibility, protein content, and mineral content have been shown to decline in sudangrass with increasing maturity (Jung and Reid, 1966).

At both cuttings, the height and vigor were increased with increasing nitrogen fertilization. Sudangrass digestibility has been positively associated with nitrogen fertilization (Jung et al., 1964). However, digestibility declines with advancing maturity (Farkoomand and Wedin, 1968; Wedin, 1970; Edwards, Fribourg, and Montgomery, 1971). In this experiment, the most mature forage had the lowest digestibility and had received the inorganic nitrogen fertilization. Cultivars receiving this treatment also had the highest nitrogen concentration.

Table 3. Chemical composition of the sudangrass cultivars in the first and second cuttings in Experiment I, averaged over 1974 and 1975.

Fertility treatment	N	P	K	Ca	Mg	IVDMD[1]
			%			
			First cutting			
1120 kg/ha 15-10-10	1.78	0.19	2.04	0.36	0.36	63.6
5.6 mt/ha poultry manure	1.58	0.20	2.12	0.33	0.34	65.8
8.4 mt/ha poultry manure	1.57	0.20	2.30	0.34	0.37	66.2
11.2 mt/ha poultry manure	1.70	0.21	2.33	0.32	0.34	65.8
Mean	1.66	0.20	2.20	0.34	0.36	65.4
			Second cutting			
1120 kg/ha 15-10-10	1.92	0.26	2.28	0.34	0.45	72.4
5.6 mt/ha poultry manure	1.63	0.30	2.31	0.36	0.43	71.6
8.4 mt/ha poultry manure	1.62	0.31	2.28	0.35	0.42	70.8
11.2 mt/ha poultry manure	1.78	0.32	2.38	0.34	0.43	72.6
Mean	1.74	0.30	2.31	0.35	0.43	71.8

[1]*In vitro* dry matter digestibility

Sudangrass fertilized with poultry manure was higher in potassium concentration and similar or slightly lower in calcium and magnesium concentrations than that fertilized with inorganic fertilizer. Papanos and Brown (1950) found similar results with Japanese millet (*Echinochloa crus-gali* var. *frumentacea* Wright).

Field Experiment II

Since poultry manure at rates of up to 11.2 mt/ha had produced lower yields and forage of lower nitrogen content than that produced with 168 kg N/ha supplied by 1120 kg/ha 15-10-10, a second field experiment was conducted to investigate the effects of a broader range of fertilizer treatments. Only one cultivar, Piper, was used. The zero fertilizer treatment received no supplemental nitrogen. However, alfalfa (*Medicago sativa* L.) had been grown on this field for three years prior to this experiment. The inorganic treatment again supplied 168 kg N/ha. Poultry manure at 8.4, 16.8, and 22.4 mt/ha supplied 115, 230, and 307 kg N/ha, respectively.

Analysis of variance indicated that banding phosphorus at 84 kg P/ha with the seeding did not increase yields at either cutting. Therefore, yield data are averaged for both the plus and minus phosphorus treatments (Table 4). This experiment and those of Abbot and Lingle (1968) suggest that P supplied in animal manures is readily available to growing plants.

Table 4. Dry matter yields for the first and second cutting and the total yields in Experiment II 1975.

Fertility treatment	First Cutting	Second Cutting	Total
		mt/ha	
No fertilizer	5.60	1.10	6.70
8.4 mt/ha poultry manure	5.97	1.57	7.54
16.8 mt/ha poultry manure	5.95	2.31	8.26
22.4 mt/ha poultry manure	6.10	2.36	8.46
1120 kg/ha 15-10-10	6.40	2.41	8.81
Mean	6.00	1.95	7.95
LSD (5%)	NS	0.28	0.79

No significant differences were observed in the yields of the first cutting. This may have been due to the availability of soil nitrogen on this site accruing from the prior growth of a nitrogen fixing legume. In the second cutting, yields obtained with 16.8 and 22.4 mt/ha poultry manure did not differ significantly ($P < 0.05$) from those obtained with the 1120 kg/ha 15-10-10. Likewise, yields obtained from the two highest rates of poultry manure did not differ significantly ($P < 0.05$) from those obtained from the inorganic fertilizer for the whole season.

Forage quality trends in Experiment II were similar to those observed in Experiment I (Table 5). Data are averaged for both plus and minus phosphorus treatments. No significant differences in chemical composition attributable to fertilizer effects were observed in the first cutting. In the second cutting, increasing rates of fertilization stimulated growth. The highest yields were obtained from the most mature forage. Low fertilizer treatments produced relatively low yields of immature forage, which was of high digestibility. High rates of nitrogen increased tissue nitrogen content. The inorganically fertilized sudangrass was lowest in potassium content and highest in calcium content. Nitrogen has been demonstrated to be positively associated with plant calcium uptake (Drake and White, 1961).

Table 5. Chemical composition of the first and second cuttings in Experiment II 1975.

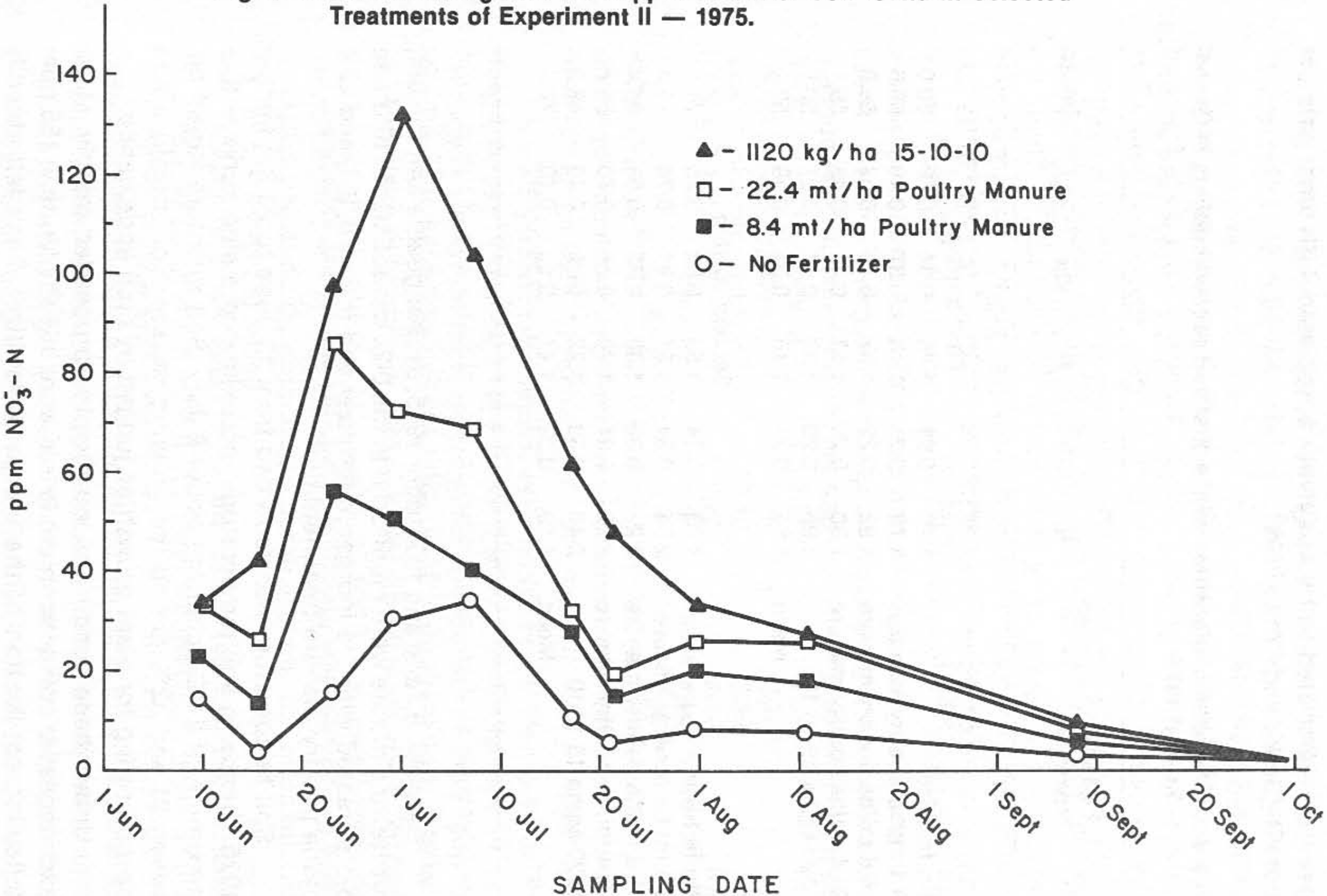
Fertility treatment	N	P	K	Ca	Mg	IVDMD
				%		
			First cutting			
No fertilizer	1.70	0.21	1.45	0.34	0.48	60.0
8.4 mt/ha poultry manure	1.72	0.21	1.48	0.37	0.48	59.6
16.8 mt/ha poultry manure	1.92	0.22	1.32	0.40	0.52	58.8
22.4 mt/ha poultry manure	1.90	0.20	1.63	0.41	0.48	59.1
1120 kg/ha 15-10-10	1.95	0.20	1.39	0.44	0.51	58.5
Mean	1.84	0.21	1.45	0.39	0.49	59.2
			Second cutting			
No fertilizer	1.93	0.34	1.50	0.82	0.75	71.4
8.4 mt/ha poultry manure	2.04	0.34	1.61	0.81	0.76	72.4
16.8 mt/ha poultry manure	2.21	0.32	1.30	0.75	0.59	69.4
22.4 mt/ha poultry manure	2.29	0.31	1.70	0.78	0.70	69.4
1120 kg/ha 15-10-10	2.47	0.30	1.22	0.85	0.70	69.3
Mean	2.19	0.32	1.47	0.80	0.70	70.4

Between 9 June and 1 October 1975, exchangeable ammonium, nitrite, and nitrate were monitored in the 0-20 cm soil depth of those plots treated with the inorganic fertilizer and the zero, 8.4, and 22.4 mt/ha poultry manure treatments.

Soil temperature was recorded from 13 June to 29 September 1975. Trends in soil temperature approximated a sine curve with a maximum of 24 C occurring about 8 July. Soil moisture varied between 21 and 32% during the growing season. Soil moisture was never limiting for plant growth as judged by crop appearance.

Under these conditions, nitrification proceeded rapidly. Mean exchangeable soil ammonium levels were initially (June 9) 155 ppm following application of the inorganic fertilizer. They fell steadily until by 21 July, they were approximately 8 ppm, equalling those of the zero fertilizer treatment. Mean levels of exchangeable am-

Figure 1. Nitrate Nitrogen in The Upper 20 cm of Soil found in Selected Treatments of Experiment II — 1975.



monium were 28 and 56 ppm following application of the 8.4 and 22.4 mt/ha poultry manure treatments, respectively. These levels declined rapidly and were comparable to those of the zero fertilizer treatment on 23 June. After 21 July, ammonium levels on all treatments were similar.

Concentration of soil nitrite as high as one ppm were not detected during the growing season. Trends in soil nitrate followed the rank order of dry matter yields for their respective treatments (Figure 1). In all cases, maximum nitrate concentrations occurred approximately thirty days following fertilizer application and fell to relatively low levels sixty days following application. Thus, the availability of nitrogen from fresh, litter-free poultry manure applied to the soil is observed to be similar to inorganic fertilizer in its rate of chemical transformation. However, quantitatively, less mineral nitrogen is measured in the soil per kg of total nitrogen applied in the poultry manure as contrasted to the inorganic fertilizer. These data are consistent with the relative efficiency of crop response.

Greenhouse Experiment

A greenhouse experiment was conducted to further investigate trends in soil nitrogen availability and changes in soil fertility which had resulted from the previous application of 1120 kg/ha 15-10-10 and zero, 8.4, and 22.4 mt/ha poultry manure, respectively.

The poultry manure applied in the spring of 1975 had increased the levels of exchangeable calcium and slightly raised the soil pH (Table 6). Applications of 1120 kg/ha 15-10-10 and 8.4 and 22.4 mt/ha poultry manure included 93, 32, and 86 kg K/ha, respectively.

Table 6. Chemical analysis of the soils in the greenhouse experiment.[1]

Fertility treatment (previous May)	pH	P	K	Ca	Mg
			kg/ha		
No fertilizer	6.5	2	118	2800	580
1120 kg/ha 15-10-10	6.5	4	174	2600	550
8.4 mt/ha poultry manure	6.6	3	134	3000	520
22.4 mt/ha poultry manure	6.8	7	224	3500	570

[1]*Soils obtained from Field Experiment II*

Despite the fact that the rate of potassium applied in these two treatments of poultry manure was less than that applied in the inorganic fertilizer, potassium content in the crop (see Table 5) was higher from the poultry manure treatments. Moreover, soil potassium was observed to increase following the highest rate of poultry manure. Liebhardt and Shortall (1974) have demonstrated that potassium is the element chiefly responsible for increasing soil salinity following heavy rates of poultry manure application. Mitchell, Liebhardt, and Chaloupka (1975) have cautioned against heavy rates of poultry manure application because high rates have decreased yields of corn due to high salt concentrations in the soil.

In the greenhouse experiment, sudangrass ratoons were grown on soils taken from the field, with and without supplemental nitrogen at 112 kg/ha. All treatments responded to supplemental nitrogen (Table 7). The yield differences between the plus and zero nitrogen amendments were 0.45, 0.79, 1.57, and 2.18 mt/ha for the zero fertilizer, the inorganic fertilizer, and the 8.4 and the 22.4 mt/ha poultry manure treatments, respectively. The extent of the plus nitrogen response may be seen as a measure of the relative deficiency of available nitrogen and the relative sufficiency of other nutritional elements. Thus, poultry manure increased soil phosphorus, potassium, and calcium, but did not increase soil nitrogen following one cropping season.

Table 7. Dry matter yields from the greenhouse experiment.

Fertility treatment (previous May)	Nitrogen fertilization (September) kg/ha 0	112	Mean
	mt/ha		
No fertilizer	1.97	2.42	2.20
1120 kg/ha 15-10-10	2.73	3.52	3.12
8.4 mt/ha poultry manure	1.50	3.07	2.28
22.4 mt/ha poultry manure	3.22	5.40	4.31
Mean	2.36	3.60	

Experiment II 1976

In 1976, a second crop of Piper sudangrass was seeded on the site of the previous experiment and no fertilizer was applied. Analysis of variance indicated that no significant differences were observed between yields obtained for any fertilizer treatments applied in 1975.

SUMMARY AND CONCLUSION

In 1974 and 1975, three cultivars of sudangrass were grown with 5.6, 8.4, and 11.2 mt/ha fresh, litter-free poultry manure and 1120 kg/ha 15-10-10. Two cuttings were made each season. Average yields for the three rates of manure from lowest to highest and the inorganic fertilizer were 6.38, 6.29, 6.89, and 8.50 mt/ha, respectively. Inorganic fertilization stimulated growth, morphological maturity, and nitrogen content. Digestibility was higher in the more immature forage. Fertilization with poultry manure increased forage potassium content.

In 1975, Piper sudangrass was grown with zero, 8.4, 16.8, and 22.4 mt/ha fresh, litter-free poultry manure and 1120 kg/ha 15-10-10. The highest manure rate contained 307 kg N/ha as applied versus 168 kg N/ha for the inorganic treatment. Two harvests were taken. Total season yields were 6.70, 7.54, 8.26, 8.46, and 8.81 mt/ha for the fertilizer treatments, respectively. Trends of forage quality were similar to those described in the previous experiment.

At the end of the growing season, a greenhouse experiment was conducted with soils removed from the field. An addition of 112 kg N/ha raised yields for the zero fertilizer, the 1120 kg/ha 15-10-10, and 8.4 and 22.4 mt/ha poultry manure treatments by 0.45, 0.79, 1.54, and 2.18 mt/ha, respectively.

In 1976, no fertilizer was applied to the plots of the second experiment which was again cropped to Piper sudangrass. No significant differences were observed in yields.

These experiments suggest that total nitrogen analysis of poultry manure does not indicate the availability of nitrogen to the crop. A conservative estimate of nitrogen availability for fresh litter-free poultry manure is 7.5 kg N/mt.

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