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ANIMAL WASTE MANAGEMENT IN THE NORTHERN GREAT PLAINS

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ANIMAL WASTE MANAGEMENT
IN THE
NORTHERN GREAT PLAINS

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ABSTRACT

The effect of salt level of the ration for beef steers upon salinity of the waste and the effects of the applied waste upon the soil and upon crop production was investigated. In addition, the study was conducted in both covered and open feedlot pens to study the effect of shelter in a northern climate upon animal performance and waste characteristics.

The field portion of the study included four rates of waste up to 179 MT/ha. applied to plots 0.02 ha. in size. Detailed soil analyses were made which included salinity, nutrients, cations, and the dispersion hazard as indicated by the level of exchangeable sodium.

The levels of salt used in the ration appeared to have little or no effect on animal performance; however, the salinity and sodium levels of the waste were directly affected. The salinity level of the surface 30 cm of soil where high rates of waste were applied was sufficiently high to affect the growth of corn. The lack of leaching water caused a maximum effect of the applied waste in the surface layer.

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SECTION I

CONCLUSIONS

1. The amount of sodium (Na) in waste from steers fed a common ration, except for the amount of salt (NaCl) added to the ration, varied directly with the level of added salt. Steers receiving no added NaCl produced waste with a Na content of 0.3% to 0.5%, while steers receiving a ration with 0.75% added NaCl produced wastes containing 1.2% to 1.6% Na on a dry weight basis.

2. The amount of wastes produced by beef steers will vary from feedlot to feedlot depending upon the composition of the ration, feed intake, weather, and management variables. During one feeding cycle, steers on a high roughage (corn silage) ration produced an average of 2.65 kg of dry waste per head per day. The same steers on a high concentrate (corn grain) ration produced only 1.79 kg of waste per head per day. These values are less than was expected for comparable size steers.

3. Steers fed a ration containing no added salt (NaCl) up to a level of 0.75% of the ration on a dry weight basis showed little or no difference in rate of gain or feed efficiency.

4. During two separate feeding periods, beef steers in open pens gave slightly higher daily rates of gain (0.08 kg/day) than similar steers housed in covered pens. During periods of extreme cold and inclement weather, rates of gain and feed efficiencies of cattle in both open and covered pens were drastically reduced. The chemical and physical properties of waste was comparable for open and covered pens except for the water content which varied with weather conditions.

5. Many of the soils of the Northern Great Plains contain large quantities of salts and high levels of salinity within the profile. Where the depth of leaching is shallow (30 to 60 cm), addition of large quantities of animal waste that contain appreciable quantities of salt will further limit the productivity of these soils. During 1974, salts in waste applied to field plots remained in the 0- to 30-cm layer and increased the salinity level, as

indicated by electrical conductivity (EC), to values in excess of 5,000 μmhos/cm. These values exceed the salt tolerance levels for proper germination and growth of many common agronomic plants.

6. Chemical analyses of corn leaf samples taken from waste disposal plots showed an increase in total N and a decrease in Mg with increased rates of applied waste.

7. Precipitation amounts and patterns were such that no runoff occurred from the field plots during the course of the study.

SECTION II

RECOMMENDATIONS

The combination of soils and climate found in the Northern Great Plains presents a number of problems in animal waste management. The high natural levels of salinity combined with small quantities of leaching water may well establish a limit on applied waste based on the increase in salinity which can be tolerated.

Recognizing that one year of data on soil effects and crop response due to applied waste is a limited data base from which to make recommendations, the following suggestions are offered:

1. The addition of salt (NaCl) to the ration for beef steers should be kept at a minimum in order to reduce the soil dispersion and salinity hazard due to the applied waste. The addition of 0.25% NaCl to the ration on a dry weight basis appears adequate under most circumstances.

2. Housing for cattle in feedlots in the Northern Great Plains may be of questionable value in improving performance except for the purpose of keeping the cattle dry.

3. The salinity and dispersion hazard of animal waste applied to high clay soils receiving a minimum of leaching water should be continually monitored to prevent damage to crop production land.

   It is recommended that additional detailed investigation of the salinity buildup, soil dispersion, crop production, and runoff characteristics under several rates of applied waste be continued.

SECTION III

INTRODUCTION

PURPOSE OF THE PROJECT

The climate and soils of the Northern Great Plains present some unique problems to the livestock feeder who uses the land for waste disposal. The importance of housing to protect the animals from the cold or to improve animal performance and disposal of the wastes are areas of concern. The nature of the soils -- large amounts of clay and large quantities of salts -- together with a variable but low quantity of leaching water raises questions regarding waste application rates which can be tolerated on crop production land. Concentration of waste components at or near the soil surface increases the pollution potential due to surface runoff or erosion.

The climate, soils, and feedlots of South Dakota exhibit a good cross section of the waste management problems of the Northern Great Plains. In an attempt to develop solutions to the waste management problems, a project was initiated at the Cornbelt Research and Extension Center near Beresford, South Dakota.

The purpose of the project was to develop guidelines relating climate, waste, soils, and crops to assist livestock feeders in cold regions in developing waste management techniques that are environmentally acceptable while retaining crop production capabilities.

The specific objectives of the project were:

1. Evaluate the effects of roughage content and salt content of the ration upon amount and composition of wastes from beef cattle in confined feedlots.

2. Evaluate the influence of covered versus open pens upon the chemical and physical properties of wastes to be removed from the pens.

3. Determine the maximum application rates for disposal of wastes on the land compatible with maintaining reasonable levels of crop production with pollution control.

4. Determine the concentration and movement of chemical and bacteriological waste components by surface runoff or leaching through the soil under the prevailing climatic conditions.

GENERAL BACKGROUND

Various authors have studied differing feedlot conditions in an attempt to establish those conditions which affect the chemical characteristics of beef cattle waste. Gilbertson, McCalla, Ellis, and Woods (1971) have examined feedlot slope and animal densities in relation to the chemical characteristics of the waste concluding that these two factors have no definite relationship with the quality of the waste. Yet, these studies have suggested that climatic conditions influenced the variability of the chemical characteristics of beef cattle waste. Frye et al. (1972) have found that the grams of NaCl fed per day per head of beef cattle directly influence the relative salinity of the feedlot waste and runoff water. They have shown that the relative salinity of the runoff water was almost linearly related to the grams of NaCl in the beef cattle ration. Research has indicated that the chemical analyses of beef cattle waste varies considerably from feedlot to feedlot and the characteristics are unique for each feedlot. This uniqueness indicates that a chemical analysis is needed to characterize the beef cattle waste of any given feedlot.

According to Martin (1970), 85% of the ingested K appears in the beef cattle waste; therefore, a large application of beef cattle waste to the soil adds a large quantity of K which may disturb the nutrient balance in the soil and eventually affect the crops grown on the soil.

When K is present in the soil in excessive amounts, plants may consume more K than is needed for normal growth (luxury consumption). The K to Mg ratio of forages grown on soils is important due to hypomagnesemia (grass tetany). Beef cattle receiving forage high in K and low in Mg may develop hypomagnesemia which causes death to the animal.

Vitosh, Davis, and Knezek (1972) harvested corn silage which contained a K to Mg ratio capable of causing hypomagnesemia. The corn silage was grown on soil receiving beef cattle waste for nine consecutive years at 67.2 MT/ha. (20 t/a.) (wet weight basis with the last year's waste containing 70% water). Vitosh et al. (1972) suggested that forage grown on soils receiving large amounts of beef cattle may have a large enough K to Mg ratio to warrant an addition of Mg to the feed if this forage is fed to beef or dairy animals.

The Relationship of Applied Beef Cattle Waste to Salt and Sodium Content

The cations Ca, Mg, Na, and K and the salts of these cations are the most abundant in beef cattle waste and the most important in affecting salinity and dispersion of soil. Soil salinity is affected by the salts which are added by waste. Soil colloids are influenced by the relative amounts of Ca, Mg, Na, and K added by the waste. In turn, the amount of salt and cation proportions in the waste are influenced by the contents of the forage used in the ration, by the feed supplements, and by any extra salt added to the feed.

The early literature of Salter and Schollenberger (1939) reported that salt fed to beef animals appears in their wastes in sufficient quantities at times to injure the quality of potatoes grown on land receiving large quantities of the waste. They attributed the bulk of the injury to the chloride in the waste.

To monitor soil salinity as affected by beef cattle waste application, Murphy et al. (1972); Mathers et al. (1972); Evans, Goodrich and Munter (1972); and Reddell, Egg, and Smith (1974) have used EC of the saturated soil extract; while Evans et al. (1972) and Reddell et al. (1974) have also examined chloride content in the soil.

Mathers et al. (1972) measured EC to a depth of 91.4 cm (36.0 in.) in the soil after three annual beef cattle waste applications at varying rates. The increase in the soil's EC was directly related to the amount of beef waste applied to the soil. The increase in EC was found to be greater at the soil surface than at the 91.4-cm (36.0 in.) depth; although, a waste rate of 123.2 MT/ha. (55 t/a.) (dry weight basis) per year increased the EC slightly at the 91.4-cm (36.0 in.) depth.

A linear relationship was established by Murphy et al. (1972) between surface soil EC and the amount of waste applied to that soil. As soon as waste application was discontinued, soil EC was reduced by nutrient removal through actively growing plants and by continued leaching of salts into lower portions of the soil profile.

After only one beef cattle waste application of 70.2 MT/ha. (31.3 t/a.) (dry weight basis), Evans et al. (1972) found only a small increase (200 μmhos/cm) in EC for the top 15 cm (5.9 in.) of the soil profile. Evans et al. (1972) also examined the chloride content in the soil profile after this waste application finding an increase in chloride concentration at all soil depths (0-15 cm, 15-30 cm, 30-61 cm, 61-91 cm, and 91-122 cm) (0-5.9 in., 5.9-11.8 in., 11.8-24 in., 24-36 in., and 36-48 in.) with the largest increase (14 ppm to 155 ppm chloride) occurring at the 61 to 91-cm (24-36 in.) depth.

A direct relationship was also shown by Reddell et al. (1974) between the EC of the saturated soil extract of surface soil and the rate of applied beef cattle waste. The EC increased in the surface soil immediately after beef cattle waste application and decreased once the annual applications were discontinued. The chloride concentration increased in the entire soil profile after application of waste and dissipated gradually once waste application was stopped.

With the possibility of Na or K at high concentrations dispersing soil colloids, Na and K have been examined in relation to reduced plant growth on soils that have received large applications of beef cattle waste. Both water soluble and exchangeable Na or water soluble and exchangeable K are used to monitor the accumulation of either Na or K in soil after heavy waste applications.

Reddell et al. (1974) have shown that water soluble Na and K increase directly in the top 30 cm (11.8 in.) of soil with the amount of beef cattle waste application. Murphy et al. (1972) have demonstrated the same relationship for both extractable Na and exchangeable K.

Cross, Mazurak, and Chesin (1971) used soil columns to study soil hydraulic conductivity as affected by the application of beef cattle wastes. The leachate collected from columns contained increasing amounts of Na and K as the waste application was increased. Cross et al. (1971) concluded that the amounts of Na and K added in the beef cattle waste when applied to soil caused dispersion of colloids which reduced the soil's hydraulic conductivity.

The ratio of Na to Ca and Mg in beef cattle waste has been suggested by Mathers et al. (1972) as being a critical property when waste is applied to the soil. Dispersion hazard ratios which are found by dividing the relative weight of Na and K in beef cattle waste by the relative weight of Na, K, Ca, and Mg in that same waste have been published by Powers et al. (1974). Dispersion ratios can be useful as guidelines in monitoring the effect of waste applied to soil.

The investigators listed in the above discussion have measured various chemical properties of the soil to monitor an increase in soil salinity or a change in exchangeable bases which may cause soil dispersion. Scientists generally agree that dispersion reduces plant growth by disturbing the air and water relations of the soil profile. However, reduced plant growth on saline soils has remained a subject of serious debate among scientists. Some authors have suggested that increased osmotic pressures caused by the salts in the soil prohibit adequate water uptake by the plant. Other authors have suggested that plants grown on saline soils are subjected to nutrient imbalances which reduce plant growth by forcing the plant to absorb an excessive amount of improper nutrients.

The stage of plant growth at which saline soils are most injurious depends on the plant species. Ayers and Hayward (1948) found corn to be less susceptible to soil salinity at germination than barley or sugar beets; however, as plant growth continues corn shows less tolerance to saline soils than barley or sugar beets.

<u>Beef Cattle Waste Application Rates on the Soil</u>

Waste application studies are conducted to arrive at an application rate which will permit crop growth without causing either excessive nutrient accumulation in the soil or soil damage. This section lists the beef cattle waste application rates suggested by various authors. Although many different units are used in waste management studies, the rates discussed here will be in units of MT/ha. (t/a.) on a dry weight basis.

After reviewing the literature, Aldrich (1973) concluded that one- or two-year applications of 168 to 225 MT/ha. (75 to 100.4 t/a.) of beef cattle waste seldom causes an adverse effect on yields of corn, sorghum, or forage grasses.

Evans et al. (1972) reported that an application of 70.2 MT/ha. (31.3 t/a.) for one year resulted in corn grain yield of 6,502 kg/ha. (5,800 lb/a.) for the plot receiving beef cattle waste compared with a check plot yield of 6,076 kg/ha. (5,420 lb/a.).

According to Cross et al. (1971), for corn under irrigation a beef cattle waste application of 269 MT/ha. (120 t/a.) for one year increased corn yields while a higher application of 582 MT/ha. (259.8 t/a.) for one year decreased corn yields significantly.

The investigations of Reddell et al. (1974) concluded that beef application rates of 86.9 and 134.4 MT/ha. (38.8 and 60 t/a.) for three consecutive years to irrigated crops did not decrease crop yields or cause damage to the soil.

Mathers and Stewart (1974) recommended 9 MT/ha. (4 t/a.) for a continued yearly application of beef cattle waste without any nutrient accumulations in irrigated soils. Any application rate exceeding 9 MT/ha. (4 t/a.) established a nutrient accumulation in the soil. However, such results are highly dependent upon soil and weather conditions.

Vitosh et al. (1972) recommends a yearly dry-land beef cattle waste application of between 6 and 18 MT/ha. (2.7 and 8 t/a.) without any unnecessary nutrient accumulation in the soil. The recommended rate depends considerably on the soil texture, the weather, and the use to be made of the crop.

Powers et al. (1974) have completed a comprehensive guide for beef cattle waste application rates. By using nomograms, the reader can arrive at the continuous rate which is safe for his particular situation. The different nomograms represent beef cattle waste application to irrigated or dry-land soils; soils of fine, medium, or coarse textures; and soils resulting in medium or low soil salinity.

The literature indicates that the disposal of wastes on soil may change the chemical properties of the soil enough to alter plant growth. The two hazards considered to be closely related to the disposal of wastes on soil are soil dispersion and soil salinity. Thus, chemical tests which are directly related to dispersion and salinity are useful for monitoring the changes in soil chemistry.

Until some more economical use is found for animal wastes, the soil will continue to be the primary disposal site. In order to protect the crop production capacity of the soil and to minimize pollution, regular waste and soil monitoring programs should be established.

SECTION IV

FACILITIES

The Southeast South Dakota Experiment Farm was selected as the site to conduct the studies under this project. The farm is located near Beresford, South Dakota, and is operated by South Dakota State University and the South Dakota Agricultural Experiment Station.

In addition to a barn and other farm buildings, the farm has a modern office and laboratory building. The farm has its own weather station and maintains a complete written record of weather data.

The open feedlot and covered lot facilities were inadequate to handle this project; therefore, construction and remodeling of facilities were necessary. The barn was remodeled to handle eight covered pens with separate feeding and waste collection for each pen. New water fountains, feed bunks, and feed handling facilities were installed.

A new open pen feedlot consisting of eight concrete-surfaced pens was constructed. Appropriate alleyways and holding pens were constructed to permit handling of the cattle during waste cleaning and animal weighing periods.

Figure 1 is two views of the feedlot showing the open pens and the barn where the covered pens were located. Although not shown in the photographs, ventilation panels were installed in the sides and roof of the barn at the end of the first feeding cycle. The added ventilation improved the odor and eliminated part of the water vapor buildup inside the barn.

Other facilities used in this study include the field plot and waste handling equipment, the Soil Testing Laboratory facilities, the Water Quality Laboratory facilities, and the Computing and Data Processing facilities located on the South Dakota State University campus.

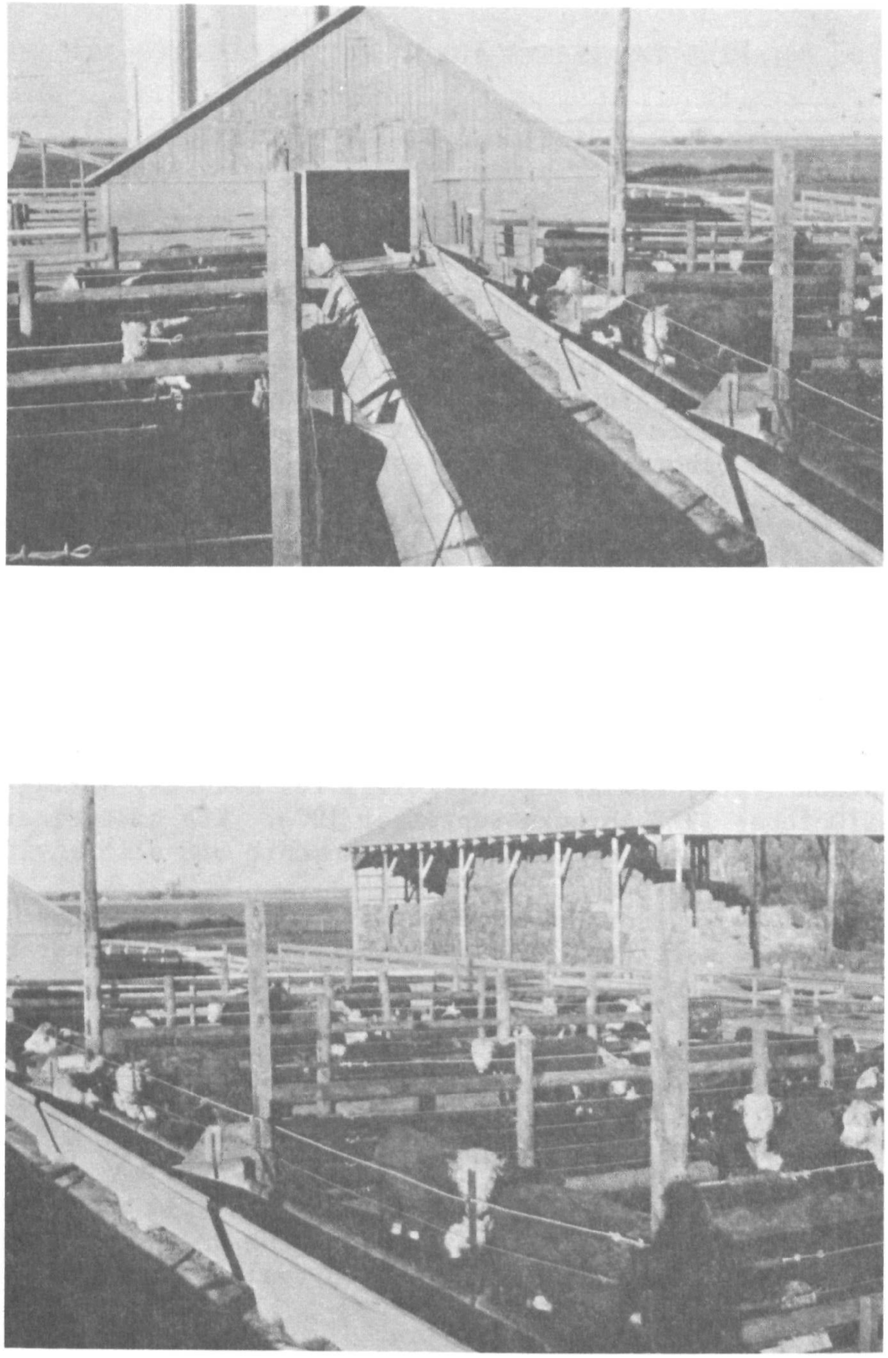


Figure 1. Feedlot facilities

SECTION V

CLIMATIC DATA AND ANIMAL ENVIRONMENT

The feedlot and field plots used in this study were located on the Southeast South Dakota Experiment Farm located in Clay County near Beresford, South Dakota. The topography of the region is flat to gently rolling.

THE CLIMATE

The climate of Clay County is classed as sub humid and is of the continental type with large contrasts in temperature from summer to winter and from day to day.

The maximum (Tmax) and minimum (Tmin) temperatures and the daily precipitation (Pptn) are given in Table 1 for each day during the months of October 1973 through September 1974. The historical highest and lowest recorded temperatures for each month are also given.

The historical average number of days with temperatures above 0° C is 153. The average date for the 0° C reading in the spring is May 4 and the first date in the fall is October 5.

A summary of monthly precipitation for the period October 1973 through September 1974 is given in Table 2. The actual precipitation is compared with the annual average to show a deficit of 18.75 cm during the period of measurement.

Winds in this region of South Dakota average about 18 km/hr during the winter with a prevailing direction from the northwest. Winds in the summer average about 16 km/hr with a prevailing direction from south-southwest.

This area receives an annual average of 64% of possible sunshine. The greatest amount of possible sunshine, 75%, is received in July, with the least amount, 52%, received during December.

The average annual Class A pan evaporation for this region is 137 cm

Table 1. TEMPERATURE AND PRECIPITATION RECORDS FOR THE SOUTHEAST SOUTH DAKOTA EXPERIMENT FARM

	October 1973			November 1973			December 1973		
Day Number	Tmax, (°C)	Tmin, (°C)	Pptn, (cm)	Tmax, (°C)	Tmin, (°C)	Pptn, (cm)	Tmax, (°C)	Tmin, (°C)	Pptn, (cm)
1	20	10		11	-3	T	4	-7	
2	16	7	T	3	-2	0.08	4	-6	
3	22	10	T	6	-4		3	-4	
4	16	0		3	-5	T	-1	-7	
5	18	2		1	-9		-1	-12	T
6	21	6		1	-7		-7	-15	T
7	22	13		5	-2		-2	-15	
8	26	13		4	-7		7	-9	
9	26	17	T	-1	-13		12	-8	T
10	25	3	1.07	1	-11		-4	-16	
11	12	2	0.61	6	-5		-5	-14	
12	21	1	0.13	12	-3		2	-11	
13	16	1		18	4		4	-11	T
14	19	3		19	2		-4	-11	0.38
15	26	5		13	3	1.37	-7	-21	0.08
16	19	-2		5	-3	0.05	-8	-21	0.03
17	9	-2		5	-2		-7	-18	
18	21	1		13	-1		-2	-11	
19	23	2		3	-2		-4	-19	T
20	20	2		8	-1	1.07	-11	-24	
21	22	3		5	-6	1.35	-7	-22	
22	24	7	T	1	-6		-4	-12	
23	25	6		8	-6		4	-11	
24	27	7		5	-4	T	-2	-9	0.28
25	22	3	1.19	7	-3		-2	-11	0.89
26	19	3		4	-2	T	-4	-11	
27	14	-1		8	-3		-3	-10	0.13
28	6	-1	T	4	-8		-3	-12	
29	8	-5		4	-7		-7	-18	
30	14	-4	T	14	-4		-9	-28	
31	11	0					-21	-32	
Long-term weather record for the month	37	-16		28	-31		19	-36	

Table 1 Cont. TEMPERATURE AND PRECIPITATION RECORDS FOR THE SOUTHEAST SOUTH DAKOTA EXPERIMENT FARM

Day Number	January 1974 Tmax, (°C)	Tmin, (°C)	Pptn, (cm)	February 1974 Tmax (°C)	Tmin, (°C)	Pptn, (cm)	March 1974 Tmax, (°C)	Tmin, (°C)	Pptn, (cm)
1	-21	-35		-8	-17		5	-6	
2	-14	-33	0.08	-6	-11	T	20	0	
3	-12	-25		-1	-18	T	24	0	
4	-11	-22		-12	-19		12	-1	
5	-9	-26		-4	-16		9	-6	
6	-13	-23	0.23	-3	-11		17	-6	
7	-14	-30		-7	-18	T	18	-5	
8	-14	-28	T	-4	-16	T	9	-9	
9	-14	-33	0.20	-1	-17	T	14	-1	T
10	-17	-33		3	-17		11	-8	
11	-14	-29		11	-7		11	-8	0.53
12	-20	-32	T	15	-12		2	-1	0.38
13	-14	-28	T	14	-7		10	-2	
14	-7	-20		-1	-7	T	10	-3	T
15	6	-12		-2	-8	T	13	-3	
16	8	-9		4	-11	T	1	-7	
17	10	-3		11	-7		-1	-8	T
18	6	-3		15	-2		12	-7	T
19	1	-15		7	-8		4	-9	0.18
20	2	-13		11	-4		4	-12	1.35
21	1	-6		8	-1	0.10	-6	-20	T
22	2	-7		0	-10		2	-17	T
23	2	-12		1	-9		-3	-18	
24	3	-12		-3	-17		-7	-21	
25	6	-12		-3	-15		2	-13	
26	9	-4		8	-11		12	-4	
27	5	-9		14	-4		4	-4	
28	2	-9		16	-4		8	-3	
29	6	-8					14	-2	
30	11	-4					15	-3	T
31	13	-17					17	-6	T
Long-term weather record for the month	19	-39		21	-36		33	-30	

Table 1 Cont. TEMPERATURE AND PRECIPITATION RECORDS FOR THE SOUTHEAST SOUTH DAKOTA EXPERIMENT FARM

	April 1974			May 1974			June 1974		
Day Number	Tmax, (°C)	Tmin, (°C)	Pptn, (cm)	Tmax, (°C)	Tmin, (°C)	Pptn, (cm)	Tmax, (°C)	Tmin, (°C)	Pptn, (cm)
1	9	0	0.23	22	4		21	7	
2	16	-1		26	8		21	6	T
3	14	-1	0.30	26	-3	T	26	11	
4	0	-6	0.20	19	3		32	16	T
5	7	-7		22	8		31	16	
6	11	-5		22	2		31	13	1.73
7	17	0		19	3	T	23	8	
8	11	-4		23	4	0.61	24	11	
9	16	-2	T	14	2	T	22	9	1.35
10	21	0		21	6	1.42	15	8	1.88
11	20	6		14	6	1.98	22	9	0.13
12	13	5	0.71	18	2	0.05	19	6	
13	9	2	0.08	14	1	2.44	25	12	
14	11	-2		16	4	T	28	14	0.48
15	13	-1	T	11	-2	T	28	11	
16	10	-6	T	17	-1	0.05	21	6	
17	16	-1		23	7		21	5	
18	22	1		23	8	0.69	24	11	
19	21	2		17	8	T	34	13	
20	24	4	0.08	22	10		33	17	
21	21	6	T	30	14	1.40	34	19	0.10
22	12	1		22	9		36	15	2.21
23	13	5		21	6		26	13	
24	16	-3		19	2		24	11	
25	20	2		20	6		23	11	
26	26	11		23	9	T	26	11	
27	27	12	0.05	23	12		28	13	
28	28	8		28	14		29	16	
29	24	5		28	15		32	16	
30	24	-2		25	10	1.19	33	8	
				22	4	T			
Long-term weather record for the month	37	-17		41	-6		41	2	

Table 1 Cont. TEMPERATURE AND PRECIPITATION RECORDS FOR THE SOUTHEAST SOUTH DAKOTA EXPERIMENT FARM

Day Number	July 1974 Tmax, (°C)	Tmin, (°C)	Pptn, (cm)	August 1974 Tmax, (°C)	Tmin, (°C)	Pptn, (cm)	September 1974 Tmax, (°C)	Tmin, (°C)	Pptn, (cm)
1	31	16		19	12	1.42	20	2	
2	32	22		27	13	0.30	13	5	0.23
3	33	18	0.94	22	7	T	17	-2	
4	26	13	0.05	23	6		21	1	
5	27	14		26	9		25	6	
6	33	18		27	9		22	7	
7	35	18		27	12		28	6	
8	37	21		26	13		31	9	0.23
9	37	22	0.56	22	16	1.63	31	8	
10	29	19	0.05	22	16	0.56	28	14	
11	33	19	0.86	24	13	0.05	32	10	
12	30	19	0.10	27	13		21	6	1.93
13	38	20		27	12		12	0	T
14	38	18	0.74	26	15		25	3	
15	31	13		31	16		26	1	
16	31	14		27	16	T	24	7	
17	34	16	0.15	30	13		28	9	
18	38	19		27	11	0.91	28	7	
19	37	21		32	11	0.43	32	9	
20	37	20		31	18		22	5	
21	37	20		36	17	0.25	19	-2	
22	37	16		26	8		21	-1	
23	33	15		26	10		22	-2	
24	36	19		26	12		27	6	
25	36	15	0.33	29	14		27	2	
26	33	16	T	34	12		28	3	
27	33	13	0.69	32	10	0.69	34	7	
28	31	13		24	7		19	-1	
29	30	7		25	8		16	-1	
30	28	7		22	8		21	-3	
31	29	12		28	1				
Long-term record for the month	46	5		44	1		40	-5	

Table 2. MONTHLY PRECIPITATION SUMMARY FOR THE SOUTHEAST SOUTH DAKOTA EXPERIMENT FARM DURING THE PERIOD OCTOBER 1973 THROUGH SEPTEMBER 1974

Month	Year	Amount received, (cm)	(in.)	U.S. Weather Bureau Average for the month, (cm)	(in.)	Amount received minus the average, (cm)	(in.)
October	1973	3.00	(1.18)	3.66	(1.44)	-0.66	(-0.26)
November	1973	3.91	(1.54)	2.41	(0.95)	1.50	(0.59)
December	1973	1.78	(0.70)	1.68	(0.66)	0.10	(0.04)
January	1974	0.51	(0.20)	1.50	(0.59)	-0.99	(-0.39)
February	1974	0.10	(0.04)	2.41	(0.95)	-2.31	(-0.91)
March	1974	2.44	(0.96)	3.45	(1.36)	-1.01	(-0.40)
April	1974	1.65	(0.65)	5.69	(2.24)	-4.04	(-1.59)
May	1974	9.83	(3.87)	9.07	(3.57)	0.76	(0.30)
June	1974	7.87	(3.10)	10.97	(4.32)	-3.10	(-1.22)
July	1974	4.47	(1.76)	7.75	(3.05)	-3.28	(-1.29)
August	1974	6.25	(2.46)	7.54	(2.97)	-1.29	(-0.51)
September	1974	2.38	(0.94)	6.81	(2.68)	-4.43	(-1.74)
Total		44.19	(17.40)	62.94	(24.78)	-18.75	(-7.38)

with 78% (107 cm) of the evaporation occurring during the period May to October.

ANIMAL ENVIRONMENT

In order to compare the environment of the covered pens with the environment of the pens in the open, a 13-week period of measurement was conducted from January 15, 1974, to April 16, 1974. The temperature of the open pens was taken from the farm weather station and the temperature of the covered pens was measured using a thermograph located centrally in the barn. A comparison of dry bulb temperatures of the open and covered pens is shown in Figure 2. Maximum temperature differences occurred in January with the covered pens averaging approximately 5.6° C warmer than the open pens.

The relative humidity in the covered pens averaged approximately 80% over the 13-week period which was about 6% higher than the relative humidity of the open pens.

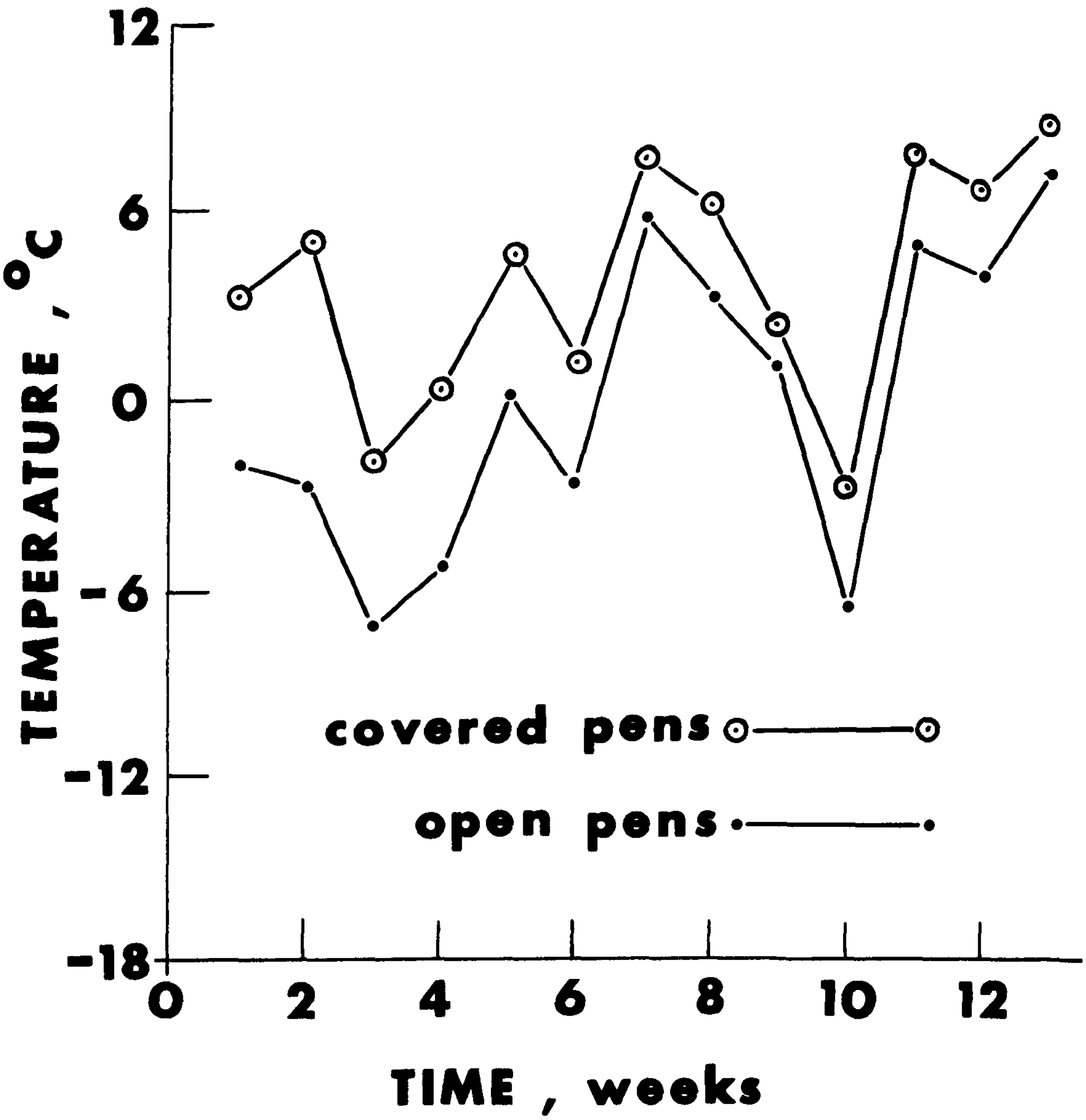


Figure 2. Temperature variation in open and covered pens

SECTION VI

MATERIALS AND METHODS

BEEF ANIMALS AND RATION

In August 1973, sixteen pens with eleven steers in each were established at the Southeast South Dakota Experiment Farm. Eight pens with dimensions of 7.62 by 4.88 m (25 by 16 ft) were located in an unheated covered environment while eight pens with dimensions of 13.11 by 4.88 m (43 x 16 ft) were located in an open environment. All pens were surfaced with concrete. Treated wood partitions were placed between each pen to prevent any mixing of waste from one pen to another and at the end of each pen to retain all solids and liquids in the waste.

Four different rations were composed by varying the NaCl content in the feed. The four levels of NaCl were 0.00%, 0.25%, 0.50%, and 0.75% NaCl added to the ration by weight on a dry-weight basis. Each NaCl level was fed to four pens of animals, two in the covered environment and two in the open environment, for the duration of the feeding trial. Concrete partitions were built in the feed bunks between each pen to prevent any mixing of rations or animal consumption of the wrong ration. Thus, the feeding phase consisted of four NaCl levels, two environments, and two replications.

Beef steers averaging 201.1 kg (443.4 lb) were delivered to the feedlot on July 27, 1973. The animals were fed baled alfalfa hay until August 6, 1973, at which time they were gradually adjusted to a corn silage, alfalfa hay, antibiotic, and supplemented-molasses ration. The feeding trial was started on September 4, 1973, with the ration containing corn silage, antibiotic, supplemented-molasses, and ground limestone with the NaCl level varying among treatments. On December 29, 1973, the corn silage in the ration was replaced with chopped alfalfa hay and ground corn. This ration was used until the steers were marketed on May 20, 1974, at an average weight of 447.7 kg (987.2 lb). The amounts of the ingredients in the ration were shifted during the feeding trial to fulfill the nutritional needs of beef steers being finished for market.

A second feeding trial was initiated on September 11, 1974. The feedlot arrangement was similar to the first feeding trial except an improved ventilation system was installed in the barn. The average initial weight of the steers for the second feeding trial was 232.8 kg (513.3 lb). The formulation of the ration and NaCl levels was unchanged for the second feeding trial except that soybean oil meal was used for the supplement in place of the molasses. The second feeding trial will continue until the steers reach market weight.

WASTE HANDLING, SAMPLING, AND ANALYSES

The wastes were removed from the feedlot pens and spread directly on the field plots except during periods of snow cover and frozen soils. When the weather did not permit spreading the wastes on the land, the pens were cleaned and the waste stored in open enclosures built on concrete pads or on plastic-covered earth pads.

The wastes were hauled and spread in the field using conventional manure spreaders except for a period of time in the spring when the high liquid content required the use of a tank spreader. Near the time of spreading, wastes were incorporated into the soil using a chisel plow. After the wastes were incorporated, ridges were established around the plots to control runoff. Waste incorporation and plot preparation are illustrated in Figure 3.

All wastes were weighed on a commercial-type scale at the time of hauling to the field. At the same time, samples were collected for chemical and water content analyses in the laboratory. From the waste weight, water content, and chemical analyses, accurate rates of application could be determined.

The water content of the waste was determined from a sample that was freeze-dried for other analyses. An extract for cation determination was obtained by ashing a sample at 450° C, extraction with 6N HCl twice, and dilution of the extract to 100 ml with distilled water as described by Chapman and Pratt (1961). The cations -- Ca, Mg, K, and Na -- were determined from the extract by atomic adsorption. The pH and electrical conductivity of waste samples was determined by instrument on a 1:20 dilution sample based on dry weight.

Total N was determined by the Kjeldahl procedure as described in the EPA Manual, Methods for Chemical Analysis of Water and Wastes, Analytical Quality Control Laboratory (1971). Nitrate nitrogen was determined by a steam distillation procedure as described by Bremner and Keeney (1966). The cellulose content of the waste was determined by the Crampton-Maynard Method (1938).

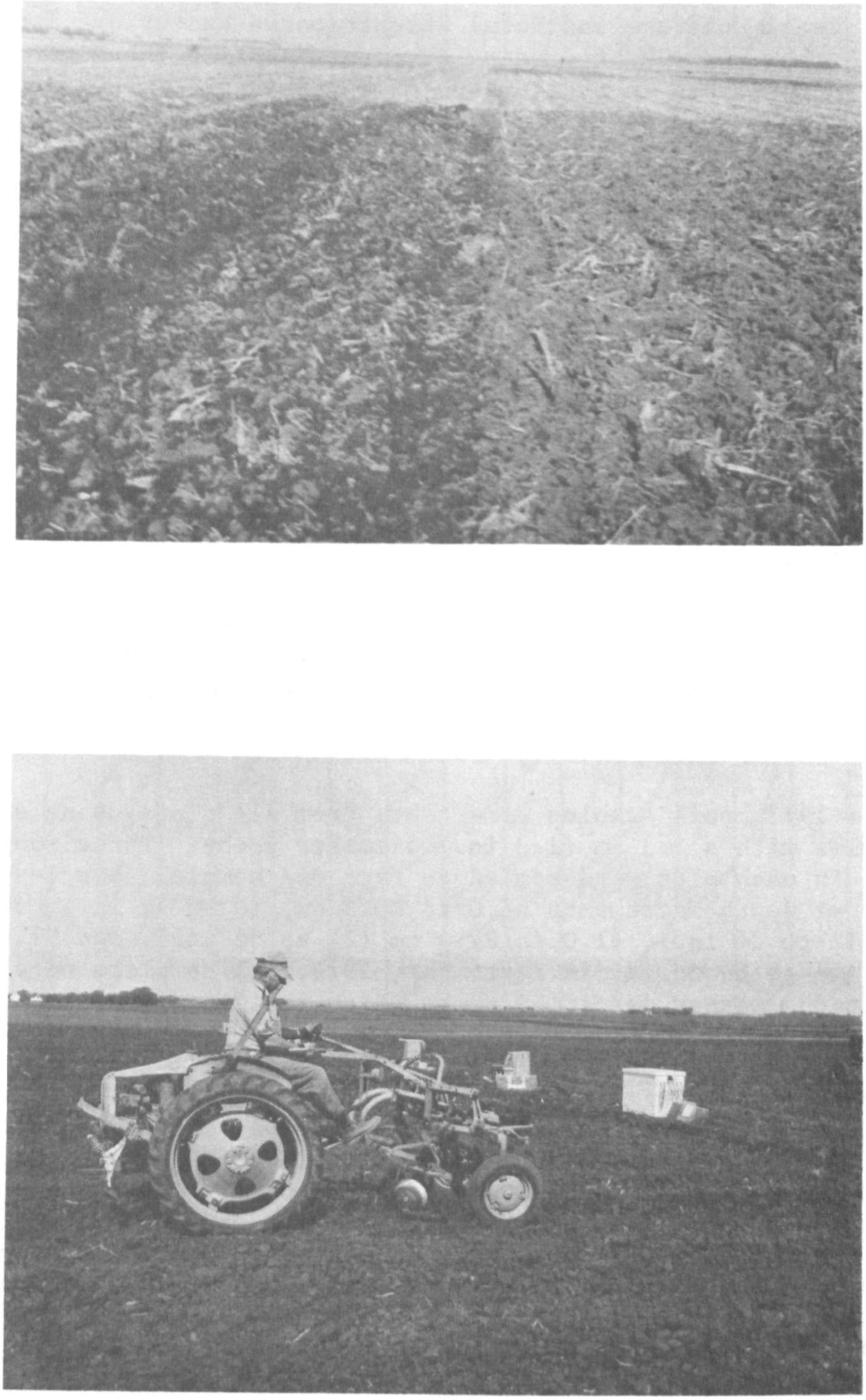


Figure 3. Waste incorporation and plot preparation

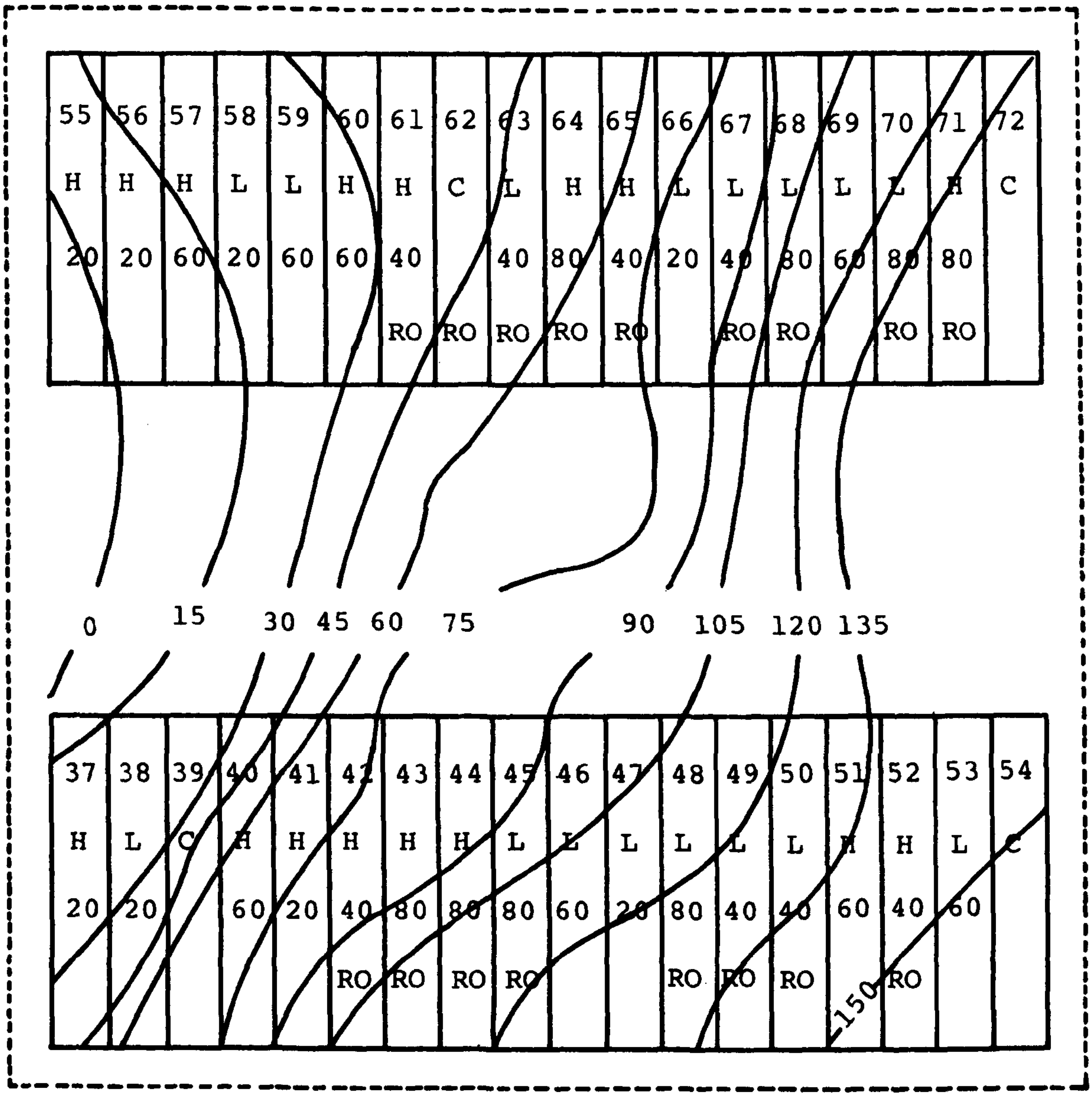
Bacteriological analyses were made on five sets of samples for Total Coliform, Fecal Coliform and Fecal Streptococcus bacteria. The Most Probable Number Index Method using five fermentation tubes per sample was used as described in Section 400 of the Standard Methods for the Analysis of Water and Waste Water, American Public Health Association et al (1971).

LAND DISPOSAL PLOTS, SOIL SAMPLING, AND ANALYSES

Field plots with dimensions of 36.6 by 6.1 m (120 by 20 ft) were established on Egan silty clay loam soil at the Southeast South Dakota Experiment Farm. The soils map and topography map for the plot area are given in Figures 4 and 5. A detailed description of the soil is given in Table 3. The field design was a randomized complete block with treatments consisting of four waste rates, 44.8, 134.4, and 179.2 MT/ha. (20, 40, 60, and 80 t/a.) dry matter, and two types of waste. One type was a combination of the waste from the pens receiving 0.00% and 0.25% NaCl (low salt) in the ration and the other type was a combination of the waste from the pens receiving 0.50% and 0.75% NaCl (high salt) in the ration. Since the animals were housed in an open environment and a covered environment, nearly equal amounts of waste from each environment were applied to each plot. The design contained four replications with one check plot in each replication. Therefore, the experiment consisted of four replications, four waste rates, two types of waste, and four check plots for a total of 36 plots.

In October 1973, soil samples were taken from all plots using a Giddings soil sampler with a 3.3 cm (1.3 in.) diameter probe. Three sub-samples collected in each plot were pooled to form one sample. Samples were collected at depth increments of 0 to 30.5 cm, (0 to 12 in.), 30.5 to 61.0 cm (12 to 24 in.), 61.0 to 91.4 cm (24 to 36 in.), and 91.4 to 152.4 cm (36 to 60 in.). In September, 1974, all 36 plots were again sampled in the manner described above which is illustrated in Figure 6.

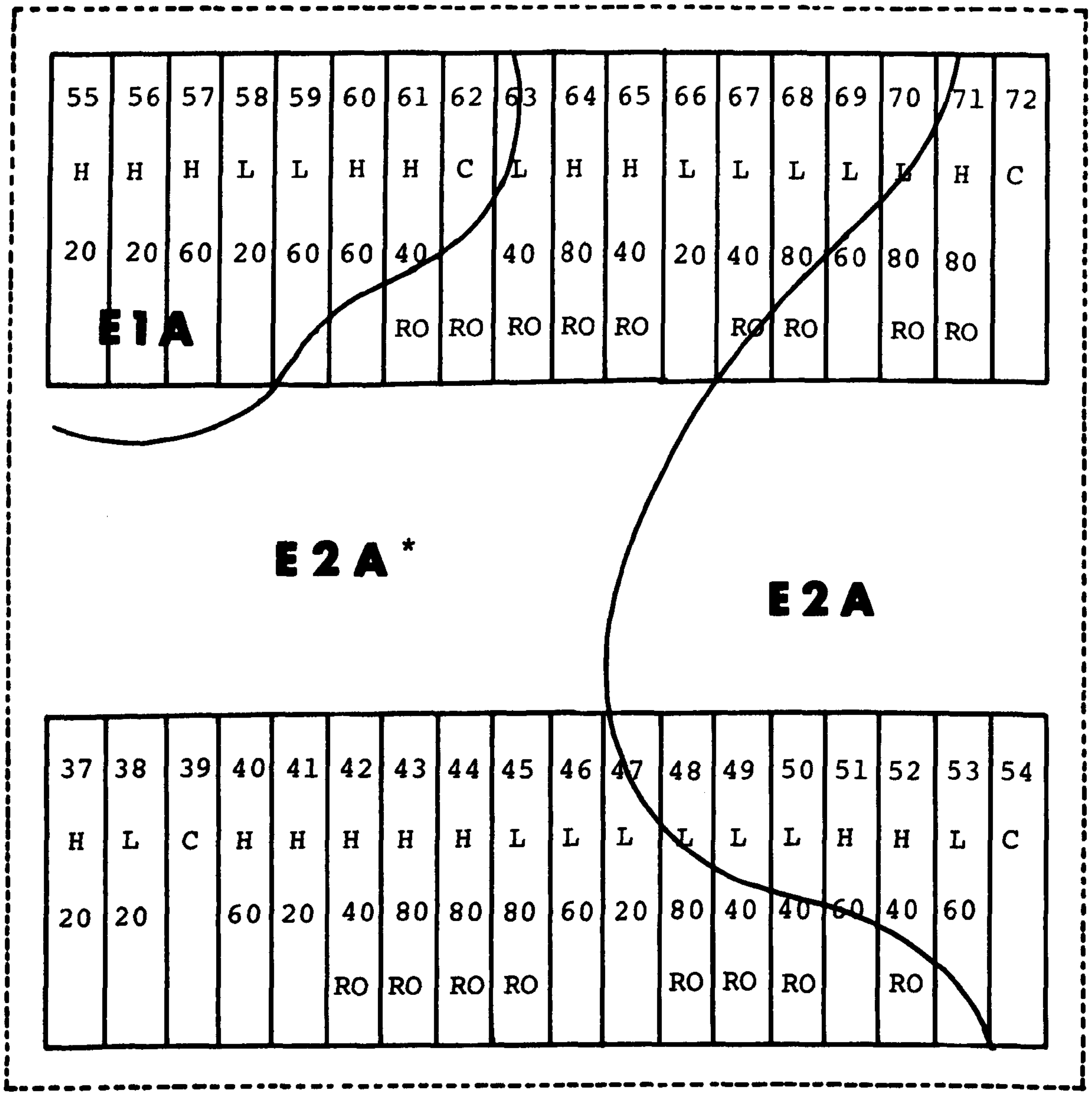
Soil samples taken in October 1973 and September 1974 were analyzed for pH and for both extractable and water soluble Ca, Mg, Na, and K. Water soluble Ca, Mg, Na, and K were obtained from analysis of the saturated extract (Bower and Wilcox, 1965) by atomic adsorption (Isaac and Kerber, 1971). Extractable Ca, Mg, Na, and K were determined by an atomic adsorption analysis (Isaac and Kerber, 1971) of an NH_4Ac extract (U.S. Salinity Laboratory Staff, 1954). Electrical conductivity was determined using the saturated extract. Soil pH determinations were made on the soil's saturated paste. Chlorides were obtained by analysis of the saturated extract (American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1971). Soil analyses were also made for available P (NH_4F extractable), organic matter, and total N (Jackson, 1958).



KEY TO PLOTS

37-72	Plot number	20	44.8 MT/ha.
H	High NaCl treatment	40	89.6 MT/ha.
L	Low NaCl treatment	60	134 MT/ha.
C	Check	80	179.2 MT/ha.
RO	Runoff devices		
-15-	Relative elevations in 15 cm intervals		

Figure 4. Field plots showing relative elevations



KEY TO SOILS

E1A	Egan silty clay loam, 0-2% slopes (deep ABC II profiles)
E2A	Egan silty clay loam, 0-2% slopes (deep AB II profiles)
E2A*	Egan silty clay loam, 0-2% slopes (deep AB II profiles), carbonates at 20 to 38 cm - not typical for the series.

Figure 5. Soils map of plot area

Table 3. DETAILED PROFILE DESCRIPTION OF THE EGAN SILTY CLAY LOAM SOIL[a]

Location: Southeast Agricultural Experiment Farm, Centerville, South Dakota.

Classification: Typic Haplustoll; fine silty, mixed mesic.

Parent Material: Loess over glacial till.

Physiography: Nearly level plain with low broad ridges.

Salt or Alkali: None. Land Use: Cropland.

Stoniness: None above 68.6 cm (27 in.). Erosion: Slight.

Slope: 1% convex. Permeability: Moderate.

Drainage: Well drained. Ground Water: Deep.

Horizon	Depth, cm (in.)	Description
Ap	0-17.8 (0-7)	Dark grayish brown (10YR 4/2) silty clay loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, slightly sticky; slightly acid; abrupt smooth boundary.
B21	17.8-38.1 (7-15)	Brown (10YR 5/3) silty clay loam, very dark grayish brown (10YR 3/2) moist, crushing to dark brown (10YR 3/3), moist, weak medium prismatic structure; parting to weak coarse and medium subangular blocky structure; slightly hard, friable slightly sticky; neutral; gradual wavy boundary.

[a]This is an approved soil series description from the State Soil Scientist's office.

Table 3 Cont. DETAILED PROFILE DESCRIPTION OF THE EGAN SILTY CLAY LOAM SOIL

Horizon	Depth, cm (in.)	Description
B22	38.1-61.0 (15-24)	Grayish brown (2.5Y 5/2) silty clay loam, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure parting to weak coarse and medium subangular blocky structure; slightly hard, friable, slightly sticky; neutral, clear smooth boundary.
B3ca	61.0-78.7 (24-31)	Light brownish gray (2.5Y 6/2) silty clay loam, grayish brown (2.5Y 5/2) moist; common fine distinct strong brown (7.5YR 5/8) mottles, weak coarse subangular blocky structure, hard, friable, slightly sticky; common fine distinct accumulations; many medium soft lime segregations; strong effervescence; moderately alkaline; gradual wavy boundary.
IIC1	78.7-106.7 (31-42)	Light brownish gray (2.5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; common fine distinct strong brown (7.5YR 5/8) mottles; moderate coarse prismatic structure parting to moderate coarse subangular blocky structure; hard, firm, slightly sticky; common fine brown accumulations; many fine soft lime segregations; strong effervescence; moderately alkaline; gradual wavy boundary.
IIC2	106.7-152.4 (42-60)	Light brownish gray (2.5Y 6/2) clay loam, dark grayish brown (2.5Y 4/2) moist; many fine distinct strong brown (7.5YR 5/8) and yellowish red (5YR 4/8) mottles; moderate coarse subangular blocky structure; hard, firm, slightly sticky; common fine and medium brown accumulations; common lime segregations; strong effervescence; strongly alkaline.

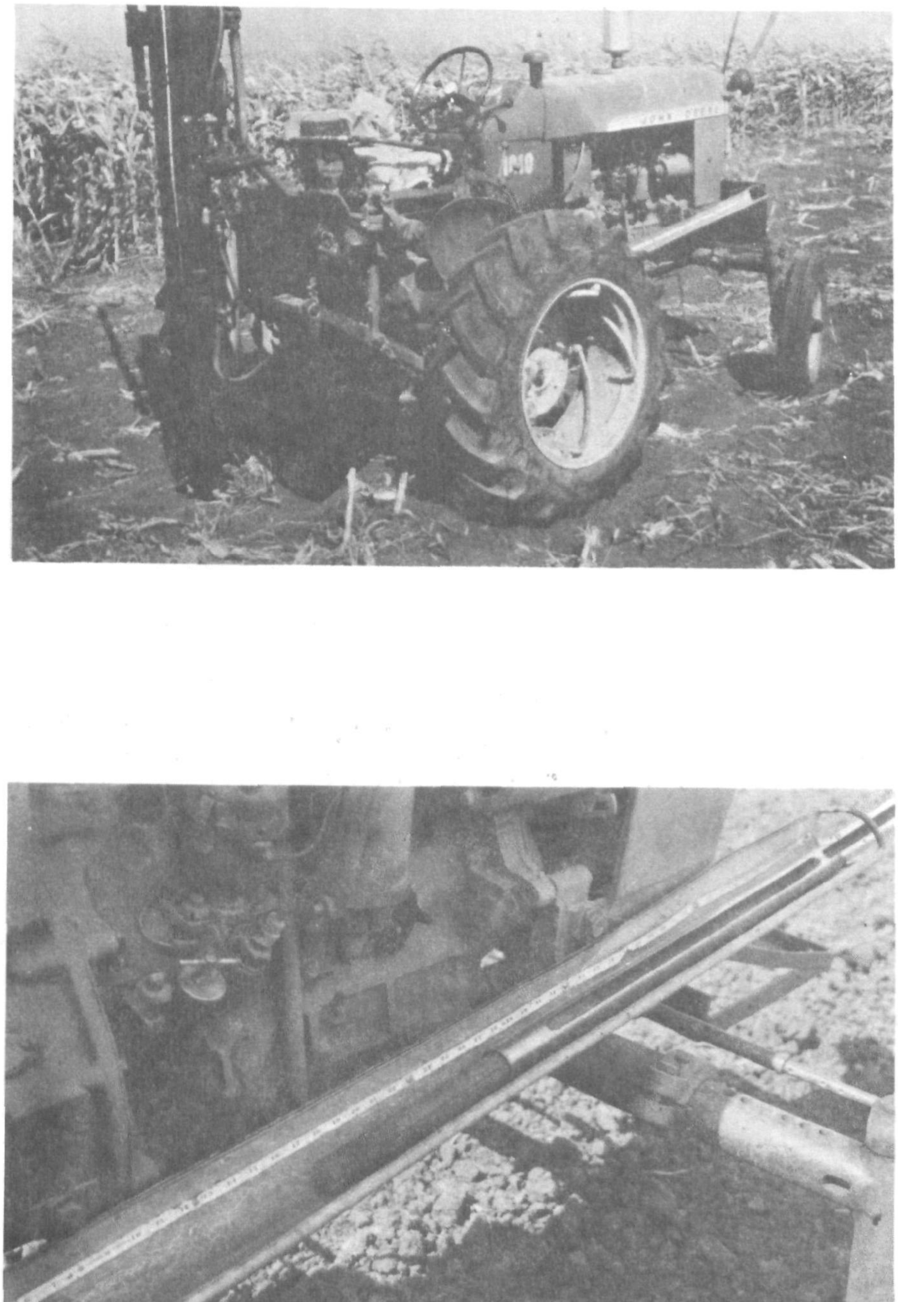


Figure 6. Soil sampling

The initial soil analyses revealed extremely high values for extractable Ca and Mg for most plots below 30.5 cm (12 in.) and for some plots at the 0- to 30.5-cm (0 to 12 in.) depth. The soils on which the plots are located have free $CaCO_3$ and related salts in the profile. Thus, it was concluded that the free $CaCO_3$ and related salts were responsible for the high and erroneous values for extractable Ca and Mg. When free $CaCO_3$ is present in the soil profile, analysis for Ca using NH_4Ac results in measurement of Ca activity above the true activity in the soil (Heald, 1965).

Cation exchange capacity (U.S. Salinity Laboratory Staff, 1954) was determined for selected plots which were representative of the particular soil area and which may have a varying cation exchange capacity due to the large amount of added waste.

Statistical analyses included several analyses of variance of a factorial experiment in a randomized complete block design. Also, multiple regression analyses were used to isolate the specific effects of NaCl level and waste rates on yield, exchangeable Na, exchangeable K, and EC.

After waste hauling and moldboard plowing were finished, all plots were disked and harrowed to establish a seedbed. The plots were planted on May 24, 1974, to corn (*Zea mays* L.'Funks G-4252') at about 47,000 plants per hectare (19,000 plants per acre). A recommended herbicide was applied in bands over the corn for weed control. Due to poor germination related to seedbed quality and low rainfall, seven plots were replanted by hand on June 19, 1974.

PLANT SAMPLING, CORN YIELDS, AND ANALYSES

Leaf samples to be used for chemical analysis were collected from all plots during the final week of July, 1974. The leaves sampled were taken from opposite and below ears which had white silks showing. Samples were dried at 100° C, ground through a stainless steel screen, and analyzed for Ca, Mg, Na, K, P, Mn, Fe, B, Cu, Zn, Al, Sr, and Mo by spark-emission spectroscopy according to the analytical procedures of the Ohio Plant Analysis Laboratory, Wooster, Ohio. Samples were analyzed for N by the Kjeldahl Method and for S by the Spectrophotometric Method using $BaCl_2$.

The corn from each plot was harvested as silage on September 9, 1974, by removing all the forage from two rows with a spacing of 76.2-cm (30 in.) and a length of 9.14 m (30 ft). The silage was weighed and subsamples for moisture analysis were taken by removing grab samples of the forage after it passed through the chopper. The dry matter yields were calculated from the total forage weight and moisture analysis of the subsamples. From these subsamples smaller subsamples were collected, dried at 70° C, and analyzed for NO_3-N.

On September 18, 1974, ear corn yields were obtained by picking the ears from two rows with a spacing of 76.2-cm (30 in.) and a length of 9.14 m (30 ft). All ears were weighed and the centers of 12 ears were removed to obtain the moisture content.

All forage was removed from the plots on September 26, 1974, in order that waste hauling could begin.

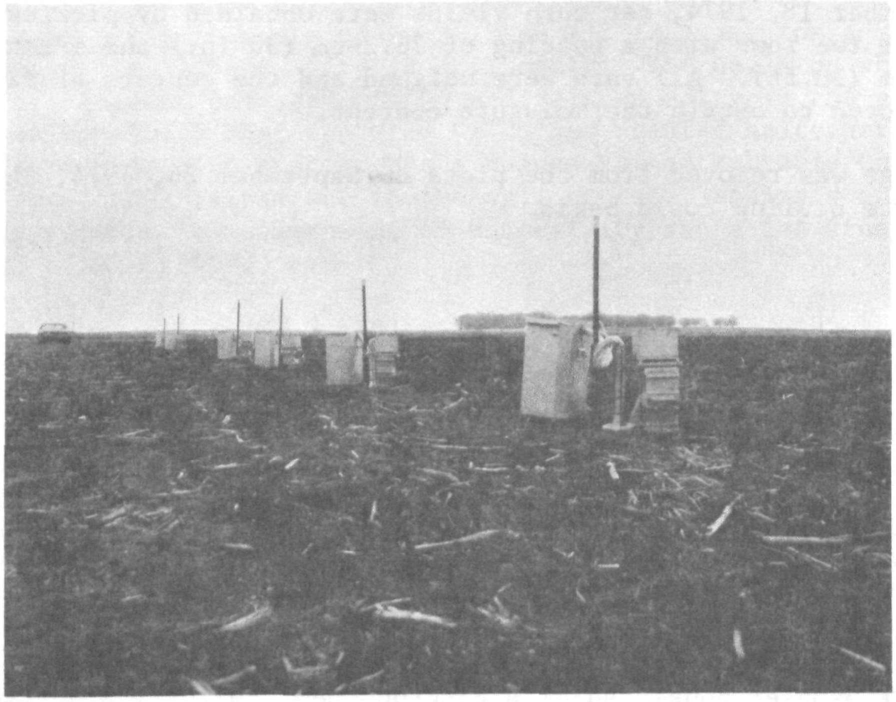
RUNOFF

Seventeen plots as identified in the plot diagram, Figure 4, were instrumented for measuring the quantity of runoff and for collecting samples for water quality analyses. The runoff plots slope gently in a northwesterly direction. An earth ridge was formed around each plot to divert runoff waters to a collection point. A Type H flume with a stilling well was installed in the ridge at the collection point. A horizontal drum water-stage recorder with float-activated clock was installed to measure runoff waters passing through the flume.

A water collection reservoir was installed on the exit side of the flume to provide a pick-up volume for the automatic water sampler. The water sampler consisted of a pick-up tube, collection bottles, and a tripping mechanism that was activated by the stage recorder. Water was drawn into the collection bottles by a 20 psi vacuum created in the bottles.

Figure 7 illustrates the runoff measuring instruments in the field installation.

Water collected during a runoff event was transported within a few hours to the Water Quality Laboratory on the South Dakota State University campus for analysis.



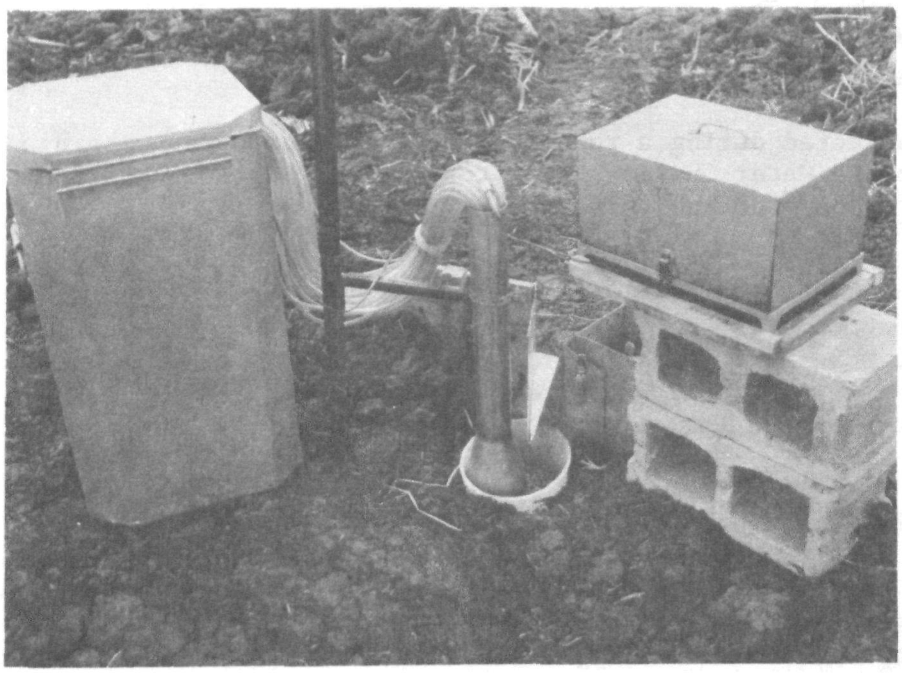


Figure 7. Runoff field installation

SECTION VII

RESULTS AND DISCUSSION

ANIMAL PERFORMANCE

Animal performance data during two periods of approximately three months each are given in Table 4. Although feed consumption and rates of gain were different during the two periods, salt levels and pen environment appeared to have little effect on the results. The data show a trend toward higher rates of gain and slightly higher feed efficiencies for cattle housed in the open pens. The cattle fed a ration low in salt (0.25%) tended to gain as well as the cattle receiving a high salt (0.75%) ration.

It should be emphasized that cattle receiving another ration or using a different source of water might perform differently.

WASTE CHARACTERISTICS

Waste Production

The average amount of dry matter produced per animal per day during the first feeding cycle is shown in Table 5. The values reflect the change in ration in January, 1974, from a high roughage to a low roughage content with a reduction in the amount of waste produced. The variability in waste production within environment and salt-level treatments appears as great as between treatments.

Water Content and Handling Characteristics

The water content of the waste samples ranged from a low of 57% to a high or 87% depending upon weather conditions prior to handling. Waste that exceeded approximately 85% water content were too fluid to handle with a conventional spreader and were hauled with a tank spreader. Although little difference could be observed in water content, wastes from the pens receiving the two highest levels of NaCl in the ration were more fluid in handling characteristics. The wastes from the high salt rations contained more Na and apparently tended to

Table 4. ANIMAL PERFORMANCE

	Covered Pens		Open Pens		Overall Average	
Added salt	Daily gain, (kg/day)	Feed amount (kg/day)	Daily gain, (kg/day)	Feed amount (kg/day)	Daily gain, (kg/day)	Feed amount (kg/day)
Period I	January 1, 1974 to April 16, 1974					
0.00%	0.68	6.02	0.93	5.41	0.80	5.72
0.25%	0.89	4.69	0.83	5.66	0.86	5.18
0.50%	0.68	7.48	0.77	5.22	0.72	6.35
0.75%	0.88	5.33	0.91	5.28	0.90	5.31
Period II	September 11, 1974 to December 5, 1974					
0.00%	0.96	3.59	1.06	3.42	1.01	3.50
0.25%	1.03	3.37	1.14	3.18	1.08	3.27
0.50%	0.99	3.51	1.09	3.31	1.04	3.41
0.75%	1.00	3.47	1.08	3.36	1.03	3.41

be more dispersed. Since no bedding was added to the wastes, the handling characteristics were directly related to water content and degree of dispersion.

Analyses

Waste analysis data are summarized in Table 6. Additional detailed analysis data are given in Appendix A. The composition of the waste reflects the salt (NaCl) content of the ration in Cl, Na, and EC. The amounts of K, P, N (total), and cellulose present in the waste are influenced by the roughage content and type.

Differences in waste composition due to the covered or open environment are small to negligible. However, the waste from the two environments were handled or stored in the same manner for the equivalent time periods.

Waste Application Rates on Field Plots

The amounts of waste applied to field plots from pens receiving the low salt ration are shown in Table 7. Rates of waste applied to plots from pens receiving the high salt ration are shown in Table 8. Although the proposed rates were not completely achieved due to a lower-than-predicted waste production, the rates achieved do give separate treatments that approach the proposed rates.

Table 5. DRY MATTER WASTE PRODUCTION[a]

Added salt %[b]	Envi-onment	Pen number	1973 Sept. and Oct., (kg)	1973 Oct. and Nov., (kg)	1974 Feb. and Mar., (kg)	1974 Mar. and Apr., (kg)
0.00	C	4	2.54	2.98	1.36	1.61
	C	9	2.42	2.78	2.00	1.51
	O	6	2.84	--	1.81	--
	O	13	2.34	2.76	1.86	1.96
0.25	C	1	2.61	2.87	2.22	1.66
	C	12	2.41	2.60	1.45	1.76
	O	7	2.14	--	2.09	--
	O	16	2.22	--	1.95	2.09
0.50	C	2	2.56	2.73	1.45	1.39
	C	10	2.58	2.62	1.72	1.45
	O	8	2.13	--	2.09	1.71
	O	15	2.43	--	2.00	1.72
0.75	C	3	2.77	2.82	1.32	1.60
	C	11	2.67	2.78	1.68	1.67
	O	5	2.49	2.95	2.22	1.97
	O	14	2.57	3.91	2.09	2.20

[a]Based on average waste produced per head per day
[b]Percent of dry matter in total ration

Bacteriological Characteristics

The most probable number (MPN) Index for the intestinal bacteria--total coliform, fecal coliform, and fecal streptococci--found in the waste on five sampling dates is shown in Table 9. As expected, the MPN for fecal streptococci exceeded the estimate for total coliform and fecal coliform on all sampling dates. Over the range of salt levels used in the ration, the NaCl content of the feed produced no observable effect upon the MPN for any of the bacterial estimates made. If an effect of salt were to be noted, it would have been expected to be observed in the numbers of total coliform or fecal coliform.

The MPN Indexes for most of the first sampling estimates (10-17-73) are lower than the Indexes on other sampling dates. The low values may have

Table 6. WASTE ANALYSES

PERIOD I HIGH ROUGHAGE RATION

	Units	No salt	0.25%	0.50%	0.75%	Avg.
B	ppm	0.19	0.17	0.18	0.17	0.18
Ca	%	0.94	0.96	0.96	0.91	0.94
K	%	3.24	3.34	3.45	3.40	3.36
Mg	%	0.74	0.74	0.74	0.73	0.74
Na	%	0.30	0.60	0.93	1.24	0.77
N-Total	%	3.00	3.07	3.11	3.00	3.05
P	%	0.61	0.62	0.63	0.63	0.62
Cellulose	%	26.50	25.90	25.60	25.60	25.90

PERIOD II LOW ROUGHAGE RATION

	Units	No salt	0.25%	0.50%	0.75%	Avg.
B	ppm	0.19	0.19	0.18	0.18	0.19
Ca	%	1.39	1.38	1.42	1.34	1.38
K	%	2.98	2.91	2.97	2.99	2.96
Mg	%	0.75	0.76	0.77	0.73	0.75
Na	%	0.51	0.89	1.20	1.58	1.05
N-Total	%	3.95	3.99	3.93	4.02	3.97
P	%	1.08	1.09	1.09	1.08	1.09
Cellulose	%	12.13	11.71	11.62	11.23	11.68

Table 7. WASTE RATES FROM THE LOW NaCl RATION APPLIED TO FIELD PLOTS

Proposed rate, MT/ha	Replication		Total waste, MT/ha	
44.8	I		38.84	
	II		44.76	
	III		33.94	
	IV		36.53	
		Average		38.52
89.6	I		96.86	
	II		96.47	
	III		99.05	
	IV		113.46	
		Average		101.46
134.4	I		139.37	
	II		129.37	
	III		147.08	
	IV		124.99	
		Average		135.20
179.2	I		165.70	
	II		176.26	
	III		169.03	
	IV		167.22	
		Average		169.55

been due to the initiation of the project in a clean feedlot with less than favorable conditions for bacterial population buildup.

CROP RESPONSE

Corn Leaf Analyses

Summary data for analyses of corn leaf samples taken from the waste treatment plots are shown in Table 10. More complete leaf analysis data are given in Appendix Tables A8 and A9. According to Jones (1967) the Ca values shown in Table 10 are in the sufficient-to-high range, while all the K values are in the excessive range. The N values increased, as expected, with increased waste rates and the Mg content

Table 8. WASTE RATES FROM THE HIGH NaCl

RATION APPLIED TO FIELD PLOTS

Proposed rate, MT/ha	Replication		Total waste, MT/ha	
44.8	I		44.38	
	II		18.26	
	III		26.54	
	IV		18.52	
		Average		26.92
89.6	I		100.69	
	II		72.20	
	III		80.55	
	IV		88.66	
		Average		85.32
134.4	I		124.81	
	II		114.07	
	III		120.68	
	IV		119.24	
		Average		119.70
179.2	I		166.59	
	II		155.97	
	III		169.48	
	IV		198.73	
		Average		172.69

of the leaves decreased with increasing waste rates. Although the Mg contents reported are considered sufficient, if the Mg content of total forage shows the same trend in other grasses, the possibility of hypomagnesemia exists for cattle grazing on the forage.

Although the N content of the leaves increased with waste rate, a nitrate analysis of whole plants removed for silage showed no evidence of nitrate accumulations in the plant due to the drought conditions.

<u>Corn Silage and Grain Yields</u>

The average yields of silage and ear corn harvested from the waste treatment plots are given in Table 11. Complete yield data are given in Appendix Table A10. The silage and ear corn yields were variable.

Table 9. BACTERIOLOGICAL CHARACTERISTICS OF BEEF WASTES

Salt level of ration	MPN/100ml x 10^6 Sampling dates 10-17-73	10-30-73	12-17-73	3-6-74	4-16-74	Average all dates
			TOTAL COLIFORM			
0%	54	33	332	62	194	155
0.25%	32	71	219	68	182	114
0.50%	55	179	117	80	128	112
0.75%	61	185	196	359	162	193
Average all salt levels	51	142	216	142	167	
			FECAL STREPTOCOCCUS			
0%	1077	1609	1610	1020	2213	1506
0.25%	409	1609	620	1573	3815	1605
0.50%	727	1609	1258	3338	2810	1948
0.75%	874	1436	2488	810	2040	1530
Average all salt levels	772	1566	1494	1685	2720	
			FECAL COLIFORM			
0%	37	91	148	49	194	104
0.25%	23	66	80	67	214	90
0.50%	162	34	81	67	128	94
0.75%	35	175	134	184	130	132
Average all salt levels	64	92	111	92	167	

Table 10. LEAF ANALYSES OF CORN PLANTS HARVESTED AT SILKING FROM PLOTS RECEIVING THE INDICATED AMOUNTS OF WASTE[a]

Waste rate, (MT/ha.)	Salt level	N[b]	P	K %	Ca	Mg
Check		2.70	0.27	2.61	0.55	0.54
38.5	Low	2.97	0.35	2.61	0.53	0.39
26.9	High	2.80	0.34	2.59	0.55	0.44
101.5	Low	3.05	0.35	2.58	0.51	0.36
85.3	High	3.06	0.35	2.68	0.53	0.34
135.2	Low	3.18	0.36	2.61	0.48	0.32
119.7	High	3.08	0.36	2.65	0.52	0.30
169.6	Low	3.25	0.35	2.69	0.47	0.32
172.7	High	3.12	0.35	2.52	0.46	0.26

[a]All Na analyses were less than 0.01%
[b]N was determined by Kjeldahl

The silage yields for the waste treatments are not significantly different. Although the ear corn yields are significantly different at the 5% level, a multiple regression analysis using ear corn yield as the dependent variable and waste rate and amount of applied Na as independent variables established an equation which explained only 16% of the variation.

The early season corn growth appeared to favor the plots receiving the lower waste rates. However, as the corn roots grew deeper and the corn reached maturity, visible early-season differences disappeared. The randomness of yields indicated that other factors, such as weather and time of waste application, were influencing results. Closer examination of the data could not establish the causes of the variable yields.

Table 11. YIELD OF EAR CORN AND SILAGE FROM PLOTS RECEIVING FOUR RATES OF APPLIED BEEF WASTE

Waste rate, (MT/ha.)	Salt treatment	Ear corn yield (15.5% water), (hl/ha.)	(bu/a.)	Silage yield (Dry weight), (MT/ha.)	(t/a.)
Check		39.22	45.08	5.67	2.53
38.5	Low	55.19	63.43	8.47	3.78
26.9	High	35.27	40.54	6.72	3.00
101.5	Low	62.32	71.64	7.54	3.37
85.3	High	54.50	62.65	7.86	3.51
135.2	Low	52.77	60.65	5.98	2.67
119.7	High	61.00	70.11	6.68	2.98
169.6	Low	62.19	71.48	7.68	3.43
172.7	High	53.89	61.94	6.37	2.85

SOIL EFFECTS

The results reported here will concentrate on the changes which occurred in the soil as a result of the first year of waste application to the field plots. The Fall 1973 soils data represent the beginning of the waste treatment phase of the project and the Fall 1974 data represent the completion of one year of study.

As can be seen in Tables 12 and 13, the effects of the applied wastes are evident in the changes which occurred in the surface layer, 0- to 30-cm depth. The chlorides (Cl) and the electrical conductivity (EC) showed manyfold increases. The increase in EC is of special significance due to the already high EC values below the 60-cm depth in the profile. Also, to be noted from Table 13 is the lack of movement of waste constituents into the underlying layers. The rainfall deficit of approximately 19 cm resulted in little or no leaching water.

Since the effects of the waste treatments are restricted to the surface layer, discussions of analyses and statistical treatments will be confined to results in the surface layer.

Table 12. SOIL ANALYSES: CHLORIDES, ELECTRICAL CONDUCTIVITY AND pH[a]

Applied waste, (MT/ha.)	Soil depth, (cm)	Fall 1973			Fall 1974		
		Cl[b], (ppm)	EC, (μmhos/cm)	pH	Cl, (ppm)	EC, (μmhos/cm)	pH
Check	0-30	37.5	630[b]	6.96[b]	10.4	1116	6.47
	30-61	29.0	2889[b]	7.62[b]	18.8	2451	7.14
	61-91	25.0	2480[b]	7.81[b]	9.4	4007	7.46
	91-152	25.0	4768[b]	7.67[b]	9.4	5506	7.46
38.52 L	0-30	25.0	682	6.47	208.3	2418	6.16
	30-61	33.4	1124	7.39	21.9	1284	7.21
	61-91	20.3	3364	7.58	21.9	3653	7.37
	91-152	22.9	6090	7.59	16.7	5678	7.40
26.92 H	0-30	43.8	461	6.54	176.1	1929	6.22
	30-61	25.0	747	7.61	35.5	636	7.05
	61-91	25.0	3018	7.47	31.3	4474	7.21
	91-152	25.0	5045	7.65	33.3	5917	7.41
101.46 L	0-30	35.4	724	6.43	328.1	4873	6.18
	30-61	36.1	2044	7.36	37.5	1584	7.22
	61-91	35.4	3941	7.62	12.5	4892	7.32
	91-152	25.0	5464	7.59	4.2	6152	7.45
85.32 H	0-30	33.3	713	6.51	422.9	3947	6.28
	30-61	29.2	1247	7.24	37.5	1409	7.16
	61-91	27.8	3434	7.42	16.7	4082	7.38
	91-152	25.0	7828	7.66	11.5	5360	7.42
135.20 L	0-30	31.2	684	6.22	552.1	5886	5.98
	30-61	30.6	1784	7.24	66.6	1513	7.09
	61-91	38.9	5437	7.51	29.2	4952	7.36
	91-152	25.0	5704	7.55	15.7	5852	7.37
119.70 H	0-30	37.5	738	6.44	689.6	5456	6.28
	30-61	33.3	949	7.25	49.0	1711	7.18
	61-91	33.3	2518	7.30	36.5	4196	7.25
	91-152	29.2	5067	7.63	6.3	5725	7.37
169.55 L	0-30	32.3	923	6.14	469.8	5020	6.27
	30-61	31.9	2802	7.48	51.1	2289	7.07
	61-91	18.8	6309	7.66	18.8	4954	7.39
	91-152	25.0	5837	7.51	6.3	6308	7.53
172.69 H	0-30	37.5	830	6.27	824.1	6017	6.13
	30-61	32.3	1840	7.40	132.3	1899	7.01
	61-91	35.4	4748	7.68	27.1	4573	7.29
	91-152	16.7	6076	7.64	15.6	5782	7.50

[a]Average of four replications
[b]Less than four replications

Table 13. SOIL ANALYSES: NITROGEN AND PHOSPHORUS[a]

Applied waste, (MT/ha.)	Soil depth, (cm)	Fall 1973 Total N, (%)	Fall 1973 NH_4FP, (ppm)	Fall 1974 Total N, (%)	Fall 1974 NH_4FP, (ppm)
Check	0-30.5	0.20[b]	4.0[b]	0.20	4.5
	30.5-61.0	0.08[b]	1.5[b]	0.09	1.3
	61.0-91.4	0.05[b]	1.8[b]		
	91.4-152.4	0.03[b]	2.0[b]		
38.52 L	0-30.5	0.20	7.3	0.22	22.5
	30.5-61.0	0.09	3.0	0.10	1.4
	61.0-91.4	0.06	4.1		
	91.4-152.4	0.04	5.9		
26.92 H	0-30.5	0.20	6.6	0.21	17.8
	30.5-61.0	0.10	2.8	0.10	2.3
	61.0-91.4	0.06	2.1		
	91.4-152.4	0.04	1.9		
101.46 L	0-30.5	0.21	6.1	0.26	>70
	30.5-61.0	0.10	2.5	0.09	1.8
	61.0-91.4	0.04	2.6		
	91.4-152.4	0.03	2.6		
85.32 H	0-30.5	0.21	6.5	0.24	48.8
	30.5-61.0	0.11	2.3	0.09	1.6
	61.0-91.4	0.05	1.8		
	91.4-152.4	0.03	2.1		
135.20 L	0-30.5	0.20	7.9	0.27	>70
	30.5-61.0	0.11	3.0	0.11	2.6
	61.0-91.4	0.05	3.1		
	91.4-152.4	0.03	4.0		
119.70 H	0-30.5	0.21	7.0	0.25	38.3
	30.5-61.0	0.10	3.6	0.10	1.6
	61.0-91.4	0.06	4.9		
	91.4-152.4	0.04	6.4		
169.55 L	0-30.5	0.21	8.8	0.25	>70
	30.5-61.0	0.09	2.9	0.11	2.1
	61.0-91.4	0.05	2.4		
	91.4-152.4	0.05	2.8		
172.69 H	0-30.5	0.19	8.6	0.25	>70
	30.5-61.0	0.10	2.4	0.10	2.6
	61.0-91.4	0.04	2.3		
	91.4-152.4	0.03	2.5		

[a]Average of four replications
[b]Less than four replications

Table 14. SOIL ANALYSES FOR PLOTS RECEIVING THE INDICATED AMOUNTS OF WASTE

Waste rate, (MT/ha.)	Salt level	Fall 1973			Fall 1974		
		Na, (meq/100g)	K,	EC, (μmhos/cm)	Na, (meq/100g)	K,	EC, (μmhos/cm)
38.5	Low	0.25	0.48	682	0.15	0.85	2418
26.9	High	0.08	0.46	460	0.18	0.88	1928
101.5	Low	0.06	0.82	724	0.27	1.86	4873
85.3	High	0.04	0.76	713	0.36	1.47	3956
135.2	Low	0.10	0.80	683	0.38	2.46	5886
119.7	High	0.06	0.77	745	0.54	1.76	5456
169.6	Low	0.08	0.84	923	0.33	2.18	4903
172.7	High	0.06	0.71	830	0.56	1.93	6016

Exchangeable Na, Exchangeable K, and EC in Soil Samples

Table 14 lists the mean values for exchangeable Na, exchangeable K, and EC for the waste treatments applied during the year. The increase in exchangeable Na within plots receiving high salt waste and high rates can be readily observed.

The results from the analysis of variance for exchangeable Na are given in Table 15. The results show that the main effects of waste rate and NaCl treatment are nonsignificant. However, since the seasonal change, Fall 1973 to Fall 1974, represents the change in soil conditions due to the application of waste, the variable of season is needed in the main effect or interaction. The significance of the season main effect, the season by waste rate interaction, and the season by NaCl treatment interaction suggest that a real difference exists for exchangeable Na with varying rates of waste. The mean values given in Table 16 for the significant tests show a larger increase in exchangeable Na for higher waste rates and high salt treatments.

After determining the significance of the various effects by the analysis of variance, a multiple regression analysis was performed

Table 15. ANALYSIS OF VARIANCE FOR EXCHANGEABLE Na IN SOIL

Source		df	Mean square
Season	(S)	1	1.0686[b]
Waste rate	(W)	3	0.4576 NS
Salt treatment	(N)	1	0.1723 NS
Replication	(R)	3	0.0126
S x W		3	0.1281[b]
S x N		1	0.1434[a]
W x N		3	0.0211 NS
S x W x N		3	0.0043 NS
S x R		3	0.0162
W x R		9	0.0186
S x W x R		9	0.0083
N x R		3	0.0186
S x N x R		3	0.0076
W x N x R		9	0.0137
Error		9	0.0112

[a]Significant at the .05 level
[b]Significant at the .01 level
NS nonsignificant at the .05 level

Table 16. THE MEAN VALUES FOR EXCHANGEABLE Na (meq/100g) FOR THE MAIN EFFECTS AND INTERACTIONS WHICH ARE SIGNIFICANT

Season x waste rate

Proposed rate MT/ha. (t/a.)	Fall 1973[a]	Fall 1974[b]
44.8 (20)	0.16	0.16
89.6 (40)	0.05	0.32
134.4 (60)	0.08	0.46
179.2 (80)	0.07	0.45

Season x salt treatment

Salt treatment	Fall 1973	Fall 1974
Low	0.12	0.28
High	0.06	0.41

[a]Season mean value = 0.09
[b]Season mean value = 0.35

to predict the change in exchangeable Na. The dependent variable was defined as the change in exchangeable Na from the Fall 1973 sampling to the Fall 1974 sampling, while the independent variables were defined as the actual amount of applied waste and the amount of applied Na.

The results of the multiple regression analysis are given in Table 17. The amount of applied Na was more strongly related to the change in exchangeable Na than was waste rate. The addition of waste rate to the equation failed to increase the precision of the equation. This is a logical result since the amount of applied Na is not independent of the waste rate; however, by using the multiple regression analysis the independent variable which best predicts the change in exchangeable Na was determined.

Table 17. EQUATIONS DEVELOPED FOR EXCHANGEABLE Na FROM THE MULTIPLE REGRESSION ANALYSIS AND SIGNIFICANCE OF THE EQUATIONS

Equation	Percent of variation explained by equation	r^2
$Y = 0.05044 + 0.00024\ Z_1 - 0.00001\ Z_2$ NS	70.0	
$Y = 0.05007 + 0.00024\ Z_1$ [a]	70.0	.69
$Y = 0.05062 + 0.00027\ X_1 - 0.00003\ X_2$ NS	70.0	
$Y = 0.05008 + 0.00026\ X_1$ [a]	70.0	.69

Y is the change in exchangeable Na (meq/100g)

Z_1 is the kilograms of applied Na (kg/ha.)

Z_2 is the waste rate (MT/ha.)

X_1 is the pounds of applied Na (lb/a.)

X_2 is the waste rate (t/a.)

[a]Significant at the .01 level
NS nonsignificant at the .05 level

The multiple regression analysis indicates that the simple linear regression equation using the weight of applied Na to predict the change in exchangeable Na is significant and explains a large part of the variation. Using this equation it is possible to predict the potential for dispersion of soil based on chemical analyses of the soil and waste. It is also necessary to make some assumptions concerning the type of clay present in the soil before predicting the possibility of soil dispersion. The critical value of 15% exchangeable Na for classification as a sodic soil may be beyond the dispersion point. Some soil scientists believe that the critical value for dispersion varies with the type of clay that is present in the soil and with the presence of other ions.

Table 18. ANALYSIS OF VARIANCE RESULTS FOR EXCHANGEABLE K IN SOIL

Source		df	Mean square
Season	(S)	1	14.9286[a]
Waste rate	(W)	3	2.0893[a]
Salt treatment	(N)	1	0.6064 NS
Replication	(R)	3	0.0958
S x W		3	0.7536 NS
S x N		1	0.2876 NS
W x N		3	0.0945 NS
S x W x N		3	0.0958 NS
S x R		3	0.1701
W x R		9	0.1442
S x W x R		9	0.2010
N x R		3	0.1164
S x N x R		3	0.1655
W x N x R		9	0.0824
Error		9	0.0408

[a]Significant at the .01 level
NS nonsignificant at the .05 level

The results from the analysis of variance for exchangeable K are given in Table 18 and the means for the significant main effects are given in Table 19. The waste rate is the variable which influences the amount of K added to the soil and, thus, affects any change in exchangeable K. However, since the application of K is directly related to season, the season variable needs to be present in the effect. Thus, the important effect is the season by waste rate interaction which is nonsignificant for exchangeable K.

Table 19. THE MEAN VALUES FOR EXCHANGEABLE K (meq/100g) FOR THE MAIN EFFECTS WHICH ARE SIGNIFICANT AT THE .01 LEVEL.

Season	
Year	Mean value meq/100g
1973	0.71
1974	1.67

Waste rate	
Proposed rate, MT/ha. (t/a.)	Mean value meq/100g
44.8 (20)	0.67
89.6 (40)	1.23
134.4 (60)	1.45
179.2 (80)	1.41

The multiple regression analysis with the change in exchangeable K from the Fall 1973 sampling to the Fall 1974 sampling as the dependent variable and waste rate and the amount of applied K as the independent variables was performed. The results in Table 20 show waste rate as the best single parameter for predicting the change in exchangeable K. Even though the simple linear regression equation is significant at the .01 level it explains very little of the variation making the equation unsuitable for prediction in the field.

The inability of the data to detect a significant change in exchangeable K for the season by waste rate interaction may be related to the presence of large amounts of illite in South Dakota soils. The illitic type clays make it difficult to accurately measure exchangeable K.

The analysis of variance results for EC are given in Table 21. The significance of the season by waste rate interaction shows that there is a significant difference among the waste rate treatments with the change in season. The mean values given in Table 22 show the EC seasonal change is greater for the higher waste rates.

Table 20. EQUATIONS DEVELOPED FOR EXCHANGEABLE K FROM THE MULTIPLE REGRESSION ANALYSIS AND SIGNIFICANCE OF THE EQUATIONS

Equation	Percent of variation explained by equation	r^2
$Y = 0.22394 + 0.02423\ Z_1 - 0.00055\ Z_2$ NS	40.0	
$Y = 0.19782 + 0.00723\ Z_1$[a]	38.3	.38
$Y = 0.22331 + 0.05422\ X_1 - 0.00061\ X_2$ NS	40.0	
$Y = 0.19777 + 0.01620\ X_1$[a]	38.3	.38

Y is the change in exchangeable K (meq/100g)

Z_1 is the waste rate (MT/ha.)

Z_2 is the kilograms of applied K (kg/ha.)

X_1 is the waste rate (t/a.)

X_2 is the pounds of applied K (lb/a.)

[a]Significant at the .01 level
NS nonsignificant at the .05 level

The nonsignificance of the season by salt treatment interaction indicates that even though the variation in the total cation contents of waste is influenced by the Na content (Appendix Table A7), the change due to the Na content is small when compared to the total cations.

With the significance of the season by waste rate interaction, a multiple regression analysis (Table 23) was performed to develop a regression equation for predicting the change in EC. The analysis included the change in EC, based on the change in EC from the Fall 1973 sampling to the Fall 1974 sampling, as the dependent variable and waste rate and amount of total cations applied as the independent variables. The waste rate was found to be a better parameter for predicting a change in EC than amount of total cations applied.

Table 21. ANALYSIS OF VARIANCE RESULTS FOR EC IN SOIL

Source		df	Mean square
Season	(S)	1	2.2016×10^{8} [a]
Waste rate	(W)	3	1.1624×10^{7} [a]
Salt treatment	(N)	1	2.4292×10^{5} NS
Replication	(R)	3	1.4291×10^{6}
S x W		3	9.0130×10^{6} [a]
S x N		1	5.2498×10^{4} NS
W x N		3	7.6699×10^{5} NS
S x W x N		3	8.4562×10^{5} NS
S x R		3	1.1470×10^{6}
W x R		9	1.0773×10^{6}
S x W x R		9	7.1483×10^{5}
N x R		3	4.4046×10^{5}
S x N x R		3	4.2689×10^{5}
W x N x R		9	3.9206×10^{5}
Error		9	3.8936×10^{5}

[a] Significant at the .01 level
NS nonsignificant at the .05 level

Although the simple linear regression equation for predicting a change in EC by using the waste rate is significant at the .01 level, it is able to only explain approximately one-half of the variation. Thus, the equation is unacceptable for making field predictions for a change in EC due to a waste application.

Table 22. THE MEAN VALUES FOR EC (μmhos/cm) FOR THE MAIN EFFECTS AND INTERACTIONS WHICH ARE SIGNIFICANT

Waste rate		Season x waste rate	
Proposed rate MT/ha. (t/a.)	(μmhos/cm)	Fall 1973 μmhos/cm	Fall 1974 μmhos/cm
44.8 (20)	1372	571	2173
89.6 (40)	2566	718	4415
134.4 (60)	3193	714	5671
179.2 (80)	3168	877	5460

Table 23. THE EQUATIONS DEVELOPED FOR EC FROM THE MULTIPLE REGRESSION ANALYSIS AND SIGNIFICANCE OF THE EQUATIONS

Equation	Percent of variation explained by equation	r^2
$Y = 1220.38 \times 14.74\ Z_1 + 0.14\ Z_2$ NS	53.2	
$Y = 1219.26 + 23.44\ Z_1$[a]	53.0	.53
$Y = 1220.19 + 32.76\ X_1 + 0.16\ X_2$ NS	53.2	
$Y = 1218.90 + 52.50\ X_1$[a]	53.0	.53

Y is the change in EC (μmhos/cm)

Z_1 is the waste rate (MT/ha.)

Z_2 is the kilograms of applied cations (kg/ha.)

X_1 is the waste rate (t/a.)

X_2 is the pounds of applied cations (lb/a.)

[a]Significant at the .01 level
NS nonsignificant at the .05 level

After a single year of waste disposal, the salinity of the surface 30 cm of soil within plots receiving high rates of waste has increased to a level normally expected to cause reduced growth for many crops. Since the soil below 60 cm in this area is naturally saline, the plots where the heavy waste applications have been made are saline throughout most of the crop rooting zone.

The corn production data for the first year are variable. The less than normal rainfall resulted in reduced water for crop growth and almost no water for leaching. Seasons with higher rainfall could be expected to result in more leaching of salts deeper into the soil profile and could be expected to give quite different crop production results. However, the precipitation patterns of the sub-humid Plains are naturally variable and variable leaching or runoff patterns can be expected.

RUNOFF

Although the runoff sampling and measuring instruments were maintained during the non-frozen soil cycle, precipitation amounts and patterns were such that no runoff occurred during the investigation period.

SECTION VIII

LITERATURE CITED

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SECTION IX

GLOSSARY OF ABBREVIATIONS AND SYMBOLS

Al - Chemical symbol for aluminum

B - Chemical symbol for boron

bu/a - Bushels per acre

C - Symbol for centigrade temperature

Ca - Chemical symbol for calcium

Cl - Chemical symbol for chlorine

cm - Centimeter

Cu - Chemical symbol for copper

EC - Electrical conductivity expressed in micromhos/cm

ft - Foot or feet

g - Gram

H - High as used to indicate salt level (0.50% - 0.75%)

hl/ha - Hectoliters per hectare

in - Inch

K - Chemical symbol for potassium

kg - kilograms

km/hr - Kilometers per hour

L - Low as used to indicate salt level (0.0% - 0.25%)

lb - Pound

m - Meter

meq - Milliequivalents

Mg - Chemical symbol for magnesium

Mn - Chemical symbol for manganese

Mo - Chemical symbol for molybdenum

MPN - Most probable number

MT/ha - Metric tons per hectare

N - Chemical symbol for nitrogen

Na - Chemical symbol for sodium

OM - Organic matter

P - Chemical symbol for phosphorus

ppm - Parts per million

S - Chemical symbol for sulfur

Sr - Chemical symbol for strontium

T - Trace

t/a - Tons per acre

μmhos - Micromhos

WS - Water soluble

Zn - Chemical symbol for zinc

SECTION X

APPENDIX

Table A1. WASTE ANALYSES FOR SEPTEMBER 1973

Salt added to the ration %	Environment	Pen No.	Ca	Mg	Na	K	Total of cations
			%				
0.00	Covered	4	1.23	0.75	0.51	2.83	5.32
	Covered	9	1.23	0.72	0.48	3.02	5.45
	Open	6	1.31	0.65	0.41	2.27	4.64
	Open	13	1.28	0.68	0.40	2.61	4.97
0.25	Covered	1	1.35	0.74	0.80	2.68	5.57
	Covered	12	1.29	0.69	0.83	2.50	5.31
	Open	7	1.16	0.72	0.80	2.68	5.36
	Open	16	1.26	0.68	0.76	2.61	5.31
0.50	Covered	2	1.43	0.77	1.15	2.84	6.19
	Covered	10	1.42	0.75	1.52	3.08	6.77
	Open	8	1.43	0.79	1.19	2.73	6.14
	Open	15	1.19	0.65	1.10	2.45	5.39
0.75	Covered	3	1.26	0.70	1.81	2.84	6.61
	Covered	11	1.15	0.73	1.63	2.91	6.42
	Open	5	1.27	0.70	1.44	2.63	6.04
	Open	14	1.20	0.67	1.57	2.75	6.19

Table A2. WASTE ANALYSES FOR OCTOBER 1973

Salt added to the ration %	Environment	Pen No.	Ca	Mg	Na	K	Total of cations
			%				
0.00	Covered	4	0.76	0.72	0.30	3.44	5.22
	Covered	9	0.79	0.66	0.18	2.62	4.25
	Open	6	0.76	0.77	0.24	3.76	5.53
	Open	13	0.91	0.89	0.20	3.37	5.37
0.25	Covered	1	0.98	0.80	0.51	3.75	6.04
	Covered	12	0.86	0.77	0.64	3.84	6.11
	Open	7	1.00	0.88	0.42	4.08	6.38
	Open	16	0.86	0.74	0.39	3.66	5.65
0.50	Covered	2	0.82	0.77	0.82	4.02	6.43
	Covered	10	0.84	0.75	0.70	3.86	6.15
	Open	8	0.81	0.79	0.69	3.73	6.02
	Open	15	0.77	0.73	0.55	3.05	5.10
0.75	Covered	3	0.92	0.79	0.96	3.46	6.13
	Covered	11	0.81	0.72	0.88	3.39	5,80
	Open	5	0.76	0.74	0.84	3.30	5.64
	Open	14	0.80	0.76	0.78	3.79	6.13

Table A3. WASTE ANALYSES FOR DECEMBER 1973

Salt added to the ration %	Environment	Pen No.	Ca	Mg	Na	K	Total of cations
			%				
0.00	Covered	4	0.77	0.72	0.25	3.62	5.36
	Covered	9	0.82	0.79	0.25	3.87	5.73
	Open	6	0.74	0.79	0.23	4.01	5.77
	Open	13	0.66	0.75	0.15	3.43	4.99
0.25	Covered	1	0.75	0.74	0.44	3.43	5.36
	Covered	12	0.72	0.73	0.75	3.98	6.18
	Open	7	0.66	0.67	0.32	3.47	5.12
	Open	16	0.62	0.71	0.50	3.44	5.27
0.50	Covered	2	0.75	0.72	0.93	3.67	6.07
	Covered	10	0.79	0.78	1.08	4.06	6.71
	Open	8	0.61	0.72	0.68	4.39	6.40
	Open	15	0.65	0.70	0.73	3.47	5.55
0.75	Covered	3	0.76	0.73	1.55	3.98	7.02
	Covered	11	0.71	0.76	1.56	4.27	7.30
	Open	5	0.63	0.70	0.70	3.32	5.35
	Open	14	0.61	0.73	1.21	4.19	6.74

Table A4. WASTE ANALYSES FOR FEBRUARY 1974

Salt added to the ration %	Environment	Pen No.	Ca	Mg	Na	K	Total of cations
			%				
0.00	Covered	4	1.45	0.77	0.51	2.96	5.69
	Covered	9	1.37	0.76	0.47	3.03	5.63
	Open	6	1.42	0.68	0.43	2.50	5.03
	Open	13	1.34	0.72	0.39	2.67	5.12
0.25	Covered	1	1.44	0.73	0.81	2.72	5.70
	Covered	12	1.64	0.76	0.96	2.84	6.20
	Open	7	1.24	0.73	0.78	2.81	5.56
	Open	16	1.36	0.71	0.76	2.65	5.48
0.50	Covered	2	1.49	0.76	1.18	2.90	6.33
	Covered	10	1.49	0.76	0.47	3.03	5.75
	Open	8	1.55	0.76	1.19	2.78	6.28
	Open	15	1.25	0.67	1.11	2.54	5.57
0.75	Covered	3	1.27	0.69	1.59	2.78	6.33
	Covered	11	1.62	0.77	1.54	2.81	6.74
	Open	5	1.35	0.69	1.37	3.64	7.05
	Open	14	1.25	0.67	1.50	2.75	6.17

Table A5. WASTE ANALYSES FOR MARCH 1974

Salt added to the ration %	Environment	Pen No.	Ca	Mg	Na	K	Total of cations
			%				
0.00	Covered	4	1.30	0.79	0.54	2.99	5.62
	Covered	9	1.26	0.74	0.49	3.10	5.59
	Open	6	1.39	0.69	0.43	2.42	4.93
	Open	13	1.38	0.74	0.43	2.81	5.36
0.25	Covered	1	1.41	0.77	0.83	2.81	5.82
	Covered	12	1.32	0.71	0.85	2.57	5.45
	Open	7	1.24	0.77	0.86	2.86	5.73
	Open	16	1.34	0.72	0.80	2.77	5.63
0.50	Covered	2	1.37	0.73	1.10	2.70	5.90
	Covered	10	1.58	0.83	1.69	3.44	7.54
	Open	8	1.48	0.81	1.23	2.82	6.34
	Open	15	1.19	0.65	1.10	2.46	5.40
0.75	Covered	3	1.26	0.71	1.81	2.84	6.62
	Covered	11	1.14	0.72	1.62	2.90	6.38
	Open	5	1.22	0.70	1.39	2.54	5.85
	Open	14	1.24	0.69	1.62	2.85	6.40

Table A6. WASTE ANALYSES FOR APRIL 1974

Salt added to the ration %	Environment	Pen No.	Ca	Mg	Na	K	Total of cations
			%				
0.00	Covered	4	1.65	0.80	0.80	3.49	6.74
	Covered	9	1.49	0.83	0.60	3.48	6.40
	Open	6	1.32	0.71	0.55	3.12	5.70
	Open	13	1.29	0.77	0.51	3.22	5.79
0.25	Covered	1	1.57	0.84	1.00	3.47	6.88
	Covered	12	1.57	0.85	1.00	3.16	6.58
	Open	7	1.25	0.78	0.72	3.05	5,80
	Open	16	1.18	0.76	1.26	3.19	6.39
0.50	Covered	2	1.46	0.81	1.40	3.40	7.07
	Covered	10	1.64	0.87	1.46	3.28	7.25
	Open	8	1.29	0.78	1.25	3.20	6.52
	Open	15	1.20	0.75	1.21	3.12	6.28
0.75	Covered	3	1.56	0.81	1.75	3.31	7.43
	Covered	11	1.49	0.80	1.69	3.09	7.07
	Open	5	1.42	0.74	1.56	3.22	6.94
	Open	14	1.23	0.72	1.50	3.12	6.57

Table A7. AVERAGE WASTE ANALYSES FOR ALL SIX COLLECTION DATES

Salt added to the ration %	Environment	Pen No.	Ca	Mg	Na	K	Total of cations
			%				
0.00	Covered	4	1.19	0.76	0.49	3.22	5.66
	Covered	9	1.16	0.75	0.41	3.19	5.51
	Open	6	1.16	0.76	0.38	3.01	5.31
	Open	13	1.14	0.76	0.35	3.02	5.27
0.25	Covered	1	1.25	0.77	0.73	3.14	5.89
	Covered	12	1.23	0.75	0.84	3.15	5.97
	Open	7	1.09	0.76	0.65	3.16	5.66
	Open	16	1.10	0.72	0.75	3.05	5.62
0.50	Covered	2	1.22	0.76	1.10	3.26	6.34
	Covered	10	1.29	0.79	1.15	3.46	6.69
	Open	8	1.20	0.78	1.04	3.28	6.30
	Open	15	1.04	0.69	0.97	2.85	5.55
0.75	Covered	3	1.17	0.74	1.58	3.20	6.69
	Covered	11	1.15	0.75	1.49	3.23	6.62
	Open	5	1.11	0.71	1.22	3.11	6.15
	Open	14	1.06	0.71	1.36	3.24	6.37

Table A8. LEAF ANALYSIS RESULTS FOR LEAVES SAMPLED AT SILKING[a]

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Replication	N[b]	P	K	Ca	Mg	S[b]
			%					
Check		I	2.37	0.29	2.49	0.71	0.54	0.098
		II	2.69	0.28	2.82	0.57	0.62	0.170
		III	2.86	0.26	2.59	0.47	0.42	0.153
		IV	2.87	0.24	2.54	0.43	0.56	0.205
44.8 (20)	Low	I	2.86	0.33	2.56	0.54	0.45	0.115
		II	3.05	0.34	2.35	0.49	0.39	0.133
		III	2.93	0.37	2.74	0.51	0.34	0.133
		IV	3.05	0.35	2.77	0.58	0.36	0.133
	High	I	2.71	0.34	2.47	0.44	0.53	0.115
		II	2.82	0.35	2.81	0.63	0.41	0.123
		III	2.77	0.39	2.60	0.54	0.42	0.140
		IV	2.91	0.29	2.46	0.60	0.39	0.140
89.6 (40)	Low	I	3.16	0.34	2.67	0.48	0.39	0.140
		II	2.88	0.39	2.99	0.48	0.40	0.133
		III	3.06	0.35	2.30	0.51	0.29	0.145
		IV	3.11	0.31	2.37	0.57	0.36	0.145
	High	I	3.02	0.36	2.77	0.46	0.26	0.125
		II	2.99	0.39	2.87	0.58	0.38	0.145
		III	3.08	0.27	2.59	0.43	0.33	0.125
		IV	3.13	0.36	2.48	0.65	0.38	0.140
134.4 (60)	Low	I	3.38	0.37	2.54	0.53	0.34	0.150
		II	3.22	0.39	2.78	0.52	0.32	0.150
		III	3.17	0.35	2.54	0.41	0.27	0.160
		IV	2.95	0.32	2.56	0.45	0.34	0.140
	High	I	2.76	0.29	2.39	0.60	0.28	0.113
		II	3.20	0.39	2.70	0.52	0.33	0.150
		III	3.32	0.37	3.17	0.47	0.28	0.160
		IV	3.03	0.37	2.32	0.50	0.32	0.153

Table A8 (continued). LEAF ANALYSES RESULTS FOR LEAVES SAMPLED AT SILKING[a]

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Replication	N[b]	P	K	Ca	Mg	S[b]
					%			
179.2 (80)	Low	I	3.28	0.29	2.74	0.36	0.25	0.140
		II	3.31	0.37	2.73	0.49	0.30	0.160
		III	2.90	0.37	2.70	0.54	0.39	0.153
		IV	3.50	0.35	2.59	0.49	0.33	0.173
	High	I	3.01	0.35	2.71	0.42	0.26	0.145
		II	3.17	0.37	2.50	0.41	0.25	0.140
		III	3.06	0.33	2.52	0.54	0.25	0.160
		IV	3.24	0.35	2.34	0.46	0.26	0.173

[a]All Na analyses were less than 0.01%
[b]The tests for these elements were performed by the Soil Testing Laboratory at South Dakota State University

Table A9. LEAF ANALYSIS RESULTS FOR LEAVES SAMPLED AT SILKING

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Replication	Mn	Fe	B	Cu	Zn	Al	Sr	Mo
			ppm							
Check		I	75	223	21	11	30	213	35	1.00
		II	67	242	25	12	26	231	39	0.97
		III	47	233	23	13	27	207	36	0.48
		IV	66	188	26	11	25	165	34	0.83
44.8 (20)	Low	I	152	218	21	11	31	196	34	0.81
		II	210	250	29	12	35	188	34	0.82
		III	167	245	25	11	39	221	36	0.46
		IV	104	237	24	11	24	216	32	0.55
	High	I	129	216	25	11	26	200	35	1.15
		II	104	233	21	11	29	212	33	0.59
		III	74	258	29	11	26	235	31	0.44
		IV	150	218	23	11	33	179	34	0.44
89.6 (40)	Low	I	127	232	21	11	32	193	36	0.49
		II	97	236	22	11	30	212	35	0.53
		III	118	250	29	11	30	216	33	0.62
		IV	140	229	25	10	30	206	34	0.38
	High	I	189	246	26	11	37	196	31	0.38
		II	137	267	24	11	33	219	36	0.52
		III	91	174	29	9	23	138	36	0.42
		IV	112	253	25	11	26	251	34	0.82
134.4 (60)	Low	I	304	280	37	12	48	222	35	0.54
		II	202	250	27	11	41	193	35	0.57
		III	183	234	38	12	34	167	36	0.47
		IV	112	252	25	11	27	244	31	0.47
	High	I	119	194	21	11	34	175	29	0.40
		II	224	270	30	11	47	226	34	0.50
		III	337	252	30	11	50	196	34	0.38
		IV	263	282	47	12	41	205	37	0.48

Table A9 (continued). LEAF ANALYSIS RESULTS FOR LEAVES SAMPLED AT SILKING

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Replication	Mn	Fe	B	Cu	Zn	Al	Sr	Mo
			ppm							
179.2	Low	I	202	195	28	10	31	142	32	0.33
(80)		II	225	264	33	12	47	204	34	0.65
		III	146	250	26	11	32	214	36	0.77
		IV	141	282	25	9	35	279	32	0.42
	High	I	334	245	30	10	51	214	31	0.37
		II	290	264	40	12	48	204	32	0.55
		III	143	281	33	12	31	277	29	0.42
		IV	340	248	36	8	47	208	31	0.49

Table A10. SILAGE AND EAR CORN YIELDS FROM WASTE DISPOSAL PLOTS

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Replication	15.5% moisture Ear corn yield, (hl/ha.)	(bu/a.)	0.0% moisture Silage, (MT/ha.)	Yield, (t/a.)
Check		I	28.22	32.44	3.99	1.78
		II	37.10	42.65	3.76	1.68
		III	45.88	52.73	9.27	4.14
		IV	45.66	52.48	5.64	2.52
44.8 (20)	Low	I	56.88	65.38	7.77	3.47
		II	71.93	82.68	9.16	4.09
		III	38.51	44.26	8.18	3.65
		IV	53.42	61.40	8.78	3.92
	High	I	30.24	34.76	6.81	3.04
		II	60.06	69.03	6.52	2.91
		III	18.58	21.36	5.87	2.62
		IV	32.20	37.01	7.68	3.43
89.6 (40)	Low	I	66.48	76.42	7.39	3.30
		II	55.00	63.22	7.46	3.33
		III	70.96	81.56	11.36	5.07
		IV	56.84	65.34	3.94	1.76
	High	I	67.71	77.83	6.54	2.92
		II	52.84	60.74	8.02	3.58
		III	48.68	55.96	8.31	3.71
		IV	48.76	56.05	8.58	3.83
134.4 (60)	Low	I	61.50	70.69	7.97	3.56
		II	55.04	63.27	8.09	3.61
		III	44.46	51.11	4.41	1.97
		IV	50.06	57.54	3.45	1.54
	High	I	61.90	71.15	6.18	2.76
		II	82.68	95.04	7.75	3.46
		III	46.38	53.31	6.52	2.91
		IV	53.02	60.94	6.27	2.80

Table A10 (continued). SILAGE AND EAR CORN YIELDS FROM WASTE DISPOSAL PLOTS

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Replication	15.5% moisture Ear corn yield, (hl/ha.)	(bu/a.)	0.0% moisture Silage, (MT/ha.)	Yield, (t/a.)
179.2	Low	I	69.41	79.78	8.47	3.78
(80)		II	63.78	73.31	7.06	3.15
		III	56.12	64.51	7.71	3.44
		IV	59.45	68.33	7.48	3.34
	High	I	52.33	60.15	6.18	2.76
		II	69.16	79.49	7.14	3.19
		III	70.60	81.15	5.76	2.57
		IV	23.46	26.96	6.41	2.86

Table A11. SOIL ANALYSES FOR PLOTS RECEIVING THE LOW SALT WASTE AT AN AVERAGE RATE OF 38.52 MT/ha. (17.25 t/a.).

Season	Depth, (cm) (ft)	Replication	Na	K, (meq/100g)	EC, (μmhos/cm)
Fall 1973	0-30.5 (0-1)	I	0.13	0.19	772
		II	0.77	0.47	650
		III	0.05	0.68	547
		IV	0.04	0.58	760
	30.5-61.0 (1-2)	I	0.10	0.41	457
		II	0.18	0.59	1333
		III	0.24	0.50	1134
		IV	0.12	0.34	1571
	61.0-91.4 (2-3)	I	1.29	0.33	633
		II	0.32	0.43	3304
		III	0.56	0.68	4577
		IV	0.33	0.32	4942
	91.4-152.4 (3-5)	I	0.39	0.37	4708
		II	0.50	0.42	5946
		III	0.60	0.52	7060
		IV	0.36	0.38	6647
Fall 1974	0-30.5 (0-1)	I	0.09	0.40	2322
		II	0.21	1.23	3532
		III	0.14	0.72	558
		IV	0.15	1.06	3261
	30.5-61.0 (1-2)	I	1.02	0.35	642
		II	0.22	0.55	900
		III	0.30	0.66	1953
		IV	0.23	0.46	1632
	61.0-91.4 (2-3)	I	0.62	0.46	469
		II	0.33	0.44	3994
		III	0.62	0.69	5644
		IV	0.49	0.39	4505
	91.4-152.4 (3-5)	I	0.85	0.31	5316
		II	0.73	0.29	4843
		III	0.60	0.52	6551
		IV	0.57	0.42	6001

Table A12. SOIL ANALYSES FOR PLOTS RECEIVING THE HIGH SALT WASTE AT AN AVERAGE RATE OF 26.92 MT/ha. (12.02 t/a.)

Season	Depth, (cm) (ft)	Replication	Na (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
Fall 1973	0-30.5	I	0.09	0.20	568
	(0-1)	II	0.07	0.25	536
		III	0.10	0.63	61
		IV	0.05	0.77	677
	30.5-61.0	I	0.03	0.35	551
	(1-2)	II	0.47	0.37	1021
		III	0.13	0.54	542
		IV	0.12	0.60	875
	61.0-91.4	I	0.93	0.42	1645
	(2-3)	II	0.58	0.34	4584
		III	0.25	0.44	3022
		IV	0.28	0.51	2822
	91.4-152.4	I	0.43	0.52	4826
	(3-5)	II	0.50	0.34	8399
		III	0.18	0.33	2083
		IV	0.40	0.37	4873
Fall 1974	0-30.5	I	0.16	0.86	1545
	(0-1)	II	0.18	0.98	2208
		III	0.14	0.71	651
		IV	0.25	0.95	3310
	30.5-61.0	I	0.14	0.47	535
	(1-2)	II	0.23	0.43	931
		III	0.17	0.49	634
		IV	0.25	0.55	444
	61.0-91.4	I	0.55	0.33	4735
	(2-3)	II	0.48	0.30	4557
		III	0.34	0.35	3810
		IV	0.55	0.71	4793
	91.4-152.4	I	0.69	0.83	4808
	(3-5)	II	0.47	0.26	7898
		III	0.43	0.29	4768
		IV	0.71	0.48	6194

Table A13. SOIL ANALYSES FOR PLOTS RECEIVING THE LOW SALT WASTE AT AN AVERAGE RATE OF 101.46 MT/ha. (45.30 t/a.)

Season	Depth, (cm) (ft)	Replication	Na	K,	EC, (µmhos/cm)
			(meq/100g)		
Fall 1973	0-30.5	I	0.07	0.94	785
	(0-1)	II	0.05	1.05	541
		III	0.03	0.59	819
		IV	0.07	0.71	749
	30.5-61.0	I	0.22	0.59	2393
	(1-2)	II	0.22	0.60	2374
		III	0.08	0.38	1625
		IV	0.16	0.42	1782
	61.0-91.4	I	0.35	0.42	4534
	(2-3)	II	0.41	0.48	4086
		III	0.24	0.35	2947
		IV	0.29	0.37	4195
	91.4-152.4	I	0.50	0.32	5736
	(3-5)	II	0.43	0.41	5627
		III	0.30	0.41	5010
		IV	0.40	0.35	5484
Fall 1974	0-30.5	I	0.26	1.57	4804
	(0-1)	II	0.24	1.65	3283
		III	0.22	1.20	3910
		IV	0.37	2.92	7496
	30.5-61.0	I	0.38	0.46	2176
	(1-2)	II	0.29	0.52	1565
		III	0.21	0.44	1268
		IV	0.22	0.47	1328
	61.0-91.4	I	0.62	0.36	5349
	(2-3)	II	0.70	0.44	5228
		III	0.28	0.35	4824
		IV	0.43	0.36	4166
	91.4-152.4	I	0.76	0.29	7332
	(3-5)	II	0.70	0.41	6758
		III	0.15	0.35	4245
		IV	0.45	0.37	6274

Table A14. SOIL ANALYSES FOR PLOTS RECEIVING THE HIGH SALT WASTE AT AN AVERAGE RATE OF 85.32 MT/ha. (38.09 t/a.)

Season	Depth, (cm) (ft)	Replication	Na (meq/100g)	K, (meq/100g)	EC, (µmhos/cm)
Fall 1973	0-30.5	I	0.06	0.88	785
	(0-1)	II	0.04	0.90	541
		III	0.04	0.68	819
		IV	0.02	0.60	749
	30.5-61.0	I	0.14	0.48	2393
	(1-2)	II	0.16	0.69	2374
		III	0.27	0.50	1625
		IV	0.09	0.38	1782
	61.0-91.4	I	1.75	0.37	4534
	(2-3)	II	0.39	0.49	4086
		III	0.10	0.33	2947
		IV	0.23	0.33	4195
	91.4-152.4	I	0.28	0.35	5736
	(3-5)	II	0.40	0.39	5627
		III	0.18	0.39	5010
		IV	0.26	0.34	5484
Fall 1974	0-30.5	I	0.49	2.00	4804
	(0-1)	II	0.23	1.30	3283
		III	0.36	1.27	3910
		IV	0.35	1.30	7496
	30.5-61.0	I	0.23	0.71	2176
	(1-2)	II	0.26	0.52	1565
		III	0.23	0.44	1268
		IV	0.17	0.40	1328
	61.0-91.4	I	0.62	0.51	5349
	(2-3)	II	0.45	0.35	5228
		III	0.36	0.46	4824
		IV	0.32	0.35	4166
	91.4-152.4	I	0.80	0.47	7332
	(3-5)	II	0.53	0.34	6758
		III	0.38	0.39	4245
		IV	0.44	0.35	6274

Table A15. SOIL ANALYSES FOR PLOTS RECEIVING THE LOW SALT WASTE AT AN AVERAGE RATE OF 135.20 MT/ha. (60.38 t/a.)

Season	Depth, (cm) (ft)	Replication	Na (meq/100g)	K,	EC, (μmhos/cm)
Fall 1973	0-30.5 (0-1)	I	0.17	0.69	438
		II	0.06	1.04	879
		III	0.04	0.72	618
		IV	0.11	0.77	800
	30.5-61.0 (1-2)	I	1.31	0.39	1034
		II	0.36	0.62	1629
		III	0.27	0.58	1388
		IV	0.27	0.55	3085
	61.0-91.4 (2-3)	I	0.39	0.42	5339
		II	0.43	0.56	4881
		III	0.46	0.60	5802
		IV	0.44	0.37	5724
	91.4-152.4 (3-5)	I	0.43	0.33	6218
		II	0.36	0.32	3149
		III	0.43	0.49	6982
		IV	0.61	0.41	6467
Fall 1974	0-30.5 (0-1)	I	0.37	3.02	7551
		II	0.21	1.49	3953
		III	0.36	2.26	5535
		IV	0.59	3.09	6503
	30.5-61.0 (1-2)	I	0.31	0.68	1360
		II	0.22	0.71	896
		III	0.22	0.56	1489
		IV	0.25	0.48	2305
	61.0-91.4 (2-3)	I	0.52	0.42	4665
		II	0.53	0.49	5397
		III	0.30	0.41	4656
		IV	0.40	0.33	5088
	91.4-152.4 (3-5)	I	0.74	0.31	6238
		II	0.60	0.29	5708
		III	0.42	0.33	5617
		IV	0.46	0.41	5845

Table A16. SOIL ANALYSES FOR PLOTS RECEIVING THE HIGH SALT WASTE AT AN AVERAGE RATE OF 119.70 MT/ha. (53.44 t/a.)

Season	Depth, (cm) (ft)	Replication	Na (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
Fall 1973	0-30.5	I	0.05	0.55	514
	(0-1)	II	0.06	1.12	625
		III	0.05	0.68	764
		IV	0.07	0.73	1050
	30.5-61.0	I	0.14	0.29	456
	(1-2)	II	0.58	0.47	955
		III	0.14	0.61	615
		IV	0.12	0.56	1769
	61.0-91.4	I	0.21	0.37	783
	(2-3)	II	0.20	0.41	2392
		III	0.35	0.69	1846
		IV	0.24	0.46	5049
	91.4-152.4	I	0.51	0.31	3606
	(3-5)	II	0.46	0.51	5438
		III	0.50	0.54	5122
		IV	0.31	0.31	6103
Fall 1974	0-30.5	I	0.59	2.07	5357
	(0-1)	II	0.52	1.41	5302
		III	0.57	1.79	5466
		IV	0.48	1.76	5700
	30.5-61.0	I	0.11	0.38	773
	(1-2)	II	0.21	0.47	3324
		III	0.25	0.58	768
		IV	0.18	0.47	1978
	61.0-91.4	I	0.34	0.37	2516
	(2-3)	II	0.64	0.29	5420
		III	0.45	0.75	4559
		IV	0.24	0.32	4290
	91.4-152.4	I	0.78	0.36	4689
	(3-5)	II	0.70	0.29	7359
		III	0.81	0.76	5851
		IV	0.33	0.35	4999

Table A17. SOIL ANALYSES FOR PLOTS RECEIVING THE LOW SALT WASTE AT AN AVERAGE RATE OF 169.55 MT/ha. (75.70 t/a.)

Season	Depth, (cm) (ft)	Replication	Na (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
Fall 1973	0-30.5	I	0.05	0.93	549
	(0-1)	II	0.09	0.92	1472
		III	0.10	0.77	613
		IV	0.09	0.74	1058
	30.5-61.0	I	0.11	0.66	1000
	(1-2)	II	0.41	0.64	4955
		III	0.26	0.52	2229
		IV	0.55	0.58	3024
	61.0-91.4	I	0.28	0.52	4491
	(2-3)	II	0.57	0.37	6261
		III	0.33	0.32	6180
		IV	0.47	0.42	8305
	91.4-152.4	I	0.51	0.36	6567
	(3-5)	II	1.22	0.35	3366
		III	0.43	0.31	5839
		IV	0.39	0.41	7574
Fall 1974	0-30.5	I	0.31	2.38	3830
	(0-1)	II	0.43	2.53	5414
		III	0.36	1.90	4871
		IV	0.23	1.89	5496
	30.5-61.0	I	0.24	0.80	1111
	(1-2)	II	0.33	0.50	2459
		III	0.45	0.55	2414
		IV	0.34	0.47	3170
	61.0-91.4	I	0.36	0.53	4172
	(2-3)	II	0.49	0.39	5072
		III	0.48	0.33	4726
		IV	0.38	0.30	5845
	91.4-152.4	I	0.60	0.38	6328
	(3-5)	II	1.68	0.30	6224
		III	0.60	0.38	6095
		IV	0.18	0.30	6585

Table A18. SOIL ANALYSES FOR PLOTS RECEIVING THE HIGH SALT WASTE AT AN AVERAGE RATE OF 172.69 MT/ha. (77.10 t/a.)

Season	Depth, (cm) (ft)	Replication	Na (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
Fall 1973	0-30.5	I	0.05	0.76	547
	(0-1)	II	0.04	0.79	461
		III	0.06	0.58	1688
		IV	0.08	0.70	625
	30.5-61.0	I	0.25	0.48	1024
	(1-2)	II	0.16	0.68	1580
		III	0.22	0.33	2398
		IV	0.27	0.49	2358
	61.0-91.4	I	0.68	0.72	4897
	(2-3)	II	0.49	0.36	5028
		III	0.25	0.34	3157
		IV	0.29	0.26	5908
	91.4-152.4	I	0.57	0.37	8334
	(3-5)	II	0.48	0.33	6045
		III	0.33	0.36	4142
		IV	0.30	0.32	5783
Fall 1974	0-30.5	I	0.58	2.15	5855
	(0-1)	II	0.48	1.99	6511
		III	0.74	2.09	6517
		IV	0.46	1.50	5183
	30.5-61.0	I	0.31	0.78	1288
	(1-2)	II	0.27	0.83	1288
		III	0.20	0.37	1782
		IV	0.28	0.54	3238
	61.0-91.4	I	0.59	0.61	4925
	(2-3)	II	0.35	0.54	4446
		III	0.34	0.37	3137
		IV	0.44	0.36	5785
	91.4-152.4	I	0.62	0.38	7086
	(3-5)	II	0.45	0.42	4966
		III	0.40	0.34	4408
		IV	0.34	0.35	6666

Table A19. MEAN VALUES FOR EXCHANGEABLE Na, K, AND EC FOR THE MAIN EFFECTS

	Season		
	Na, (meq/100g)	K, (meq/100g)	EC (μmhos/cm)
Fall 1973	0.09	0.71	720
Fall 1974	0.35	1.67	4430

	Waste rate		
Proposed rate, (MT/ha.)(t/a.)	Na (meq/100g)	K (meq/100)	EC (μmhos/cm)
44.8 (20)	0.16	0.67	1372
89.6 (40)	0.18	1.23	2566
134.4 (60)	0.27	1.45	3193
179.2 (80)	0.26	1.41	3168

	Salt treatment		
	Na (meq/100g)	K (meq/100g)	EC (μmhos/cm)
Fall 1973	0.20	1.29	2636
Fall 1974	0.23	1.09	2513

Table A20. MEAN VALUES FOR EXCHANGEABLE Na, EXCHANGEABLE K AND EC FOR THE SEASON BY WASTE RATE INTERACTION

Proposed rate, (MT/ha.) (t/a.)	Season	Na, (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
44.8 (20)	Fall 1973	0.16	0.47	571
	Fall 1974	0.16	0.86	2173
89.6 (40)	Fall 1973	0.05	0.79	718
	Fall 1974	0.32	1.66	4415
134.3 (60)	Fall 1973	0.07	0.79	714
	Fall 1974	0.46	2.11	5671
179.2 (80)	Fall 1973	0.07	0.77	877
	Fall 1974	0.45	2.05	5460

Table 21. MEAN VALUES FOR EXCHANGEABLE Na, EXCHANGEABLE K, AND EC FOR THE SEASON BY SALT TREATMENT INTERACTION

Season	Salt treatment	Na, (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
Fall 1973	Low	0.12	0.74	753
	High	0.06	0.68	687
Fall 1974	Low	0.28	1.84	4520
	High	0.41	1.51	4339

Table A22. MEAN VALUES FOR EXCHANGEABLE Na, EXCHANGEABLE K, AND EC FOR THE WASTE RATE BY SALT TREATMENT INTERACTION

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Na, (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
44.8 (20)	Low	0.20	0.67	1550
	High	0.13	0.67	1194
89.6 (40)	Low	0.16	1.34	2798
	High	0.20	1.12	2335
134.4 (60)	Low	0.24	1.64	3285
	High	0.30	1.26	3101
179.2 (80)	Low	0.21	1.51	2913
	High	0.31	1.32	3423

Table A23. MEAN VALUES FOR EXCHANGEABLE Na, EXCHANGEABLE K AND EC FOR THE SEASON BY WASTE RATE BY SALT TREATMENT INTERACTION

Proposed rate, (MT/ha.) (t/a.)	Salt treatment	Fall 1973			Fall 1974		
		Na (meq/100g)	K (meq/100g)	EC, (μmhos/cm)	Na (meq/100g)	K, (meq/100g)	EC, (μmhos/cm)
44.8 (20)	Low	0.25	0.48	682	0.15	0.85	2418
	High	0.08	0.46	460	0.18	0.88	1928
89.6 (40)	Low	0.06	0.82	724	0.27	1.86	4873
	High	0.04	0.76	713	0.36	1.47	3956
134.4 (60)	Low	0.10	0.80	683	0.38	2.46	5886
	High	0.06	0.77	745	0.54	1.76	5456
179.2 (80)	Low	0.08	0.84	923	0.33	2.18	4903
	High	0.06	0.71	830	0.56	1.93	6016

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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16. ABSTRACT

The effect of salt level of the ration for beef steers upon salinity of the waste and the effects of the applied waste upon the soil and upon crop production was investigated. In addition, the study was conducted in both covered and open feedlot pens to study the effect of shelter in a northern climate upon animal performance and waste characteristics.

The field portion of the study included four rates of waste up to 179 MT/ha. applied to plots 0.02 ha. in size. Detailed soil analyses were made which included salinity, nutrients, cations, and the dispersion hazard as indicated by the level of exchangeable sodium.

The levels of salt used in the ration appeared to have little or no effect on animal performance; however, the salinity and sodium levels of the waste were directly affected. The salinity level of the surface 30 cm of soil where high rates of waste were applied was sufficiently high to affect the growth of corn. The lack of leaching water caused a maximum effect of the applied waste in the surface layer.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Soil analysis Disposal Wastes Saline soil Soil properties	Soil disposal fields Application rates Waste composition Corn yields Climatic factors Crop production	2A

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