This is to certify that the

thesis entitled

ESTIMATING ANIMAL MANURE AND PAPER MILL SLUDGE NUTRIENT CREDITS FOR CROP PRODUCTION

presented by

Sven Bohm

has been accepted towards fulfillment
of the requirements for

Master degree in Crop & Soil Sciences

Lee W. Jacobs
Major professor

Date 12/13/96

**PLACE IN RETURN BOX** to remove this checkout from your record.
**TO AVOID FINES** return on or before date due.

| DATE DUE | DATE DUE | DATE DUE |
|---|---|---|
| July 24, 1997<br>~~MO34630~~ | | |
| [illegible] | | |
| ~~1004 03~~<br>DEC 1 5 2003 | | |
| | | |
| | | |
| | | |
| | | |

# ESTIMATING ANIMAL MANURE AND PAPER MILL SLUDGE NUTRIENT CREDITS FOR CROP PRODUCTION

By

Sven Böhm

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crop and Soil Sciences

1996

# ABSTRACT

## ESTIMATING ANIMAL MANURE AND PAPER MILL SLUDGE NUTRIENT CREDITS FOR CROP PRODUCTION

By

Sven Böhm

The studies reported in this thesis relate to the problem of estimating the fertilizer value of manures. The N, P, and K equivalence values for nutrients derived from manure as opposed to inorganic fertilizer are estimated. No evidence was found to reject the assumed P and K availability factors of 75% and 100% respectively. No significant N residual was found at agronomic application rates. The use of cover crops in retarding N leaching is examined. Although the rye cover crop took up 2000 to 3000 lb of N/acre, it slightly decreased the corn yield in the following year. An attempt is made to quantify the N mineralization of a paper mill sludge. And finally a nutrient recordkeeping system is presented.

# ACKNOWLEDGMENTS

I would like to thank the members of my committee, Lee Jacobs, Boyd Ellis, Jim Tiedje, and Steve Harsh for their support. Thanks to all the people who helped me with the lab and field work for their assistance. Acknowledgement is made to the Michigan Agricultural Experiment Station for its support of this research.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# INTRODUCTION

The five studies reported in this thesis relate to the question of using manure/waste as a fertilizer substitute for crop production. The studies are:

- Manure N, P and K study
- Fall vs. spring manure application practices
- N mineralization in a paper mill sludge
- Paper recordkeeping system

The manure N, P and K studies were conducted with financial support from the Michigan Energy Conservation Program (MECP). The purpose of MECP was to find ways to reduce established energy use and /or increase energy use efficiency on Michigan farms. The manure P, K and N sites were started in 1988 by B. Lentz and C. Rice. In 1989 B. Vaughan took responsibility for the manure N study and made several changes to simplify the experimental design. The author assumed responsibility for the manure P and K sites in 1989 and the manure N sites in 1990. The N study was designed to estimate manure N mineralization and residual manure N accumulation in the soil. The P and K studies were designed to estimate the P and K supplying capability of manures as compared with inorganic fertilizers.

The fall vs. spring manure application study was established in 1990 in cooperation with B. Vaughan to evaluate management practices for fall manure applications. The efficiency of cover crops or delaying manure applications, to prevent the winter leaching of fall applied manure N from the rooting zone was studied.

The paper sludge study was conducted in late 1991 to estimate the mineralization of N from a paper sludge via laboratory incubations. The results were to provide information that would be used to estimate a safe sludge rate for land application.

The paper recordkeeping system was developed in cooperation with B. MacKellar and L.W. Jacobs in 1990. The goal was to design a field by field recordkeeping system that farmers could use to manage fertilizer and manure nutrients on the farm. The need to develop this "management tool" evolved when management practices, adopted under the Michigan *Right-to-Farm Act*, recommended that farmers keep records of the practices they used.

# CHAPTER 1

## Estimating Manure P and K Nutrient Credits

### Abstract

To predict the phosphorus buildup in the soil due to manure applications the residual fertilizer value of manures was investigated. The efficiency and residual value of manure derived P and K was compared to triple superphosphate (0-46-0) and potash (0-0-60) during a three year field trial. Triple superphosphate and potash or manure were applied in the spring of 1988. Pit and solid manure P was assumed to be 50% and liquid manure P 75% as available as triple superphosphate, while liquid manure K was assumed to be 100% as available as potash. Application method (broadcast vs. injected) was a secondary factor on the P study. Hybrid corn (*Zea mays L.*) was grown. Grain and stover yields, and 5th/10th leaf, earleaf, grain, stover and soil test P and K levels were monitored for the next three years. No significant differences in the efficiencies between broadcast and injected treatments were detected. Manure P availability in subsequent years seems to be similar to that of triple superphosphate.

### Introduction

Manure has long been used to maintain agricultural productivity. With the development of inexpensive chemical fertilizers and the increasing specialization of farms, manure has become a disposal problem for many farmers. High rates of manure application will lead to the accumulation of available N, P, K, Mg, Ca, and soil organic matter (Mackowiak, 1988; Mathers and Stewart, 1974; Olsen et al., 1970; Singh et al., 1983; Vitosh et al., 1973). This buildup of nutrients can lead to water quality problems via non-point source losses from a watershed into surface waters. The key to preventing nutrient pollution is to manage nutrient additions.

Since P is usually the limiting nutrient in aquatic systems, P enriched sediment can contribute to rapid eutrophication. Over-fertilization and excessive manure application can contribute to this enrichment. Therefore, an evaluation of the proper P credits or equivalents for manure is needed. The P equivalents of manure depend on the nature of the manure, and its behavior once it is added to the soil. While K is not considered a potential water quality problem, high accumulations of K in soils can be a problem for proper plant and animal nutrition. Thus, knowing what credits should be given for manure K additions can improve the management of this nutrient.

The P content of manures is extremely variable. In a survey conducted in 1989, we found that the total P content of solid manures varied from 1.4 to 96.5 lb $P_2O_5$ per ton of manure. In manures, P can occur in organic and inorganic forms. Since plants can only take up inorganic P, the proportion of organic and inorganic P in manure is important. Broomfield (1961) reported that 60 to 70% of the P in sheep manure was in the organic form. On the other hand, McAuliffe and Peech (1949) reported that most of the P in sheep feces was in the inorganic form. They reported that 16% of the total P was organic and most of that organic P was protein bound. Peperzak et al. (1959) fractionated manures and found they contained an average of 27% organic P. Barrow (1975) reported that most of the P in sheep manure is present as calcium phosphate, and that more inorganic P was excreted when the P concentration in the feed was high. van Fassen and van Dijk (1987) reported that 80 to 90% of the total P in manure slurries was present as calcium phosphates. After two months of anaerobic storage, organic P was 5 to 15% of the total P regardless of the initial P distribution (van Fassen and van Dijk, 1987). The main organic P forms in manure are inositol hexaphosphate and adenosine triphosphate (Caldwell and Black, 1958; Gerritse, 1978).

If the C:P ratio of a material is less than 200, P should be mineralized, but when the C:P ratio is above 300, organic P should be immobilized (Stevenson, 1992; Dalai, 1977; Fuller et al., 1956). The organic P compounds are broken down in the soil by the activity of phosphatases. This breakdown is influenced by a number of factors, including the temperature, moisture, and organic matter content of the soil.

Gerritse and Zugec (1977) investigated the P-cycle in pig slurry using radioactive $^{32}PO_4$ and found that all of the manure P seemed to be part of the microbial cycle. So manure P availability could be increased by mineralization or decreased by immobilization of available P, depending on the C:P and N:P ratios of the soil environment.

Sorption competition has been suggested as a method of maintaining a higher level of phosphates in solution since organic phosphates seemed to be preferentially sorbed. Reddy et al. (1980) reported that the addition of beef, poultry, and swine wastes to a Norfolk soil decreased the sorption capacity and increased soluble P, equilibrium P, and P desorption. They attributed the decrease in sorption to the relative stabilities of the Fe (or Al)-organic anion complex and the Fe (or Al)-phosphate complex. Their report is supported by the earlier findings of Singh and Jones (1976).

In P fertilizer trials, banded applications have proven more efficient than broadcast treatments (Engelstad and Terman, 1980). McAuliffe et al. (1949) reported that plants absorbed slightly more P from banded manure applications than from banded superphosphate applications. On the other hand, Abbott and Tucker (1973) reported that on calcareous soils, manure P can be mixed with the soil, i.e. broadcast applied, without loosing effectiveness.

Manure P availability has been assessed in a variety of ways. Most have centered around the percent of the added manure P recovered, either by plants or by chemical methods, divided by the percent of P recovered from an equivalent application of inorganic P fertilizer. This assumes that the amount of indigenous P removed from the soil is the same regardless of fertilization. Morel and Fardeau (1990) showed by using isotropic tracers, that the amount of P utilized from the soil decreased when P was supplied in the fertilizer. However, without resorting to tracers, the assumption of unchanged native P availability has to be made.

Table 1.1 shows some of the efficiencies reported in the literature. Montavalli et al. (1989) reported first year P equivalents from injected dairy manures to be 14% to 88% with a large amount of variability between sites and years. McAllister (1977) found that less responsive sites showed little differences between applications of fertilizer versus manure P. McAuliffe et al. (1949) reported that while superphosphate was more effective for the first cutting of Italian rye grass, manure P proved more effective for subsequent cuttings. This indicated that the manure P might remain available for a longer time.

Goss and Eck (1983) found no difference between feedlot manure derived P and 0-46-0 for the production of alfalfa, although Goss and Stewart (1979) had earlier found that manure P was more efficient than superphosphate. They also reported that superphosphate gave higher yields for the first cutting, while the manured plots provided more P for the next several cuttings which is in agreement with the findings of McAuliffe et al. (1949). Given the low amount of organic P reported in manures, differences in "fertilizer value" between manure P and fertilizer P might not due to the presence of organic P (van Fassen and van Dijk, 1987). Manure applications seem to increase P availability in calcareous desert soils (Meek et al., 1979; Abbott and Tucker, 1973), and Hensler et al. (1970) reported lower P recoveries from unlimed than from limed soils.

Table 1.1. Manure P efficiencies reported in the literature.

| Manure | Phosphorus Efficiency | Reference |
|---|---|---|
| | % | |
| Cattle slurry | 60 | Prummel and Sissingh (1983) |
| Liquid sludge | 60 | de Haan (1983) |
| Sheep dung | 90 | McAuliffe and Peech (1949) |
| Sheep dung (banded) | 118 | McAuliffe et al. (1949) |
| Dairy (injected) | 14-88 | Montavalli et al. (1989) |
| Any | 50 | Smith et al. (1984) |

Manure derived K has been considered 100% as effective as K derived from potash (0-0-60) (Azevedo and Stout, 1974). Recently some re-evaluation of the efficiency of manure derived K has been done. Montavalli et al. (1989) reported that on several loamy soils in Wisconsin, K from dairy manure was 72% as available as potash, although their estimates for the various years and sites varied from 24% to 152%. Smith et al. (1984) suggests that manure K is 90% as available as potash.

## Objectives

The purpose of this study was to determine the efficiency and residual P and K value of manures applied at agronomic rates. A secondary goal was to evaluate whether the application method or tillage system influenced the efficiency.

## Hypothesis

- Solid manure P is 50% as available as triple superphosphate (0-46-0).
- Liquid manure P is 75% as available as triple superphosphate (0-46-0).
- The residual value of manure derived P is the same as that of triple superphosphate, if the manure is applied with the above first year availability factors.

- Liquid manure K is as available as potash (0-0-60).

- The residual K value of liquid manure is the same as that of potash (0-0-60).

### Methods and Materials

In 1988 sites were established at the Michigan State University (MSU) University Farms and the Kellogg Biological Station (KBS), and on private farms in St. Clair county and in St. Joseph county near Sturgis, MI. Sites selected had not been manured in the past 5 years, were in close proximity to a source of manure, and had uniform, well-drained soils. The site at MSU was located north of Jolly Road near the intersection of Jolly Road and Collins Road. The KBS site was located just south of Baseline Road on the KBS Experimental Station near Kalamazoo, MI. The St. Clair site was located in southern St. Clair county, and the Sturgis site was located on the farm of Mr. Dave Sturgis just west of Sturgis, MI. All sites had a P study, but only the St. Clair site had a K study, since only the St. Clair soils had K levels low enough to be responsive to potash fertilization.

Table 1.2 summarizes the characteristics of the manures used at each location. Details about the manure and fertilizer applications have been given by Lentz (1989)[1] Except for the St. Clair site, all of the sites had been in active agricultural production prior to the start of this study. The St. Clair site had been fallow since 1953. Table 1.3 shows the soil types and initial soil test values at each location.

### St. Clair Site

A randomized complete block design was used in the K study. The treatments were 95 and 190 lb/acre of $K_2O$ applied as potash (0-0-60) or liquid dairy manure (4200

[1]Benjamin Eaton Lentz research paper for Plan B, M.S. degree, 1989. ***Availability and Replacement Values of Potassium and Phosphorus in Animal Manures and Different Soil Types Amended with Manures.*** Department of Crop and Soil Sciences, Michigan State University, East Lansing

Table 1.2. Characteristics of the manures used at each location for the P/K study.

| Characteristic | Site MSU | Sturgis | St. Clair | KBS |
|---|---|---|---|---|
| Animal species | Swine | Swine | Diary | Diary |
| Storage type | Lagoon | Liquid pit | Lagoon | Free stall |
| Percent moisture | 98.7 | 89.9 | 93.8 | 65.5 |
| | lb/1000 gal | | | lb/wet ton |
| Total N | 9.5 | 52.0 | 27.5 | 15.1 |
| $NH_4$-N | 7.2 | 37.8 | 17.1 | 1.0 |
| $NO_3$-N | 0.5 | 0.8 | 2.3 | 0.0 |
| $P_2O_5$ | 6.6 | 50.0 | 11.3 | 14.0 |
| $K_2O$ | 11.3 | 21.0 | 23.6 | 66.0 |

Table 1.3. Characteristics of the soils at each location.

| Parameter † | MSU | KBS | Sturgis | St. Clair |
|---|---|---|---|---|
| Soil series | Capac sandy loam loam | Kalamazoo sandy loam | Schoolcraft sandy loam | Spinks loamy sand |
| Classification | Fine-loamy mixed, mesic Aeric Endoaqualfs | Fine-loamy, mixed, mesic Typic Hapludalfs | Fine-loamy, mixed, mesic Typic Argiudolls | Sandy, mixed, mesic Psammentic Hapludalfs |
| Soil pH | 6.5 | 6.8 | 6.2 | 5.45 |
| | lb/acre | | | |
| P | 32 | 48 | 58 | 21 |
| K | 98 | 136 | 213 | 84 |
| Ca | 3200 | 1818 | 2000 | 753 |
| Mg | 528 | 93 | 444 | 62 |

† Values for P, K, Ca, and Mg are extractable concentrations determined by soil fertility testing.

and 8400 gal/acre). Characteristics of the dairy manure used are shown in Table 1.2. In early spring the site had been plowed twice and treated with "Round-up" herbicide. The manure was surface applied by EnviroLand Inc.[2], with a commercial shank type slurry applicator and then incorporated by disking. Nitrogen (ammonium nitrate) and P (triple superphosphate) were supplied in excess of fertilizer recommendations. In the spring of 1990 the cooperator mistakenly applied starter fertilizer containing 36 pounds of potash to the plots, so the K study was not continued in the 1990 growing season.

### KBS, MSU, and Sturgis Sites

The P experiments were designed as an incomplete three factor factorial, randomized complete block. The factorial design was incomplete because only one rather than two controls was used per block. Alternatively the design could be viewed as a two factor factorial plus a control. The factors were P carrier (manure, triple superphosphate), P rate (0, 30, 60 lb $P_2O_5$/acre), taking the manure efficiencies into account, and application method (broadcast, injected). At the KBS site the third factor was tillage (no-till vs. moldboard plow followed by disking) and the P was broadcast applied. At the KBS site both a plowed and a no-till control were used.

Manure and fertilizer P were applied in the spring of 1988. The nutrient content of the manure was established by a prior manure test. Initial manure P was assumed to be 50% as available as triple-superphosphate for the KBS manure, while the MSU, Sturgis, and St. Clair manures P was assumed to be 75% as available as triple-superphosphate. At the KBS site, manure was applied with a normal solid manure spreader. However the low rate turned out to be too low to be applied with a manure spreader so it was applied by weighing the manure into clean garbage barrels and

[2]EnviroLand Inc. is a commercial contractor that applied municipal, industrial, and agricultural wastes residues to land.

spreading the manure by hand. The other (liquid) manures were applied with a shank injection system. Broadcast manure applications were made by applying the manure with the injectors out of the ground. After the initial fertilizer and manure application, $NH_4NO_3$ (34-0-0) and $K_2O$ (0-0-60) were applied to all plots each year in accordance with fertilizer recommendations.

### All Experimental Sites

Hybrid corn was planted in each of the three years (1988–1990). The plot size was 30 feet by 60 feet. Corn was planted the long way at 30 inch row spacing, giving 12 rows per plot. Plant and soil samples were collected from the middle 10 corn rows and 2 feet from each end of the plot. Normal pesticide and herbicide applications were done. In 1989 and 1990, adequate moisture was supplied by precipitation, while 1988 was very dry and the corn was under considerable drought stress. None of the sites was irrigated.

Whole plant samples were taken at the 10th leaf stage in 1988, and at the 5th leaf stage in 1989 and 1990. All of the aboveground plant matter from 10 (1988) and 20 (1989 and 1990) plants was taken. Earleaf samples were taken each year at silking, by collecting twenty individual leaves from each plot. For yield measurements 20 feet of row in each of the two center rows were hand harvested. The grain was shelled from the ear and bagged. The stover (whole aboveground biomass minus the grain) was weighed and shredded. In 1988 and part of 1989 a flail shredder was used, whereas in 1989 and 1990 a silage chopper was used. A subsample of the chopped corn stover was taken back to the lab for moisture determination and analysis.

Wet weights of the stover subsamples were taken as soon as possible after shredding (within 2 hours). All plant tissue materials were dried in a forced air dryer at 65°C prior to chemical analysis. After drying the plant biomass samples were weighed to determine moisture content. The grain moisture was gravimetrically determined with a Borroughs Moisture Computer 2000 in 1988 and 1990. In 1989 grain moisture was determined by difference between wet and dried (1 week at 65°C) weights. Plant tissue samples and stover were ground in a steel mill to pass a 1 mm sieve, and corn grain was ground in a cyclone mill.

One foot soil samples were taken each spring, at the 5th or 10th leaf sample and at harvest. A minimum of 20 cores (10 cores at KBS) were taken from each plot and composited. At the KBS site the cores were split into 0-2", 2-6" and 6-12" depths, to monitor movement of the broadcast applied P in the no-till treatments.

Plant samples were dry-ashed to determine the nutrient content. In 1988 one gram of plant material was dry-ashed at 500°C for 6 hours and diluted with 5ml of 6M $HNO_3$. The ash and solution was mixed to extract the ash. After one hour the samples were brought to 10 ml volume with 2000 mg/L $LiCl_2$ in distilled water. Then a 0.2 ml subsample was diluted with 9.8 ml of 1000 mg/L $LiCl_2$ in distilled water. Both the sample and the subsample were analyzed by direct current plasma atomic emission spectroscopy (DCP-AES). In 1989 and 1990 the procedure was simplified to eliminate the dilution step as follows: 0.25 grams of plant material was dry-ashed in a porcelain crucible at 500°C for 6 hours; 12.5 ml of 1000 mg/L $LiCl_2$ in 3M $HNO_3$ was added and mixed with the residue. After one hour the supernatant was decanted into 20 ml scintillation vials. The samples were stored at room temperature until analyzed for P and K by DCP-AES.

Soil samples were air dried and ground with a hammer mill to pass a 5 mm mesh. Phosphorus levels were determined by Bray-Kurtz P1 extraction at a 1:10 soil:solution ratio with a shaking time of 10 minutes on a rotary shaker. The extract was filtered for 20 minutes through Whatman No. 5 filter paper and the filtrates were refrigerated until analysis. The samples were analyzed on a Lachat Flow Injection analyzer using a molybdate blue colorimetric method (USEPA, 1979).

Ammonium acetate extractable K, Ca and Mg in soil samples was determined by extracting 2.5 grams of soil with 20 ml of 1N $NH_4OAc$ at pH 7. The mixture was shaken for 5 minutes at 200 rpm and filtered through Whatman #1 filter paper. Three ml of extractant were diluted with 3ml of 2000 ppm $LiCl_2$ and refrigerated until analyzed by DCP-AES.

The statistical analysis of the data was done using the PC-SAS system (SAS Institute, 1985). Least significant differences were calculated with the method described by Steel and Torrie (1980). A linear regression equation relating the grain yield of the fertilizer treatments to the amount of P fertilizer applied was obtained (for example equation 1.1 where $a$ and $b$ are obtained from the regression). Then this equation was solved for the fertilizer application and used to calculate equivalent fertilizer applications from the yields of the manure treatments (for example equation 1.2).

$$yield = a \times fertilizer^2 + b \tag{1.1}$$

$$fertilizer = \sqrt{\frac{yield - b}{a}} \tag{1.2}$$

The ratio between the equivalent fertilizer application and the total amount of P supplied by the manure was taken to be the efficiency.

### Phosphorus Studies Results and Discussion

At the KBS site, the corn on the no-till treatment initially lagged behind the plowed treatments in 1988, while in 1989 and 1990 the no-till did slightly better (Table 1.4). The early differences in biomass were not reflected in the grain yield except in 1988. In 1988 drought prevented the no-till treatment from catching-up (Table 1.4). In 1988 the plowed manure treated plots had higher yields than the plowed fertilizer and plowed control treatments, while in 1989 and 1990, no consistent yield response to the P fertilization or tillage was observed. Table 1.5 shows the P concentrations in the plant tissues. The differences in P uptake (Table 1.6) parallel those in the biomass yields (Table 1.4).

Table 1.4. Biomass yields from the P experiment at the KBS site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1989 | Stover 1990 | Grain 1988 | Grain 1989 | Grain 1990 |
|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | | bu/acre | | |
| | | | | | No-till | | | | |
| Control | 280 | 100 | 100 | 3700 | 9700 | 8700 | 50 | 131 | 118 |
| 30 lb as TSP | 370 | 110 | 110 | 3800 | 9100 | 8400 | 58 | 118 | 116 |
| 60 lb as TSP | 280 | 120 | 110 | 3300 | 10600 | 7400 | 49 | 104 | 104 |
| 30 lb as manure | 360 | 110 | 110 | 2900 | 9300 | 7600 | 47 | 119 | 86 |
| 60 lb as manure | 350 | 130 | 130 | 4000 | 9500 | 8200 | 64 | 124 | 114 |
| | | | | | Plowed | | | | |
| Control | 790 | 80 | 80 | 3600 | 10100 | 8100 | 58 | 114 | 108 |
| 30 lb as TSP | 770 | 90 | 90 | 3600 | 9400 | 8200 | 58 | 129 | 121 |
| 60 lb as TSP | 860 | 100 | 100 | 3300 | 9600 | 7800 | 60 | 121 | 116 |
| 30 lb as manure | 920 | 70 | 70 | 4400 | 10000 | 8000 | 73 | 123 | 115 |
| 60 lb as manure | 1000 | 110 | 100 | 4400 | 10500 | 7700 | 78 | 122 | 113 |
| LSD (0.05) | 200 | 35 | 33 | n.s | n.s. | n.s. | 17 | 18 | 19 |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).
‡ In 1988 the 10th leaf stage was sampled.

Table 1.5. Biomass P concentrations from the P experiment at the KBS site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1989 | Stover 1990 | Grain 1988 | Grain 1989 | Grain 1990 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | % | | | | |
| | | | | | No-till | | | | |
| Control | 0.34 | 0.35 | 0.34 | 0.10 | 0.11 | 0.06 | 0.24 | 0.28 | 0.27 |
| 30 lb as TSP | 0.31 | 0.35 | 0.33 | 0.10 | 0.11 | 0.06 | 0.26 | 0.28 | 0.29 |
| 60 lb as TSP | 0.29 | 0.37 | 0.34 | 0.12 | 0.13 | 0.08 | 0.27 | 0.27 | 0.27 |
| 30 lb as manure | 0.29 | 0.35 | 0.30 | 0.11 | 0.08 | 0.07 | 0.26 | 0.26 | 0.33 |
| 60 lb as manure | 0.30 | 0.37 | 0.32 | 0.09 | 0.11 | 0.06 | 0.25 | 0.27 | 0.30 |
| | | | | | Plowed | | | | |
| Control | 0.29 | 0.33 | 0.32 | 0.10 | 0.08 | 0.10 | 0.24 | 0.25 | 0.26 |
| 30 lb as TSP | 0.29 | 0.32 | 0.31 | 0.07 | 0.09 | 0.06 | 0.25 | 0.24 | 0.25 |
| 60 lb as TSP | 0.27 | 0.31 | 0.33 | 0.12 | 0.07 | 0.07 | 0.25 | 0.28 | 0.28 |
| 30 lb as manure | 0.28 | 0.31 | 0.32 | 0.09 | 0.09 | 0.07 | 0.25 | 0.25 | 0.27 |
| 60 lb as manure | 0.30 | 0.33 | 0.30 | 0.09 | 0.11 | 0.07 | 0.25 | 0.27 | 0.29 |
| LSD (0.05) | 0.03 | n.s. | 0.03 | n.s | n.s. | n.s. | 0.02 | n.s. | 0.04 |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).
‡ In 1988 the 10th leaf stage was sampled.

Table 1.6. P uptake from the P experiment at the KBS site.

| Treatment[†] | 5th leaf | | | Stover | | | Grain | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1988[‡] | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 |
| | lb/acre | | | | | | | | |
| | | | | No-till | | | | | |
| Control | 1.0 | 0.38 | 0.36 | 3.6 | 10 | 5.7 | 6.7 | 20 | 18 |
| 30 lb as TSP | 1.2 | 0.39 | 0.39 | 3.8 | 10 | 5.5 | 8.4 | 20 | 19 |
| 60 lb as TSP | 0.97 | 0.45 | 0.38 | 4.0 | 12 | 6.1 | 7.0 | 17 | 16 |
| 30 lb as manure | 1.1 | 0.40 | 0.33 | 3.0 | 7.9 | 5.4 | 6.9 | 17 | 16 |
| 60 lb as manure | 1.1 | 0.50 | 0.41 | 3.6 | 11 | 5.2 | 9.1 | 21 | 19 |
| | | | | Plowed | | | | | |
| Control | 2.3 | 0.26 | 0.25 | 3.5 | 8.3 | 7.8 | 7.8 | 14 | 16 |
| 30 lb as TSP | 2.3 | 0.29 | 0.27 | 2.8 | 8.8 | 4.9 | 8.1 | 17 | 17 |
| 60 lb as TSP | 2.4 | 0.30 | 0.31 | 4.7 | 6.8 | 5.6 | 8.4 | 17 | 18 |
| 30 lb as manure | 2.6 | 0.23 | 0.22 | 4.0 | 8.9 | 5.8 | 10 | 16 | 18 |
| 60 lb as manure | 3.1 | 0.37 | 0.33 | 3.9 | 11 | 5.3 | 11 | 19 | 17 |
| LSD (0.05) | 0.57 | 0.14 | 0.11 | n.s | n.s. | n.s. | 2.4 | 2.8 | *n.s.* |

[†] Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

[‡] In 1988 the 10th leaf stage was sampled.

Soil tests show accumulation of P in the surface layer (0–2") of the no-till vs. the plowed treatments. No significant differences were found for the deeper layers in any of the treatments (Tables 1.7–1.9). Treatments fertilized with manure or TSP generally had higher P levels than the control, but no significant differences were observed between the manure and TSP treatments.

At the MSU site, no significant differences in yield were observed, except at the 5th leaf stage in 1990 where the 30 lb TSP broadcast application and the 30 lb manure injected treatment resulted in a lower yield compared to some of the other treatments (Table 1.10). This difference also shows up in the P uptake data (Table 1.12). Biomass P concentrations did not show any significant differences, except that in 1989 the grain P concentrations were reduced in the 60 lb manure broadcast and the 30 lb manure injected treatment than in the other treatments (Table 1.11).

At the St. Clair site, grain yields on the injected 60 lb treatments were significantly higher than the control in 1988. In 1990, grain and silage yields were higher on

Table 1.7. Soil Bray-Kurtz P1 levels in the spring for the KBS P site.

| Treatment† | 1988 0-2" | 1988 2-6" | 1988 6-12" | 1989 0-2" | 1989 2-6" | 1989 6-12" | 1990 0-2" | 1990 2-6" | 1990 6-12" |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | lb/acre | | | | |
| | | | | | No-till | | | | |
| Control | 23.7 | 11.8 | 19.6 | 33.7 | 20.4 | 20.4 | 28.0 | 10.6 | 9.6 |
| 30 lb as TSP | 27.0 | 14.7 | 21.8 | 48.6 | 23.9 | 23.9 | 33.8 | 14.4 | 11.7 |
| 60 lb as TSP | 34.9 | 15.3 | 20.4 | 42.9 | 21.2 | 21.2 | 32.2 | 13.6 | 7.6 |
| 30 lb as manure | 28.9 | 16.6 | 24.9 | 43.2 | 22.8 | 22.8 | 35.6 | 14.7 | 11.4 |
| 60 lb as manure | 24.6 | 14.9 | 20.0 | 40.6 | 20.6 | 20.6 | 32.8 | 12.3 | 6.7 |
| | | | | | Plowed | | | | |
| Control | 11.3 | 11.3 | 17.6 | 18.9 | 18.9 | 18.9 | 11.9 | 10.8 | 7.1 |
| 30 lb as TSP | 15.8 | 15.8 | 18.2 | 23.7 | 23.7 | 23.7 | 15.9 | 14.0 | 9.1 |
| 60 lb as TSP | 16.2 | 16.2 | 20.5 | 24.5 | 24.5 | 24.5 | 18.1 | 18.1 | 10.3 |
| 30 lb as manure | 13.7 | 13.7 | 21.7 | 22.9 | 22.9 | 22.9 | 16.3 | 16.6 | 11.3 |
| 60 lb as manure | 16.9 | 16.9 | 23.7 | 24.4 | 24.4 | 24.4 | 18.9 | 18.0 | 11.6 |
| LSD (0.05) | 7.8 | n.s. | n.s. | 11.5 | n.s. | n.s. | 7.8 | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

Table 1.8. Soil Bray-Kurtz P1 levels at 5th leaf stage for the KBS P site‡.

| Treatment† | 1989 0-2" | 1989 2-6" | 1989 6-12" | 1990 0-2" | 1990 2-6" | 1990 6-12" |
|---|---|---|---|---|---|---|
| | | | lb/acre | | | |
| | | | No-till | | | |
| Control | 39.4 | 16.9 | 11.6 | 31.5 | 9.8 | 10.9 |
| 30 lb as TSP | 48.9 | 20.3 | 16.7 | 43.3 | 8.9 | 15.0 |
| 60 lb as TSP | 46.8 | 19.5 | 9.5 | 40.0 | 10.9 | 9.0 |
| 30 lb as manure | 48.1 | 25.5 | 14.4 | 35.4 | 17.2 | 14.5 |
| 60 lb as manure | 36.5 | 20.1 | 10.5 | 37.3 | 12.3 | 11.5 |
| | | | Plowed | | | |
| Control | 17.6 | 18.2 | 10.6 | 13.5 | 13.0 | 10.1 |
| 30 lb as TSP | 19.2 | 20.1 | 11.8 | 18.9 | 14.7 | 13.4 |
| 60 lb as TSP | 24.3 | 27.5 | 14.5 | 17.8 | 13.2 | 14.3 |
| 30 lb as manure | 20.8 | 22.3 | 14.7 | 18.7 | 17.1 | 18.6 |
| 60 lb as manure | 22.9 | 22.3 | 13.1 | 18.7 | 14.6 | 15.9 |
| LSD (0.05) | 11.5 | n.s. | n.s. | 11.9 | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

‡ No 5th leaf samples taken in 1988.

Table 1.9. Soil Bray-Kurtz P1 levels at harvest for the KBS P site.

| Treatment† | 1988 0-2" | 1988 2-6" | 1988 6-12" | 1989 0-2" | 1989 2-6" | 1989 6-12" | 1990 0-2" | 1990 2-6" | 1990 6-12" |
|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | | | | |
| | | | | | No-till | | | | |
| Control | 39.2 | 24.9 | 15.9 | 43.8 | 20.4 | 14.5 | 45.7 | 29.4 | 10.9 |
| 30 lb as TSP | 44.2 | 26.3 | 18.9 | 55.6 | 25.0 | 19.3 | 54.0 | 37.0 | 14.8 |
| 60 lb as TSP | 47.7 | 25.5 | 14.7 | 53.9 | 27.2 | 12.7 | 50.7 | 31.0 | 9.7 |
| 30 lb as manure | 45.2 | 32.1 | 18.9 | 46.9 | 26.5 | 18.5 | 50.1 | 27.9 | 15.0 |
| 60 lb as manure | 38.7 | 26.6 | 16.4 | 46.5 | 21.4 | 12.4 | 47.3 | 26.7 | 8.8 |
| | | | | | Plowed | | | | |
| Control | 24.3 | 26.2 | 15.9 | 21.0 | 20.5 | 15.9 | 27.3 | 26.8 | 10.9 |
| 30 lb as TSP | 25.2 | 28.6 | 16.8 | 23.5 | 27.9 | 17.8 | 29.1 | 37.0 | 9.9 |
| 60 lb as TSP | 30.9 | 33.5 | 19.9 | 28.5 | 32.9 | 22.7 | 33.0 | 34.2 | 12.9 |
| 30 lb as manure | 26.7 | 30.2 | 18.6 | 23.6 | 28.8 | 21.2 | 33.1 | 31.1 | 13.5 |
| 60 lb as manure | 25.3 | 29.0 | 18.4 | 25.8 | 30.8 | 21.0 | 35.5 | 33.1 | 14.0 |
| LSD (0.05) | 8.0 | n.s. | n.s. | 14.0 | n.s. | n.s. | 11.9 | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

Table 1.10. Biomass yields from the P experiment at the MSU site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1989 | Stover 1990 | Grain 1988 | Grain 1989 | Grain 1990 |
|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | | bu/acre | | |
| Control | 2500 | 400 | 320 | 4000 | 9800 | 3800 | 62 | 71 | 123 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 2200 | 370 | 290 | 4300 | 11700 | 3800 | 66 | 67 | 121 |
| 60 lb as TSP | 2100 | 510 | 340 | 4200 | 10000 | 4800 | 61 | 75 | 135 |
| 30 lb as manure | 2100 | 520 | 390 | 4400 | 10000 | 4400 | 61 | 63 | 144 |
| 60 lb as manure | 2000 | 470 | 370 | 3500 | 11200 | 4200 | 62 | 68 | 133 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 2000 | 420 | 370 | 4300 | 10400 | 4900 | 61 | 69 | 135 |
| 60 lb as TSP | 2300 | 420 | 330 | 4500 | 11000 | 4700 | 75 | 69 | 143 |
| 30 lb as manure | 2300 | 340 | 270 | 3800 | 8000 | 4700 | 58 | 72 | 139 |
| 60 lb as manure | 2300 | 420 | 310 | 4100 | 10000 | 4500 | 60 | 64 | 136 |
| LSD (0.05) | n.s. | n.s. | 80 | n.s | n.s. | n.s. | n.s. | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).
‡ In 1988 the 10th leaf stage was sampled.

Table 1.11. Biomass P concentrations from the P experiment at the MSU site.

| Treatment[†] | 5th leaf | | | Stover | | | Grain | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1988[‡] | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 |
| | % | | | | | | | | |
| Control | 0.34 | 0.26 | 0.43 | 0.10 | 0.21 | 0.05 | 0.31 | 0.33 | 0.25 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 0.34 | 0.27 | 0.45 | 0.09 | 0.14 | 0.08 | 0.36 | 0.34 | 0.26 |
| 60 lb as TSP | 0.31 | 0.27 | 0.46 | 0.11 | 0.17 | 0.07 | 0.37 | 0.36 | 0.26 |
| 30 lb as manure | 0.33 | 0.28 | 0.45 | 0.12 | 0.13 | 0.06 | 0.35 | 0.31 | 0.28 |
| 60 lb as manure | 0.33 | 0.28 | 0.45 | 0.11 | 0.13 | 0.08 | 0.30 | 0.28 | 0.28 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 0.33 | 0.27 | 0.47 | 0.10 | 0.18 | 0.07 | 0.27 | 0.32 | 0.28 |
| 60 lb as TSP | 0.27 | 0.28 | 0.46 | 0.09 | 0.13 | 0.07 | 0.28 | 0.31 | 0.25 |
| 30 lb as manure | 0.28 | 0.28 | 0.42 | 0.11 | 0.13 | 0.06 | 0.26 | 0.28 | 0.26 |
| 60 lb as manure | 0.33 | 0.28 | 0.44 | 0.11 | 0.15 | 0.08 | 0.34 | 0.33 | 0.26 |
| LSD (0.05) | n.s. | n.s. | n.s. | n.s | n.s. | n.s. | n.s. | 0.04 | n.s. |

[†] Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

[‡] In 1988 the 10th leaf stage was sampled.

Table 1.12. P uptake from the P experiment at the MSU site.

| Treatment[†] | 5th leaf | | | Stover | | | Grain | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1988[‡] | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 |
| | lb/acre | | | | | | | | |
| Control | 8.5 | 1.0 | 1.4 | 4.2 | 20 | 1.9 | 11 | 13 | 17 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 7.4 | 1.0 | 1.3 | 3.9 | 17 | 3.1 | 13 | 13 | 18 |
| 60 lb as TSP | 6.4 | 1.4 | 1.6 | 4.5 | 17 | 3.3 | 9.3 | 12 | 20 |
| 30 lb as manure | 6.9 | 1.6 | 1.8 | 5.5 | 13 | 2.9 | 12 | 11 | 23 |
| 60 lb as manure | 6.6 | 1.3 | 1.7 | 3.7 | 15 | 3.4 | 11 | 11 | 21 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 6.5 | 1.2 | 1.8 | 4.5 | 20 | 3.1 | 9.2 | 12 | 21 |
| 60 lb as TSP | 6.1 | 1.2 | 1.5 | 4.1 | 14 | 3.1 | 12 | 12 | 20 |
| 30 lb as manure | 6.5 | 0.95 | 1.2 | 4.3 | 10 | 3.0 | 8.3 | 8.1 | 20 |
| 60 lb as manure | 7.8 | 1.2 | 1.4 | 4.7 | 15 | 3.4 | 11 | 8.5 | 19 |
| LSD (0.05) | n.s. | n.s. | 0.45 | n.s | n.s. | n.s. | n.s. | n.s. | n.s. |

[†] Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

[‡] In 1988 the 10th leaf stage was sampled.

Table 1.13. Biomass yields from the P experiment at the St. Clair site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1990 | Grain 1988 | Grain 1990 |
|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | – bu/acre – | |
| Control | 220 | 90 | 30 | 2800 | 1300 | 41 | 18 |
| | | | Broadcast Application | | | | |
| 30 lb as TSP | 80 | 160 | 60 | 1900 | 2100 | 29 | 34 |
| 60 lb as TSP | 130 | 220 | 60 | 2100 | 2300 | 36 | 43 |
| 30 lb as manure | 170 | 240 | 70 | 2700 | 2600 | 46 | 49 |
| 60 lb as manure | 210 | 270 | 70 | 2800 | 3000 | 53 | 52 |
| | | | Injected Application | | | | |
| 30 lb as TSP | 170 | 170 | 60 | 2000 | 1900 | 33 | 31 |
| 60 lb as TSP | 220 | 170 | 60 | 3000 | 2300 | 60 | 39 |
| 30 lb as manure | 150 | 240 | 80 | 2800 | 2100 | 39 | 42 |
| 60 lb as manure | 130 | 220 | 70 | 3200 | 2900 | 62 | 52 |
| LSD (0.05) | n.s. | 110 | n.s. | n.s | 660 | 17 | 10 |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).
‡ In 1988 the 10th leaf stage was sampled.

all the treated plots compared to the control, and the manured treatments yielded more than the fertilizer treatments (Table 1.13). Silage yields in 1990 for the 60 lb manure treatments were also significantly higher than the 30 lb TSP treatment on both broadcast and injected plots. The St. Clair site was the only site where P deficiency symptoms were noted in the control plots at the 2–3 leaf stage, although the symptoms had disappeared by the 5th leaf stage. In 1989 the manure treatments resulted in increased yields at the 5th leaf stage, which might be a reflection of low P bioavailability. No harvest data is available for 1989 due to premature harvesting by the cooperator. No significant differences were found in the P content of plant tissues except that the 60 lb injected manure treatment in 1988 was higher than the control (Table 1.14). Phosphorus uptake only showed significant differences in the 1990 harvest data (Table 1.15), mostly a reflection of similar differences in grain yields.

Table 1.14. Biomass P concentrations from the P experiment at the St. Clair site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1990 | Grain 1988 | Grain 1990 |
|---|---|---|---|---|---|---|---|
| | % | | | | | | |
| Control | 0.26 | 0.23 | 0.26 | 0.06 | 0.05 | 0.19 | 0.26 |
| | Broadcast Application | | | | | | |
| 30 lb as TSP | 0.24 | 0.28 | 0.32 | 0.07 | 0.06 | 0.23 | 0.24 |
| 60 lb as TSP | 0.23 | 0.26 | 0.33 | 0.06 | 0.06 | 0.14 | 0.23 |
| 30 lb as manure | 0.22 | 0.30 | 0.37 | 0.07 | 0.05 | 0.23 | 0.22 |
| 60 lb as manure | 0.23 | 0.29 | 0.36 | 0.08 | 0.07 | 0.22 | 0.23 |
| | Injected Application | | | | | | |
| 30 lb as TSP | 0.24 | 0.29 | 0.23 | 0.06 | 0.05 | 0.20 | 0.24 |
| 60 lb as TSP | 0.24 | 0.30 | 0.34 | 0.07 | 0.05 | 0.22 | 0.24 |
| 30 lb as manure | 0.21 | 0.25 | 0.35 | 0.08 | 0.05 | 0.23 | 0.21 |
| 60 lb as manure | 0.26 | 0.26 | 0.36 | 0.07 | 0.05 | 0.35 | 0.26 |
| LSD (0.05) | n.s. | n.s. | n.s. | n.s | n.s. | 0.06 | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).
‡ In 1988 the 10th leaf stage was sampled.

Table 1.15. P uptake from the P experiment at the St. Clair site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1990 | Grain 1988 | Grain 1990 |
|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | | |
| Control | 0.59 | 0.21 | 0.06 | 1.7 | 0.68 | 4.4 | 2.6 |
| | Broadcast Application | | | | | | |
| 30 lb as TSP | 0.20 | 0.32 | 0.18 | 1.3 | 1.2 | 3.7 | 4.6 |
| 60 lb as TSP | 0.32 | 0.61 | 0.20 | 1.3 | 1.4 | 2.8 | 5.5 |
| 30 lb as manure | 0.38 | 0.52 | 0.26 | 1.9 | 1.4 | 5.9 | 6.0 |
| 60 lb as manure | 0.48 | 0.85 | 0.29 | 2.2 | 2.0 | 6.5 | 6.7 |
| | Injected Application | | | | | | |
| 30 lb as TSP | 0.39 | 0.50 | 0.22 | 1.2 | 0.92 | 3.7 | 4.2 |
| 60 lb as TSP | 0.56 | 0.48 | 0.22 | 2.1 | 1.1 | 6.7 | 5.2 |
| 30 lb as manure | 0.33 | 0.63 | 0.32 | 2.2 | 1.0 | 5.0 | 4.9 |
| 60 lb as manure | 0.33 | 0.59 | 0.24 | 2.2 | 1.5 | 12 | 7.9 |
| LSD (0.05) | n.s. | n.s. | n.s. | n.s. | 0.48 | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).
‡ In 1988 the 10th leaf stage was sampled.

Table 1.16. Biomass yields from the P experiment at the Sturgis site.

| Treatment† | 5th leaf | | | Stover | | | Grain | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1988‡ | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 |
| | lb/acre | | | | | | bu/acre | | |
| Control | 430 | 110 | 130 | 2400 | 31500 | 15300 | 56 | 123 | 113 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 400 | 100 | 100 | 2400 | 52800 | 12900 | 50 | 120 | 113 |
| 60 lb as TSP | 390 | 130 | 100 | 2200 | 41400 | 13600 | 46 | 111 | 113 |
| 30 lb as manure | 340 | 140 | 100 | 2200 | 41500 | 11900 | 53 | 113 | 106 |
| 60 lb as manure | 410 | 130 | 90 | 2400 | 56000 | 14500 | 54 | 117 | 120 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 410 | 120 | 90 | 2700 | 40600 | 11000 | 60 | 121 | 122 |
| 60 lb as TSP | 480 | 120 | 100 | 2300 | 40300 | 12700 | 55 | 110 | 123 |
| 30 lb as manure | 400 | 120 | 110 | 2100 | 47500 | 15000 | 49 | 115 | 111 |
| 60 lb as manure | 610 | 110 | 90 | 2700 | 44400 | 13400 | 53 | 116 | 120 |
| LSD (0.05) | n.s. | n.s. | 4.1 | n.s | 22700 | n.s. | n.s. | 6 | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

‡ In 1988 the 10th leaf stage was sampled.

At the Sturgis site, the control treatments often resulted in the highest yields. In 1989 the 30 lb TSP and 60 lb manure broadcast application resulted in significant increases in stover yield, but not in grain yields (Table 1.16). No significant difference in P concentration or P uptake was detected at any of the sampling times (Tables 1.17–1.18).

The strongest soil test P response to P fertilization was observed at the St. Clair site. This was expected because of the extremely low P levels prior to the study. The St. Clair site is also the site with the coarsest texture, which might have helped the soil to respond to the fertilization. The MSU and Sturgis sites had finer grained soils which might have had a higher buffering capacity i.e. more clay, so that the response to P fertilization was less clear. Consistent increases in Bray-Kurtz P1 levels were only observed at the St. Clair site (Table 1.19–1.21), while no consistent increases in P soil test levels were observed at the MSU and Sturgis sites. No consistent significant differences were found between broadcast and injected applications or between the

Table 1.17. Biomass P concentrations from the P experiment at the Sturgis site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1989 | Stover 1990 | Grain 1988 | Grain 1989 | Grain 1990 |
|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | | |
| Control | 0.45 | 0.45 | 0.53 | 0.14 | 0.06 | 0.09 | 0.38 | 0.28 | 0.29 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 0.21 | 0.41 | 0.49 | 0.13 | 0.05 | 0.08 | 0.40 | 0.26 | 0.26 |
| 60 lb as TSP | 0.25 | 0.45 | 0.55 | 0.14 | 0.06 | 0.08 | 0.39 | 0.28 | 0.28 |
| 30 lb as manure | 0.26 | 0.46 | 0.53 | 0.13 | 0.06 | 0.10 | 0.36 | 0.28 | 0.29 |
| 60 lb as manure | 0.24 | 0.30 | 0.52 | 0.11 | 0.06 | 0.06 | 0.38 | 0.27 | 0.28 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 0.24 | 0.43 | 0.51 | 0.11 | 0.05 | 0.06 | 0.34 | 0.28 | 0.25 |
| 60 lb as TSP | 0.24 | 0.43 | 0.52 | 0.12 | 0.05 | 0.06 | 0.37 | 0.26 | 0.28 |
| 30 lb as manure | 0.21 | 0.43 | 0.53 | 0.10 | 0.05 | 0.08 | 0.39 | 0.27 | 0.28 |
| 60 lb as manure | 0.26 | 0.46 | 0.54 | 0.11 | 0.05 | 0.07 | 0.36 | 0.25 | 0.28 |
| LSD (0.05) | n.s. | n.s. | n.s. | n.s | n.s. | n.s. | n.s. | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

‡ In 1988 the 10th leaf stage was sampled.

Table 1.18. P uptake from the P experiment at the Sturgis site.

| Treatment† | 5th leaf 1988‡ | 5th leaf 1989 | 5th leaf 1990 | Stover 1988 | Stover 1989 | Stover 1990 | Grain 1988 | Grain 1989 | Grain 1990 |
|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | | | | |
| Control | 1.9 | 0.52 | 0.71 | 3.4 | 19 | 13 | 12 | 19 | 18 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 0.86 | 0.54 | 0.52 | 3.2 | 27 | 9.7 | 11 | 18 | 16 |
| 60 lb as TSP | 0.98 | 0.57 | 0.52 | 3.1 | 26 | 9.3 | 10 | 17 | 18 |
| 30 lb as manure | 0.88 | 0.62 | 0.50 | 2.9 | 25 | 11 | 11 | 18 | 17 |
| 60 lb as manure | 0.98 | 0.60 | 0.48 | 2.8 | 33 | 8.9 | 12 | 18 | 19 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 0.98 | 0.52 | 0.45 | 3.2 | 22 | 6.8 | 11 | 19 | 17 |
| 60 lb as TSP | 1.1 | 0.52 | 0.57 | 2.9 | 22 | 7.4 | 11 | 16 | 19 |
| 30 lb as manure | 0.84 | 0.51 | 0.59 | 2.1 | 26 | 11 | 11 | 17 | 17 |
| 60 lb as manure | 1.5 | 0.52 | 0.49 | 3.2 | 26 | 9.3 | 11 | 16 | 19 |
| LSD (0.05) | n.s. | n.s. | n.s. | n.s | n.s. | n.s. | n.s. | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

‡ In 1988 the 10th leaf stage was sampled.

TSP and manure applications, although the 60 lb treatments showed the largest number of samples with a significant increase above the control treatments.

At the MSU site, soil test P levels at the 10th leaf sampling in 1988 the 30 lb TSP and the manure broadcast treatments were higher than the control. No significant differences were observed in 1989 and 1990 (Table 1.20). On the harvest sample the 60 lb TSP injected treatment was higher than the control in 1988, while in 1989 the broadcast applications resulted in higher soil test levels than the control. In 1990 the 30 lb manure injected treatment showed significantly lower P levels than the other treatments (Table 1.21).

At the St. Clair site the $P_2O_5$ additions resulted in significantly elevated P soil test levels compared to control soils not receiving any $P_2O_5$, but no consistent differences were observed between the 30 and 60 lb or the broadcast vs. injected or the manured vs. fertilizer treatments (Tables 1.19–1.21).

At the Sturgis site in the spring of 1989, the 60 lb manure broadcast application and both 60 lb injected treatments resulted in significantly increased soil test P levels compared to the control (Table 1.19). At the 5th leaf sample no significant differences were observed in 1989, but in 1988 the 60 lb manure injected application resulted in higher soil test levels. In 1990 both the 60 lb manure treatments and the 60 lb TSP injected treatment resulted in higher soil test levels than the control (Table 1.20). At the harvest sample the only significant difference was observed in 1988 where the 60 lb injected treatments showed soil test levels higher than the control (Table 1.21).

No basis was found to reject the assumed P availability factors as hypothesized. Table 1.22 shows the calculated P efficiencies. The average first year availability factor for the liquid manures applied at the 30 lb $P_2O_5$/acre rate was 88%, while the solid manure was 48% as available as triple superphosphate. These values agree well with the assumed values of 75% for the liquid manures and 50% for the solid manure. First year availability factors for the the 60 lb/acre rate where 48% for the solid manures

Table 1.19. Soil Bray-Kurtz P1 levels in the spring at the MSU, St. Clair, and Sturgis sites.

| Treatment[†] | MSU 1988 | MSU 1989 | MSU 1990 | St. Clair 1988 | St. Clair 1989 | St. Clair 1990 | Sturgis 1988 | Sturgis 1989 | Sturgis 1990 |
|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | | | | |
| control | 10.8 | 35.5 | 12.0 | 14.5 | 21.1 | 18.4 | 24.5 | 25.4 | 15.8 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 13.5 | 33.1 | 16.4 | 70.3 | 65.2 | 53.9 | 23.6 | 22.7 | 15.5 |
| 60 lb as TSP | 12.9 | 40.1 | 15.2 | 35.9 | 45.7 | 29.4 | 26.6 | 26.0 | 17.2 |
| 30 lb as manure | 14.0 | 46.4 | 16.7 | 76.0 | 93.4 | 61.8 | 28.5 | 26.9 | 15.9 |
| 60 lb as manure | 13.8 | 37.7 | 15.9 | 60.7 | 95.6 | 51.5 | 25.4 | 31.6 | 19.9 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 13.4 | 31.0 | 16.0 | 62.5 | 54.9 | 42.3 | 30.5 | 27.8 | 16.8 |
| 60 lb as TSP | 9.7 | 41.6 | 15.6 | 29.7 | 56.1 | 30.2 | 24.4 | 43.4 | 19.9 |
| 30 lb as manure | 10.6 | 31.7 | 12.7 | 40.7 | 43.8 | 35.4 | 23.0 | 27.1 | 18.9 |
| 60 lb as manure | 14.1 | 38.7 | 14.2 | 39.8 | 71.1 | 35.3 | 27.5 | 31.4 | 19.0 |
| LSD (0.05) | n.s. | 13.2 | 4.7 | 29.9 | 32.0 | 18.8 | n.s. | 5.1 | n.s. |

[†] Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

Table 1.20. Soil Bray-Kurtz P1 levels at the 5th leaf[†] stage for the MSU, St. Clair, and Sturgis sites.

| Treatment[‡] | MSU 1988 | MSU 1989 | MSU 1990 | St. Clair 1988 | St. Clair 1989 | St. Clair 1990 | Sturgis 1988 | Sturgis 1989 | Sturgis 1990 |
|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | | | | |
| control | 15.2 | 16.1 | 11.5 | 10.6 | 16.4 | 8.7 | 29.4 | 22.3 | 18.1 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 21.0 | 19.9 | 12.7 | 28.6 | 60.2 | 38.1 | 24.3 | 21.1 | 17.1 |
| 60 lb as TSP | 19.4 | 18.6 | 11.5 | 18.5 | 31.8 | 21.6 | 26.6 | 24.4 | 19.2 |
| 30 lb as manure | 22.4 | 20.3 | 14.8 | 31.8 | 63.4 | 39.0 | 30.2 | 21.8 | 19.6 |
| 60 lb as manure | 22.0 | 20.9 | 13.0 | 26.0 | 49.8 | 31.6 | 29.2 | 25.8 | 26.4 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 16.2 | 17.9 | 10.3 | 25.0 | 37.9 | 23.5 | 30.3 | 21.7 | 18.4 |
| 60 lb as TSP | 11.8 | 21.3 | 13.0 | 25.0 | 42.6 | 20.1 | 27.3 | 25.6 | 23.6 |
| 30 lb as manure | 15.3 | 13.8 | 10.5 | 18.2 | 38.7 | 23.6 | 33.5 | 28.2 | 20.3 |
| 60 lb as manure | 19.1 | 21.0 | 12.6 | 14.3 | 26.9 | 17.1 | 38.0 | 30.4 | 23.5 |
| LSD (0.05) | 5.7 | n.s. | n.s. | 9.3 | 20.8 | 15.5 | 4.8 | n.s. | 4.1 |

[†] In 1988 samples were taken at the 10th leaf time.

[‡] Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

Table 1.21. Soil Bray-Kurtz P1 levels at harvest for the MSU, St. Clair, and Sturgis sites.

| Treatment† | MSU | | | St. Clair | | | Sturgis | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 |
| | lb/acre | | | | | | | | |
| control | 14.4 | 9.5 | 15.8 | 15.7 | 18.5 | 27.4 | 27.0 | 21.8 | 21.8 |
| | | | | Broadcast Application | | | | | |
| 30 lb as TSP | 17.1 | 15.2 | 16.6 | 68.2 | 66.7 | 48.6 | 23.9 | 23.2 | 23.2 |
| 60 lb as TSP | 13.9 | 15.7 | 19.1 | 32.8 | 32.1 | 43.2 | 27.3 | 23.2 | 23.2 |
| 30 lb as manure | 16.1 | 16.6 | 16.9 | 69.5 | 56.6 | 49.1 | 28.1 | 24.5 | 24.5 |
| 60 lb as manure | 14.6 | 12.3 | 13.1 | 61.7 | 54.3 | 49.8 | 32.3 | 29.5 | 29.5 |
| | | | | Injected Application | | | | | |
| 30 lb as TSP | 15.6 | 11.9 | 14.9 | 47.9 | 60.1 | 38.0 | 24.9 | 24.5 | 24.5 |
| 60 lb as TSP | 28.1 | 15.9 | 17.3 | 23.6 | 40.5 | 37.0 | 38.0 | 28.0 | 28.0 |
| 30 lb as manure | 10.6 | 11.4 | 7.5 | 38.7 | 44.6 | 43.3 | 24.5 | 24.6 | 24.6 |
| 60 lb as manure | 14.1 | 11.8 | 10.6 | 28.2 | 32.9 | 38.5 | 33.6 | 28.5 | 28.5 |
| LSD (0.05) | 5.7 | 5.6 | 5.2 | 26.3 | 23.8 | 9.2 | 6.0 | n.s. | n.s. |

† Quantities of $P_2O_5$ applied as manure or triple superphosphate (TSP).

and 22% for the liquid manure. This decrease might be due to P saturation. Adequate P was available for corn growth so the additional P supplied by the 60 lb treatment did not increase yields as much as the 30 lb treatment. Efficiencies seemed to increase during the residual period, however the increase was not statistically significant, so that the residual availability of manure P was the same as triple superphosphate-P. The high value for the third year residual efficiency at St. Clair is probably due to the starter fertilizer applied in the spring of 1990. The calculated efficiencies ranged from 22% for the 60 lb $P_2O_5$ manure treatment in the first year at KBS to about 130% on the 30 lb $P_2O_5$ manure treatment in the third year at MSU. These values are in the same range as those reported by Montavalli et al. (1989).

Table 1.22. Calculated manure P availability factors based on corn grain yields.

| | 30 lb applied† | | | 60 lb applied† | | |
|---|---|---|---|---|---|---|
| | 1 year | 2 year | 3 year | 1 year | 2 year | 3 year |
| | % | | | | | |
| MSU | 65 | 74 | 133 | 35 | 33 | 52 |
| Sturgis | 103 | 120 | 51 | 46 | 45 | 52 |
| St. Clair‡ | 95 | -- | 172 | 63 | -- | 107 |
| KBS | 48 | 49 | 75 | 22 | 24 | 28 |

† Values are relative to the fertilizer treatments.

‡ No values for the second year due to premature harvesting by the cooperator.

## Potassium Study Results and Discussion

Table 1.23 shows the soil test K levels at all of the sampling dates in 1988 and 1989. The K study was not continued in 1990 due to starter potash fertilizer application at planting. Soil test K levels showed a difference between the two rates as well as between the manure and fertilizer treatments. Higher rates tended to result in higher soil test levels. The manure treatments consistently showed higher soil test K levels than the fertilizer treatments, although the increase was not statistically significant. The difference can be explained, since the actual rate of manure $K_2O$ applied contained about 8 lb $K_2O$ per acre more than the fertilizer rate.

Grain yields for the two years were highly variable between replicates (Table 1.24). Yields did not show a response to $K_2O$ treatments in either year. Taken over both years however the rate component became significant. The average grain yield increased from 59 bu/acre in the control treatment to 62 and 84 bu/acre in the 95 and 190 lb $K_2O$ treatment. Stover yields did not show any significant differences due to the treatments.

The average K content of the grain did not increase due to increased fertilization (Table 1.25). Stover K content in the high manure treatments was highest of any of

Table 1.23. Potassium soil test levels at the St. Clair site.

| Treatment† | 1988 spring | 1988 10th leaf | 1988 harvest | 1989 spring | 1989 5th leaf | 1989 harvest |
|---|---|---|---|---|---|---|
| | mg K/kg soil | | | | | |
| Control | 48 | 43 | 49 | 38 | 35 | 40 |
| 95 lb as potash | 60 | 50 | 60 | 56 | 45 | 53 |
| 95 lb as manure | 67 | 59 | 66 | 66 | 46 | 55 |
| 190 lb as potash | 89 | 63 | 78 | 83 | 61 | 69 |
| 190 lb as manure | 77 | 76 | 86 | 100 | 65 | 74 |
| LSD (0.05) | 22 | n.s. | n.s. | 19 | 20 | 17 |

† Quantities of $K_2O$ applied as potash or manure.

Table 1.24. St Clair Potassium study grain and stover yields at harvest.

| Treatment† | Grain 1988 | Grain 1989 | Grain Average | Stover 1988 | Stover 1989 | Stover Average |
|---|---|---|---|---|---|---|
| | bu/acre | | | lb/acre | | |
| Control | 56 | 61 | 59 | 5000 | 4200 | 3500 |
| 95 lb as potash | 42 | 65 | 54 | 3800 | 4900 | 3500 |
| 95 lb as manure | 59 | 82 | 71 | 5000 | 6100 | 5000 |
| 190 lb as potash | 71 | 85 | 78 | 6300 | 6600 | 4800 |
| 190 lb as manure | 63 | 116 | 90 | 5100 | 6900 | 4800 |
| LSD (0.05) | n.s. | n.s. | 31 | n.s. | n.s. | n.s. |

† Quantities of $K_2O$ applied as potash or manure.

Table 1.25. St. Clair Potassium study nutrient concentrations at harvest.

| Treatment† | Grain 1988 | Grain 1989 | Stover 1988 | Stover 1989 |
|---|---|---|---|---|
| | % | | | |
| Control | 0.39 | 0.36 | 1.4 | 0.81 |
| 95 lb as potash | 0.42 | 0.34 | 1.8 | 1.0 |
| 95 lb as manure | 0.41 | 0.34 | 1.8 | 1.0 |
| 190 lb as potash | 0.40 | 0.34 | 1.6 | 1.0 |
| 190 lb as manure | 0.41 | 0.34 | 2.2 | 1.3 |
| LSD (0.05) | n.s. | n.s. | 0.38 | 0.027 |

† Quantities of $K_2O$ applied as potash or manure.

the treatments. The stover K content of most treatments significantly exceeded the control. The overall K uptake increased (Table 1.26) mostly due to the larger grain production. The was no significant difference in K content, uptake or yield between manure and fertilizer derived K. Therefore the hypothesis that liquid manure K is as available as potash could not be rejected. This agrees with the findings of Azevedo and Stout (1974).

Table 1.26. St. Clair Potassium study nutrient uptake at harvest.

| Treatment† | Grain 1988 | Grain 1989 | Stover 1988 | Stover 1989 |
|---|---|---|---|---|
| | lb/acre | | | |
| Control | 6.6 | 10 | 69 | 35 |
| 95 lb as potash | 4.6 | 10 | 66 | 51 |
| 95 lb as manure | 7.8 | 13 | 87 | 59 |
| 190 lb as potash | 9.1 | 13 | 100 | 66 |
| 190 lb as manure | 8.6 | 18 | 112 | 84 |
| LSD (0.05) | n.s. | n.s. | 39 | 30 |

† Quantities of $K_2O$ applied as potash or manure.

# CHAPTER 2

# Residual N Accumulation Due to Low Annual Applications of Manure


## Abstract

Long-term large manure application can lead to increased soil N levels, due to the accumulation of residual manure. It is not clear if this accumulation also takes place when manure is applied at agronomic rates i.e. to satisfy the N requirement of the crop. Therefore the residual effect of agronomic rates of manure applications was investigated. Manure was applied at agronomic rates for one, two, and three years consecutively. Corn (*Zea mays L.*) was grown, and the yields on the manure plots compared to the yields of fertilized plots. Three years of annual manure application to loamy and sandy loam soils in Michigan did not significantly increase soil inorganic and total nitrogen (N) levels, corn grain yields, or dry matter production.


## Introduction

Traditionally manure has been applied to land as a fertilizer and an expedient method of disposal. Manures have varying N availability compared to inorganic N salt. Coleman (1917) reviewed early experiments on the N efficiency of manures. He reported that experimenters between 1895 and 1914 found cow manure to be between 18 to 58% as available as $NaNO_3$. These factors are similar to the manure N efficiencies used currently (Vitosh et al., 1990).

Large applications of manure increase the levels of N in the soil (Meek et al., 1974; Adriano et al., 1971). The question we wanted to address was: Will low, agronomic rates of manure applications also result in significant increases in soil N levels? Sommerfeldt et al. (1988) found that long term (11 year) application of cattle feedlot manure resulted in an increase of organic matter and total N. This increase could be modeled with a Michaelis-Menten type model. Application rates ranged from the recommended rate (30 wet metric tons $ha^{-1}$ $year^{-1}$) to three times the recommended rate.

Smith et al. (1980) reported increases in total N content, nitrate levels and N mineralization, although statistically significant increases were only found at rates higher than 67 wet metric tons $ha^{-1}$ $year^{-1}$ applied annually for 8 years. From the application of 0, 10, and 20 tons $acre^{-1}$ of manure over three years, Herron and Erhart (1965) calculated that one ton of cattle feedlot manure was equivalent to 22 lb N from $NH_4NO_3$. They also reported that the residual value of their manure after three years of application was less than 2 lb N per ton manure. Smith et al. (1984) reported that residual effects were generally small, except where large applications of manure had been made. Lund and Doss (1980) reported increased yields of bermuda grass after 6 years of annual manure applications and attributed this to the residual N released. The yields remained above those of fertilizer controls for 3 to 4 years after manure applications had ceased. Mugwira (1979) reported increased yields of millet and rye forage due to residual N effects from three years of manure applications at 180 dry metric tons $ha^{-1}$ $year^{-1}$ or higher. He also reported evidence that these high rates might potentially contaminate groundwater from nitrate leaching.

The organic N in manures applied to soils can be expected to break down in successive years. A decay series is often used to estimate the N release from manure applications. The premise for this decay is that a certain percentage of the added organic matter breaks down each year, and the percentage of that annual breakdown will decrease each year (Powers et al., 1975; Pratt et al., 1973). Decay series have been proposed for different manures (Mathers and Goss, 1979; Pratt et al., 1973). Pratt et al. (1976) demonstrated a good agreement between the residuals calculated with a decay series and those measured during four years of manure applications. The use of decay series for predicting residual N availability is currently recommended in Michigan (Vitosh et al., 1990). Mathers and Goss (1979) developed a relationship to estimate the shape of the decay series from the initial N content of the manure.

## Objective

The objective of this study was to determine if low, agronomic applications of manure result in a significant accumulation of residual N.

## Methods and Materials

In 1988 four sites were established, but one of the original four sites was dropped in 1989 and the Chatham site was added. Table 2.1 gives the soil types and initial soil test at the experimental sites. The study sites used for this experiment were located in the following places:

- MSU University Farm, East Lansing MI
- KBS Experimental Farm, Hickory Corners MI
- Dave Sturgis Farm, Sturgis MI
- Upper Peninsula Experimental Station, Chatham MI (established in 1989)

Manure was applied for one, two, or three years in a row. The first year manure was applied to three treatments, so we had a "check" i.e. no manure was applied and three "one year" manure treatments, the second year manure was applied to two of the three manure treatments. This resulted in a "check" treatment, a "one

Table 2.1. Characteristics of the soils at each site.

| Parameter† | MSU | KBS | Sturgis | Chatham |
|---|---|---|---|---|
| Soil series | Capac loam | Kalamazoo sandy loam | Schoolcraft sandy loam | Munising sandy loam |
| Classification | Fine-loamy, mixed, mesic Aeric Endoaqualfs | Fine-loamy, mixed, mesic Typic Hapludalfs | Fine-loamy, mixed, mesic Typic Argiudolls | Coarse-loamy, mixed, frigid Oxyaquic Fragiorthods |
| pH | 6.6 | 6.8 | 6.2 | 6.7 |
| | lb/acre | | | |
| P | 95 | 48 | 25558 | 182 |
| K | 211 | 136 | 213 | 302 |
| Ca | 2743 | 1818 | 2000 | 1760 |
| Mg | 480 | 93 | 444 | 356 |

† Values of P, K, Ca, and Mg are extractable concentrations determined by soil fertility testing.

year" manure treatment and two "two year" manure treatments. In the third year manure was applied to one of the "two year" treatments. Now we had one "check", one "one year", one "two year", and one "three year" manure treatment. In the forth year no manure was applied. The manure application rates were chosen to release an estimated 100 lb N during the growing season, on the assumption that one-third of the organic matter breaks down during the first year, and no $NH_4$-N is volatilized. Due to the year to year variability of the manure, the actual application rates varied somewhat (Table 2.3). Manure application methods varied. In 1988 the manure was applied with manure spreaders, while during 1989 – 1991 manure was spread by hand, except at the MSU site.

The nutrient composition of the manures is given in Table 2.2, and 2.3 shows the amount of manures applied each year. Since the manure applications were based on estimated or "quick-tested" nutrient values, the actual amounts of plant-available N applied varied significantly over the years (Table 2.3). In the fourth year no manure was applied. In 1988 and 1989 inorganic N treatments were 0, 60, and 160 lb N/acre and were 0, 40, 80, and 120 lb N/acre in 1990 and 1991. The experimental design was a randomized complete block design with four replications.

In 1988 and 1989 soil samples were taken to 2 feet depth at one foot intervals, while in 1990 and 1991 only the top foot was sampled. A minimum of 15 cores were composited for each sample. In 1988, soil samples were extracted in a field moist state, but where air-dried in the other years.

Soil samples (10 grams) were extracted with 2M KCL at a 1:10 soil:solution ratio. The samples were shaken for one hour at 240 rpm on a rotary shaker and then vacuum filtered through Whatman GF/C glass fiber filters. The filtrate was analyzed for nitrate and ammonium using a Latchat Flow Injection Analyzer (USEPA, 1979). In 1988 field moist soil samples were extracted by shaking with 1M KCl solution (1:10 soil:solution ratio) for 1 hour followed by centrifugation and analysis of the supernatant. The results were then corrected for moisture. In 1990 total soil N was determined by Total Kjeldahl N (TKN) digestion (0.5 grams) of the spring and fall samples from the MSU, KBS, and Chatham site.

Hybrid corn was planted at all sites. While 1988 was a dry year, the other three years had normal moisture patterns. None of the sites was irrigated, so during 1988 the corn suffered severe drought stress. Herbicide and pesticide applications were made as necessary.

Grain and stover (whole, above-ground plant matter minus grain) were hand harvested. In 1988 two 20 foot rows were harvested, while only three rows of 3 feet were taken from each plot in the other years. Grain and stover were weighed separately. The grain was dried if necessary and shelled with a commercial stationary sheller. The stover samples were shredded in the field and a subsample was taken to the lab for moisture determination and analysis. Grain moistures were determined gravimetrically with a Boroughs Moisture Computer, except in 1990 when the moisture was determined by weigh loss after oven drying. Grain weights were corrected to 15.5%

Table 2.2. Characteristics of the manures used at each site.

| Parameter | Chatham | | | KBS | | | MSU | | | Sturgis | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1989 | 1990 | 1991 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 |
| Animal Species | Beef | | | Beef | | | Swine | | | Swine | | |
| Storage Type | Free Stall | | | Free Stall | | | Lagoon | | | Liquid Pit | | |
| Moisture (%) | 81.0 | 83.1 | 80.0 | 65.5 | 78.0 | 84.7 | 98.7 | 99.5 | 99.5 | 89.9 | 91.2 | 91.7 |
| | lb/wet ton | | | | | | lb/1000 gal | | | | | |
| Total N | 11.1 | 8.8 | 10.2 | 15.1 | 12.6 | 8.9 | 9.5 | 7.4 | 4.5 | 52.0 | 58.2 | 46.8 |
| $NH_4^+$ | 3.5 | 1.6 | 1.8 | 1.0 | 3.0 | 4.0 | 7.2 | 6.3 | 4.1 | 37.0 | 47.8 | 33.8 |
| $NO_3^-$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.5 | 0.2 | 0.0 | 0.8 | 0.4 | 0.0 |
| $P_2O_5$ | 4.2 | 4.3 | 4.2 | 14.0 | 4.4 | 3.3 | 6.6 | 1.9 | 1.6 | 50.0 | 35.1 | 26.0 |
| $K_2O$ | 13.5 | 15.7 | 14.7 | 66.0 | 21.9 | 15.1 | 11.3 | 6.6 | 4.2 | 21.0 | 25.0 | 23.3 |

Table 2.3. Amount of manure and plant-available N applied at each site.

| | Manure | | | | Plant-available N | | | |
|---|---|---|---|---|---|---|---|---|
| | Chatham[†] | KBS | MSU | Sturgis | Chatham[†] | KBS | MSU | Sturgis |
| | — tons/acre — | | — gal/acre — | | lb/acre | | | |
| 1988 | - | 18 | 20,000 | 3,000 | - | 100 | 201 | 158 |
| 1989 | 14 | 25 | 15,000 | 3,100 | 96 | 170 | 128 | 202 |
| 1990 | 14 | 23 | 10,800 | 1,600 | 59 | 153 | 59 | 76 |
| 1991 | 13 | - | - | - | 68 | - | - | - |

[†] Experiment at Chatham began a year later than at the other sites.

moisture. The grain samples were ground in a cyclone mill. Stover moisture was determined by weight loss on drying at 65°C. Stover samples were ground using a steel mill.

Total N in plant samples was determined using a micro TKN digestion followed by analysis on a Latchat Flow Injection Analyzer (USEPA, 1979). The TKN procedure involves weighing 0.1 grams (dry) of green plant tissue or 0.2 grams (dry) of stover material into a 75 ml TKN tube. Three ml of concentrated sulfuric acid ($H_2SO_4$) and one Kjeldahl tablet were added, and samples were digested in a block digester at 375°C for 2 to 2.5 hours.

The statistical analysis of the data was done using PC-SAS system (SAS Institute, 1985). Least significant differences were calculated with the method described by Steel and Torrie (1980). A linear regression equation relating the grain yield of the fertilizer treatments to the amount of N applied was obtained (for example equation 2.1 where $a$ and $b$ are obtained from the regression). Both linear and quadratic models were tried. Then this equation was solved for the fertilizer application and used to calculate equivalent fertilizer applications from the yields of the manure treatments (for example equation 2.2).

$$yield = a \times fertilizer^2 + b \tag{2.1}$$

Table 2.4. Inorganic N ($NO_3$-N + $NH_4$-N) concentrations in soil samples at harvest 1991.

| Treatment | KBS | MSU | Sturgis |
|---|---|---|---|
| | | lb/acre | |
| 0 lb N | 8.1 | 15.8 | 6.8 |
| 40 lb N | 9.7 | 15.9 | 11.2 |
| 80 lb N | 13.0 | 20.8 | 9.6 |
| 120 lb N | 19.5 | 16.7 | 16.4 |
| 1 year | 8.7 | 14.1 | 6.7 |
| 2 years | 9.0 | 14.8 | 7.1 |
| 3 years | 9.5 | 15.2 | 8.0 |
| LSD (0.05) | 4.2 | n.s. | 7.2 |

$$fertilizer = \sqrt{\frac{yield - b}{a}} \tag{2.2}$$

## Results and Discussion[1]

Table 2.4 shows the inorganic N (nitrate plus ammonium) levels in the soil at harvest (1991). No significant differences were found between the control and the manure treatments at any of the sites. Since the inorganic treatments had received $NH_4NO_3$ in the spring the soil N levels for these plots are higher. Treatments accounted for 59% of the variability. Soil inorganic N levels were higher at MSU than at the other sites. However the residual manure treatments did not result in significantly increased (or decreased) levels of inorganic N.

In 1990 replication and treatments accounted for 68% of the variability in the soil N levels on the manure treatments. The only significant differences at the 5% level were between sites. The MSU site contained significantly more total N in the soil (4500 lb N/acre) than the other three sites (2400 lb N/acre). On the fertilizer treatments:

[1]Since the Chatham site lags one year behind the other sites the results are not reported here.

Table 2.5. Corn grain yields at manure residual N sites.

| | KBS | | | MSU | | | Sturgis | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1989 | 1990 | 1991 | 1989 | 1990 | 1991 | 1989 | 1990 | 1991 |
| | bu/acre | | | | | | | | |
| 0 lb N | 65 | 60 | 91 | 92 | 139 | 88 | 52 | 112 | 77 |
| 40 lb N‡ | 99 | 81 | 128 | 137 | 134 | 114 | 111 | 130 | 131 |
| 80 lb N† | – | 89 | 131 | – | 142 | 106 | – | 142 | 160 |
| 120 lb N‡ | 112 | 85 | 157 | 140 | 136 | 130 | 136 | 158 | 172 |
| 1 year | 86 | 67 | 114 | 130 | 142 | 85 | 100 | 132 | 81 |
| 2 years | 112 | 68 | 127 | 140 | 139 | 68 | 121 | 136 | 81 |
| 3 years† | – | 62 | 125 | – | 134 | 63 | – | 137 | 86 |
| LSD (0.05) | 16 | 24 | 44 | n.s. | 8 | 26 | n.s. | 14 | 29 |

† In 1989 no 80 lb N and 3 years manure treatment were created.

‡ In 1989 the 120 lb N treatment received 160 lb N, while the 40 lb N treatment received 60 lb N.

site, replication and treatments accounted for 86% of the soil N variability. Site and the linear rate components are significant at the 1% level.

Corn yields were variable (Table 2.5–2.6). In general we observed a response to the inorganic N, and manure fertilization. However significant yield increases due to residual N were not detected. The reason might be that the inputs of N were small enough so that residuals would not be detectable after only three years of application. Or small applications of manure might establish a new equilibrium between manure addition and mineralization that is not significantly higher than the old equilibrium.

The N removal and manure N additions were nearly the same (Table 2.3 and 2.7). this might account for the lack of residual response.

In 1991 when no manure was applied, the residual manure mineralization from one, two and three years of manure application was calculated using a linear or quadratic regression of the yields from the inorganic N treatments onto the amount of N added. Table 2.8 summarizes the pounds inorganic N equivalents produced by one, two, and three years of manure applications at agronomic rates. Due to the large variability between treatment reps, the differences in residual N at each site are

Table 2.6. Corn stover yields at manure residual N sites.

| | KBS | | | MSU | | | Sturgis | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1989 | 1990 | 1991 | 1989 | 1990 | 1991 | 1989 | 1990 | 1991 |
| | lb/acre | | | | | | | | |
| 0 lb N | 4800 | 4400 | 13600 | 4100 | 8500 | 11900 | 4100 | 4500 | 5400 |
| 40 lb N‡ | 5800 | 4900 | 17000 | 4400 | 8800 | 15000 | 6100 | 8200 | 5600 |
| 80 lb N† | – | 5200 | 18600 | – | 8800 | 13500 | – | 7100 | 5800 |
| 120 lb N‡ | 6700 | 5200 | 19900 | 4700 | 8400 | 15500 | 5200 | 10300 | 6200 |
| 1 year | 5700 | 5200 | 16400 | 4100 | 9600 | 12600 | 5100 | 8500 | 4400 |
| 2 years | 6400 | 5000 | 16900 | 5000 | 9800 | 11300 | 5000 | 7700 | 5200 |
| 3 years† | – | 4800 | 16600 | – | 9600 | 11700 | – | 8200 | 4100 |
| LSD (0.05) | 640 | n.s. | n.s. | n.s. | n.s. | 2300 | n.s. | n.s. | n.s. |

† In 1989 no 80 lb N and 3 years manure treatment were created.

‡ In 1989 the 120 lb N treatment received 160 lb N, while the 40 lb N treatment received 60 lb N.

Table 2.7. Total N uptake by the Corn Crop at the manure residual N sites.

| | KBS | | | MSU | | | Sturgis | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1989 | 1990 | 1991 | 1989 | 1990 | 1991 | 1989 | 1990 | 1991 |
| | lb/acre | | | | | | | | |
| 0 lb N | 44 | 67 | 76 | 119 | 169 | 79 | 39 | 86 | 147 |
| 40 lb N‡ | 68 | 98 | 102 | 102 | 189 | 125 | 91 | 143 | 200 |
| 80 lb N† | – | 100 | 151 | – | 212 | 109 | – | 142 | 243 |
| 120 lb N‡ | 101 | 124 | 185 | 124 | 219 | 152 | 142 | 232 | 386 |
| 1 year | 73 | 106 | 100 | 96 | 164 | 71 | 86 | 179 | 117 |
| 2 years | 98 | 103 | 100 | 119 | 168 | 63 | 108 | 148 | 109 |
| 3 years† | – | 93 | 123 | – | 188 | 69 | – | 146 | 108 |
| LSD (0.05) | 45 | 38 | 42 | n.s. | 34 | 35 | n.s | 51 | n.s. |

† In 1989 no 80 lb N and 3 years manure treatment were created.

‡ In 1989 the 120 lb N treatment received 160 lb N, while the 40 lb N treatment received 60 lb N.

Table 2.8. Fertilizer N equivalents observed in 1991 for residual manure N.

| Consecutive Manure Applications | Sturgis | MSU | KBS |
|---|---|---|---|
| | –lb/1000 gal– | | lb/ton |
| 1 year | 6.0 | n.m.† | 0.5 |
| 2 years | 7.0 | 5.1 | 1.7 |
| 3 years | 3.6 | 1.3 | 1.6 |
| LSD (0.05) | n.s. | n.s. | n.s. |

† not meaningful; a negative value was obtained.

not significant. The amount of residual manure N at the KBS site is similar to the amount reported by Herron and Erhart (1965). The average first year residual at the MSU site was negative, meaning that the control plot yielded more than the first year manure residual. Past manure applications explained 40% of the variability in residual N at Sturgis, 54% at MSU, and 34% at KBS.

Three years of manure application at agronomic rates did not seem to increase grain yields, dry matter production, inorganic or total soil N levels. Residual manure applied at agronomic rates provided an average of 4 lb N acre$^{-1}$ from the swine manure residual and 1.3 lb N acre$^{-1}$ from beef manure residual (Table 2.8). This contribution does not seem to be significant considering that 100–150 lb N acre$^{-1}$ are normally applied to a corn crop. But it may be that three years is not sufficient to allow for a measurable accumulation of residual manure applied at agronomic rates.

# CHAPTER 3

## The Effect of Delayed Manure Application and Cover Crops on Manure N Availability When Applying Manure in the Fall

### Abstract

The effectiveness of several strategies designed to reduce fall manure nitrogen losses were compared. The strategies included planting a cover crop (rye and mammoth clover) and delaying manure application until the soil has cooled. Manure was applied in the early fall (soil temperatures above 60°F), in the late fall (soil temperatures below 40°F) and in the spring. Rye, clover and no cover crops were planted on the early fall application. Hybrid corn (*Zea mays L.*) was grown. Grain yields, stover yields, tissue nutrient concentrations and soil inorganic N levels were monitored. The rye cover crop used a 90 to 120 lb N in the fall, while the clover cover crop used less than 30 lb N. No significant grain yield or soil N differences were detected between the different manure treatments.

### Introduction

Nitrate pollution of surface and groundwater is one of the major concerns on soils receiving large quantities of manures (Gilmour et al., 1977). Nitrate may be leached during periods when no crop is grown. To minimize the potential leaching losses, manure should be applied as close to the time of active crop growth as possible.

This usually means applying manures in the spring rather than in the fall or winter. However, few farmers have storage for a year's production of manure, so manure can not be held until spring. Producers having storage typically have a maximum storage capacity for six months manure production and must apply manure in the fall and in the spring. Producers without storage are forced to apply manure during unfavorable conditions. Therefore strategies to reduce the potential of nitrate leaching from fall and winter applied manures need to be found. The following strategies were tried:

1. Delay the application of manures until the soils have cooled. Cool temperatures reduce the rate of mineralization (Stanford et al., 1973; Harmsen and Kolenbrander, 1965). Applying manure to cool soils might delay or reduce mineralization until soils warm up in the spring. This would reduce the amount of leachable $NO_3^-$-N during the winter when there is no plant uptake.

2. Plant a cover crop. The cover crop would remove available N from the soil, and store the N in the plant biomass. In the spring the cover crop would be killed with an herbicide and incorporated into the soil. Breakdown of the plant matter will release N back into the soil, where it can be used by the next crop. The effectiveness of this technique depends on the ability of the cover crop take up any available N in the fall and then to release the N in time for the growth of the spring planted crop. This might not always be the case, for example Vilsmeier and Gutser (1987) reported no N mineralization from rye grass, during a 50 week incubation, due to high C to N ratios.

## Objectives

The objectives of this study were to compare the effectiveness of (1) delaying manure applications until the soils are cool and (2) cover cropping, to provide more manure N to the next crop and reduce nitrate losses, versus a control receiving no N and a spring manure application.

## Methods and Materials

Three sites were established in the fall of 1989. The experiment was designed as a randomized complete block with four replications with a plot size of 30'x 15'. The following treatments were used:

- No N applied (control)
- 40 lb/acre N as $NH_4NO_3$ applied in the spring (40 lb/acre)
- 80 lb/acre N as $NH_4NO_3$ applied in the spring (80 lb/acre)
- 120 lb/acre N as $NH_4NO_3$ applied in the spring (120 lb/acre)
- manure applied in the fall after the soil temperature had dropped below 40°F (Fall 40)
- manure applied in the fall when the soil temperature was about 60°F, no cover crop was grown (Fall 60-Weed)
- manure applied in the fall when the soil temperature was about 60°F, seeded to a rye cover crop (Fall 60-Rye)
- manure applied in the fall when the soil temperature was about 60°F, seeded to a mammoth clover cover crop (Fall 60-Clover)
- manure applied in the spring prior to planting (Spring).

The sites were located on the Chatham Experimental Station (Chatham) in Chatham MI, at the Kellogg Biological Station (KBS) in Hickory Corners MI, and on Jim

Table 3.1. Soil types at the Chatham, KBS, and Marlette study sites.

| Site | Soil Series | Taxonomic Classification |
|---|---|---|
| Chatham | Chatham stony loam | Typic Haplorthods |
| KBS | Kalamazoo sandy loam | Typic Hapludalfs |
| Marlette | Marlette loamy sand | Haplic Glossudalfs |

Calendar's farm in Sanilac Co. MI, east of Marlette and south of M-28 (Marlette). The soil types at each location are summarized in Table 3.1.

Solid dairy cattle manure was used at all sites. The Chatham and Marlette manures contained straw bedding, while the KBS manure consisted of scrapings without bedding. Sixty pounds of $P_2O_5$ (0-27-0) and 150 pounds of $K_2O$ (0-0-60) was broadcast on all plots in the spring of 1990. Table 3.2 shows some of the characteristics of the manures used and the rates of manure application.

Manure was applied at rates expected to release an 100 lb N/acre of plant-available N, assuming that one third of the organic N is mineralized in the first year, and no $NH_4$-N was volatilized. The Fall 60 manure applications were made with manure spreaders, while all subsequent manure applications were made by weighing the ma-

Table 3.2. Characteristics of the manures used at Chatham, KBS, and Marlette.

| Site | Time | Moisture | Total N | $NH_4^+$ | $P_2O_5$ | $K_2O$ | Rate |
|---|---|---|---|---|---|---|---|
| | | — % — | lb/wet ton | | | | tons/acre |
| Chatham | Fall 60 | 74.9 | 7.0 | 3.0 | 4.3 | 9.4 | 21 |
| | Fall 40 | 80.7 | 12.0 | 3.5 | 4.8 | 7.9 | 18 |
| | Spring | 83.1 | 8.8 | 1.6 | 6.9 | 15.7 | 14 |
| KBS | Fall 60 | 86.5 | 8.3 | 2.7 | 3.0 | 13.8 | 31 |
| | Fall 40 | 82.9 | 11.6 | 3.5 | 3.8 | 9.4 | 30 |
| | Spring | 84.7 | 8.9 | 4.0 | 3.3 | 15.1 | 23 |
| Marlette | Fall 60 | 84.1 | 10.8 | 3.6 | 5.4 | 10.9 | 38 |
| | Fall 40 | 84.4 | 10.2 | 3.1 | 4.9 | 11.0 | 25 |
| | Spring | 85.3 | 11.2 | 3.8 | 4.4 | 12.2 | 25 |

nure into clean garbage cans and spreading the manure by hand. Therefore the later manure applications were more consistent and uniform. All manure applications were disked in within 6 hours. No attempt was made to control weeds in the fall. The cover crops and weeds were killed with Roundup in the spring. The plots were plowed and hybrid corn was planted in late May.

Soil samples from the top foot, consisting of a minimum of 15 cores per plot, were taken from all plots in the middle of June and in late October. Biomass samples were obtained from the rye and clover in early spring. They were analyzed for N by TKN analysis. Ear leaf samples were taken in early August. Two rows of ten feet each were hand-harvested in October. Grain and stover were separated. Ten to twenty stalks were bagged in plastic garbage bags and transported back to MSU for shredding the same day. The rest of the sample handling was as described in Chapter 1.

To check for possible nutrient deficiencies, 0.25 g of the earleaf samples was dry-ashed 6 hours at 550°C, diluted with 12.5 ml 3M $HNO_3$ containing 1000 mg LiCl/L, and analyzed for P, K, Ca, Mg, Fe, Mn, Cu, Zn, B, Mo by direct current plasma atomic emission spectroscopy (DCP-AES).

N recovery was calculated with the following formula (Mengel and Kirkby, 1987).

$$Nrecovery = \frac{Uptake_F - Uptake_C}{FertilizerApplied} * 100 \tag{3.1}$$

Where $\text{Uptake}_F$ is the N uptake by the corn from the fertilized or manured plots, and $\text{Uptake}_C$ is the N uptake from the control plots

### Results and Discussion

The manure treatments had average levels of soil $NO_3$-N comparable to the 40 lb N/acre $NH_4NO_3$ treatment (Table 3.3). Levels of $NO_3$-N on the manure treatments declined from 46 lb/acre in June to 11 lb/acre in October. For comparison the average $NO_3$-N levels on the control declined from 33 lb/acre in June to 4 lb/acre in October.

Table 3.3. Soil $NO_3$-N levels at Chatham, KBS, and Marlette.

| Treatment | Chatham | | KBS | | Marlette | |
|---|---|---|---|---|---|---|
| | June | October | June | October | June | October |
| | lb/acre | | | | | |
| Control | 39.7 | 6.1 | 29.3 | 2.9 | 29.9 | 3.5 |
| 40 lb N | 40.8 | 10.6 | 31.6 | 3.9 | 41.6 | 4.4 |
| 80 lb N | 72.7 | 28.8 | 64.6 | 7.7 | 48.6 | 5.4 |
| 120 lb N | 111.3 | 32.8 | 73.7 | 12.7 | 63.3 | 13.8 |
| Spring | 66.9 | 10.4 | 35.6 | 3.8 | 50.4 | 10.4 |
| Fall 40 | 46.1 | 9.0 | 58.8 | 13.2 | 39.3 | 7.7 |
| Fall 60 Weed | 43.1 | 22.8 | 34.7 | 3.9 | 42.8 | 8.4 |
| Fall 60 Rye | 52.1 | 27.7 | 33.3 | 4.9 | 43.7 | 8.6 |
| Fall 60 Clover | 36.6 | 16.7 | 39.8 | 5.2 | 45.3 | 6.6 |
| LSD (0.05) | 42.4 | 14.2 | 19.9 | 8.3 | 13.2 | 3.1 |

From June to October, $NO_3$-N levels declined less on the manured treatments than on the fertilizer treatments, but average June $NO_3$-N levels in June where higher in the fertilizer treatments than in the manure treatments. Nitrate-N levels at harvest were higher at the Chatham site than at the two downstate sites (Table 3.3). This difference may be due to the earlier harvest at Chatham. The earlier harvest resulted in lower nitrogen uptake due to reduced corn grain yields. Average soil $NH_4$-N levels for all treatments declined from an average of 11 lb/acre in June to 7 lb/acre in October, but at the KBS site $NH_4$-N levels stayed at 8 to 9 lb/acre (Table 3.4). The average soil $NH_4$-N level of the manure treatments showed little change from June to October.

Early rye establishment was good. But since a successful clover establishment requires good seed to ground contact, and only the KBS site was rolled after seeding, clover establishment in the fall was poor to non-existent, except at the KBS site. The clover establishment improved somewhat in the spring. Prior to winter dormancy the rye produced 2000 to 3000 lb of dry matter/acre or 90 to 120 lb N uptake per acre. Clover biomass was less than 700 lb dry matter/acre or less than 30 lb N/acre. Weed

Table 3.4. Soil $NH_4$-N levels at Chatham, KBS, and Marlette.

| Treatment | Chatham | | KBS | | Marlette | |
|---|---|---|---|---|---|---|
| | June | October | June | October | June | October |
| | lb/acre | | | | | |
| Control | 27.4 | 7.7 | 5.5 | 8.2 | 14.6 | 5.1 |
| 40 lb N | 13.1 | 8.2 | 3.9 | 10.8 | 13.1 | 6.4 |
| 80 lb N | 11.5 | 5.8 | 8.3 | 8.1 | 9.7 | 5.7 |
| 120 lb N | 24.7 | 11.2 | 9.6 | 6.8 | 14.9 | 5.9 |
| Spring | 7.9 | 5.8 | 8.6 | 7.4 | 13.2 | 4.1 |
| Fall 40 | 7.4 | 9.3 | 7.7 | 13.7 | 12.1 | 4.4 |
| Fall 60 Weed | 10.0 | 8.4 | 6.6 | 7.3 | 9.3 | 5.5 |
| Fall 60 Rye | 7.1 | 6.6 | 11.4 | 8.3 | 10.2 | 4.9 |
| Fall 60 Clover | 7.6 | 6.1 | 7.8 | 8.9 | 9.2 | 5.6 |
| LSD (0.05) | 19.9 | 3.8 | 9.6 | 4.3 | 5.6 | 3.8 |

biomass on the non-cover crop treatment looked to be more than the clover treatment but less than the rye treatment, however no biomass samples were taken from the weed plots.

Earleaf samples showed no nutrient deficiencies or consistent differences between treatments and sites. Visual observation at the earleaf stage showed that the corn on the Fall 60 Rye treatment did not grow as well as on other plots. None of the manure N treatments caused a significant difference in the apparent N recovery.

Because of weather conditions, the Chatham corn was harvested just after the milk stage. This resulted in very low yields (Table 3.6). Grain yields for the Fall 60-rye treatments were lower than for the clover or non-cover crop treatments. The reason could be an allelopathic effect, or the failure of the rye to release N at the time necessary for corn growth. Stover yields did not show a significant difference between the treatments. N uptake from the manured treatments did not show significant differences, except that at Chatham the Spring manure treatment resulted in lower N grain uptake than the Fall 60-clover treatment (Table 3.7).

Soil $NO_3$-N levels for the manured treatments were similar to the 40 lb N treatment, but no consistent difference between the soil $NO_3$-N levels of the manured

Table 3.5. Earleaf nutrient concentrations in 1990 at Chatham, KBS, and Marlette.

| | Chatham | | | | KBS | | | | Marlette | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | Mg | Ca | K | P | Mg | Ca | K | P | Mg | Ca | K |
| | | | | | | % | | | | | | |
| Control | 0.36 | 0.49 | 0.68 | 1.87 | 0.35 | 0.17 | 0.52 | 2.33 | 0.32 | 0.24 | 0.55 | 1.88 |
| 40 lb N | 0.40 | 0.55 | 0.73 | 1.97 | 0.36 | 0.16 | 0.56 | 2.39 | 0.34 | 0.28 | 0.58 | 2.02 |
| 80 lb N | 0.40 | 0.54 | 0.71 | 1.87 | 0.36 | 0.15 | 0.48 | 2.55 | 0.34 | 0.29 | 0.61 | 1.87 |
| 120 lb N | 0.42 | 0.61 | 0.76 | 1.75 | 0.35 | 0.15 | 0.48 | 2.48 | 0.33 | 0.25 | 0.56 | 2.00 |
| Spring | 0.42 | 0.46 | 0.66 | 2.16 | 0.35 | 0.16 | 0.51 | 2.47 | 0.32 | 0.27 | 0.55 | 1.90 |
| Fall 40 | 0.39 | 0.44 | 0.68 | 2.22 | 0.34 | 0.16 | 0.53 | 2.42 | 0.33 | 0.30 | 0.60 | 1.86 |
| Fall 60 weed | 0.44 | 0.38 | 0.67 | 2.24 | 0.33 | 0.16 | 0.52 | 2.36 | 0.34 | 0.29 | 0.57 | 1.93 |
| Fall 60 rye | 0.46 | 0.38 | 0.58 | 2.27 | 0.36 | 0.17 | 0.53 | 2.36 | 0.32 | 0.24 | 0.54 | 1.92 |
| Fall 60 clover | 0.43 | 0.37 | 0.63 | 2.30 | 0.36 | 0.15 | 0.54 | 2.39 | 0.32 | 0.28 | 0.57 | 1.94 |
| LSD (0.5) | 0.05 | 0.24 | 0.08 | 0.25 | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |

Table 3.6. Corn yields harvested in 1990 at Chatham, KBS, and Marlette.

| | Stover | | | Grain | | |
|---|---|---|---|---|---|---|
| | Chatham | KBS | Marlette | Chatham | KBS | Marlette |
| | lb/acre | | | bu/acre | | |
| Control | 3800 | 7490 | 3890 | 16 | 127 | 134 |
| 40 lb N | 3280 | 7240 | 3880 | 15 | 102 | 134 |
| 80 lb N | 3870 | 7250 | 3950 | 23 | 116 | 140 |
| 120 lb N | 4240 | 7620 | 4230 | 22 | 120 | 141 |
| Spring | 4210 | 7610 | 3540 | 21 | 113 | 136 |
| Fall 40 | 4370 | 8710 | 3860 | 27 | 125 | 139 |
| Fall 60 weed | 4020 | 8170 | 4380 | 29 | 138 | 143 |
| Fall 60 rye | 3750 | 7870 | 3560 | 25 | 95 | 125 |
| Fall 60 clover | 4030 | 7490 | 4450 | 33 | 119 | 136 |
| LSD (0.05) | n.s. | n.s. | n.s. | 9 | n.s. | n.s. |

Table 3.7. Corn N uptake in 1990 at Chatham, KBS, and Marlette.

| | Stover | | | Grain | | |
|---|---|---|---|---|---|---|
| | Chatham | KBS | Marlette | Chatham | KBS | Marlette |
| | lb/acre | | | | | |
| Control | 63 | 60 | 30 | 16 | 116 | 109 |
| 40 lb N | 56 | 70 | 34 | 17 | 102 | 119 |
| 80 lb N | 69 | 77 | 39 | 28 | 119 | 128 |
| 120 lb N | 80 | 87 | 44 | 25 | 126 | 128 |
| Spring | 64 | 69 | 34 | 20 | 112 | 117 |
| Fall 40 | 71 | 105 | 36 | 26 | 134 | 118 |
| Fall 60 weed | 58 | 73 | 44 | 29 | 138 | 129 |
| Fall 60 rye | 47 | 81 | 33 | 31 | 98 | 105 |
| Fall 60 clover | 60 | 80 | 45 | 33 | 124 | 130 |
| LSD (0.05) | n.s. | 23 | 10 | 12 | n.s. | n.s. |

treatments could be detected. Although the rye crop removed 90 to 120 lb N from the soil, it did not significantly increase the corn grain yield or the $NO_3$-N levels in the soil. There was no detectable yield difference between the treatments. This lack of response precludes the detection of a "preferred" manure strategy.

# CHAPTER 4

## Mineralization of Nitrogen in a Paper Mill Sludge


### Abstract

This study attempted to determine the initial N mineralization rate of a paper mill sludge. Soil-sludge mixtures at several rates were incubated for 38 days. Evolution of $CO_2$, and $NO_3$-N and $NH_4$-N levels in the soil were measured at 7, 14, 22, and 38 days. Cumulative $CO_2$ release could be modeled successfully by first order kinetics. The N results were too variable for a reliable interpretation.


### Introduction

Packaging Corporation of America (PCA) located in Filer City, MI has land applied their biological wastewater treatment sludge for many years. The Filer City plant uses a semi-chemical pulping process to produce paper, and currently treats its wastewater flow by a secondary activated sludge process, with inputs of N and P to effect biological treatment. Biomass from this process is collected and dewatered to about 10% solids content using a belt filter press.

The paper mill sludge contains nutrients that can be recycled to land for field crop production and to enhance tree growth on forest land. Not all of the nutrients in this sludge are readily available for plant growth, particularly N. The majority of the N in the PCA sludge is present in the organic form and must be mineralized in the soil.

The process of mineralization converts organic N to $NH_4$-N and then to $NO_3$-N, a form which is available for plant growth.

We were asked by RMT, Inc. (Grand Ledge, MI) to conduct a laboratory study to help estimate how much plant-available N would be released from this PCA sludge following land application. This report describes the microbial incubation study we conducted, the results of the N mineralization evaluation, and our interpretation of the laboratory results.

### Methods and Materials

Three five-gallon pails of soil and two five-gallon pails of sludge were received from RMT. The soil was collected from a field in Manistee county that is used for application of PCA sludge. The soil was mixed and dried with forced air at 28°C for one day. Subsamples of the air-dried soil were oven-dried and found to contain 0.93% moisture (determined by weight loss after 24 hours at 104°C).

A subsample of the sludge was dried at 85°C and sent to the MSU Soil Testing Laboratory for a total carbon determination (LECO furnace combustion). Two one gram subsamples of sludge were dry-ashed at 500°C for 6 hours and taken up in 5 ml of 6M $HNO_3$. After one hour, 5 ml of 2000 ppm LiCl solution was added. B, Zn, Cd, P, Mn, Cu, Mo, Pb, Ni, Fe, Cr, Al, and Na were determined by direct current plasma atomic emission spectroscopy (DCP-AES). A subsample, diluted 1:50 with 1000 ppm LiCl was used for the determination of P, Mg, Cu, Fe, Ca, K and Al with the DCP-AES. Three one gram subsamples were taken from the wet sludge for a Total Kjeldahl N (TKN) determination. The sludge was found to contain 90.6% moisture on a wet weight basis.

Soil texture was determined by feel. Three subsamples of soil ($\approx$ 50 g) were placed in filter funnels, wetted thoroughly, and allowed to drain for one hour. The percent moisture remaining was multiplied by 0.55 to get an estimate of the water-holding capacity. Soil pH was measured in a 1:1 soil:water suspension on the original soil and the 20 dry ton/acre treatment after 38 days.

Air-dried soil (1100 grams) was mixed with 0, 59, 118, 176 and 235 grams of wet sludge to obtain the equivalent of 0, 5, 10, 15 and 20 dry tons/acre-furrow slice of soil (assuming 2 million pounds of soil per acre-furrow slice). Water was added to the 0, 5, 10, and 15 ton treatments to bring the moisture content of the mixture up to 19.9%, the level of the 20 ton treatment. No water was added during the incubation. After the sludge and soil were mixed thoroughly with a spatula, subsamples (50 dry grams) were placed in 2 oz. plastic Whirl-Pak bags. Five bags from each treatment were placed in a separate Mason jar and sealed with a lid containing a septum to allow the withdrawal of gas samples. The jars were then incubated in the dark at a temperature of 23 $\pm$ 2°C. The experiment was replicated four times.

At the end of 7, 14, 22, and 38 days, the $CO_2$ levels in each jar were measured with an Aerograph Model 90-P3 gas chromatograph using a thermal conductivity detector. At each sampling time one of the bags in each jar was removed. A 5 gram (5.99-wet gram) subsample was taken from each bag of soil, placed into an Erlenmeyer flask, and 50 ml of 2M KCL solution added. The flasks were shaken on a rotary shaker for one hour. The solution was filtered by vacuum filtration through Whatman GF/C glass-fiber filters, and the filtrate was analyzed for $NO_3$-N and $NH_4$-N on a Lachat Flow Injection Analyzer (USEPA, 1979).

A second incubation with 0 and 40 dry tons/acre was started on the 19th of December 1991 to determine mineralization at higher rates or application. For the 40 ton rate, 235 grams of wet sludge were mixed with 1100 grams of air-dried soil. The mixture was air-dried, and another 235 grams of wet sludge was added. Half pint mason jars were filled about three quarters with the soil or soil:sludge mixture. This experiment was replicated 6 times. After 12, 20, 62 and 75 days, the $CO_2$, $NO_3$-N and $NH_4$-N levels were measured as described above.

Table 4.1. Concentrations of inorganic compounds and elements present in the PCA paper sludge

| Constituent | Concentration† | Constituent | Concentration† |
|---|---|---|---|
| | —— % —— | | — mg/kg — |
| C | 43.0 | B | 29 |
| Total N | 5.9 | Cu | 49 |
| $NH_4$-N | 0.17 | Mn | 500 |
| $NO_3$-N | 0.0001 | Mo | 6 |
| P | 1.8 | Zn | 120 |
| K | 0.58 | Cd | 1 |
| Ca | 1.1 | Cr | 13 |
| Mg | 0.38 | Pb | 15 |
| Fe | 0.21 | Ni | 4 |
| | | Al | 1.0 |

† Dry weight basis.

## Results and Discussion

Table 4.1 lists the chemical composition of the PCA paper sludge. The C:N ratio, approximately 7:1, is slightly below that of stable organic matter, but above that of microbial biomass. With this C:N ratio, immobilization of inorganic N forms would not be expected during incubation.

The soil was a loamy sand with a water-holding capacity of 17%, while the water content during the first incubation was 19.9%. The initial soil pH was 5.2 but increased to 5.9 after 38 days of incubation with 20 dry tons/acre of sludge.

Table 4.2, shows the average cumulative milligrams of C mineralized after each incubation period. For the first two incubation periods, the cumulative amount of C released during microbial respiration increased. By the third sampling date, the rate of C release had begun to decrease.

If we assume that the breakdown follows first order reaction kinetics, then the equation for C release is:

$$C_1 = C_0 * e^{-kt} \tag{4.1}$$

Table 4.2. Cumulative C released as $CO_2$ during incubation of sludge-treated soils.

| Sludge Rate | Days of Incubation | | | |
|---|---|---|---|---|
| | 7 | 14 | 22 | 38 |
| tons/acre | mg C/g soil | | | |
| 0 | 0.059 | 0.114 | 0.143 | 0.152 |
| 5 | 0.149 | 0.282 | 0.415 | 0.503 |
| 10 | 0.164 | 0.319 | 0.450 | 0.585 |
| 15 | 0.180 | 0.357 | 0.497 | 0.602 |
| 20 | 0.189 | 0.380 | 0.533 | 0.653 |

where $C_1$ is the amount of added C remaining at time t, $C_0$ is the amount of C initially added, and k is the mineralization constant. Taking the natural log of both sides we get:

$$\ln \frac{C_1}{C_0} = -kt \tag{4.2}$$

The mineralization constant k is determined by fitting a straight line to the plot of the natural log of $C_1/C_0$ vs. time and is equal to 1.01 x $10^{-2}$ days$^{-1}$ (Figure 4.1). This k underestimates the C release at low rates and overestimates it at high rates of sludge addition (Figure 4.2 – 4.3).

While this equation can be used to estimate the breakdown of the C in the sludge, it does not necessarily describe the availability of N from the sludge. Attempts to fit the N data to the same equation form have not been successful.

Table 4.3 shows the levels of $NH_4$-N plus $NO_3$-N measured for the different sludge rates at each sampling time. The large variability between replications makes it difficult to determine trends. Treatments only accounted for 48% of the variability, and no rate by time interaction could be detected. Several samples appear to be higher (5 tons 0.1 days, 15 and 20 tons 7 days, 0 and 10 tons 38 days), and one sample (15 tons 38 day) seems to be lower than they should be. In general mineral

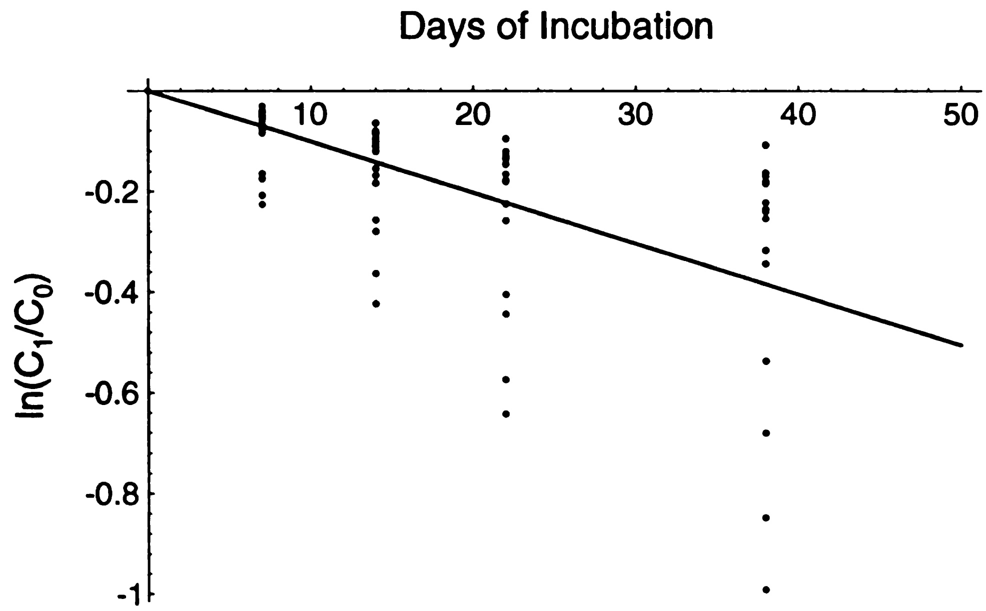


Figure 4.1. Fit of the first order C mineralization equation against the data points.

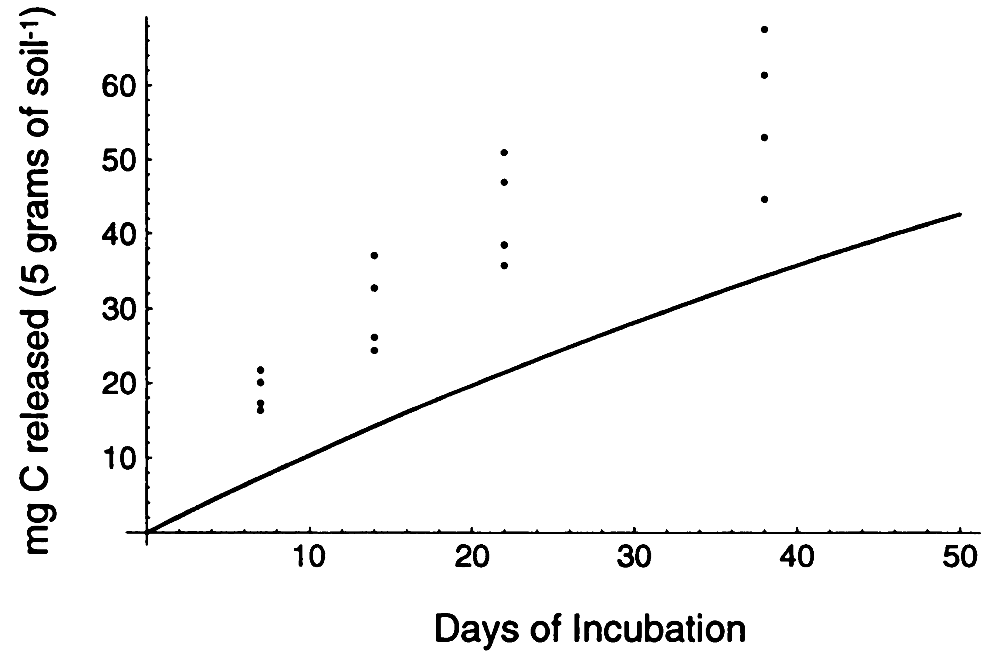


Figure 4.2. Comparison of the actual vs. the calculated amounts of C released as $CO_2$ during incubation of soils treated with 5 tons acre$^{-1}$ of paper mill sludge

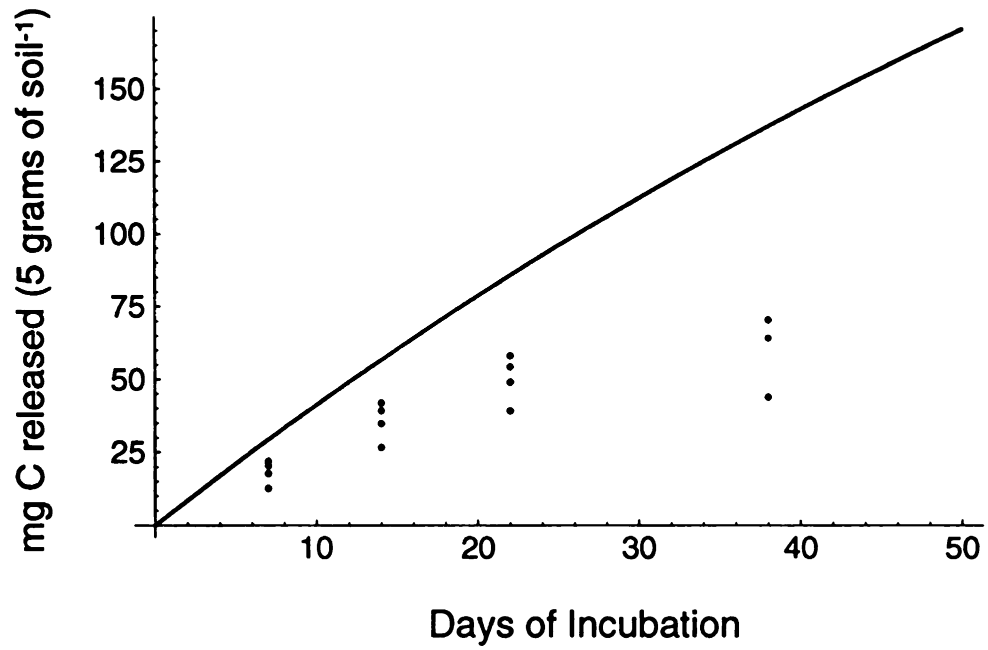


Figure 4.3. Comparison of the actual vs. the calculated amounts of C released as $CO_2$ during incubation of soil treated with 20 tons acre$^{-1}$ of paper mill sludge

N levels increased with increasing sludge application. The mineral N levels seem to increase up to the 7 day sample, then plateau until day 22 before increasing once more by day 38.

If we assume that the sludge addition had no effect on the mineralization rate of native soil organic matter, Table 4.4 shows the amount of additional N that was released. The variability in the results seem to indicate that some denitrification loss or immobilization into microbial biomass or organic matter may have occured. The microbial $CO_2$ respiration data seems to indicate that mineralization was taking place, so the variability in N levels is likely due to the dynamic nature of the N cycle. Since $CO_2$ was purged at each sampling date, it did not have the opportunity to be reincorporated into the organic matter. On the other hand, the N was not purged and therefore was available for further transformation.

Table 4.3. Amounts of $NH_4$-N plus $NO_3$-N present in soils after incubation with paper mill sludge.

| Sludge Rate | Days of Incubation | | | | |
|---|---|---|---|---|---|
| | 0.1 | 7 | 14 | 22 | 38 |
| tons/acre | lb N/acre | | | | |
| 0 | 17 | 35± 6 | 39±14 | 37± 2 | 98± 75 |
| 5 | 91 | 45± 7 | 46±26 | 77±35 | 96± 42 |
| 10 | 69 | 89±46 | 96±11 | 84±49 | 237±149 |
| 15 | 113 | 167±96 | 113±79 | 137±92 | 109± 75 |
| 20 | 145 | 230±29 | 168±77 | 198±76 | 279±113 |

Table 4.4. Amounts of $NH_4$-N plus $NO_3$-N present in sludge-treated soils above background levels obtained in control soils.

| Sludge Rate | Days of Incubation | | | | |
|---|---|---|---|---|---|
| | 0.1 | 7 | 14 | 22 | 38 |
| tons/acre | lb N/acre | | | | |
| 5 | 74 | 9 | 7 | 41 | −2 |
| 10 | 52 | 53 | 57 | 48 | 139 |
| 15 | 96 | 134 | 74 | 101 | 11 |
| 20 | 128 | 198 | 129 | 162 | 181 |

Table 4.5. $NO_3$-N plus $NH_4$-N present in soils incubated with 0 and 40 ton $acre^{-1}$ of paper mill sludge

| Sludge Rate | Days of Incubation | | | | |
|---|---|---|---|---|---|
| | 0.1 | 12 | 28 | 62 | 75 |
| tons/acre | lb N/acre | | | | |
| 0 | 233 | 341 | 402 | 541 | 611 |
| 40 | 28818 | 675305 | 139150 | 152062 | 150148 |

Given the caveats mentioned above, the actual amount of sludge which could be safely applied to land should be based on supplying the amount of N that the planned crop can be expected to use. Based on the N recommendation for the planned crop, Table 4.4 can be used to estimate the rate of sludge application. For example if we look at the 22nd incubation day (since the 38th incubation day seems to have a couple of unexpected numbers) and dividing the 'lb N/acre' by the 'Sludge Rate', the sludge contributes approximately 7 lb N/acre for every ton of sludge applied. Based on an organic N content of 5.7% or 114 lb N/dry ton, 7 lb N mineralized would equal about 6% mineralization.

Table 4.5 shows the results from the 0 and 40 dry ton/acre incubation study. Calculating the pounds of N released per ton of sludge applied after 75 days, yields 36 lb N/acre for every ton of sludge applied. This works out to be about 30% of the organic N mineralized, which is in the range of 25–30% often reported for this type of biological sludge.

Since mineralization carried out in the laboratory is conducted under more ideal temperature and moisture conditions than would be expected in the field, the actual mineralization rate is probably between 7 lb and 36 lb N per dry ton. Further study in the field would be required to better determine what mineralization rate should be used for estimating available N from field-applied PCA sludge.

# CHAPTER 5

## Recordkeeping System for Crop Production

### Abstract

A simple flexible and modular paper recordkeeping system for nutrient management and pesticide application recordkeeping was developed. The system is composed of an annual recordbook, individual field files, a set of manure management sheets and a set of enhanced recordkeeping sheets. The system was field tested with 120 farmers in Michigan.

### Introduction

In 1987 Michigan amended the **Michigan Right to Farm Act** (MCL– 286.471) to state that a farm shall not be found a public or private nuisance, if it follows "generally accepted agricultural and management practices" (GAAMP). Since then a number of amendments to environmental statues, (e.g., the Air Pollution Control Act and Polluters Pay Act) have been written to exempt farmers who are following the GAAMP. Defining the GAAMP is left to task forces comprised of university researchers, federal and state government officials and industry representatives. Michigan State University's College of Agriculture and Natural Resources (MSU-CANR) was asked to organize the task forces to draft the GAAMP. The task forces meet annually to review and amend these practices as necessary. Practices have been formulated for (1) management and utilization of manure, (2) nutrient (fertilizer) utilization, and (3) pesticide utilization and pest control. Each set of these guidelines lists recordkeeping as a recommended GAAMP.

In response to producers who asked "What records should I keep?", we initiated the development of a simple, flexible paper recordkeeping system (RKS). It is designed primarily as a management tool to help crop and livestock producers become better nutrient managers by increasing their awareness of the *whole farm* nutrient planning. This is done by encouraging soil fertility testing, following fertilizer recommendations, and the determination of nutrient credits for manure applications, previous legume crops grown, high organic matter levels in soils, and soil nitrate testing. Balancing nutrient inputs to the farm with crop outflows increases on-farm nutrient utilization, reduces nutrient losses, and minimizes the impact of the farm on the environment. A second goal in developing this system was to use it as a *stepping stone* to get information from the field into computer-based expert systems, decision support systems, and transactions systems that have been developed in recent years (Lanyon and Meij, 1992; Harsh et al., 1992).

## Development

The idea for the system grew out of talks with extension agents in the late summer of 1990. The basic concept was that of a field by field record system. Dennis Stein (then Ag Agent for Tuscola Co.) suggested a system similar to a dairy health record system used to keep track of the health record and breeding cycles of individual cows. Therefore we borrowed the folder idea from the dairy health record system.

An advisory committee of county extension agents and campus specialists was assembled to review, comment and offer suggestions on the RKS as it was developed. The initial focus of the paper RKS was nutrient management. Additional provisions for recording pesticide application information were added during development in response to suggestions by the advisory committee.

One of our goals was to develop a modular system where a farmer could use those parts that he feels are most pertinent to his operation. Another goal was to minimize the copying of numbers from one sheet to another. In general some sort of calculation is done in transferring numbers from one sheet or column to another.

The system was tested during the summer of 1991. Extension agents willing to participate in a field trial were identified and the system was distributed to about 120 farms in Michigan. During this test, the prototype of the small annual record book was the most popular item.

In the fall we conducted a series of extension agent/farmer meetings to collect feedback and suggestions for improvement. In response to these comments we made several changes in the layout of the tables. One frequent request was for more space to record pesticide applications. Another was the addition of a numbering system to aid in finding the correct field in the annual record books. These and some other changes were made after the field test, and the revised RKS was sent out to the advisory committee for a final review before publication.

### Description of the system

The paper RKS is composed of an annual record book, a set of field files, and two sets of supplemental sheets. The annual record book is used to record information about planting, fertilizing, manuring, pesticide spraying, and harvesting as it is done. It is available in two sizes, a small size (3.5" x 5.5") designed to fit in a shirt pocket and a larger (8.5" x 5.5") size to be carried in the cab of a tractor or pickup truck. The large record book holds all of the information for one field on one double page, in the small record book the same forms occupy two consecutive double pages. Using the annual record book constitutes a *basic level* of recordkeeping. If a producer saves the annual record books he will have some documentation about his management practices. A farmer who uses a computer based recordkeeping system can also use the annual record book to carry information between the field and the office.

At the *basic level* of recordkeeping, the information gathered is not very usable for planning purposes. The next step in this recordkeeping system is to transfer the information from the annual record book to a set of field files and recordkeeping sheets (Figure 5.1). Using the field files constitutes a *recommended level* of recordkeeping that will allow the producer to make the best use of his information for management decisions.

A field file consists of a three panel folder with four tables to summarize some of the more important nutrient and pesticide management information. One field file should be established for each field. The field file becomes the container for all of the information, such as soil test reports, SCS plans, etc., unique to that field. The field file contains tables to (1) record soil test information, (2) determine nitrogen credits, (3) determine future nutrient additions, and (4) record past pesticide applications. For a livestock producer, the recommended level of recordkeeping would also include the use of the *manure management sheets.*

A set of *enhanced recordkeeping sheets* is available to keep track of additional information about fertilizer additions and crop rotations and comprises the *enhanced level* of recordkeeping. The manure management and enhanced recordkeeping sheets are provided on heavy weight paper and are intended as a template. The producer would photocopy the sheets to make as many copies as he needs.

The information flow between the different parts of the RKS and its relationship to the levels of recordkeeping is illustrated in Figure 5.1. Information flows from the field to the annual record book, and then into the field file, the manure management sheets, and the enhanced recordkeeping sheets. Some planning information from the field file returns to next year's annual record book for the new growing season. By keeping the system modular we hope to have given the farmer maximum flexibility in choosing the level of recordkeeping that he would like to practice. In addition, the producer can start out simple and increase the detail and level of recordkeeping at a later time.

### Annual Record Book

A set of pages from the larger annual record book is shown in Figure 5.2. The *Crop Production Plans* should be filled out before the field activities begin each growing season. It serves as a reminder during planting, spraying, and tillage operations. The information about planting, fertilizer/lime application, presticide applications, etc., is recorded during the growing season as these activities are done. While the amount of space for pesticide applications is considered adequate for most field and vegetable crop producers it will not be sufficient for orchard growers. Space is provided for notes and field sketches. The *Spreader Speed* and *Setting* columns in the manure table are provided to assist with manure spreader calibration and recording how the application was done. This way a producer can use the same settings to apply a similar rate of manure in the future.

### Field File

The field file consists of a tri-fold folder and is used to collect the information from a single field. The Historic Soil Test Summary table (Figure 5.3) is used to record soil fertility test results and to evaluate the effect of current management practices on the nutrient, especially P, status of the field.

The *Nitrogen Credits for Nutrient Planning* table (Figure 5.4) has been included in the field file to stress the importance of giving credits for previous legume crops and previous manure additions. The table is used to add up all of the expected N credits for a particular growing season. For some crops a pre-sidedress nitrate soil test (PSNT) can be done in place of using this table to estimate N credits.

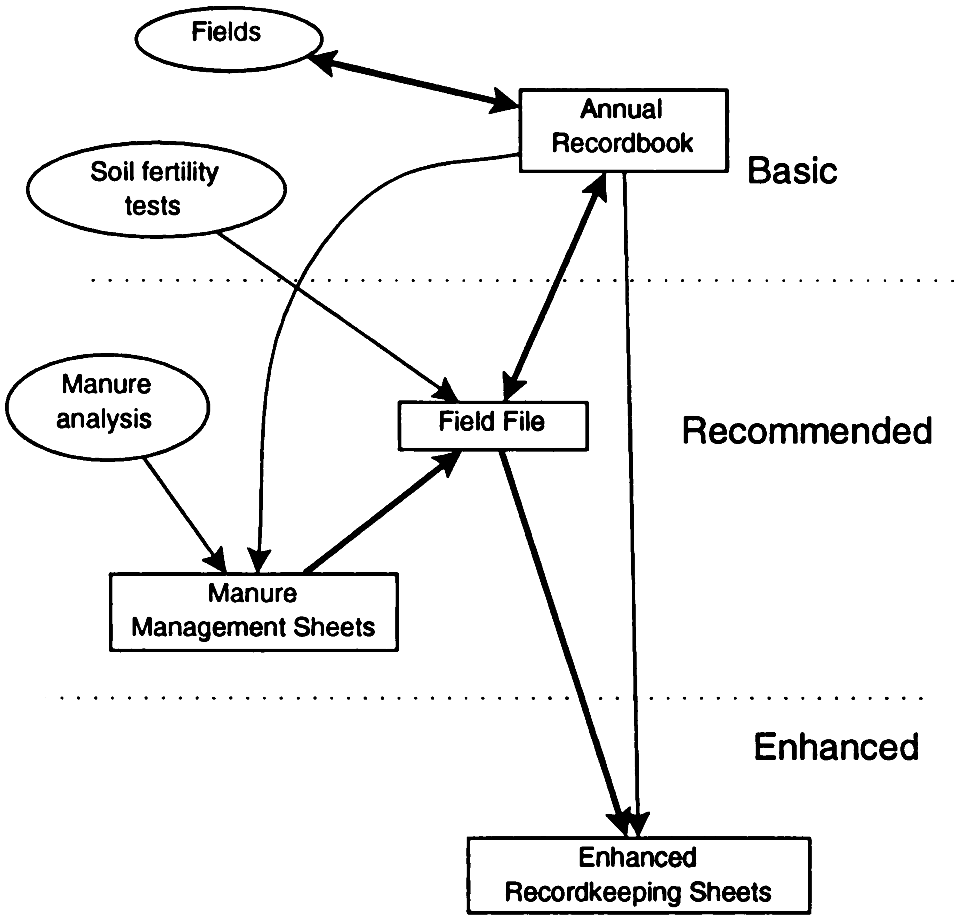


Figure 5.1. Information flow in the paper RKS.

1

**Field ID**__________ **Acres**_______

**Crop Production Plans**
Crop____________ Pesticide ____________________
Nutrients Needed (lb/acre) N______ $P_2O_5$______ $K_2O$______

**Planting Informations**
Planting Date _____________
Population/seeding rate used ____________________
Tillage used ____________________________

**Fertilizer/Lime Application**

| Date | Type & Analysis | Rate Applied | Method of Application |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

**Pesticide Applications**

| | 1st | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|
| Date | | | | | |
| Time of Day | | | | | |
| Chemical Applied (Trade Name and Formulation) | | | | | |
| Rate per Acre | | | | | |
| Carriers, Additives used | | | | | |
| Method of Application* | | | | | |
| Target Pest / Pest State | | | | | |
| Crop Growth Stage | | | | | |
| Wind Speed | | | | | |
| Wind Direction | | | | | |
| Temperature | | | | | |
| Name of Applicator | | | | | |

* If the whole field was not covered, note area treated on the Field Sketch.

**Manure Applied***

| Date | Source of Manure | No. of Loads | Spreader used | Speed (mph) | Spreader Setting |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Manure incorporated on (Date) ____________________
* If the whole field was not covered, note area treated on the Field Sketch.

| Notes or Harvest Information | Date |
|---|---|
| | |
| | |
| | |
| | |
| | |

**Field Sketch**

1

Figure 5.2. Pages from the larger Annual Record Book.

The *Nutrient Planning* table (Figure 5.5) is used to estimate the amount of additional nutrients that should be applied to the field, given a fertilizer recommendation and then subtracting N credits and recent manure nutrient additions. The amount of "additional fertilizer nutrients" needed should then be recorded in the upcoming year's annual record book for reference during the planting season.

The *Pesticide Use Information* table (Figure 5.6), located on the back of the folder, is used to record pesticide application information. This table provides a history of pesticides applied to that field and makes it easier to check for possible interactions or residue carryover for future crops. A table of nutrient removal values for Michigan crops has also been included on the back pannel of the Individual Field File Folder for reference.

## Table 1. Historic Soil Test Summary

| Date of Soil Test Report | Name of Soil Testing Laboratory | Sample ID | pH | Lime Index | Amount of Nutrients (lb/acre) * | | | | Lime Recommendation | | | Micronutrients, sulfur, or organic matter ** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | P | K | Ca | Mg | Rate (tons/acre) | Dolomitic? Yes | Dolomitic? No | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

* If your soil test laboratory reports soil nutrient concentrations in ppm, convert to lb/acre by multiplying the values by 2, i.e., ppm x 2 = lb/acre. If the test results are given in lb/acre of $P_2O_5$ and $K_2O$, convert to P and K by: lb $P_2O_5$ ÷ 2.3 = lb P and lb $K_2O$ ÷ 1.2 = lb K

** Generally soil tests for micronutrients (B, Cu, Fe, Mn, Mo, Zn), sulfur(S), or organic matter, are not routinely recommended in Michigan. If you are testing for organic matter or any of these nutrients, label one of these columns and use them to record the soil test results.

Figure 5.3. Historic Soil Test Summary table in Individual Field File folder.

## Table 2. Nitrogen Credits (lb/acre) for Nutrient Planning

**Importance of Nitrogen Management and the PSNT**

Sources of nitrogen (N) for crop growth (i.e., fertilizers, manure, legume N fixation, etc.) should be managed so that additions of N do not greatly exceed crop needs. This can be done by following MSU fertilizer recommendations and by giving appropriate N credits for legumes, manures and/or for other residual N remaining in the soil from a previous growing season.

Without proper N management, the risk of losing nitrate N from the soil plant system by leaching is increased. Excess additions of N may contaminate groundwater. If that groundwater is used as a source of drinking water and the nitrate concentration is greater than the U.S. Public Health Service standard of 10 mg N/l (i.e., 10 ppm), then the water may not be safe for drinking.

A new soil test, called the pre-sidedress nitrate test (PSNT), can help producers evaluate the amount of nitrate N present in their soil. This soil test can measure residual nitrate N left in the soil profile from the previous growing season. It can also measure nitrate N that was recently mineralized from N present in organic matter and organic materials in the soil.

These quantities of nitrate N are readily available for crops to use and should be credited against the total N needed by the crop to be grown. To provide good results, soil samples for the PSNT should be taken in June, after the soil has warmed up (>50 °F), and within two weeks of the time when additional N could be sidedressed.

The PSNT has its greatest use (at the present time) for adjusting fertilizer N additions at sidedress time for corn grain, corn silage, seed corn, and sugar beets. Farmers can benefit from the use of the PSNT for: fields where corn or sugar beets are to be grown, crops following legumes, manured fields, fields heavily fertilized with N the previous year, and fields with medium or fine textured soils.

Contact your county Cooperative Extension Service office for current recommendations in using the PSNT or other tests for managing N.

**Directions for Using Table 2**

• If the PSNT is used, the N credit recommended by this test can be substituted for legume and/or manure N credits in Table 2 (to the right). Place the PSNT credit directly in the "N Credit" column in Table 3.

• If the PSNT is not used, determine the proper credits for a previous legume and/or manure application(s) and record these credits in Table 2 (to the right). Total these credits and place the value in the "N Credit" column in Table 3.

| Year | Previous Legume* | Manure** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

* Refer to the table "Suggested Nitrogen Credit for the Previous Crop" to obtain the proper value.

** Repeated applications of manure result in greater quantities of mineralized N being available for crop growth. Refer to MSU-CES Bulletin WQ12, "Livestock Manure Management", for guidance on estimating these N credits.

**Suggested Nitrogen Credit for the Previous Crop**

| Previous Crop | Nitrogen Credit (lb N/A) |
|---|---|
| Alfalfa | |
| 100 % stand | 100 |
| 80 % stand | 90 |
| 60 % stand | 75 |
| 40 % stand | 60 |
| 20 % stand | 50 |
| Clovers and Birdsfoot Trefoil | |
| 100 % stand | 60 |
| 80 % stand | 55 |
| 60 % stand | 50 |
| 40 % stand | 40 |
| 20 % stand | 35 |
| Soybeans | 30 * |
| All other crops | 0 |

* Take credit only for corn grain, corn silage, and seed corn. For all other crops take no credit.
Source: MSU-CES Bulletin E-550A and MSUFR (a computer program).

Figure 5.4. Nitrogen Credits for Nutrient Planning table in Individual Field File folder.

**Table 3. Nutrient Planning**

| Year | Crop to be grown | Expected Yield (per acre) | Fertilizer Recommendations* (lb/acre) | | | N Credit** (lb/acre) | Manure Nutrients Applied † (lb/acre) | | | Additional Fertilizer Nutrients Needed by the Crop (lb/acre) ‡ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | $P_2O_5$ | $K_2O$ | | Avail. N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

* The quantities of nutrients needed for crop growth (i.e., the "Fertilizer Recommendations") should be based on soil test information, the crop to be grown, and a realistic yield goal, i.e., the "Expected Yield". These recommendations can be obtained from the soil fertility test report, MSU-CES Bulletins B-550A and B-550B, or MSUFR (a computer program)

** Nitrogen recommendations can be reduced by the amount of estimated N credits (Table 2) or by the N credit determined by using the pre-sidedress nitrate soil test (PSNT). Record the amount of N credit here and reduce the recommended N rate by this amount.

† The amount of "Manure Nutrients Applied" are calculated by dividing the "Total Manure Nutrients Applied" (from Manure Management Sheet #4) by the number of acres in the field

‡ If manure was applied to the field, subtract the amount of nutrients added(i.e., "Manure Nutrients Applied") from the "Fertilizer Recommendations" to calculate the additional amount of fertilizer nutrients needed. If the N credit for a legume and/or previous manure applications have been determined (Table 2), the recommended N rate can be reduced by the amount of this credit. If a PSNT is done, then this credit should be used in place of manure and legume N credits. If there are no "N credits" or no manure was applied, then the amount of "Additional Fertilizer Nutrients Needed" will be the same as the "Fertilizer Recommendations".

Figure 5.5. Nutrient Planning table in Individual Field File folder.

**Table 4. Pesticide Use Information**

| Date | Crop | Chemical Applied (Trade Name and Formulation) | Rate per Acre | Method of Application | Target Pest * | Name of Applicator | Notes ** |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

* i.e., kind of weed, insect, nematode or disease

** "Notes" could include information such as weather, wind conditions, crop stage, pest stage, etc.

Figure 5.6. Pesticide Use Information table in Individual Field File folder

## Manure Management Sheets

A livestock producer can use the *manure management sheets* (MMS) to help determine the amount of manure nutrients that have been applied to the field. The first sheet (MMS #1) is used to provide a quick estimate of a farm nutrient balance. On one side of the sheet (Part A.) a farmer can add-up his annual manure nutrient production based on the number of animals present of the farm (Figure 5.7). The other side (Part B.) has space to add-up the annual crop nutrient removal using the tables of nutrient removal values for crops found on the field file folder (Figure 5.8). Subtracting the crop nutrient removal from the manure nutrients produced gives a rough nutrient balance for the farm (Part C.). This estimate can be used to find out if a potential for environmental pollution exists. If more manure nutrients are produced than the crops can use, then excess nutrients might be released into the environment.

Using the other *manure management sheets* (MMS) requires a bit of work by the user. A manure analysis should be on hand, and the capacities of the spreaders used need to be determined. In lieu of manure spreader calibration, a farmer may keep track of the amount of manure being applied to a field by counting the number of spreader loads and using the spreader capacities to estimate the actual quantity applied. By knowing the total amount of manure applied (i.e. tons or gallons) and ther area covered (i.e. acres) a reasonable estimate of the amount of nutrients applied (i.e. tons/acre or gallons/acre) can be obtained. MMS #2 (Figure 5.9) can be used to record manure analysis information, and the amount of organic N and first year available organic N can be calculated in the last two columns. Table A at the bottom of MMS #2 contains average manure nutrient values (for use when no manure analysis is available), and mineralization factors to estimate mineralizable available organic N using the equations provided.

**Manure Management Sheet #1**

## Nutrient Budget for a Livestock Farm

**Part A. Estimate of the Annual Manure Nutrient Production**

Enter the average number of livestock in each of the categories below. Multiply those numbers by the appropriate multiplication factors. Total the results to get the minimum volume of manure and the minimum amount of nutrients produced per year on the facility. If bedding, runoff water, feed or other substances enter the manure storage facility, the total volume of manure and pounds of nutrients will change.

| Livestock Type | | Average Size | Average Number of Livestock Housed Annually * | Manure Production | | Pounds of Nutrients Produced per Year | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Nitrogen (N) | | Phosphate ($P_2O_5$) | | Potash ($K_2O$) | |
| | | | | cubic feet of manure per year per animal ** | total volume produced annually | lbs per year per animal ** | total produced annually | lbs per year per animal ** | total produced annually | lbs per year per animal ** | total produced annually |
| **Dairy Cattle** | | 150 lb | | x 69 = | | x 22 = | | x 8.4= | | x 18 = | |
| | | 250 lb | | x 120 = | | x 36 = | | x 16 = | | x 31 = | |
| | | 500 lb | | x 240 = | | x 73 = | | x 30 = | | x 62 = | |
| | | 1,000 lb | | x 480 = | | x 150 = | | x 61 = | | x 120 = | |
| | | 1,400 lb | | x 680 = | | x 210 = | | x 85 = | | x 170 = | |
| **Beef Cattle** | | 500 lb | | x 180 = | | x 62 = | | x 46 = | | x 53 = | |
| | | 750 lb | | x 270 = | | x 95 = | | x 70 = | | x 84 = | |
| | | 1,000 lb | | x 360 = | | x 120 = | | x 91 = | | x 110 = | |
| | | 1,250 lb | | x 440 = | | x 160 = | | x 120 = | | x 140 = | |
| | Beef Cow | | | x 380 = | | x 130 = | | x 100 = | | x 110 = | |
| **Swine** | Nursery Pig | 35 lb | | x 14 = | | x 5.8= | | x 4.3= | | x 4.4= | |
| | Growing Pig | 65 lb | | x 26 = | | x 11 = | | x 8.1= | | x 8.8= | |
| | Finishing Pig | 150 lb | | x 58 = | | x 25 = | | x 18 = | | x 20 = | |
| | Finishing Pig | 200 lb | | x 80 = | | x 33 = | | x 25 = | | x 26 = | |
| | Gestating Sow | 275 lb | | x 55 = | | x 23 = | | x 18 = | | x 18 = | |
| | Sow and Litter | 375 lb | | x 200 = | | x 84 = | | x 63 = | | x 66 = | |
| | Boar | 350 lb | | x 69 = | | x 28 = | | x 22 = | | x 22 = | |
| **Sheep** | | 100 lb | | x 23 = | | x 16 = | | x 5.5= | | x 14 = | |
| **Horse** | | 1,000 lb | | x 270 = | | x 99 = | | x 38 = | | x 75 = | |
| **Poultry** (per 100 birds) | | | | | | | | | | | |
| | Turkey | 16 lb | | x 510 = | | x 420 = | | x 360 = | | x 200 = | |
| | Chicken Layers | 4 lb | | x 130 = | | x 110 = | | x 91 = | | x 51 = | |
| | Chicken Broilers | 2 lb | | x 88 = | | x 88 = | | x 45 = | | x 33 = | |
| | | | | ***Totals:*** | | | | | | | |

* Average number of livestock housed on the farm during 12 months. If animals are not housed for the full 12-month period, multiply the number of animals times the number of months the animals are housed on the farm, then divide by 12 to get the "Average Number of Livestock Housed Annually".

** Numbers adapted from MWPS-18, "Livestock Waste Facilities Handbook," 2nd Ed., 1985.

Figure 5.7. Manure Management Sheet #1, Part A. Nutrient Budget for a Livestock Farmer.

**Manure Management Sheet #1**

## Nutrient Budget for a Livestock Farm

**Part B. Estimate of the Annual Nutrient Removal by Crops**

| Field ID | Crop | No. of Acres (A) in the Field | Expected Yield (Y) per Acre | Estimated Quantities of Nutrients Removed by the Harvested Crops * | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Nitrogen (N) | | Phosphate ($P_2O_5$) | | Potash ($K_2O$) | |
| | | | | Total Yield for Field (A × Y) | lb N per Unit of Yield | Total lb N Removed from Field | lb $P_2O_5$ per Unit of Yield | Total lb $P_2O_5$ Removed from Field | lb $K_2O$ per Unit of Yield | Total lb $K_2O$ Removed from Field |
| 1 | | | | | x | = | x | = | x | = |
| 2 | | | | | x | = | x | = | x | = |
| 3 | | | | | x | = | x | = | x | = |
| 4 | | | | | x | = | x | = | x | = |
| 5 | | | | | x | = | x | = | x | = |
| 6 | | | | | x | = | x | = | x | = |
| 7 | | | | | x | = | x | = | x | = |
| 8 | | | | | x | = | x | = | x | = |
| 9 | | | | | x | = | x | = | x | = |
| 10 | | | | | x | = | x | = | x | = |
| 11 | | | | | x | = | x | = | x | = |
| 12 | | | | | x | = | x | = | x | = |
| 13 | | | | | x | = | x | = | x | = |
| 14 | | | | | x | = | x | = | x | = |
| 15 | | | | | x | = | x | = | x | = |
| 16 | | | | | x | = | x | = | x | = |
| 17 | | | | | x | = | x | = | x | = |
| 18 | | | | | x | = | x | = | x | = |
| 19 | | | | | x | = | x | = | x | = |
| 20 | | | | | x | = | x | = | x | = |
| | | | | | **Totals** | | | | | |

**Part C. Total Farm Nutrient Balance for Livestock Farm**

| | | | |
|---|---|---|---|
| **Manure Nutrients Produced **** | **Total N :** | **Total $P_2O_5$ :** | **Total $K_2O$ :** |
| **Nutrient Removal by Crop Harvest †** | **Total N :** | **Total $P_2O_5$ :** | **Total $K_2O$ :** |
| **Farm Nutrient Balance ‡** | **N Balance :** | **$P_2O_5$ Balance :** | **$K_2O$ Balance :** |

* To calculate the quantities of N, $P_2O_5$, and $K_2O$ removed from each field, multiply the total yield for each field listed (i.e., A x Y) times the lb of N, $P_2O_5$ and $K_2O$ contained in each unit of yield. The "lb of nutrient per unit of yield" values can be obtained from the "Nutrient Removal" charts on the back of the Field File.

** Use the total pounds of N, $P_2O_5$, and $K_2O$ produced in manures (from Part A).

† Use the total pounds of N, $P_2O_5$, and $K_2O$ removed from all fields by harvest (Part B).

‡ Subtract the "Nutrient Removal by Crop Harvest" from the "Manure Nutrients Produced" to get each nutrient balance. If the balance is positive, then more manure nutrients are being generated by the livestock than the crops on the farm may be able to effectively utilize. If your farm falls into that category, seek assistance from your county Cooperative Extension Service office in developing a nutrient management plan. Improper handling of these excess nutrients may result in pollution of surface and groundwaters.

Figure 5.8. Manure Management Sheet #1, Part B. and C. Nutrient Budget for a Livestcok Farmer.

MMS #3 (Figure 5.10) is used to record spreader capacities, and then calculating the amount of nutrients that would be applied with one spreader load of manure. The nutrient content of manures than might be spread is obtained from MMS #2 and used to calculate the total quantity of manure nutrients in each load. MMS #4 (Figure 5.11), is used to record the actual number of loads of manure applied and then helps to calculate the amount of manure nutrients applied to a particular field. The number of loads applied is obtained from the Annual Record Book. A copy of MMS #4 can be kept in the Field File of each field receiving manure. The "Total Manure Nutrients Applied" is divided by the acres covered to calculate the "Manure Nutrients Applied (lb/acre)" which is recorded in Table 3 of the Field File (Figure 5.5). The field sketch areas on Sheet #4 can be used to record where manure has been applied, if the whole field did not receive manure.

### Enhanced Recordkeeping Sheets

If a producer would like to keep more detailed information beyond the *recommended level*, the *enhanced recordkeeping sheets* (Figure 5.12–5.14) can be used. The information collected on these sheets comes from the Annual Record Book and may be used to develop a historical record of crops and varieties grown and yields obtained over time, as well as quantities and types of fertilizers and lime applied. This information could enhance the management and planning for crop production.

### Benefits

The paper RKS provides a way to document the management practices used by the producer. For Michigan producers it provides a simple system to do recordkeeping as recommended in the Right-to-Farm GAAMP.

This paper RKS can help producers evaluate farming practices and provide documentation when trying new or different farming approaches. The RKS can also help

| Manure Management Sheet #2 |
|---|

## Manure Analysis Information

**Farm________**

| Manure Sampling Information * | | | Manure Analysis Results | | | | | | | Calculated Values for Nitrogen ** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (lb/1,000 gal) or (lb/wet ton) | | | | check(✓) correct units | | | |
| Date | ID | Source of Manure | % Dry Matter | Total N | $NH_4$-N | $P_2O_5$ | $K_2O$ | /wet ton | /1,000 gal | Organic N | Available Organic N |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

* Record date of the manure analysis report, select ID from Table A below, and indicate where the manure came from, ex., free stall barn, farrowing house.

** Calculations:

Organic N = Total N − $NH_4$-N

Available Organic N = Organic N x Mineralization Factor (see Table A)

**Table A. Mineralization factors for organic N and average nutrient contents of manures.**

| Manure Type | Manure ID | Manure Handling | Mineralization Factor | Average Nutrient Content | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $NH_4$-N | Total N | Total $P_2O_5$ | Total $K_2O$ | units |
| Swine | A | Fresh | 0.50 | 6 | 10 | 9 | 8 | /ton |
| | B | Anaerobic liquid | 0.35 | 26 | 36 | 27 | 22 | /1000gal |
| Beef | C | Solid without bedding | 0.35 | 4 | 11 | 7 | 10 | /ton |
| | D | Solid with bedding | 0.25 | 8 | 21 | 18 | 26 | /ton |
| | E | Anaerobic liquid | 0.30 | 24 | 40 | 27 | 34 | /1000gal |
| Dairy | F | Solid without bedding | 0.35 | 4 | 9 | 4 | 10 | /ton |
| | G | Solid with bedding | 0.25 | 5 | 9 | 4 | 10 | /ton |
| | H | Anaerobic liquid | 0.30 | 12 | 24 | 18 | 29 | /1000gal |
| Sheep | I | Solid with bedding | 0.25 | 5 | 14 | 9 | 25 | /ton |
| Poultry | J | Deep pit | 0.45 | 44 | 68 | 64 | 45 | /ton |
| | K | Solid without litter | 0.35 | 26 | 33 | 48 | 34 | /ton |
| | L | Solid with litter | 0.30 | 36 | 56 | 45 | 34 | /ton |
| Horses | M | Solid with bedding | 0.20 | 4 | 14 | 4 | 14 | /ton |

Source: MWPS-18, "Livestock Waste Facilities Handbook," 2nd Ed., 1985.

Figure 5.9. Manure Management Sheet #2. Manure Analysis Information.

**Manure Management Sheet #3**

**Quantities of Manure Nutrients per Spreader Load** **Farm__________**

**Chart #1**

- **Spreader:** __________
- **Capacity:** __________

| | Manure Analysis | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**Chart #2**

- **Spreader:** __________
- **Capacity:** __________

| | Manure Analysis | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**Chart #3**

- **Spreader:** __________
- **Capacity:** __________

| | Manure Analysis | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**Chart #4**

- **Spreader:** __________
- **Capacity:** __________

| | Manure Analysis | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

* If you use more than one manure spreader, identify the spreader by name or type on each chart. If the spreader is a tank wagon, indicate the "Capacity:" in gallons from the manufacturer's specifications. If it is a box or side slinger type spreader, use the ASAE heaped rated capacity for the volume, determine the density of the manure, and calculate the "Capacity:" in tons for one spreader load

** Multiply the calculated "Available Organic N" value and the manure analysis values for "$NH_4$ N, $P_2O_5$ and $K_2O$", from Manure Management Sheet #2, times the spreader capacity to determine the quantities of each nutrient per spreader load. For example, 4 lb $P_2O_5$/ton x 3.5 tons/spreader load = 14 lb of $P_2O_5$ per spreader load. Use the analysis information for the manure listed on the Manure Management Sheet #2 that corresponds to the "Source of Manure" specified

Figure 5.10. Manure Management Sheet #3. Quantities of Manure Nutrients per Spreader Load.

increase the awareness of all nutrient sources on the farm and develop a better understanding of the *whole farm* nutrient balance. Balancing nutrient inputs and outflows reduces the chances that the farm will have a negative impact on the environment.

With the paper RKS and computer based systems, producers now have several options and levels of recordkeeping available. Therefore, the farmer can choose the system most appropriate for his operation.

Manure Management Sheet #3

**Quantities of Manure Nutrients per Spreader Load** **Farm________**

**Chart #1**

• **Spreader:**____________
• **Capacity:**____________

| Manure Analysis | | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**Chart #2**

• **Spreader:**____________
• **Capacity:**____________

| Manure Analysis | | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**Chart #3**

• **Spreader:**____________
• **Capacity:**____________

| Manure Analysis | | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**Chart #4**

• **Spreader:**____________
• **Capacity:**____________

| Manure Analysis | | | lb of Nutrients per Load ** | | | |
|---|---|---|---|---|---|---|
| | Date | Source of Manure | $NH_4$-N | Available Organic N | $P_2O_5$ | $K_2O$ |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

* If you use more than one manure spreader, identify the spreader by name or type on each chart. If the spreader is a tank wagon, indicate the "Capacity:" in gallons from the manufacturer's specifications. If it is a box or side slinger type spreader, use the ASAE heaped rated capacity for the volume, determine the density of the manure, and calculate the "Capacity:" in tons for one spreader load.

** Multiply the calculated "Available Organic N" value and the manure analysis values for "$NH_4$-N, $P_2O_5$ and $K_2O$", from Manure Management Sheet #2, times the spreader capacity to determine the quantities of each nutrient per spreader load. For example, 4 lb $P_2O_5$/ton x 3.5 tons/spreader load = 14 lb of $P_2O_5$ per spreader load. Use the analysis information for the manure listed on the Manure Management Sheet #2 that corresponds to the "Source of Manure" specified.

Figure 5.10. Manure Management Sheet #3. Quantities of Manure Nutrients per Spreader Load.

increase the awareness of all nutrient sources on the farm and develop a better understanding of the *whole farm* nutrient balance. Balancing nutrient inputs and outflows reduces the chances that the farm will have a negative impact on the environment.

With the paper RKS and computer based systems, producers now have several options and levels of recordkeeping available. Therefore, the farmer can choose the system most appropriate for his operation.

Manure Management Sheet #4

**Worksheet to Estimate the Quantity of Manure Nutrients Applied**

**Field ID:______**
Acres ________

| Application Period (Mo/Yr) | Number of Loads Applied | Source of Manure | Days Before Incorpn. | Manure Spreader Chart # | Total Manure Nutrients Applied (lb)* | | |
|---|---|---|---|---|---|---|---|
| | | | | | Total Avail. N† | $P_2O_5$ | $K_2O$ |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Field Sketch **

* The "Total Manure Nutrients Applied" is calculated by multiplying the total loads of manure applied times the "lb of Nutrients per Load" from Manure Management Sheet #3.

** Manure should be uniformly applied to the whole field. If the whole field was not treated uniformly with manure, areas receiving different quantities of manure nutrients should be noted on the Field Sketch. Then, the quantity of manure nutrients applied to each area should be determined separately, and each area managed accordingly when planning for further nutrient additions (see Field File Table 3).

† The "Total Available N" is calculated with the following equation, which takes into account the losses of $NH_4$ by volatilization: "Total Available N" = ["Available Organic N/load" + ("$NH_4$-N/load" x RF)] x "Number of Loads Applied". Refer to MSU CES Bulletin E 2340, "Recordkeeping System for Crop Production," p.17.

Figure 5.11. Manure Management Sheet #4. Worksheet to Estimate the Quantity of Manure Nutrients Applied.

**Enhanced Recordkeeping Sheet #1**

**Lime and Fertilizer N, $P_2O_5$, $K_2O$ Applications** **Field ID:________**

| Date | Type of Fertilizer Used* | Fertilizer Rate (lb/acre) | Method of Application** | Amount of Nutrients Applied by Fertilizer (lb/acre) | | | Lime Applied | |
|---|---|---|---|---|---|---|---|---|
| | | | | N | $P_2O_5$ | $K_2O$ | Rate (tons/acre) | Type† |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

* Liquid, granular, or anhydrous $NH_3$ and grade such as 45-0-0, 28% N, 0-0-60, etc.
** i.e., banded, broadcast, sidedressed, etc
† i.e., calcitic, dolomitic, marl etc

Figure 5.12. Enhanced Recordkeeping Sheet #1. Lime and Fertilizer N, $P_2O_5$, $K_2O$ applications.

**Enhanced Recordkeeping Sheet #2**

**Micronutrient and Sulfur Fertilizer Applications** **Field ID:________**

| Date | Type of Fertilizer Used* | Fertilizer Rate (lb/acre) | Method of Application** | Amount of Nutrients Applied (lb/acre) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sulfur S | Boron B | Copper Cu | Iron Fe | Manganese Mn | Molybdenum Mo | Zinc Zn |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

* Liquid, granular, or anhydrous $NH_3$ and grade plus supplemental nutrient content, such as 6-24-24 + 3 Mn + 2 Zn, etc.
** Foliar application to crop or soil application by banding, broadcasting, etc.

Figure 5.13. Enhanced Recordkeeping Sheet #2. Micronutrient and Sulfur Fertilization Applications.

**Enhanced Recordkeeping Sheet #3**

**Crop History Information** **Field ID:________**

| Planting Date | Crop | Variety | Seeding Rate or Plant Population | Tillage Used | Yield per Acre | |
|---|---|---|---|---|---|---|
| | | | | | Expected | Harvested |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Figure 5.14. Enhanced Recordkeeping Sheet #3. Crop History Information.

# BIBLIOGRAPHY

# BIBLIOGRAPHY


Abbott, J. L. and T. C. Tucker. 1973. Persistence of manure availability in calcareous soil. *Soil Sci. Soc. Am. Proc. 37*: 60–63.

Adriano, D. C., P. F. Pratt, and S. E. Bishop. 1971. Nitrate and salt in soils and ground waters from land disposal of dairy manure. *Soil Sci. Soc. Am. Proc. 35*: 759–762.

Azevedo, J. and P. R. Stout. 1974. *Farm animal manures: an overview of their role in the agricultural environment. Manual 44*. California Agricultural Experimental Station Extension Service: Berkeley, CA.

Barrow, N.. 1975. Chemical form of inorganic phosphate in sheep feces. *Australian Journal of Soil Research 13*: 63–67.

Broomfield, S. M.. 1961. Sheep feces in relation to the phosphorus cycle under pastures. *Australian Journal of Agricultural Research 12*: 111–123.

Caldwell, A. G. and C. A. Black. 1958. Inositol hexaphosphate: I. quantitive determination in extracts of soils and manures. *Soil Sci. Soc. Am. Proc. 22*: 290–293.

Coleman, D. A.. 1917. The influence of sodium nitrate upon transformation in soil, with special reference to its availability and that of other nitrogenous manures. *Soil Science 4*: 345–432.

Dalai, R. C.. 1977. Soil organic phosphorus. *Advances in Agronomy 29*: 83–117.

de Haan, S.. 1983. *Landbouwkundige weerde van zuiveringsslib*. Sticht. Postacad. Vorming Gezondh.: Techn. TH Delft.

Engelstad, O. P. and G. L. Terman. 1980. Agronomic effectiveness of phosphate fertilizers. pp. 311–332. In F. E. Khasawneh, E. C. Sample, and E. J. Kamprath (Eds.), *The Role of Phosphorus in Agriculture*. ASA: Madison WI.

Fuller, W. H., D. R. Nielsen, and R. W. Miller. 1956. Some factors influencing the utilization of phosphorus from crop residues. *Soil Sci. Soc. Am. Proc. 20*: 218–224.

Gerritse, R.. 1978. Assessment of a procedure for fractionating organic phosphates in soil and organic materials using gel filtration and HPLC. *Journal of the Science of Food and Agriculture 29*: 577–586.

Gerritse, R. G. and I. Zugec. 1977. The phosphorus cycle in pig slurry measured from $^{32}PO_4$ distribution rates. *Journal of Agricultural Science (Cambridge) 88*: 101–109.

Gilmour, C. M., F. E. Broadbent, and S. M. Beck. 1977. Recycling of carbon and nitrogen through land disposal of various wastes. pp. 172–194. In L. F. Elliott and F. J. Stevenson (Eds.), *Soils for management of organic wastes and wastewaters.* ASA: Madison WI.

Goss, D. W. and H. V. Eck. 1983. *Phosphorus fertilizer for alfalfa – concentrated superphosphate or feedlot manure.* U.S. Department of Agriculture. Agricultural Research Service. Conservation and Production Research Laboratory: Bushland, Texas.

Goss, D. W. and B. A. Stewart. 1979. Efficiency of phosphorus utilization by alfalfa from manure and superphosphate. *Soil Sci. Soc. Am. J. 43*: 523–528.

Harmsen, G. W. and G. J. Kolenbrander. 1965. Soil inorganic nitrogen. pp. 43–92. In W. V. Bartholomew and F. E. Clark (Eds.), *Soil Nitrogen*, Number 10 in Agronomy. Madison WI.

Harsh, S. B., L. W. Jacobs, and M. L. Vitosh. 1992. Nutrient management system for agricultural producers. In *Proceedings of the 4th International Conference on Computers in Agricultural Extension Programs. January 28-31, 1992.* Orlando FL.

Hensler, R. F., R. J. Olsen, and O. J. Attoe. 1970. Effect of soil pH and application rate of dairy cattle manure on yield and recovery of twelve plant nutrients by corn. *Agronomy Journal 62*: 828–830.

Herron, G. M. and A. B. Erhart. 1965. Value of manure on an irrigated calcareous soil. *Soil Sci. Soc. Am. Proc. 29*: 278–281.

Lanyon, L. E. and H. K. Meij. 1992. FINFO: A field and farm technical information management program. *J. Prod. Agric. 5*: 88–94.

Lund, Z. F. and B. D. Doss. 1980. Costal bermudagrass yield and soil properties as affected by surface-applied dairy manure and its residue. *J. Environ. Qual. 9*: 157–162.

Mackowiak, C.. 1988. Effect of a long-term application of cattle and pig slurry on yield and chemical properties of the soil. pp. 165–170. In E. Welte and I. Szabolcs (Eds.), *Agricultural Waste Management and environmental protection – 4th International Symposium of CIEC 11-14 May 1987 Braunshweig Federal Republic of Germany*, Volume 2. Goltze-Druck: Goettingen, FRG.

Mathers, A. C. and D. W. Goss. 1979. Estimating animal waste applications to supply crop nitrogen requirements. *Soil Sci. Soc. Am. J. 43*: 364–366.

Mathers, A. C. and B. A. Stewart. 1974. Corn silage yield and soil chemical properties as affected by cattle feedlot manure. *J. Environ. Qual. 3*: 143–147.

McAllister, J. S. V.. 1977. Efficient recycling of nutrients. pp. 87–103. In J. H. Voorburg (Ed.), *Utilization of manure by land spreading.* Commission European Communities: Luxembourg, Belgium.

McAuliffe, C. M. and M. Peech. 1949. Utilisation by plants of phosphorus in farm manure I. Labeling of phosphorus in sheep manure with $P^{32}$. *Soil Science 68*: 179–184.

McAuliffe, C. M., M. Peech, and R. Bradfield. 1949. Utilisation by plants of phosphorus in farm manure II. Availability of plants of organic and inorganic forms of phosphorus in sheep manure. *Soil Science 68*: 185–195.

Meek, B. D., L. E. Graham, T. J. Donovan, and K. S. Mayberry. 1979. Phosphorus availability in a calcareous soil after high loading rates of animal manure. *Soil Sci. Soc. Am. J. 43*: 741–743.

Meek, B. D., A. J. MacKenzie, T. J. Donovan, and W. F. Spencer. 1974. The effect of large applications fo manure on movement of nitrate and carbon in an irrigated desert soil. *J. Environ. Qual. 3*: 253–258.

Mengel, K. and E. A. Kirkby. 1987. *Principles of plant nutrition* (4th ed.). International Potash Institue: Bern Switzerland.

Montavalli, P. P., K. A. Kelling, and J. C. Converse. 1989. First-year nutrient availability from injected dairy manure. *J. Environ. Qual. 18*: 180–185.

Morel, C. and J. C. Fardeau. 1990. Uptake of phosphate from soils and fertlizers as affected by soil P availability and solubility of phosphorus fertilizers. *Plant and Soil 121*: 217–224.

Mugwira, L. M.. 1979. Residual effects of dairy cattle manure on millet and rye forage and soil properties. *J. Environ. Qual. 8*: 251–255.

Olsen, R. J., R. F. Hensler, and O. J. Attoe. 1970. Effect of manure application, aeration and soil pH on soil nitrogen transformations and certain soil test values. *Soil Sci. Soc. Am. Proc. 34*: 222–225.

Peperzak, P., A. G. Caldwell, R. R. Hunziker, and C. A. Black. 1959. Phosphorus fraction in manures. *Soil Science 87*: 293–302.

Powers, W. L., G. W. Wallingford, and L. S. Murphy. 1975. *Research status on effects of land application of animal wastes; Pub. EPA-660/2-75-010.* Government Printing Office: Washington DC 20403. June.

Pratt, P., F. Broadbent, and J. Martin. 1973, June. Using organic wastes as nitrogen fertilizers. *Calif. Agric.*: 10–13.

Pratt, P. F., S. Davis, and R. G. Sharpless. 1976. A four-year field trail with animal manures II. Mineralization of nitrogen. *Hilgardia 44*: 113–125.

Prummel, J. and H. A. Sissingh. 1983. Fosfaatwerking van dierlijke mest. *Bedrijfsontw. 14*: 963–966.

Reddy, K. R., M. R. Overcash, R. Khaleel, and P. W. Westerman. 1980. Phosphorus adsorption-desorption characteristics of two soils utilized for disposal of animal wastes. *J. Environ. Qual. 9*: 86–92.

SAS Institute. 1985. *SAS User's Guide: Statistics, Version 5 Edition.* SAS Institute Inc.: Cary, NC.

Singh, B., K. N. Sharma, D. S.Rana, J. S. Sodhi, and M. L. Kapur. 1983. Available phosphorus and potassium and soil organic matter contents as influenced by long term application of fertilizers and farmyard manure to wheat-maize rotation. *J. Indian Soc. Soil Sci. 31*: 491–494.

Singh, B. B. and J. P. Jones. 1976. Phosphorus sorbtion and desorbtion characteristics of soil as affected by organic residues. *Soil Sci. Soc. Am. Proc. 40*: 384–394.

Smith, K. A., R. J. Unwin, and J. H. Williams. 1984. Experiments on the fertiliser value of animal waste slurries. pp. 124–135. In J. H. Williams, G. Guidi, and P. L.'Hermite (Eds.), *Long-term effects of sewage sludge and farm slurries applications.* Elsevier Applied Science Publishers: London and New York.

Smith, S. J., A. C. Mathers, and B. A. Stewart. 1980. Distribution of nitrogen forms in soil receiving cattle feedlot waste. *J. Environ. Qual. 9*: 215–218.

Sommerfeldt, T. G., C. Chang, and T. Ents. 1988. Long-term annual manure application increase soil organic matter and nitrogen, and decrease carbon to nitrogen ratio. *Soil Sci. Soc. Am. J. 52*: 1668–1672.

Stanford, G., M. H. Frere, and D. H. Schwaninger. 1973. Temperature coefficient of soil nitrogen mineralization. *Soil Science 115*: 321–323.

Steel, R. G. D. and J. H. Torrie. 1980. *Principles and procedures of Statistics* (2nd ed.). McGraw-Hill Book Company: New York.

Stevenson, F. J.. 1992. *Humus Chemistry.* John Wiley & Sons: New York.

USEPA. 1979. *EPA Methods for Chemical Analysis of Water and Wastes.* EPA: Washington DC.

van Fassen, H. G. and H. van Dijk. 1987. Manure as a source of nitrogen and phosphorus in soils. In H. G. von der Meer (Ed.), *Animal Manure on Grassland and Fodder Crops.* Martinus Nijhoff Publishers: Dordrecht.

Vilsmeier, K. and R. Gutser. 1987. Mineralization of nitrogen from catch crops in model trails. pp. 185–190. In E. Welte and I. Szabolcs (Eds.), *Agricultural Waste Management and environmental protection - 4th International Symposium of CIEC 11-14 May 1987 Braunshweig Federal Republic of Germany*, Volume 2. Goltze-Druck: Goettingen, FRG.

Vitosh, M. L., J. F. Davis, and B. D. Knezek. 1973. Long term effects of manure fertilizer, and plow depth on chemical properties of soils and nutrient movement in a mono-culture corn system. *J. Environ. Qual. 2*: 296–299.

Vitosh, M. L., H. L. Person, and E. D. Purkhiser. 1990. *Livestock manure management for efficient crop production and water quality preservation.* Michigan State University Cooperative Extension Service: East Lansing MI.