DAIRY CATTLE WASTE MANAGEMENT: ITS EFFECT ON FORAGE PRODUCTION AND RUNOFF WATER QUALITY

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CONTENTS

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DAIRY CATTLE WASTE MANAGEMENT: Its Effect on Forage Production and Runoff Water Quality[1]

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MANAGEMENT OF ANIMAL WASTES to maximize farm efficiency and minimize pollution is important to agriculture. The need for animal waste management research has been intensified in recent years as a result of (1) increasing numbers of animals being maintained in confinement in areas of high animal density, (2) movement of nonfarm people into livestock production areas, and (3) increasing concern by the public for a less polluted environment. Animal waste management systems are being sought to control air and water pollution without sacrificing efficiency and economy of operation.

Land spreading of animal waste is an effective means of disposal that may partially overcome the rising costs of mineral fertilizers for certain crops. For use in forage production, information is needed about maximum rates to safely produce satisfactory yield and quality of forage. A better understanding of the agronomic value of high rates of animal manure is needed to encourage the waste-recycle trend.

The objectives of these investigations were (1) to determine how much dairy manure can be disposed of on crop land without damaging soil properties or lowering the quality of forage produced on the soil, and (2) to determine if moderate amounts of manure (20 tons per acre) can be disposed of without damaging the quality of runoff water or soil properties.

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[1] Contribution from Soil and Water Research, Southern Region, Agricultural Research Service, U.S. Department of Agriculture, in Cooperation with Department of Agronomy and Soils, Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama; and Department of Natural Resources and Environmental Studies, Alabama A&M University, Normal, Alabama.

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METHODS

Rates-of-Manure-Application Experiment

Field experiments were conducted in Alabama for a 3-year period (1970-73) on a Dothan loamy sand (Plinthic Paleudult) at Auburn, on Lucedale fine sandy loam (Rhodic Paleudult) at Thorsby, and on Decatur silty clay loam (Rhodic Paleudult) at Normal. The plow layer of the Dothan soil was composed of 82, 13, and 5 percent sand, silt, and clay, respectively; the Lucedale was 55, 27, and 18 and the Decatur 22, 48, and 30 percent. Sheet-metal borders formed plots 9 $\times$ 9 feet on the Dothan and Decatur soils and 7.5 $\times$ 8.5 feet on the Lucedale soil.

Nitrogen (N), phosphorus (P), and potassium (K) were rototilled into the no-manure check plots at rates of 100 pounds per acre each before planting. An additional 80 pounds per acre each of N and K were surface-applied after each cutting. The average annual application of 520 pounds N, 100 pounds P (230 pounds P_2O_5), and 520 pounds K (625 pounds K_2O) was higher than is normally used in these cropping sequences, but was comparable to the total nutrients applied at the lower manure rates. Fresh manure from lactating cows was surface-applied each spring before planting and rototilled into the top 6 inches of soil of the other plots at rates of 10, 20, 40, 80, and 120 tons per acre (dry weight basis). Four replications were used for each treatment.

Six to 12 manure samples were analyzed from each location each year. Average N, P, and K composition of manure was 2.00, 0.40, and 0.96 percent, respectively, on Dothan soil, 1.70, 0.54, and 1.10 percent on Lucedale soil, and 2.40, 1.02, and 1.60 percent, respectively, on Decatur soil, Appendix Table 1. This averages about 400, 130, and 240 pounds of N, P, and K per acre, respectively, from manure at the 10 tons per acre rate.

Pearlmillet (*Pennisetum americanum* L. [K. Schum] variety 'Gahi-l') was planted in the spring and Wren's 'Abruzzi' rye (*Secale cereale* L.) in the fall. Millet was cut when 4 to 6 feet tall and rye when 2 to 3 feet tall. Millet was cut two to four times and rye two to three times each year on the Dothan soil. On Lucedale soil, millet and rye were cut three times each year. Millet was cut twice and rye once each year on the Decatur soil. The soil was analyzed for organic-nitrogen (organic-N), carbon (C), and nitrate-nitrogen (NO_3-N). Calcium (Ca), magnesium (Mg), and potassium (K) were determined on dilute double-acid extract. Soil pH was determined using a 1:1 ratio of soil to water. Plant material was analyzed for organic-N, then composited within treatments and analyzed for Ca, Mg, K, P, and trace elements by emission spectroscopy by the Plant and Soil Testing Laboratory, University of Georgia.

Runoff Experiment

An experiment was conducted at Auburn on four 0.1-acre runoff plots of Norfolk sandy loam (Typic Paleudult) with less than 2 percent slope. A Coshocton wheel was utilized to quantitatively sample a portion of the runoff water during each runoff event. Dairy cattle manure was applied to two of the plots each spring for 3 years (1970, 1971, and 1972) at the rate of 20 tons per acre per year (dry weight basis). It was spread on the soil surface and incorporated into the top 6 inches with a rototiller. The two check plots received 400 pounds N, 140 pounds P, and 160 pounds K per acre per year as commercial fertilizer – amounts considered adequate to remove N, P, and K as limiting factors in plant growth on this soil.

The plots were double-cropped with 'Gahi-l' pearlmillet and 'Abruzzi' rye. The amount of runoff water was measured and samples were collected for analysis. Water measurements included biochemical oxygen demand (BOD), ammonium-N (NH_4-N), nitrate-N (NO_3-N), and pH. Soil samples were taken periodically from each 6-inch increment to a depth of 36 inches for pH, C, NO_3, and organic-N determinations. Forage yields were determined, and forage and applied manure analyzed for P, K, Ca, Mg, boron (B), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), and iron (Fe) by emission spectroscopy. Forage and manure samples were also analyzed for NO_3 and organic-N.

RESULTS AND DISCUSSION

Rates-of-Manure-Application Experiment

Forage

YIELD

Overall average forage yield for the 3-year period showed no detrimental effect from applied manure, Figure 1. Yields were

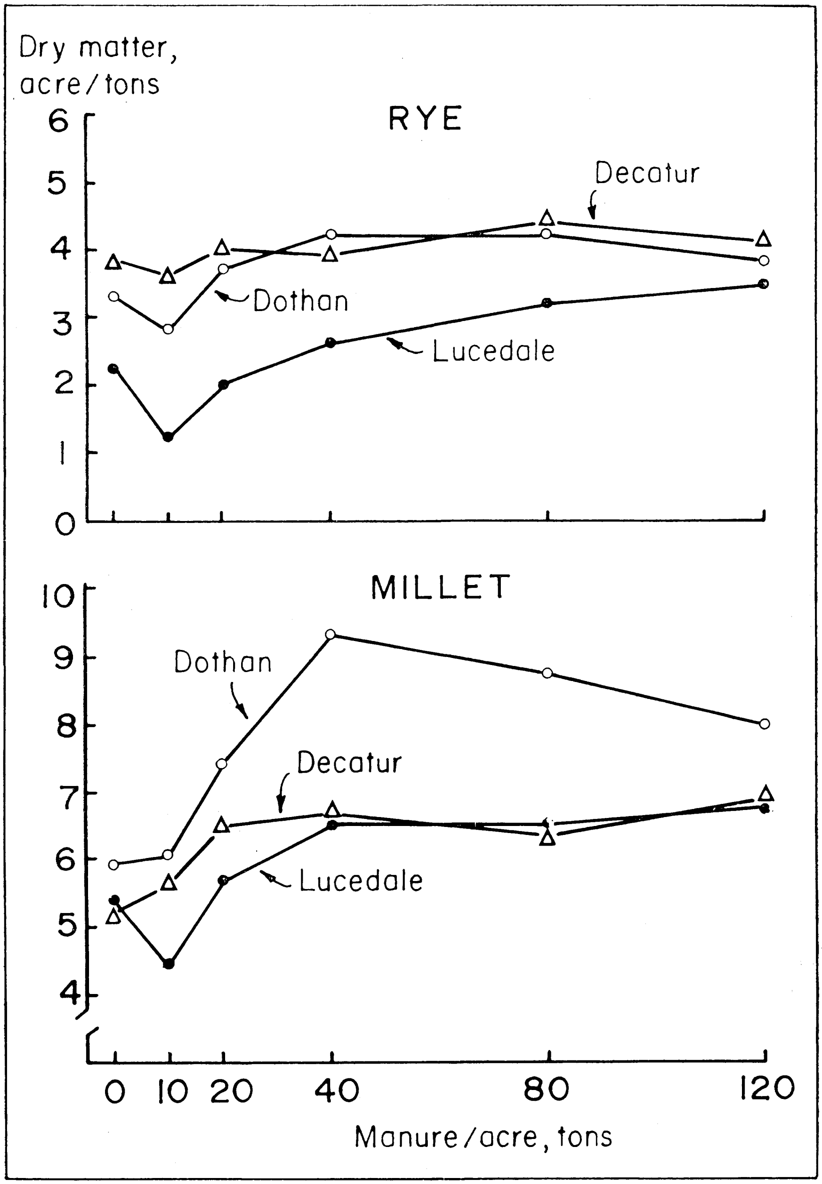

FIG. 1. Dry matter yields of forage from three soils as affected by rate of manure application (3-year average).

generally higher on the manure-treated plots than on the check plots. There was a large response to manure application on the Dothan soil, probably due to the beneficial effects of increased organic matter content of the soil. The higher organic matter content increased the total water-holding capacity of the soil, thus increasing movement of water and nutrients to plant roots.

The 10-ton application rate did not produce as much rye or millet forage as did the check treatment on the Lucedale soil. The total amount of nutrients applied in the 10 tons of manure was equivalent to that applied to the well-fertilized check plot. Evidently the plant nutrients were not as readily available in the manure as in commercial fertilizer, and the crops were capable of responding to more than was released from the 10-ton rate of manure.

Detrimental effects on yields from the high application rates were apparent when individual years were presented, Appendix Tables 2 and 3. Emergence and early growth of millet were severely reduced with both the 80- and 120-ton application rates on the Dothan and Lucedale soils following the first application, probably a result of ammonia toxicity. One week after the application of manure, pH in the surface soil increased to above 8 in both soils. Under these conditions free ammonia was liberated from the manure, causing reduced germination and growth of the seedlings. The increase in pH did not occur when manure was applied the second and third years because the residue had increased the exchange capacity of the soil, and thus prevented the increase in pH. There was no difficulty with emergence and early growth on the Decatur soil, Appendix Table 4. This soil had a higher clay content and exchange capacity, which adsorbed the ammonia released from manure and prevented pH increase, thereby avoiding toxicity. Apparently there is less danger of ammonia toxicity from large amounts of manure on fine-textured soils than on coarse soils.

Yield of rye was reduced at the highest rate of application the last year of the test on Dothan soil. Plants in the middle of the plots were shorter, many of the heads turned white, and seed formation was poor. This appeared to be salt damage. The surface soil (0- to 6-inch depth) was checked for excessive salt and found to be within plant tolerance level; however, the surface soil was quite dry and excessive salts from deeper in the soil could have been causing these symptoms and the accompanying yield loss.

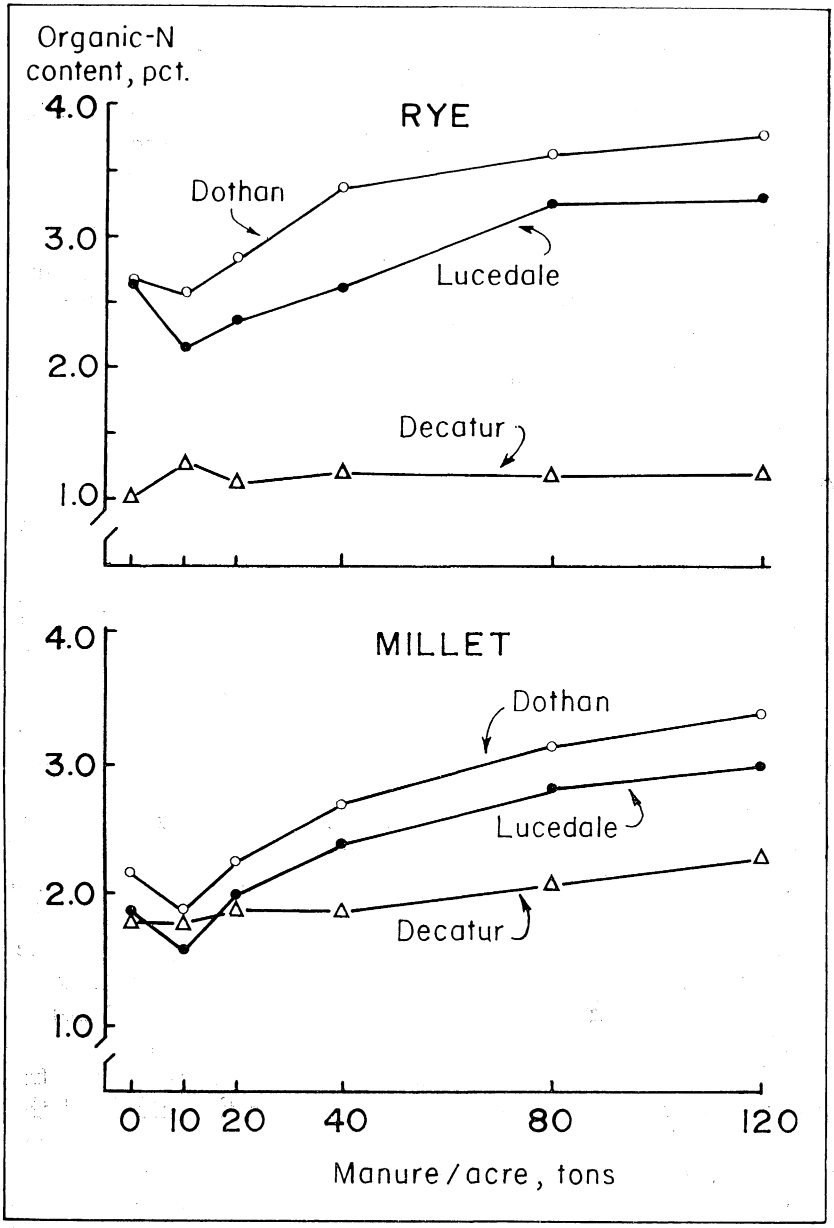

FIG. 2. Organic nitrogen content of forage from three soils as affected by rate of manure application (3-year average).

Rye yields were lower on Lucedale than on Dothan soil, possibly because of the number of cuttings. The rye was harvested in March and again in April on the Dothan soil in 1970. March and April harvests were made all 3 years on the Lucedale soil. Total rye production on Lucedale and Dothan was much lower in 1970, indicating that March harvest was detrimental to forage production. High yields in 1972 and 1973 on Dothan soil support this hypothesis.

Organic-N Content

Organic-N content of rye and millet forage went up as manure application rate was increased on both Dothan and Lucedale soils, Figure 2. The increase was less on the Decatur soil, which produced fewer cuttings of each crop, than on the other two soils. The harvested forage was more mature on Decatur and contained more stem material, and this accounted for the lower N content. In general, organic-N was lower in the forage produced at the 10-ton application rate, for the same reason that yields were lower from this rate of manure – the N was not as available as that in the commercial fertilizer.

Organic-N usually decreased in the forage as the season progressed, Appendix Tables 5, 6, and 7. This was particularly true of the forages grown on lower rates of manure. Some of the N from manure was quickly available, but part of it was only slowly available, and this resulted in depressed uptake of N late in the season. The last cutting of rye was always lowest, probably due to the high straw content. The rye was usually cut at the soft-dough stage. Usually the N is being mobilized in the grain at this stage and uptake is also slower.

Nitrate-N Content

Nitrate-N was above 0.4 percent in the millet forage produced on soil treated with 80 or 120 tons of manure per acre, Figure 3. This level of NO_3-N is considered potentially toxic to ruminant animals. Although NO_3-N toxicity is not frequently found in summer forages, millet with this nitrate-N level should be fed with caution. Even though these manure rates produced high forage yields, the forage quality was such that rates of 80 or 120 tons should not be used.

High levels of NO_3-N were found in rye only on the Dothan soil. The rye produced on the 80- and 120-ton manure plots was above 0.4 percent NO_3-N. Only one cutting of rye was made each

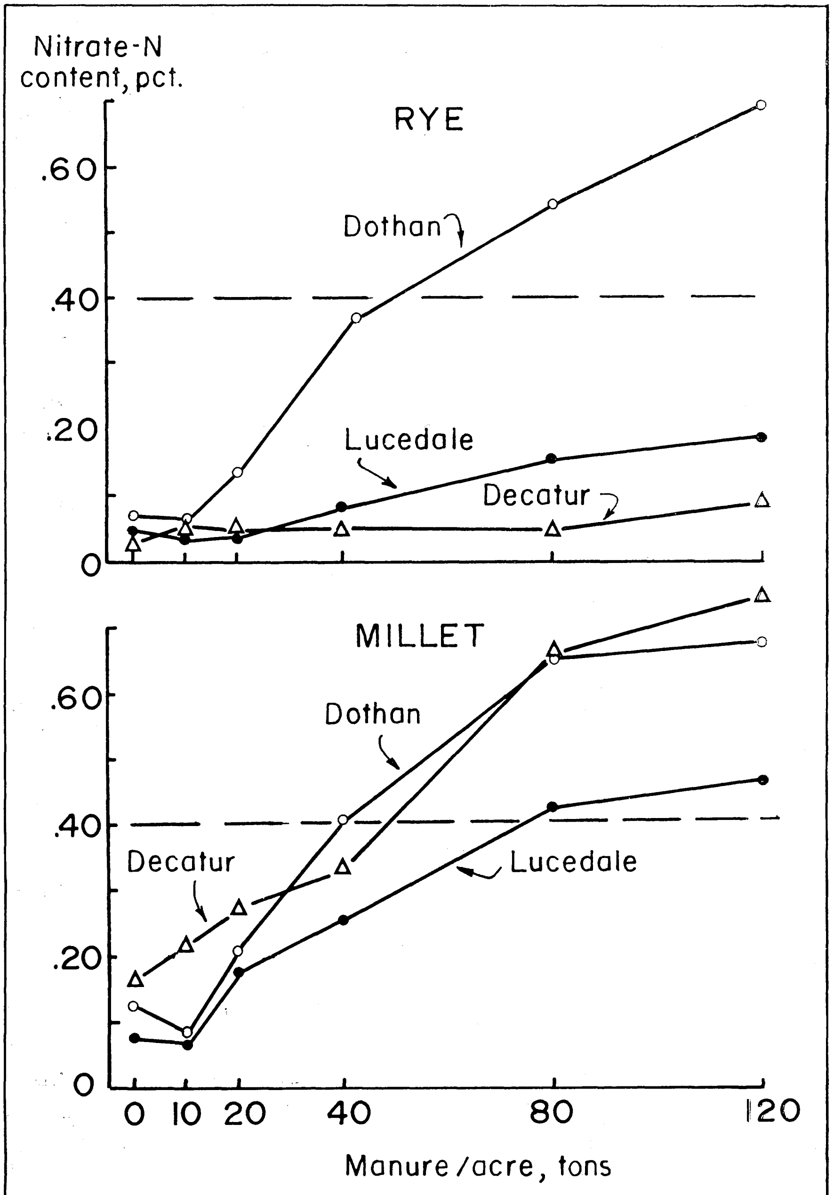

FIG. 3. Nitrate-N content of forage from three soils as affected by rate of manure application (3-year average).

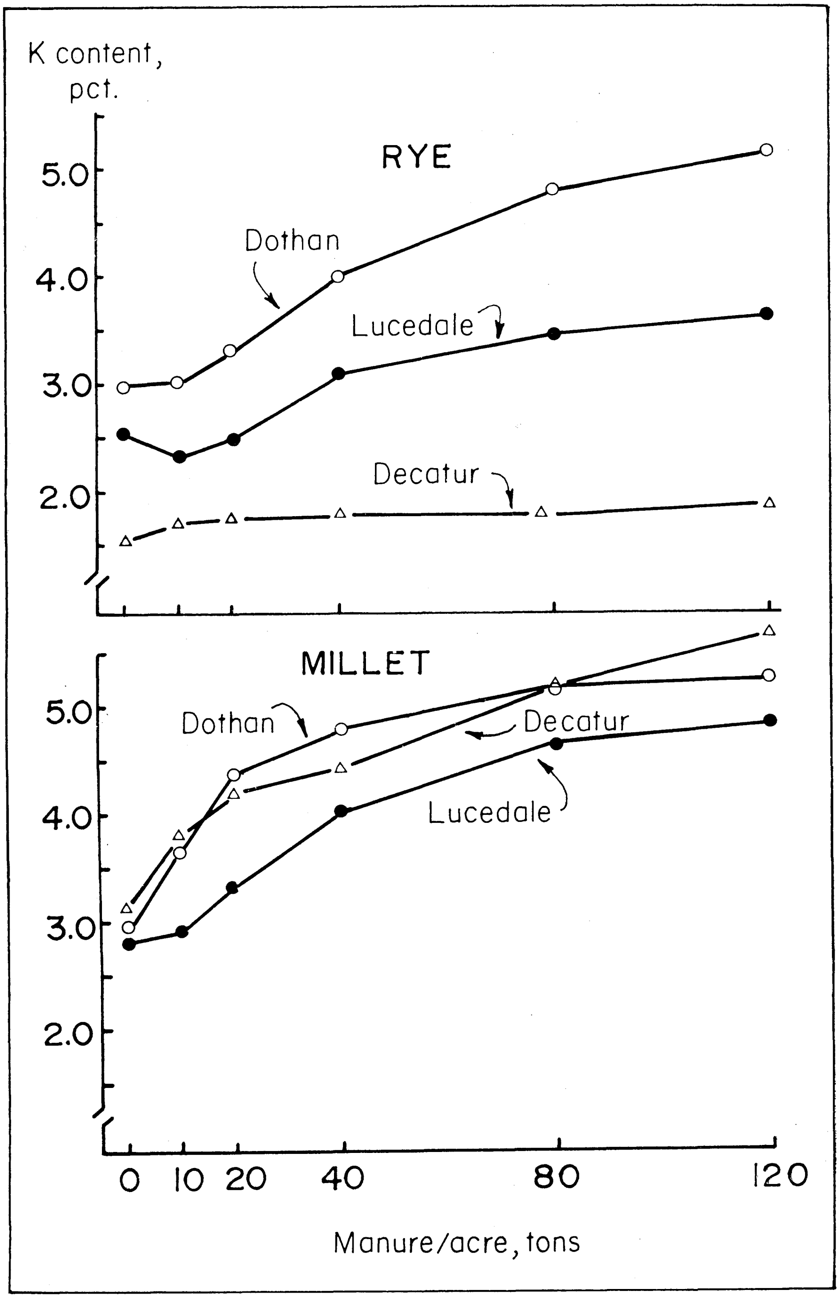

FIG. 4. Potassium content of forage from three soils as affected by rate of manure application (3-year average).

year on Decatur soil. This cutting was on mature rye, which would be expected to have high NO_3-N levels. Nitrate-N contents of rye forage were within the suggested tolerance levels throughout the season, however, so this forage was safe for grazing.

Frequently, high NO_3-N levels can be avoided by timing the cutting of the forage. The first cuttings of millet frequently had the highest NO_3-N levels, Appendix Tables 5, 6, and 7, with cuttings made in the middle of the season frequently lowest in NO_3-N. The last cutting of millet was usually high again, because the cutting was made before the millet was mature so the rye could be planted. Usually NO_3-N levels in plants decrease as the plant matures. Therefore, if the last cutting had been delayed, the level of NO_3-N in the millet would have been lower. Rye was cut in the spring after heading out, and was always lower in NO_3-N levels than cuttings made earlier.

Other Nutrient Contents

Rate of manure application affected forage contents of K, P, Ca, Mg, and Mn, but response varied among soils and between plant species. In general, the K content increased as rate of manure application increased. An exception was the rye on the Decatur soil, Figure 4. Larger uptake of K with increasing rate of manure application would be expected. Plants accumulate K in excess of plant needs if large quantities are readily available in the soil. Younger plants have higher K concentrations in the tissue than do older plants, Appendix Tables 5, 6, and 7.

Average phosphorus content of forage did not increase at the same rate as did K, Figure 5. Phosphorus uptake by millet did not increase with manure rate. There were wide differences in P content of rye grown on different soils. The first harvests made in the growth cycle of the plants had higher P levels than harvests made when the plants were closer to maturity. Millet had highest levels of P in forage grown at the low levels of manure application. This may have been caused by subsoil pH going above 6.5 on high application rates of manure. High pH can decrease solubility of some forms of P in the soil.

There was no consistent response of Ca concentration in the forage to manure application rate, but Ca level varied widely among forages grown on the different soils, Figure 6. Plants do not ordinarily take up Ca in excess of needs, so the divergence caused by soils cannot be explained. The millet was harvested

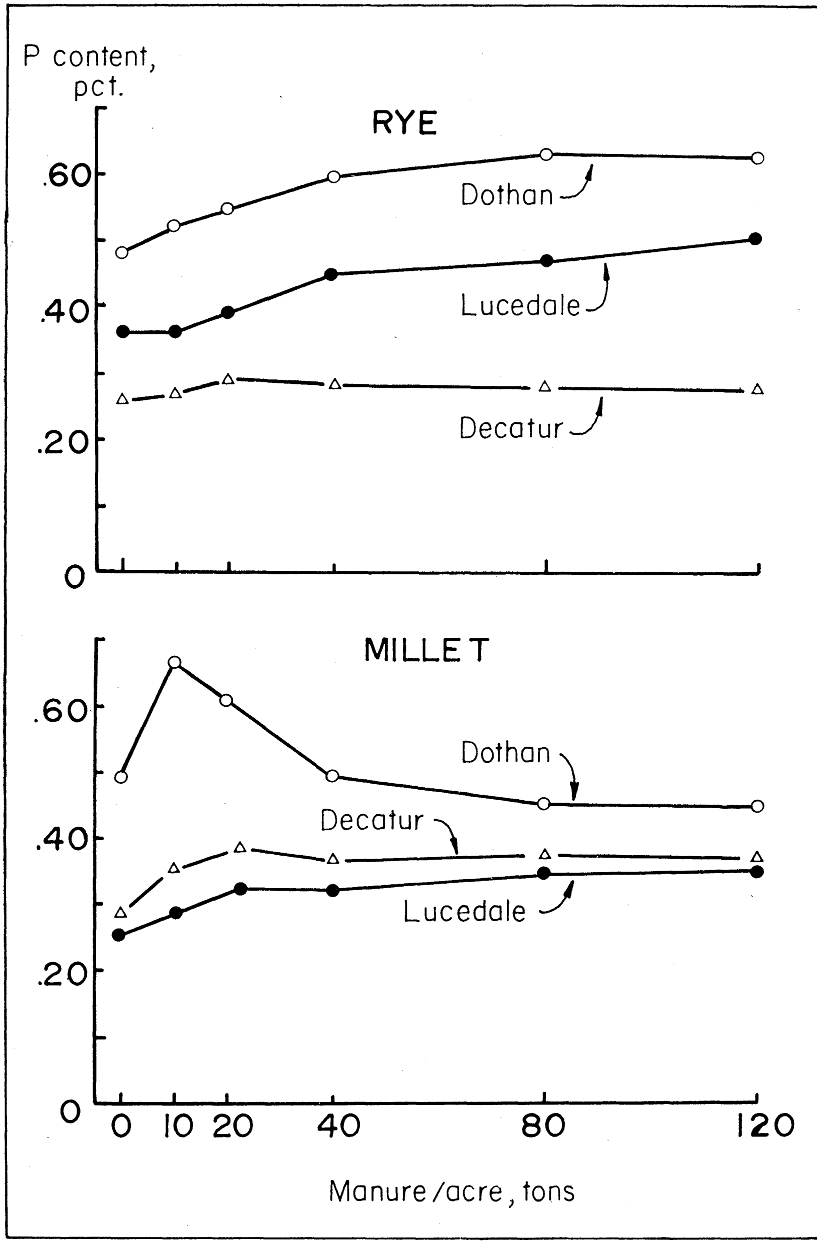

FIG. 5. Phosphorus content of forage from three soils as affected by rate of manure application (3-year average).

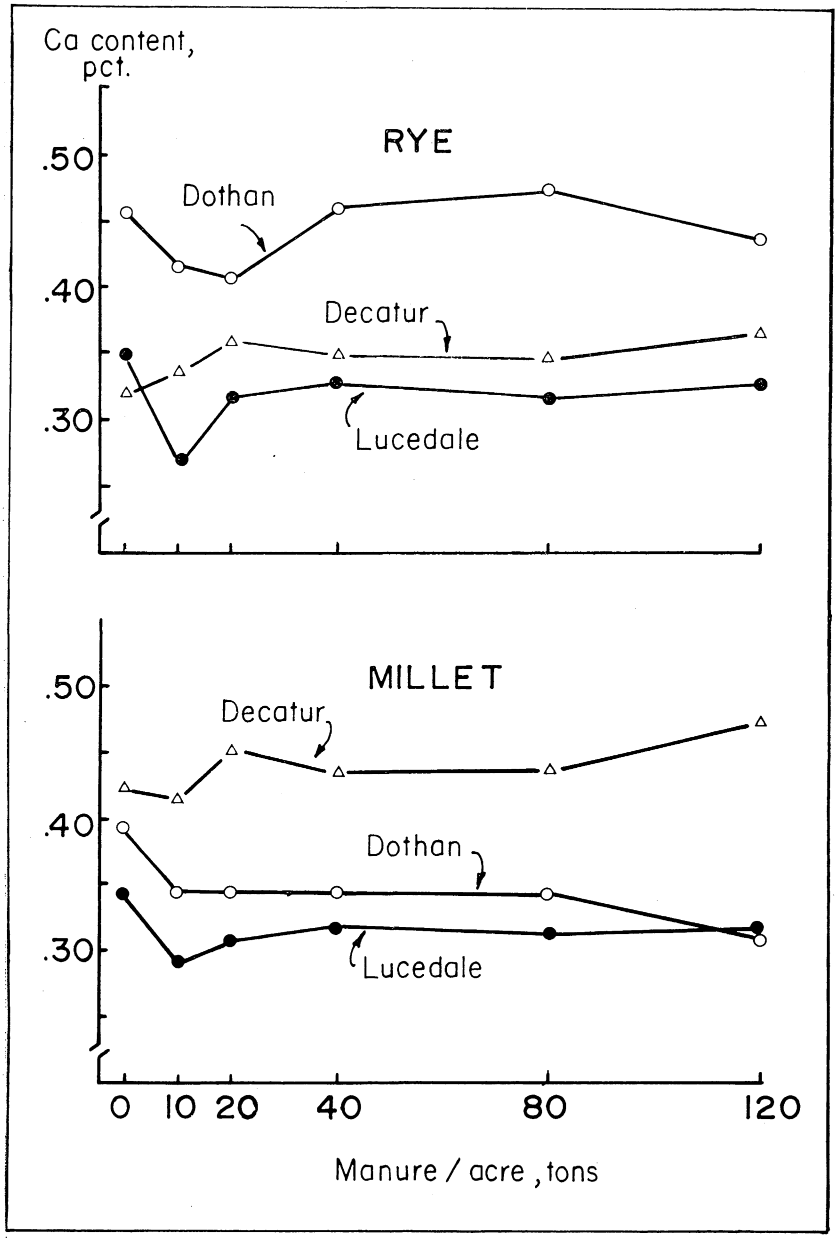

FIG. 6. Calcium content of forage from three soils as affected by rate of manure application (3-year average).

fewer times on the Decatur, and the higher levels of Ca were due to more mature tissue being harvested. This, however, does not account for the higher levels in the rye harvested on the Dothan soil.

Magnesium contents varied between soils but showed little response to manure application except on the Dothan soil, Figure 7. Magnesium contents of rye increased as rates of manure application went up. The millet had a larger response to the first two increments of manure application, with decreasing response to the higher rates.

Manganese uptake was depressed by application of manure. The first increment of added manure had the greatest effect, Figure 8, but the first cuttings after the first manure application also showed increased uptake of Mn. This could have been due to the chelating effects of the increased organic matter or to the increased Mn under a lower oxygen content resulting from rapid decomposition of organic compounds formed in the soil. Thereafter, the dominating effect of added manure was on soil pH. The subsoil pH in particular was increased by the manure added to the surface soil, Appendix Tables 8, 9, and 10. The increase in pH decreased both solubility and uptake of Mn.

Ratios of K:(Ca + Mg)

Most manure treatments produced tetany-prone forage having K:(Ca + Mg) equivalent ratios above 2.2, which is considered to be the critical level, Figure 9. Only millet forage produced with the lowest manure application rate and the check (mineral-fertilized) treatments could be considered safe. All manure treatments on Decatur soil produced millet forage with ratios above 2.2. The K:(Ca + Mg) ratios for rye forage were above the 2.2 level for all manure treatments on Dothan and Lucedale soils but were below the critical tetany-prone level for all treatments on the Decatur soil. The Lucedale soil produced rye forage with highest ratios and the Decatur soil produced millet forage with highest ratios. The K:(Ca + Mg) ratios of both millet and rye forage were generally higher for the first harvest than for subsequent harvests, Appendix Tables 5, 6, and 7. Since high K:(Ca + Mg) ratios are usually associated with high K uptake, they were expected to be greater in the spring for millet and in fall for rye because of the higher K content of forage when plants were young. Ratios were low for rye on the Decatur soil since only one harvest was made on each planting.

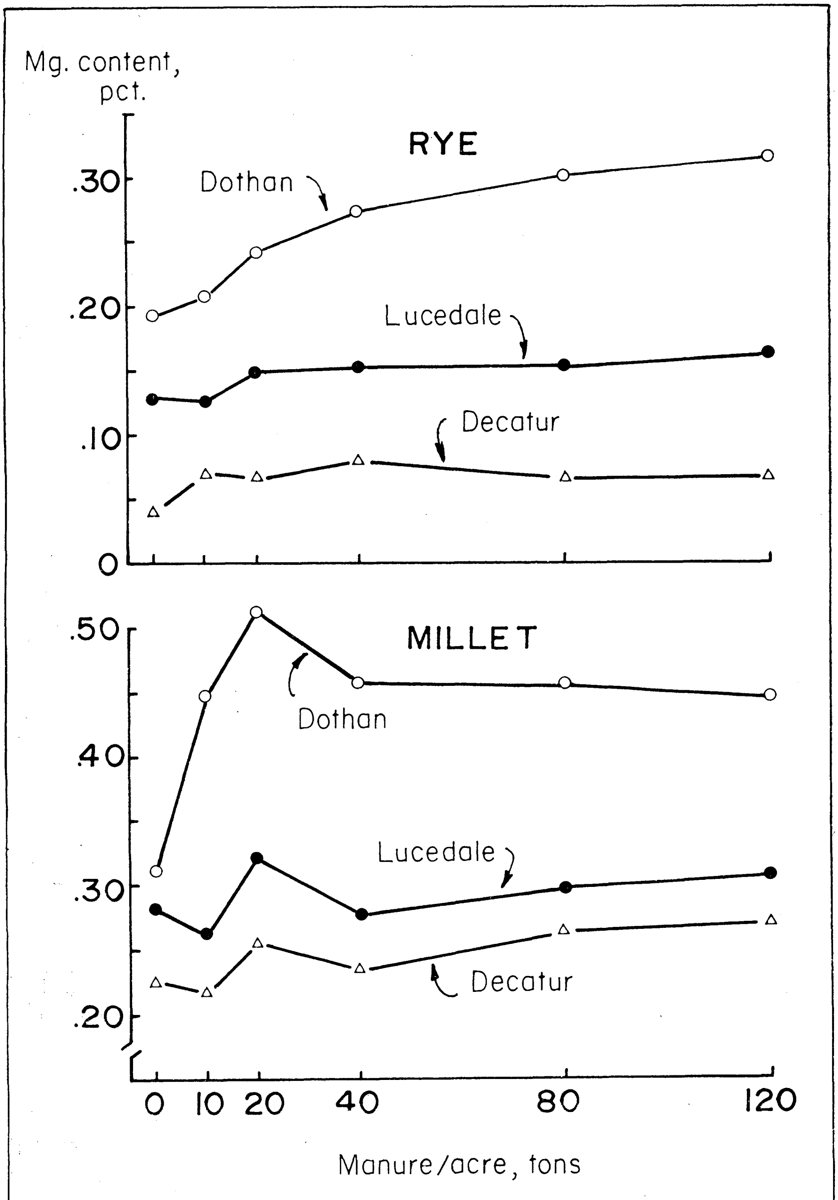

FIG. 7. Magnesium content of forage from three soils as affected by rate of manure application (3-year average).

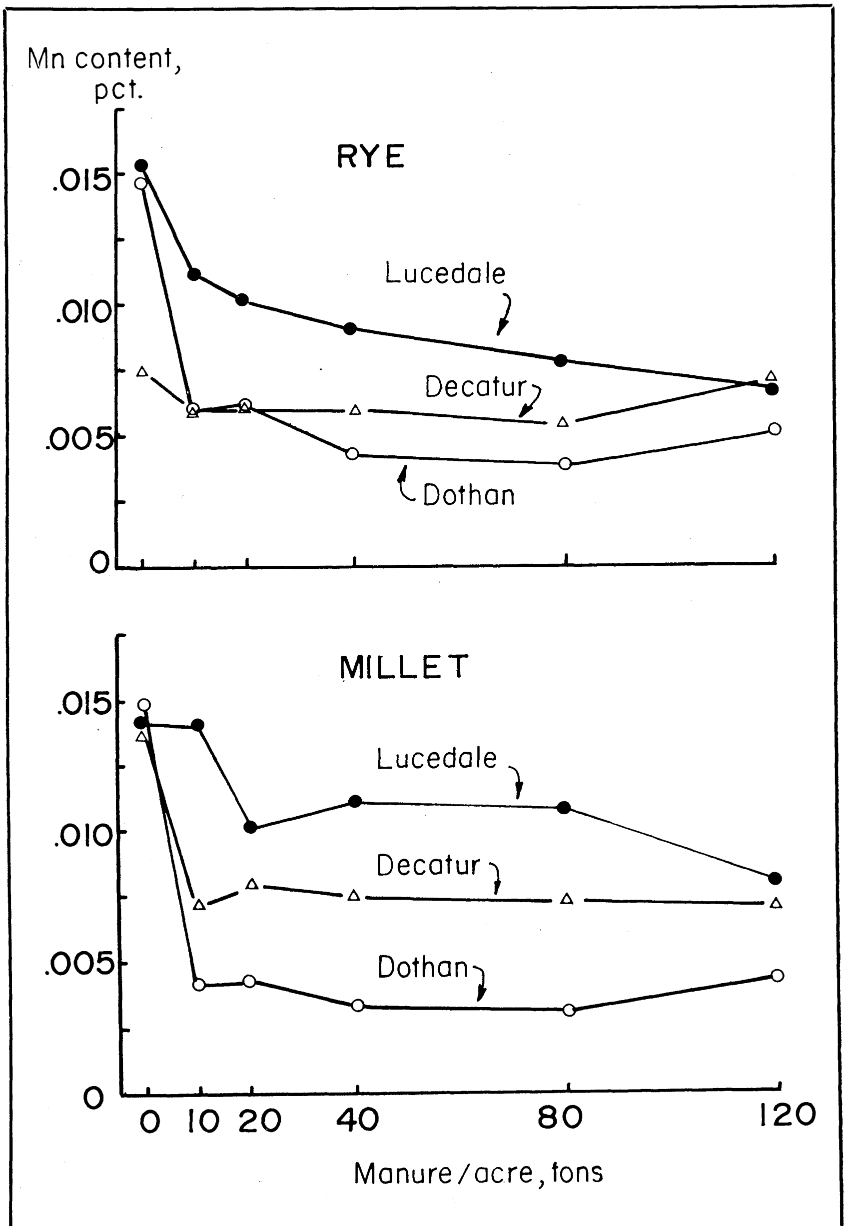

FIG. 8. Manganese content of forage from three soils as affected by rate of manure application (3-year average).

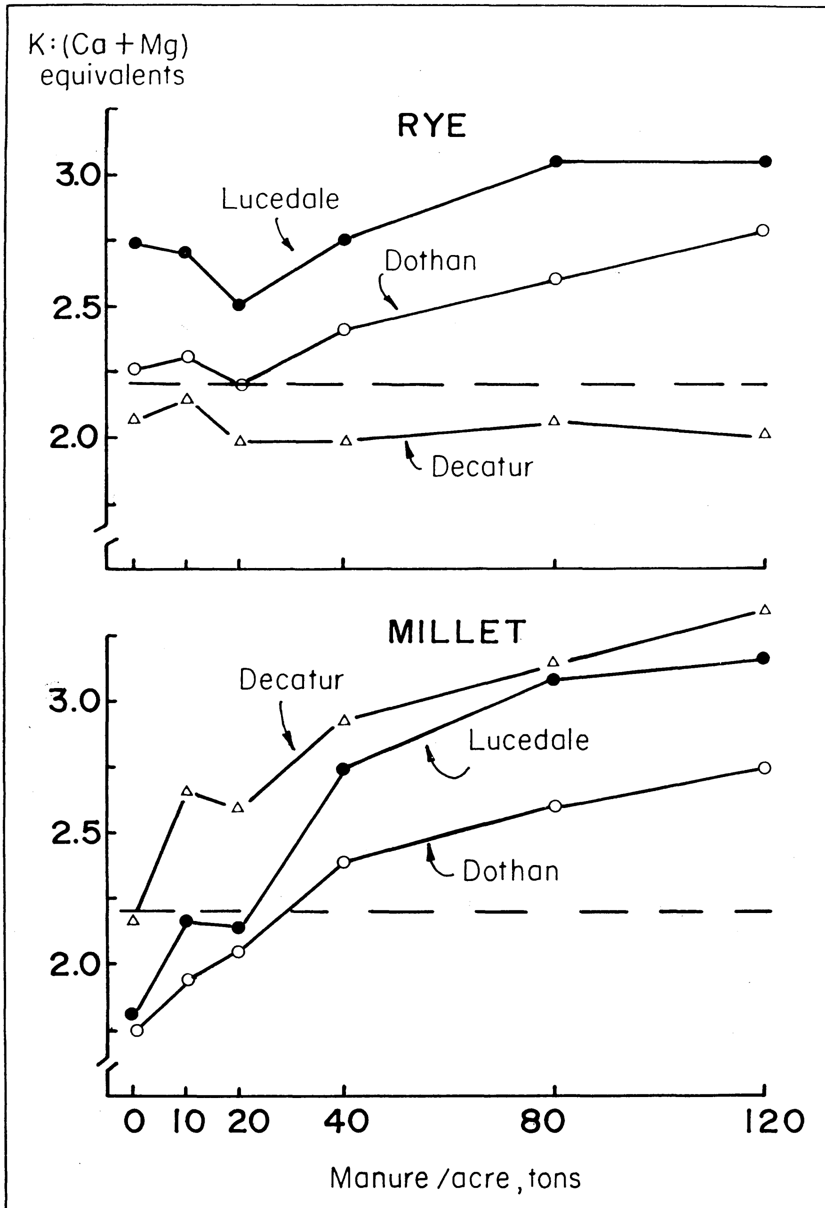

FIG. 9. Equivalent ratios of K:(Ca + Mg) from three soils as affected by rate of manure application (3-year average).

Soil Properties

Soil properties in the surface 36 inches of Dothan, Lucedale, and Decatur soils 1 year after the last annual manure application are given in Appendix Tables 8, 9, and 10. Manure application increased the levels of all properties measured. The effects from manure were more evident at the higher application rates.

pH

The pH values increased as manure rate increased except in the surface of the Dothan soil. At the lowest soil depth measured (30 to 36 inches) pH ranged from 5.6 for the check treatment to above 7.0 at the higher rates of manure. The Lucedale soil showed increased pH in the surface 2 feet with increasing rates of manure, but rate of manure made little difference in pH below 2 feet, Appendix Table 9. On Decatur soil, pH values in the surface 12 inches of soil increased with manure rate but below 12 inches showed little difference between treatments. Permeability of this soil limited downward movement of K and Ca from the manure.

Organic Matter Content

Manure applications increased organic matter on all three soils at all soil depths measured. The greatest increase was in the surface 12 inches, with effect decreasing at the lower depths, Appendix Tables 8, 9, and 10. A greater organic matter increase from manure applications was obtained on the Decatur soil than on Dothan and Lucedale soils.

Organic-N and Nitrate-N Contents

Organic-N and NO_3-N were increased in all soils by manure application, with the effect being limited mainly to the surface 12 inches of soil. Other plant nutrients (K, Ca, and Mg) were increased by manure application, but there was little downward movement below 12 inches. The one exception was on Dothan soil, where K contents increased at the lowest depth measured.

Runoff Experiment

Runoff Water Quality

Biochemical Oxygen Demand (BOD)

One measure of the pollution potential of a material is the amount of oxygen it requires for oxidation. BOD values of runoff

TABLE 1. BIOCHEMICAL OXYGEN DEMAND (BOD) VALUES OF RUNOFF WATER FROM CHECK AND MANURED PLOTS

Year	BOD of check plots			BOD of manured plots		
	Max.	Min.	Mean	Max.	Min.	Mean
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1970[1]	11.9	2.5	8.0	10.7	3.6	8.0
1971	9.6	3.0	5.7	8.9	3.5	6.1
1972	9.9	3.0	5.0	6.3	1.5	4.3
1973[2]	4.4	0.0	1.5	5.4	5.4	1.8
3-year mean			4.7			4.7

[1] July 23 through December.
[2] January through April 23.

water were unaffected by applied manure over the 3-year period. In fact, the 3-year means for check and manured plots were the same, 4.7 p.p.m., Table 1. In all cases, the values were low.

AMMONIUM-N CONTENT

Mean NH_4-N values in runoff water from the manured plots were low and, except for 1971, only slightly higher than those from the check, Table 2. The highest value from the manured plot, 4.8 p.p.m., occurred when there was only a very small amount of runoff and, consequently, contributed little to nitrogen runoff.

TABLE 2. AMMONIUM-NITROGEN (NH_4-N) CONCENTRATION IN RUNOFF WATER FROM CHECK AND MANURED PLOTS

Year	NH_4-N of check plots			NH_4-N of manured plots		
	Max.	Min.	Mean	Max.	Min.	Mean
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1970[1]	1.99	0.23	0.61	2.69	0.23	0.66
1971	1.33	.14	.68	4.76	.34	1.75
1972	1.97	.00	.86	2.78	.29	.95
1973[2]	2.08	.04	.43	.55	.18	.56

[1] July 23 through December.
[2] January through April 23.

NITRATE-N CONTENT

Annual manure applications at the rate of 20 tons per acre incorporated into the surface 6 inches of soil had no effect on the NO_3-N content of runoff water, Table 3. Values for both the check and manured plots were well within acceptable NO_3-N levels, even for drinking water. There was no definite seasonal fluctua-

TABLE 3 NITRATE-NITROGEN (NO_3-N) CONCENTRATION IN RUNOFF WATER FROM CHECK AND MANURED PLOTS

Year	NO_3-N of check plots			NO_3-N of manured plots		
	Max.	Min.	Mean	Max.	Min.	Mean
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1970[1]	2.73	0.38	1.30	2.33	0.25	1.47
1971	2.94	.70	1.48	3.50	.84	1.82
1972	3.70	.42	1.68	3.07	.43	1.37
1973[2]	2.56	.96	1.46	2.65	.79	1.70

[1] July 23 through December.
[2] January through April 23.

tion and no indication of increasing NO_3-N in the runoff water over the 3-year period. Analysis of water samples taken from the water table upslope and downslope from the plots indicated no increase in nitrate due to manure treatment. The nitrate content of water from the water table fluctuated with time and ranged from less than 1 to about 7 p.p.m., but this could not be related to manure treatment.

TOTAL N CONTENT

As shown in Table 4, N in runoff from July 23 through December 1970 was only 1.1 and 2.0 pounds per acre from the check and manured plots, respectively. The highest N runoff for both the check and manured plots (less than 5 pounds per acre) occurred during 1971 and was associated with the highest amount of rainfall and runoff of any year during the study. In 1972 there was little N runoff (less than 1.5 pounds per acre) from the check or manured plots, with slightly above-normal rainfall (55 inches) for the year. During the first 4 months of 1973, N runoff was considerably less from the manured plots than from the checks. Over

TABLE 4. RAINFALL, RUNOFF, AND TOTAL N LOSS IN RUNOFF WATER FROM CHECK AND MANURED PLOTS

Year	Rain-fall	Check				Manured			
		Runoff	N loss/acre			Runoff	N loss/acre		
			NH_4-N	NO_3-N	Total		NH_4-N	NO_3-N	Total
	Inches	*Inches*	*Lb.*	*Lb.*	*Lb.*	*Inches*	*Lb.*	*Lb.*	*Lb.*
1970[1]	20.9	3.92	0.25	0.88	1.13	4.16	0.43	1.59	2.02
1971	61.2	13.26	1.44	2.78	4.22	8.18	1.30	2.47	3.77
1972	55.4	3.72	.28	1.20	1.48	2.84	.37	1.05	1.42
1973[2]	19.8	4.32	.29	1.87	2.10	1.52	.09	.37	.46

[1] July 23 through December.
[2] January through April 23.

the 3-year period total N runoff was slightly less from the manured plots. In 1970, the amount of water that ran off the check and manured plots was about equal. Subsequently, runoff was consistently less from the manured plots. The decreased water runoff may have been due in part to increased water-holding capacity. However, an increase in infiltration would have given the same result.

Forage

Yield

Forage yields of millet and rye were higher each year from manured plots than from check plots, Table 5, even though N, P, and K were applied to the check plots in amounts considered adequate to remove them as growth-limiting factors. The differences were consistent, averaging 1,100 pounds per acre for the millet and 700 pounds for the rye.

Table 5. Forage Yields and Nitrate-Nitrogen Content of Millet and Rye from Check and Manured Plots in Runoff Experiment

Year	Millet				Rye			
	Check		Manured		Check		Manured	
	Yield/ acre	NO_3-N	Yield/ acre	NO_3-N	Yield/ acre	NO_3-N	Yield/ acre	NO_3-N
	Lb.	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*
1970	4,370	0.09	5,220	0.18	--------	--------	--------	--------
1971	9,073	.17	10,389	.42	5,372	0.007	6,423	0.008
1972	8,645	.13	9,750	.62	4,057	.044	4,186	.102
1973	--------	-------	--------	------	6,568	.027	7,502	.073

Nitrate-N Content

Rye forage produced on manured plots averaged 0.06 percent NO_3-N for the 3-year period, and did not exceed 0.1 percent, Table 5. Millet forage, however, showed a gradual increase in NO_3-N over the 3 years, averaging 0.2 percent NO_3-N per year, Table 5. By the second year (1971), it had reached 0.4 percent NO_3-N, and by the third year 0.6 percent NO_3-N. Thus, second year millet was borderline, and third year millet was potentially toxic to ruminant animals.

Plants vary considerably in the amount of NO_3-N they accumulate under high-N fertilization. Therefore, crops to be grown on highly-manured land should be carefully selected. For crops that accumulate large amounts of NO_3-N, the amount of manure that can be used may be limited more by the NO_3-N content of the forage than by runoff or percolating water quality.

Soil

Organic-N Content

Organic-N increased in the 0- to 6-inch depth in the manured plots but not below that depth, Figure 10, indicating little or no downward movement of organic-N compounds from the manure. Apparently the N in the manure must be mineralized before there is any significant downward movement.

Nitrate-N Content

At the end of the 3-year study, NO_3-N had increased considerably in the soil profile of plots receiving manure, Figure 10. However, the concentration of NO_3-N was only about 40 p.p.m. in the 0- to 18-inch depth and about 28 p.p.m. in the 18- to 36-inch depth. This increase in NO_3-N in the 36-inch profile would be about 180 pounds N per acre, an amount equivalent to that removed by one millet crop.

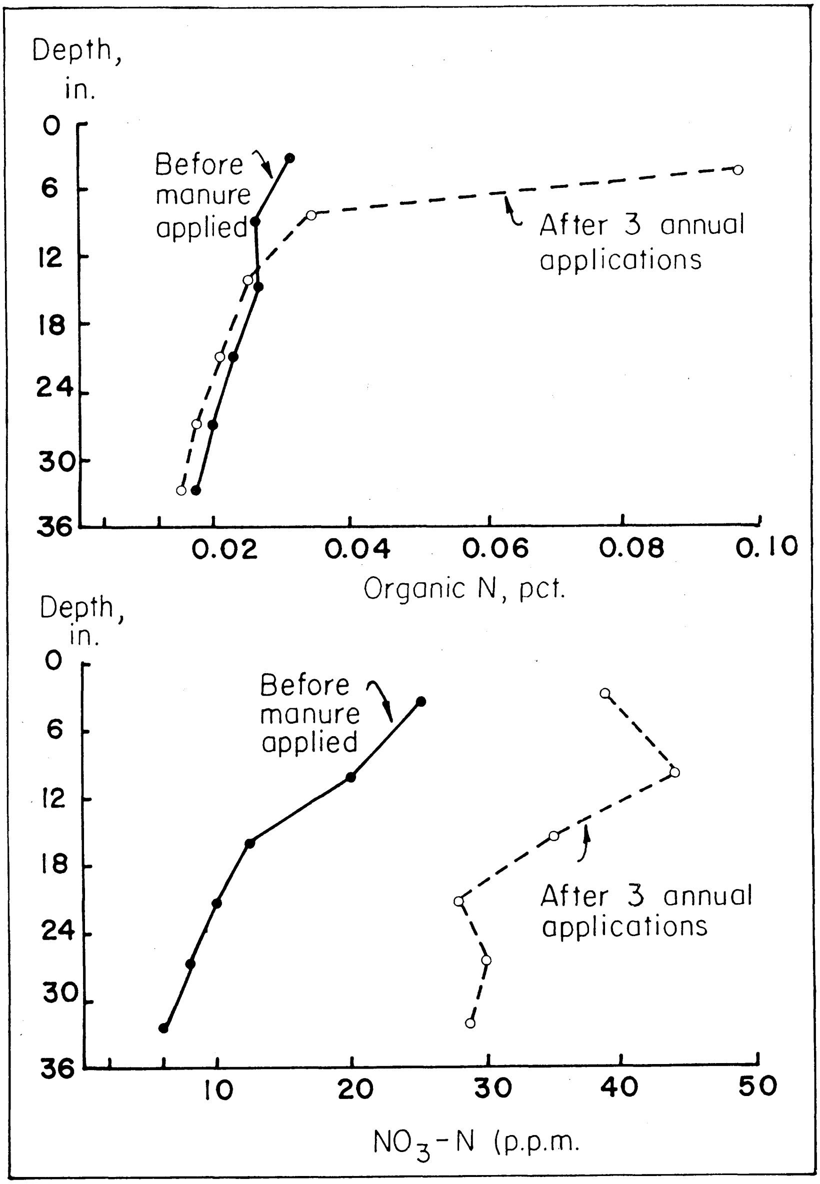

FIG. 10. Nitrate-N and organic-N in soil profile before and after three annual manure applications.

CONCLUSIONS

Objective 1

Rates of dairy cattle manure of 10 and 20 tons per acre incorporated into the surface 6 inches of soil had no detrimental effect on soil properties. Millet and rye forage produced were of good quality. When rates of application exceeded 20 tons per acre, forage was high in NO_3-N and had K:(Ca + Mg) ratios that could be detrimental to animal health. When high rates of manure were used, Dothan soil produced rye forage with higher NO_3-N contents than did Lucedale and Decatur soils, but millet forage produced on Decatur soil had NO_3-N contents as high as on Dothan soil. Manure application rates of 40 tons per acre and above produced tetany-prone forage having K:(Ca + Mg) ratios above the 2.2 critical level, except for rye on Decatur soil. The K:(Ca + Mg) ratios were generally higher for the first harvest when plants were young for both millet and rye than for later harvests. The quality of forage produced is the limiting factor in rate of manure application rather than adverse effects of manure on soil properties or plant growth.

Objective 2

Incorporating dairy cattle manure at the rate of 20 tons per acre into the top 6 inches of Norfolk sandy loam for 3 consecutive years had little effect on the NO_3-N or NH_4-N concentration of runoff water or on soil properties. Total N lost in runoff water was greatest when rainfall and runoff were highest. The maximum was less than 4.5 pounds N per acre for both the check and manured plots, and the average was less than 3 pounds per acre. After the first year there was less runoff water from manured plots than from check plots, which may have resulted from increased water-holding capacity and/or increased infiltration of water into the soil. Nitrate-N increased in the manured soil profile, but the top 36 inches contained only an amount equivalent to that removed by one millet crop. Organic-N increased only to the depth of manure incorporation (0 to 6 inches). At least 20 tons per acre of dairy cattle manure can be incorporated into the surface 6 inches of a Norfolk sandy loam for 3 consecutive years without adversely affecting quality of runoff water or soil.

APPENDIX

APPENDIX TABLE 1. MINERAL COMPOSITION OF MANURE APPLIED TO PLOTS

Year	Percent dry weight					Parts per million	
	N	P	K	Ca	Mg	Mn	Na
Auburn							
1970	1.88	0.52	1.55	0.88	0.59	180	2,057
1971	1.77	.37	.58	.60	.29	107	1,564
1972	2.34	.31	.76	1.23	.36	73	1,770
Thorsby							
1970	1.40	.37	1.51	.46	.18	240	2,047
1971	1.50	.49	.70	1.22	.41	230	1,857
1972	2.10	.76	1.10	2.17	.56	310	2,436
Normal							
1971	2.40	.99	2.30	2.00	.50	------	1,900
1972	2.20	.94	1.60	2.40	.56	------	1,600
1973	2.50	1.12	.80	3.00	.65	------	1,100

APPENDIX TABLE 2. DRY MATTER YIELDS OF RYE AND MILLET FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION ON DOTHAN LOAMY SAND

Tons/ acre manure	Millet yield/acre					Rye yield/acre			
	Harvest no.				Total	Harvest no.			Total
	1	2	3	4		1	2	3	
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1970									
0	1,940	8,040			9,980c[1]	940	1,560	1,190	3,690c
10	2,090	8,140			10,230bc	860	1,120	1,280	3,260c
20	2,610	9,840			12,090b	1,080	1,890	1,630	4,600b
40	2,370	12,950			15,320a	1,930	2,170	2,150	6,250b
80	630	9,700			10,320bc	2,380	2,310	1,850	6,540a
120	110	6,290			6,400d	2,240	1,720	1,340	5,300b
1971									
0	2,600	3,570	2,470	4,590	13,230c	1,040	8,030		9,070a
10	4,530	2,440	2,310	4,660	13,940c	660	6,060		6,720b
20	5,340	3,230	3,320	4,730	16,620b	1,400	7,610		9,010a
40	5,700	4,400	4,110	5,950	20,160a	1,750	7,830		9,580a
80	5,720	4,490	4,530	6,060	20,800a	1,950	8,420		10,370a
120	5,630	4,450	4,760	5,770	20,610a	1,550	8,440		9,990a
1972									
0	2,050	2,490	2,620	5,290	12,450c	1,480	5,720		7,200cd
10	4,250	1,530	1,910	4,580	12,270c	1,420	5,560		6,980d
20	4,580	2,270	3,060	6,050	15,960b	1,920	6,900		8,820ab
40	4,870	3,240	4,330	8,160	20,600a	2,290	7,200		9,490a
80	4,700	3,150	4,710	8,860	21,420a	2,370	6,200		8,570ab
120	3,870	4,010	4,450	8,540	20,870a	2,090	5,810		7,900bc

[1] Values within a column for each year followed by the same letter are not significantly different at the 5 percent level.

APPENDIX TABLE 3. DRY MATTER YIELDS OF RYE AND MILLET FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION ON LUCEDALE FINE SANDY LOAM

Tons/acre manure	Millet yield/acre				Rye yield/acre			
	Harvest no.			Total	Harvest no.			Total
	1	2	3		1	2	3	
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1970								
0	2,140	3,010	1,110	6,260d[1]	350	850	4,560	5,760b
10	3,380	2,290	1,480	7,150cd	160	760	2,420	3,340d
20	4,000	3,680	1,310	8,990b	510	1,280	2,500	4,290c
40	5,530	4,530	830	10,890a	930	1,670	3,320	5,920b
80	2,970	5,850	90	8,910b	1,540	1,650	4,010	7,200a
120	2,680	6,000	90	8,770bc	1,660	1,540	4,550	7,550a
1971								
0	2,840	4,690	4,210	11,740b	1,390	790	2,540	4,720bc
10	2,220	2,070	3,520	8,010d	350	480	1,270	2,100d
20	3,560	2,410	4,060	10,030c	1,460	820	1,740	4,020c
40	4,740	2,750	4,640	12,130b	1,790	1,250	2,330	5,370b
80	4,410	3,280	4,860	12,550b	2,540	1,120	3,480	7,140a
120	4,250	4,310	5,260	13,820a	2,500	1,060	3,850	7,410a
1972								
0	3,160	3,950	7,390	14,500d	600	710	1,600	2,910e
10	3,650	2,730	5,200	11,580e	360	600	1,000	1,960f
20	5,040	3,780	6,450	15,270cd	1,440	1,020	1,370	3,830d
40	5,030	4,010	7,300	16,340bc	1,590	960	2,020	4,570c
80	5,430	4,600	7,680	17,710ab	1,600	380	2,900	4,880b
120	5,170	4,690	8,180	18,050a	1,670	660	3,340	5,670a

[1] Values within a column for each year followed by the same letter are not significantly different at the 5 percent level.

APPENDIX TABLE 4. DRY MATTER YIELDS OF RYE AND MILLET FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION ON DECATUR SILTY CLAY

Tons/acre manure	Millet yield/acre			Rye yield/acre
	Harvest no.		Total	Harvest no. 1
	1	2		
	Lb.	*Lb.*	*Lb.*	*Lb.*
1971				
0	2,640	7,370	10,000b[1]	6,730 NS
10	4,630	7,210	11,840ab	6,440
20	5,270	7,370	12,640a	7,070
40	5,430	7,640	13,070a	5,640
80	5,430	7,100	12,530a	7,070
120	5,380	8,390	13,770a	6,780
1972				
0	5,500	9,850	15,350ab	10,850 NS
10	5,090	8,700	13,790b	10,640
20	6,050	9,170	15,220ab	10,930
40	5,760	10,810	16,570a	9,520
80	6,310	10,330	16,640a	10,270
120	6,450	10,930	17,380a	8,350
1973				
0	1,150	4,710	5,860c	5,590b
10	4,390	3,950	8,340bc	4,790b
20	6,590	4,550	11,140a	6,280b
40	6,970	3,560	10,530ab	8,290a
80	6,930	2,230	9,160ab	9,380a
120	8,160	2,050	10,210ab	9,770a

[1] Values within a column for each year followed by the same letter are not significantly different at the 5 percent level.

APPENDIX TABLE 5. MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON DOTHAN LOAMY SAND, AT DIFFERENT HARVEST DATES

Tons/ acre manure	Content, percent						p.p.m. Mn	K:(Ca + Mg) ratio
	Org.-N	NO_3-N	P	K	Ca	Mg		
8-7-70 (millet)								
0	2.49	0.17	0.36	3.80	0.36	0.28	65	2.36
10	2.36	.32	.47	5.64	.47	.27	49	3.14
20	2.79	.39	.42	6.88	.42	.35	61	3.51
40	2.99	.50	.46	7.10	.46	.24	69	4.23
80	3.93	.58	.40	6.08	.40	.34	92	3.23
120	4.51	.62	.40	5.38	.40	.44	126	2.42
9-10-70 (millet)								
0	.99	.15	.26	2.26	.35	.28	68	1.42
10	1.16	.21	.34	3.20	.31	.25	39	2.26
20	1.38	.36	.37	4.53	.34	.40	57	2.31
40	2.12	.48	.23	4.04	.27	.30	65	2.69
80	2.55	.52	.27	5.97	.21	.27	76	4.64
120	2.80	.56	.27	5.53	.17	.22	69	5.29
11-30-70 (rye)								
0	3.46	.12	.47	2.99	.64	.21	131	1.55
10	3.14	.25	.62	3.93	.54	.25	104	2.11
20	3.21	.42	.66	4.52	.49	.24	85	2.60
40	3.73	.64	.76	5.23	.41	.24	39	3.31
80	4.52	.88	.89	8.22	.38	.29	45	4.88
120	4.89	1.30	.91	8.37	.33	.29	52	5.27
3-4-71 (rye)								
0	1.81	.03	.51	3.30	.47	.17	139	2.24
10	2.21	.01	.58	3.68	.43	.20	68	2.47
20	2.53	.02	.59	3.47	.43	.25	61	2.10
40	3.06	.11	.80	4.54	.60	.33	89	2.02
80	3.59	.24	.80	5.05	.64	.36	73	2.09
120	4.68	.66	.81	5.80	.58	.39	96	2.42
4-12-71 (rye)								
0	2.26	.02	.49	2.78	.50	.17	252	1.82
10	2.44	.02	.51	2.70	.47	.20	81	1.72
20	3.10	.03	.56	3.12	.49	.27	73	1.70
40	4.09	.13	.66	4.01	.59	.32	72	1.83
80	3.53	.46	.77	5.22	.64	.44	61	1.95
120	2.55	.50	.73	5.49	.56	.43	77	2.21
6-17-71 (millet)								
0	2.28	.04	.44	3.71	.43	.23	96	2.34
10	2.20	.04	.48	4.31	.34	.29	41	2.68
20	2.45	.35	.43	5.44	.32	.37	43	2.98
40	2.91	.50	.43	5.97	.32	.37	29	3.27
80	3.29	.73	.43	6.12	.32	.37	17	3.35
120	3.10	.99	.44	7.34	.32	.37	27	4.02
7-15-71 (millet)								
0	1.91	.04	.57	3.19	.23	.23	151	2.66
10	1.91	.02	.82	3.92	.27	.42	53	2.07
20	2.30	.09	.66	4.84	.32	.41	55	2.47
40	2.92	.53	.61	5.64	.32	.56	39	2.31
80	2.94	.77	.56	5.84	.33	.50	25	2.57
120	3.25	.63	.54	5.98	.31	.50	37	2.68

APPENDIX TABLE 5 (*Cont.*). MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON DOTHAN LOAMY SAND, AT DIFFERENT HARVEST DATES

Tons/ acre manure	Content, percent						p.p.m.	K:(Ca + Mg)
	Org.-N	NO_3-N	P	K	Ca	Mg	Mn	ratio
8-12-71 (millet)								
0	2.34	0.03	0.58	3.65	0.34	0.27	122	2.37
10	1.83	.01	.90	3.89	.27	.53	45	1.73
20	2.28	.08	.73	4.21	.35	.60	43	1.60
40	2.51	.18	.61	5.64	.35	.49	31	2.48
80	3.22	.72	.50	5.91	.35	.52	19	2.49
120	3.32	.52	.49	5.56	.31	.56	21	2.29
9-14-71 (millet)								
0	1.94	.17	.35	2.33	.38	.36	258	1.22
10	1.53	.09	.66	2.73	.37	.90	64	.75
20	2.30	.36	.48	2.73	.43	1.00	51	.67
40	2.58	.49	.41	3.56	.43	.71	33	1.13
80	2.67	.68	.38	4.32	.38	.54	21	1.73
120	2.99	.85	.37	4.06	.31	.56	25	1.67
12-16-71 (rye)								
0	4.52	.05	.76	4.77	.56	.29	259	2.34
10	4.50	.05	.76	3.95	.56	.39	81	1.67
20	4.86	.13	.82	4.17	.47	.42	57	1.83
40	5.40	.49	.72	4.92	.46	.42	33	2.18
80	5.35	.71	.71	5.88	.40	.40	27	2.83
120	5.50	.83	.70	6.18	.36	.41	37	3.04
4-19-72 (rye)								
0	.97	.01	.26	1.89	.21	.04	88	3.51
10	.86	.03	.30	1.84	.19	.06	41	3.25
20	.96	.03	.27	1.69	.24	.10	32	2.13
40	1.45	.03	.30	2.44	.29	.13	32	2.47
80	1.80	.13	.30	2.75	.34	.14	17	2.46
120	2.03	.22	.31	3.29	.35	.19	32	2.53
6-14-72 (millet)								
0	2.64	.31	.54	2.65	.51	.29	147	1.37
10	2.16	.07	.59	3.65	.39	.35	35	1.92
20	2.48	.17	.59	4.08	.30	.35	29	2.37
40	2.81	.31	.56	4.53	.28	.37	15	2.59
80	3.22	.52	.51	4.64	.29	.36	14	2.67
120	3.78	.55	.57	5.27	.29	.39	39	2.88
7-7-72 (millet)								
0	2.77	.12	.60	2.99	.46	.39	149	1.38
10	2.47	.04	.84	3.93	.39	.37	30	2.00
20	2.91	.11	.90	4.74	.40	.48	21	2.02
40	3.34	.51	.66	4.69	.34	.44	8	2.24
80	3.61	.69	.57	5.41	.39	.49	7	2.30
120	3.81	.74	.57	5.09	.32	.36	22	2.84
8-1-72 (millet)								
0	2.91	.20	.73	2.84	.49	.42	221	1.22
10	2.17	.03	.90	3.20	.40	.53	36	1.28
20	2.31	.11	.81	3.69	.37	.59	35	1.40
40	2.94	.34	.61	4.03	.40	.60	29	1.48
80	3.46	.60	.56	4.51	.43	.57	21	1.68
120	3.65	.62	.52	4.52	.40	.47	32	1.96

APPENDIX TABLE 5 (*Cont.*). MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON DOTHAN LOAMY SAND, AT DIFFERENT HARVEST DATES

Tons/ acre manure	Content, percent						p.p.m. Mn	K:(Ca + Mg) ratio
	Org.-N	NO_3-N	P	K	Ca	Mg		
9-6-72 (millet)								
0	1.32	0.04	0.52	1.94	0.37	0.36	201	1.03
10	1.05	.02	.64	2.08	.24	.57	33	.90
20	1.27	.02	.69	2.65	.21	.59	32	1.14
40	1.80	.22	.40	2.72	.27	.51	24	1.25
80	2.39	.70	.34	3.62	.34	.59	17	1.40
120	2.60	.70	.32	3.93	.29	.61	27	1.54
11-27-72 (rye)								
0	4.33	.25	.59	3.00	.60	.36	106	1.28
10	3.74	.09	.57	3.24	.53	.29	40	1.64
20	3.94	.31	.61	3.81	.50	.31	37	1.92
40	4.28	1.09	.58	4.06	.50	.34	26	1.95
80	4.48	1.01	.53	3.42	.51	.30	35	1.74
120	4.47	.88	.49	3.38	.45	.29	38	1.86
4-18-73 (rye)								
0	1.25	.02	.30	2.23	.21	.10	49	3.04
10	1.07	.02	.32	1.92	.20	.06	14	3.28
20	1.16	.02	.33	2.41	.22	.10	14	3.20
40	1.54	.09	.37	2.97	.27	.13	13	3.13
80	2.10	.35	.41	3.07	.41	.18	9	2.22
120	2.35	.46	.43	3.55	.43	.22	25	2.29

APPENDIX TABLE 6. MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON LUCEDALE FINE SANDY LOAM, AT DIFFERENT HARVEST DATES

Tons/ acre manure	Content, percent						p.p.m. Mn	K:(Ca + Mg) ratio
	Org.-N	NO_3-N	P	K	Ca	Mg		
7-1-70 (millet)								
0	2.32	0.01	0.14	3.18	0.41	0.25	120	1.97
10	2.09	.02	.14	3.30	.28	.17	106	3.00
20	2.36	.02	.17	3.84	.34	.28	118	2.44
40	2.99	.04	.19	4.72	.33	.25	184	3.24
80	3.53	.05	.25	5.19	.29	.24	181	3.86
120	3.75	.06	.27	5.39	.26	.20	151	4.65
8-4-70 (millet)								
0	1.25	.01	.20	2.42	.31	.30	142	1.53
10	1.38	.01	.28	2.75	.28	.30	155	1.81
20	1.62	.02	.28	3.33	.27	.28	112	2.32
40	1.94	.03	.30	3.71	.27	.26	155	2.70
80	2.30	.04	.27	4.74	.35	.34	201	2.65
120	2.98	.05	.30	5.18	.36	.31	153	3.03
9-2-70 (millet)								
0	1.53	.13	.28	2.11	.31	.29	154	1.36
10	1.51	.30	.34	2.21	.24	.31	132	1.50
20	2.32	.46	.37	3.19	.34	.39	128	1.65
40	3.05	.63	.28	3.86	.43	.36	144	1.92
80	3.49	.90	.29	4.41	.40	.38	123	2.19
120	3.64	1.08	.31	4.21	.46	.38	105	1.97
12-1-70 (rye)								
0	3.86	.10	.36	2.54	.66	.23	210	1.25
10	3.24	.13	.27	2.05	.44	.19	186	1.39
20	3.64	.03	.45	3.10	.63	.29	204	1.43
40	2.38	.06	.48	3.59	.46	.23	182	2.18
80	3.90	.04	.57	5.04	.40	.20	147	3.52
120	3.69	.10	.56	5.06	.38	.19	120	3.73
3-5-71 (rye)								
0	2.32	.01	.38	2.63	.23	.11	149	3.26
10	2.46	.01	.38	2.65	.21	.12	140	3.31
20	2.63	.01	.44	2.89	.25	.15	121	2.96
40	3.00	.02	.55	3.71	.32	.19	133	2.99
80	3.88	.10	.57	3.65	.33	.18	89	2.97
120	4.01	.13	.66	3.93	.37	.20	88	2.86
4-20-71 (rye)								
0	1.62	.05	.25	2.21	.24	.13	132	2.49
10	.99	.02	.22	1.76	.16	.08	115	3.07
20	1.18	.02	.28	2.01	.21	.12	108	2.51
40	1.27	.02	.29	2.08	.20	.11	104	2.78
80	1.63	.03	.34	2.57	.27	.15	93	2.53
120	1.74	.05	.38	2.83	.27	.15	75	2.79
6-24-71 (millet)								
0	2.02	.04	.31	4.91	.34	.19	65	3.84
10	1.80	.01	.11	4.17	.62	.09	358	2.78
20	2.00	.12	.27	4.45	.32	.24	120	3.17
40	2.24	.28	.27	5.65	.27	.19	53	4.95
80	2.49	.24	.49	6.82	.25	.23	57	5.51
120	2.57	.28	.47	7.20	.27	.26	47	5.24

APPENDIX TABLE 6 *(Cont.)*. MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON LUCEDALE FINE SANDY LOAM, AT DIFFERENT HARVEST DATES

Tons/acre manure	Content, percent						p.p.m. Mn	K:(Ca + Mg) ratio
	Org.-N	NO_3-N	P	K	Ca	Mg		
7-26-71 (millet)								
0	1.84	0.07	0.23	2.40	0.27	0.29	231	1.63
10	1.41	.04	.31	3.13	.22	.16	79	3.30
20	1.78	.07	.35	3.12	.25	.17	61	3.00
40	2.41	.18	.34	3.69	.31	.19	85	3.02
80	2.89	.40	.42	4.40	.31	.23	85	3.25
120	2.72	.35	.40	4.49	.29	.21	52	3.60
8-31-71 (millet)								
0	1.74	.17	.23	1.98	.27	.38	213	1.12
10	1.24	.05	.40	2.19	.18	.31	96	1.61
20	1.67	.41	.39	2.04	.27	.35	105	1.22
40	2.07	.34	.34	3.59	.34	.29	85	2.24
80	2.50	.82	.31	4.29	.33	.30	88	2.65
120	2.71	.80	.38	4.32	.33	.41	48	2.19
12-8-71 (rye)								
0	3.66	.02						
10	2.29	.01						
20	2.36	.01						
40	3.70	.03						
80	4.39	.25						
120	4.55	.31						
3-13-72 (rye)								
0	1.90	.01	.36	1.96	.18	.06	174	3.59
10	1.96	.01	.54	2.65	.27	.14	94	2.70
20	2.01	.01	.35	1.90	.19	.07	73	3.18
40	2.20	.01	.46	2.73	.25	.10	83	3.37
80	2.93	.01	.40	1.98	.19	.09	64	2.99
120	3.15	.01	.55	2.69	.27	.13	57	2.84
4-17-72 (rye)								
0	2.15	.14	.30	2.69	.25	.07	205	3.77
10	1.22	.01	.32	1.71	.19	.07	114	2.87
20	1.34	.01	.36	1.73	.24	.09	97	2.27
40	1.48	.02	.37	1.97	.28	.10	81	2.27
80	1.58	.03	.36	2.01	.24	.10	59	2.54
120	1.50	.03	.34	1.97	.21	.08	41	2.94
6-20-72 (millet)								
0	2.08	.06	.34	3.18	.41	.35	101	1.65
10	2.27	.12	.31	3.77	.34	.40	100	1.92
20	2.85	.35	.34	4.03	.40	.53	95	1.61
40	2.81	.43	.35	4.17	.34	.32	100	2.45
80	3.14	.60	.37	4.52	.27	.29	81	3.07
120	2.97	.64	.39	4.90	.26	.33	49	3.10
7-18-72 (millet)								
0	2.26	.08	.33	2.80	.38	.25	108	1.80
10	1.50	.02	.33	2.52	.25	.20	108	2.21
20	2.02	.08	.35	3.13	.29	.26	85	2.22
40	2.36	.23	.42	3.45	.32	.29	101	2.20
80	2.70	.28	.34	3.25	.29	.23	73	2.47
120	3.00	.42	.38	3.89	.28	.29	57	2.61

APPENDIX TABLE 6 (*Cont.*). MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON LUCEDALE FINE SANDY LOAM, AT DIFFERENT HARVEST DATES

Tons/ acre manure	Content, percent						p.p.m. Mn	K:(Ca + Mg) ratio
	Org.-N	NO_3-N	P	K	Ca	Mg		
8-17-72 (millet)								
0	1.60	0.14	0.26	2.28	0.37	0.24	135	1.52
10	1.01	.02	.38	2.25	.21	.41	110	1.29
20	1.30	.06	.40	2.90	.27	.39	81	1.62
40	1.51	.13	.37	3.35	.25	.35	86	2.06
80	2.33	.51	.36	4.51	.32	.45	91	2.16
120	2.50	.55	.30	4.07	.32	.39	64	2.15
11-29-72 (millet)								
0	3.70	.04	.47	2.34	.54	.20	153	1.37
10	3.20	.05	.37	2.41	.40	.17	114	1.81
20	3.54	.14	.43	2.52	.44	.19	81	1.71
40	4.29	.35	.52	3.77	.43	.19	64	2.59
80	4.27	.51	.53	4.01	.38	.19	61	2.95
120	4.43	.51	.50	3.73	.38	.19	57	2.75
3-12-73 (rye)								
0	2.29	.02	.43	3.33	.26	.10	101	4.01
10	2.53	.02	.46	3.07	.21	.13	78	3.70
20	2.80	.04	.48	3.48	.25	.14	61	3.69
40	3.46	.13	.56	4.36	.33	.16	57	3.75
80	4.83	.38	.57	5.31	.41	.19	49	3.75
120	4.69	.42	.64	5.71	.40	.20	51	3.99
4-23-73 (rye)								
0	2.23	.12	.35	2.76	.43	.13	110	2.19
10	1.59	.03	.35	2.51	.27	.12	86	2.74
20	1.87	.07	.37	2.54	.33	.14	45	2.31
40	1.78	.09	.38	2.44	.36	.14	53	2.11
80	1.88	.07	.42	3.23	.31	.13	48	3.15
120	1.95	.14	.40	3.03	.34	.16	41	2.56

APPENDIX TABLE 7. MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON DECATUR SILTY CLAY LOAM, AT DIFFERENT HARVEST DATES

Tons/ acre manure	Content, percent						p.p.m. Mn	K:(Ca + Mg) ratio
	Org.-N	NO_3-N	P	K	Ca	Mg		
7-28-71 (millet)								
0	1.54	0.19	0.32	2.61	0.36	0.27	80	1.65
10	1.74	.30	.38	3.29	.43	.30	71	1.81
20	2.13	.50	.37	3.89	.57	.35	81	1.73
40	1.85	.50	.37	3.31	.43	.27	65	1.93
80	2.16	.50	.44	4.41	.47	.30	67	2.33
120	2.27	.58	.35	3.83	.59	.34	77	1.70
9-10-71 (millet)								
0	2.91	.40	.24	4.95	.51	.29	69	2.55
10	2.84	.60	.37	5.64	.51	.36	63	2.61
20	2.82	.64	.38	5.65	.51	.35	68	2.65
40	2.84	.67	.41	5.72	.46	.31	62	3.01
80	2.84	.84	.41	6.33	.46	.35	67	3.11
120	3.07	.87	.44	7.14	.45	.31	72	3.79
5-5-72 (rye)								
0	1.29	.06	.26	1.39	.32	.04	47	1.85
10	1.66	.11	.30	1.67	.44	.10	45	1.41
20	1.62	.10	.28	1.60	.43	.08	62	1.45
40	1.59	.08	.31	1.61	.41	.10	68	1.43
80	1.49	.07	.27	1.48	.38	.07	55	1.53
120	1.41	.08	.26	1.41	.39	.06	59	1.48
7-25-72 (millet)								
0	2.08	.15	.26	2.61	.50	.30	159	1.34
10	1.79	.11	.24	3.24	.45	.19	81	2.17
20	1.85	.12	.30	3.68	.40	.21	81	2.52
40	2.16	.26	.30	3.38	.46	.22	77	2.10
80	2.63	.76	.35	4.18	.38	.25	55	2.69
120	2.95	.78	.37	4.32	.46	.23	61	2.62
10-14-72 (millet)								
0	1.39	.09	.32	1.88	.45	.19	187	1.26
10	1.33	.06	.48	2.19	.44	.18	73	1.52
20	1.50	.10	.51	2.21	.47	.19	74	1.44
40	1.53	.17	.48	2.45	.52	.19	84	1.50
80	2.00	.48	.41	2.61	.50	.21	77	1.57
120	2.57	.69	.40	3.29	.52	.24	78	1.83
5-5-73 (rye)								
0	.92	.03	.26	1.73	.32	.04	103	2.30
10	1.23	.04	.26	1.78	.23	.04	67	3.08
20	.83	.02	.30	1.91	.29	.05	61	2.62
40	1.03	.05	.27	2.00	.29	.06	53	2.63
80	.80	.05	.29	2.15	.31	.06	49	2.69
120	.94	.08	.29	2.33	.34	.07	77	2.62
8-20-73 (millet)								
0	1.41	.06	.34	4.51	.34	.10	89	4.57
10	1.37	.06	.40	5.29	.28	.15	49	5.12
20	1.40	.09	.42	5.77	.31	.18	53	4.85
40	1.30	.09	.35	6.41	.27	.17	45	5.93
80	1.17	.71	.36	7.91	.35	.20	51	5.93
120	1.26	.80	.35	8.10	.32	.20	48	6.35

APPENDIX TABLE 7 *(Cont.)*. MINERAL COMPOSITION OF FORAGE AS AFFECTED BY RATE OF MANURE APPLICATION AND EQUIVALENT RATIO OF K:(CA + MG) ON DECATUR SILTY CLAY LOAM, AT DIFFERENT HARVEST DATES

Tons/ acre manure	Content, percent						p.p.m. Mn	K:(Ca + Mg) ratio
	Org.-N	NO_3-N	P	K	Ca	Mg		
10-25-73 (millet)								
0	1.54	0.08	0.25	2.29	0.37	0.20	237	1.67
10	1.64	.12	.27	3.19	.38	.13	99	2.74
20	1.61	.20	.34	4.16	.45	.27	128	2.37
40	1.53	.31	.30	5.43	.47	.25	106	3.14
80	1.69	.67	.30	5.76	.47	.26	110	3.27
120	1.56	.77	.32	7.37	.49	.30	88	3.82
5-30-74 (rye)								
0	.82	.01	.26	1.56	.32	.04	91	2.07
10	.94	.02	.25	1.73	.34	.07	48	1.95
20	.95	.02	.29	1.76	.36	.07	42	1.90
40	1.01	.02	.29	1.81	.35	.08	38	1.92
80	1.29	.02	.28	1.82	.35	.07	38	2.00
120	1.28	.11	.28	1.87	.37	.07	37	1.97

APPENDIX TABLE 8. CHEMICAL PROPERTIES OF DOTHAN LOAMY SAND SOIL AT SIX SOIL DEPTHS, AFTER THREE ANNUAL APPLICATIONS OF DAIRY MANURE

Soil depth, inches	pH	Organic matter	Organic-N	NO_3-N	K	Ca	Mg
		Pct.	*Pct.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
No manure							
0-6	5.9	0.705	0.040	209	41	400	93
6-12	5.4	.602	.032	210	19	247	39
12-18	5.7	.160	.015	178	17	212	15
18-24	5.9	.125	.012	178	15	207	13
24-30	5.9	.116	.014	164	18	255	23
30-36	5.6	.098	.016	149	20	250	60
10 tons manure							
0-6	5.9	.696	.070	189	31	436	70
6-12	6.0	.589	.047	173	27	373	69
12-18	6.2	.214	.018	164	24	197	35
18-24	6.3	.125	.017	160	31	205	40
24-30	6.2	.062	.016	138	35	305	46
30-36	5.9	.083	.017	124	41	315	77
20 tons manure							
0-6	5.9	1.285	.115	170	34	692	142
6-12	6.4	.553	.039	203	29	348	78
12-18	6.5	.250	.016	187	40	190	63
18-24	6.5	.178	.016	181	54	193	56
24-30	6.5	.152	.015	152	68	234	68
30-36	6.3	.134	.014	129	61	290	77
40 tons manure							
0-6	6.0	1.812	.162	167	47	1,048	173
6-12	6.3	.821	.064	156	44	649	159
12-18	6.6	.312	.020	155	57	246	99
18-24	6.8	.170	.014	146	73	158	67
24-30	6.7	.143	.017	161	162	158	91
30-36	6.6	.134	.016	124	258	148	72
80 tons manure							
0-6	5.8	2.312	.303	273	140	1,836	371
6-12	6.3	1.094	.147	200	90	1,302	260
12-18	6.7	.487	.033	182	75	529	117
18-24	7.0	.232	.016	169	108	217	97
24-30	7.2	.160	.019	152	287	208	142
30-36	7.3	.071	.016	146	422	183	134
120 tons manure							
0-6	5.8	3.543	.426	417	266	2,523	552
6-12	6.2	2.178	.227	266	216	1,745	402
12-18	6.7	.553	.037	217	118	511	123
18-24	6.9	.357	.016	180	136	232	95
24-30	6.6	.321	.019	164	246	156	137
30-36	7.1	.401	.021	143	416	154	126

APPENDIX TABLE 9. CHEMICAL PROPERTIES OF LUCEDALE FINE SANDY LOAM SOIL AT SIX SOIL DEPTHS, AFTER THREE ANNUAL APPLICATIONS OF DAIRY MANURE

Soil depth, inches	pH	Organic matter	Organic-N	NO_3-N
		Pct.	*Pct.*	*p.p.m.*
No manure				
0-6	5.4	0.724	0.058	180
6-12	5.2	.414	.036	108
12-18	5.1	.310	.022	89
18-24	5.0	.248	.022	88
24-30	4.9	.192	.019	56
30-36	4.7	.140	.016	57
10 tons manure				
0-6	5.6	.896	.076	140
6-12	5.4	.350	.035	93
12-18	5.2	.218	.023	74
18-24	5.2	.218	.022	66
24-30	5.1	.125	.019	64
30-36	5.0	.152	.018	58
20 tons manure				
0-6	5.9	1.108	.104	180
6-12	5.8	.364	.039	128
12-18	5.6	.228	.029	76
18-24	5.3	.192	.022	60
24-30	5.1	.130	.019	52
30-36	5.0	.136	.019	49
40 tons manure				
0-6	6.2	1.526	.157	270
6-12	5.7	.382	.042	122
12-18	5.4	.248	.028	82
18-24	5.1	.176	.024	76
24-30	5.0	.156	.020	73
30-36	5.0	.170	.020	64
80 tons manure				
0-6	6.6	2.386	.259	528
6-12	6.4	.694	.070	242
12-18	5.2	.321	.040	156
18-24	4.9	.202	.027	88
24-30	4.9	.212	.026	80
30-36	5.0	.145	.022	66
120 tons manure				
0-6	6.4	3.276	.342	706
6-12	6.7	1.014	.101	248
12-18	5.9	.342	.038	150
18-24	5.2	.284	.031	88
24-30	4.9	.233	.026	60
30-36	4.8	.218	.024	60

Appendix Table 10. Chemical Properties of Decatur Silty Clay Loam Soil at Six Soil Depths, After Three Annual Applications of Dairy Manure

Soil depth, inches	pH	Organic matter	Organic-N	NO_3-N	P	K	Ca	Mg	Na
		Pct.	*Pct.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
No manure									
0-6	5.6	2.4	0.14	21	20.6	169	798	52	19
6-12	5.7	1.9	.12	21	19.2	90	999	58	21
12-18	6.5	1.6	.10	21	8.2	83	1,192	66	21
18-24	6.1	1.6	.12	12	9.7	72	1,045	49	20
24-30	6.7	1.6	.10	8	4.5	62	1,405	64	23
30-36	6.7	1.5	.09	14	11.6	57	1,181	58	21
10 tons manure									
0-6	6.3	3.0	.20	29	15.8	428	1,377	174	97
6-12	6.3	2.0	.14	16	10.7	287	1,293	120	70
12-18	6.6	1.7	.11	27	4.5	80	1,080	62	32
18-24	6.5	1.5	.15	10	6.3	59	1,199	51	28
24-30	6.7	1.7	.10	8	5.9	93	1,399	67	35
30-36	6.8	1.6	.09	14	7.0	72	1,206	57	28
20 tons manure									
0-6	6.4	3.5	.33	44	19.7	760	1,341	210	110
6-12	6.4	2.2	.23	29	16.6	182	1,181	146	79
12-18	6.6	1.8	.20	27	14.9	73	1,417	81	55
18-24	6.7	1.5	.17	18	12.4	73	1,433	70	36
24-30	6.8	1.5	.11	18	9.3	56	1,414	60	40
30-36	6.8	1.4	.10	12	7.8	57	1,117	67	36
40 tons manure									
0-6	6.7	4.4	.28	59	22.9	970	1,872	296	92
6-12	6.5	2.0	.16	23	12.4	233	1,447	155	73
12-18	6.4	1.7	.15	23	7.8	112	1,313	112	59
18-24	6.5	1.6	.14	21	7.8	73	1,296	64	46
24-30	6.6	1.8	.12	14	8.5	63	1,570	83	40
30-36	6.6	1.8	.11	14	4.5	63	1,216	130	25
80 tons manure									
0-6	6.8	6.8	.47	64	36.4	2,009	3,056	758	241
6-12	6.7	2.4	.21	29	15.8	899	2,377	366	134
12-18	6.6	1.8	.15	27	11.2	247	1,502	169	74
18-24	6.6	1.6	.15	16	7.4	174	1,352	168	61
24-30	6.6	2.0	.14	12	9.3	186	1,487	159	54
30-36	6.7	1.7	.12	10	7.0	192	1,588	133	49
120 tons manure									
0-6	6.9	10.4	.67	116	61.3	3,024	3,458	855	380
6-12	6.7	2.4	.24	54	30.7	1,543	2,016	423	243
12-18	6.6	2.2	.20	39	17.0	1,137	1,529	329	127
18-24	6.6	2.0	.13	34	7.0	533	1,458	90	83
24-30	6.6	2.1	.11	21	7.8	147	1,433	90	55
30-36	6.7	2.0	.09	29	6.3	156	1,406	187	64

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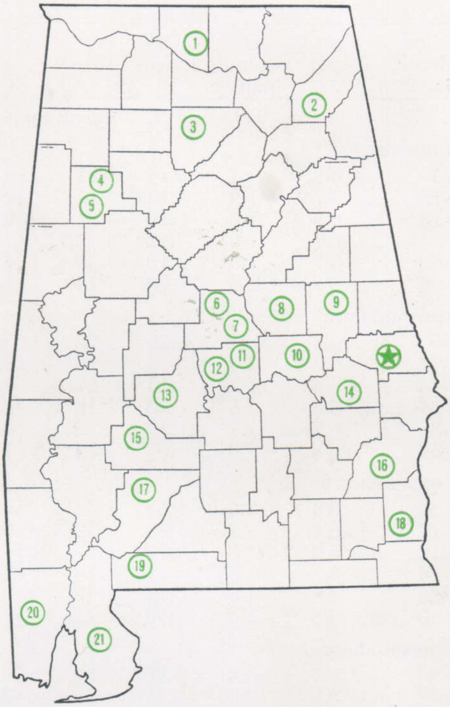

Research Unit Identification

Main Agricultural Experiment Station, Auburn.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Tuskegee Experiment Field, Tuskegee.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Ornamental Horticulture Field Station, Spring Hill.
21. Gulf Coast Substation, Fairhope.