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Project Summary

Animal Waste Effects Upon Crop Production, Soil and Runoff Waters

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This investigation was initiated to study the effects of application of differing rates of manure to the land on crops, soil, and runoff water. The study was conducted under field conditions in the sub-humid climate of the Northern Great Plains. Manure application rates included levels from 0 to 180 MT/ha/yr. Manure applied to field plots was incorporated using a chisel plow as soon after application as possible. The test crop grown on the manure treatment plots was corn. One-half of the field plots were instrumented to automatically collect samples of any runoff waters leaving the plots.

Soil salinity levels increased due to high rates of application so that the entire profile was saline. Corn yields were variable and low due to drought stress and saline conditions. Runoff occurred only twice during the course of the study. Chemical analysis of runoff waters indicated almost no differences due to plot treatments. Natural precipitation occurring after the cessation of manure treatments leached the surface soil to a non-saline condition during the first year. Although crop production was generally poor on the waste treatment plots, runoff waters from the plots did not reflect the waste treatments.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A result of making agriculture more cost effective has been and continues to be a shift from the small diversified operation towards larger, more specialized agricultural enterprises. When livestock is raised for human consumption and concentrated in a small area, large quantities of animal wastes accumulate, creating a major disposal problem.

A seemingly large number of alternatives are available to the producer for waste disposal. These alternatives run the gamut from land application through refeeding and methane production to incineration; however, nearly all disposal methods leave by-products which require further disposal. The prohibitive costs of many of these methods combined with legislation prohibiting the dumping of wastes into waterways ultimately result in application of most animal wastes to the soil.

The area of land available to the operator for disposal, and the distance wastes must be hauled to the disposal site are factors which in practice influence application rates. Hauling distances influence application costs and as a result make it attractive to dispose of wastes close to the production site.

The operator with little available land and large amounts of wastes to be removed from the production facility may view the land solely as a disposal site with little regard for future productivity. Major concerns with that type of operation are adequate incorporation of the wastes to minimize runoff and odor problems and prevention of leaching of toxic substances to ground water.

The operator with sufficient land to serve as a disposal site and a clear commitment to maintaining the productivity of his land may view animal wastes as a resource capable of reducing his fertilizer costs. This operator must concern himself with factors that reduce the value of crops grown on his land, factors that limit its productivity, or with pollutants that affect the soil or waters. Nitrates and potassium may accumulate in plants to levels toxic to animals. Salts present in the waste may cause the soil solution to exhibit a high osmotic potential and limit water availability to plants. Adsorption of monovalent cations on soil clays may cause degradation of soil structure and limit movement of water into and through the soil.

An experiment was conducted at the Southeast South Dakota Experiment Farm to establish relationships between animal wastes applied to the soil and their effect on the soil and plants grown on it. Feeder steers were fed a common ration differing only in the amount of salt, sodium chloride (NaCl), added to the feed. The levels of added NaCl used during the feeding period were 0.00, 0.25, 0.50 and 0.75 percent of the ration on a dry weight basis.

The manure from these steers was collected and segregated into two salt levels: manure collected from animals fed 0.00 and 0.25 percent added NaCl, hereafter referred to as "low," and manure collected from animals fed 0.50 and 0.75 percent added NaCl, hereafter referred to as "high."

Manure was applied as soon after collection as practical to field plots with dimensions of 36.6 by 6.1 m established on Egan silty clay loam at the Southeast South Dakota Experiment Farm. The field design was a randomized complete block including treatments of 0, 45, 90, 135 and 180 MT/ha/yr (check, 20, 40, 60, and 80 T/ac/yr) dry waste at both low and high salt levels. Manure applications were made during the period from harvest until spring tillage for 1973 until the 1975 growing season with no applications thereafter. At the time of application, each load was weighed and a sample taken for water content and chemical analysis.

The objectives of this investigation were: (1) to determine if, under dryland conditions, the salts present in manure applied to the land would accumulate in the root zone to levels high enough to seriously limit crop production; (2) to determine if the ratio of monovalent to divalent cations present in the manure would upset the balance of these cations in the soil and cause soil structure problems; (3) to determine if the salts and organic matter added by the manure would affect the ability of the soil to transmit water; and (4) to determine the effect of applied wastes upon the quantity and quality of runoff waters.

In a previous study conducted by Horton, Wiersma, and Halbeisen,[1] the effect of salt level and roughage content of a ration for beef steers upon animal performance and manure characteristics was investigated. The present study extended the earlier work to include effects upon the land and upon runoff waters leaving the treated land. Information from the two studies will be useful in determining the value of manure for crop production during periods of limited rainfall. The soil salinity and runoff water quality data will be useful in developing best management practices under Section 208 P.L. 92-500.

Conclusions

1. Soils developed under sub-humid conditions such as the Northern Great Plains frequently contain considerable quantities of salt within their profiles. When only the surface is naturally leached free of salts, addition of large quantities of manure can salinize the entire soil profile and affect crop production.

2. Although exchangeable sodium level in the soils studied increased due to manure application, they remained below the level at which dispersion of the soil structure would be expected to occur.

3. Water infiltration rates were reduced during the year following high rates of applied manure; however, the infiltration rates recovered to nearly the level of the untreated soil within one year following cessation of waste application.

4. Runoff waters were not significantly affected by waste rates two years following application. Precipitation was insufficient to produce runoff earlier.

Recommendations

Waste from cattle feedlots can be a source of nutrients and organic matter for growing crops or a source of chemicals which pollute waters and salinize soils in the environment.

The following recommendations assume that the land upon which wastes are being applied is to be used for crop production:

1. Development of the best management practices for applying wastes to the land should account for soil properties, chemical composition of the wastes, availability of leaching waters and the crop to be grown.

2. Incorporation of manure applied to the land reduces the opportunity for pollution of surface waters and utilizes the large buffering capacity of the soil to reduce chemical effects.

3. Availability of rainfall or irrigation water will influence crop response to added nutrients and will influence leaching of salts from the soil. Drought conditions reduce the fertilizer value of manure for crop production and increase salinity build-up within the soil.

4. Since the major annual runoff from cropland in the Northern Great Plains occurs at the time of melting of the winter snowpack, management of manure applied to the land so as to minimize the concentration during snowmelt should qualify as a best management practice.

5. Annual applications of manure in excess of 45 MT/ha should be avoided where the soil contains excess salts within 60 cm of the surface and where less than 20

[1] Horton, M L., J. L. Wiersma, and J. L. Halbeisen 1976 Animal Waste Management in the Northern Great Plains. EPA-600/2-76-188. U.S Environmental Protection Agency. Ada, OK. 84 pps

inches of water is applied to the land as rainfall or irrigation.

Results

Actual amounts of manure applied to field treatments prior to the 1974 and 1975 growing seasons are given in Table 1. No additional manure was applied to any treatments following the 1975 season.

The results of the analysis of the waste for major cations appear in Table 2. While not literally correct, total cation concentration is taken to be the sum of the four major cations. In Table 2, it is shown that Na is the only salt constituent in the manure which varies to an appreciable extent with the NaCl level of the ration. Consequently, the amount of Na and total salts applied to field plots varied according to the amount of NaCl added to the ration.

Total precipitation for 1975 and 1977 was normal. Total precipitation for 1974 was 59 percent of normal and for 1976 was 50 percent of normal. Average or below average rainfall was recorded during June and July for all years of the study. The growing season of 1976 was one of the worst droughts on record for the region.

A summary of the electro-conductivity (EC) of the upper 30 cm of plot soils is shown in Table 3 for all years of the study. Detailed EC information including individual replicated plot values and accompanying statistical treatment for all plots to a depth of 150 cm is presented in the Appendices.

Accepting the U.S. Department of Agriculture's EC value of 4.0 mmhos/cm as the value separating non-saline from saline soils, it is apparent from the data presented in Table 3 that, given the limited rainfall during the study, two consecutive applications of manure exceeding 45 MT/ha/yr will supply sufficient salts to salinize the upper 30 cm of the soil profile. The data also indicate that, with the below normal rainfall, within two years after the end of treatment, the upper 30 cm of all plots was leached sufficiently to be classed in the non-saline category.

In addition to salinity of the surface soil, attention must be given to the salinity condition of the entire root zone as summarized in Table. 4. Prior to onset of this investigation, the EC of all plots at a depth of 90 cm exceeded 4.0 mmhos/cm. The results show completely saline root zones after two yearly applications of manure at a rate of 90 MT/ha/yr or greater.

Runoff Waters

Due to below average rainfall, runoff waters occurred from the plots on only two occasions—June 22, 1977 and March 20, 1978. The automatic sampling equipment collected runoff waters from only four treatments—90-L, 90-H, 180-L and 180-H—in 1977. Runoff waters were collected manually from all plots in 1978.

Complete results of the chemical analyses of runoff waters are given in the Appendices. The results were quite variable with few significant differences

Table 1. *Manure Application Rates Prior to 1974 and 1975 Growing Seasons*

Treatment	1974 MT/ha*	1975 MT/ha*	Two Year Total MT/ha*
Check	0.0	0.0	0.0
45-L**	38.5	48.6	87.1
45-H†	26.9	50.8	77.7
90-L	101.5	92.5	194.0
90-H	85.3	92.3	177.7
135-L	135.2	138.0	273.2
135-H	119.7	139.6	259.3
180-L	169.6	181.8	351.3
180-H	172.7	182.9	355.6

*On a dry weight basis.
**L = Low.
†H = High.

Table 2. *Average Composition of Manure Applied to Field Plots Prior to the 1975 Growing Season*

	Low salt (%)*	High salt (%)*
Na	0.37	0.75
K	3.19	3.16
Ca	1.05	1.05
Mg	0.88	0.89
Total cations	5.49	5.85

* On a dry weight basis.

Table 3. *Average Electrical Conductivity of the Saturation Extracts for the Surface 30 cm of Plot Soils*

Treatment (MT/ha)	Fall 1973 (mmhos/cm)	Fall 1974 (mmhos/cm)	Fall 1975 (mmhos/cm)	Fall 1976 (mmhos/cm)	Fall 1977 (mmhos/cm)
Check	0.70	1.12	1.30	1.67	1.15
45-L*	0.68	2.42	4.52	3.04	1.28
45-H†	0.46	1.93	3.73	3.46	2.04
90-L	0.72	4.87	5.39	6.36	1.84
90-H	0.71	3.96	5.96	4.92	2.11
135-L	0.68	5.89	7.80	6.19	2.87
135-H	0.74	5.46	7.14	5.79	2.25
180-L	0.92	4.90	7.23	5.84	3.29
180-H	0.83	6.02	8.84	6.06	3.08
Mean	0.72	4.06	5.77	4.81	2.21

*L = Low.
†H = High.

Table 4. *Electrical Conductivity of the Subsurface Soil Following Treatment*

Year and Treatment	*30-60 cm (mmhos/cm)*		*60-90 cm (mmhos/cm)*		*90-150 cm (mmhos/cm)*	
	1974	*1975*	*1974*	*1975*	*1974*	*1975*
Check	*2.45*	*3.05*	*4.01*	*4.28*	*5.51*	----
*45-L**	*1.28*	*2.39*	*3.65*	*3.57*	*5.68*	----
45-H†	*0.64*	*2.10*	*4.47*	*2.37*	*5.92*	----
90-L	*1.58*	*4.07*	*4.89*	*4.38*	*6.15*	----
90-H	*1.41*	*4.09*	*4.08*	*4.29*	*5.36*	----
135-L	*1.51*	*4.67*	*4.95*	*5.55*	*5.85*	----
135-H	*1.71*	*4.94*	*4.20*	*3.73*	*5.72*	----
180-L	*2.29*	*4.96*	*4.95*	*5.34*	*6.31*	----
180-H	*1.90*	*5.05*	*4.57*	*4.83*	*5.78*	----

**L = Low.*
†H = High.

between the check and treatment plots except for chloride ions. Incorporation of the manure into the soil apparently protected runoff waters from contamination due to waste treatments.

Plant Performance

Plant population data is presented in Table 5. Populations were significantly different at 99 percent level for treatments and years. Manure application rates in excess of 45 MT/ha/yr resulted in reduced populations when compared with the check.

Plant height data was collected during 1975 and 1976. Statistical analysis of these data showed significant differences in plant height among waste rates at the 99 percent level for all sampling dates except July 21, 1976. Plant heights on plots receiving wastes at rates of 135 MT/ha/yr or more were significantly different from check height at the 99 percent level on June 27, 1975. The height of plants on plots manured at rates of 90 MT/ha/yr or more were significantly different from check heights at the 99 percent level on July 7, 1975, June 10, 1976, and June 22, 1976.

One of the reasons for collecting the plant height data was to test the idea that satisfactory plant growth could be attained on saline soils if a portion of the root zone was maintained in a non-saline condition. A corollary being that, despite early growth depression, if plant roots were able to penetrate to a non-saline portion of the soil profile, the plants could recover and attain yields equal to plants grown on non-saline soil. Conversely, if the soil were non-saline and roots penetrated into a saline portion of the profile, the growth of plants would fall behind that of plants

Table 5. *Average Plant Populations*

Treatment	*1974 (plants/ha)*	*1975 (plants/ha)*	*1976 (plants/ha)*	*1977 (plants/ha)*
Check	*49,511*	*34,351*	*40,364*	*33,463*
*45-L**	*48,435*	*34,890*	*39,018*	*33,463*
45-H†	*48,436*	*34,620*	*40,274*	*32,150*
90-L	*40,902*	*31,660*	*37,135*	*31,494*
90-H	*45,206*	*28,791*	*38,301*	*34,119*
135-L	*39,826*	*28,611*	*35,969*	*31,494*
135-H	*38,210*	*28,702*	*38,032*	*32,807*
180-L	*36,596*	*29,866*	*37,942*	*34,119*
180-H	*30,676*	*28,818*	*36,058*	*32,807*
Mean	*41,977*	*30,756*	*38,151*	*32,879*

**L = Low.*
†H = High.

grown on entirely non-saline soil. Collection of good data and straightforward interpretation of the data were hampered by below normal rainfall which caused early drought stress and provided conditions favorable for smut disease in 1975. Corn borer damage affected crop growth and yield in 1976.

The greatest infestation of European corn borer occurred in plots with a history of low or no applications of manure. There was a significant difference in total number of burrows among waste rates at the 95 percent level. Visual observations indicated that corn smut and weed density followed the pattern set by the corn borer data. The problems were of greater magnitude on plots with low accumulated applications. Two possible reasons for these observations come to mind: (1) that the causative organisms were salt sensitive or unable to obtain sufficient moisture to remain vigorous, and (2) the chemicals used to control insects, weeds, and disease were moisture activated. Better chemical control would be expected on high application plots if the causative organisms were salt sensitive due to the higher osmotic potential of water in these plots and also if moisture activation of the chemicals was required for control since those plots had a greater gravimetric moisture content when they were sampled at the time the infiltration tests were performed.

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The complete report, entitled ***"Animal Waste Effects Upon Crop Production, Soil and Runoff Waters,"*** *(Order No. PB 82-113 887; Cost: $9.50, subject to change) will be available only from:*

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