# Improving Soil Quality by Soil Injecting Liquid Hog Manure and Elemental Sulphur

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## Introduction

The relatively low grain prices in the 80's and early 90's have sparked a greater interest in livestock production, in particular with respect to hog opemtions. A number of large scale hog operations have been established and a number of others are being planned. Despite rural Saskatchewan's low population, proponents of setting up intensive livestock operations meet with local concern regarding odour control, groundwater contamination, as well as other concerns (Saskatchewan Agriculture and Food. 1993).

Manure has been recognized as a valuable source of plant nutrients, for it's positive effect on soil tilth and for improving crop production in general. However, manure contains a number of ingredients, some of which are harmful to the environment at high concentrations. Manure applied to soil increases the content of various plant macronutrients such as nitrogen and phosphorus, micronutrients such as zinc and copper, and other elements such as cadmium.

Odour problems from manure-applied soils can be addressed by using application methods that incorporate the manure into the soil. A soil-injection system allows for the minimum amount of odours to escape into the atmosphere. The injection of liquid manure into the soil can be achieved by using a ripper-type of system, where a flexible hose immediately behind the ripping shank allows the manure to be injected into the slot of soil opened by the ripper.

Solonetzic soils are well suited for soil injection of liquid hog manure, as these soils are poorly drained and the risk of groundwater contamination by leaching would therefore be minimal. There are 4.5 million acres of Solonetzic soils (hardpan soils) in Saskatchewan (Stonehouse, H.B); crop production on these soils is limited due to poor soil structure and low fertility. Solonetzic soils have a shallow hardpan layer that limits water movement and root growth. Soil management practices for improving crop production on Solonetzic soils includes deep ripping and/or the incorporation of amendments such as gypsum (Grevers, and de Jong. 1993).

Elemental sulphur (a virtual waste product from the oil and gas industry) added to the hog manure should further improve the productivity of Solonetzic soils. The application of elemental sulphur to Solonetzic soils has shown limited benefits in terms of crop production (Carter et al. 1986; Webster and Nyborg 1986). However, combinations of elemental sulfur with organic amendments (e.g. hog manure) enhances the oxidation rate of elemental sulfur to sulfuric acid (Cowell and Schoenau, 1994). which increases the effectiveness of sulphur on improving soil productivity. Injecting sulphur/hog manure mixtures into the soil has the potential for increasing crop production on Solonetzic soils and on soils with crusting problems. This practice would substantially reduce odour problems and because of the poor drainage characteristics of Solonetzic soils would be an environmentally friendly method for manure disposal.

The objectives of this study were to evaluate soil-injected liquid hog manure for improving crop production on poorly structured soils (hardpan soils and soil with crusting problems), and to determine if the addition of elemental sulfur to soil-injected hog manure increases soil productivity.

## Materials and Methods

A total of four sites were established in consultation with extension personnel and farm co-operators; these involved fields in the vicinity of large hog operations. The fields were selected to provide a range of soil conditions; including Solonetzic (hardpan) and

Chemozemic soils, and soils of different textures. The sites were surveyed extensively to determine the suitability for applying manure. The sites and the soil classifications are shown below:

| |
|---|
| 1. Central Butte, Echo Clay Loam, a solodized Solonetzic soil |
| 2. Birsay, Kindersley Clay Loam, Brown Solonetzic soil |
| 3. Star City, Waitville Loam, Luvisolic (Gray Wooded) soil |
| 4. Tisdale, Tisdale Clay to Clay Loam, Dark Gray Chemozemic soil |

Soils #l and #2 have soil structure problems involving hardpan layers and poorly structured topsoil. Soil #3 has soil crusting problems and low soil fertility. Soil #4 has less severe soil structure and soil fertility problems; however, farmer experience with similar soils in the area suggests that it requires considerable inputs to be productive.

The treatments are as follows:

| | |
|---|---|
| **BC:** | broadcast hog manure @ 4,000 gallons per acre |
| **RIP:** | the injector shanks ripped through the soil without adding manure |
| **HM1:** | soil inject hog manure @ 4,000 gallons per acre |
| **HM2:** | soil inject hog manure @ 8,000 gallons per acre |
| **CNTL:** | no hog manure applied |
| **BC+S:** | broadcast hog manure @ 4,000 gallons per acre + elemental sulfur |
| **HM+S** | soil inject hog manure @ 4,000 gallons per acre + elemental sulfur |
| **HM2+S** | soil inject hog manure @ 8,000 gallons per acre + elemental sulfur |

The field plots were arranged in a replicated block design, consisting of 3 blocks, each with either 4 or 7 treatments. At Site #l, only four treatments were used; CNTL, RIP, HM2, and HM2+S. At the other sites 7 treatments were used; CNTL, BC, BC+S, HM, HM+S, HM2, and HM2+S.

The supply of liquid hog manure was obtained from local hog producers. The manure in the lagoons was first agitated for a two hour period before it was pumped into the manure applicator tank. The manure was injected using a deep ripper hooked up to a flexible hose system connected to a pump and supply (holding tank) of liquid hog manure. The depth of soil injection was around 20 cm. The broadcast treatment was carried out by setting the injection system to a depth of 5 cm. The elemental sulfur/hog manure mixtures were prepared separately by incorporating the sulfur with the hog manure in the holding tank before field application. The chemical characteristics of the hog manure and the concentration of nutrients etc. applied with the hog manure are shown in Table 1. At rates of 4,000 and 8,000 gallons per acre, the application rates of N, P, K, etc. are shown in Table 2.

Soil samples were collected in the subsequent spring from each of the plots to a depth of 60 cm in increments of O-15, 1530, and 30-60 cm. The samples were transported to the laboratory, where they were dried and ground (&mm) for soil chemical and mechanical analysis. Soil chemical analysis involved pH, salinity (EC in dS/m), Sodium Absorption Ratio (SAR), nitrate nitrogen ($NO_3$-N) and sulphate sulphur ($SO_4$-S) content. The pH and EC measurements were carried out on 1: 1 basis (soil/water). The SAR, $NO_3$-N, $NH_4$-N and $SO_4$-S were determined using cation exchange membranes (Greer and Schoenau, 1994). At the Birsay site, the $NO_3$-N, $NH_4$-N and $SO_4$-S levels were not determined. Soil mechanical analysis (texture) was carried out using the pipette method, following pre-treatment with peroxide to remove organic matter.

Soil bulk density and soil-water content were determined using a density/moisture probe (gamma radiation attenuation) and a neutron probe (neutron thermalization) which were lowered into the aluminum access tubes to depth intervals of 20,40,60,80 and 100 cm. The bulk density and soil-water content of the surface 10 cm was determined gravimetrically by taking soil cores.

Table 1. Analysis of hog manure used in the study

| Analysis | Star City Hog Manure † | | Birsay Hog Manure ¥ | |
|---|---|---|---|---|
| | HM | HM+S | HM | HM+S |
| PH | 8.8 | 8.8 | 8.6 | 8.5 |
| EC (dS/m) | 12.2 | 12.0 | 16.1 | 14.0 |
| SAR | 12.8 | 11.7 | 14.1 | 9.9 |
| swc (%) | 95.2 | 95.2 | 95.1 | 95.4 |
| Total N (mg/L) | 1461 | 1500 | 2270 | 1528 |
| $NO_3^-$ (mg/L) | <0.4 | <0.4 | <0.4 | <0.4 |
| $NH_4^+$ (mg/L) | 1180 | 1125 | 1800 | 1205 |
| Organic N (mg/L) | 281 | 375 | 470 | 323 |
| Total S (mg/L) | 117 | 837 | 607 | 4876 |
| $SO_4^{=}$ (mg/L) | 26 | 171 | 84 | 1315 |
| P (mg/L) | 267 | 256 | 444 | 345 |
| K (mg/L) | 1175 | 1207 | 1414 | 1230 |
| Na (mg/L) | 390 | 378 | 384 | 405 |
| Ca (mg/L) | 6 | 69 | 51 | 96 |
| Mg (mg/L) | 766 | 6 | <1 | 18 |
| Cl (mg/L) | | 735 | 726 | 812 |
| $HCO_3$ (mg/L) | 3100 | 2817 | 3469 | 2054 |
| Total Cu (mg/L) | 11 | 10 | 4 | 12 |
| Total Zn (mg/L) | 15 | 13 | 17 | 17 |

† and ¥ denotes the manure source used for sites 3 & 4 and sites 1 & 2, respectively
HM= hog manure, HM+S= hog manure with elemental sulfur

Soil aggregation was measured by dry sieving air-dried bulk surface samples using a rotary sieving machine (Yoder, 1936). The crusting strength of the samples was determined by the Modulus of Rupture test (Reeve 1976).

Crop yield was determined by using square meter frames to harvest crop samples just prior to swathing. A total of six replicate samples were taken for each treatment in each of the replicate blocks (6 reps for each treatment for each replicate block). The crop samples were taken to the Crop Development Centre at the U. of S where they were allowed to dry and subsequently threshed. Total weight and grain weights were determined. The grain was analyzed for % C, N, and S using a CNS analyzer.

**1. Soil chemical properties and mechanical properties.**

The pH, EC, and SAR measured in May of 1995 are shown in Table 6. The pH values indicate near neutral to alkaline condition for three of the sites, while the pH values for the Tisdale site indicate slightly acidic conditions. The highest pH values were associated with high SAR values. Sodic soil layers typically have pH values at or greater than 8.5 (Brady, 1984). The low pH values found at the Tisdale site are in line with those for Luvisolic soils.

Table 2. The amounts of nutrients added to the soil in the hog manure

| Nutrient | Star City Hog Manure † | | | | Birsay Hog Manure ¥ | | | |
|---|---|---|---|---|---|---|---|---|
| | HM | HM+S | HM2 | HM2+S | HM | HM+S | HM2 | HM2+S |
| | lb. per acre | | | | | | | |
| Total N | 58.4 | 60.0 | 116.8 | 120.0 | 90.8 | 61.1 | 181.6 | 122.2 |
| $NH_4^+$ | 47.2 | 45.0 | 94.4 | 90.0 | 72.0 | 48.2 | 144.0 | 96.4 |
| $P_2O_5$ | 10.7 | 10.2 | 21.4 | 20.4 | 17.8 | 13.8 | 35.6 | 27.6 |
| $K_2O$ | 56.4 | 58.0 | 113.8 | 116.0 | 67.9 | 59.0 | 135.8 | 118.0 |
| Total S | 4.7 | 33.5 | 9.4 | 67.0 | 24.3 | 195.0 | 48.6 | 390.0 |
| $SO_4^=$ | 1.0 | 6.8 | 2.0 | 13.6 | 3.4 | 52.6 | 6.8 | 105.2 |
| Ca | 2.4 | 2.8 | 4 8 | 5 6 | 2.0 | 3.8 | 4.0 | 7.6 |
| Mg | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.4 |
| Na | [illegible] | 15.1 | 31.2 | 31.2 | [illegible] | [illegible] | [illegible] | 32.4 |
| Cl | 30.6 | 29.4 | 61.2 | 58.8 | 29.0 | 32.5 | 58.0 | 65:0 |
| CU | 0.4 | 0.4 | 0.8 | 0.8 | 0.0 | 0.5 | 0.4 | 1.0 |
| Zn | 0.6 | 0.5 | 1.2 | 1.0 | 0.7 | 0.7 | 1.4 | 1.4 |

† and ¥ denotes the manure source used for sites 3 & 4 and sites 1 & 2, respectively
HM= 4,000 gallons per acre of hog manure, HM2= 8,000 gallons per acre of hog manure
HM+S= 4,000 gallons per acre of hog manure plus elemental S
HM2+S= 8,000 gallons per acre of hog manure plus elemental S

The salinity values (EC) indicate non-saline conditions (< 4 dS/m) for all the soils. The lowest salinity values were found in the irrigated (Bit-say site) and Luvisolic soils (Tisdale and Star City). The highest salinity values were found in the dryland Solonetzic soil (Central Butte).

Table 3. Soil chemical and mechanical characteristics of the four sites

| Depth | Site | pH | EC | SAR | Soil Mechanical Properties | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Sand | Silt | Clay | Texture |
| cm | | | dS/m | | % | | | |
| O-10 | **C.Butte** | 7.34 | 1.84 | 7.71 | 45.3 | 23.9 | 15.4 | L |
| 10-30 | | 7.77 | 2.46 | 11.52 | 42.7 | 27.4 | 18.3 | L |
| 30-60 | | 8.24 | 3.16 | ND | 40.8 | 28.2 | 19.7 | L |
| o-15 | Birsay | 7.40 | 0.68 | 1.35 | 32.7 | 28.5 | 38.8 | CL |
| 15-30 | | 8.18 | 0.56 | 2.55 | 24.4 | 25.9 | 49.6 | C |
| 30-60 | | 8.65 | 0.58 | 5.06 | 23.5 | 29.8 | 46.8 | C |
| o-15 | S. City | 7.20 | 0.17 | 0.56 | 74.3 | 15.7 | 10.0 | SL |
| 15-30 | | 7.75 | 0.18 | 0.63 | 64.6 | 21.4 | 14.1 | SL |
| 30-60 | | 8.16 | 0.19 | 0.54 | 62.7 | 22.6 | 14.9 | SL |
| o-15 | Tisdale | 6.07 | 0.32 | 1.16 | 16.9 | 38.4 | 44.7 | C |
| 15-30 | | 6.01 | 0.22 | 1.63 | 14.7 | 36.4 | 48.9 | C |
| 30-60 | | 6.97 | 0.37 | 3.55 | 10.9 | 31.6 | 57.5 | C |

The sodicity values (SAR) show a wide range in values from SAR <1 to SAR **>l 1.** The B horizon (l0-30 cm) at Central Butte is a sodic layer, the resulting hardpan layer was verified by field observations of limited root penetration below 10 cm depth. The C horizon at the Birsay site is near sodic. The two Luvisolic soils are non-sodic.

The percentage of sand, silt and clay and the soil texture for the sites are shown in Table 6. The texture of the soils ranged from sandy loam to clay. The highest clay content of 0- 15 cm depth was 58% at the Tisdale site, whereas the lowest clay content was 10% at the Star City site.

## 2. **The effect of the treatments on soil fertility at the start of the 1995 growing season.**

Ammonium ($NH_4^+$) nitrogen and nitrate ($NO_3^-$) nitrogen levels in the top 60 cm depth are shown in Fig. 1. The hog manure treatments increased plant available nitrogen by up to 64 lb./acre when applied at 8,000 gallons per acre. Most of the increase in plant available nitrogen was in the form of nitrate.

The relative concentration of ammonium- versus nitrate-nitrogen was markedly different between the plots. At Central Butte and at Birsay (data not shown), most of the plant available nitrogen was in the nitrate form (88% and 90% of plant available N, respectively), whereas at Star City and at Tisdale the percentage of nitrate nitrogen was considerable smaller (only 45% and 33% of plant available N, respectively).

There was no significant effect of adding elemental sulphur on plant available nitrogen levels. However, there was a trend in the data for the Central Butte and the Tisdale sites showing a negative effect of S on soil nitrate nitrogen levels. The oxidation process of elemental S to sulphate is an acidifying process which effects nitrification, and lower soil nitrate-nitrogen levels may therefore be expected when sulphur is added to hog manure.

## 3. **Soil structure and soil-water content**

The injection of liquid hog manure reduced the bulk density of the surface 10 cm at the Central Butte and at the Tisdale sites (data not shown); there were no significant differences in soil density at the other sites. The hog manure application did not effect soil crust formation or soil strength. There were no differences in soil-water content.

Hog manure application had a significant effect on soil aggregation (aggregate size) (Table 3). The average diameter of soil aggregates was increased by 38%. There was no effect on soil aggregation regarding the rate of hog manure applied (4,000 versus 8,000 gallons per acre), the incorporation of S with the manure, or the method of manure application (broadcast versus injected).

Table 3. The effect of hog manure on soil aggregation

| Treatment | Birsay | Star City | Tisdale | Central Butte | Relative size |
|---|---|---|---|---|---|
| | Aggregate size (MWD in mm) | | | | |
| Hog manure | 14.7 | 8.1 | 14.7 | 23.7 | 138 **b** |
| Control | 8.5 | 5.8 | 10.6 | 19.5 | 100 **a** |

MWD= Mean Weighted Diameter

## 5. **Crop production and grain quality.**

The 1995 yield results (the first year since manure application) show two sites with a substantial response to hog manure, especially at the high rate (8,000 gallons per acre), and one site with a strong response to sulphur but not to hog manure; the remaining site showed little response (Table 4). The low rate of hog manure increased total dry matter production between 9% and 15%. while the high rate of hog manure increased total dry matter production between 33% and 36%. Hog manure increased the average grain yield by 30%; however, there was little difference between the hog manure rates. There was no effect of the treatments on the % carbon in the grain, nor on the %N (or protein content) of the grain.

Crop production in the second year since hog manure application was increased at Central Butte, Birsay, and at Tisdale. Hog maure @ 8,000 g.p.a. increased crop production at the Birsay and at the Tisdale sites, while hog manure + S @ 8,000 g.p.a increased crop production at the Central Butte and at the Birsay sites.

Table 4. The effect of different hog manure treatments on crop production

| Treatment | Central Butte | Birsay | Star City | Tisdale |
|---|---|---|---|---|
| | | **1995 Growing season** | | |
| | | ---------- Dry matter production in t/ha -------- | | |
| tipped | 6.13a | | | |
| Control | 5.27a | 6.38a | 3.45a | 6.01 |
| HM | | 8.31b | 3.89ac | 5.55 |
| HM+S | | 7.81ab | 5.06bc | 5.34 |
| HM2 | 9.55b | 8.18b | 3.89ac | 6.48 |
| HM2+S | 8.87b | 8.56b | 5.37b | 5.81 |
| | | ------------ Grain production in t/ha ------------ | | |
| Ripped | 2.37a | | | |
| Control | 2.08a | 2.3 lac | 1.82a | 3.33 |
| HM | | 2.14c | 1.79a | 3.12 |
| HM+S | | 3.01a | 2.60bc | 2.92 |
| HM2 | 3.33b | 3.25b | 2.03ac | 3.69 |
| HM2+S | 3.36b | 3.271, | 2.69bc | 3.22 |
| | | **1996 Growing season** | | |
| | | ---------- Dry matter production in t/ha -------- | | |
| Ripped | 1.30a | | | |
| Control | 0.74a | 6.3 la | 5.38 | 4.21a |
| BC | | 6.86ab | 5.57 | 4.50a |
| BC+S | | 7.61ab | 5.47 | 4.23a |
| HM | | 7.10ab | 5.48 | 4.65ab |
| HM+S | | 7.35ab | 5.80 | 4.16a |
| HM2 | 1.92ab | 7.92b | 5.45 | 5.07c |
| HM2+S | 2.89b | 7.83b | 5.34 | 4.07a |
| | | ------------ Grain production in t/ha --- --------- - | | |
| Ripped | 0.67a | | | |
| Control | 0.34a | 3.07 | 2.29 | 1.23a |
| BC | | 3.18 | 2.22 | 1.3 la |
| BC+S | | 3.61 | 2.13 | 1.24a |
| HM | | 3.16 | 2.17 | 1.36ab |
| HM+S | | 3.56 | 2.06 | 1.27a |
| HM2 | 0.95ab | 3.55 | 2.32 | 1.52b |
| HM2+S | 1.35b | 3.59 | 1.86 | 1.27a |

HM+S and HM2+S= 4,000 and 8,000 g.p.a. of hog **manure, respectively**
HM+S and HM2+S= 4,000 and 8,000 g.p.a. of hog manure plus elemental S, respectively
a-c: different letters following means for each year indicate sign. diff. at 95%.

## DISCUSSION

The application of hog manure resulted in significant increases in soil fertility, soil aggregation and crop production; and when applied at a rate of 8,000 gallons per acre, these effects lasted into the second year. The most important aspect of the treatments was the hog manure itself, regardless of the application method (broadcast versus injected) or of the application rate (4,000 versus 8,000 gallons per acre). The inclusion of elemental sulphur resulted in the greatest increase in crop production on a sulfur-deficent Gray Luvisol (Star City). However, at the other sites the sulphur appeared to decrease the effectiveness of the hog manure. Lower available nitrogen levels in the HMS treatments compared to that of the HM treatments suggests an inhibitory effect of S on plant available N. Research indicates that the acidification process of S-mineralization may negatively affect N-mineralization. The Tisdale soil has the lowest surface soil pH of the sites (the pH of the top 30 cm varied between 6.0 and 6.1, whereas the pH at the Central Butte site varied between 7.3 and 7.8), and N-mineralization may therefore be the more affected by elemental S application.

## References


Brady, N. C. 1984. The Nature and Properties of Soils. Macmillan Publ. Co. NY, NY (750 PP).

Carter, M.R., J.R. Pearen, P.G. Karkanis, R.R. Cairns, and D. W. McAndrew 1986. Improvement of soil properties and plant growth on a Brown Solonetzic soil using irrigation, calcium amendments and nitrogen. Can. J. Soil Sci. 66: 581-589.

Cowell, L. E. and J.J. Schoenau. 1994. Potential for combined elemental sulphur and sewage sludge as a fertilizer. Proc. 1994 Soils & Crop Workshop. University of Saskatchewan. Saskatoon, SK.

Greer, K.J. and J.J. Schoenau. Rapid Method for Assessing Sodicity Hazard using Cation Exchange Membrane. Joum. Prod. Agric. (In Press)

Grevers, M.C.J. and E. de Jong. 1993. Soil structure and crop yield over a 5-year period following subsoiling Solonetzic and Chemozemic soils in Saskatchewan. Can. J. Soil Sci. 73: 81-91.

Reeve, R.C. 1976. Modulus of Rupture. Pages 466471. *In* C.A. Black (ed.) Methods of Soil Analysis. Part 1. Agronomy No. 9. Am. Soc Agron., Madison, Wis.

Saskatchewan Agriculture and Food. 1993. Proceedings and recommendations for manure management workshop. December 8 & 9,1993. Extension Service, Lands and Regulatory Management, and Sustainable Production, Saskatchewan Agriculture and Food

Stonehouse, H.B. 1991. Solonetzic Soils: Their nature and Distribution in Saskatchewan. PP 537-544 IN Proc. 1991 Soils & Crops Workshop. Univ. of Saskatchewan. Saskatoon SK.

Webster, G.R. and M. Nyborg. 1986. Effects of tillage and amendments on yields and selected soil properties of two Solonetzic soils. Can. J. Soil Sci. 66: 455-470.

Yoder, 1936. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. J. Am. Soc. Agron. 28: 337-351.

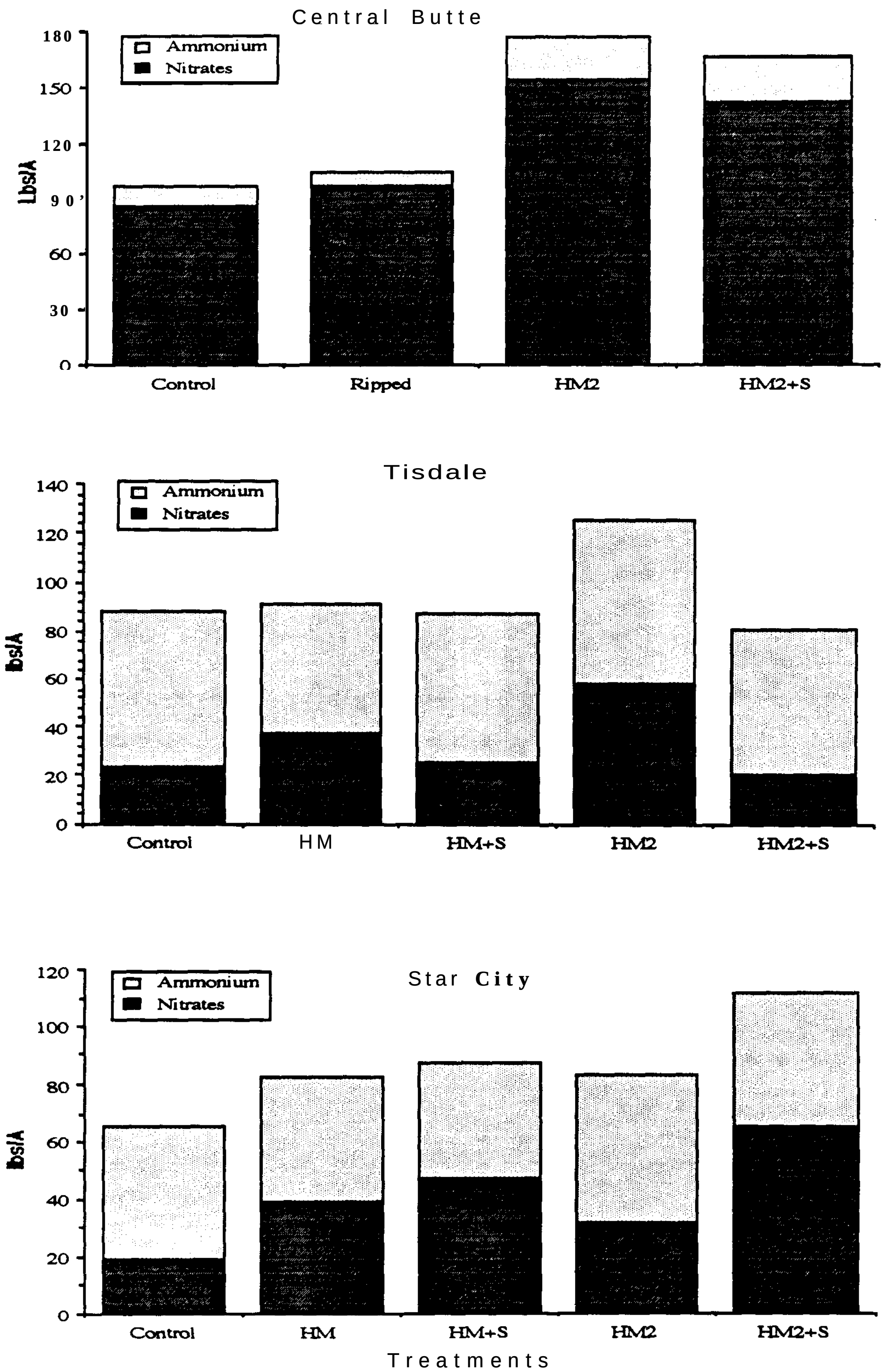


Fig. 1. Spring available nitrogen values in the top 60 cm at three sites.