RESEARCH REPORT

ENVIRONMENT

Title: Establishing Effects of application of Swine Manure on Crop Leaf Damage to Growing Crops - **NPB #02-193**

Investigator: Charles Shapiro

Co-Investigator: William L. Kranz

Institution: University of Nebraska

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Abstract: Swine manure from a below barn storage facility was applied to growing corn and soybeans to determine phytotoxic effects. The manure had an electrical conductivity of around 20 mmhos/cm and was diluted for treatment at full, half, quarter and none. The manure mixtures were applied at a rate of 0.5 in/acre using a procedure that wet the foliage three times in a 15-minute time span. Manure mixtures were applied at V7 and V14 for corn and V3 and R1 for soybeans. Phytotoxic effects were shown at the high rate for both crops, but soybeans were killed at the early application date. Yields were decreased at the 20 EC rate for the first application by 89% and 15% for the soybeans and corn, respectively. At the second application the 20 EC mixture decreased yields by 45% for the soybeans and increased yields by 13% for the corn. For both soybean stages EC values of 12 and 6 decreased yields 8% and 6%, respectively. For the V8 application on corn, the 12 and 6 EC mixtures decreased yield 12% and increased yield 4%, respectively. For the V14 application on corn the 12 and 6 EC mixture increased yields 10 and 13%, respectively. Phytotoxicity ratings of leaf burn, stunting and leaf area generally showed results consistent with yield influences. These results indicate that applications of manure with an EC of 6 or less will most likely be safe for mid-season applications to both soybeans and corn.

Introduction: The use of irrigation systems to apply swine (*Sus scrofa*) effluent and liquids from holding ponds is a popular application method due to labor savings, increased use of lagoon storage systems, and the improved crop utilization of the nutrients in the manure when applied close to when the crop needs the nutrients.

Anecdotal reports from producers using center pivot and other irrigation systems to apply swine wastes have reported incidents of crop damage. When available, extension literature recommendations are based on salt effects. However, most of the literature on the salt effects on crop growth is on long term reduction in crop growth from both soil salt and irrigation water effects. These effects were determined by continual irrigation with known salt concentrations and the salt effects accumulate overtime. [Usually salt in irrigation water is measured in electrical conductivity (EC).]

Aerial application of swine manure is a different situation than flood or furrow irrigation with salty water. Swine manure applications to a particular field may be an annual event but not a continued event. In the areas of Nebraska where sprinkler applied swine wastes is practiced 30-year normal annual precipitation varies from 381 to 686 mm (15 to 27 in) (HPRCC, 2003). This is enough rainfall to flush salts below the root zone when salt is applied at moderate levels. Hence, long term salt buildup is usually not a problem. Swine manure contains more than salt and so there may be non-salt related phyto-toxic effects.

The concern by producers is of immediate damage to growing crops. Producers want to know how much effluent can be applied with the irrigation system at one time without damaging the crops. Application by center pivot may include the renting of an agitator to mix the manure liquids and solids. This means that dilution of swine wastes increases the cost of application due to the need for multiple applications.

An alternative to dilution of swine waste is the opportunity to wash off swine waste residue by irrigating with straight water after the manure is applied. Due to the engineering of center pivots, making a second application of fresh water would be delayed at least 24 hours and possibly as long as 48 hours.

Objectives: The objectives of this study were to determine the maximum EC of swine effluent that can be irrigated on corn and soybeans without immediate crop damage at several crop stages and determine if injury is reduced by irrigating with fresh water to wash off the waste in a time frame equivalent to the revolution time of a 51 ha (125 ac) center pivot.

Methods and Methods: The project was conducted at the Haskell Agricultural Laboratory of the University of Nebraska located near Concord, NE. The site was a Kennebec silt loam, (fine-silty, mixed, mesic cumulic hapludoll). Soil samples taken from the field before planting indicated a pH of 7.3, soil organic matter of 3.5%, surface texture of silty clay loam, Bray –1 P 63 ppm, Olsen P 51 ppm, and potassium 532 ppm. Soil nitrates in the surface were 12.6 ppm; irrigation water was predicted to supply 31 lbs N thru the growing season. With a previous crop of soybeans and a corn yield goal of 180 bu/acre the recommended nitrogen rate was 55 lbs N/acre. In order to avoid any potential nutrient deficiencies prior to manure applications 150 lbs N as urea was applied preplant. The experimental area was irrigated with a lateral move sprinkler irrigation system equipped with low-pressure spray nozzles mounted on top of the pipeline. Irrigation was applied as needed to maintain at least 50% available moisture in the rooting depth. At season end there were 8 in of irrigation water applied and there were 14.4 inches of rainfall from May 1 to the end of the season.

Swine waste from a confined feeding operation was used in the experiment. The manure was pumped from an under-building storage pit to transport tanks. At the time of pumping a screen (2 mm) was used to filter out large particles in the manure. Waste was filtered again to remove solids greater than (0.4 mm). After the solids were separated, the manure was pumped to transfer tanks which were plumbed to allow agitation.

The experiment was designed to have four effluent EC levels applied at three growth stages to corn and soybeans. Due to difficulty obtaining suitable effluent and separating the large particles from the effluent, the first two planned timings were not accomplished early in the season. Two additional stage of growth applications were applied to plants planted later in the season to determine immediate plant toxicity, but were not taken to yield.

In experiment 1, corn variety Pioneer Brand 34N43 was planted on 16 May 2003 at 27,000 plants/acre (66,690 plants ha^{-1}). Soybeans Garst variety 2502 was planted on 28 May 2003 at 189,000 plants/acre (466,830 plants ha^{-1}). Experimental units were 8 rows wide in 2.5 ft (0.76 m) row spacing and approximately 40 ft (10 m) long. The experiment was designed as a randomized complete block with three replications. A fourth replication was designated as the wash off treatment. The target ECs for the experiment were based on dilutions of the source manure. The concentrations used were 100, 50, 25 and 0% swine waste. Treatment EC was determined using a (ATI Orion Model 130 Conductivity Meter, Analytical Technology, Incorporated, Boston, MA) calibrated with either a 100 micro Siemen or 1000 micro Siemen calibration solution. Swine waste was diluted with water at approximately 1:1 ratio for the 50% treatment. The remaining 50% solution was diluted again at a 1:1 ratio to achieve the 25% treatment. Each treatment was checked with the EC meter. A sample was collected and sent to a commercial laboratory for confirmation of the EC and other chemicals. Table 1a, b, c contains the EC and chemical content of the mixtures for each treatment at each application time.

Corn and soybean blocks were adjacent. Alleys were cut to allow treatment irrigation system to be moved from one experimental unit to another. Alleys were either on the north or south side of the experimental unit. The treatment irrigation system was positioned over the middle four rows of the experimental unit.

The liquid manure application system (LMAS) consisted of a modified HiBoy (Hanhn 670). The boom supported a PVC pipe manifold constructed to apply uniform liquid to a 2.3 m wide by 7 m long pattern (7.7 ft x 23.3 ft). Nozzles were arranged in a grid of 3 nozzles wide by 7 nozzles long. Each nozzle (Spraying Systems, Model WSQ17) produced a 0.8 m square (2 ft 7 in square in) pattern at 2.2 kPa (15 psi; Figure 1).

The LMAS was calibrated with effluent and water prior to conduct of the experiment. The application of liquid manure was approximately 12 mm min^{-1} (0.47 in min^{-1}). Due to the concentration of N in the liquid manure and to more closely simulate the application time of a center pivot, treatments were applied using the following procedure: 20 sec of application at pressure, followed by 5 minutes of no application, 20 sec of application, followed by 5 minutes of no application, 20 sec of application.

Application timing one (AT1) was conducted when the corn was in the V8 leaf stage (July 2, 2003) and the soybeans were in the V3 leaf stage (Ritchie and Hanway, 1984; Ritchie et al. 1996). Application timing two (AT2) was conducted when the corn was in V14 (July 24, 2003) and the soybeans were in the R1, flowering stage and had 7 trifoliates. Weather conditions at the time of application may affect plant reaction to swine manure damage. The precipitation, maximum and minimum air temperatures, relative humidity, incoming solar radiation and estimated potential evapotranspiration (PET) are given in Table 2 for seven days beginning with each application date.

In order to determine the effect of swine manure application on early season growth, corn (Asgrow 601) and soybeans (Asgrow 3003) were planted 25 Aug 03 with a two-row planter. Since these crops were not to be taken to yield, both corn and soybeans were planted in alternating two-row strips. Four rows of each crop had treatments applied perpendicular to row direction at the appropriate growth stages. Using the LMAS, the same swine manure treatments were applied at two additional growth stages: V2 (AT3; 5 September 2003) and V5 for corn (AT4; 23 September 2003), and unifoliate and 2nd trifoliate for soybeans. Only population and phytotoxcity ratings were taken for these manure applications.

For all applications, AT1, AT2, AT3 and AT4 wash off treatments were conducted between 24 and 36 hours after application with fresh water. For AT1 and AT2 the lateral move irrigation system applied 0.5 in of water over the wash-off block. For AT3 and AT4, the LMAS was positioned over the experimental units and water applied for one minute (12 mm; 0.47 in).

Plant population was taken from 6.1 m (20 ft) of row before manure application and again at harvest. After application, plants were visually examined every 3 days until visible effects were stabilized. All treatments were rated for leaf necrosis (28 July 2003 and 6 August 2003) and for degree of stunting 6 August 2003). At the end of the season plant height was measured (26 August 2003) and for corn ear height measured.

For the AT1 and AT2 applications leaf area measurements were taken at the R5 stage in corn (beginning dent) and soybeans (beginning seed) using a (LI3100 area meter, LI-COR Inc., Lincoln, NE). Four consecutive plants from corn and 0.5 m of soybean row were taken from each experimental unit for the AT1 and AT2 treatments. Results are reported on a per plant basis for both soybeans and corn. Soybean leaf area was converted to leaf area index by dividing the sq cm of leaf area by the area from which the plants were harvested to give a unitless measure of leaf surface relative to the ground area. Due to the late planting for the AT3 and AT4 only visual ratings were taken from those treatments.

Whole plant samples were taken from 1 m of row from the soybeans at R6 stage on 19 September 2003 and from the corn at the R9 stage on 22 September 2003. Soybeans were weighed; five plants were ground and a subsample weighed before drying at 60 degrees C until dry. For soybeans, subsample dry weight was used to adjust total dry matter to 0% moisture and weights given in lbs/acre. Soybean grain yield was taken from 12.2 m (2 rows 20 ft.) of row on 17 October 2003. Soybeans were shelled and grain moisture taken (Dickey-John Model GAC2000 grain analysis computer Dickey-John Corporation, Auburn, IL 62615). Grain yield is reported in bu/acre at 13.5% moisture.

For corn, total drymatter was based on six plants taken at random from each plant. Ears were removed and weighed and dried separately. Corn stalks were chopped and a subsample weighed wet, dried until constant weight, and reweighed. Stalk and leaf weights are given at 0% moisture in lbs/acre. Grain samples were collected on 23 October 2003 from two rows (12.1 m), and shelled in the field. Grain moisture was taken with a Dickey-John and grain yield reported at 15.5% moisture in bu/acre.

Statistical analysis was accomplished using SAS Proc Mixed. One of the objectives was to determine if washing off the manure changed plant reaction to the application. Due to the design of the experiment, which was limited by our ability to accomplish the wash off as a true treatment, there is no completely valid test to determine significance. Because there was significant rain following the AT1 treatment and the AT3 and AT4 treatment were frost killed this aspect of the analysis was abandoned. All results are presented based on three replications.

Results:

Manure application

Swine manure treatments while not exactly at the 0, 25, 50, and 100% of the swine manure were close at 3, 32, 58, and 100 % that averaged 0.6, 6.4, 11.7, and 20.3 EC, respectively. From the literature, the expectation was that the 0 and 25% application rates should not cause damage, while some damage might be expected with the higher rates.

Application rate was just about 0.5 inches per treatment so the applied quantities for the chemicals is about half of the values in table 1. At the high concentration treatments significant nitrogen, phosphorus, potassium, sulfur and soluble salts were applied. Soil samples were not taken from the AT1 and AT2 treatments after application, but soil samples were taken from the top 2 in of the AT4 treatments 7 days after application from the 0, 50 and 100 % treatments. Soil pH was not changed, but soil nitrates, Mehlich3 P and ammonium were increased due to manure application (data not shown). Most dramatically soil ammonium was 5.2, 59, and 166 ppm for the 0, 50, and 100% application concentrations, respectively.

Plant damage indicators

Phytotoxic effects to leaf tissue were rated visually several times after application and photographs were taken as documentation (Table 3 and 4; Figures 2, 3, 4 and 5). Statistical analysis was not conducted on the ratings since the differences were striking and obvious. The July 28 leaf burn ratings don't have data for the AT1 application on corn or soybeans.

The ratings for corn on August 6 indicate that damage was not detectable for the 0, 25 and 50% treatments and only 9% of the 100% treatment showed continued leaf effects for the AT1 treatments. The AT2 treatment showed even less damage, most likely due to the fully developed cuticle on the corn leaves that was resistant to damage. The rating for stunting showed that the 100% treatment slightly decreased the plant height. These ratings were relative to controls in the field, if this damage was in a whole field then it might not be detectable. Rated on August 26, none of the corn plants were dead. Plant height and ear height show a trend toward stunting with the 100% treatment. However, there were occasional plants that had necrotic spots.

For the soybeans at the V3 application, the 100% treatment killed most of the plants with a few escapes. The July 28 evaluation, which came four days after the R1 application, documented the almost complete burning (74%) of the plants when the 100% solution was applied. The 50% solution showed about 16 percent burning and the 0 and 25% solution showed no leaf burn. Due to continued leaf growth and new leaves 'hiding' older and burnt leaves, the August 6 ratings showed a reduction in damage compared to the July 28 ratings. The stunted plants on August 6 and the dead plants on August 26 show similar trends. The high rate stunted and killed over 80% of the plants in the AT1 application. However, while the AT2 application burnt the plants, initially, they were not killed and were able to recover. Plant height shows this also: The 100% rate severely injured the plants, reducing the height to 6.5 inches at the AT1 application. At the AT2 application plants withstood the damage and while reduced in height did not show as much damage at the 100% application rate.

These trends held with the other indicators of plant growth. For the soybeans, plant population decreased compared to pre-application counts at the AT1 application by 24,000 and not at the AT2 application (Table 5). The difference was due to the decrease at the 100% application rate at the AT1 application (71,500 plant decrease); as the swine manure got stronger the final population decreased. Statistically only the difference in population at the 100% rate was significant.

The soybean leaf area is presented two ways; the leaf area per plant and the leaf area index. Interestingly, the AT1 application (1368 sq cm/plant), on average had greater leaf area than the AT2 treatment (1036 sq cm/plant; prob. >F 0.05). This was due to two reasons. First, the time to recover was longer and second, the per plant basis masks the effect of the population decreases. When the plant population is taken into account, which is what the leaf area index does, the same trends are seen for leaf area index as for population and stunting. The 100% rate decreased crop growth and the effect was more severe in the AT1 application. Leaf area index went from 4.6 and 3.5 at the 0% control treatment to 0.3 and 1.5 for the 100% application rate for the AT1 and AT2 treatments, respectively.

For corn, the initial population had statistically significant differences by treatment before the treatments were applied (Table 6). There is no agronomic reason for this and the difference seems to be that the experimental units allocated for the 50% rate at the early application had fewer corn plants than the rest of the experiment. This difference held up and was actually greater after the treatments were applied.

Leaf area per plant was consistent with the stunting and burning data. The AT1 application at the 100% rate decreased the per plant leaf area compared to the AT2 treatment. Because the populations were not skewed like the soybeans, the leaf area index showed the same trends as the leaf area per plant: there was a slight increase in leaf area index at the second application (2.6 vs 2.8; NS).

Dry Matter and Grain Yield

Total drymatter at physiological mature for soybeans was the same, on average between the two application dates, averaging almost three tons for the whole plant, including soybean seeds. The only differences were with the 100% application rate. The 100% rate had lower weight than the other application rates, averaging approximately 2500 lbs per acre compared to over 7,100 lbs per acre. The dry weight at AT1 100% rate was 1070 lbs per acre compared to the AT2 100% rate of 3908 pounds per acre.

Soybean yield showed similar trends for the manure rate effect. Yields of both AT1 and AT2 timings were the same for the 0, 25, and 50% manure rate, averaging 42.6 bu/acre compared to 14.6 bu per acre for the 100% application. As with the soybean drymatter, the AT2 100% application had much higher yields (24.3 bu/acre) compared to the AT1 100% application (5.0 bu/acre).

Corn dry matter is reported as the plant only without the ear. Regression analysis was not conducted, but the since the dry matter increased at the 25 and 50% application rates and decreased at the 100%, the regression probably would show a significant quadratic model as being a better fit than a linear response. Statistics indicate the rate effect was consistent between the two application timings.

The grain yield showed similar effects as noted for the soybeans, the corn grain yield showed timing, rate and interaction effects, but the magnitude was not as great. Yields were not decreased by manure application at the AT2 application. They actually were increased by the manure application for the 25 and 100 % application. Manure application at AT1 decreased yields for both the 50% and 100% application rates. The interaction effect was due to the yield decrease for the AT1 100% application compared to the AT2 100% which had yields increased compared to the control. Overall the manure increased the corn yields when applied at AT2 (178.4 bu/acre) compared to AT1 (164.8 bu/acre).

Young Plant Damage (late planting study)
Soybean populations before application showed no difference for either application. Phytotoxicity ratings showed 87 percent damage at the 100% treatment and 48% at the 50% treatment for the AT3 application that was at soybean emergence. Corn populations were also equal before application and were not decreased by the AT3 (V2) application, although phytotoxicity was greater than the later season applications described previously. Phytotoxicity readings at four days after application showed zero effect for the 0 and 25% application and 9 and 28 % for the 50 and 100% application, respectively.

Discussion: Application of swine manure through a sprinkler system is feasible with proper management and care. The research reported here supports the hypothesis that stage of growth and EC of the material are important management considerations when determining how to apply swine manure. The analysis of the manure at the various applications was very similar. The results indicate that once the characteristics from a particular facility are known, the analysis will be consistent over at least a span of a few months. Inexpensive EC meters can assist producers determine the EC and hence help predict the potential for damage from the manure at the time of application.

Soybeans were more sensitive to the manure application than corn. The V3 applications at the over 20 EC (100% treatment) decreased yields significantly and all the indicators associated with plant growth. EC at the 50% level, which was approximately 12 EC showed initial plant damage, reduced height and reduced leaf area index, but since the plants were still in the vegetative stage and were not killed, they regrew and yielded statistically similarly to the controls (Prob.>F 0.30), but in absolute terms, yield was only 93% of the control. This response is consistent with soybean response to hail damage. If there is no loss of nodes, defoliation before reproductive stages does not affect soybean yield (Shapiro et al., 1985). However, population reduction does and, therefore, the reduced population was the major determinate of yield loss. There was a non-significant reduction in yield between the control and the 6-7 EC (25%) rate. The non-yield crop factors all showed little effect at this EC. With soybeans, at least, if no visible leaf damage occurs right after application yields will not be affected.

At the R1/V7 stage, yield reductions were significant at the 20+ EC application rate, but not to the degree of the V3 stage. Yields were statistically the same for the 0, 25, and 50% application rates (EC of 0.6, 7, 12). As with the V3 application, the 50% rate yield was less than the control. So even though no statistical difference (Prob.>F 0.15), it may not be prudent to apply at the EC 12 without further research.

Corn was more resistant to plant phytotoxicity symptoms from swine manure than the soybeans. The early application at V8 reduced yield for both the 50% and 100% application rates yet population was not reduced and leaf area was only marginally reduced at the 20+ EC rate. At the V14 stage all manure treatments had higher yield levels than the control and the 25 and 100% treatments were significantly higher yielding by an average of over 20 bushels per acre. While soil tests and applied fertilizer would indicate no nutrient deficiencies, the high application rate of several nutrients may have contributed to the increased yield. This data indicates that high rates of swine manure at high ECs can be applied to corn at the V14 stage. Yield losses from swine manure at the V8 stage would indicate that applications of less than 6 EC would be appropriate at this stage.

Using these results in production situations directly may be premature without further research. This data was collected using an artificial technique that applied manure at a heavier than normal rate. Real sprinkler situations may keep the foliage wet for longer periods of time than the approximate 20 minutes in our study. Our application rate was at 0.5 in and it is possible to apply at 0.25 in/acre and presumably decrease potential problems even more. If we accept the technique as being appropriate we can suggest the following for further research and for tentative management ideas:

Research:

1. Increase the number of stages at which manure is applied, especially early in the season.
2. Determine if the duration of application and multiple applications make a difference, it may be possible to put on a high EC application at 0.25 in/acre and avoid phytotoxicity.
3. Conduct research on other crops.
4. Determine the effect of wash-off in a replicated study.
5. Solar radiation, temperature and humidity effects on manure phytotoxicity need to be quantified.

Management:

1. When possible dilute material to under 10 EC.
2. Apply later in the season compared to earlier. For soybeans after flowering and corn after V14.
3. Lowering the duration and the total quantity will probably decrease damage.
4. Corn may appear less damaged than soybeans, but yields may be decreased with lower EC values.
5. If soybeans are not defoliated, damage is probably minimal.

Lay Interpretation: The use of irrigation systems to apply swine effluent and liquids from storage and holding ponds is a popular application method due to the labor savings, large volumes of liquid, and when applied close to when the crop needs the nutrients, the improved crop utilization of the nutrients in the manure.

Anecdotal reports from producers using center pivot and other irrigation systems to apply swine wastes have reported incidents of crop damage. There are very few written recommendations in the extension literature on how to apply swine manure directly to crops without damaging the plants. Most recommendations are based on salt effects. However, the literature on the salt effects on crop growth is on long term reduction in crop growth from both soil salt concentration and irrigation water effects. These effects were determined by continual irrigation with known salt concentrations and the salt effects accumulating overtime. Usually salt in irrigation water is measured in electrical conductivity (EC).

Aerial application of swine manure is a different situation than flood or furrow irrigation with salty water. Swine manure applications to a particular field may be done annually but not at every irrigation. In the areas of Nebraska where sprinkler applied swine wastes is practiced 30-year normal annual precipitation varies from 15 to 27 in. When salt is applied at moderate levels this is enough rainfall to flush salts below the root zone. Hence, long-term salt buildup is usually not a problem. The salt in manure is a consequence of the diet fed to swine and the natural internal metabolic processes. It can’t be reduced to zero. Swine manure contains more chemical compounds than salt and so there may be non-salt related phytotoxic effects.

The concern by producers is the immediate damage to growing crops. Producers want to know how much effluent can be applied with the irrigation system at one time without damaging the crops. Application by center pivot may include the renting of an agitator to mix the manure liquids and solids. This means that dilution of swine wastes increases the cost of application due to the need for either multiple applications or longer application times to empty the storage facility.

The objectives of this study were to determine the maximum EC of swine effluent that can be irrigated on corn and soybeans without immediate crop damage at several crop stages.

Swine manure was applied in early July and toward the end of July. Corn growth stage was at V8 and V14. Soybean growth stage was at V3 and beginning flowering (R1). Therefore the results are most applicable to this period. Concern about May applications also exists, but there are no results to provide answers for early season application. The Electrical Conductivity of the manure is reported in units called mmhos/cm. Underbarn storage facilities may have manure in the 20 EC range, whereas an anaerobic lagoon may have an EC of up to 7 or 8. The research conducted here used manure diluted to achieve 0, 6, 12, and 20 EC.

The application technique in the study kept the foliage wet for a minimum of 15 minutes and applied about 0.5 in. Duration of exposure is probably an important factor. The results reported here need to be interpreted in the context of the application system used. With that understood, manure in the range below 6 EC is probably safe for both soybeans and corn when applied in July. Dilution to that level would be preferred to higher EC values, although both soybeans and corn will tolerated the 12 EC manure with only minor yield losses. Corn yields were actually increased with all manure rates at the V14 application.

Early season application should be avoided since plants are very sensitive and ponding or other concentration of liquids can cause damage to the roots as well as foliage. It would be prudent to try the application on a small area before applying to the whole field when making the initial application. Soybean leaf damage was evident a day after application. If the leaves are not severely browned, and the plant survives, the crop will recover and produce sufficient yield.

References:

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Table 1a. Laboratory analysis of swine effluent applied to corn and soybeans on July 1, 2003 at several dilutions.

	0%	25%	50%	100%
	---------------------- lbs/acre-in			-----------------------
Organic N	0.1	57.6	104.7	442.8
Ammonium N	1.4	143.2	346.6	808.2
P_2O_5	2.3	61.2	142.1	657.5
K_2O	2.1	116.0	262.8	659.2
S	6.6	22.9	47.5	121.2
Ca	16.6	39.1	65.6	276.4
Mg	4.6	17.2	31.8	126.9
Na	5.4	26.5	55.7	135.0
Soluble Salts	75	772	1537	2910
Electrical Conductivity, mmho/cm	0.6	5.7	11.3	21.4
pH	8.7	7.0	6.5	6.1
% DM	0.06	0.46	1.16	4.20

Table 1b. Laboratory analysis of swine effluent applied to soybeans on July 25, 2003 at several dilutions.

	0%	25%	50%	100%
	---------------------- lbs/acre-in			-----------------------
Organic N	0.0	44.5	188.4	280.7
Ammonium N	0.9	176.5	370.8	741.1
P_2O_5	1.1	72.2	386.3	473.9
K_2O	1.7	130.5	297.8	552.9
S	7.0	24.7	65.0	95.9
Ca	20.8	39.4	209.7	210.0
Mg	4.0	18.7	74.5	92.4
Na	5.1	29.3	59.9	122.7
Soluble Salts	80	895	1632	2734
Electrical Conductivity, mmho/cm	0.6	6.6	12.0	20.1
pH	7.4	7.0	6.6	6.3
% DM	0.04	0.51	2.92	3.27

Table 1c. Laboratory analysis of swine effluent applied to corn on July 23, 2003 at several dilutions.

	0%	25%	50%	100%
	lbs/acre-in			
Organic N	0.2	49.1	111.2	415.2
Ammonium N	0.9	180.2	365.3	775.0
P_2O_5	0.5	80.8	188.3	781.2
K_2O	2.2	139.5	269.0	577.4
S	8.5	30.1	49.6	122.7
Ca	19.2	45.0	92.4	349.5
Mg	4.2	20.8	41.1	148.8
Na	5.3	31.7	60.5	121.5
Soluble Salts	80	953	1618	2638
mmho/cm	0.6	7.0	11.9	19.4
pH	7.5	6.8	6.6	6.3
%DM	0.04	0.56	1.35	4.98

Table 2 . Climatic conditions following swine manure application. Concord, NE.

CONCORD (NE) Lat.(deg)= 42.38 Long.(deg)= 96.95 Elevation (m)= 445.

Month	Day	Year	T-High F	T-Low F	Rel Hum %	Soil Tmp F@4 in.	Wind Spd mi/hr	Solar langleys	Precip inches	PET-NE inches
7	1	2003	84.7	60.2	69.1	77.7	10.8	614.2	0	0.326
7	2	2003	91.0	65.9	67.5	79.4	14.6	595.9	0	0.362
7	3	2003	92.6	68.0	69.8	83.1	8.5	598.6	0.234	0.32
7	4	2003	80.1	61.9	77.4	77.2	12.3	470.1	0.216	0.241
7	5	2003	81.7	60.7	82.9	74.3	8.8	293.0	1.093	0.156
7	6	2003	86.4	61.3	82.2	74.5	8.4	594.9	0	0.257
7	7	2003	79.3	68.8	72.6	76.5	10.6	371.8	0	0.223
7	8	2003	80.0	60.8	81.9	76.7	12.5	515.7	0.562	0.236
7	9	2003	81.8	65.4	77.2	76.2	10.2	462.8	0.398	0.233
7	10	2003	82.1	57.9	68.9	75.2	11.0	601.9	0	0.317
7	11	2003	80.7	59.5	60.6	76.9	8.6	629.2	0	0.315
7	12	2003	81.9	54.8	65.7	78.5	4.5	629.7	0	0.252
7	13	2003	86.2	60.1	65.5	80.0	11.2	591.6	0	0.348
7	14	2003	91.4	69.3	73.2	80.5	11.9	439.5	0	0.29
7	15	2003	85.9	61.5	61.9	81.7	5.3	609.8	0	0.279
7	16	2003	87.8	63.5	66.0	81.7	10.9	548.7	0	0.335
7	17	2003	91.2	67.8	72.5	83.3	8.6	517.0	0	0.283
7	18	2003	83.0	67.9	87.2	82.1	8.9	284.1	0	0.137
7	19	2003	87.3	63.3	79.2	82.0	7.3	530.9	0	0.241
7	20	2003	95.8	67.1	77.4	83.8	8.4	523.8	0.102	0.285
7	21	2003	76.4	59.4	76.3	80.0	6.6	347.8	0	0.161
7	22	2003	77.8	55.9	75.6	75.8	7.0	436.8	0	0.195
7	23	2003	77.4	52.6	70.7	77.0	6.1	546.8	0	0.226
7	24	2003	85.2	56.0	61.1	77.7	13.9	554.7	0	0.358
7	25	2003	90.6	66.6	61.4	79.8	16.4	533.9	0	0.368
7	26	2003	93.4	72.6	64.7	83.9	10.2	491.6	0	0.332
7	27	2003	74.5	64.7	81.8	77.6	5.7	136.7	0.05	0.081
7	28	2003	81.4	60.4	70.2	78.0	4.6	562.0	0.01	0.226
7	29	2003	82.3	57.6	74.0	79.6	6.5	523.5	0	0.23
7	30	2003	87.3	59.3	61.5	81.4	3.9	573.0	0	0.251
7	31	2003	86.3	61.8	66.1	81.5	7.4	527.4	0	0.274
8	1	2003	82.7	63.6	66.8	82.0	5.1	495.6	0	0.223

Note: Areas in gray are for the week of application.

Table 3. Visual ratings and plant height of soybeans sprayed with swine manure at several dilutions.

	0%	25%	50%	100%
	---------------------- % damage -----------------------			
July 28 leaf burn rating				
V3[1]	----------------------not available -----------------------			
R1(V7)[2]	0	0.5	16.3	73.8
August 6 leaf burn rating				
V3	0	0	0	0
R1(V7)	0	0	10	57.5
August 6 plants stunted				
V3	0	10	42.5	88.3
R1(V7)	0	0	7.5	28.8
August 26 plants dead				
V3	0	0	33.8	87.5
R1(V7)	0	0	2.5	7.5
	---------------------- inches ----------------------			
Plant height at maturity				
V3	37	35.1	25.8	6.5
R1(V7)	36	34.8	28.8	23.3

[1]V3 and R1 indicate the different application times and are comparable to AT1 and AT2 in the text.
[2]R1 was the stage of growth, but V7 indicates 7 trifoliates were on the plant at application.

Table 4. Visual ratings, plant and ear height of corn sprayed with swine manure at several dilutions.

	0%	25%	50%	100%
	---------------------- % damage -----------------------			
July 28 leaf burn rating				
V8[1]	---------------------not available -----------------------			
V14	0	0	0	4
August 6 leaf burn rating				
V8	0	0	0	8.8
V14	0	0	0	1.3
August 6 plants stunted				
V8	0	0	2.5	17.5
V14	0	0	0	0
August 26 plants dead				
V8	0	0	0	0
V14	0	0	0	0
	---------------------- inches ----------------------			
Plant height at maturity				
V8	95.8	98.3	92.8	85
V14	96.8	95.5	98.5	93.5
Ear height at maturity				
V8	32.5	33.3	31.3	27.3
V14	34.5	33.0	35.3	34.5

[1]V8 and V14 indicate different application times and are comparable to AT1 and AT2 in text.

Table 5. Effect of swine manure timing and rate on soybean populations, leaf area, dry matter and yield. 2003.

Variable Application timing	Manure concentration (% of full strength) 0	25	50	100	Mean	Analysis of Variance Timing	Rate	T* R
Emergent pop (plants/acre)						----------- Pr > F ----------		
T1	106,600	106,000	102,200	100,500	103,300	0.52	0.77	0.75
T2	108,900	105,100	103,400	109,500	106,700			
(Pr>F)	NS	NS	NS	NS				
Harvest pop (plants/acre)								
V3	93,800	102,700	92,000	24,300	78,200	0.0012	0.0032	0.2615
R1(V7)	100,900	106,200	102,700	104,400	103,600			
Mean	97,400	104,400	97,400	64,400				
(Pr>F)	NS	NS	NS	<0.0001				
Change in population (initial – final) (plants/acre)								
V3	12,800	3,300	10,200	71,500	24,427	0.006	0.008	0.017
R1(V7)	8,000	-1,100	700	5,000	3,161			
Mean	10,373	1,114	5,436	38,251				
(Pr>F)	NS	NS	NS	0.0003				
Leaf area (cm^2/plant)								
V3	1,639	1.670	1,578	583	1,368	0.05	0.0015	0.57
R1(V7)	1,401	1,354	881	508	1,036			
Mean	1,520	1,512	1,230	546				
(Pr>F)	NS	NS	0.04	NS				
LAI								
V3	4.6	4.5	2.2	0.3	2.9	0.85	0.0001	0.03
R1(V7)	3.5	4.1	2.5	1.5	2.9			
Mean	4.1	4.3	2.4	0.9				
(Pr>F)	0.06	NS	NS	0.03				
Dry matter at physiological maturity (lbs/acre)								
V3	7,745	7,891	7,394	1,070	5,950	0.52	<0.0001	0.07
R1(V7)	6,759	7,398	7,042	3,908	6,277			
Mean	7,103	7,644	7,218	2,489				
(Pr>F)	NS	NS	NS	0.01				
Grain yield (bu/acre)								
V3	45.6	40.9	42.5	5.0	33.5	0.01	<0.0001	0.0003
R1(V7)	43.9	43.4	39.5	24.3	37.8			
Mean	44.7	42.1	41.0	14.6				
(Pr>F)	NS	NS	NS	<0.0001				

V3 and V7 are leaf stage at application; Analysis of Variance: Prob.> F less then 0.05 can be considered significant; T * R is the Timing x Rate interaction. NS: non-significant difference. R1 was the stage of growth, but V7 indicates 7 trifoliates were on the plant at application

Table 6. Effect of swine manure timing and rate on corn populations, leaf area, dry matter and yield. 2003. Variable Manure concentration (% of full strength)

	0	25	50	100	Mean	Analysis of Variance Timing	Rate	T* R
Emergent pop (plants/acre)						---------- Pr > F ----------		
T1(future)	24,394	27,007	23,813	24,974	25,047	0.71	0.05	0.50
T2(future)	24,394	26,426	25,555	24,684	25,265			
Mean	24,394	26,717	24,684	24,829				
(Pr>F)	NS	NS	0.15	NS				
Harvest pop (plants/acre)								
V8	23,522	24,103	22,216	24,684	23,631	0.12	0.11	0.04
V14	22,506	25,410	25,555	24,394	24,466			
Mean	23,014	24,757	23,885	24,539				
(Pr>F)	NS	NS	0.005	NS				
Leaf area (cm^2/plant)								
V8	5,161	5,211	5,149	4,428	4,987	0.09	0.41	0.16
V14	4,899	5,667	5,326	5,543	5,356			
Mean	5,031	5,439	5,237	4,985				
(Pr>F)	NS	NS	NS	0.02				
Dry matter at Physiological Maturity (lbs/acre)								
V8	6,987	7,800	6,883	5,784	6,863	0.15	0.04	0.35
V14	6,894	7,654	7,944	6,874	7,342			
Mean	6,940	7,727	7,413	6,329				
(Pr>F)	NS	NS	NS	NS				
Grain yield (bu/acre)								
V8	174.8ab	181.5a	153.8c	148.9c	164.8	0.02	0.08	0.02
V14	163.5b	186.2a	179.4ac	184.6a	178.4			
Mean	169.2	183.8	166.6	166.8				
(Pr>F)	NS	NS	0.02	0.003				

V8 and V14 are leaf stage at application;
Analysis of Variance: Prob.> F less then 0.05 can be considered significant;
T * R is the Timing x Rate interaction. NS: non-significant difference.
For grain yield, within stage of application, yields with the same letter are not significantly different.

Figure 1. Manure applicator on soybeans and corn.

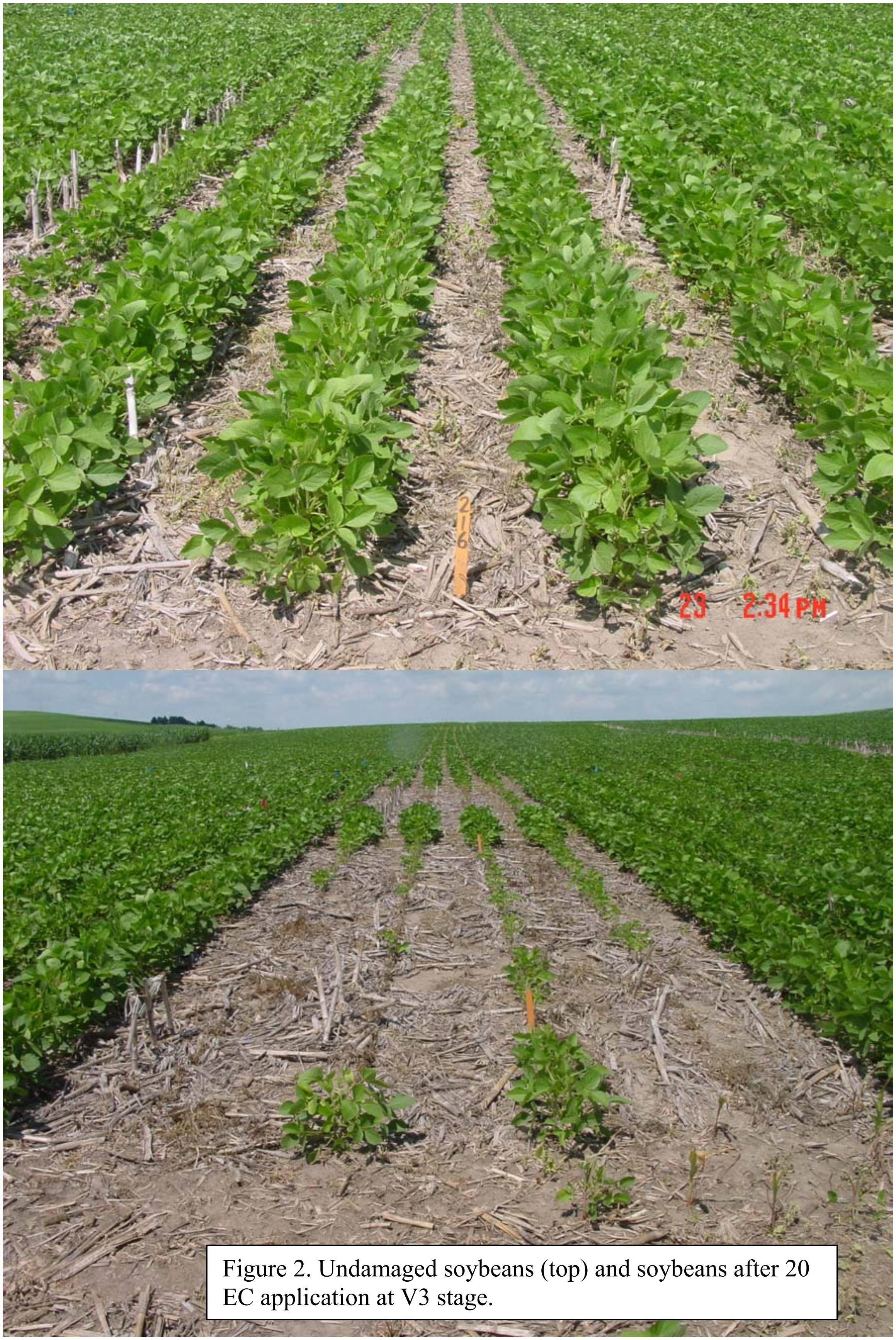

Figure 2. Undamaged soybeans (top) and soybeans after 20 EC application at V3 stage.

Figure 3. Soybean damage at 20 EC applied at R1 stage.

Figure 4. Corn damage at V8 application at 20 EC rate.

Figure 5. Swine manure residual on corn leaf and V14 application plant stunting at 20 EC.