SALT THRESHOLDS FOR LIQUID MANURE APPLICATIONS THROUGH A CENTER PIVOT

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INTRODUCTION

Application of liquid manure to growing crops is often a convenient and agronomically acceptable means of land application. Center pivots have been adapted to apply a broad range of fertilizers and pesticides. Development of large animal production facilities has added manure application to the list of materials that can be applied via center pivots. Al-Kaisi, et al. (2002) reported on the impact of using a center pivot to apply dilute swine lagoon water to cropland in Colorado. However, some producers have learned the hard way that manure contains some good and some bad materials. Occasionally, crop damage occurs as a result of application of concentrated manure presumably because of high salt concentrations.

Sprinkler application of animal manure to growing crops is a different issue than most of the salinity research that has been conducted across the country. Soluble salt levels in liquid manures are often higher than in the saline water used for irrigation in the western U.S. When irrigating with saline irrigation water the major problem is buildup of salt over time due to removal of the water by the crop leaving the salts behind. However, application of manure occurs at relatively low rates per acre and the annual rainfall or irrigation tends to leach the undesirable salts from the profile between applications. An additional concern with center pivot application of concentrated swine manure is the potential for plant damage (phytotoxicity) due to high ammonia levels.

Crop damage due to sprinkler application of manure with high EC levels occurs because of the direct contact of the salt with plant leaves and potentially the roots. Early research reporting the salinity thresholds for induced foliar injury concluded that since damage was caused by salt absorption into plant tissues, foliar application should be avoided in hot, dry, windy conditions that produce high potential evapotranspiration (PET). It was noted that species varied in the rate of foliar absorption of salts, such as: sorghum < cotton = sunflower < alfalfa = sugar beet < barley < potato. However, the susceptibility to injury was not related to salt absorption, as injury varied as: sugar beet < cotton < barley = sorghum < alfalfa < potato (Maas, et al., 1985; Maas, 1982). They found that leaf absorption of salts may be affected by leaf age, with generally less permeability in older leaves, and by angle and position of the leaf, which may affect the time and amount of leaf salt exposure. Producers need to know what the safe levels are and the effect of timing on potential plant damage for corn and soybeans.

The goal of the project was to establish the safe level of salt that could be applied to corn and soybean at different stages of growth. To accomplish this goal, a range of swine manure concentrations was applied to a growing crop in a manner that simulated application via a center pivot.

METHODS

Salt and ammonia concentration data from over 2700 manure samples were obtained from a private laboratory to determine the range in concentrations that should be evaluated in the field research. The EC level is an indication of the salt concentration in the manure sample. Figure 1 is a summary of the samples analyzed where the median EC level was 6.7 dS m^{-1} with a range from 0.1 to 70 dS m^{-1}. The median ammonia concentration was 497 ppm NH_4-N with a range from 0.03 to 12646 ppm NH_4-N.

The field research was conducted at the Haskell Agricultural Laboratory of the University of Nebraska located near Concord, Nebraska. The soil was a Kennebec silt loam with a pH of 7.3, and 3.5% soil organic matter. Corn (cv. Pioneer Brand 34N43) was planted on 16 May 2003 at 27,000 seeds per acre. Soybean (cv. Garst 2502) was planted on 28 May 2003 at 189,000 seeds per acre. Field plots were 8-30 inch rows wide and 35 feet long randomly arranged with three replications. The experimental area was irrigated with a lateral-move sprinkler irrigation system equipped with low-pressure spray nozzles mounted on top of the pipeline. The EC of the irrigation water was 0.6 dS m^{-1}. Irrigation was applied as needed to maintain greater than 50% available water in the rootzone. Irrigation supplied 8 inches of irrigation water to both crops, and precipitation supplied 14.4 inches between 1 May and the end of the season.

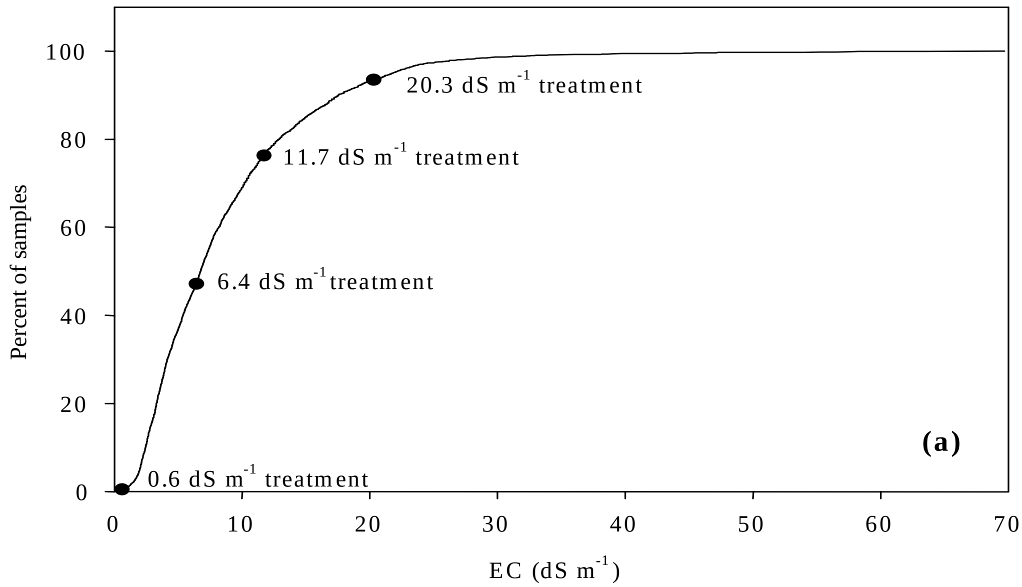

Figure 1. Cumulative distribution of electrical conductivity of liquid manure submitted for analysis to a commercial laboratory in Nebraska. The concentrations used in this study are also presented.

Swine manure from a commercial confined feeding operation was pumped from an under-building storage pit through a 2 mm screen to remove large solids. The liquid manure was passed through a 0.4 mm screen and then pumped to transfer tanks equipped to continuously agitate the liquid. Multiple screening was necessary to prevent the applicator nozzles from plugging during application. The EC of the solutions was determined using a conductivity meter (ATI Orion model 130, Analytical Technology, Inc., Boston, Mass.) calibrated with either a 1 or 10 dS m^{-1} solution. Liquid manure samples for both applications were collected from the supply tank outlet between the tank and the applicator and sent to Ward Laboratories to determine EC and nutrient concentration (Table 1).

The screened manure was diluted with fresh water to create four levels of EC in the liquid manure. The original manure had an EC level of 20.3 dS m^{-1}. Fresh water was added to dilute the manure down to 6.4 and 11.7 dS m^{-1}. Fresh water with an EC of 0.6 dS m^{-1} was used as a control treatment.
A portable applicator was developed and attached to the boom of a Hi-Boy sprayer (Figure 2). The applicator consisted of 21 nozzles arranged in a 3-nozzle wide by 7-nozzle long grid with a spacing of 3 feet between nozzles in each direction. The liquid manure application treatments consisted of a single application of four soluble salt concentrations applied at one of two selected

Table 1. Chemical analysis of liquid manure applied to corn and soybean at Concord, Nebraska, in 2003 (all values in lb/ac except where noted).

	EC Level ($dS\ m^{-1}$)[1]							
	0.6		6.4		11.7		20.3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Organic N	0.04	0.04	23.8	3.1	63.6	22.0	179.2	41.0
Ammonium N	0.5	0.1	78.6	9.6	170.4	6.0	365.7	15.9
P as P_2O_5	0.6	0.4	33.7	4.6	112.8	61.3	301.0	72.9
K as K_2O	0.9	0.1	60.7	5.6	130.6	8.8	281.5	26.3
S	3.5	0.5	12.2	1.8	25.5	4.5	53.4	7.1
Ca	8.9	1.0	19.4	1.6	57.9	36.2	131.6	33.0
Mg	2.0	0.1	8.9	0.9	23.2	10.6	57.9	13.4
Na	2.5	0.1	13.8	1.2	27.7	1.2	59.7	3.6
Soluble salts	37.0	1.3	412.4	43.6	753.5	24.2	1303.1	65.0
EC ($dS\ m^{-1}$)	0.60	0.00	6.4	0.67	11.7	0.38	20.3	1.01
pH	7.87	0.72	6.9	0.12	6.6	0.06	6.2	0.12
Dry matter (%)	0.05	0.01	0.5	0.05	1.8	0.97	4.2	0.86

[1] Mean EC levels for the fresh water used as a control treatment and liquid manure dilutions applied to corn and soybean.

growth stages of corn and soybean. The first application was applied on July 2when corn was at the V7 growth stage and soybean was in the V3 stage (Ritchie, et al., 1996; Ritchie and Hanway, 1984). Air temperatures during application were in the upper 80's. The second application was applied on July 24 when corn was at the V14 stage and soybean was at the R1 stage. Air temperatures during application were again in the upper 80's. Approximately 0.5 inches of liquid manure was applied over a 10-minute period to corn and soybeans at each EC level.

Figure 2. Applicator used to apply liquid swine manure to corn and soybean.

RESULTS

Soybean

Each of the production indices was decreased by the 20.3 dS m^{-1} liquid manure for both application times (Table 2). Soybean plant population at harvest was less with the V3 application of 20.3 dS m^{-1} liquid manure than with the 0.6, 6.4, or 11.7 dS m^{-1} treatments, but the R1 application did not affect plant population. Leaf area was damaged by the V3 application but the plants recovered due to less inter-plant competition from a reduced plant population. Thus, the final plant LAI was not significantly different between application dates except for the 20 dS m^{-1} application.

Table 2. Effects of EC level of liquid manure and application time on soybean plant populations, leaf area, dry matter production, and grain yield for the 2003 growing season.

	EC Level (dS m^{-1})				Analysis of Variance[1] (P > F)		
	0.6	6.4	11.7	20.3	Time	EC Level	T × R[2]
Harvest population (pl/ac)							
V3[3]	93800	102700	92000	24300	0.001*	0.003*	0.26
R1 (V7)[3]	100900	106200	102700	104400			
P > F	0.67	0.82	0.55	<0.0001*			
LAI							
V3	4.6	4.5	2.2	0.3	0.85	0.0001*	0.03*
R1 (V7)	3.5	4.1	2.5	1.5			
P > F	0.06	0.46	0.48	0.03*			
Whole-plant dry matter at maturity (lb/ac)							
V3	7447	7893	7395	1071	0.52	< 0.0001*	0.07
R1 (V7)	6760	7400	7044	3909			
P > F	0.50	0.63	0.73	0.01*			
Grain yield (bu/ac)							
V3	43	39	40	5	0.12	< 0.0001*	0.02*
R1 (V7)	42	41	38	23			
P > F	0.57	0.40	0.32	<0.0001*			

1 Statistical significance of ANOVA main effects are given by the probability of the F-test (α = 0.05); significant differences are indicated by *.
2 T × R is the timing × rate interaction.
3 V3 and V7 are leaf stage at the time of application. R1 is the stage of growth, but V7 indicates that seven trifoliates were on the plant at the time of application.

When averaged over both application timings, grain yields were the same for the 0.6, 6.4, and 11.7 dS m^{-1} manure applications, averaging 41 bu/ac, as compared to 14 bu/ac for the 20.3 dS m^{-1} application. Soybean with the 20.3 dS m^{-1} application at R1 had much higher grain yield (23 bu/ac) than with the 20.3 dS m^{-1} application at V3 (5 bu/ac). Thus, swine manure applied at EC levels less than 11.7 dS m^{-1} have little impact on final yield despite causing plant damage at lower concentrations early in the growing season.

Corn

Corn growth was less affected than soybean, and damage was detected only with the V8 application at the 20.3 dS m^{-1} concentration (Table 3). The V14 application caused even less damage, likely due to salt tolerance of the fully developed cuticle on the corn leaves. The V8 application of 20.3 dS m^{-1} concentration caused some stunting of plants but no plant death. Overall, the manure increased the corn yields when applied at V14 (178 bu/ac) compared to V8 (165 bu/ac).

Table 3. Effects of EC level of liquid manure and application time on corn plant populations, leaf area, dry matter production and grain yield for the 2003 growing season.

	EC Level (dS m^{-1})				Analysis of Variance[1] (P > F)		
	0.6	6.4	11.7	20.3	Time	EC Level	T × R[2]
Mature plant population (pl acre)							
V8[3]	23522	24103	22216	24684	0.12	0.11	0.04*
V14[3]	22506	25410	25555	24394			
P > F	0.33	0.22	0.005*	0.78			
Leaf area (cm^2 $plant^{-1}$)							
V8	5161	5211	5149	4428	0.09	0.41	0.17
V14	4899	5667	5326	5543			
P > F	0.53	0.29	0.67	0.02*			
Whole plant dry matter at maturity (lbs/ac)							
V8	6987	7800	6883	5784	0.15	0.04*	0.35
V14	6894	7654	7944	6874			
P > F	0.89	0.82	0.11	0.11			
Grain yield (Mg ha^{-1})							
V8	175	181	154	149	0.02*	0.08	0.02*
V14	164	186	179	185			
P > F	0.28	0.65	0.02*	0.003*			

[1] Statistical significance of ANOVA main effects are given by the probability of the F-test (α = 0.05); Significant differences are indicated by *.
[2] T × R is the Timing × Rate statistical interaction.
[3] V8 and V14 are leaf stages at the time of application.

Weather conditions following liquid manure application may be important to crop tolerance. Crop damage is expected to be more severe under dry, hot, and windy conditions (Nielson and Cannon, 1975; Maas et al., 1982) with more foliar absorption of salts at higher temperatures (Busch and Turner, 1967). Although this study was conducted during one growing season, the weather conditions were within the range of most likely conditions for the time of application.

The liquid manure applications in this study were greater than typically applied by farmers in order to induce measurable damage. Application through a center pivot may keep the foliage wet and the salts soluble longer than the approximate 10 min in our study, especially near the center of the pivot circle. Our application rate was 0.5 ac-inches, but some pivots can apply as little as 0.2 ac-in), reducing the total amount of soluble salts applied and the potential for leaf damage.

SUMMARY

Producers can use inexpensive EC meters to estimate the potential for damage with liquid manure application. Application of liquid manure to corn and soybean through a sprinkler system is feasible with proper management. The results support the hypothesis that growth stage and liquid manure soluble salt concentration (EC levels) influence plant damage. Based on the conditions of this study, liquid manure with EC levels greater than 6.4 dS m^{-1} should not be applied to soybean during early vegetative growth. Liquid manure with EC levels less than 11.7 dS m^{-1} can be applied to corn and to soybean after flowering. If the soybean plants are not defoliated as a result of liquid manure application, yield is not likely to be reduced. Crop tolerance to soluble salt application is greater during the reproductive growth stages of the season than during the early vegetative stages. Applications of liquid manures that keep the foliage wet for longer periods than used in this study should be done on an experimental basis to make sure phytotoxicity is not increased by increased wetting periods.

REFERENCES

Al-Kaisi, M. M., and R. M. Waskom. 2002. Utilizing swine effluent for sprinkler-irrigated corn production. *J. Soil and Water Conserv.* 57(1): 111-120.

Busch, C. D., and F. Turner, Jr. 1967. Sprinkler irrigation with high salt-content water. *Trans. ASAE* 10(2): 494-496.

Maas, E. V. 1985. Crop tolerance to saline sprinkling water. *Plant and Soil* 89(2): 273-284.

Maas, E. V., S. R. Gratton, and G. Ogata. 1982. Foliar salt accumulation and injury in crops sprinkled with saline water. *Irrig. Sci.* 34): 157-168.

Nielson, R. F., and O. S. Cannon. 1975. Sprinkling with salty well water can cause problems. *Utah Sci.* 36: 61-63.

Ritchie, S., J. Hanway, H. Thompson, and G. Benson. 1996. How a soybean plant develops. Special Report No. 53. Ames, Iowa: Iowa State University.

Ritchie, S., and J. Hanway. 1984. How a corn plant develops. Special Report No. 48. Ames, Iowa: Iowa State University.