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THE EFFECTS OF NITROGEN AND TILLAGE ON DENITRIFICATION RATES AND THE YIELD OF CORN, OATS, AND SOYBEANS IN EASTERN SOUTH DAKOTA

BY

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1985

THE EFFECTS OF NITROGEN AND TILLAGE ON DENITRIFICATION RATES AND THE YIELD OF CORN, OATS, AND SOYBEANS IN EASTERN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree of, Doctor of Philosophy, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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" A student is not above his teacher, but every one who is fully trained will be like his teacher" (Luke 6:40). If anyone told me that I was like Paul Fixen, I would consider that a real compliment. I'm grateful for Paul's personal involvement in my work and willingness to help me. He was an excellent teacher.

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Ultimately, though, I am thankful to God for the opportunity of furthering my education. "See the plans I have for you declares the Lord, plans to prosper you and not to harm you, plans to give you a hope and a future" (Jer. 29:11).

DEDICATION

This thesis is dedicated to my parents Robert and Genevieve Hilton. Words cannot express the love and gratitude I feel toward them.

Abstract

Two field experiments were established in 1983 to evaluate the effect of nitrogen (N) on corn, oats and soybeans grown under various tillage sytems in east central South Dakota. A corn-oats rotation was grown under moldboard plow (MP), chisel plow (CH), and no-till (NT) tillage systems in a Poinsett silty clay loam soil (Udic Haplaboroll, fine-silty, mixed). In southeast South Dakota a corn-soybean rotation and a continous corn rotation were grown under MP NT and till plant (TP) and MP CH and NT systems, respectively on an Egan silty clay loam soil (Udic Haplustoll fine silty mixed). Nitrogen was applied at 4 rates (including a check) as either topdressed ammonium nitrate or injected urea-ammonium nitrate. Denitrification at the east central site in 1984 measured 11, 16, and 25 kg N ha^{-1} in MP, CH, and NT systems in which 112 kg N ha^{-1} was topdressed, respectively. Rates of denitrification in the NT system were significantly reduced by injecting 112 kg N ha^{-1}. However, missing data prevented the difference from being accurately estimated. Nitrogen mineralization rates appeared to be higher under MP tillage than under reduced tillage in both years at both locations. This difference was estimated to be 24 kg N ha^{-1} at the east central site (ave of oats and corn) in 1983. Leaching prevented accurate N mineralization rate caluclations at the other sites/years. At the Poinsett site, total N requirement of corn at optimum yield was the same for different tillage systems. However, N required per Mg of grain was slightly lower for the MP system because of the slightly higher optimal yield compared to the reduced tillage systems. Oat yield under reduced tillage resulted in a slightly lower yield potential and slightly higher N requiremnt than under MP tillage. Two unusually wet springs occurred at the southeast site which delayed the planting of corn. This coupled with very dry summers resulted in low yields in both years. The CH system yielded significantly less corn grain and silage in 1983 and significantly more silage in 1984 than other sytems in the continous corn rotation. Tillage method did not affect yield of corn in the corn-soybean rotation in either year. Soybean yield was significantly higher in the TP system than the MP and NT systems in 1983, but significantly lower than in to the MP system in 1984.

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INTRODUCTION

Conservation tillage has drawn a tremendous amount of attention from researchers in the past 15 years. The U.S.D.A. estimates that 45% of U.S. cropland will be under no-till by the year 2000. The possibilities of increased yield and decreased fuel consumption are evident when using reduced tillage.

Along with the possibility of increased yield, researchers have cited an increased N requirement of corn grown under reduced tillage compared to conventional tillage. Explanations for this increased N requirement include denitrification of N, decreased mineralization of organic matter, and increased leaching of N due to increased infiltration of water under reduced tillage.

The goal of this study was to determine yield potential and which factor or factors was responsible for higher N requirements for crops grown under reduced tillage. Several field experiments were conducted to accomplish these goals. The results are reported as independent chapters. The specific objectives of the studies reported in each chapter are:

Chapter I: 1) to construct equipment that can accurately measure denitrification in the field and 2) measure denitrification as affected by wheel traffic, N placement, and tillage.

Chapter II. 1) to compare yield potential, mineralization rates, and N requirements of corn grown in rotation with oats under moldboard plow (MP), chisel plow (CH), and no-till (NT) systems, and 2) determine if soil nitrate interpretations should be altered for reduced tillage.

Chapter III. 1) to compare yield potential, mineralization rates, and N requirements of oats grown in rotation with corn under moldboard plow (MP), chisel plow (CH), and no-till (NT) systems, and 2) determine if soil nitrate interpretations should be altered for reduced tillage.

Chapter IV: 1) to compare yield potential, mineralization rates, and N requirements of continous corn and a corn-soybean rotation under various tillage sytems, and 2) determine if soil nitrate interpretations should be altered for reduced tillage.

Chapter I

The Effects of Tillage, N Placement, and Wheel Traffic on Denitrification Rates in the Corn Cycle of a Corn-Oats Rotation

Abstract

Denitrification rates under various tillage systems were determined in the corn cycle of a corn-oats rotation on a Poinsett silty clay loam soil (Udic Haploboroll, fine-silty, mixed). Denitrification was measured directly using a modification of the in-situ method developed by Ryden et al. The procedure was modified by placing a single 0.64-cm diameter acetylene supply probe 30 cm deep into the soil through a 7-cm diameter by 12 cm access tube in the center of a 38-cm diameter by 12-cm deep cylindrical soil cover. Concentrations of C_2H_2 beneath soil covers between 0.1 and 10.0% were readily and predictably established by radial diffusion from the supply probe. Over 94% of nitrous oxide (N_2O) released into the enclosed air space of the soil cover was recovered at an air flow rate of 21 L hr^{-1}. Recovery decreased rapidly with increased flow rates of 31 and 37 L hr^{-1}.

Nitrous oxide effusing from the soil surface was contained by soil covers and sorbed on a 5A molecular sieve. Two soil covers were placed in non-wheel-track (NWT) areas and one cover was placed in a wheel-track (WT) area of moldboard plow (MP), chisel plow (CH), and no-till (NT) plots. These plots were topdressed with 112 kg N ha^{-1} as

ammonium nitrate. An additional NT treatment was tested in which 112 kg N ha^{-1} as urea-ammonium nitrate was injected 10-15 cm below the soil surface. Percent surface residue cover was used as an independent variable to indicate the intensity of tillage in regression analysis. Results from regression analysis indicated that denitrification rates in NWT areas but not WT areas could be reduced by injecting N or decreasing surface residues (increasing tillage). Denitrification rates from WT areas averaged 1.4 times higher than from NWT areas. Cumulative N losses were estimated by integrating WT and NWT regression equations over the period June 6-27 and adding 3 kg N ha^{-1} to each treatment to account for denitrification outside that period. The calculations assumed that WT and NWT areas represented 15% and 85% of the field, respectively. Cumulative N loss was estimated at 11, 16, and 25 kg N ha^{-1} from May 29-Sept 8 for MP, CH, and NT treatments, respectively when N was topdressed. Cumulative N loss could not be accurately estimated for NT treatments that recieved injected N because of missing data during the peak denitrification event. Most of the cumulative N loss occurred over a 14 day period in mid-June. Significant denitrification from soil near saturation did not occur in late May and early June due likely to low soil temperatures. Results suggest that denitrification in the NT system occurred higher in the soil profile than in CH and MP systems.

Additional Index words: nitrous oxide, acetylene inhibition, N losses

Introduction

Both actual and potential denitrification rates have been reported higher under no-till (NT) compared to conventionally tilled soils (Aulakh et al., 1982; Aulakh et al., 1984a; Aulakh et al. 1984b; W.H. Caskey personal communications, 1983; Rice and Smith, 1982). Several factors may contribute to increased denitrification in NT soils. Higher water contents creating more anaerobic conditions have been observed in no-till soils (Aulakh et al., 1984b; Linn and Doran, 1984). Gaseous N loss from no-till soils was halved by removal of surface residue (Aulakh et al., 1984a). Residues are believed to increase the surface wetness of soil, and offer a carbon source to microbes near the soil surface where high soil temperatures may favor denitrification. No-till systems have been reported to raise the organic C content of the upper 15 cm of soil (Dick, 1983), increase the number of denitrifying bacteria in the top 7.5 cm of soil (Doran, 1980) and increase the water-filled porosity (Linn and Doran, 1984) compared to conventional systems.

A significant relationship between soil nitrate and denitrification rate has not been established (Aulakh et al., 1984b; Ryden and Lund, 1980). If denitrification is dependent on nitrate concentration, deeper placement of N may reduce denitrification rates by placing N below the zone of greatest microbial activity into a zone of relatively low microbial activity (Aulakh et al., 1984b).

All of the above information concerning tillage is from studies in which denitrification rates were measured from soil removed from the field and taken to the laboratory for analysis. Questions have arisen as to the validity of removing soil from the field because of temperature and aeration changes due to soil disturbance and incubation. These changes may alter the subtle differences between tillage systems and affect denitrification.

Until recently, measuring denitrification directly in the field could only be accomplished through isotopes. Methodologies are now available which do not require isotopes. These methods use acetylene to block N_2O (nitrous oxide) reduction, a chamber or cover to collect N_2O effusing from the soil surface, and a trap to collect the N_2O.

The method developed by Ryden et al. (1979b) employed retangular soil covers measuring 50 cm x 10 cm x 17 cm and covered a soil area of $0.05\ m^2$. Acetylene inhibition of N_2O reduction was accomplished by radial diffusion of acetylene from 8 supply probes (per 2 soil covers) inserted 1 m into the soil. The soil cover air was continously swept by drawing external air though the cover with a small vacuum pump. Nitrous oxide in the air swept from the cover was trapped in a 5A molecular sieve. However, the method of Ryden et al. requires many acetylene supply probes and air flow lines to measure 0.10 m^2. The purpose of this study was to: 1) design a system which reduced the number of acetylene supply probes and air flow lines needed to measure denitrification from a 0.10 m^2 area, thus simplifying the in-situ method of Ryden et al. and 2) determine the effect of tillage, N placement and wheel traffic on in-situ denitrification rate in a corn-oats rotation.

Materials and Methods

I. Basic Methodology

Trapping and Recovery of Nitrous Oxide

The field equipment (Fig. 1-1) used was a modification of the design used by Ryden et al. (1979b). Cylindrical soil covers were made of 18-guage galvanized sheet metal and painted white to reflect radiation and reduce heat adsorption. Covers were 12 cm high and had a 38-cm diameter top that had a 7-cm diameter by 12-cm deep pipe welded into the center creating a hollow core. The core prohibited sampling of that area inside the core and resulted in a sampling area of 0.11 m^2.

Covers were inserted 10 cm deep into the soil leaving a 2-cm head space. A small vacuum pump was used to sweep the air space under the soil cover by drawing external air through the cover. Air entry and exit ports consisted of a small hole and a male pipe fitting located on opposite sides of the cover providing 0.64 cm diameter openings (Fig. 1-1. no. 1 and 2). Traps for water and CO_2 removal were made from 20 and 14-cm lengths of 3.5-cm I.D. clear acrylic tubing which was sealed with number 7 one-holed rubber stoppers (Fig. 1-1, no.4 and 5). A second trap for water removal was made from 2-cm I.D. clear acrylic tubing which was sealed with number 5.5 one-holed rubber stoppers (Fig. 1-1, no. 4). Water was removed with Drierite and CO_2 was removed with a combination of NaOH pellets and

Figure 1-1. Soil cover system for in-situ measurement of denitrification.

1) Fitting connecting air line to the soil cover (air exit)

2) Air inlet hole, 0.4 cm diameter

3) Acetylene supply tube

4) Two H_2O traps

5) CO_2 trap

6) N_2O trap without molecular sieve showing capilary tube

7) N_2O trap with molecular sieve

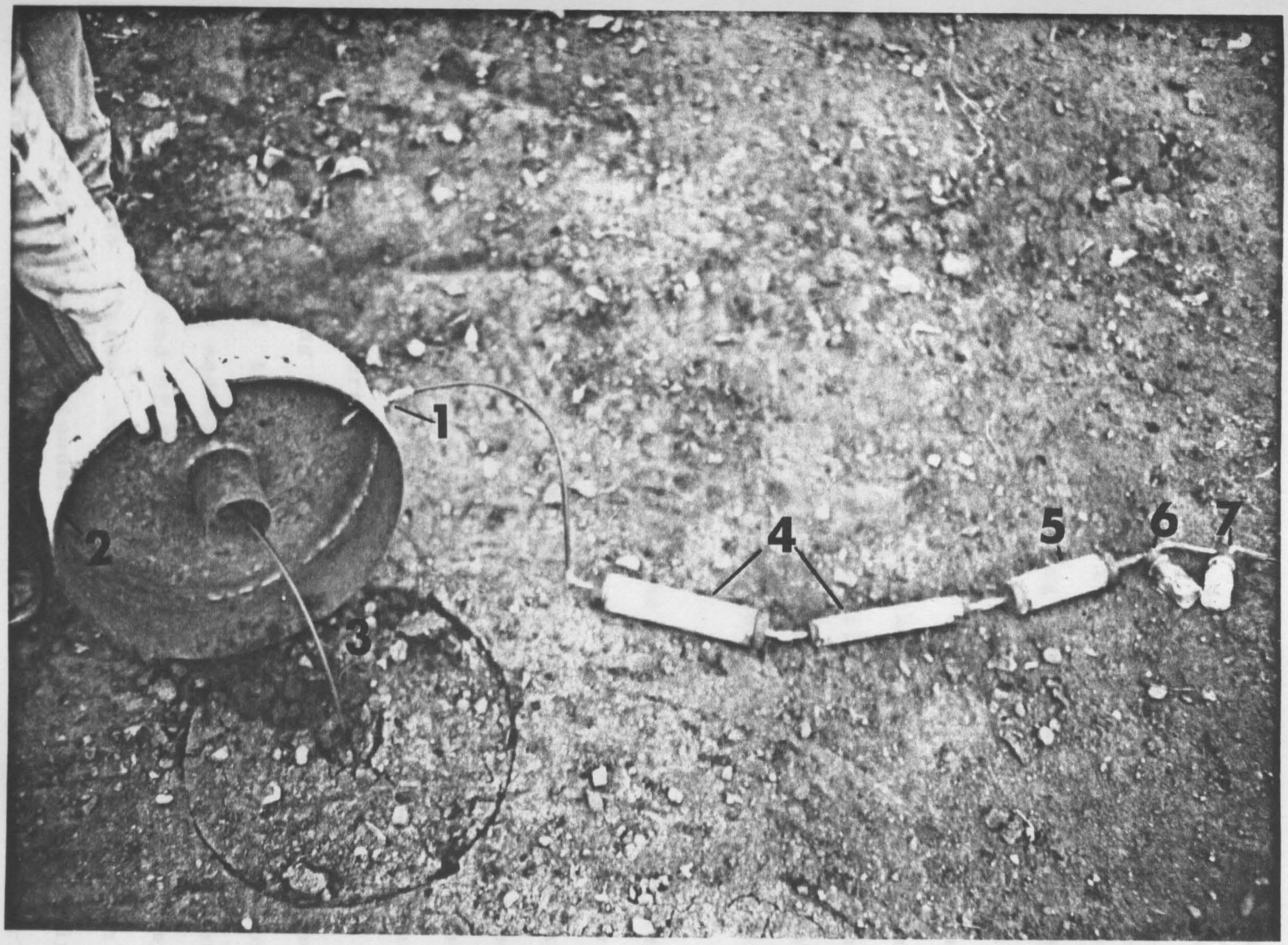

Figure 1-1.

Ascarite. Nitrous oxide was trapped using 5A molecular sieve (8-12 mesh) material. Twenty three grams of molecular sieve were placed in each of two bottles (Fig. 1-1, no. 6 and 7). A 10-cm long, 1-mm (I.D.) flexible plastic tube was inserted into the bottles containing the molecular sieve. The tube was closed by melting the distal end. Ten small holes were made in the lower 5 cm of the tubing so that the air containing N_2O would be drawn through the molecular sieve material. This gave effects similiar to that of a gas washing bottle and ensured good contact between the air and the molecular sieve. The end of the tube outside the bottle was connected to a vacuum line.

Nitrous oxide adsorbed on the molecular sieve was recovered in the following manner. The molecular sieve material was placed in a 500 mL Erlenmeyer side-arm flask. The flask was stoppered at the top and the side-arm fitted with a 10-cm length of pressure tubing so that it could be attached to various apparatuses. The flask was evacuated and 60 mLs of water were introducted into the flask from a burette. The tubing was clamped and the contents of the flask were allowed to equilibrate for 5-10 hrs at room temperature. After equilibrium, a stopper type septum was inserted into the end of the pressure tubing and the clamp released. The flasks were back-filled with Ar to equal atmospheric pressure. Standard N_2O samples were treated in the same manner because of the solubility of N_2O in water.

Samples of the enclosed gas (50-1000 uL) were removed by syringe for gas chromatographic analysis.

Nitrous oxide was separated from other gases by injection into a column of Porapak Q material heated to 75 ^{o}C in a gas chromatograph. A ^{63}Ni-source electron capture detector, heated to 320 ^{o}C, was used with N_2 as the carrier gas at 36 cm^{3} min^{-1}.

Acetylene Supply to the Soil

Ryden et al. (1979a) and Yoshinari et al. (1977) found complete acetylene inhibition of N_2O reduction in soil when using atmospheric acetylene concentrations from 0.1 to 10.0%. Nitrous oxide reduction was also inhibited for several hours at a C_2H_2 concentration as low as 0.01%. Even though Smith et al. (1978) did not show complete inhibition over a 1-2 day period with 0.1% C_2H_2, this concentration appeared to inhibit N_2O reduction over a several hour period. This extremely wide concentration range simplifies the job of N_2O inhibition. In this study it was desired to use as low a concentration of C_2H_2 as possible because the 5A molecular sieve sorbs C_2H_2 as well as N_2O. Sorption of large amounts of C_2H_2 greatly complicated laboratory analysis.

Preliminary studies indicated predictable and uniform C_2H_2 diffusion patterns which related fairly well to the theoretical diffusion patterns calculated by Ryden et al. (1979a; p. 111, Fig. 1). Uniform diffusion of C_2H_2

occurred to a depth of at least 20 cm which also agreed with the results of Ryden et al. (1979b). The results suggested that longer flow durations of C_2H_2 may be needed under wet soil conditions.

A C_2H_2 diffusion study was conducted on a Poinsett silty clay loam soil (Udic Haploboroll, fine-silty, mixed). Poinsett soils are deep, fine, loamy soils developed in stratified silty glacial drift. Two tillage systems were selected to represent soils of diverse air filled porosities. A moldboard plowed (MP) soil was used for acetylene diffusion under moist conditions an adjacent no-till (NT) soil was selected for the wet conditions. Soil characteristics are presented in Table 1-1.

One acetylene supply probe was operated from an acetylene tank and was regulated with a gas flowmeter. A 2-cm diameter by 30-cm deep core of soil was removed from the center of each cover with a soil probe to allow insertion of the acetylene supply probe. Acetylene was diffused radially (and vertically) from a 0.64-cm (I.D.) plastic supply probe inserted 30 cm deep into the soil through the center of the soil cover core (Fig. 1-1, no. 3). The acetylene probes were left open at the bottom with several holes within 5 cm of the bottom to ensure that soil did not plug the openings. Soil was gently packed around the top of the supply probe to hinder loss of C_2H_2.

Acetylene was supplied at a rate of 0.6 L hr^{-1} for

Table 1-1. Soil organic matter content and residue cover of Poinsett soil.

Tillage	Bulk density	Air filled porosity	Organic Matter
	Mg/m^3	%	%
Moldboard plow @	0.86	37	3.2
No-till	1.06	19	3.2

@ The soil was tilled to a depth of 15 cm

75 minutes previous to cover insertion under the moist condition and at 0.5 L hr^{-1} for 90 minutes previous to cover insertion under the wet condition (as suggested by preliminary results). Acetylene samples were collected at distances of 3, 11, and 19 cm from the acetylene supply probe at a 10 cm depth. Three samples were taken at each distance immediately before soil cover insertion, one half hour after cover insertion (this required brief removal of covers) and one hour after the cover was placed. This coincided with the one hour denitrification measurement. Five cm^3 of soil atmosphere were removed with a syringe from a 0.3 mm (I.D.) tube inserted 10 cm into the soil. Acetylene was then transferred from the syringe to a 25 mL erlenmeyer flask from which it displaced water. Standard acetylene samples were also prepared by displacing water. The acetylene was analysed by injection into a column of Porapak R material heated to 180 ^{o}C in a gas chromatograph. A flame ionization detector, heated to 220 ^{o}C was used with N_2 as the carrier gas at 36 cm^3 min^{-1}.

Efficiency of Nitrous Oxide Recovery

The efficiency of N_2O recovery from the cylindrical soil covers was tested in the greenhouse (because of possible N_2O production by field soils). A 5-mL syringe with an 18-guage needle containing pure N_2O was placed on the surface of moist coarse sand. A soil cover was placed over the syringe and inserted 10 cm deep into the sand leaving a 2-cm head space. The air space was swept for one hour at an air flow rate of 21, 31, or 37 L hr^{-1}. At the end of one hour both the residual N_2O in the syringe and N_2O adsorbed on the molecular sieve were analyzed.

A second experiment was conducted to verify the efficiency of the nitrous oxide traps. Known amounts of nitrous oxide were metered into the air flow line for 30 minutes at an air flow rate of 21 L hr^{-1}. Nitrous oxide trapped by the molecular sieve was recovered and compared to the known amount injected.

Results and Discussion

Acetylene Diffusion

Concentrations of C_2H_2 between 0.1 and 10.0% under the soil cover were readily and predictably established at an approximate depth of 10 cm by radial diffusion from a single supply probe (Table 1-2). Acetylene diffusion patterns in this study generally agree with those found by Ryden et al. (1979b). Acetylene concentrations were somewhat lower than predicted flow rates by Ryden et al. (1979b; p.111, Fig.1). However the low flow rates of C_2H_2 probably created a core near the supply probe which was less than the 100% C_2H_2 concentration which was used in the theoretical calculations. Lower concentrations of C_2H_2 were observed in the moldboard plowed soil than in the no-till soil at the third measurement. Acetylene flow was shut off 30 minutes previous to this measurement. Higher air-filled porosity likely caused more rapid dispersal of acetylene in the moldboard-plowed soil. Several measurements from the 19 cm radius resulted in C_2H_2 concentrations as low as 0.07-0.09%. This was not seen as a problem because work of Ryden et al. (1979a) and Yoshinari et al. (1977) suggested that C_2H_2 concentrations of 0.01% would at least inhibit N_2O reduction for several hours. One measurement from the 3 cm radius resulted in a C_2H_2 concentration of 14%, but this was from the inside core and not underneath the cover. Acetylene concentrations underneath the cover at 3.5 cm were

Table 1-2. Average and range of acetylene concentrations under soil covers at three time intervals on a Poinsett soil.

Distance from probe	Concentration of Acetylene #		
	0 minutes @	30 minutes	60 minutes
cm	%C_2H_2		
		No-till	
3	9.81 (5.78-14.28)$	3.40 (1.88-5.75)	0.92 (0.62-1.30)
11	1.90 (1.56-2.15)	1.16 (1.02-1.30)	0.88 (0.46-1.31)
19	0.25 (0.15-0.38)	0.17 (0.09-0.22)	0.16 (0.11-0.19)
		Moldboard plow	
3	2.02 (1.79-2.32)	2.58 (1.65-4.26)	0.45 (0.43-0.49)
11	0.81 (0.27-1.48)	1.75 (0.24-2.61)	0.23 (0.12-0.32)
19	0.17 (0.07-0.33)	0.23 (0.15-0.30)	0.12 (0.09-0.16)

@ Acetylene was diffused at a rate of 0.50 L/hr for 1.5 hrs and at 0.60 L/hr for 1.25 hrs before cover placement (initial sample, 0 minutes) in no-till (air-filled porosity=0.19) and moldboard plow soils (air-filled porosity=0.37), respectively. Acetylene flow was shut off 30 minutes prior to the final sampling (at 60 min.).

$ Range

Average of three samples taken to a depth of approximately 10 cm

likely lower.

Since C_2H_2 is a gas, diffusion to soil depths above and below 10 cm was eminent (Ryden et al., 1979b). Preliminary studies confirmed this. Acetylene could be smelled when the covers were removed indicating that N_2O reduction was probably inhibited even in the top 1 cm of soil.

Nitrous Oxide Recovery

Nitrous oxide recovery from the greenhouse experiment is reported in Table 1-3. Nitrous oxide recovery from the molecular sieve (plus residual nitrous oxide in the syringe) was highest at a flow rate of 21 L hr^{-1} and decreased dramatically as the air flow rate was increased. These results follow the same pattern as those of Ryden et al. (1978). Apparently high flow rates were inferior to low flow rates because the air-N_2O mixture was passed over the 5A molecular sieve too rapidly for efficient sorbtion to occur. Recovery averaged 95% at an air flow rate of 21 L hr^{-1}, but enough variability existed to warrant a second experiment to determine the efficiency of the N_2O traps. The results of the second experiment are reported in Table 1-4. In this experiment N_2O recovery averaged 104%. Results indicate that nitrous oxide could be trapped efficiently at an air flow rate of 21 L hr^{-1} from cylindrical soil covers.

Table 1-3. Recovery of nitrous oxide.

Flow Rate	Average nitrous oxide recovered#
L/hr	%
21	94.6 ±18.8##
31	65.1 ±21.1
37	56.2 ±24.9

\# nitrous oxide released from an unsealed gas syringe into the enclosed air space of a soil cover and trapped by 5A molecular sieve at various air flow rates.

\## Standard Deviation

Table 1-4. Recovery of nitrous oxide in a mixture with air passed through 46 g of 5A molecular sieve at a flow rate of 21 L/hr for 30 min.

Run Num.	N_2O passed	N_2O recovered#	Recovery
	ug	ug	%
1	12.7	13.6	108
2	12.9	13.5	105
3	12.7	12.3	97
4	12.9	13.7	106

atmospheric N_2O contribution subtracted

Materials and Methods
II. Denitrification Measurements

This study was conducted in east central South Dakota on a Poinsett silty clay loam soil (referred to as the E.C. site) The tillage variable was established in the spring of 1983. Tillage information and selected soil characteristics are presented in Table 1-5. Denitrification measurements were taken from 10.7 m x 5.5 m plots in NT, CH

was applied on May 7. Corn was planted on May 18 in 90 cm rows at a population (measured at harvest) of 50,000 plants ha^{-1}. Residual soil nitrate values are reported in Table 1-6.

Three cylindrical soil covers were used in each of the 4 treatments. Two covers were placed in non-wheel-track (NWT) areas and one cover was placed in a wheel-track (WT) area. A total of 12 covers were operated simultaneously. Soil cover placement was identical to that

Table 1-5. Organic matter content and residue cover of Poinsett soil.

Tillage	Tillage Operations	N Placement	O.M. 0-15 cm	pH	Residue Cover #
			%		%
MP	MP-disked	topdressed	3.2	6.6	14
CH	CH-disked	topdressed	3.2	6.6	25
NT ##	No-till	topdressed	3.2	6.6	43
NT ##	No-till	injected	3.2	6.6	41

\# Recorded on June 15, 1984
\## NT systems were disked on alternate years

Table 1-6. Nitrogen application and residual soil nitrate at E.C. site, 1984.

Tillage	N Source	N Placement	Soil Nitrate @		Fertilizer N + Soil Nitrate	
			0-15cm	15-60cm	0-15cm	15-60cm
		112 kg N/ha	------------kg N/ha----------			
MP	AN #	topdressed	52	123	164	123
CH	AN	topdressed	40	124	152	124
NT	AN	topdressed	29	74	141	74
NT	UAN ##	injected	15	58	15	170

@ Soil Nitrates were determined from soil samples taken in the fall of 1983.
\# Ammonium nitrate
\## Urea ammonium nitrate

presented in the basic methodology section. White plastic was also placed over the covers (painted white) on sunny days to further reduce heat adsorption.

Acetylene was supplied at a rate of 0.60 L hr^{-1} for 75 minutes previous to the initial sample (and cover placement) and allowed to flow for an additional 0.5 hour during sampling (after cover placement) under most (unsaturated) conditions. Under extremely wet conditions (saturation), acetylene was supplied at a rate of 0.50 L hr^{-1} for 90 minutes before commencing sampling. On days in which more than one sample was taken within 4 hours of the initial sample acetylene was supplied at the same rate but only for 40 minutes (while covers were still in place). Acetylene concentrations were occasionally checked at the edge of the cover to make sure the concentrations were at least 0.1% by the method described in the basic methodology section. Acetylene flow to six supply probes was controlled by one flowmeter.

Air under the cover was swept by drawing external air through the soil cover at a rate of 21 L hr^{-1}. Air flow was controlled by needle valves inserted into the air flow line of each cover. Nitrous oxide effusing from the soil was sorbed on a 5A molecular sieve, and then stored until laboratory analysis. Samples were generally taken from 10:30-11:30 A.M. to avoid diurnal temperature variation. The one hour sampling period was mandatory because the 5A molecular sieve sorbs C_2H_2 as well as N_2O (sorbance of large amounts of C_2H_2 made laboratory analysis difficult). Sampling began the day after a rainfall and continued for several days until the soil dried. Soil covers were moved to new locations within the plots each day and were moved to a different replication on June 24.

Daily denitrification rate estimates were made by multiplying the single one hour measurement or average (if more than one measurement was taken) by 24 since measurements were taken as close to the diurnal temperature midpoint as possible. Wheel-track values were multiplied by 0.15 to account for that portion of the field estimated to be in a WT. Non-wheel-track values were multiplied by 0.85 and averaged to account for the non-wheel-tracked portion of the field.

Soil temperature at 5 cm was taken from three thermistors (read to 1 °C) inserted at various locations in each tillage system. Soil water potential at 10 cm was recorded from three tensiometers placed in each tillage system. Residue cover was measured in each plot following planting by counting the number of residue points (versus bare soil) in a 100 point grid. Bulk density measurements were collected from within the row, WT and the undisturbed inter-row (NWT) for each tillage treatment. A minimum of two subsamples were taken to a depth of 40 cm from each replication using a hydraulic core sampler.

Results and Discussion

The spring of 1984 was one of the wettest on record in east central South Dakota. Total precipitation in June measured 17.2 cm (Fig. 1-2). Wet field conditions or rain often made measuring denitrification difficult. A water table existed within one meter of the soil surface until late August due to some lateral movement of water down slope.

Denitrification rates ranged from a daily average of 0.007 to 2.9 kg N ha^{-1} day^{-1} per treatment. The highest singular value was 6.1 kg N ha^{-1} day^{-1} recorded from a WT area of the CH system. Most of the cumulative N loss from May 29-Sept 8 (average of all treatments) occurred during the period of June 11-24 (Fig. 1-2). Because of excessively wet conditions only three measurements were taken over those 14 days. The greatest denitrification rate occurred on June 18. Soils had been saturated before June 18, but soil temperatures were cool. As soil temperatures warmed from early June to June 18 denitrification rates increased dramatically (Fig. 1-2). An increase in soil temperature on June 26 resulted in a subsequent increase in denitrification rates, even though soils had dried considerably. Dentrification virtually ceased after early July. Surface soil conditions were dry in July and August and the several small rainfalls that occurred were probably not enough precipitation to cause anaerobic conditions. Gaseous N

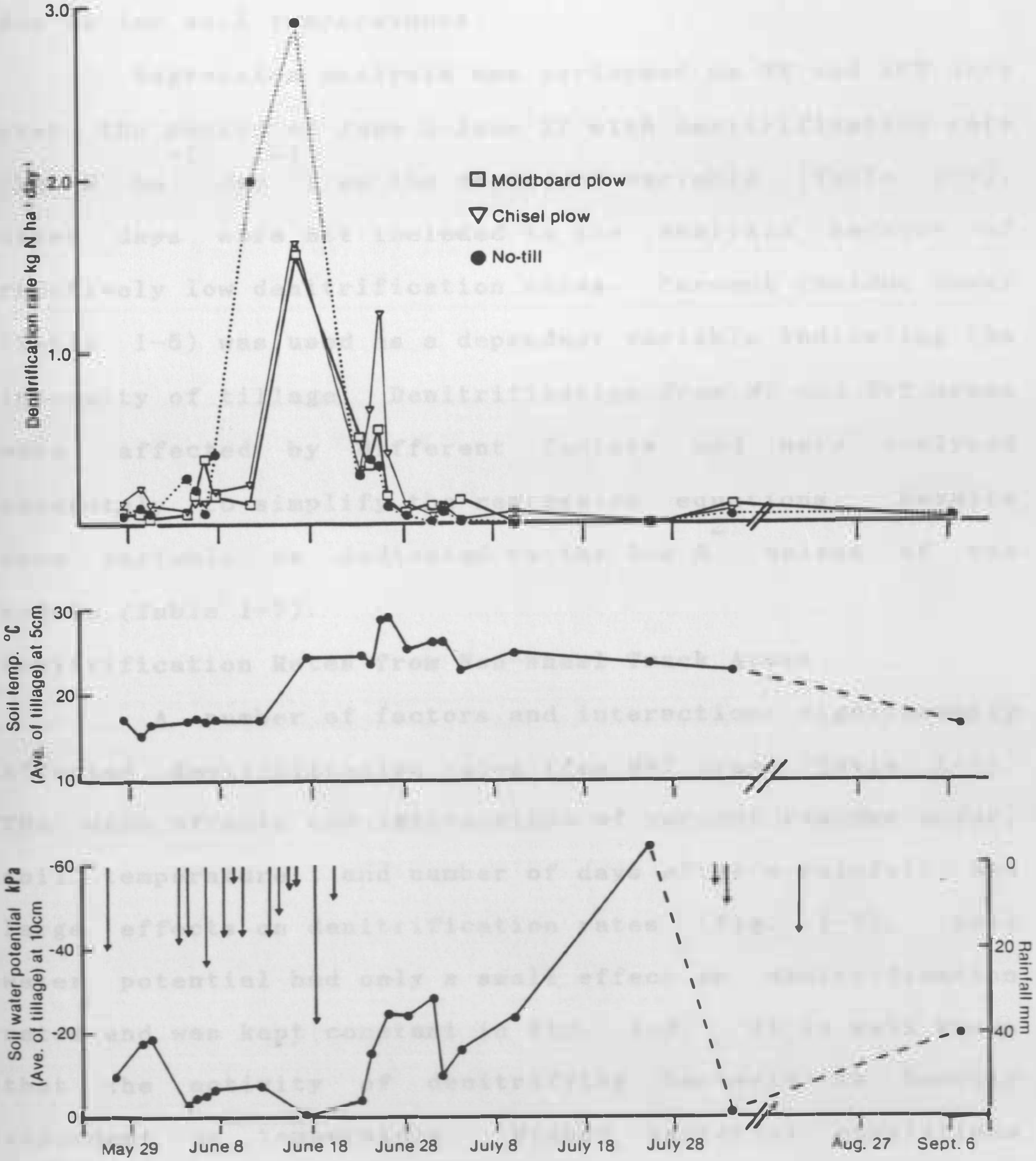

Figure 1-2. Daily denitrification rates, temperature, soil water potential from E.C. site.

losses before May 29 and after Sept. 8 were probably small due to low soil temperatures.

Regression analysis was performed on WT and NWT data over the period of June 6-June 27 with denitrification rate (kg N ha^{-1} day^{-1}) as the dependent variable (Table 1-7). Other days were not included in the analysis because of relatively low denitrification rates. Percent residue cover (Table 1-5) was used as a dependent variable indicating the intensity of tillage. Denitrification from WT and NWT areas were affected by different factors and were analyzed separately to simplify the regression equations. Results were variable as indicated by the low R^2 values of the models (Table 1-7).

Denitrification Rates from Non-Wheel-Track Areas

A number of factors and interactions significantly affected denitrification rates from NWT areas (Table 1-7). The main effects and interactions of percent residue cover, soil temperature, and number of days after a rainfall had large effects on denitrification rates (Fig. 1-3). Soil water potential had only a small effect on denitrification rates and was kept constant in Fig. 1-3. It is well known that the activity of denitrifying bacteria is heavily dependent on temperature. Higher bacterial populations (Aulakh et al., 1984b) and lower air-filled porosity in NT systems (Linn and Doran, 1984) probably caused the reduced tillage systems to be more responsive to changes in soil

Table 1-7. Summary of regression analysis, denitrification study, E.C. site, 1984.

Dependent Variable Y	Location	equation #	R^2
kg N lost/ha/day	NWT	$Y=0.2388 - 0.0867(a) + 0.00627(b)$ $0.00000865\ (c) + 0.0000148\ (d)$ $- 0.226\ (e)$	0.407
kg N lost/ha/day	WT	$Y=-3.9026 + 0.25367\ (f) -$ $0.01507\ (g)$	0.289

\# All variables were significant at the 0.05 leves except e which was significant at the 0.08 level.

a = Residue cover (%)

b = Residue cover*Soil temperature (C)

c = Residue cover squared x Number of days after a rainfall x Soil temp.

d = Soil water potential (kPa) x Soil Temp. x Number of Days after a rainfall squared

e = 1=Dummy variable for injected N treatment (0=topdressed N)

f = Soil Temperature

g = Soil Temperature*Number of days after a rainfall

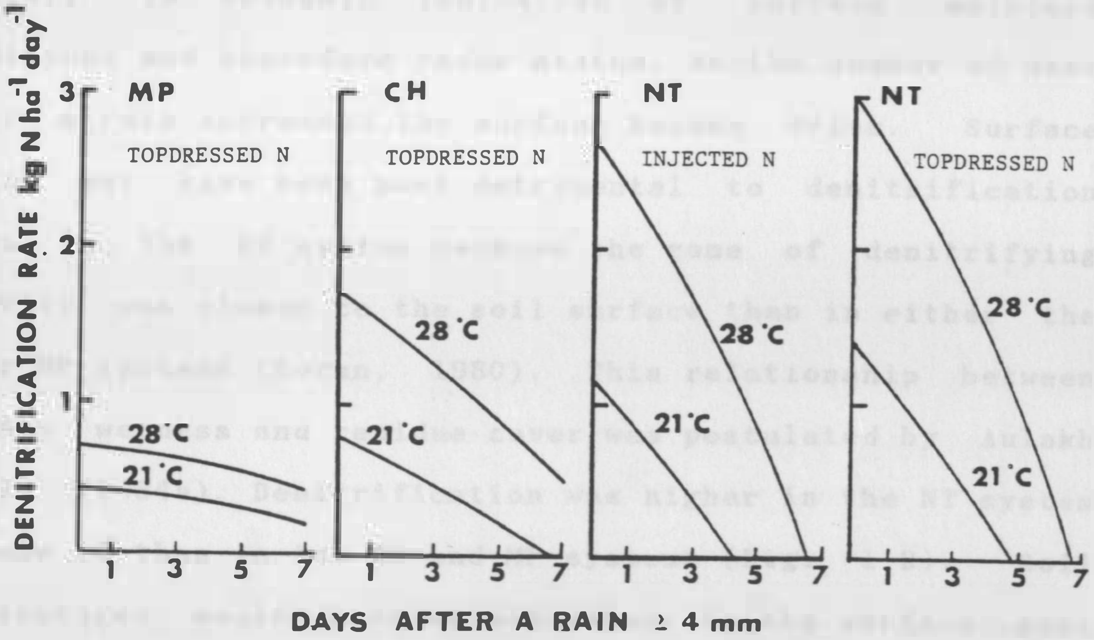

Figure 1-3. The effects of temperature, days after a rain, tillage, and N placement on denitrification rates in non-wheel-track areas of a Poinsett soil

temperatures.

The number of days after a rainfall (of at least 4 mm) had larger effects on denitrification in treatments with greater residue cover (Fig. 1-3). The number of days after a rainfall is probably indicative of surface moisture conditions and therefore redox status. As the number of days after a rain increased the surface became drier. Surface drying may have been most detrimental to denitrification rates in the NT system because the zone of denitrifying activity was closer to the soil surface than in either the CH or MP systems (Doran, 1980). This relationship between surface wetness and residue cover was postulated by Aulakh et al. (1984a). Denitrification was higher in the NT system on June 13 than in the CH and MP systems (Fig. 1-2). Soil temperatures would have warmed sooner in the surface soil further supporting the hypothesis that denitrification in the NT system occurred primarily near the soil surface.

Denitrification rates were significantly lower (0.08 level) in NT plots which received injected N compared to topdressed N (Table 1-7). The difference between the two treatments seems to be fairly large (Fig. 1-4), however data were missing during a critical period (June 18). Placement of N below the zone of greatest denitrifying activity was probably responsible for decreased denitrification. Pre-season soil nitrate in the injected N plots was substantially lower than other treatments (Table 1-6).

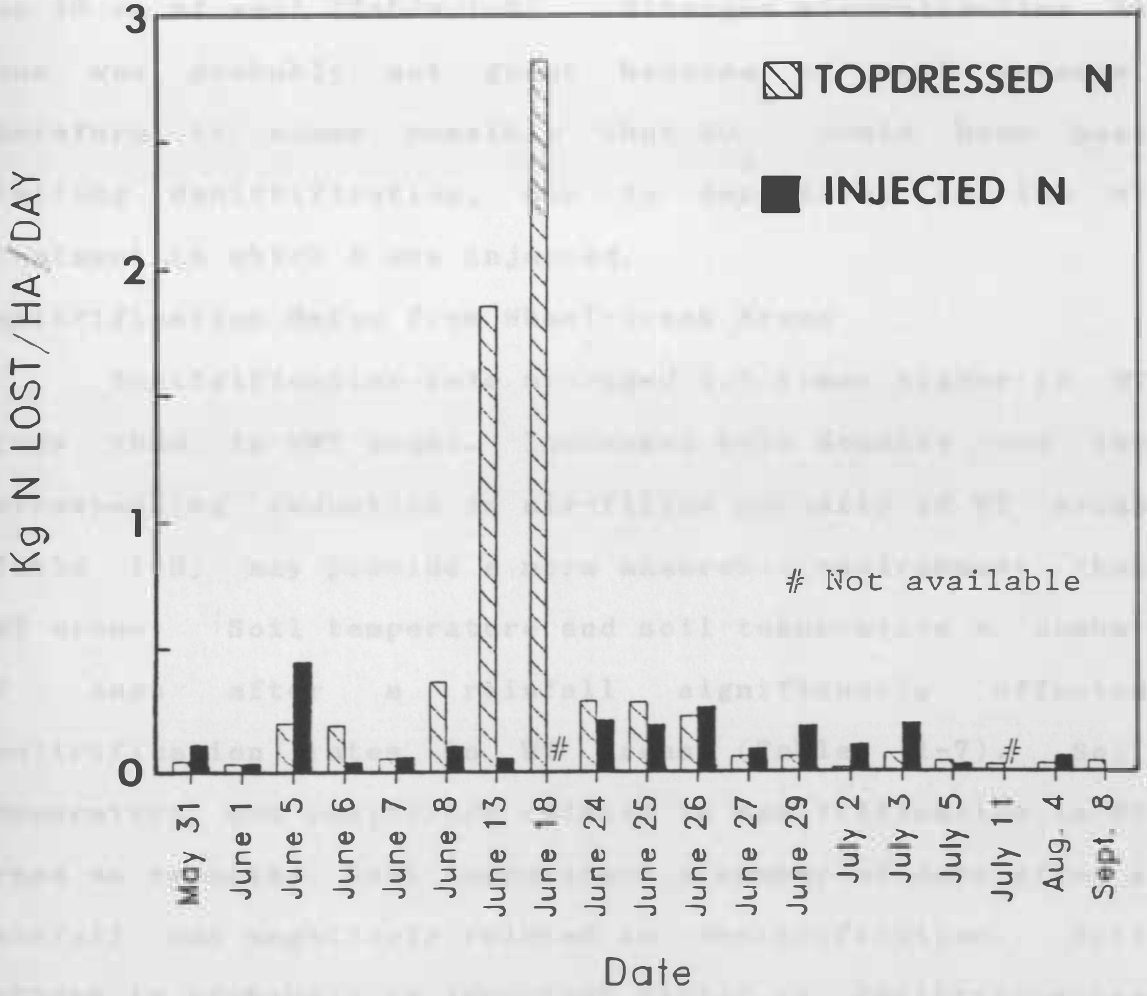

Figure 1-4. Denitrification rates from a no-till Poinsett soil recieving either topdressed or injected N.

After N fertilization, greater differences in nitrate between topdressed and injected N treatments existed in the top 15 cm of soil (Table 1-6). Nitrogen mineralization in June was probably not great because of soil wetness. Therefore it seems possible that NO_3 could have been limiting denitrification, due to depletion, in the NT treatment in which N was injected.

Denitrification Rates from Wheel-Track Areas

Denitrification rate averaged 1.4 times higher in WT areas than in NWT areas. Increased bulk density and the corresponding reduction in air-filled porosity of WT areas (Table 1-8) may provide a more anaerobic environment than NWT areas. Soil temperature and soil temperature x number of days after a rainfall significantly affected denitrification rates in WT areas (Table 1-7). Soil temperature was positively related to denitrification in WT areas as expected. Soil temperature x number of days after a rainfall was negatively related to denitrification. Soil wetness is probabaly an important factor in denitrification from WT areas. However, it is not certain why days after a rainfall was more significant in the interaction than soil water potential. Neither soil water potential, N placement, or percent residue cover were significant in the regression model. Wheel-track areas are compacted zones that have properties that may mask small effects such as N placement and precent residue cover. Denitrification from WT areas

Table 1-8. Bulk density measurements from a Poinsett siltly clay loam, 1984.

	Tillage								
depth	MP			CH			NT		
	WT	Row	NWT	WT	Row	NWT	WT	Row	NWT
cm	Mg/m^3								
0-10	1.41	1.26	1.15	1.40	1.23	1.24	1.41	1.30	1.25
10-20	1.36	1.22	1.25	1.37	1.35	1.30	1.38	1.35	1.32
20-30	1.28	1.30	1.28	1.29	1.30	1.34	1.31	1.31	1.26

Least significant difference = 0.11
(Courtesy of T.E. Schumacher)

appeared to be more variable than from NWT areas.

Cumulative N Losses

Cumulative N loss from May 29-Sept. 8 was estimated by adding the cumulative N loss from the June 6-27 period plus cumulative N loss outside that period. Cumulative N loss from May 29-June 6 and June 28-Sept. 8 was approximated at 3 kg N ha^{-1} for all treatments. Cumulative denitrification from June 6-27 was estimated by integrating WT and NWT regression equations over that period using average soil water potential values for all treatments (rather than individual tillage suction values, Table 1-9). Much of the soil water potential differences between tillage systems (Table 1-9) was probably due to microrelief. Slight depressional areas produced standing water in NT plots on June 18 and 24, and in CH plots on June 25. Since the difference in soil water potential between the tillage systems due to microrelief and the effects of tillage could not be seperated, average soil water potential values (of the three tillage systems) were used for integration. Wheel-track and NWT values were multiplied by 0.15 and 0.85, respectively as in daily denitrification estimates. Cumulative N loss from May 28-Sept 8 was estimated at 11, 16, and 25 kg ha^{-1} from MP, CH, and NT treatments in which N was topdressed, respectively. Cumulative N loss could not be accurately estimated from NT treatments in which N was injected because of missing data during the peak

Table 1-9. Soil water potential at 10 cm and replication number of denitrification measurements per day, E.C. site, 1984.

Date	Tillage			Denitrification measurements, no. of replicates per day
	MP	CH	NT#	
	-------------	kPa	---------	
May 29	8	8	5	2
31	14	11	8	2
June 1	13	14	9	2
5	0	0	0	2
6	0	0	0	3
7	0	0	0	1
8	0	0	0	1
13	6	2	1	1
18	0	0	0	1
24	2	0	1	1
25	12	7	7	3
26	27	12	17	3
27	27	12	17	2
29	27	11	13	1
July 2	25	22	20	1
3	3	3	6	1
5	13	5	13	1
11	16	18	15	1
26	75	75	75	1
Aug 4	18	18	18	1
Sept. 8	18	N/A ##	18	1

\# used for both NT topdressed and injected N treatments

\## Not Available

denitrification event (June 18).

Conclusions

Most of the cumulative N loss from May 29-September 8 occurred over a 14 day period, June 11-24, when soil temperatures were high and soils were saturated. In NWT areas, the zone of denitrification appeared to occur closer to the soil surface in the NT system than in the CH or MP systems. As a result surface drying (number of days after a rainfall) reduced denitrification at a much faster rate in the NT system. Increased soil temperatures also increased denitrification rates, especially in the NT system. Denitrification from May 29-Sept. 18 was proportional to the percent surface residue cover except in the NT treatment in which N was injected in NWT areas. Injecting N significantly decreased denitrification rates in the NT system probably by placing N below the zone of greatest denitrifying activity. The effects of injecting N and residue cover amounts were not evident in WT areas. The R^2 values of regression equations were fairly low indicating variability.

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Chapter II

Influence of Tillage on Nitrogen Response of Corn and Oats Grown in Rotation. I. Soil Nitrates and Corn Response

Abstract

Corn (Zea mays L.) was grown in rotation with oats on a Poinsett silty clay loam soil (Udic Haplaboroll fine silty mixed) in east central South Dakota. The tillage systems studied were moldboard plow (MP), chisel plow (CH), and no-till (NT). Four nitrogen rates (including a check) were applied using topdressed ammonium nitrate. The MP and CH systems were disked once in the spring prior to planting but after N was topdressed. Residual soil nitrate (RSN) was generally higher following oats than following corn and higher under MP tillage than under CH tillage or NT. Apparent N mineralization rates were greater under the MP system than under the reduced tillage systems in 1983. Nitrogen uptake was higher from MP check plots in 1984 but leaching precluded apparent N mineralization estimates. The NT system yielded lower at high fertilizer N (FN) plus RSN rates than the MP and CH systems in 1983. This may have been partly due to heavy annual grassy weed competition. More FN+RSN was required in the CH system to equal yields of the MP system in 1983. Corn under the MP system yielded significantly higher than the reduced tillage systems in 1984. The higher yields seem to be due to lower bulk densities under the MP system and wet soil conditions over slightly lower under reduced tillage, but no additional FN+RSN was necessary to obtain optimal yield over that required by the MP system. However, more FN was necessary under reduced tillage due likely to lower N mineralization rates and greater denitrification rates.

Additional index words: N mineralization, reduced tillage

Introduction

No-till corn (Zea mays L.) production has generally been most succussful in relatively dry environments or seasons (Lal, 1979; Legg et al., 1979; Thomas et al., 1973). Yield increases under no-till systems compared to conventional systems have been attributed to increased soil water content for the NT system (Blevins, 1971). However, no-till corn has yielded less than conventionally tilled corn, particularly in wet growing seasons (Thomas et al., 1973). Decreased yields under no-till systems have generally been attributed to adverse soil physical characteristics and poor weed control.

Increased N requirement by no-till corn compared to conventionally tilled corn has also been observed in some cases (Thomas et al, 1973; Legg et al.,1979). Several reasons have been given for this higher N requirement. Organic N content has increased under no-till systems due likely to less soil disturbance (Dick, 1983; Blevens et al., 1977). Higher nitrate concentrations have been found under conventional tillage systems compared to no-till systems, due to greater mineralization under conventional tillage (Dowdell et al., 1983; Thomas et al, 1973). Increased nitrate leaching in no-till systems has occurred from greater water infiltration (Thomas et al. 1973). Denitrification has also been blamed for the higher N requirement under reduced tillage. Denitrification rates from a no-till system in a corn-oats rotation were reported to average approximately 14 kg N ha^{-1} higher than under conventional tillage (Chapter I).

Yield reductions from continous no-till corn were decreased but not eliminated by rotating corn with soybeans or with oats-alfalfa (Dick and Van Doren, 1985). Little additional research involving a corn-small grain rotation is available. Therefore, an experiment was established to: 1) compare yield potential, N uptake, and N requirements of corn grown in rotation with oats under moldboard plow (MP), chisel plow (CH), and no-till (NT) systems, and 2) determine if soil nitrate interpretations should be altered for reduced tillage systems.

Materials and Methods

Field experiments were conducted on a Poinsett silty clay loam soil (Udic haplaboroll, fine-silty, mixed). The Poinsett soil has developed in stratified silty glacial drift. The site was located on a gently sloping landscape causing some lateral movement of water during periods of heavy rainfall. The site had been predominately chisel plowed since 1970, but was moldboard plowed several times including 1982. Selected soil characteristics are presented in Table 2-1. This site will be referred to as the E.C. site.

A split plot randomized complete block design was utilized, with tillage strips as the main plots and nitrogen treatments as the subplots. Corn was planted in the preceeding year's oat stubble and oats were planted in the preceeding year's corn stubble. Three tillage systems were employed for each crop: MP, CH, and NT. The tillage variable was established in 1983. Primary tillage was done in the spring of 1983 (due to a wet fall in 1982) and in the fall of 1983. Moldboard plow and CH (equiped with sweeps) systems were tilled to a depth of 15 cm. Corn plots in CH and MP systems were disked after N application. All plots planted to oats were disked once to reduce corn residue and to incorporate topdressed fertilizer treatments. Therefore, the NT system was disked once every two years. The planter used a fluted coulter in front of the seeding unit to till a

Table 2-1 . Selected soil characteristics, Poinsett soil.

Tillage operations	Residue Cover # corn after oats	oats after corn	OM	pH	NH_4OAc K	Bray P	EC
	-------%	---------	---------		-kg/ha-		S/m
(MP) Moldboard-disk	12	9	3.2	6.6	600	50	0.05
(CH) Chisel-disk	24	30					
(NT) ##	66	36					

\# Recorded following planting in May 1983

\## NT systems were disked on alternate years to prepare a seedbed for oats establishment

5-cm strip over each row. Fertilizer nitrogen (FN) was applied at 0, 73, 109, 170 and 0, 37, 75, and 112 kg N ha^{-1} in 1983 and 1984, respectively. Nitrogen was applied as either topdressed ammonium nitrate (AN) or injected urea-ammonium nitrate (UAN) several days before planting. Nitrogen was injected 12-15 cm deep using an applicator with a knife spacing of 45 cm. Check plots for injected N treatments were knifed without applying fertilizer. Plot dimensions were 11m x 5.5m.

‘Pioneer 3906’ corn was planted in 91 cm rows on May 10 in 1983 and on May 18 in 1984. Triple super phosphate was applied at a rate of 18 kg P/ha with a starter attachment. No additional fertilizer other than N was needed according to soil tests. Weeds were controlled by a preplant application of Lasso/Bladex and one cultivation when corn was in the four leaf stage. Fifteen earleaves were taken at silk initation from each plot. Nitrogen content was determined using a micro-Kjeldahl method (Bremner, 1965). Quadradic or linear regression equations were used to fit earleaf data according to the highest R^2 obtained. Six and three meters of the inner two rows were harvested for corn grain and stover yield, respectively. Stover and grain yields were summed to determine silage yield.

Wet planting conditions in 1983 resulted in low plant populations on some plots . Yields were therefore statistically adjusted to compensate for poor stands (Steele and Torrie, 1980). Regression analysis indicated that only one regression line was necessary for all N levels to adjust yields to a harvest population of 48,400 plants/ha. The harvest population of corn in 1984 was 50,000 plants/ha.

Four soil samples from the 0-60 cm depth and three from the 60-120 cm depth were taken from each plot in the fall to determine residual soil nitrate (RSN) concentration. Soil nitrate concentrations were determined using nitrate specific ion electrode.

Bulk density measurements were collected from within the row, the wheel-tracked, and the undisturbed inter-row for each tillage treatment. A minimum of two subsamples were taken from each replication. Samples were taken with a Uhland type hand soil sampler in 1983 from two depths within the top 20 cm. In 1984, a hydraulic core sampler was used to obtain samples to a depth of 40 cm.

Plant height and shoot dry weight were periodically sampled for the first 20 days after emergence. Plant height was determined by measuring the distance from the soil to the youngest fully expanded leaf on ten plants per plot. Shoot dry weights were determined from samples consisting of five randomly selected plants from each plot.

Leaf area measurements were made during the period of rapid vegetative growth between 20 and 50 days after emergence. Five randomly selected plants were initially tagged and measured nondestructively for leaf area at weekly intervals. A Li-Cor LI-3000 portable area meter was used for leaf area determination.

Results and Discussion

Residual Soil Nitrate

Residual soil nitrate N was measured in the fall of 1982, 1983, and 1984 (Figs. 2-1, and 2-2). Residual soil nitrate was generally higher following oats than following corn. Oats were harvested in early August, which left two months during which conditions were favorable for mineralization and no crop was present to take up N. The highest FN rate applied in 1983 and 1984 was more N than normally recommended for oats. Consequently high RSN (0-60 cm) levels resulted from these treatments (Fig. 2-2).

Residual soil nitrate was higher in the MP system compared to the reduced tillage systems (Fig. 2-1 and 2-2.) This probably reflects greater mineralization in the MP system and supports previous research (Dowdell et al., 1983). The differences between RSN levels were greater following oats than following corn particularly at high FN rates (Table 2-2). Corn was generally able to extract more N from the soil profile than oats. Moist soil conditions at the 0-60 cm depth throughout the summer of 1984 and greater N uptake by corn favored depletion of soil N by corn.

Residual soil nitrate levels following oats from the 60-120 cm depth were relatively low in 1982 and 1983 compared to 1984 (Fig. 2-2). In 1984, RSN from the 0-60 cm depth was high at planting (RSN following corn 1983). The extremely wet weather leached N deeper in the soil profile

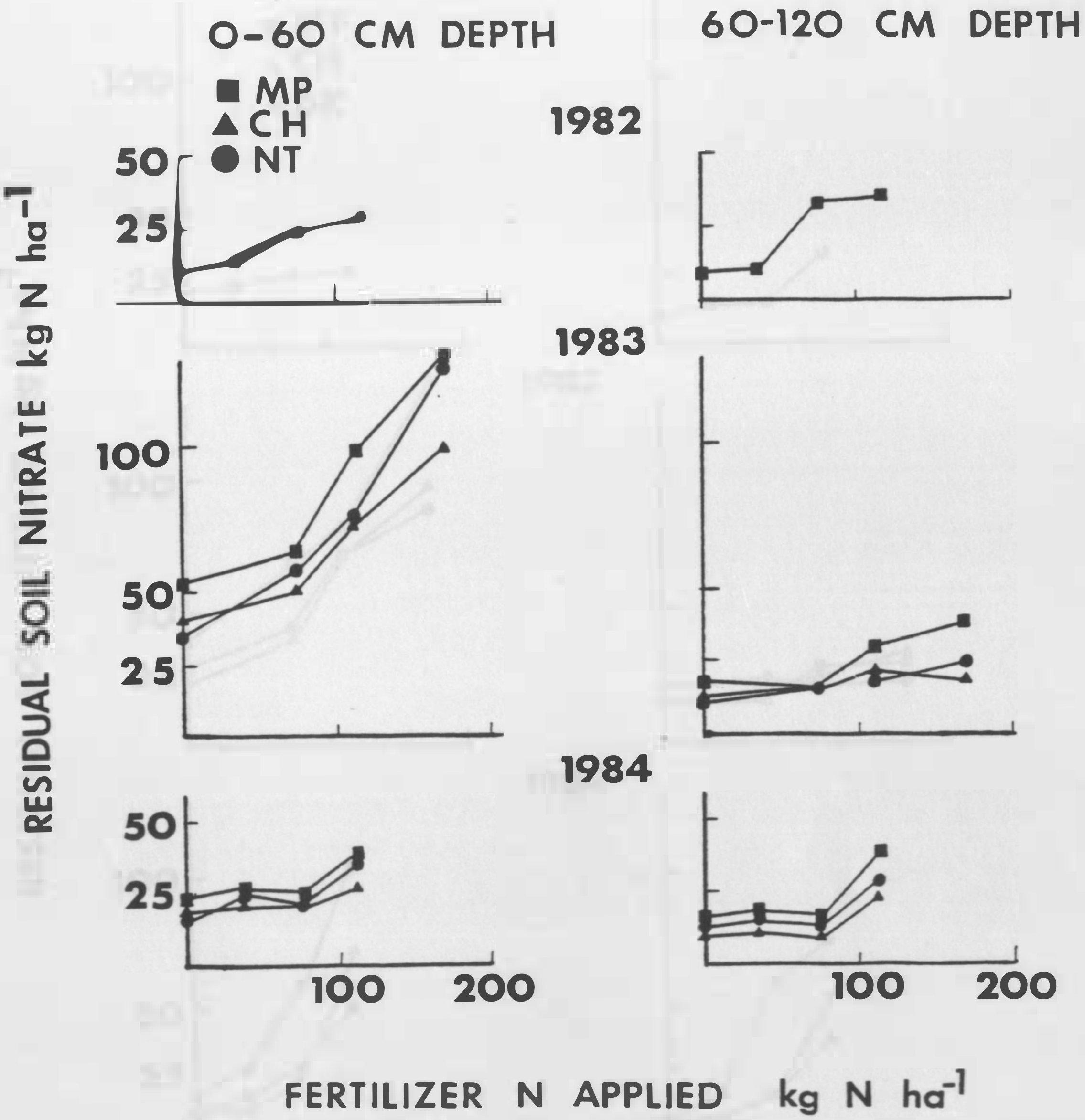

Figure 2-1. Residual soil nitrate resulting from fertilizer N applied to corn in moldboard plow (MP), chisel plow (CH), and no-till (NT) systems, E.C. site.

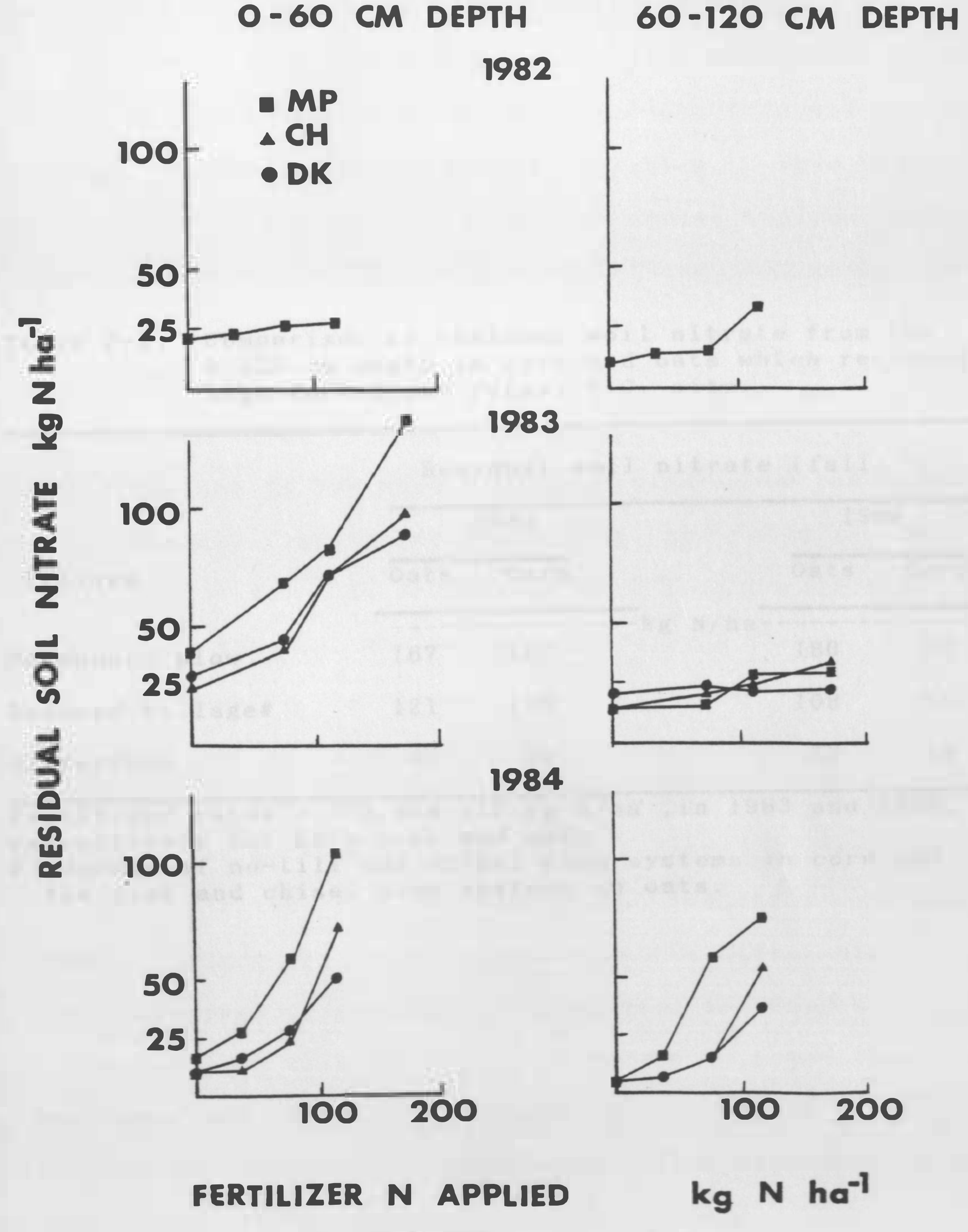

Figure 2-2. Residual soil nitrate resulting from fertilizer N applied to oats in moldboard plow (MP), chisel plow (CH), and no-till (NT) systems, E.C. site.

Table 2-2. Comparison of residual soil nitrate from the 0-120 cm depth in corn and oats which recieved high fertilizer rates, E.C. site.

	Residual soil nitrate (fall)			
	1983		1984	
Tillage	Oats	Corn	Oats	Corn
	---------------kg N/ha-------------			
Moldboard plow	167	167	180	77
Reduced tillage#	121	135	108	59
difference	46	32	72	18

Fertilizer rates = 170,and 112 kg N/ha ,in 1983 and 1984, respectively for both corn and oats.

Average of no-till and chisel plow systems in corn and the disk and chisel plow systems in oats.

as indicated by other data, not presented here.

Results from both corn and oats showed no greater accumulation of RSN at the 60-120 cm depth from the reduced tillage systems compared to the MP system. This indicated no increased leaching of N from the reduced tillage systems (from increased infiltration of water) as previously found (Thomas et al., 1973).

Residual soil nitrate was lower in plots which recieved injected N compared to topdressed N (Fig. 2-3). The difference in RSN values between topdressed and injected N treatments increased from 1983 to 1984. Several possibilities for this difference have been considered. The applicator for injected N was calibrated a number of times with no apparent problems and fertilizer used in the experiment was in agreement with the calculated amount. A detailed soil sampling excercise indicated that no N spatial distribution pattern existed (from injected N treatments), and analysis of the UAN solution indicated correct N content. Since it is not known why the difference in RSN levels occurred , results from injected treatments will not be presented in this paper. It should be noted that once the lower RSN levels in the injected treatments were taken into account, there was little effect of N placement on corn grain yield, silage yield, or total N uptake.

Preliminary regression analysis indicated that FN and RSN (0-60 cm) and their squared terms (FN^2 and RSN^2)

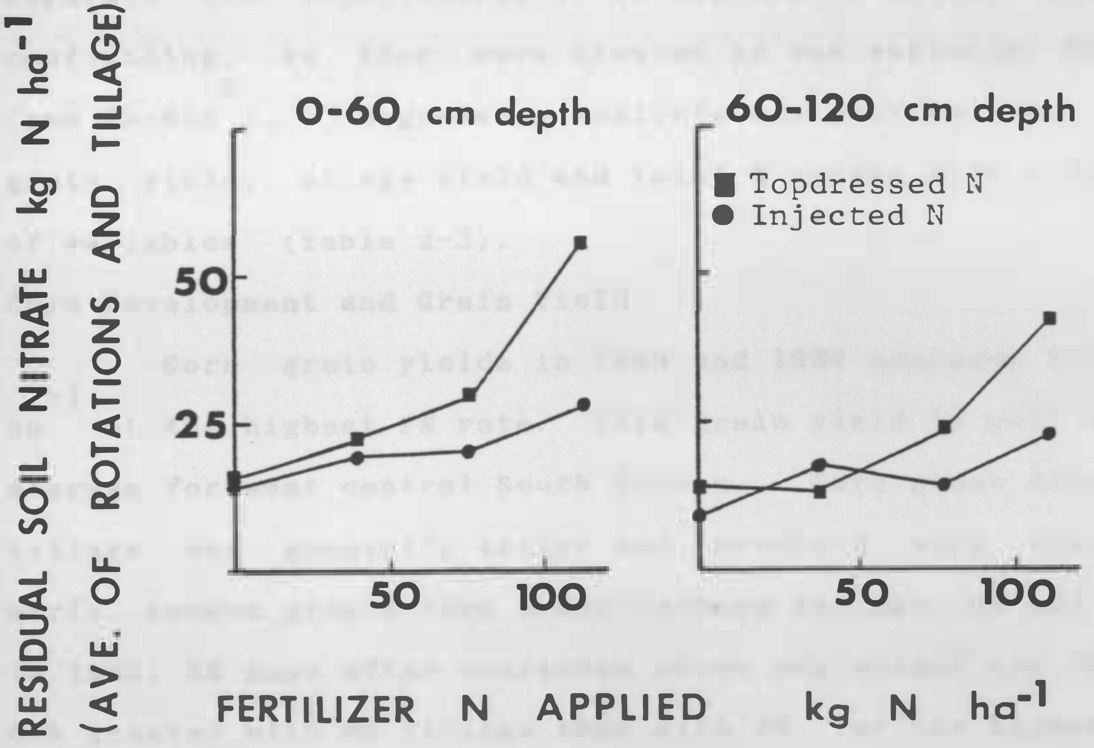

Figure 2-3. Residual soil nitrate resulting from topdressed or injected N applied in 1984, E.C. site

significantly influenced corn grain yield, silage yield, and total N uptake. Adding RSN (60-120 cm) to the models did not significantly increase the R^2, and was therefore not used in statistical analysis. It was not possible to separate the efficiencies of FN and RSN (0-60 cm) due to confounding, so they were treated as one variable FN+RSN (and $FN+RSN^2$). Regression analysis was performed on corn grain yield, silage yield and total N uptake with a number of variables (Table 2-3).

Corn Development and Grain Yield

Corn grain yields in 1983 and 1984 averaged 7.6 Mg ha^{-1} at the highest FN rate. This grain yield is well above average for east central South Dakota. Corn grown under MP tillage was generally taller and produced more vigorous early season growth than under reduced tillage (CH and NT). In 1983, 26 days after emergence shoot dry weight was 70 and 87% greater with MP tillage than with NT for the highest FN rate and the check treatment, respectively. Plant height differences were less pronounced but followed the same pattern as the shoot dry weight. Leaf area measurements taken in 1983 indicated that similiar leaf area was maintained for all tillage systems at the highest FN rate (Fig. 2-4). In contrast the corn grown in MP check plots had markedly greater leaf area as the season progressed compared to the reduced tillage systems (Fig. 2-4). This difference in vegetative growth was related to the more

Table 2-3. Regression equations for corn grain, silage, and total N uptake, E.C. site.

dependent variable Y	equation	R^2
corn grain Mg/ha at 15.5% moisture	$Y=4.68 + 0.0265\,(FN+RSN) - 0.00007176(FN+RSN)^2 + 0.57(MP) - 1.69\,(1984=1) + 0.0098\,(FN+RSN)(1984=1) + 0.00002(CH)(FN+RSN)^2 - 0.000042\,(CH)(FN+RSN)^2\,(1984=1)$	0.720
corn silage Mg/ha at 60% moisture	$Y=17.6 + 0.1267(FN+RSN) - 0.0002731\,(FN+RSN)^2 + 7.6(MP) - 8.5\,(MP)(1984=1) - 0.03644(FN+RSN)(MP) + 0.0623(MP)(FN+RSN)(1984=1)$	0.704
total N uptake kg/ha	$Y=54.3 + 0.666\,(FN+RSN) - 0.00110\,(FN+RSN)^2 + 18.0\,(MP) - 0.1294\,(FN+RSN)\,(1984=1) - 29.7\,(MP)(1984=1) - 10.2\,(CH)(1984=1) + 0.178\,(FN+RSN)(MP)(1984)$	0.859

FN+RSN=fertilizer N + residual soil nitrate N-60 cm
MP=molboard plow (dummy variable=1, other tillage systems=0)
CH=chisel plow (dummy variable=1, other tillage systems=0)
year=1984 (dummy variable 1984=1;1983=0
0.10 level of entry was required for each variable

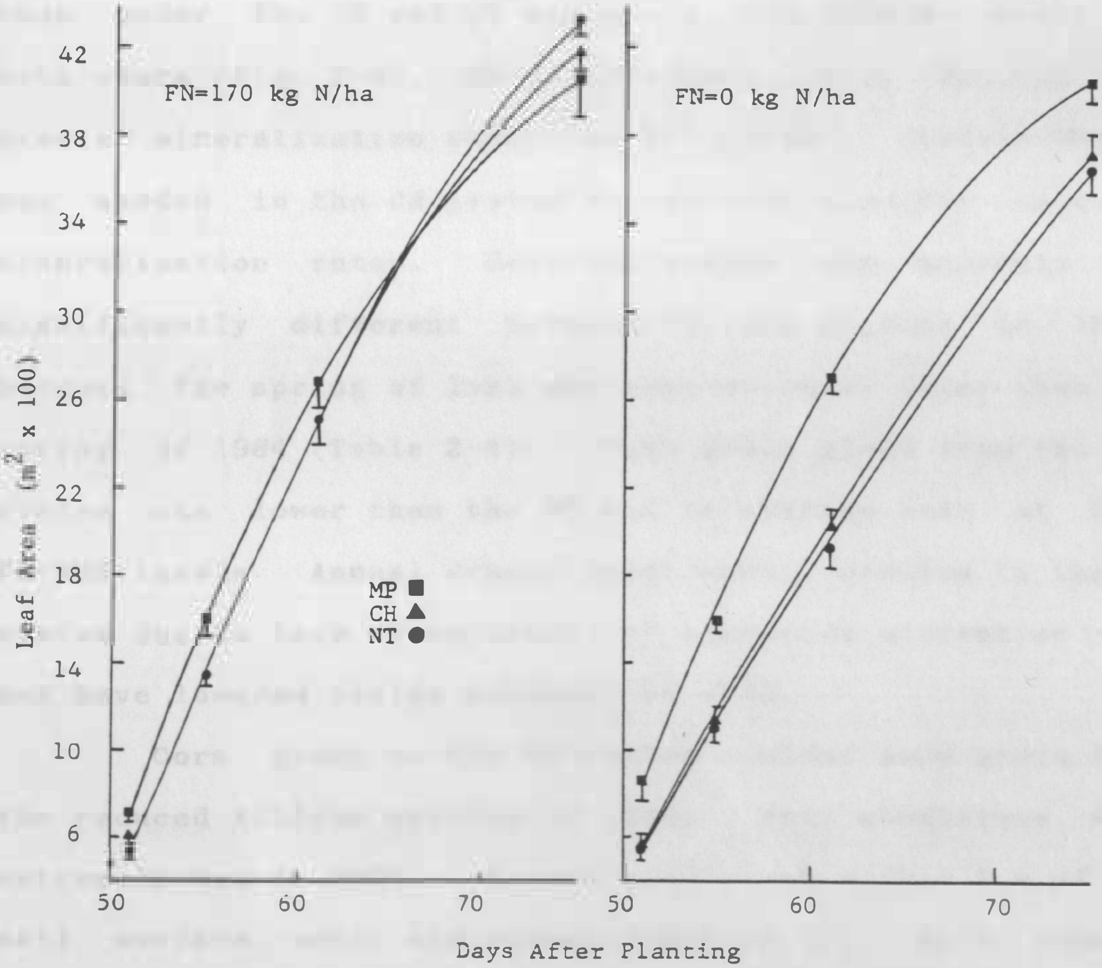

Figure 2-4. The effects of moldboard plow (MP), chisel plow (CH), and no-till (NT) tillage and fertilizer N (FN) on leaf area, E.C. site 1983. Measurements are for a per plant basis and represent the mean of twenty observations. Brackets indicate the standard error of the mean (Courtesy of T.E. Schumacher).

pronounced nitrogen deficiency symptoms observed in the corn grown under reduced tillage.

Higher corn grain yields occurred under the MP system than under the CH and NT systems at low FN+RSN levels in both years (Fig. 2-5). This difference likely resulted from greater mineralization under the MP system. Greater FN+RSN was needed in the CH system to overcome possibly lower N mineralization rates. Denitrification was probably not significantly different between tillage systems in 1983, because the spring of 1983 was substantially drier than the spring of 1984 (Table 2-4). Corn grain yield from the NT system was lower than the MP and CH systems even at high FN+RSN levels. Annual grassy weeds were a problem in the NT system due to lack of rainfall for herbicide activation and may have lowered yields somewhat in 1983.

Corn grown in the MP system yielded more grain than the reduced tillage systems in 1984. Soil conditions were extremely wet in 1984. A water table was within 1 m of the soil surface until mid-August (Chapter I). Bulk density measurements indicated similiar patterns among tillage systems in 1983 (Table 2-5). The higher bulk densities in 1984 reflect tillage and traffic which occurred at higher water contents than in 1983. The MP tillage tended to lower the bulk density in the plow zone unaffected by traffic. This may have increased early season growth in the MP system during periods of high soil water content by affecting root

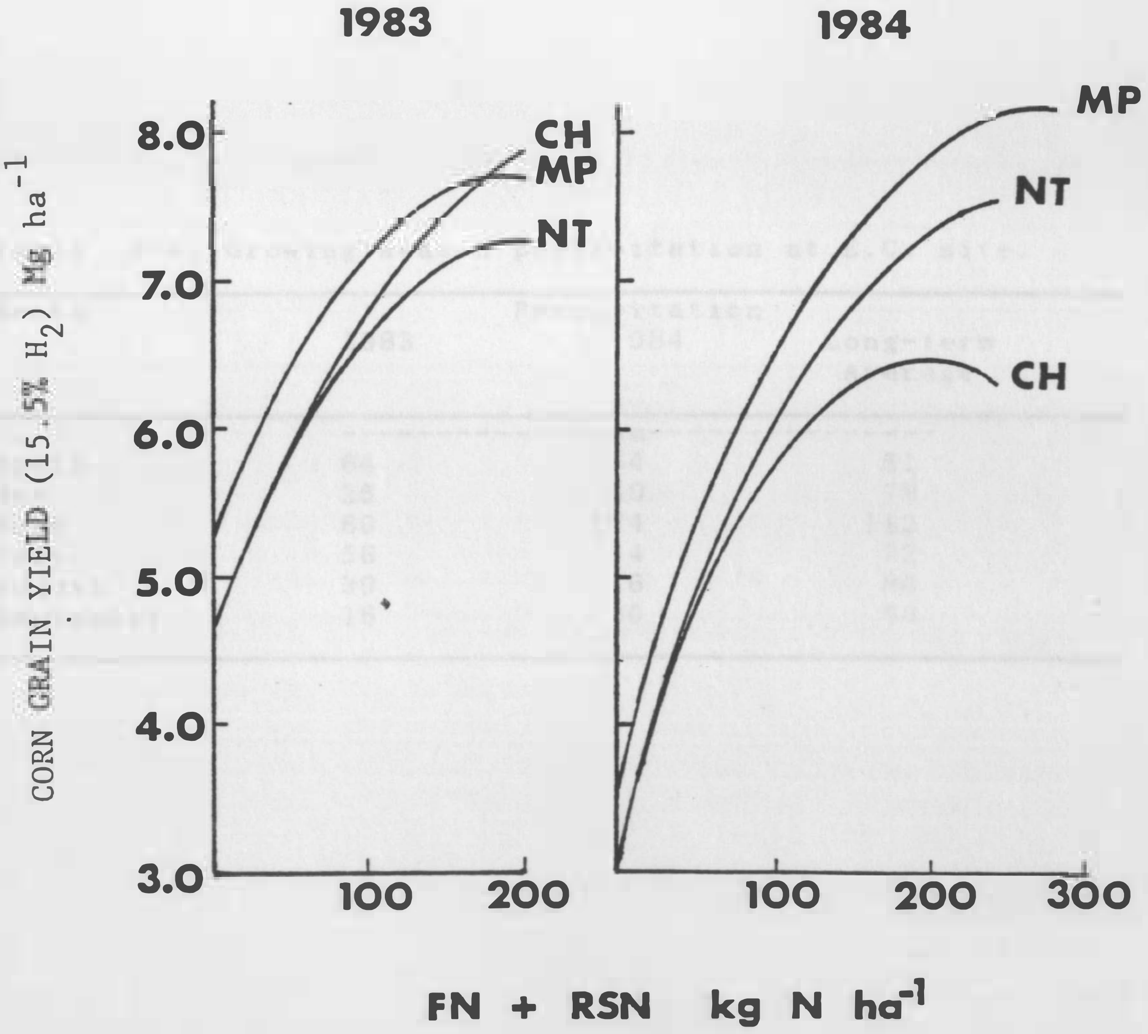

Figure 2-5. Corn grain yield under moldboard plow (MP), chisel plow (CH), and no-till (NT) systems as affected by fertilizer N (FN) plus residual soil nitrate (RSN) (derived from Table 2-3 equations) , E.C. site.

Table 2-4. Growing season precipitation at E.C. site.

Month	Precipitation		
	1983	1984	Long-term Average
	mm		
April	64	64	51
May	25	59	78
June	60	174	112
July	56	4	72
August	39	16	80
September	16	80	50

Table 2-5. Bulk density from wheel-track, non-wheel-track, and row areas, E.C. site.

	Tillage								
depth	MP			CH			NT		
	WT	Row	NWT	WT	Row	NWT	WT	Row	NWT
cm	Mg/m3								
	1983								
0-10	1.25	1.12	1.01	1.26	1.07	1.01	1.32	1.13	1.07
10-20	1.19	1.16	1.11	1.18	1.14	1.11	1.23	1.17	1.10
	1984								
0-10	1.41	1.26	1.15	1.40	1.23	1.24	1.41	1.30	1.25
10-20	1.36	1.22	1.25	1.37	1.35	1.30	1.38	1.35	1.32
20-30	1.28	1.30	1.28	1.29	1.30	1.34	1.31	1.31	1.26

Least significant difference=0.06 and 0.11 in 1983 and 1984 respectively.
(Courtesy from Dr. Tom Schumacher)

zone aeration. Standing water was observed more frequently in the reduced tillage systems. Corn grain yield under the CH system was lower than under the NT system at high FN+RSN levels (Fig. 2-5). However, two of the four plots in the CH system which recieved the highest FN rate were flooded for several days in June. These plots yielded poorly and lowered the regression line. A negative relationship between soil water drainage and no-till corn yield has been observed (Dick and Van Doren 1985).

Corn Silage Yield

Silage yields were higher under the MP system than under reduced tillage systems in 1983, especially at low FN+RSN levels (Fig. 2-6). At high FN+RSN levels the reduced tillage systems yielded similiar to the MP system. In 1984, the trend was reversed as silage yields for the three systems converged at low FN+RSN levels. Nitrogen mineralization may have been similiar between tillage systems in 1984. The yield potential in 1984 was higher in the MP system. The corn in the MP system yielded more grain and more total vegetation than corn in either the CH or NT systems.

N Uptake

Nitrogen uptake was higher in the MP system in 1983 (Fig. 2-7). Some luxury consumption of N may have occurred in 1983 because silage yields maximized near the 200 kg N ha^{-1} FN+RSN level and total N uptake did not. Earleaf N

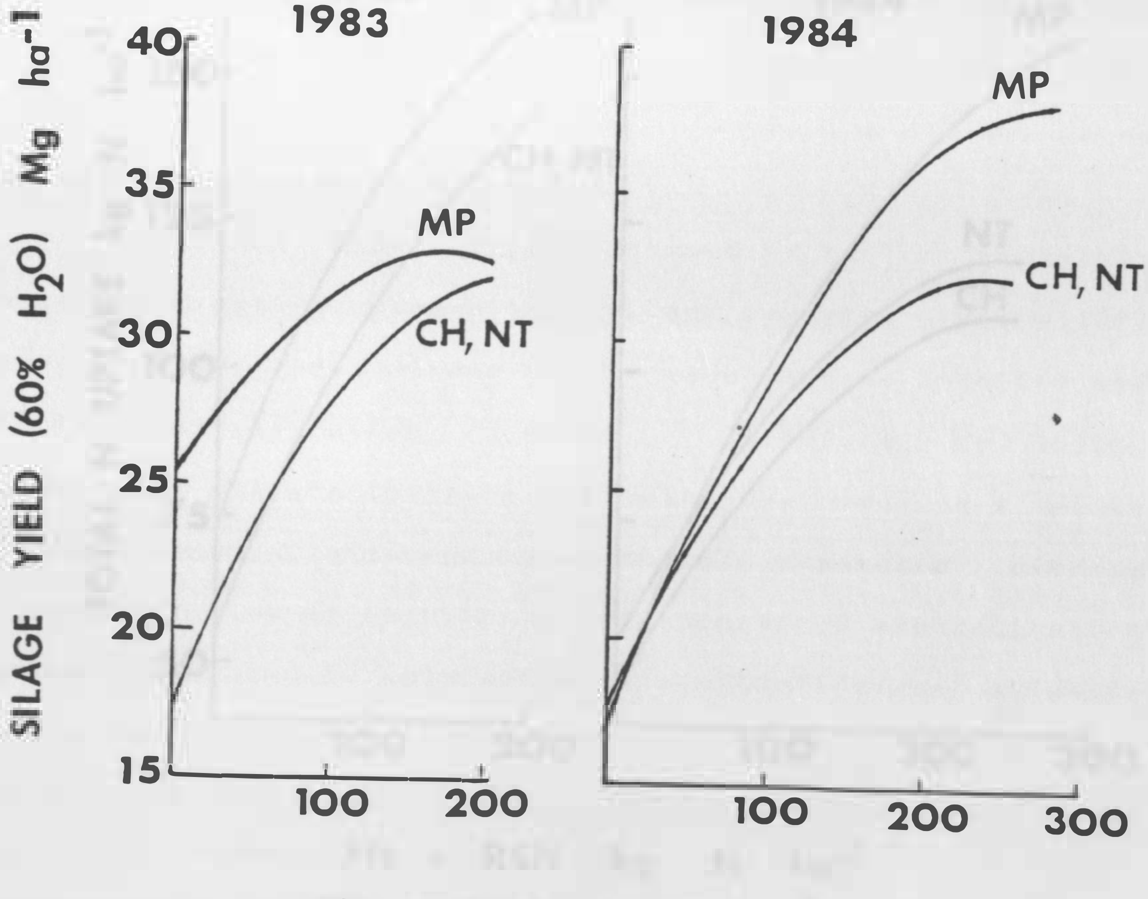

Figure 2-6. Corn silage yield under moldboard plow (MP), chisel plow (CH), and no-till (NT) systems as affected by fertilizer N (FN) plus residual soil nitrate (RSN) (derived from Table 2-3 equations), E.C. site.

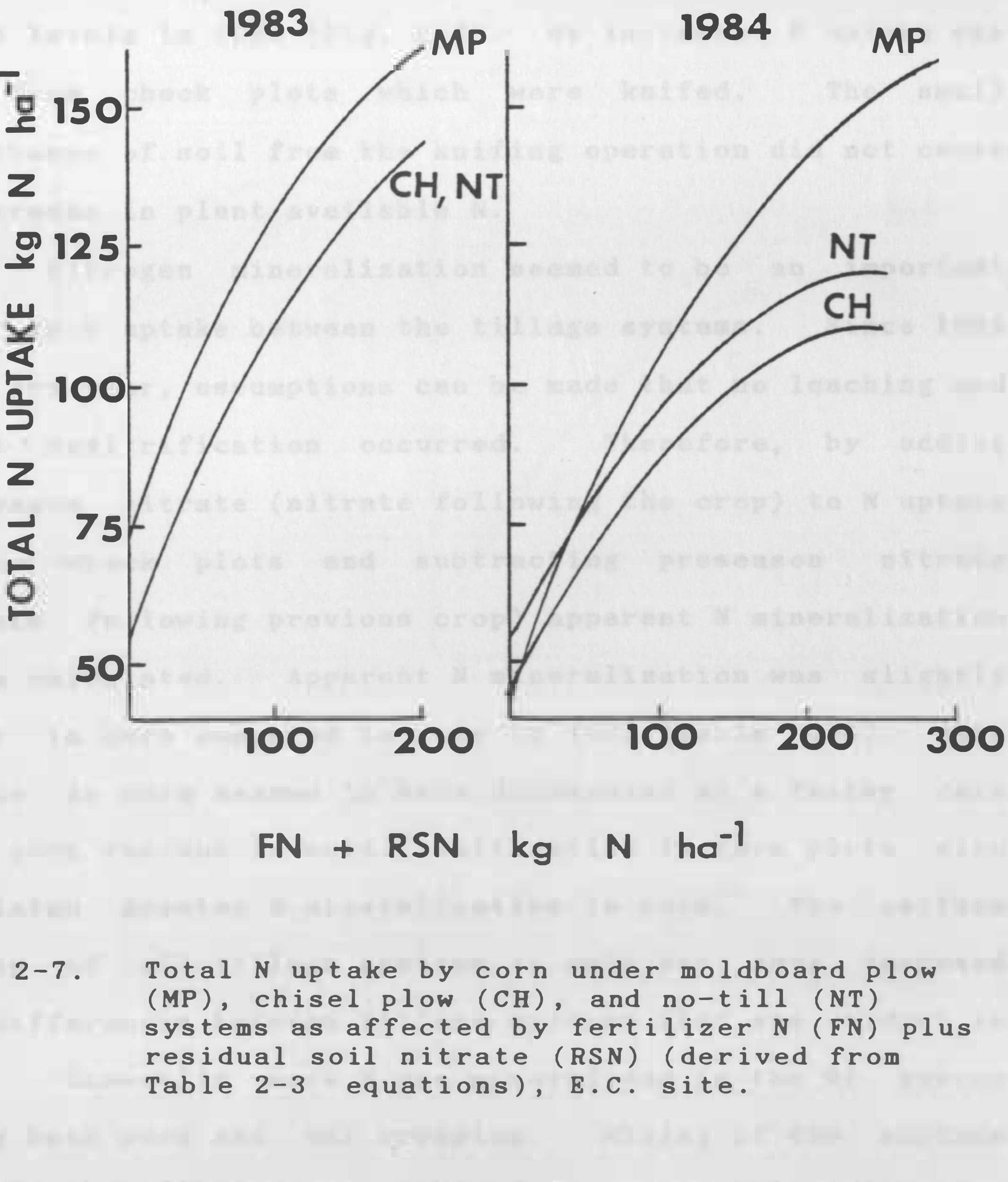

Figure 2-7. Total N uptake by corn under moldboard plow (MP), chisel plow (CH), and no-till (NT) systems as affected by fertilizer N (FN) plus residual soil nitrate (RSN) (derived from Table 2-3 equations), E.C. site.

contents at silking (Fig. 2-8) also indicate high consumption of N in 1983 in contrast to 1984 at high FN+RSN values. Total N uptake in the MP system was greater relative to reduced tillage systems at high FN+RSN levels in 1984. This closely reflects grain yield patterns at high FN+RSN levels in 1984 (Fig. 2-4). No increased N uptake was seen from check plots which were knifed. The small disturbance of soil from the knifing operation did not cause an increase in plant available N.

Nitrogen mineralization seemed to be an important factor in N uptake between the tillage systems. Since 1983 was a dry year, assumptions can be made that no leaching and little denitrification occurred. Therefore, by adding postseason nitrate (nitrate following the crop) to N uptake of the check plots and subtracting preseason nitrate (nitrate following previous crop) apparent N mineralization can be calculated. Apparent N mineralization was slightly higher in corn compared to oats in 1983 (Table 2-6). Oats residue in corn seemed to have decomposed at a faster rate than corn residue in oats. Cultivation in corn plots also stimulated greater N mineralization in corn. The uniform disking of all tillage systems in oats may have dampened the differences between tillage systems that are evident in corn. Generally more N was mineralized in the MP system during both corn and oat cropping. Mixing of the surface residues are likely responsible for greater mineralization

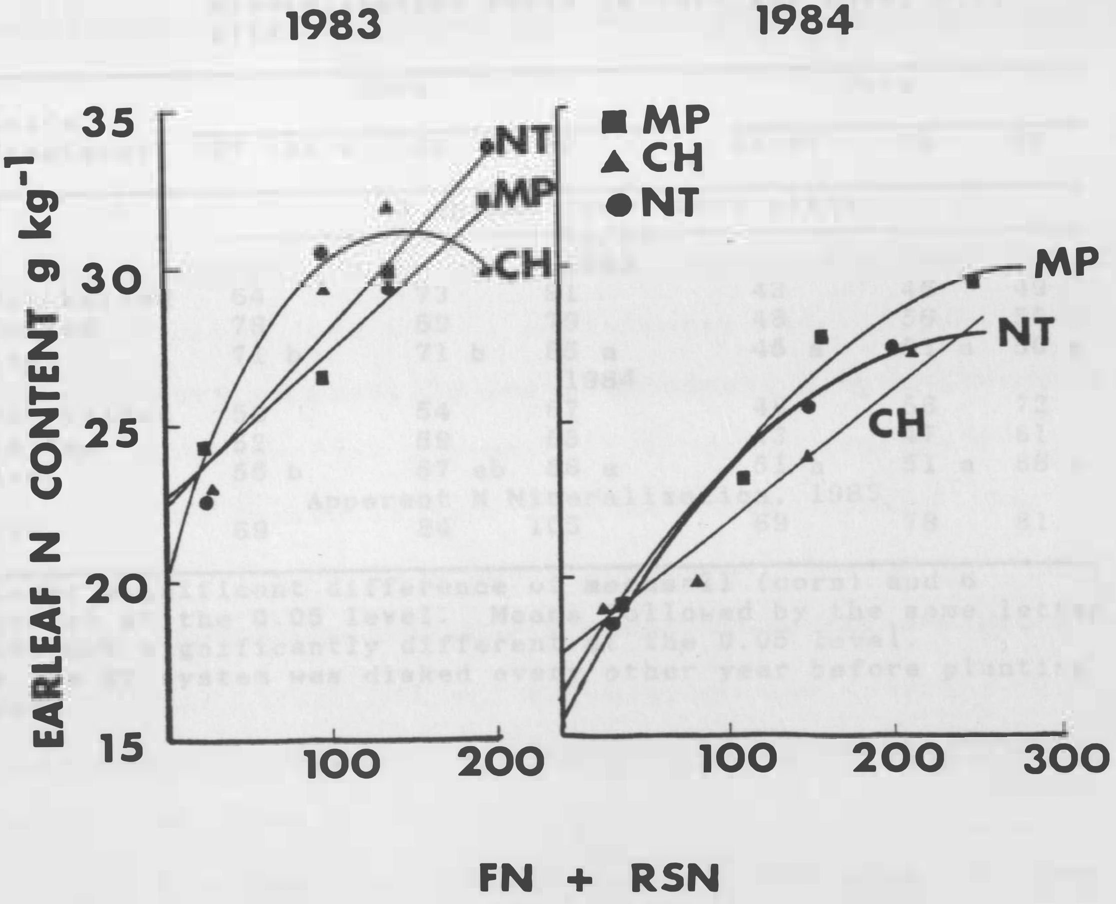

Figure 2-8. Nitrogen content of corn earleaves under moldboard plow (MP), chisel plow (CH), and no-till (NT) systems as affected by fertilizer N (FN) plus residual soil nitrate (RSN), E.C. site

Table 2-6. Nitrogen uptake from check plots and apparent mineralization rates in corn and oats, E.C. site.

Knife Treatment	Corn NT (DK)@	Corn CH	Corn MP	Oats DK(NT)	Oats CH	Oats MP
			N uptake from check plots			
			kg/ha			
			1983			
Not knifed	64	73	91	43	46	49
Knifed	78	69	79	48	56	50
Ave.	71 b	71 b	85 a	45 a	51 a	50 a
			1984			
Not knifed	58	54	67	48	56	72
Knifed	52	59	65	43	47	61
Ave.	55 b	57 ab	66 a	51 a	51 a	66 b
			Apparent N Mineralization, 1983			
Ave.	69	84	105	69	78	81

Least significant difference of means=11 (corn) and 6 (oats) at the 0.05 level. Means followed by the same letter are not significantly different at the 0.05 level.

@ The NT system was disked every other year before planting oats.

in the MP system. Apparent N mineralization rate in the CH system was intermediate between MP and NT systems. Chisel tillage does not mix the soil as well as MP tillage but more than NT(DK-oats). The results indicated that organic matter decomposed at rates 2.4,2.0, and 1.6% in MP, CH, and NT systems, respectively in 1984 (assumes soil weight of 2,000,000 kg ha^{-1}, organic matter content of 3.2%, and 0.067 kg N per kg O.M.).

Assumptions of no leaching and little denitrification can not be confidently made in 1984 because of the heavy rainfall in June. However, N uptake from check plots indicate that N mineralization was probabaly greater in the MP system in both corn and oats (Table 2-6). The regression lines from total N uptake (Fig. 2-7) do not necessarily support higher N uptake from check plots of the MP system. But RSN was taken into consideration in the regression equation, and leaching could have altered the regression lines.

Knowledge of the timing of N mineralization can be obtained from N uptake data. In 1983 approximately 20-30 kg N ha^{-1} was mineralized late in the season after oats had matured as evidenced by the greater N uptake in corn compared to oats (Table 2-6). Several rainfalls in late July and August in 1983 (Table 2-4) were likely responsible for this mineralization. In 1984 little N mineralization seemed to occur after oats harvest, because N uptake was similiar for both crops (Table 2-6). Almost no precipitation occurred from June to late September in 1984 (Table 2-4). These conditions were unfavorable for late season mineralization.

Nitrogen requirement varied between tillage systems and years (Table 2-7). The CH system was the highest and lowest yielding system in 1983 and 1984 with the highest and lowest N requirement, respectively. Average FN+RSN requirements were quite similiar for the three tillage treatments, but FN requirements were lower under the MP system. This was probably due to greater N mineralization rates in both years, lower denitrification rates (Chapter I) and higher preseason RSN levels in 1984. Lower FN+RSN requirements per Mg corn grain yield in the MP system were due to the low FN+RSN requirements at optimum yield and the high optimum yield averages in contrast to the reduced tillage systems.

Conclusions

Altering tillage can have a marked effect on the RSN level of soils. High RSN amounts were achieved through more intensive tillage, and are likely due to greater N mineralization rates. The differences in RSN levels between tillage systems were accentuated following an oat crop compared to following a corn crop.

Corn grain yields were highest in the CH system at sufficient FN+RSN levels in 1983. Corn grain yields were

Table 2-7. Nitrogen requirement for corn, E.C. site.

tillage	optimum yield	percent of yield max.	FN+RSN required	FN req.	FN+RSN req./ Mg corn grain
	Mg/ha		---kg/ha---		
		1983			
MP	7.52	98	152	128	20.2
CH	7.96	99	210	180	26.4
NT	6.95	97	152	128	21.9
		1984			
MP	8.08	99	221	100	27.4
CH	6.45	99	169	88	26.2
NT	7.51	99	221	121	29.4
		Average			
MP	7.80	99	187	114	23.8
CH	7.21	99	190	134	26.3
NT	7.23	98	187	125	25.7

Optimum yield was determined using the regression equation in Table 3 for corn grain yield combined with a cost return ratio of 215:1 (return for corn grain/Mg:cost of N fertilizer/kg) lowest under the NT system in 1983. In 1984, corn under the MP system yielded significantly higher than under reduced tillage. Higher soil bulk densities (in the row) and longer periods of standing water may have lowered yield of the reduced tillage systems. Rotating corn with oats did not seem to alter the propensity for the reduced tillage systems to yield less than the MP system in a wet year at this specific site. Lower FN requirements for corn under the MP system probably resulted from greater N mineralization rates and lower denitrification rates compared to the reduced tillage system. However, FN+RSN requirement was the same for all tillage systems because of slightly lower optimum yields under reduced tillage. These results indicate the importance of measuring profile nitrate levels under reduced tillage. The major portion of fertilizer N adjustments required when tillage is reduced appears to be reflected by the nitrate soil test in areas where significant amounts of N are not leached from the profile. Additional research is needed to determine if soil nitrate interpretations should be altered due to tillage system.

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Chapter III

Influence of Tillage and Nitrogen on Corn and Oats Grown in Rotation. II. Oats response

Abstract

Oats (Avena sativa L.) were grown in rotation with corn on a Poinsett silty clay loam soil (Udic Haplaboroll, fine-silty, mixed) in east central South Dakota. Three tillage systems were used; moldboard plow (MP), chisel plow (CH), and disk (DK). Nitrogen was applied at four levels (including a check) as topdressed ammonium nitrate. All systems were disked twice to incorporate corn residue and topdressed N. Oatlage yield was significantly higher in the CH and DK systems in 1983 and significantly lower in 1984 than oatlage yield from the MP system. Oat grain yields were not significantly affected by tillage in 1983. Hot dry weather occurred at anthesis in 1983 and probably nullified any yield advantages that the CH and DK systems had at the time of oatlage harvest. Oat grain yield was significantly higher in the MP system compared to the DK and CH systems in 1984. Although there were no distinct growth differences during 1984, there was less standing water in the MP system during heavy rainfall periods in June. No significant difference in apparent N mineralization rates were evident between tillage treatments in 1983. Nitrogen uptake from check plots was significantly higher in the MP system compared to the CH and DK system in 1984, but leaching

precluded apparent N mineralization estimates. Oats grown under reduced tillage required more FN+RSN than oats under MP tillage. Results suggest that more nitrogen should be recommended for oats grown under reduced tillage than under MP tillage for at least two years after changing from conventional to reduced tillage. During the study the CH and DK systems performed quite similarly.

Introduction

South Dakota ranks first in the U.S. in oat (Avena sativa L.) production with 703,000 hectares planted in 1984. Little research has been conducted on oats to determine the affects of tillage on yield. Hamilton and Lessard (1963) found a large response to nitrogen by oats, but no tillage x N interaction. The tillage treatments were disking, 15-cm plowing, 30-cm plowing, and 60-cm plowing. Dick and Van Doren (1985) found consistantly higher oat yields under no-till compared to conventional tillage on a well drained soil during a 20 year period. However, the opposite results occurred on a poorly drained soil. There have been several tillage studies done with wheat. Wheat grown under NT has outyielded wheat grown under conventional tillage in some cases (Fredrickson et al., 1982; Vaidyanathan and Leitch, 1980; Farooqi, 1983) This is generally attributed to the moisture conservation of NT systems (Farooqi, 1983). Decreased wheat yields have been reported under reduced tillage in wet years (Farber 1984). The decreased wheat yields under reduced tillage have been attributed to increased phytotoxin activity and poor physical characteristics of soil under reduced tillage. Wheat yield has also been unaffected by tillage (Cochran et al.,1982) Higher N requirements have been observed for wheat growing under reduced tillage (Vaidyanathan and Leitch, 1980). Banded N was reported to be more efficient in NT systems compared to surface applied N (Reinerstsen et al., 1982).

This study was established in 1982 to: 1) compare yield potential, mineralization rates, and N requirement of oats grown under chisel plow (CH), disk (DK), and moldboard plow (MP) systems, and 2) to determine the suitability of existing soil nitrate interpretations for oats grown under reduced tillage.

Materials and Methods

Field experiments were conducted at the east central site on a Poinsett silty clay loam soil. Properties of the Poinsett soil were discussed in Chapter II. Corn was planted in the preceeding year's oat stubble and oats were planted in the preceeding year's corn stubble. Three tillage systems were employed for each crop; MP, CH, and DK. The tillage variable was established in 1983. Primary tillage was done in the spring of 1983 (due to a wet fall in 1982) and in the fall of 1983. All plots planted to oats were disked once to reduce corn residue after N had been topdressed. Residue cover measured 9, 30, 36% for MP, CH, and DK systems, respectively. Nitrogen was applied at three rates as either topdressed ammonium nitrate (AN) or injected urea-ammonium nitrate (UAN) several days before planting. Nitrogen was injected approximately 10-15 cm into the soil with a applicater having 45 cm between knives. Check plots for injected N treatments were knifed without applying fertilizer. Plots measured 11m x 5.5m.

Oats (Moore 1983, Lancer 1984) were planted in the first week in May. Triple super phosphate was applied at a rate of 18 kg P ha^{-1} at planting. No other fertilization except nitrogen was predicted by soil tests. Weeds were controlled with separate applications of Mowdown and Bronate. Oatlage was harvested from a 0.67 m^2 area in 1983 and a 1 m^2 area in 1984. Grain was harvested from 10.5

m^2 of plot area.

Four soil samples from the 0-60 cm depth and three from the 60-120 cm depth were taken from each plot in the fall to determine residual nitrate concentration. Soil nitrate concentration was determined using a nitrate specific ion electrode.

Results and Discussion

This site was characterized by hot dry weather in 1983, and cool wet weather in 1984. Precipitation has been reported in Chapter II. Oat grain yield was greatly reduced in 1983 by hot weather which occurred at anthesis. Temperatures were as high as 42 °C during this period. Stem rust (Puccinia graminis Pers. f. sp. avenae (Eriks. and Henn.)) and leaf rust (Puccinia coronata Cda. f. sp. avenae (Eriks.and Henn.)) also likely reduced yields somewhat in both years.

Residual Soil Nitrate

Residual soil nitrate (RSN) levels have been reported and discussed in Chapter II. Injected N treatments were eliminated from oat data for reasons discussed in Chapter II. Preliminary regression analysis results indicated that both fertilizer N (FN), and RSN to a depth of 60 cm and their respective squared terms, $(FN)^2$ and $(RSN)^2$, significantly influenced yield . Residual soil nitrate from 60-120 cm did not significantly influence yields and was not used in statistical analysis. Since the efficiency of FN and RSN (from 0-60 cm) could not be separated, due to confounding, they were treated as one variable FN+RSN (and $(FN+RSN)^2$). Regression analysis was performed on the dependent variables oat grain yield, oatlage yield, and total N uptake, using a number of independent variables (Table 3-1). Quadratic models

Table 3-1. Stepwise regression analysis on oat yield parameters at E.C. site.

dependent variable Y	equation	R^2
oat grain yield Mg/ha	$Y = 1.4 + 0.01711(FN+RSN) - 0.0000547 (FN+RSN)^2 + 0.48(1984=1) + 0.0000838 (FN+RSN)^2 + 0.60(MP=1,1984=1) - 0.02645(FN+RSN)(1984=1)$	0.792
oatlage yield at 60% moisture	$Y=8.64 + 0.0913(FN+RSN) - 0.00023 (FN+RSN)^2 - 1.87(1984=1) + 2.21 (MP=1)(1984) - 0.00737(FN+RSN)(MP=1)$	0.638
total N uptake kg/ha	$Y=42.9 + 0.656(FN+RSN) - 0.001448 (FN+RSN)^2 - 15.55(1984=1) + 15.14(MP=1)(1984=1) - 0.048(MP=1)(FN+RSN)$	0.729

FN+SN=fertilizer N + soil nitrate N-60 cm
MP=molboard plow (dummy variable=1)(dummy variable=0 for reduced tillage)
year=1984 (dummy variable 1984=1;1983=0)

generally fit the data well because of yield depressions at higher FN+RSN levels due to lodging.

Oatlage Yield

Oatlage yield was lower in 1984 than in 1983 (Fig. 3-1) even though 1984 was a wet year. Due to the rust infestation encountered in 1983 on Moore oats, Lancer oats, a more resistant variety, was used in 1984. Lancer is a shorter earlier maturing oat variety than Moore and was responsible for the lower oatlage yields. Oatlage yields were lower in the MP system compared to the CH and DK systems in 1983 (Fig. 3-1). The dry weather in 1983 probably gave an advantage to the reduced tillage systems which generally conserve water over the MP system (Farooqi, 1983). The trend was reversed in 1984 as conventional tillage gave significantly higher oatlage yields than reduced tillage. Oatlage yield data from 1984 indicate a slightly higher yield potential in the MP system. Although no distinct growth differences were observed between tillage systems, the MP system had less standing water during periods of heavy rainfall in June.

Grain Yield

There was no difference in grain yield between tillage treatments in 1983 (Fig. 3-2). The oatlage yield advantage of the reduced tillage systems seemed to be negated by the hot dry weather which occurred at anthesis. Oats grown under the MP system may have matured earlier than

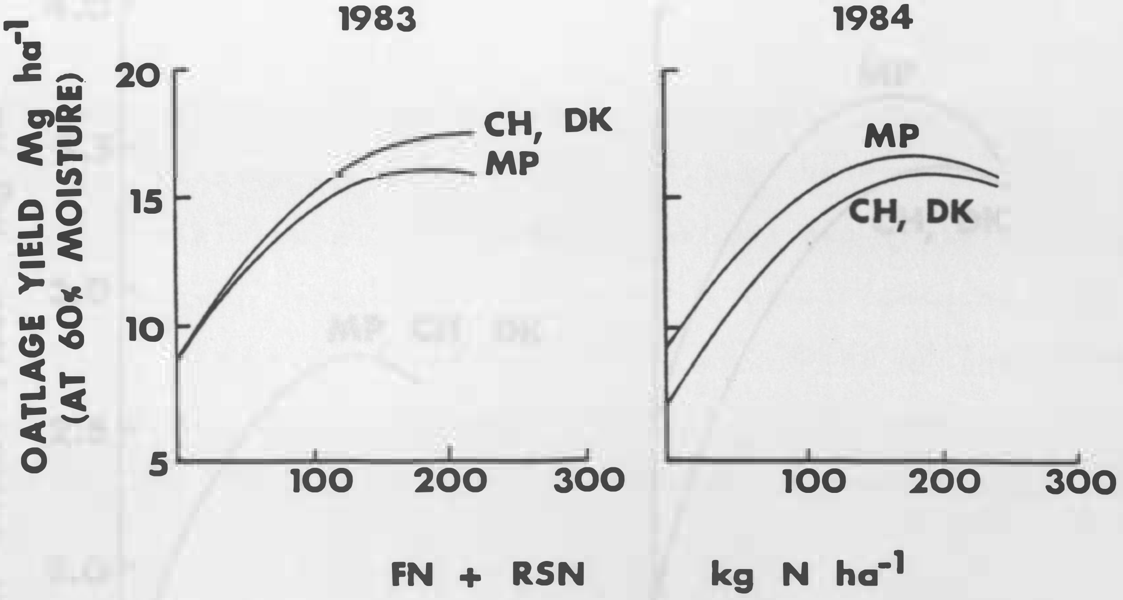

Figure 3-1. Oatlage yield under moldboard plow (MP), chisel plow (CH), and disk (DK) systems as affected by fertilizer N (FN) plus residual soil nitrate (RSN) (derived from Table 3-1 equations), E.C. site.

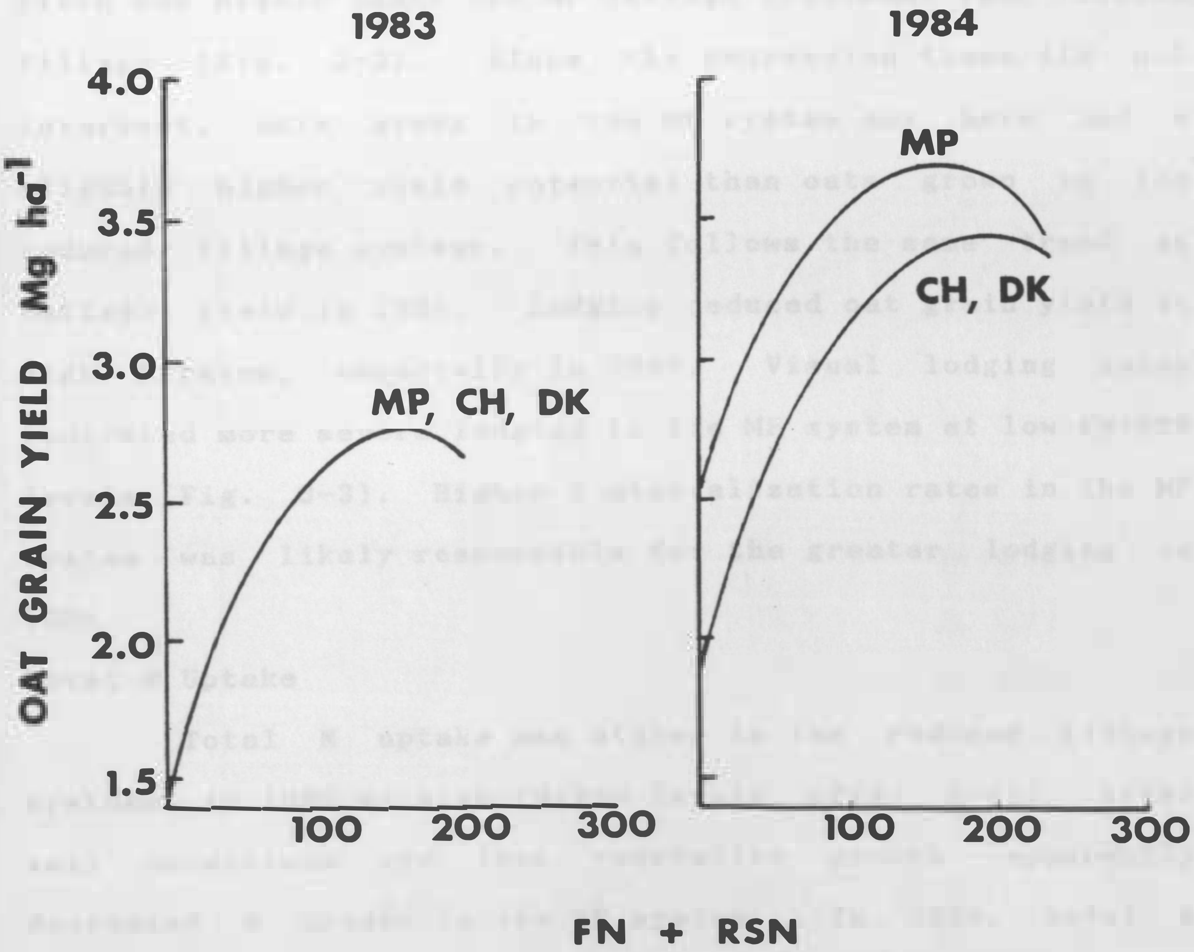

Figure 3-2. Oat grain yield under moldboard plow (MP), chisel plow (CH), and disk (DK) systems as affected by fertilizer N (FN) plus residual soil nitrate (RSN) (derived from Table 3-1 equations), E.C. site.

oats under the reduced tillage systems because of possible moisture differences between tillage systems (more stress in the MP system). However, this was not obvious from heading observations. Earlier maturation could have helped oats in the MP system avoid some drought stress. In 1984, grain yield was higher under the MP tillage treatment than reduced tillage (Fig. 3-2). Since the regression lines did not intersect, oats grown in the MP system may have had a slightly higher yield potential than oats grown in the reduced tillage systems. This follows the same trend as oatlage yield in 1984. Lodging reduced oat grain yield at high N rates, especially in 1984. Visual lodging notes indicated more severe lodging in the MP system at low FN+RSN levels (Fig. 3-3). Higher N mineralization rates in the MP system was likely responsible for the greater lodging in 1984.

Total N Uptake

Total N uptake was higher in the reduced tillage systems in 1983 at high FN+RSN levels (Fig. 3-4). Drier soil conditions and less vegetative growth apparently decreased N uptake in the MP system. In 1984, total N uptake was higher in the MP system than in the reduced tillage systems (Fig. 3-4). The higher oatlage yield potential, higher N mineratization rates and a better rooting environment in the MP system likely caused this difference.

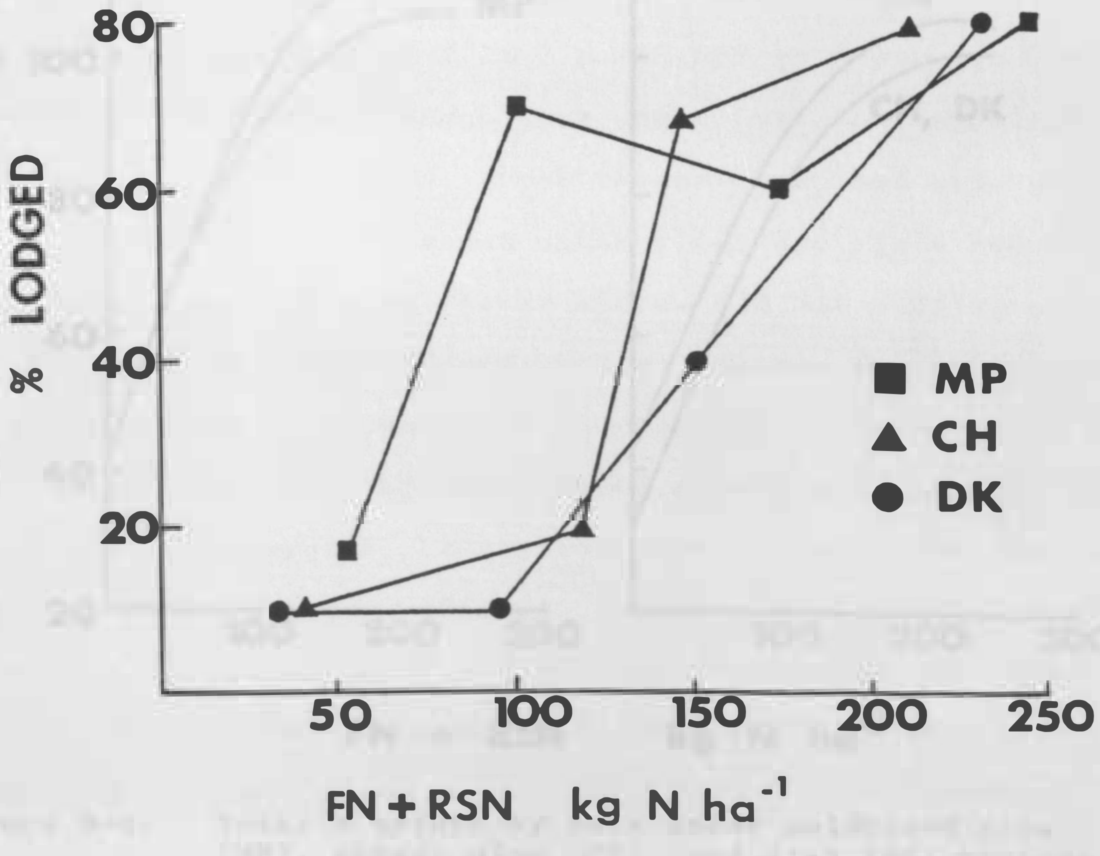

Figure 3-3. Relationship between oat lodging and fertilizer N (FN) plus residual soil nitrate RSN.

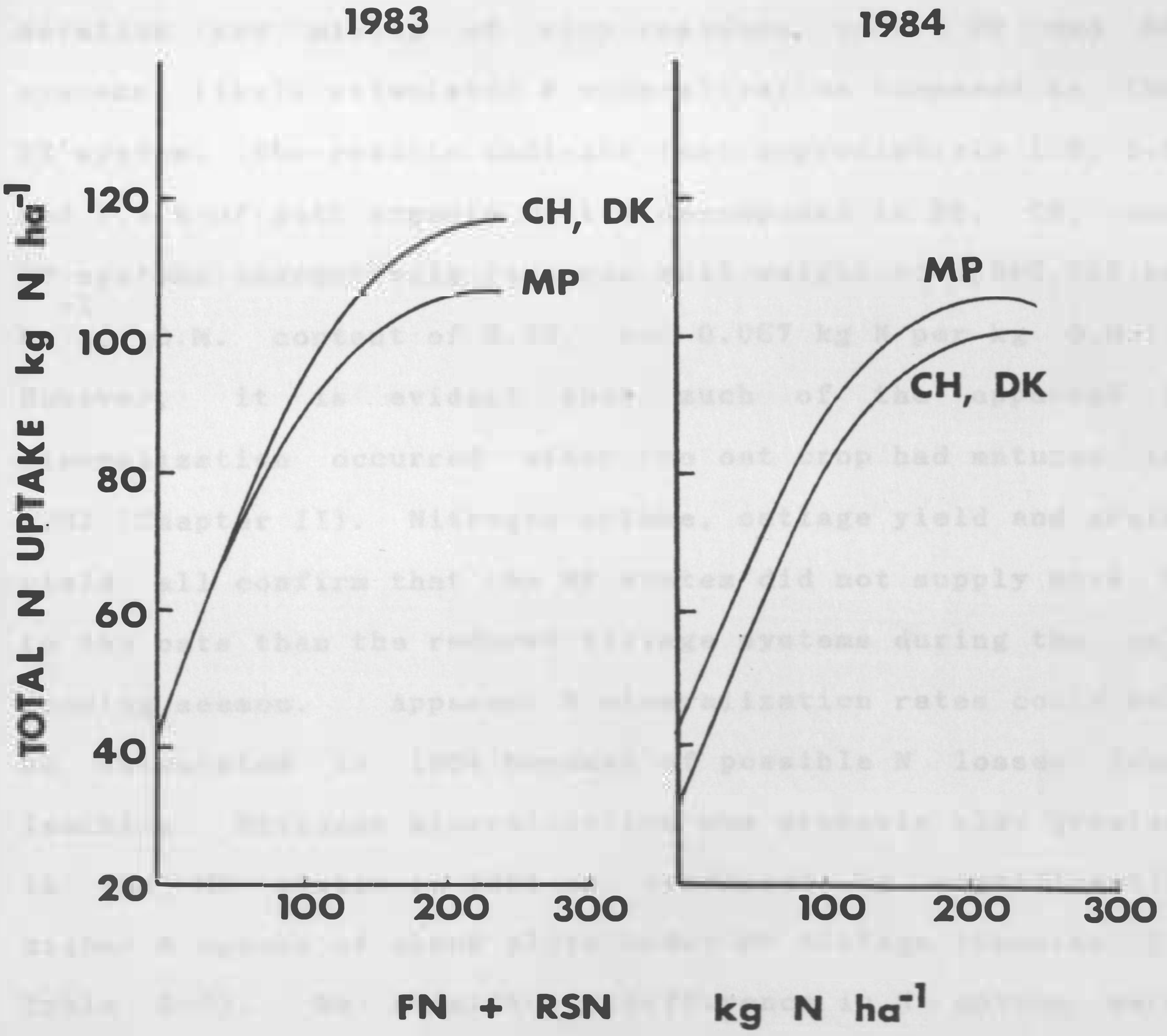

Figure 3-4. Total N uptake by oats under moldboard plow (MP), chisel plow (CH), and disk (DK) systems as affected by fertilizer N (FN) plus residual soil nitrate (RSN) (derived from Table 3-1 equations), E.C. site.

Apparent N mineralization rates were 69, 78, and 81 kg N ha^{-1} from DK, CH and MP systems, respectively in 1983 (Chapter II). Apparent N mineralization seemed to be proportional to the intensity of tillage. Better soil aeration and mixing of crop residues under CH and MP systems likely stimulated N mineralization compared to the DK system. The results indicate that approximately 1.6, 1.8 and 1.9 % of soil organic matter decomposed in DK, CH, and MP systems respectively (assumes soil weight of 2,000,000 kg ha^{-1}, O.M. content of 3.2%, and 0.067 kg N per kg O.M.). However, it is evident that much of the apparent N mineralization occurred after the oat crop had matured in 1983 (Chapter II). Nitrogen uptake, oatlage yield and grain yield all confirm that the MP system did not supply more N to the oats than the reduced tillage systems during the oat growing season. Apparent N mineralization rates could not be calculated in 1984 because of possible N losses from leaching. Nitrogen mineralization was probably also greater in the MP system in 1984 as evidenced by significantly higher N uptake of check plots under MP tillage (Chapter II Table 2-6). No significant difference in N uptake were observed between check plots which were knifed compared to those that were not knifed (Chapter II Table 2-6). The knifing operation apparently did not stimulate N mineralization.

Nitrogen requirement for optimum yield was the same for all tillage systems in 1983 (Table 3-2). Nitrogen requirement in 1984 was 28 kg ha^{-1} higher under the reduced tillage systems than the MP system. Greater N mineralization and possibly less denitrification (Chapter II) in the MP system in 1984 may account for the lower FN requirement. Nitrogen required per Mg of oat grain was lower for the MP system because of lower N requirement (at optimal yield) and slightly higher optimum yield of the MP system. The results suggest that more N should be recommended for oats grown under reduced tillage for at least two years following a switch from conventional tillage. However additional research is needed to determine if these results consistantly occur.

Table 3-2. Nitrogen requirement for oat grain, E.C. site,

Tillage	Optimum Yield	Percent of Yield Max.	FN+RSN Required	FN Required	N required/Mg Oat Grain
	Mg/ha	%	-------------kg/ha-------		
			1983		
MP,CH,NT	2.67	97	120	94	44.9
			1984		
MP	3.61	98	113	37	31.3
CH	3.38	97	141	62	41.7
NT	3.38	97	141	62	41.7
			Average		
MP	3.14	98	117	66	38.1
CH	3.03	97	131	78	43.3
NT	3.03	97	131	78	43.3

Optimum yield was determined using the regression equation in Table 2 for corn grain yield combined with a cost return ratio of 250:1 (return for oat grain/Mg : cost of N fertilizer/kg N)

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Chapter IV

Effect of Tillage N Rate and Placement on Yield of Corn and Soybeans

Abstract

Continuous corn (Zea mays L.) was grown under moldboard plow (MP), till plant-ridged (TP) and chisel plow (CH) tillage systems. Corn was also grown in rotation with soybeans under MP,TP, and no-till (NT) systems. Nitrogen was applied at four levels (including a check) to corn as either topdressed ammonium nitrate or knifed urea-ammonium-nitrate. Nitrogen was not applied to soybeans. Corn was planted on May 23 in 1983, due to a wet spring, and on July 6 in 1984, due to another extremely wet spring. Fertilizer N (FN) increased residual soil nitrate (RSN) concentration following the continuous corn rotation in both 1983 and 1984. Soybeans depleted RSN if high amounts were present at planting. Tillage did not affect RSN levels in either year. Injected N resulted in lower RSN amounts than topdressed N in 1983, and approximately equal RSN amounts in 1984.

Continuous corn grain and silage yields from the CH system were significantly lower than TP or MP systems in 1983. However, in 1984 corn silage yield was significantly higher in the CH system. The reason for this is not known at this time. Nitrogen rate significantly influenced yield in both continous corn and corn following soybeans in both years. Corn silage yield was significantly lower from

injected N compared to topdressed N in the corn-soybean rotation in 1984. This likely occurred because injection of N was delayed until July and N was placed in dry soil.

Soybean yields were significantly higher under the TP system compared to the MP and NT system in 1983. This was probably caused by the ridges keeping the soybeans from being submerged during the heavy rainfall in June. In 1984, soybean yields under the TP system were significantly lower than the MP system. A heavier infestation of weeds in the TP system was likely responsible for the yield difference. Soybeans did not respond to RSN from the previous corn crop in either 1983 or 1984.

Introduction

The till plant (TP) system is one conservation tillage system that has gained interest in recent years. Till planting involves planting on the preceeding year's ridge. The only preparatory operations are ridging by cultivation and chopping corn stalks in the fall. The major benifits of the TP system are that it places the seed in warmer, drier soil which may speed germination in a cool wet year, and it involves fewer tillage operations before planting compared to conventional tillage.

The TP system is not new. It originated in 1955 by Hurlbut and Wittmuss. Early results in 1960 showed average corn grain yields of the TP system were slightly higher than conventionally tilled systems (Neb ext. bull E.C. 61-714).

However, equipment problems and difficulty controlling weeds were major drawbacks. Better chemical control of weeds and new equipment have spurred renewed interest in the TP system.

The TP system has been utilized in the North Central U.S. Randall and Langer (1981) found sidedress applications of 84 kg N ha^{-1} gave the highest N efficiency in corn grown under the TP system. Injected anhydrous ammonia and surface spray urea-ammonium nitrate (UAN) applications resulted in reduced yield compared to urea, because of volatilization of N and poor soil retention of ammonia. Randall et al. (1980) found corn yields of moldboard plowed (MP) treatments greater than TP, chisel plow (CH,) and no-till (NT) treatments. Corn from the NT system yielded significantly less grain than the other tillage systems. Schulte and Moncrief (1980) reported that corn grain yields were 1.25 Mg ha^{-1} lower in a TP system than in a MP system. The difference was thought to be due, at least in part, to surface crusting in the TP system from heavy early season rains. A review of the effects of tillage on corn has been presented in Chapter II.

Touchton and Johnson (1982) reported no difference in soybean yield from no-till (NT), chisel plow (CH), and moldboard plow (MP) treatments. Lindemann et al. (1982) found an average yield reduction of 22% from NT soybeans compared to five other tillage treatments. No difference in number or activity of nodules was found between tillage systems. Yield differences were due to heavier competition from weeds in the NT system.

An experiment was established to compare yield potential, N mineralization rates, N placement, and N requirement of: 1) a continuous corn rotation under CH, TP and MP tillage and 2) a corn-soybean rotation under NT, TP, and MP tillage.

Materials and Methods

Field experiments were conducted in southeast South Dakota on an Egan silty clay loam soil (Udic Haplustoll fine-silty, mixed). Egan soils are deep, well-drained soils formed in a mantle of silty sediments over loamy glacial till. Selected soil characteristics are presented in Table 4-1. This site will be referred to as the S.E. site.

A split plot design with four replications was used in each rotation. Main plots represented the tillage strips. Nitrogen treatments were the subplots. Subplots measured 11 x 5.5 m.

Three tillage systems were used in each of two crop rotations. Moldboard plow, CH, and TP systems were employed in a continuous corn rotation. No-till, MP, and TP systems were employed in the corn-soybean rotation. The tillage variable was established in 1983. In the rotation study, corn was planted in the preceeding year's soybean stubble and soybeans were planted in the preceeding year's corn stubble. Nitrogen was applied at four levels (including checks) as either topdressed ammonium nitrate (AN) or injected urea-ammonium nitrate (UAN). Nitrogen was injected approximately 10-15 cm below the soil surface with an applicator having 45 cm between injector knives. Check plots for injected N treatments were knifed without applying fertilizer. Nitrogen was not applied to soybeans. Because

Table 4-1. Selected soil characteristics, Egan soil.

Depth	Sand	Silt	Clay	OM	pH	K	P	EC
cm	----------%----------					-kg/ha-		mmho/cm
0-15	18.1	46.3	35.6	2.7	6.6	648	23	0.5
15-30	12.8	44.6	42.6					
30-60	27.2	33.2	39.6					

of varying operations in 1983 and 1984, methods of each year will be reported separately.

1983

Wet soil conditions delayed primary tillage until May 28. Nitrogen was injected at rates of 0, 71, 137, and 168 kg N ha^{-1} in the continuous corn rotation on June 2. The resulting RSN (60 cm depth) plus fertilizer N (FN) levels were 26, 95, 174, and 216 kg N ha^{-1}. Nitrogen was also injected at rates of 0, 81, 146, and 207 kg N ha^{-1} to corn following soybeans giving FN+RSN levels of 34, 101,168, and 235 kg N ha^{-1}. Nitrogen was applied to topdressed N treatments on June 3 at the same rates giving the same FN+RSN levels as in injected N treatments. Moldboard plow and CH tillage systems were disked once after topdressing N but before planting. 'Pioneer 3906' corn was planted in 91-cm rows on June 2 in the continuous corn rotation and on June 3 in the corn-soybean rotation (harvest population, 52,000 plants ha^{-1}). 'Corsoy' soybeans were planted in 91-cm rows on June 3 at a population of 290,000 plants ha^{-1}.

Bladex/Lasso was applied preplant to control weeds in corn and Lasso/Sencor was applied preplant to control weeds in soybeans. Counter was applied to control corn rootworm in continous corn. Phosphorous was applied with a starter attachment at a rate of 18 kg P ha^{-1} to all plots. Corn and soybeans were cultivated on July 13. Corn earleaf samples were taken at silk initiation on August 13.

Nitrogen content of earleaves was determined by a micro-Kjeldahl method (Bremner, 1965). Corn was harvested from 6 m of the center two rows on September 9. Corn stover was harvested from 3 m from the center two rows on September 22. Soybeans were harvested from 8.8 m of the center two rows on Oct. 24. Nitrogen requirements were estimated by fitting average corn yield data to quadradic, or linear plateau response functions. Maximum yield was used as the most profitable yield in all cases.

1984

Excessively wet soil conditions in June delayed corn planting until July 5 for both rotations. The wet weather disrupted normal planting operations. Bladex/Lasso and Sencor/Lasso were applied preplant on May 18 to control weeds in corn and soybeans, respectively. However, MP and CH plots were disked on July 3 to eliminate weeds that had emerged during the long interim. Roundup was applied to NT and TP systems to eliminate weeds on July 5. Topdressed N was spread on May 17 and was incorporated by vibrashanking on May 20. Nitrogen was applied to continuous corn at rates of 0, 50, 101, and 151 kg N ha^{-1} and to corn following soybeans at rates of 0, 56, 112, and 168 kg N ha^{-1}, respectively. Residual soil nitrates (RSN) varied for each treatment and are taken into consideration in results. ‘Pioneer 3994’ (78 day) corn was planted on July 5 in 91-cm rows in both rotations. Phosphorous was applied at planting with a starter attachment at a rate of 18 kg P ha^{-1} to all plots. ‘Corsoy’ soybeans were planted in 91-cm rows on July 12. Corn plots were cultivated on July 20. Nitrogen was applied to injected N treatments on July 23. Soybeans were sprayed with separate applications of Blazer and Post, and corn was sprayed with 2,4-D on July 27 to control weeds. Corn grain was harvested on Oct 5. Eight ears were randomly selected from a 6 m length of the center two rows. Yields were then estimated from an equation having an r^2 value of 0.88. Corn silage was harvested from 3 m of the center two rows on Oct 4 and 16. Soybeans were harvested from 1.54 m of the center two rows on Nov. 2.

Results and Discussion

Rainfall patterns were very abnormal in both 1983 and 1984. In 1983, late planting was followed by 280 mm of rain over a 10 day period in June causing some flooding. In 1984, 468 mm of rain occurred from April through mid-June and delayed planting until July. July and August of both years were quite dry (Table 4-2).

Residual Soil Nitrate

Residual soil nitrate levels from continous corn did not appear to be affected by tillage in 1983 or 1984 (Fig. 4-1). Either there was little difference in N mineralization rates between tillage systems, or leaching nullified any differences that did exist. Residual soil nitrate levels were somewhat lower in 1983 and 1984 compared to 1982, especially at the 60-120 cm depth. Increased leaching due the heavy rainfall of both years may be responsible. Increasing FN rates increased RSN levels in all three years, particularly in 1982. Corn did not respond to FN in 1982 due to extremely high RSN levels (to begin the season).

Residual soil nitrate amounts were lower, at high FN rates in treatments that received injected N compared to topdressed N treatments in 1983 (Fig. 4-2). The same result occurred at the east central site and was discussed in chapter II. The difference in RSN values between N placements in 1983 was alleviated in 1984 (Fig. 4-3). Since

Table 4-2. Growing season precipitation, S.E. site 1983-84.

Month	Precipitation		
	1983	1984	Long-term Average
	mm		
April	51	163	60
May	80	103	82
June	280	202	101
July	75	52	82
August	27	29	80
September	55	34	66

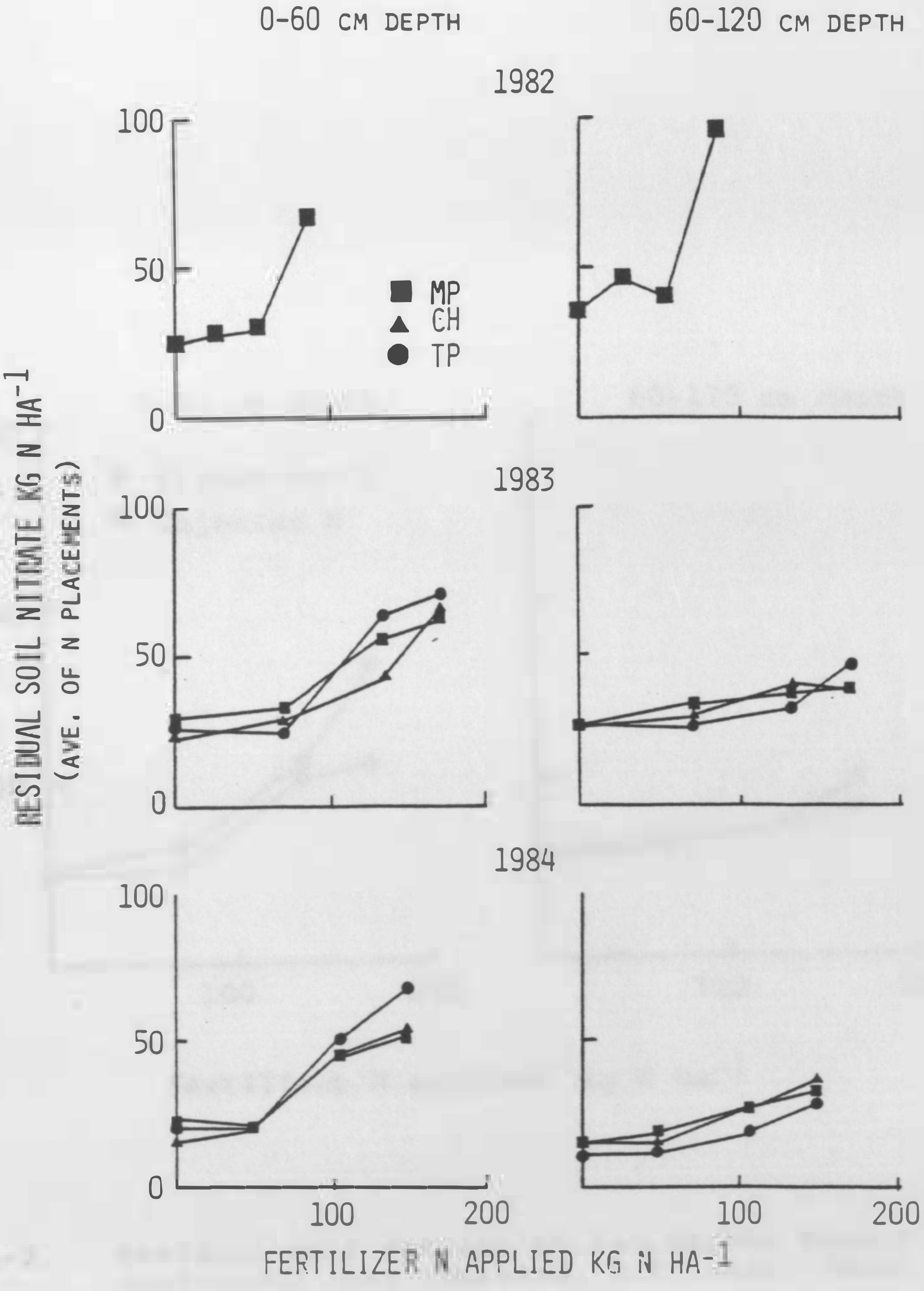

Figure 4-1. Residual soil nitrate at two depths from a continuous corn rotation, S.E. site.

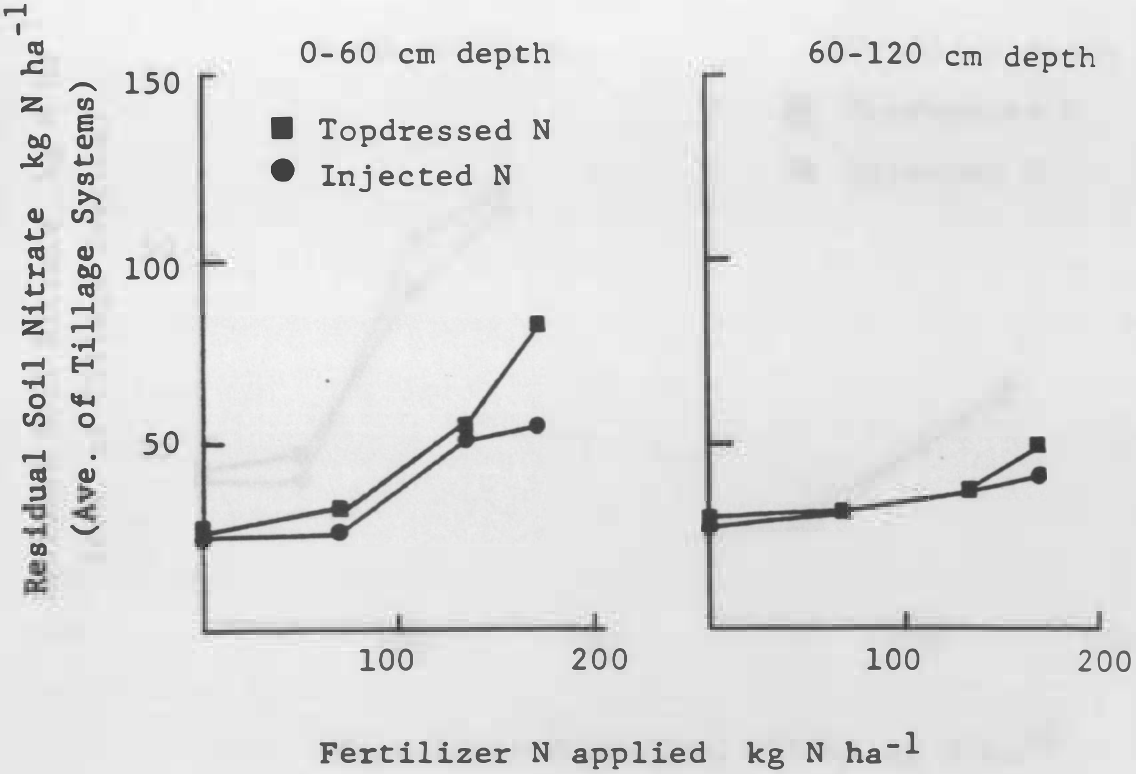

Figure 4-2. Residual soil nitrate at two depths from a continuous corn rotation, S.E. site, 1983.

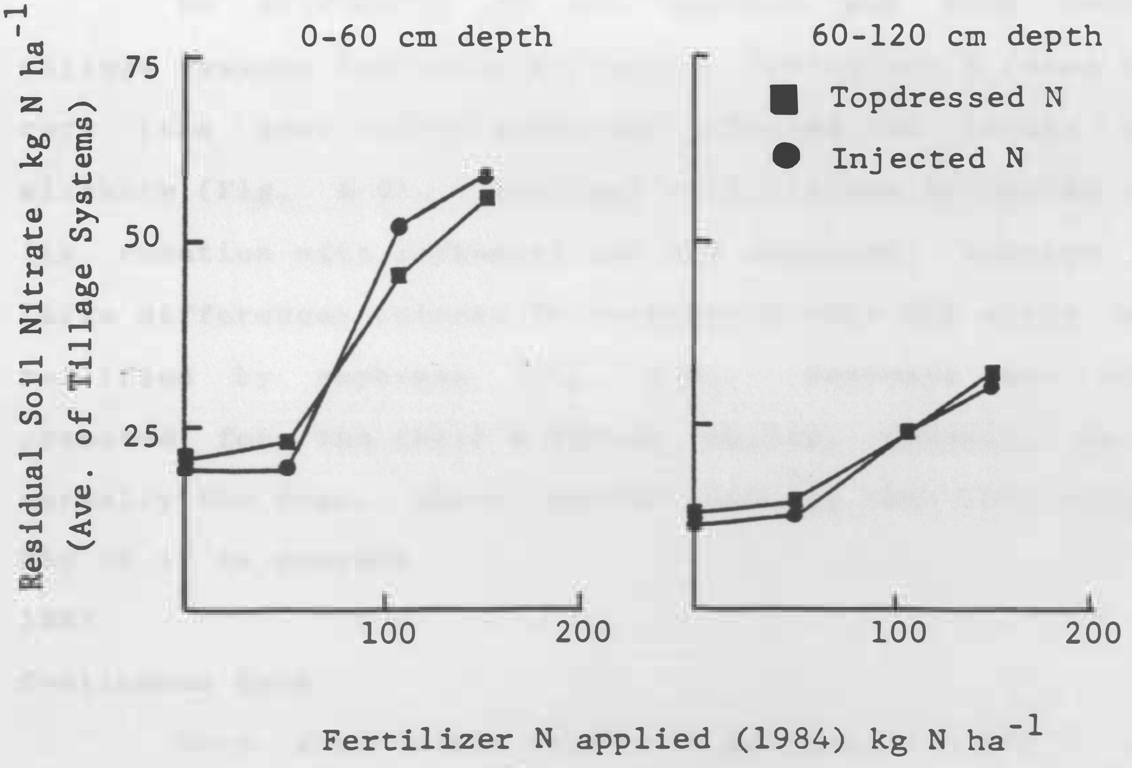

Figure 4-3. Residual soil nitrate at two depths from a continuous corn rotation, S.E. site, 1984.

topdressed N was applied in May, some N could have been lost through leaching. Injected N was applied into rapidly drying soil in July which may have prevented plant uptake. The combination of these two factors likely increased the RSN levels of injected N treatments relative to topdressed N treatments in 1984.

No difference in RSN amounts was seen between tillage systems following soybeans. Fertilizer N rates from corn (the year before soybeans) affected RSN levels only slightly (Fig. 4-4). Residual soil nitrate following corn (in rotation with soybeans) was not measured, however any large differences between FN treatments that did exist were nullified by soybeans (Fig. 4-4). Soybeans are often promoted for the their N fixing abilty, however, as is normally the case, these results indicate that they deplete RSN if it is present.

1983

Continuous Corn

Corn grain yield reached a maximum of 5.2 M g ha^{-1} in the continuous corn rotation. Late planting coupled with a drought in late summer produced only modest yields. Only 3 replications were harvested because of flooding damage to the fourth. Both N rate and tillage influenced grain yields at the 0.01 level (Table 4-3). A significant tillage x N rate x N placement interaction occurred at the 0.09 level but the variability makes it difficult to interpret (Table

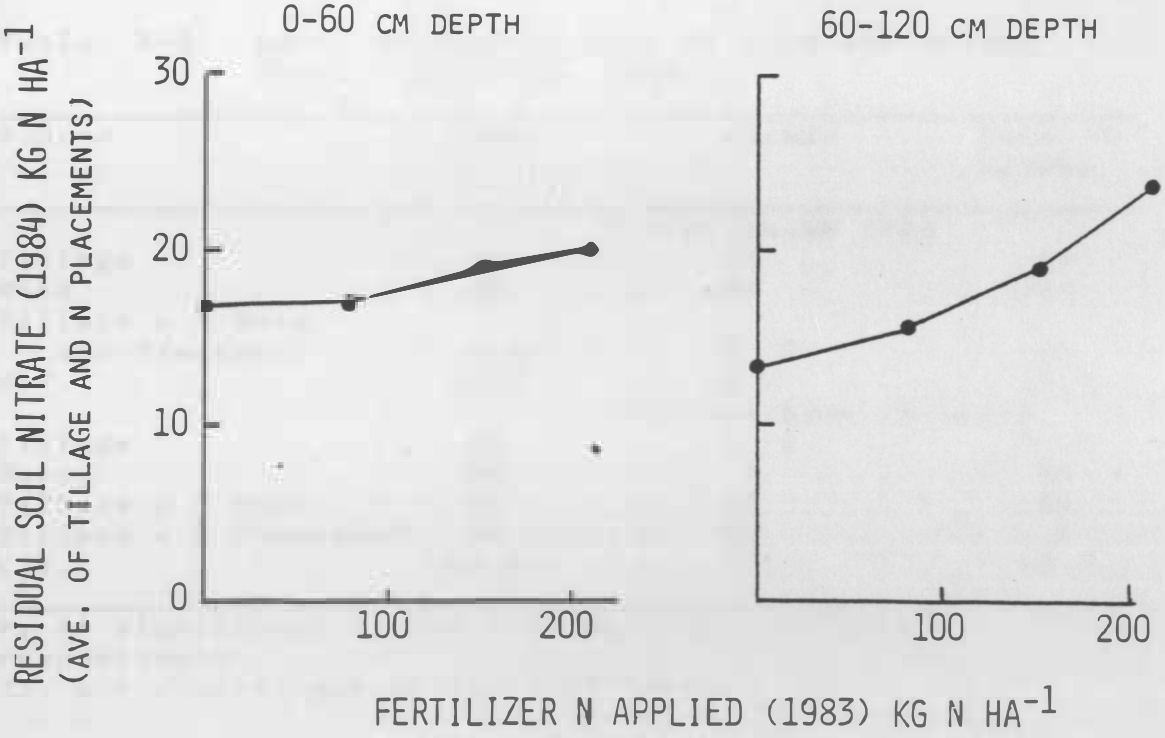

Figure 4-4. Residual soil nitrate (fall) at two depths following soybeans in a corn-soybean rotation, S.E. site, 1984.

Table 4-3. Level of significance of corn and silage yield, S.E. site, 1983.

Source	grain	silage	total N uptake
		continuous corn	
Tillage	**	**	**
Rate	**	**	**
Tillage x N Rate x N Placement	0.09	0.10	NS
C.V.	17.9	14.6	15.9
		corn-soybean rotation	
Tillage	NS	0.12	0.17
Rate	**	*	**
Tillage x N Rate	NS	NS	**
Tillage x N Placement	NS	NS	*
C.V.	26.2	7.1	19.5

*, ** significant at the 0.05 and the 0.01 level, respectively.
NS, not significant at the 0.20 level.

4-4). Chisel plowed plots consistantly yielded less grain than either MP or TP plots (Fig. 4-5). The cause of the lower yields may be related to the effect chisel points have on physical characteristics of fine textured soils tilled under moist conditions. Grain yields for the TP and MP system were similiar at high FN levels. At low FN rates grain yields from the TP system were less than the MP system. Nitrogen mineralization may have been greater in the MP system. Yields of the CH and MP systems followed a linear plateau response whereas the TP system probably followed a curvilinear response.

Corn silage yields showed a similar trend to grain yields (Fig. 4-6). Nitrogen rate and tillage was significant at the 0.01 level while the N rate x tillage x N placement was significant at the 0.10 level (Table 4-3). Silage yields of the MP system reached a maximum at a lower FN rate than did grain yield (Fig. 4-6). This may indicate that FN over 100 kg N ha^{-1} was primarily used for increased grain yield rather than stover yield in the MP system.

Nitrogen uptake was significantly affected by both tillage and FN rate (Table 4-3). The MP system resulted in greater N uptake than the TP or CH systems at low FN rates (Table 4-5). This difference was very evident in check plots (Table 4-4) and was probably due to higher N mineralization rates under the MP system. Earleaf N content supported this trend. Corn grown using MP tillage

Table 4-4. Corn grain yield, silage yield, and total N uptake from a continuous corn rotation, S.E. site, 1983.

	Tillage								
	MP N Placement			CH N Placement			TP N Placement		
N rate	Td	Inj	Ave	Td	Inj	Ave	Td	Inj	Ave
Kg/ha	Mg/ha								
	Corn Grain Yield (15.5% moisture)								
0	3.57	3.03	3.30	1.91	2.35	2.13	2.51	1.58	2.05
71	4.62	3.53	4.08	3.29	3.08	3.19	3.70	4.03	3.87
137	4.76	4.94	4.85	5.05	3.44	4.25	4.88	4.47	4.68
168	5.31	4.64	4.98	3.93	4.70	4.32	5.05	5.26	5.16
	Silage Yield (60% moisture)								
0	21.4	19.2	20.3	13.8	15.3	14.6	16.0	12.4	14.2
71	23.7	20.6	24.3	18.6	19.8	19.2	20.3	22.4	21.4
137	24.8	24.8	24.8	24.5	19.3	21.9	24.6	23.7	24.2
168	26.7	23.5	25.1	21.1	24.2	22.7	24.5	25.5	25.0
	Total N Uptake								
	kg/ha								
0	68.2	57.4	62.7	37.5	41.0	39.3	45.2	35.7	40.5
71	91.1	68.5	79.2	66.6	62.6	64.6	62.8	71.6	67.2
137	103.1	102.3	102.7	103.4	93.9	98.7	99.5	110.1	105.0
168	110.6	109.5	110.1	105.1	127.3	116.2	125.8	122.5	124.2

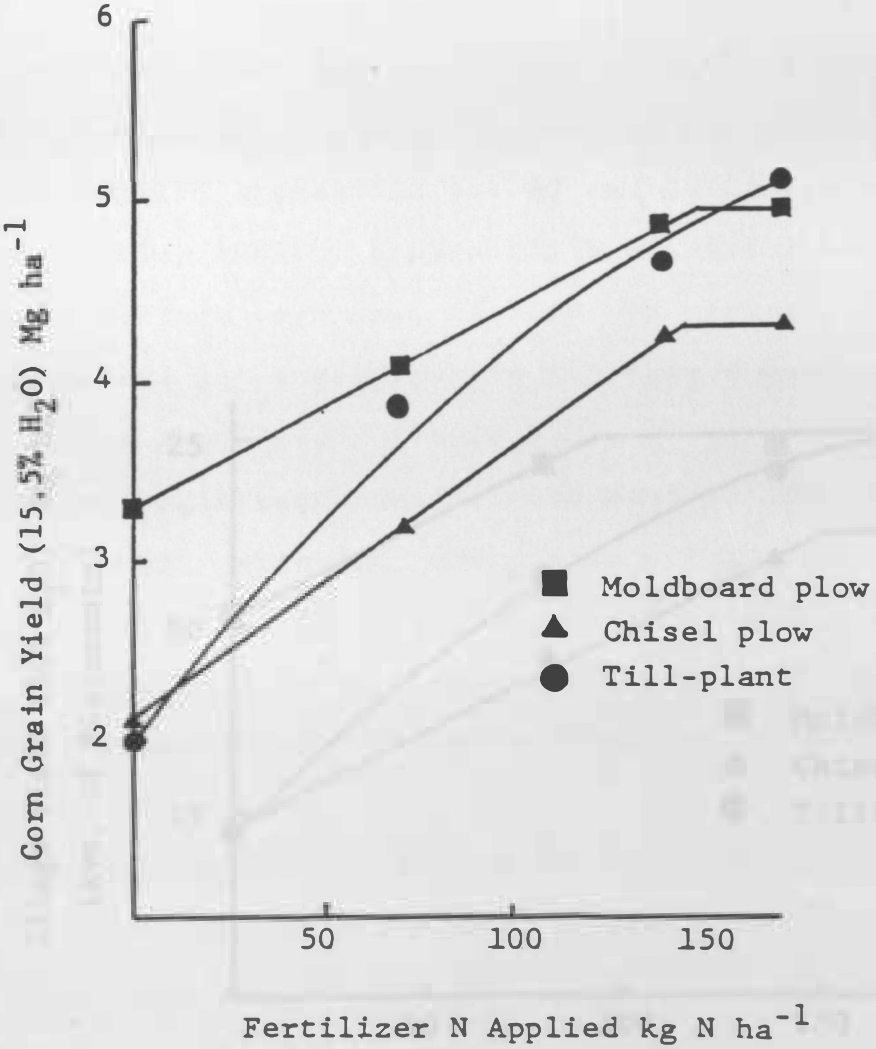

Figure 4-5. Corn grain yield (ave. of 3 reps.) from the continuous corn rotation, S.E. site, 1983

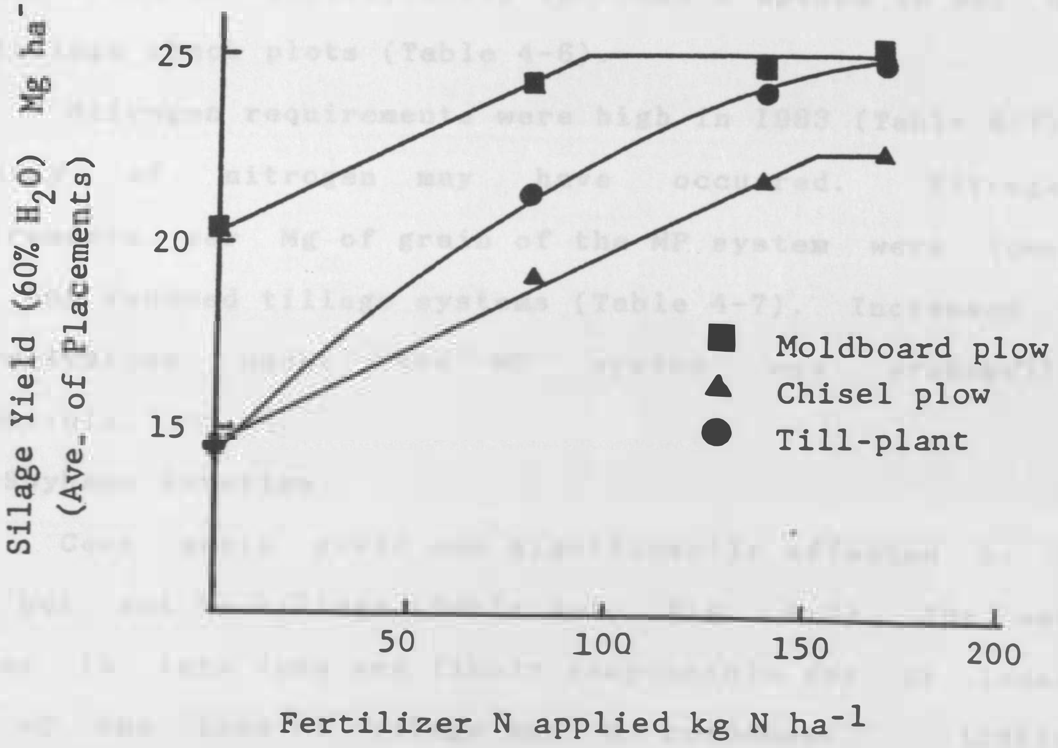

Figure 4-6. Corn silage yield (ave. of 3 reps.) from a continuous corn rotation, S.E. site, 1983

consistantly had higher earleaf N contents than corn grown using reduced tillage (Table 4-5) at low FN levels. Better soil aeration and mixing of crop residues probably caused greater N mineralization in the MP system. Nitrogen uptake was generally highest in the TP and CH system at high FN rates (Table 4-4). Apparently N was not limiting in the reduced tillage systems at high FN rates. The knifing operation did not significantly increase N uptake in any of the tillage check plots (Table 4-6).

Nitrogen requirements were high in 1983 (Table 4-7). Leaching of nitrogen may have occurred. Nitrogen requirements per Mg of grain of the MP system were lower than the reduced tillage systems (Table 4-7). Increased N mineralization under the MP system was probabally responsible.

Corn-Soybean Rotation

Corn grain yield was significantly affected by N rate but not by tillage (Table 4-4, Fig. 4-7). The wet weather in late June was likely responsible for at least part of the lack of tillage and N response. Little signficance of other variables besides FN was evident from corn silage yield data. A trend of lower silage yield from the TP system existed (0.12 level) (Fig. 4-8), but it is not known what caused this.

Nitrogen uptake was generally higher in the MP system except from check plots (Table 4-8). Nitrogen uptake

Table 4-5. Corn earleaf N content from continuous corn and corn-soybean rotations, S.E. site, 1983.

	N Placement			N Placement			N Placement		
N rate	Td	Inj	Ave	Td	Inj	Ave	Td	Inj	Ave
Kg/ha	% N								
	continuous corn								
	moldboard plow			chisel plow			till-plant		
0	2.01	2.05	2.03	1.58	1.48	1.53	1.82	1.51	1.67
71	2.48	2.11	2.30	2.19	2.11	2.15	1.96	1.98	1.97
137	2.80	2.98	2.89	2.82	2.73	2.78	2.51	2.86	2.69
168	3.00	3.00	3.00	2.96	2.86	2.91	2.73	2.95	2.84
	corn-soybean rotation								
	moldboard plow			till-plant			no-till		
0	2.57	2.47	2.52	2.04	2.22	2.13	2.40	2.42	2.41
81	2.91	2.68	2.80	2.38	2.34	2.36	2.72	2.51	2.62
146	2.81	3.24	3.03	2.88	2.89	2.89	3.00	3.08	3.04
207	3.00	3.34	3.17	2.65	2.97	2.81	2.92	2.86	2.89

Table 4-6. Total N uptake by corn from check plots, S.E. site, 1983.

	N uptake from check plots		
	N Placement		
Tillage	Topdressed	Injected	Mean
	------------kg/ha----------		
	continuous corn		
MP	68.2	57.4	62.8 a
TP	45.2	35.7	40.5 b
CH	37.5	40.9	39.2 b
	corn-soybean rotation		
MP	55.3	53.7	54.5 b
TP	50.7	54.9	52.8 b
NT	61.4	71.9	66.7 a

Least significant difference =7.2 and 6.9 for continous corn and corn-soybean rotation means, respectively

Table 4-7. Corn grain yield, silage yield, and total N uptake from a corn-soybean rotation, S.E. site, 1983.

	Tillage								
	MP			TP			NT		
	N Placement			N Placement			N Placement		
N rate	Td	Inj	Ave	Td	Inj	Ave	Td	Inj	Ave
Kg/ha	---------------------M g/ha						-------------------------		
	Corn Grain (15.5% moisture)								
0	2.84	2.80	2.82	2.83	3.55	3.19	3.37	4.06	3.72
81	3.94	4.32	4.13	3.71	3.62	3.67	4.57	4.02	4.30
146	3.84	4.30	4.07	3.88	4.22	4.05	4.26	4.07	4.17
207	4.58	3.55	4.07	4.14	4.61	4.38	4.66	4.36	4.51
	Silage Yield (60% moisture)								
0	20.9	20.8	20.9	19.4	21.0	20.2	21.6	26.7	24.2
81	26.3	27.1	26.7	22.7	21.2	22.0	26.4	25.3	25.9
146	25.9	28.5	27.2	23.6	24.2	23.9	25.3	25.2	25.3
207	28.1	25.3	26.7	24.1	25.9	25.0	27.8	27.3	27.6
	Total N Uptake								
	--------------------kg/ha						----------------------------		
0	55.3	53.7	54.5	50.7	55.0	52.9	61.4	71.9	66.7
81	80.5	92.7	86.6	63.1	57.0	60.1	77.4	70.6	74.0
146	74.9	101.6	88.3	82.4	84.9	83.7	88.9	94.7	91.8
207	93.6	101.7	97.7	95.3	95.4	95.4	97.3	95.9	96.6

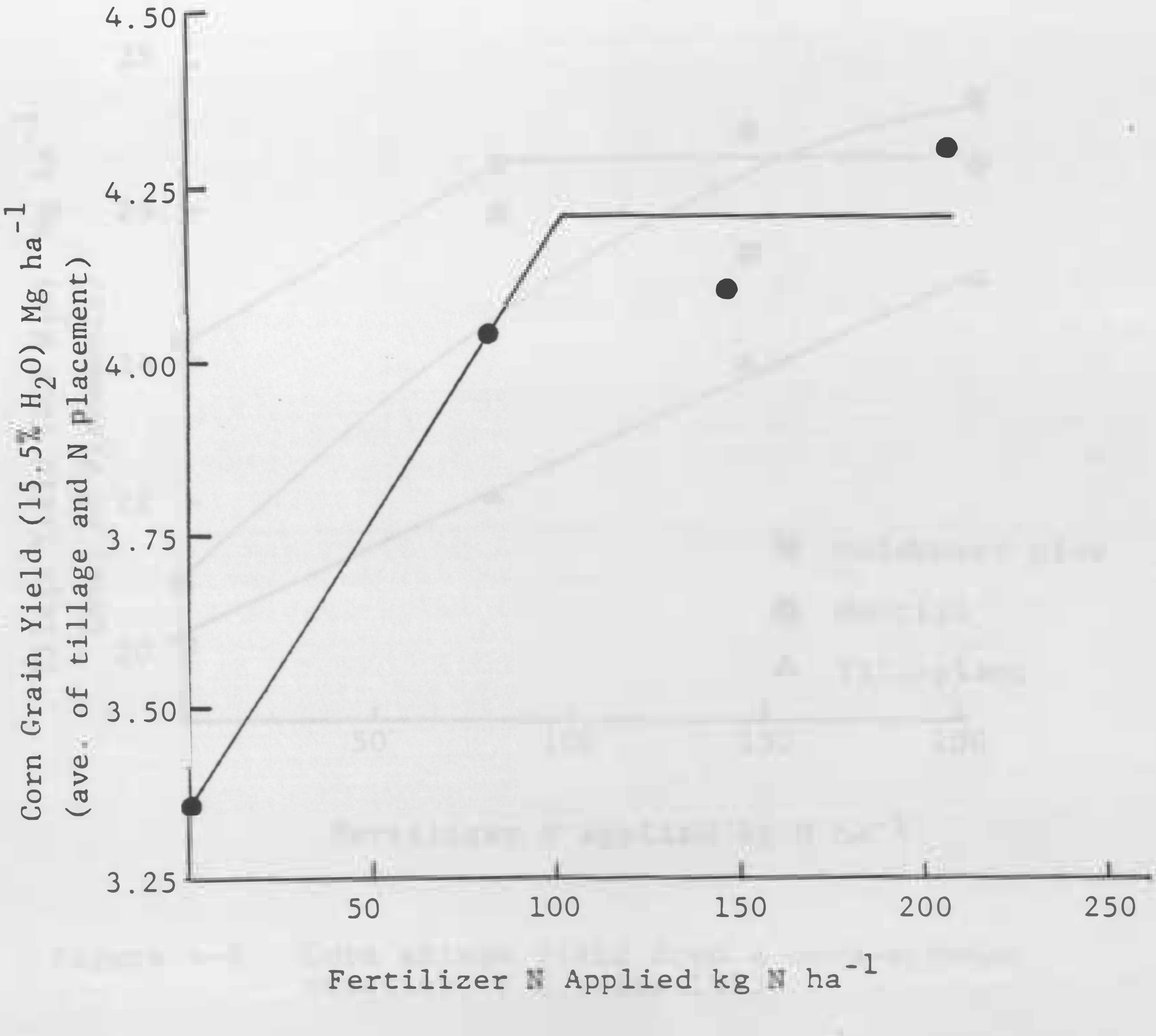

Figure 4-7. Corn grain yield from a corn-soybean rotation, S.E. site, 1983.

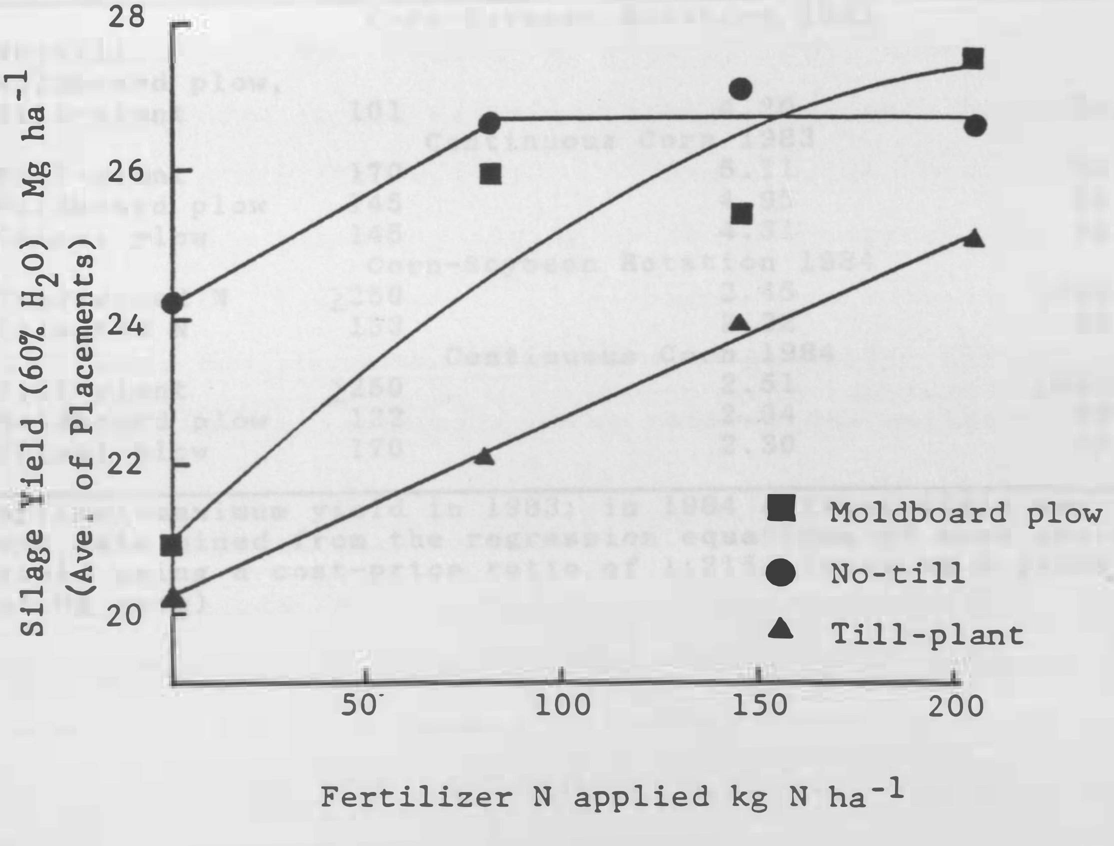

Figure 4-8. Corn silage yield from a corn-soybean rotation, S.E. site 1983.

Table 4-8. Nitrogen requirement of corn, S.E. site.

Treatment	N required kg/ha	optimal yield Mg grain/ha	kg N/Mg grain
	Corn-Soybean Rotation 1983		
No-till, Moldboard plow, Till-plant	101	4.20	24.0
	Continuous Corn 1983		
Till-plant	170	5.11	33.3
Moldboard plow	145	4.95	29.3
Chisel plow	145	4.31	33.6
	Corn-Soybean Rotation 1984		
Topdressed N	≥250	2.45	≥102.0
Injected N	133	2.22	59.9
	Continuous Corn 1984		
Till-plant	≥250	2.51	≥99.6
Moldboard plow	122	2.04	59.8
Chisel plow	170	2.30	73.9

optimal=maximum yield in 1983; in 1984 optimal yield was was determined from the regression equations of corn grain yield using a cost-price ratio of 1:215 (cost kg N:price of Mg corn) from check plots was significantly higher in the NT system compared to the CH and MP systems. This may suggest greater N mineralization from the NT system. However this is not likely and conflicts with N uptake data at higher FN+RSN levels. Nitrogen content from earleaves support greater N mineralizatiom from the MP system. Higher N uptake occurred from injected N treatments in the MP system (Table 4-5). The reason for this in not known. The knifing operation did not significantly increase N uptake in MP check plots (Table 4-6). Nitrogen uptake and earleaf N content were generally higher in the corn-soybean rotation compared to those from the continuous corn rotation (Tables 4-7 and 4-5). This occurrence is probably due to the positive impact decaying soybean residue has on the N status of soil.

Nitrogen requirements were the same for all tillage systems (since tillage did not significantly affect grain yield Table 4-8). The N requirements were higher than expected, possibly because of leaching from the heavy rains in June. Nitrogen requirements were less in the corn-soybean rotation than the continuous corn rotation. This was probably caused by higher N release from soybean residue compared to corn residue.

Soybean Yield

Soybean yield averaged 2.15, 2.08, and 2.35 Mg ha^{-1} from MP NT and TP systems respectively. Soybean yield from the TP system was significantly higher than the other two tillage systems. Soybeans in the TP system were not as damaged by early season flooding since the ridges acted as a channel for the water. Soybeans planted in other tillage systems were partially submerged. Residual soil nitrate from fertilizer treatments applied in the spring of 1982 did not significantly influence soybean yield.

1984

Since RSN values were not the same for all treatments at planting in 1984 (RSN following corn 1983) regression analysis was performed using FN+RSN as a continous variable on yield parameters (Table 4-9). Residual soil nitrate from 0-60 cm was used in all models. Residual soil nitrates from 60-120 cm were also used if R^2 values were further increased. It was not possible to separate the efficiencies of FN and RSN. The R^2 values were generally low in 1984, and probably were related to the abnormal weather patterns.

Continuous Corn

A combination of extremely late planting and an early frost kept corn yields very low. The frost occurred when moisture in corn grain was about 50%. The highest yielding treatment in the continuous corn rotation was only 2.6 Mg grain ha^{-1}. A response to N was observed at all FN rates in all tillage systems (Fig. 4-9). This is unusual considering the extremely low yield levels. The TP system

Table 4-9. Regression analysis results, 1984.

rotation	dependent variable Y	equation	R^2
corn/soy	corn grain Mg/ha (15.5% H_2O)	$Y=1.69 + 0.00319(A) + 0.01367(A)(P) - 0.0000457(B)(P) - 0.91(P)$	0.49
corn/soy	silage Mg/ha (60% H_2O)	$Y=14.3 + 0.067(C) - 0.0001979(D) - 1.7(P)$	0.45
cont. corn	corn grain Mg/ha (15.5% H_2O)	$Y= 0.55 + 0.00784(A) + 0.73(E) + 0.69(F) - 0.0000129(B)(E) - 0.00000943(B)(F)$	0.60
cont. corn	silage Mg/ha (60% H_2O)	$Y=6.4 + 0.0866(A) - 0.0001816(B) + 0.01617(A)(F)$	0.45

A=Residual soil nitrate (0-120 cm depth) + fertilizer N kg N/ha

$B=A^2$

C=Residual soil nitrate (0-60 cm depth) + fertilizer N kg N/ha

$D=C^2$

E=Moldboard plow (dummy variable=1)

F=Chisel plow (dummy variable=1)

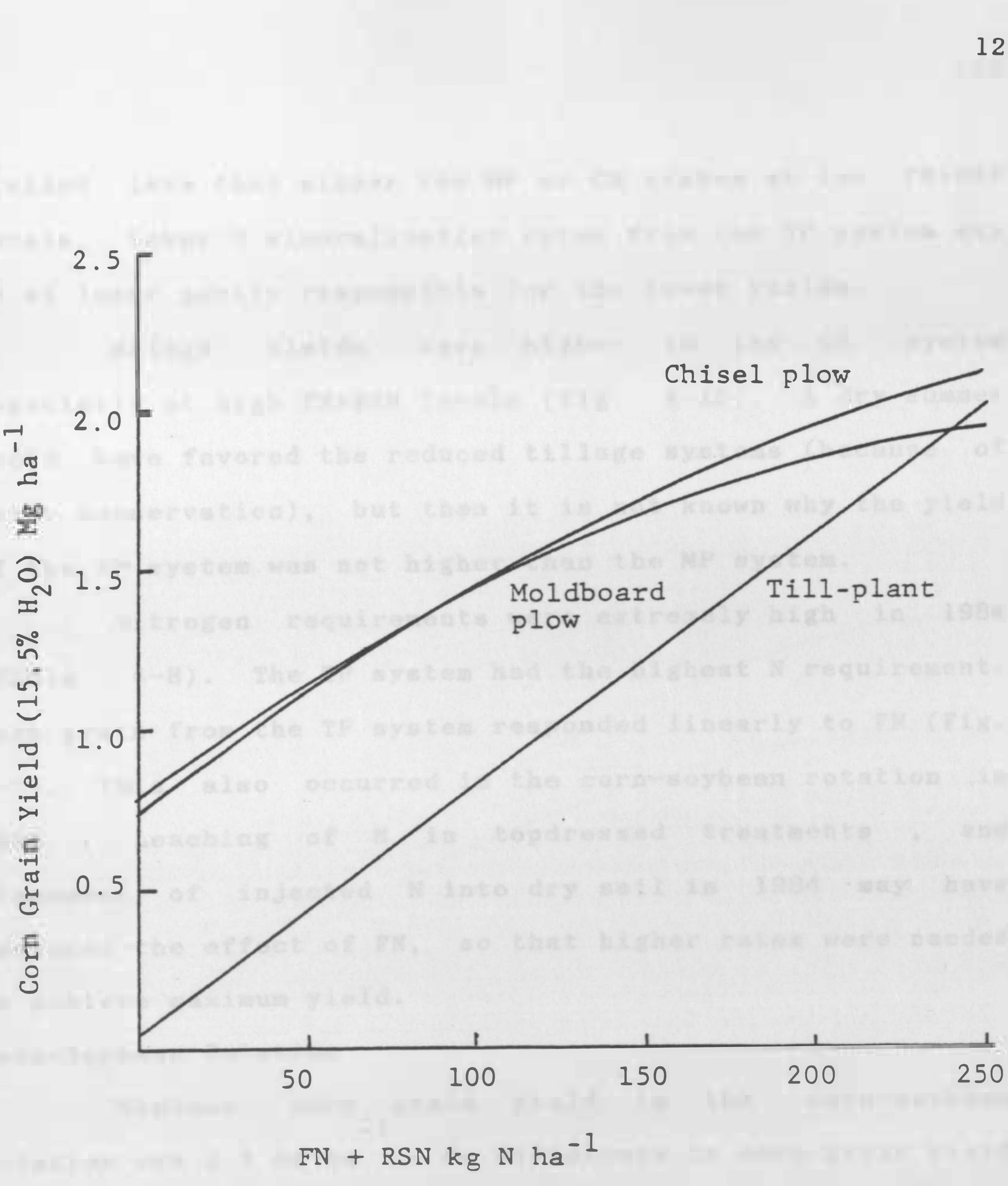

Figure 4-9. The effect of fertilizer N (FN) plus residual soil nitrate (RSN) on corn grain yield from a continuous corn rotation (derived from regression equations, Table 9), S.E. site, 1984.

yielded less than either the MP or CH system at low FN+RSN levels. Lower N mineralization rates from the TP system may be at least partly responsible for the lower yields.

Silage yields were higher in the CH system especially at high FN+RSN levels (Fig. 4-10). A dry summer would have favored the reduced tillage systems (because of water conservation), but then it is not known why the yield of the TP system was not higher than the MP system.

Nitrogen requirements were extremely high in 1984 (Table 4-8). The TP system had the highest N requirement. Corn grain from the TP system responded linearly to FN (Fig. 4-7). This also occurred in the corn-soybean rotation in 1983. Leaching of N in topdressed treatments , and placement of injected N into dry soil in 1984 may have lessened the effect of FN, so that higher rates were needed to achieve maximum yield.

Corn-Soybean Rotation

Maximum corn grain yield in the corn-soybean rotation was 2.6 Mg ha^{-1}. No difference in corn grain yield was observed between tillage systems in 1984. Similiar results occurred in 1983. Rotating corn with soybeans may have dampened the grain yield differences between tillage systems that occur in the continuous corn rotation. There seemed to be a difference in grain yield between N placements at both low FN+RSN levels (Fig. 4-11), but it is not known what caused this.

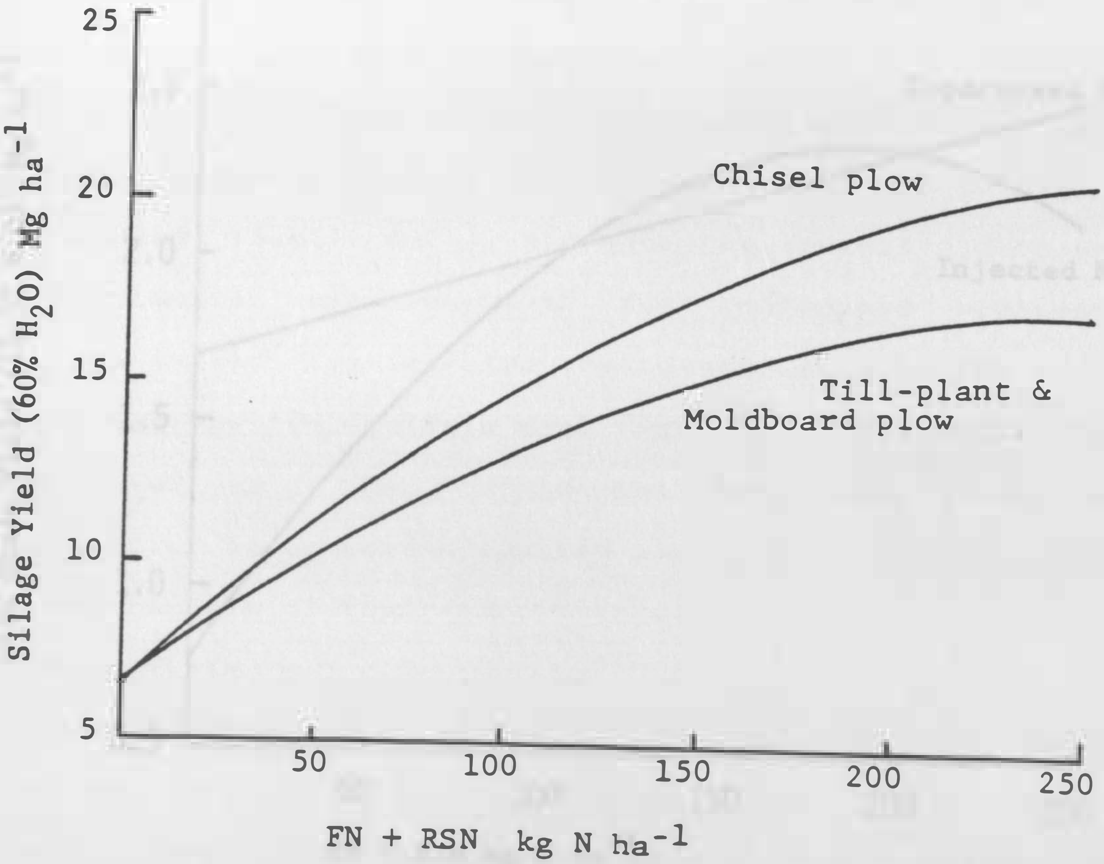

Figure 4-10. The effect of fertilizer N (FN) plus residual soil nitrate (RSN) on corn silage yield from a continuous corn rotation (derived from regression equations, Table 4-9), S.E. site, 1984.

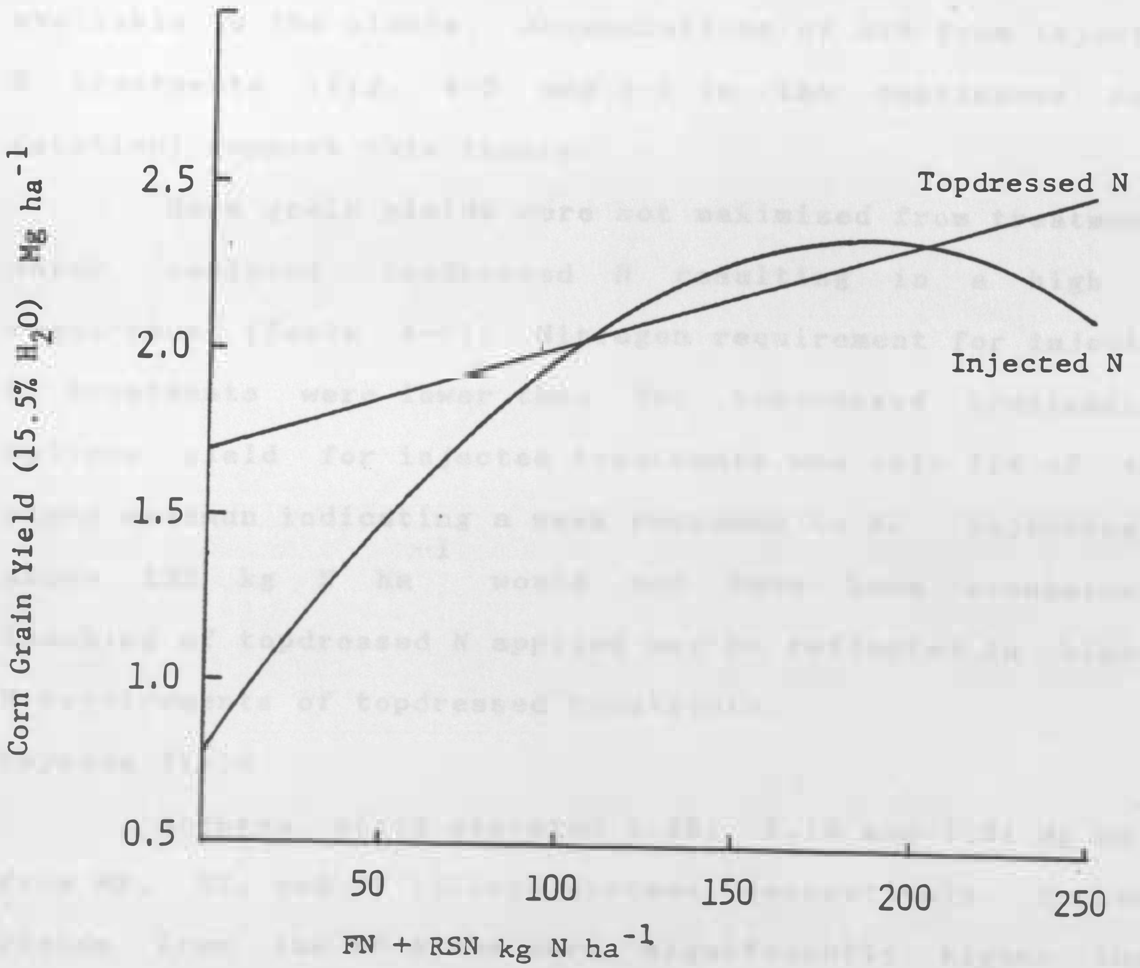

Figure 4-11. The effect of fertilizer N (FN) plus residual soil nitrate (RSN) on corn grain yield from a corn-soybean rotation (derived from regression equations, Table 4-9), S.E. site, 1984.

Silage yields were consistantly lower from injected N treatments compared to topdressed N treatments (Fig. 4-12). Injected N was applied in mid-July into rapidly drying soil. It is likely that much of the injected N was not available to the plants. Accumulations of RSN from injected N treatments (Fig. 4-2 and 4-3 in the continuous corn rotation) support this theory.

Corn grain yields were not maximized from treatments which recieved topdressed N resulting in a high N requirement (Table 4-7). Nitrogen requirement for injected N treatments were lower than for topdressed treatments. Optimum yield for injected treatments was only 72% of the yield maximun indicating a weak response to N. Injecting N above 133 kg N ha^{-1} would not have been economical. Leaching of topdressed N applied may be reflected in higher N requirements of topdressed treatments.

Soybean Yield

Soybean yield averaged 1.35, 1.18 and 1.01 Mg ha^{-1} from MP, NT, and TP tillage systems, respectively. Soybean yields from the MP plots were significantly higher than yields from the TP plots (but not higher than NT). There was no visible growth difference between tillage systems during 1984. However, there was a heavier weed infestation in reduced tilled areas. Considering the dry growing season, it is likely that weeds decreased yield in the TP sytem.

Summary of 1984 Results

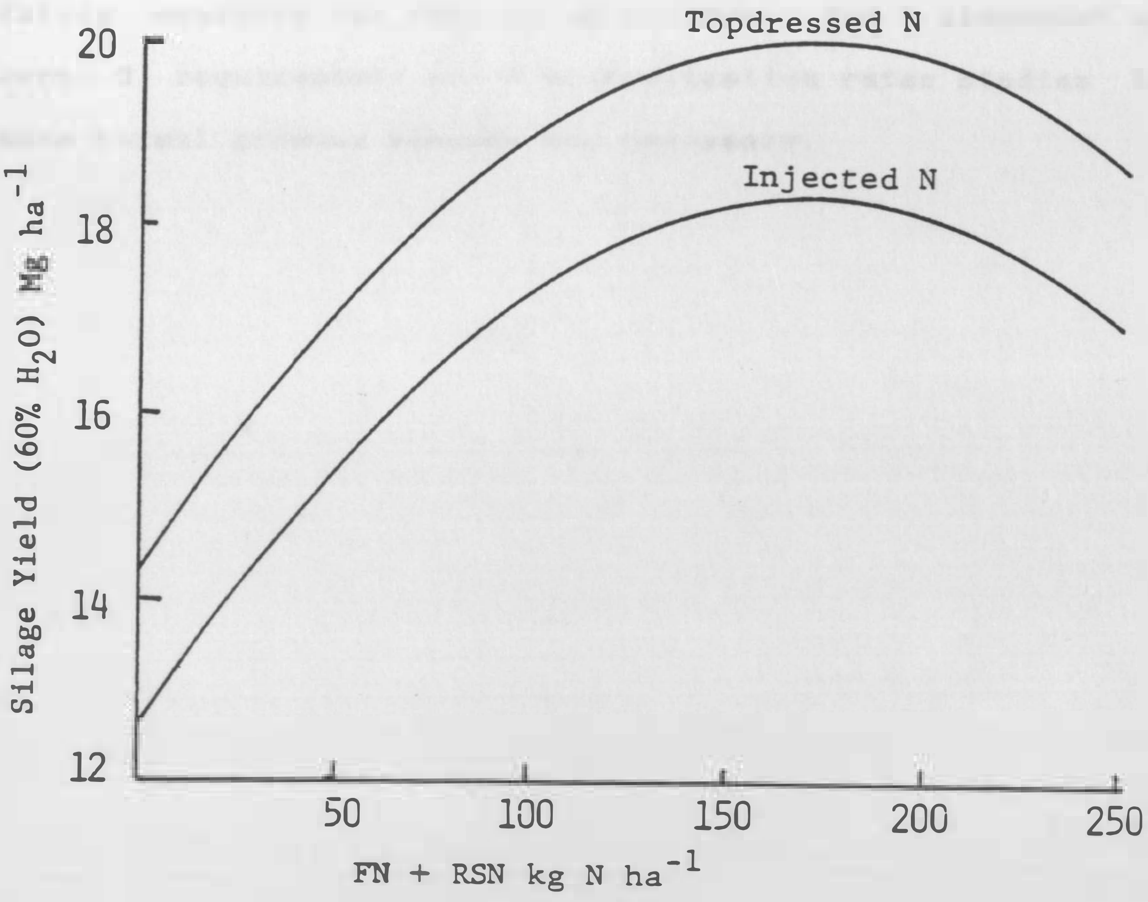

Figure 4-12. The effect of fertilizer N (FN) plus residual soil nitrate (RSN) on corn silage yield from a corn-soybean rotation (derived from regression equations, Table 4-9), S.E. site, 1984.

Caution should be used when applying the results of 1984 to other situations. Nineteen eighty four was a very abnormal year. The management of the site was dictated by weather patterns. Management practices such as planting on July 5 or injecting N on July 23 are not recommended. To fairly evaluate the effects of tillage, and N placement on corn N requirements and N mineralization rates studies in more normal growing seasons are necessary.

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Summary and Conclusions

Two years of field research has elucidated two sinks of N under reduced tillage compared to conventional tillage and eliminated a third possibility. Nitrogen mineralization in the MP system was probably higher than in the reduced tillage systems at all sites in both 1983 and 1984. This was suggested by RSN data, earleaf N content data, and N uptake data from check plots. Leaching of N occurred at all sites except the east central site in 1983 and precluded apparent mineralization estimates. In 1983, at the east central site, apparent N mineralization rate averaged (over corn and oats) 24 kg N ha^{-1} higher in the MP system compared to the reduced tillage systems. Nitrogen immobilized in organic matter represents a major sink for N applied to reduced tillage systems. It should be noted, however, that the immobilized N is not lost. It is simply stored in soil organic matter (as O.M rises under reduced tillage).

The other sink for N under reduced tillage is increased denitrification. Denitrification rates averaged 10 kg N ha^{-1} higher under reduced tillage compared to conventional tillage from topdressed N treatments. This N loss cannot be recovered. However, denitrification was significantly reduced in NT treatments which recieved injected N. Although it was not possible to quantify this difference between N placements because of missing data, injecting N under reduced tillage may decrease denitrification to levels of conventional tillage.

The third possible sink for N under reduced tillage was increased leaching. This possibility was eliminated. Residual soil nitrate data showed no accumulations of N at the 60-120 cm depth from reduced tillage systems compared to conventional tillage that would have resulted from increased leaching under reduced tillage.

Generally, lower FN requirements for corn occurred under the MP system. Greater N mineralization rates and lower denitrification rates in the MP system compared to the reduced tillage systems were probably responsible. The FN+RSN requirement was about the same for all tillage systems because of the slightly lower yield potential observed from the E.C. site. The FN and FN+RSN requirement of oats was slightly higher in oats grown under reduced tillage probably due to higher N mineralization from the MP system. Further research is needed to determine if soil nitrate interpretations for both oats and corn should be altered due to tillage.

Appendix

The following abreviations are used for data collected from both sites. Soil samples were taken in the fall and used in the analysis of the next summer's data. For instance soil samples taken the fall of 1982 appear as residual soil nitrate data in 1983. The data for each site and crop is first printed and summarized in all possible combinations down to averages for the four replications.

Abreviation	Meaning and Units
Cobup	N taken up by corn cobs, kg N/ha
Earln	N content of corn earleaf at silking, %N
Fert	Fertilizer rate: 1zero=check; 2low=low rate; 3med=medium rate; 4high=high rate;
Freq	Number of observations used in averages
FN	Fertilizer nitrogen applied, kg N/ha
FNRSN	FN + RSN
Grainn	N in grain (corn or oats), %N
Grainup	N uptake in corn grain, kg N/ha
Kggrain	Oat grain yield, kg/ha
Kgnup	Total N Uptake in oats, kg/ha
Mgcorn	Corn grain yield Mg/ha (15.5% moisture)
Mgoatl	Oatlage yield, Mg/ha (60% moisture)
Mgsil	Corn silage yield, Mg/ha
Oatln	N in oatlage, %N
Obs	Observation number

PH2O	Water content in oat grain, % water
RSN	Residual soil nitrate, kg N/ha (0-60 cm depth)
RSNDEEP	Residual soil nitrate, N kg N/ha (60-120 cm depth)
Source	AN=topdressed ammonium nitrate; Kn=injected urea-ammionum nitrate:
Stovn	N content of corn stover, %N
Stovup	N uptake in corn stover kg N/ha
Till	Tillage system, CH=Chisel plow, MP=Moldboard plow, NT=No-till, TP=Till-plant
Type	Number of factors considered in average

Table 1. Data summary, corn, E.C. site.

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	MGSIL	MGCORN	FN	FNRSN	RSN	RSNDEEP	EARLN	GRAINN	STOVN
1				.	0	288	78.741	21.1040	3.27444	27.9418	6.23703	66.733	102.872	36.1391	29.3508	2.54266	1.47708	0.522292
2				83	1	96	87.019	21.7367	3.48109	28.2238	6.63065	88.200	112.280	24.0800	42.8750	2.79240	1.54125	0.552083
3				84	1	96	70.464	20.4713	3.06780	27.6598	5.84342	56.000	112.617	56.6172	22.4238	2.29292	1.41292	0.492500
4				85	1	96	.	.	.	.	.	56.000	83.720	27.7200	22.6841	.	.	.
5			AN	.	2	144	82.033	22.0327	3.35467	28.4648	6.38985	66.733	109.037	42.3033	32.9486	2.60323	1.49833	0.537083
6			KN	.	2	144	75.450	20.1754	3.19421	27.4187	6.08422	66.733	96.708	29.9749	25.7278	2.48208	1.45583	0.507500
7			AN	83	3	48	90.902	22.8383	3.54977	28.5909	6.76147	88.200	112.420	24.2200	47.6700	2.84729	1.57583	0.574167
8			AN	84	3	48	73.165	21.2270	3.15957	28.3387	6.01823	56.000	122.399	66.3994	23.0148	2.35917	1.42083	0.500000
9			AN	85	3	48	.	.	.	.	.	56.000	92.290	36.2903	28.1610	.	.	.
10			KN	83	3	48	83.135	20.6351	3.41241	27.8566	6.49983	88.200	112.140	23.9400	38.0800	2.73750	1.50667	0.530000
11			KN	84	3	48	67.764	19.7157	2.97602	26.9808	5.66861	56.000	102.835	46.8349	21.8328	2.22667	1.40500	0.485000
12			KN	85	3	48	.	.	.	.	.	56.000	75.150	19.1497	17.0907	.	.	.
13		CH		.	4	96	74.319	20.1697	3.18065	27.1513	6.05839	66.733	99.557	32.8239	27.7355	2.52703	1.43625	0.511875
14		MP		.	4	96	86.596	23.0075	3.46250	29.7591	6.59524	66.733	110.159	43.4255	33.8451	2.57937	1.54000	0.540625
15		NT		.	4	96	75.369	20.1349	3.18017	26.9149	6.05747	66.733	98.901	32.1677	26.5186	2.52156	1.45500	0.514375
16		CH		83	5	32	84.027	20.4312	3.47759	27.7344	6.62398	88.200	112.280	24.0800	42.8750	2.82156	1.48875	0.537500
17		CH		84	5	32	64.610	19.9082	2.88372	26.5681	5.49279	56.000	106.742	50.7423	24.2630	2.23250	1.38375	0.486250
18		CH		85	5	32	.	.	.	.	.	56.000	79.649	23.6495	16.0685	.	.	.
19		MP		83	5	32	93.604	23.4545	3.59757	30.0315	6.85252	88.200	112.280	24.0800	42.8750	2.75875	1.61000	0.560000
20		MP		84	5	32	79.589	22.5606	3.32743	29.4867	6.33797	56.000	124.652	68.6521	20.5551	2.40000	1.47000	0.521250
21		MP		85	5	32	.	.	.	.	.	56.000	93.544	37.5445	30.2426	.	.	.
22		NT		83	5	32	83.425	21.3245	3.36811	26.9053	6.41545	88.200	112.280	24.0800	42.8750	2.79687	1.52500	0.558750
23		NT		84	5	32	67.194	18.9452	2.99224	26.9246	5.69950	56.000	106.457	50.4570	22.4532	2.24625	1.38500	0.470000
24		NT		85	5	32	.	.	.	.	.	56.000	77.966	21.9660	14.2275	.	.	.
25		CH	AN	.	6	48	75.889	20.4309	3.21454	27.1989	6.12294	66.733	104.723	37.9897	30.8789	2.53906	1.44625	0.522500
26		CH	KN	.	6	48	72.748	19.9084	3.14676	27.1036	5.99383	66.733	94.391	27.6582	24.5922	2.51500	1.42625	0.501250
27		MP	AN	.	6	48	92.399	24.7305	3.61559	30.8551	6.88685	66.733	115.632	52.8985	30.7781	2.64531	1.57250	0.562500
28		MP	KN	.	6	48	80.794	21.2845	3.30941	28.6631	6.30364	66.733	100.686	33.9526	28.8071	2.51344	1.50750	0.518750
29		NT	AN	.	6	48	77.812	20.9365	3.23388	27.3404	6.15976	66.733	102.755	36.0215	29.1888	2.62531	1.47625	0.526250
30		NT	KN	.	6	48	72.806	19.3333	3.12647	26.4895	5.95518	66.733	95.047	28.3138	23.8483	2.41781	1.43375	0.502500
31		CH	AN	83	7	16	88.211	21.5727	3.56174	28.1443	6.78426	88.200	112.420	24.2200	47.6700	2.83312	1.52500	0.567500
32		CH	AN	84	7	16	63.567	19.2892	2.86735	26.2535	5.46162	56.000	115.306	59.3061	23.6026	2.24500	1.36750	0.477500
33		CH	AN	85	7	16	.	.	.	.	.	56.000	86.443	30.4430	21.3640	.	.	.
34		CH	KN	83	7	16	79.843	19.2896	3.39344	27.3245	6.46370	88.200	112.140	23.9400	38.0800	2.81000	1.45250	0.507500
35		CH	KN	84	7	16	65.653	20.5272	2.90008	26.8828	5.52397	56.000	98.178	42.1785	24.9235	2.22000	1.40000	0.495000
36		CH	KN	85	7	16	.	.	.	.	.	56.000	72.856	16.0560	10.7730	.	.	.
37		MP	AN	83	7	16	99.005	25.9015	3.73645	30.8488	7.11704	88.200	112.420	24.2200	47.6700	2.80812	1.64000	0.607500
38		MP	AN	84	7	16	85.792	23.5595	3.49474	30.8615	6.65666	56.000	137.955	81.9546	22.3944	2.48250	1.50500	0.517500
39		MP	AN	85	7	16	.	.	.	.	.	56.000	108.521	52.5210	46.2700	.	.	.
40		MP	KN	83	7	16	88.203	21.0074	3.45870	29.2143	6.58800	88.200	112.140	23.9400	38.0800	2.70937	1.58000	0.512500
41		MP	KN	84	7	16	73.386	21.5616	3.16012	28.1118	6.01928	56.000	111.350	55.3497	18.7159	2.31750	1.43500	0.525000
42		MP	KN	85	7	16	.	.	.	.	.	56.000	78.568	22.5680	29.6800	.	.	.
43		NT	AN	83	7	16	85.489	21.0408	3.35113	26.7795	6.38311	88.200	112.420	24.2200	47.6700	2.90062	1.56250	0.547500
44		NT	AN	84	7	16	70.136	20.8322	3.11662	27.9012	5.93642	56.000	113.938	57.9376	23.0475	2.35000	1.39000	0.505000
45		NT	AN	85	7	16	.	.	.	.	.	56.000	81.907	25.9070	16.8490	.	.	.
46		NT	KN	83	7	16	81.361	21.6083	3.38509	27.0311	6.44779	88.200	112.140	23.9400	38.0800	2.69312	1.48750	0.570000
47		NT	KN	84	7	16	64.252	17.0583	2.86785	25.9479	5.46258	56.000	98.976	42.9765	21.8589	2.14250	1.38000	0.435000
48		NT	KN	85	7	16	.	.	.	.	.	56.000	74.025	18.0250	11.6060	.	.	.
49	1ZERO			.	8	72	50.665	14.2665	2.44786	21.4872	4.66258	0.000	20.352	20.3520	15.8931	2.09667	1.29083	0.444167

Table 1. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	MGSIL	MGCORN	FN	FNRSN	RSN	RSNDEEP	EARLN	GRAINN	STOVN
50	2LOW			.	8	72	75.730	19.2851	3.25055	27.7027	6.19153	48.907	78.970	30.063	31.146	2.45021	1.44667	0.482500
51	3MED			.	8	72	87.536	23.1937	3.52673	29.8691	6.71759	86.613	125.420	38.807	38.297	2.71000	1.54333	0.550833
52	4HIGH			.	8	72	101.034	27.6709	3.87263	32.7082	7.37644	131.413	186.740	55.334	31.880	2.91375	1.62750	0.611667
53	1ZERO			83	9	24	58.341	14.4744	2.82480	23.0374	5.38057	0.000	19.740	19.740	18.760	2.34833	1.28667	0.446667
54	1ZERO			84	9	24	42.988	14.0585	2.07091	19.9369	3.94460	0.000	30.517	30.517	16.688	1.84500	1.29500	0.441667
55	1ZERO			85	9	24	.	.	.	.	.	0.000	10.799	10.799	12.072	.	.	.
56	2LOW			83	9	24	85.948	19.5527	3.52977	28.4320	6.72338	72.800	99.120	26.320	56.700	2.75375	1.51833	0.456667
57	2LOW			84	9	24	65.512	19.0175	2.97133	26.9734	5.65967	36.960	81.883	44.923	19.793	2.14667	1.37500	0.468333
58	2LOW			85	9	24	.	.	.	.	.	36.960	55.907	18.947	16.945	.	.	.
59	3MED			83	9	24	95.637	24.2874	3.65202	29.4958	6.95623	109.760	135.240	25.480	69.020	2.95167	1.63500	0.598333
60	3MED			84	9	24	79.436	22.0999	3.40145	30.2423	6.47895	75.040	138.629	63.589	24.578	2.46833	1.45167	0.503333
61	3MED			85	9	24	.	.	.	.	.	75.040	102.391	27.351	21.294	.	.	.
62	4HIGH			83	9	24	108.147	28.6324	3.91777	31.9299	7.46241	170.240	195.020	24.780	27.020	3.11583	1.72500	0.666667
63	4HIGH			84	9	24	93.922	26.7094	3.82749	33.4864	7.29046	112.000	199.439	87.439	28.636	2.71167	1.53000	0.556667
64	4HIGH			85	9	24	.	.	.	.	.	112.000	165.783	53.783	39.984	.	.	.
65	1ZERO		AN	.	10	36	50.506	14.7786	2.45936	21.4543	4.68449	0.000	21.272	21.272	21.134	2.11125	1.27833	0.463333
66	1ZERO		KN	.	10	36	50.823	13.7544	2.43635	21.5200	4.64067	0.000	19.432	19.432	10.503	2.08208	1.30333	0.425000
67	2LOW		AN	.	10	36	80.812	19.2856	3.37961	28.5102	6.43696	48.907	80.202	31.295	15.015	2.51833	1.48500	0.473333
68	2LOW		KN	.	10	36	70.648	19.2846	3.12170	26.8952	5.94609	48.907	77.738	28.831	47.277	2.38208	1.40833	0.491667
69	3MED		AN	.	10	36	90.763	23.9947	3.60722	30.1868	6.87089	86.613	132.946	46.333	58.157	2.79917	1.56500	0.570000
70	3MED		KN	.	10	36	84.310	22.3926	3.44625	29.5513	6.56429	86.613	117.894	31.281	18.438	2.62083	1.52167	0.531667
71	4HIGH		AN	.	10	36	106.053	30.0717	3.97271	33.7079	7.56706	131.413	201.727	70.313	37.490	2.98417	1.66500	0.641667
72	4HIGH		KN	.	10	36	96.016	25.2701	3.77255	31.7084	7.18582	131.413	171.768	40.355	26.271	2.84333	1.59000	0.581667
73	1ZERO		AN	83	11	12	57.902	15.2975	2.80732	22.7325	5.34728	0.000	21.000	21.000	28.840	2.33250	1.28333	0.480000
74	1ZERO		AN	84	11	12	43.111	14.2592	2.11139	20.1761	4.02170	0.000	31.139	31.139	18.153	1.89000	1.27333	0.446667
75	1ZERO		AN	85	11	12	.	.	.	.	.	0.000	11.676	11.676	16.408	.	.	.
76	1ZERO		KN	83	11	12	58.781	13.6510	2.84227	23.3422	5.41385	0.000	18.480	18.480	8.680	2.36417	1.29000	0.413333
77	1ZERO		KN	84	11	12	42.866	13.8578	2.03044	19.6978	3.86750	0.000	29.896	29.896	15.224	1.80000	1.31667	0.436667
78	1ZERO		KN	85	11	12	.	.	.	.	.	0.000	9.921	9.921	7.341	.	.	.
79	2LOW		AN	83	11	12	92.309	19.2353	3.65680	29.0255	6.96532	72.800	95.200	22.400	14.280	2.85333	1.57667	0.486667
80	2LOW		AN	84	11	12	69.314	19.3360	3.10202	27.9949	5.90860	36.960	88.575	51.615	20.142	2.18333	1.39333	0.460000
81	2LOW		AN	85	11	12	.	.	.	.	.	36.960	56.831	19.871	10.621	.	.	.
82	2LOW		KN	83	11	12	79.588	19.8700	3.40275	27.8384	6.48144	72.800	103.040	30.240	99.120	2.65417	1.46000	0.506667
83	2LOW		KN	84	11	12	61.709	18.6991	2.84064	25.9520	5.41074	36.960	75.190	38.230	19.443	2.11000	1.35667	0.476667
84	2LOW		KN	85	11	12	.	.	.	.	.	36.960	54.983	18.023	23.268	.	.	.
85	3MED		AN	83	11	12	98.212	25.9966	3.71667	29.7681	7.07938	109.760	136.360	26.600	119.280	3.03167	1.65000	0.630000
86	3MED		AN	84	11	12	83.313	21.9928	3.49776	30.6055	6.66240	75.040	150.525	75.485	24.941	2.56667	1.48000	0.510000
87	3MED		AN	85	11	12	.	.	.	.	.	75.040	111.953	36.913	30.249	.	.	.
88	3MED		KN	83	11	12	93.062	22.5783	3.58737	29.2235	6.83308	109.760	134.120	24.360	18.760	2.87167	1.62000	0.566667
89	3MED		KN	84	11	12	75.559	22.2069	3.30514	29.8791	6.29551	75.040	126.734	51.694	24.215	2.37000	1.42333	0.456667
90	3MED		KN	85	11	12	.	.	.	.	.	75.040	92.829	17.789	12.339	.	.	.
91	4HIGH		AN	83	11	12	115.183	30.8236	4.01829	32.8373	7.65388	170.240	197.120	26.880	28.280	3.17167	1.79333	0.700000
92	4HIGH		AN	84	11	12	96.922	29.3198	3.92712	34.5785	7.48023	112.000	219.359	107.359	28.823	2.79667	1.53667	0.583333
93	4HIGH		AN	85	11	12	.	.	.	.	.	112.000	188.701	76.701	55.365	.	.	.
94	4HIGH		KN	83	11	12	101.111	26.4412	3.81725	31.0225	7.27094	170.240	192.920	22.680	25.760	3.06000	1.65667	0.633333
95	4HIGH		KN	84	11	12	90.921	24.0991	3.72786	32.3944	7.10069	112.000	179.520	67.520	28.449	2.62667	1.52333	0.530000
96	4HIGH		KN	85	11	12	.	.	.	.	.	112.000	142.865	30.865	24.603	.	.	.
97	1ZERO	CH		.	12	24	47.419	13.9965	2.34293	20.6626	4.46273	0.000	19.717	19.717	14.154	2.06000	1.26750	0.445000
98	1ZERO	MP		.	12	24	57.665	15.1040	2.69562	23.9269	5.13452	0.000	23.078	23.078	19.051	2.19500	1.33500	0.435000

Table 1. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	CGBUP	MGSIL	MGCGRN	FN	FNRSN	RSN	RSNDEEP	EARLN	GRAINN	STGVN
99	1ZERO	NT		.	12	24	46.910	13.6989	2.30501	19.8720	4.39050	0.000	18.261	18.261	14.6062	2.03500	1.2700	0.4525
100	2LOW	CH		.	12	24	70.767	18.4329	3.08151	26.4400	5.86955	48.907	75.077	26.171	29.5283	2.40375	1.4225	0.4675
101	2LOW	MP		.	12	24	81.281	20.8799	3.46237	29.4651	6.59500	48.907	85.598	36.691	35.6146	2.44187	1.4600	0.5050
102	2LOW	NT		.	12	24	75.143	18.5426	3.20777	27.2030	6.11003	48.907	76.234	27.328	28.2945	2.50500	1.4575	0.4750
103	3MED	CH		.	12	24	84.487	21.9812	3.49769	29.4362	6.66226	86.613	122.043	35.429	35.3673	2.77750	1.5050	0.5275
104	3MED	MP		.	12	24	98.446	26.5813	3.74612	32.1609	7.13546	86.613	132.078	45.465	43.9101	2.71500	1.6400	0.5900
105	3MED	NT		.	12	24	79.677	21.0186	3.33640	28.0101	6.35505	86.613	122.140	35.526	35.6146	2.63750	1.4850	0.5350
106	4HIGH	CH		.	12	24	94.601	26.2682	3.80048	32.0662	7.23901	131.413	181.392	49.979	31.8925	2.86687	1.5500	0.6075
107	4HIGH	MP		.	12	24	108.994	29.4650	3.94590	33.4836	7.51600	131.413	199.881	68.468	36.1886	2.96562	1.7250	0.6325
108	4HIGH	NT		.	12	24	99.508	27.2795	3.87151	32.5747	7.37431	131.413	178.969	47.556	27.5550	2.90875	1.6075	0.5950
109	1ZERO	CH		83	13	8	53.954	14.2650	2.70691	21.8516	5.15602	0.000	19.740	19.740	18.7600	2.28500	1.2450	0.4550
110	1ZERO	CH		84	13	8	40.884	13.7281	1.97895	19.4737	3.76943	0.000	29.947	29.947	16.8280	1.83500	1.2900	0.4350
111	1ZERO	CH		85	13	8	.	.	.	.	.	0.000	9.464	9.464	6.8740	.	.	.
112	1ZERO	MP		83	13	8	66.530	15.2914	3.08975	26.3335	5.88523	0.000	19.740	19.740	18.7600	2.46000	1.3450	0.4200
113	1ZERO	MP		84	13	8	48.801	14.9166	2.30150	21.5202	4.38380	0.000	35.970	35.970	14.8568	1.93000	1.3250	0.4500
114	1ZERO	MP		85	13	8	.	.	.	.	.	0.000	13.524	13.524	24.1760	.	.	.
115	1ZERO	NT		83	13	8	54.540	13.8669	2.67773	20.9270	5.10044	0.000	19.740	19.740	18.7600	2.30000	1.2700	0.4650
116	1ZERO	NT		84	13	8	39.281	13.5309	1.93229	18.8169	3.68056	0.000	25.634	25.634	18.3806	1.77000	1.2700	0.4400
117	1ZERO	NT		85	13	8	.	.	.	.	.	0.000	9.408	9.408	6.6780	.	.	.
118	2LOW	CH		83	13	8	84.663	19.8984	3.50213	27.9111	6.67072	72.800	99.120	26.320	56.7000	2.85250	1.5100	0.5050
119	2LOW	CH		84	13	8	56.872	16.9673	2.66090	24.9690	5.06839	36.960	74.144	37.184	23.2190	1.95500	1.3350	0.4300
120	2LOW	CH		85	13	8	.	.	.	.	.	36.960	51.968	15.008	8.6660	.	.	.
121	2LOW	MP		83	13	8	90.357	21.0921	3.64978	29.9674	6.95196	72.800	99.120	26.320	56.7000	2.59875	1.5450	0.5100
122	2LOW	MP		84	13	8	72.204	20.6677	3.27497	28.9627	6.23804	36.960	93.708	56.748	15.6618	2.28500	1.3750	0.5000
123	2LOW	MP		85	13	8	.	.	.	.	.	36.960	63.966	27.006	34.4820	.	.	.
124	2LOW	NT		83	13	8	82.825	17.6676	3.43742	27.4174	6.54747	72.800	99.120	26.320	56.7000	2.81000	1.5000	0.4750
125	2LOW	NT		84	13	8	67.460	19.4176	2.97811	26.9886	5.67260	36.960	77.797	40.837	20.4974	2.20000	1.4150	0.4750
126	2LOW	NT		85	13	8	.	.	.	.	.	36.960	51.786	14.826	7.6860	.	.	.
127	3MED	CH		83	13	8	92.094	20.9432	3.61417	28.3861	6.88413	109.760	135.240	25.480	69.0200	3.11500	1.5900	0.5500
128	3MED	CH		84	13	8	76.880	23.0191	3.38120	30.4864	6.44039	75.040	136.360	61.320	24.2298	2.44000	1.4200	0.5050
129	3MED	CH		85	13	8	.	.	.	.	.	75.040	94.528	19.488	12.8520	.	.	.
130	3MED	MP		83	13	8	104.382	28.5855	3.79537	32.1610	7.22928	109.760	135.240	25.480	69.0200	2.85500	1.7200	0.6350
131	3MED	MP		84	13	8	92.510	24.5770	3.69686	32.1607	7.04164	75.040	145.103	70.063	24.9942	2.57500	1.5600	0.5450
132	3MED	MP		85	13	8	.	.	.	.	.	75.040	115.892	40.852	37.7160	.	.	.
133	3MED	NT		83	13	8	90.436	23.3336	3.54652	27.9403	6.75528	109.760	135.240	25.480	69.0200	2.88500	1.5950	0.6100
134	3MED	NT		84	13	8	68.917	18.7035	3.12629	28.0798	5.95483	75.040	134.425	59.385	24.5098	2.39000	1.3750	0.4600
135	3MED	NT		85	13	8	.	.	.	.	.	75.040	96.754	21.714	13.3140	.	.	.
136	4HIGH	CH		83	13	8	105.397	26.6182	4.08715	32.7890	7.78504	170.240	195.020	24.780	27.0200	3.03375	1.6100	0.6400
137	4HIGH	CH		84	13	8	83.805	25.9182	3.51381	31.3434	6.69297	112.000	186.518	74.518	32.7754	2.70000	1.4900	0.5750
138	4HIGH	CH		85	13	8	.	.	.	.	.	112.000	162.638	50.638	35.8820	.	.	.
139	4HIGH	MP		83	13	8	113.146	28.8489	3.85539	31.6642	7.34360	170.240	195.020	24.780	27.0200	3.12125	1.8300	0.6750
140	4HIGH	MP		84	13	8	104.842	30.0810	4.03641	35.3030	7.68839	112.000	223.828	111.828	26.7078	2.81000	1.6200	0.5900
141	4HIGH	MP		85	13	8	.	.	.	.	.	112.000	180.796	68.796	54.8380	.	.	.
142	4HIGH	NT		83	13	8	105.898	30.4300	3.81076	31.3365	7.25859	170.240	195.020	24.780	27.0200	3.19250	1.7350	0.6850
143	4HIGH	NT		84	13	8	93.118	24.1290	3.93226	33.8129	7.49002	112.000	187.972	75.972	26.4250	2.62500	1.4800	0.5050
144	4HIGH	NT		85	13	8	.	.	.	.	.	112.000	153.916	41.916	29.2320	.	.	.
145	1ZERO	CH	AN	.	14	12	47.085	13.9137	2.35006	20.4663	4.47630	0.000	18.774	18.774	17.1976	2.09750	1.2500	0.4500
146	1ZERO	CH	KN	.	14	12	47.753	14.0793	2.33581	20.8589	4.44916	0.000	20.660	20.660	11.1104	2.02250	1.2850	0.4400
147	1ZERO	MP	AN	.	14	12	59.397	16.6721	2.78354	24.3625	5.30198	0.000	25.506	25.506	26.8660	2.17125	1.3300	0.4800

Table 1 Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STCVUP	COBUP	MGSIL	MGCGRN	FN	FNRSN	RSN	RSNDEEP	EARLN	SRAINN	STCVN
148	1ZERO	MP	KN	.	14	12	55.933	13.5358	2.60771	23.4913	4.96706	0.000	20.650	20.6500	10.5249	2.21875	1.340	0.390
149	1ZERO	NT	AN	.	14	12	45.037	13.7498	2.24448	19.5340	4.27520	0.000	19.535	19.5347	19.3377	2.06500	1.255	0.460
150	1ZERO	NT	KN	.	14	12	46.784	13.6479	2.36555	20.2099	4.50581	0.000	16.987	16.9867	9.8747	2.00500	1.285	0.445
151	2LOW	CH	AN	.	14	12	73.949	18.6607	3.15860	26.6553	6.01638	48.907	74.953	26.0465	14.1437	2.42125	1.450	0.475
152	2LOW	CH	KN	.	14	12	67.585	18.2051	3.00443	26.2248	5.72272	48.907	75.201	26.2948	44.9129	2.38625	1.395	0.460
153	2LOW	MP	AN	.	14	12	87.324	21.1199	3.61537	30.8088	6.88642	48.907	88.862	39.9551	15.4607	2.48375	1.505	0.490
154	2LOW	MP	KN	.	14	12	75.237	20.6398	3.30938	28.1213	6.30357	48.907	82.334	33.4273	55.7685	2.40000	1.415	0.520
155	2LOW	NT	AN	.	14	12	81.162	18.0763	3.36425	28.0665	6.40810	48.907	76.751	27.8843	15.4392	2.65000	1.500	0.455
156	2LOW	NT	KN	.	14	12	69.123	19.0088	3.05128	26.3395	5.81197	48.907	75.677	26.7708	41.1497	2.36000	1.415	0.495
157	3MED	CH	AN	.	14	12	86.343	21.5369	3.54197	29.7693	6.74662	86.613	127.814	41.2011	53.8860	2.78875	1.515	0.515
158	3MED	CH	KN	.	14	12	82.631	22.4254	3.45340	29.1032	6.57790	86.613	116.271	29.6576	16.8485	2.76625	1.495	0.540
159	3MED	MP	AN	.	14	12	103.895	27.5837	3.92112	32.9530	7.46879	86.613	142.743	56.1297	68.0923	2.85625	1.655	0.610
160	3MED	MP	KN	.	14	12	92.997	25.5788	3.57112	31.3687	6.80212	86.613	121.414	34.8003	19.7279	2.57375	1.625	0.570
161	3MED	NT	AN	.	14	12	82.050	22.8636	3.35856	27.8382	6.39725	86.613	128.281	41.6677	52.4916	2.75250	1.525	0.585
162	3MED	NT	KN	.	14	12	77.304	19.1735	3.31425	28.1820	6.31286	86.613	115.998	29.3851	18.7376	2.52250	1.445	0.485
163	4HIGH	CH	AN	.	14	12	96.179	27.6125	3.80754	31.9047	7.25246	131.413	197.351	65.9372	38.2881	2.84875	1.570	0.650
164	4HIGH	CH	KN	.	14	12	93.023	24.9239	3.79341	32.2276	7.22555	131.413	165.433	34.0200	25.4968	2.88500	1.530	0.565
165	4HIGH	MP	AN	.	14	12	118.978	33.5463	4.14235	35.2962	7.89020	131.413	221.417	90.0032	44.6936	3.07000	1.800	0.670
166	4HIGH	MP	KN	.	14	12	99.011	25.3837	3.74945	31.6710	7.14180	131.413	178.346	46.9327	27.6836	2.86125	1.650	0.595
167	4HIGH	NT	AN	.	14	12	103.001	29.0563	3.96822	33.9228	7.55852	131.413	186.413	54.9995	29.4868	3.03375	1.625	0.605
168	4HIGH	NT	KN	.	14	12	96.015	25.5028	3.77480	31.2266	7.19009	131.413	171.526	40.1128	25.6312	2.78375	1.550	0.585
169	1ZERO	CH	AN	83	15	4	55.407	14.8127	2.74720	21.7677	5.23277	0.000	21.000	21.0000	28.8400	2.29500	1.260	0.480
170	1ZERO	CH	AN	84	15	4	38.762	13.0148	1.95291	19.1650	3.71983	0.000	25.662	25.6620	16.2848	1.90000	1.240	0.420
171	1ZERO	CH	AN	85	15	4	.	.	.	.	.	0.000	9.660	9.6600	6.4680	.	.	.
172	1ZERO	CH	KN	83	15	4	52.501	13.7174	2.66662	21.9354	5.07928	0.000	18.480	18.4800	8.6800	2.27500	1.230	0.430
173	1ZERO	CH	KN	84	15	4	43.005	14.4413	2.00499	19.7824	3.81904	0.000	34.233	34.2328	17.3712	1.77000	1.340	0.450
174	1ZERO	CH	KN	85	15	4	.	.	.	.	.	0.000	9.268	9.2680	7.2800	.	.	.
175	1ZERO	MP	AN	83	15	4	69.504	18.3210	3.21642	26.9416	6.12651	0.000	21.000	21.0000	28.8400	2.43250	1.350	0.510
176	1ZERO	MP	AN	84	15	4	49.291	15.0232	2.35066	21.7834	4.47745	0.000	39.278	39.2784	15.0780	1.91000	1.310	0.450
177	1ZERO	MP	AN	85	15	4	.	.	.	.	.	0.000	16.240	16.2400	36.6800	.	.	.
178	1ZERO	MP	KN	83	15	4	63.555	12.2618	2.96308	25.7255	5.64396	0.000	18.480	18.4800	8.6800	2.48750	1.340	0.330
179	1ZERO	MP	KN	84	15	4	48.311	14.8099	2.25233	21.2571	4.29016	0.000	32.662	32.6620	14.6356	1.95000	1.340	0.450
180	1ZERO	MP	KN	85	15	4	.	.	.	.	.	0.000	10.808	10.8080	7.5040	.	.	.
181	1ZERO	NT	AN	83	15	4	48.795	12.7601	2.45836	19.4883	4.68258	0.000	21.000	21.0000	28.8400	2.27000	1.240	0.450
182	1ZERO	NT	AN	84	15	4	41.279	14.7395	2.03060	19.5798	3.86781	0.000	28.476	28.4760	23.0972	1.86000	1.270	0.470
183	1ZERO	NT	AN	85	15	4	.	.	.	.	.	0.000	9.128	9.1280	6.0760	.	.	.
184	1ZERO	NT	KN	83	15	4	60.286	14.9737	2.89711	22.3657	5.51831	0.000	18.480	18.4800	8.6800	2.33000	1.300	0.480
185	1ZERO	NT	KN	84	15	4	37.282	12.3222	1.83399	18.0540	3.49331	0.000	22.792	22.7920	13.6640	1.68000	1.270	0.410
186	1ZERO	NT	KN	85	15	4	.	.	.	.	.	0.000	9.688	9.6880	7.2800	.	.	.
187	2LOW	CH	AN	83	15	4	87.926	21.1750	3.52117	27.7900	6.70698	72.800	95.200	22.4000	14.2800	2.86250	1.560	0.540
188	2LOW	CH	AN	84	15	4	59.972	16.1463	2.79603	25.5205	5.32577	36.960	79.232	42.2716	20.1152	1.98000	1.340	0.410
189	2LOW	CH	AN	85	15	4	.	.	.	.	.	36.960	50.428	13.4680	8.0360	.	.	.
190	2LOW	CH	KN	83	15	4	81.399	18.6218	3.48309	28.0321	6.63445	72.800	103.040	30.2400	99.1200	2.84250	1.460	0.470
191	2LOW	CH	KN	84	15	4	53.771	17.7883	2.52577	24.4175	4.81100	36.960	69.056	32.0964	26.3228	1.93000	1.330	0.450
192	2LOW	CH	KN	85	15	4	.	.	.	.	.	36.960	53.508	16.5480	9.2960	.	.	.
193	2LOW	MP	AN	83	15	4	96.302	21.9832	3.78385	31.1967	7.20734	72.800	95.200	22.4000	14.2800	2.64750	1.590	0.510
194	2LOW	MP	AN	84	15	4	78.347	20.2567	3.44689	30.4209	6.56550	36.960	105.613	68.6532	16.3660	2.32000	1.420	0.470
195	2LOW	MP	AN	85	15	4	.	.	.	.	.	36.960	65.772	28.8120	15.7360	.	.	.
196	2LOW	MP	KN	83	15	4	84.413	20.2010	3.51570	28.7380	6.69657	72.800	103.040	30.2400	99.1200	2.55000	1.500	0.510

Table 1. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	CCBUP	MGSIL	MGCORN	FN	FNRSN	RSN	RSNDEEP	EARLN	GRAINN	STOVN
197	2LOW	MP	KN	84	15	4	66.061	21.0787	3.10305	27.5045	5.91057	36.96	81.802	44.842	14.958	2.2500	1.33	0.53
198	2LOW	MP	KN	85	15	4	.	.	.	.	.	36.96	62.160	25.200	53.228	.	.	.
199	2LOW	NT	AN	83	15	4	92.700	14.5477	3.66537	28.0898	6.98165	72.80	55.200	22.400	14.280	3.0500	1.58	0.41
200	2LOW	NT	AN	84	15	4	69.624	21.6049	3.06313	28.0432	5.83454	36.96	80.881	43.921	23.946	2.2500	1.42	0.50
201	2LOW	NT	AN	85	15	4	.	.	.	.	.	36.96	54.292	17.332	8.092	.	.	.
202	2LOW	NT	KN	83	15	4	72.950	20.7874	3.20940	26.7449	6.11329	72.80	103.040	30.240	59.120	2.5700	1.42	0.54
203	2LOW	NT	KN	84	15	4	65.296	17.2302	2.89309	25.9341	5.51065	36.96	74.712	37.752	17.049	2.1500	1.41	0.45
204	2LOW	NT	KN	85	15	4	.	.	.	.	.	36.96	49.280	12.320	7.280	.	.	.
205	3MED	CH	AN	83	15	4	98.781	21.6383	3.78601	29.6064	7.21145	109.76	136.360	26.600	119.280	3.1975	1.63	0.56
206	3MED	CH	AN	84	15	4	73.905	21.4354	3.29794	29.9321	6.28178	75.04	147.179	72.139	25.438	2.3800	1.40	0.47
207	3MED	CH	AN	85	15	4	.	.	.	.	.	75.04	99.904	24.864	16.940	.	.	.
208	3MED	CH	KN	83	15	4	85.406	20.2481	3.44233	27.1657	6.55681	109.76	134.120	24.360	18.760	3.0325	1.55	0.54
209	3MED	CH	KN	84	15	4	79.855	24.6028	3.46447	31.0407	6.59899	75.04	125.541	50.501	23.022	2.5000	1.44	0.54
210	3MED	CH	KN	85	15	4	.	.	.	.	.	75.04	89.152	14.112	8.764	.	.	.
211	3MED	MP	AN	83	15	4	106.745	31.0031	3.96950	33.0850	7.56094	109.76	136.360	26.600	119.280	2.9525	1.68	0.67
212	3MED	MP	AN	84	15	4	101.044	24.1644	3.87274	32.8211	7.37664	75.04	157.637	82.597	27.737	2.7600	1.63	0.55
213	3MED	MP	AN	85	15	4	.	.	.	.	.	75.04	134.232	59.192	57.260	.	.	.
214	3MED	MP	KN	83	15	4	102.018	26.1680	3.62124	31.2371	6.89761	109.76	134.120	24.360	18.760	2.7575	1.76	0.60
215	3MED	MP	KN	84	15	4	83.976	24.9896	3.52099	31.5003	6.70664	75.04	132.569	57.525	22.252	2.3900	1.45	0.54
216	3MED	MP	KN	85	15	4	.	.	.	.	.	75.04	97.552	22.512	18.172	.	.	.
217	3MED	NT	AN	83	15	4	89.110	25.3485	3.39451	26.6130	6.46574	109.76	136.360	26.600	119.280	2.9450	1.64	0.66
218	3MED	NT	AN	84	15	4	74.990	20.3787	3.32260	29.0634	6.32876	75.04	146.759	71.719	21.647	2.5600	1.41	0.51
219	3MED	NT	AN	85	15	4	.	.	.	.	.	75.04	101.724	26.684	16.548	.	.	.
220	3MED	NT	KN	83	15	4	91.763	21.3187	3.69853	29.2676	7.04482	109.76	134.120	24.360	18.760	2.8250	1.55	0.56
221	3MED	NT	KN	84	15	4	62.845	17.0284	2.92997	27.0963	5.58090	75.04	122.091	47.051	27.373	2.2200	1.34	0.41
222	3MED	NT	KN	85	15	4	.	.	.	.	.	75.04	91.784	16.744	10.080	.	.	.
223	4HIGH	CH	AN	83	15	4	110.731	28.6649	4.19256	33.4132	7.98583	170.24	197.120	26.880	28.280	2.9775	1.65	0.69
224	4HIGH	CH	AN	84	15	4	81.628	26.5601	3.42252	30.3962	6.51909	112.00	209.152	97.152	32.572	2.7200	1.45	0.61
225	4HIGH	CH	AN	85	15	4	.	.	.	.	.	112.00	185.780	73.780	54.012	.	.	.
226	4HIGH	CH	KN	83	15	4	100.064	24.5714	3.98174	32.1647	7.58426	170.24	192.920	22.680	25.760	3.0900	1.57	0.55
227	4HIGH	CH	KN	84	15	4	85.982	25.2764	3.60509	32.2906	6.86684	112.00	163.884	51.884	32.978	2.6800	1.45	0.54
228	4HIGH	CH	KN	85	15	4	.	.	.	.	.	112.00	139.496	27.496	17.752	.	.	.
229	4HIGH	MP	AN	83	15	4	123.468	32.2989	3.97602	32.1717	7.57336	170.24	197.120	26.880	28.280	3.2000	1.94	0.74
230	4HIGH	MP	AN	84	15	4	114.487	34.7937	4.30869	38.4207	8.20703	112.00	249.290	137.290	30.397	2.9400	1.66	0.60
231	4HIGH	MP	AN	85	15	4	.	.	.	.	.	112.00	217.840	105.840	75.404	.	.	.
232	4HIGH	MP	KN	83	15	4	102.824	25.3989	3.73477	31.1567	7.11384	170.24	192.920	22.680	25.760	3.0425	1.72	0.61
233	4HIGH	MP	KN	84	15	4	95.197	25.3684	3.76412	32.1854	7.16976	112.00	198.366	86.366	23.015	2.6800	1.58	0.58
234	4HIGH	MP	KN	85	15	4	.	.	.	.	.	112.00	143.752	31.752	34.272	.	.	.
235	4HIGH	NT	AN	83	15	4	111.351	31.5069	3.88629	32.9270	7.40245	170.24	197.120	26.880	28.280	3.3375	1.79	0.67
236	4HIGH	NT	AN	84	15	4	94.652	26.6056	4.05015	34.9186	7.71458	112.00	199.634	87.634	23.500	2.7300	1.46	0.54
237	4HIGH	NT	AN	85	15	4	.	.	.	.	.	112.00	162.484	50.484	36.680	.	.	.
238	4HIGH	NT	KN	83	15	4	100.446	29.3532	3.73524	29.7460	7.11473	170.24	192.920	22.680	25.760	3.0475	1.66	0.70
239	4HIGH	NT	KN	84	15	4	91.584	21.6524	3.81436	32.7072	7.26546	112.00	176.310	64.310	29.350	2.5200	1.50	0.47
240	4HIGH	NT	KN	85	15	4	.	.	.	.	.	112.00	145.348	33.348	21.784	.	.	.

Table 2. Data summary, oats, E.C. site.

OBS	FERT	TILL	SOURCE	YEAR	_TYPE_	_FREQ_	OATLN	GRAINM	KGNUP	MGOATL	KGGRAIN	FN	RSN	FNRSN	RSNDEEP	PH2O
1				.	0	264	1.47798	1.94827	84.860	14.1079	2816.43	64.782	38.3864	102.908	18.8209	68.7117
2				83	1	72	1.49750	2.00208	88.488	14.4735	2360.13	88.200	20.4867	108.687	19.1333	68.1412
3				84	1	96	1.46333	1.90792	82.177	13.8375	3158.65	56.000	66.3411	122.341	20.1210	69.1396
4				85	1	96	.	.	.	.	.	56.000	23.5474	78.356	17.2865	.
5			AN	.	2	132	1.51250	1.94119	85.702	14.0661	2797.88	64.782	42.6201	107.041	19.9698	68.9750
6			KN	.	2	132	1.44345	1.95536	83.040	14.1493	2834.98	64.782	34.1527	98.574	17.6721	68.4484
7			AN	83	3	36	1.51917	2.02389	87.522	14.0343	2276.08	88.200	18.6667	106.867	21.7467	68.5535
8			AN	84	3	48	1.50750	1.87917	86.104	14.0892	3189.23	56.000	77.5747	133.575	19.6252	69.2911
9			AN	85	3	48	.	.	.	.	.	56.000	25.2691	80.078	18.9817	.
10			KN	83	3	36	1.47583	1.98028	89.427	14.9005	2444.18	88.200	22.3067	110.507	16.5200	67.7290
11			KN	84	3	48	1.41917	1.93667	78.249	13.5858	3128.07	56.000	55.1075	111.107	20.6169	68.9880
12			KN	85	3	48	.	.	.	.	.	56.000	21.8257	76.634	15.5913	.
13		CH		.	4	88	1.46250	1.91143	83.687	14.0366	2786.52	64.782	36.3040	99.988	16.8607	68.3646
14		MP		.	4	88	1.50268	2.05339	87.467	14.3594	2950.17	64.782	41.7111	105.493	21.8527	68.5033
15		NT		.	4	88	1.46875	1.88000	83.473	13.9322	2712.60	64.782	37.0968	101.879	17.7493	69.2672
16		CH		83	5	24	1.51083	2.00500	90.766	14.7512	2401.90	88.200	20.4867	108.687	19.0867	68.0114
17		CH		84	5	32	1.42625	1.84125	78.377	13.5007	3074.98	56.000	61.2965	117.297	16.7289	68.6295
18		CH		85	5	32	.	.	.	.	.	56.000	22.2992	74.566	15.3230	.
19		MP		83	5	24	1.50292	2.03625	84.251	13.7142	2417.54	88.200	20.4867	108.687	19.1333	67.8104
20		MP		84	5	32	1.50250	2.06625	89.778	14.8231	3349.64	56.000	75.3375	131.337	26.4880	69.0230
21		MP		85	5	32	.	.	.	.	.	56.000	24.0030	80.003	19.2570	.
22		NT		83	5	24	1.47875	1.96500	90.271	14.9235	2260.95	88.200	20.4867	108.687	19.1800	68.6019
23		NT		84	5	32	1.46125	1.81625	78.375	13.1887	3051.34	56.000	62.3892	118.389	17.1461	69.7662
24		NT		85	5	32	.	.	.	.	.	56.000	24.2620	80.262	17.2795	.
25		CH	AN	.	6	44	1.53571	1.89286	88.789	14.2047	2781.88	64.782	40.3416	104.025	17.8123	68.5799
26		CH	KN	.	6	44	1.38929	1.93000	78.584	13.8686	2791.15	64.782	32.2664	95.950	15.9091	68.1494
27		MP	AN	.	6	44	1.54179	2.06786	90.684	14.4456	2848.65	64.782	46.6434	111.425	23.0165	68.7177
28		MP	KN	.	6	44	1.46357	2.03893	84.365	14.2763	3051.68	64.782	36.7788	101.561	20.6889	68.2889
29		NT	AN	.	6	44	1.46000	1.86286	80.776	13.5615	2763.11	64.782	40.8235	105.605	19.0805	69.6274
30		NT	KN	.	6	44	1.47750	1.89714	86.170	14.3029	2662.10	64.782	33.3701	98.152	16.4182	68.9070
31		CH	AN	83	7	12	1.56667	2.02667	89.781	13.9791	2246.26	88.200	18.6667	106.857	21.6533	68.2018
32		CH	AN	84	7	16	1.51250	1.79250	88.045	14.3739	3183.60	56.000	73.0331	129.033	17.3229	68.8634
33		CH	AN	85	7	16	.	.	.	.	.	56.000	22.8107	75.077	15.4210	.
34		CH	KN	83	7	12	1.45500	1.98333	91.752	15.5233	2557.55	88.200	22.3067	110.507	16.5200	67.8210
35		CH	KN	84	7	16	1.34000	1.89000	68.709	12.6275	2966.35	56.000	49.5600	105.560	16.1350	68.3957
36		CH	KN	85	7	16	.	.	.	.	.	56.000	21.7877	74.054	15.2250	.
37		MP	AN	83	7	12	1.52417	2.05167	85.140	13.5285	2296.20	88.200	18.6667	106.867	21.7467	68.2945
38		MP	AN	84	7	16	1.55500	2.08000	94.496	15.0751	3262.98	56.000	86.2764	142.276	24.7044	69.0351
39		MP	AN	85	7	16	.	.	.	.	.	56.000	27.9930	83.993	22.2810	.
40		MP	KN	83	7	12	1.48167	2.02083	83.437	13.8844	2538.87	88.200	22.3067	110.507	16.5200	67.3263
41		MP	KN	84	7	16	1.45000	2.05250	85.060	14.5701	3436.29	56.000	64.3986	120.399	28.2716	69.0109
42		MP	KN	85	7	16	.	.	.	.	.	56.000	20.0130	76.013	16.2330	.
43		NT	AN	83	7	12	1.46667	1.99333	87.448	14.5532	2285.77	88.200	18.6667	106.867	21.8400	69.1642
44		NT	AN	84	7	16	1.45500	1.76500	75.772	12.8177	3121.11	56.000	73.4146	129.415	16.8483	69.9749
45		NT	AN	85	7	16	.	.	.	.	.	56.000	24.8500	80.850	19.2430	.
46		NT	KN	83	7	12	1.49083	1.93667	93.094	15.2939	2236.13	88.200	22.3067	110.507	16.5200	68.0396
47		NT	KN	84	7	16	1.46750	1.86750	80.978	13.5598	2981.57	56.000	51.3639	107.364	17.4440	69.5575
48		NT	KN	85	7	16	.	.	.	.	.	56.000	23.6740	79.674	15.3160	.
49	1ZERO			.	8	66	1.29952	1.82857	53.087	10.1739	2180.20	0.000	24.6683	24.668	11.6989	67.1710
50	2LOW			.	8	66	1.43857	1.91452	82.395	14.1730	2938.33	46.735	32.6651	79.400	15.2975	68.4791
51	3MED			.	8	66	1.53929	2.00000	98.539	15.9640	3052.58	84.509	41.8065	126.316	21.0297	68.9106
52	4HIGH			.	8	66	1.63452	2.05000	105.362	16.1224	3094.60	127.884	54.9062	183.286	27.2576	70.2861
53	1ZERO			83	9	18	1.28556	1.88444	43.577	9.4287	1585.93	0.000	11.2000	11.200	7.8400	65.4080
54	1ZERO			84	9	24	1.31000	1.78667	56.469	10.7327	2625.91	0.000	39.7913	39.791	13.7293	68.4932
55	1ZERO			85	9	24	.	.	.	.	.	0.000	19.6467	19.647	12.5627	.

Table 2. Continued

OBS	FERT	TILL	SOURCE	YEAR	_TYPE_	_FREQ_	OATLN	GRAINN	KGNUP	MGOATL	KGGRAIN	FN	RSN	FNRSN	RSNDEEP	PH2O
56	2LOW			83	9	18	1.47889	1.97833	92.922	15.4978	2528.04	72.800	13.440	86.240	9.5200	68.0542
57	2LOW			84	9	24	1.40833	1.86667	74.938	13.2347	3246.06	36.960	57.041	94.001	20.0695	68.7978
58	2LOW			85	9	24	.	.	.	.	.	36.960	22.708	59.668	14.8587	.
59	3MED			83	9	18	1.58056	2.07333	105.768	16.7338	2647.23	109.760	28.684	138.444	28.3733	68.9420
60	3MED			84	9	24	1.50833	1.94500	93.117	15.3866	3356.59	75.040	70.565	145.605	20.0177	68.8871
61	3MED			85	9	24	.	.	.	.	.	75.040	22.890	97.930	16.5340	.
62	4HIGH			83	9	18	1.64500	2.07222	106.933	16.2907	2679.32	170.240	28.622	198.862	30.8000	70.1608
63	4HIGH			84	9	24	1.62667	2.03333	104.183	15.9961	3406.06	112.000	97.967	209.967	26.6677	70.3801
64	4HIGH			85	9	24	.	.	.	.	.	112.000	29.436	141.436	25.1907	.
65	1ZERO		AN	.	10	33	1.29333	1.76143	52.888	10.1540	2178.19	0.000	25.646	25.646	12.2837	67.1984
66	1ZERO		KN	.	10	33	1.30571	1.87571	53.286	10.1937	2182.21	0.000	23.690	23.690	11.1141	67.1435
67	2LOW		AN	.	10	33	1.50143	1.91952	89.053	14.6208	2954.24	46.735	37.136	83.870	14.0302	68.9670
68	2LOW		KN	.	10	33	1.37571	1.90952	76.053	13.7465	2922.43	46.735	28.194	74.929	16.5648	67.9912
69	3MED		AN	.	10	33	1.58095	2.03381	100.450	15.8880	3060.42	84.509	44.482	128.991	23.1002	69.0537
70	3MED		KN	.	10	33	1.49762	1.96619	96.627	16.0399	3044.74	84.509	39.131	123.640	18.9592	68.7676
71	4HIGH		AN	.	10	33	1.67429	2.05000	104.530	15.6278	2998.68	127.884	63.860	192.240	30.4650	70.6808
72	4HIGH		KN	.	10	33	1.59476	2.05000	106.193	16.6169	3190.53	127.884	45.953	174.333	24.0501	69.8914
73	1ZERO		AN	83	11	9	1.25778	1.89222	45.911	9.0945	1522.71	0.000	10.080	10.080	8.5867	65.4456
74	1ZERO		AN	84	11	12	1.32000	1.66333	58.120	10.9486	2669.81	0.000	42.919	42.919	14.1708	68.5130
75	1ZERO		AN	85	11	12	.	.	.	.	.	0.000	20.048	20.048	13.1693	.
76	1ZERO		KN	83	11	9	1.31333	1.87667	51.243	9.7629	1649.15	0.000	12.320	12.320	7.0933	65.3704
77	1ZERO		KN	84	11	12	1.30000	1.91000	54.819	10.5168	2582.01	0.000	36.663	36.663	13.2879	68.4734
78	1ZERO		KN	85	11	12	.	.	.	.	.	0.000	19.245	19.245	11.9560	.
79	2LOW		AN	83	11	9	1.55222	2.01222	100.355	15.7220	2434.38	72.800	14.560	87.360	10.0800	68.9132
80	2LOW		AN	84	11	12	1.46333	1.85000	81.519	13.8867	3344.13	36.960	67.086	104.046	15.1564	69.0074
81	2LOW		AN	85	11	12	.	.	.	.	.	36.960	24.117	61.077	15.8667	.
82	2LOW		KN	83	11	9	1.40556	1.94444	86.315	15.2984	2621.69	72.800	12.320	85.120	8.9600	67.1951
83	2LOW		KN	84	11	12	1.35333	1.89333	68.356	12.5826	3147.99	36.960	46.996	83.956	24.9825	68.5882
84	2LOW		KN	85	11	12	.	.	.	.	.	36.960	21.299	58.259	13.8507	.
85	3MED		AN	83	11	9	1.58667	2.10556	101.609	16.0328	2598.48	109.760	23.022	132.782	32.4800	69.1008
86	3MED		AN	84	11	12	1.57667	1.98000	99.581	15.7794	3406.87	75.040	81.549	156.589	22.3655	69.0185
87	3MED		AN	85	11	12	.	.	.	.	.	75.040	23.511	98.551	16.8000	.
88	3MED		KN	83	11	9	1.57444	2.04111	109.926	17.4348	2695.98	109.760	34.347	144.107	24.2667	68.7832
89	3MED		KN	84	11	12	1.44000	1.91000	86.653	14.9938	3306.30	75.040	59.580	134.620	17.66[illegible]	68.7558
90	3MED		KN	85	11	12	.	.	.	.	.	75.040	22.269	97.309	16.2680	.
91	4HIGH		AN	83	11	9	1.68000	2.08556	103.640	15.4754	2548.74	170.240	27.004	197.244	35.8400	70.7544
92	4HIGH		AN	84	11	12	1.67000	2.02333	105.198	15.7422	3336.13	112.000	118.744	230.744	26.8081	70.6256
93	4HIGH		AN	85	11	12	.	.	.	.	.	112.000	34.140	146.140	30.0907	.
94	4HIGH		KN	83	11	9	1.61000	2.05899	110.226	17.1060	2809.91	170.240	30.240	200.480	25.7600	69.5671
95	4HIGH		KN	84	11	12	1.58333	2.04333	103.169	16.2501	3475.99	112.000	77.190	189.190	26.5272	70.1346
96	4HIGH		KN	85	11	12	.	.	.	.	.	112.000	24.732	136.732	20.2907	.
97	1ZERO	CH		.	12	22	1.25857	1.83857	51.150	10.1125	2064.60	0.000	24.073	24.073	11.1700	66.8350
98	1ZERO	MP		.	12	22	1.33714	2.00071	60.002	11.1853	2496.86	0.000	27.012	27.012	12.3169	67.0471
99	1ZERO	NT		.	12	22	1.30286	1.64643	48.109	9.2237	1979.15	0.000	22.920	22.920	11.6098	67.6308
100	2LOW	CH		.	12	22	1.45143	1.88286	84.792	14.3823	2902.52	46.735	33.710	80.445	12.5623	68.1522
101	2LOW	MP		.	12	22	1.45643	1.98071	84.101	14.3034	3022.38	46.735	33.060	79.795	20.1855	68.2339
102	2LOW	NT		.	12	22	1.40786	1.89000	78.413	13.8427	2890.10	46.735	31.225	77.959	13.1447	69.0512
103	3MED	CH		.	12	22	1.49786	1.91071	93.117	15.5236	3043.40	84.509	38.501	123.010	20.3285	68.6353
104	3MED	MP		.	12	22	1.60071	2.13000	102.899	16.0731	3154.08	84.509	48.207	132.716	23.0247	68.9532
105	3MED	NT		.	12	22	1.51929	1.95929	99.600	16.2952	2960.25	84.509	38.711	123.220	19.7359	69.1434
106	4HIGH	CH		.	12	22	1.64214	2.01357	105.688	16.1280	3135.55	127.884	50.194	179.665	23.3820	69.8360
107	4HIGH	MP		.	12	22	1.61643	2.10214	102.625	15.8718	3127.34	127.884	58.564	186.449	31.8839	69.7790
108	4HIGH	NT		.	12	22	1.64500	2.0342[illegible]	107.772	16.3673	3020.92	127.884	55.532	183.415	26.5069	71.2433
109	1ZERO	CH		83	13	6	1.25000	1.89000	51.199	10.1448	1561.82	0.000	11.200	11.200	7.8400	64.8201
110	1ZERO	CH		84	13	8	1.26500	1.80000	51.114	10.0883	2441.63	0.000	39.026	39.026	13.3434	68.3462

Table 2. Continued

OBS	FERT	TILL	SOURCE	YEAR	_TYPE_	_FREQ_	OATLN	GRAINN	KGNUP	MGOATL	KGGRAIN	FN	RSN	FNRSN	RSNDEEP	PH2O
111	1ZERO	CH		85	13	8	.	.	.	.	.	0.000	18.774	18.774	11.4940	.
112	1ZERO	MP		83	13	6	1.30000	1.94833	49.446	9.5250	1718.62	0.000	11.200	11.200	7.8400	65.4970
113	1ZERO	MP		84	13	8	1.36500	2.04000	67.919	12.4306	3080.54	0.000	45.612	45.612	14.8876	68.2098
114	1ZERO	MP		85	13	8	.	.	.	.	.	0.000	20.272	20.272	13.1040	.
115	1ZERO	NT		83	13	6	1.30667	1.81500	45.087	8.6163	1477.35	0.000	11.200	11.200	7.8400	65.9070
116	1ZERO	NT		84	13	8	1.30000	1.52000	50.375	9.6792	2355.49	0.000	34.735	34.735	12.9570	68.9237
117	1ZERO	NT		85	13	8	.	.	.	.	.	0.000	19.894	19.894	13.0900	.
118	2LOW	CH		83	13	6	1.54000	1.96667	101.016	16.3158	2629.46	72.800	13.440	86.240	9.5200	68.2857
119	2LOW	CH		84	13	8	1.38500	1.82000	72.624	12.9322	3107.32	36.960	60.756	97.716	14.5124	68.0521
120	2LOW	CH		85	13	8	.	.	.	.	.	36.960	21.868	58.828	12.8940	.
121	2LOW	MP		83	13	6	1.47167	2.01500	86.428	14.2989	2376.41	72.800	13.440	86.240	9.5200	67.8159
122	2LOW	MP		84	13	8	1.44500	1.95500	82.647	14.3062	3506.85	36.960	57.512	94.472	32.2140	68.5474
123	2LOW	MP		85	13	8	.	.	.	.	.	36.960	23.324	60.284	16.1560	.
124	2LOW	NT		83	13	6	1.42500	1.95333	90.240	15.6787	2578.24	72.800	13.440	86.240	9.5200	68.0509
125	2LOW	NT		84	13	8	1.39500	1.82500	69.542	12.4657	3124.00	36.960	52.856	89.816	13.4820	69.7940
126	2LOW	NT		85	13	8	.	.	.	.	.	36.960	22.932	59.892	15.5260	.
127	3MED	CH		83	13	6	1.58833	2.07167	100.767	15.9289	2654.73	109.760	28.747	138.507	28.1867	68.8722
128	3MED	CH		84	13	8	1.43000	1.79000	87.379	15.2196	3334.90	75.040	61.036	136.076	18.6214	68.4576
129	3MED	CH		85	13	8	.	.	.	.	.	75.040	23.282	98.322	16.1420	.
130	3MED	MP		83	13	6	1.60167	2.11000	99.359	15.5236	2810.07	109.760	28.747	138.507	28.3733	68.7403
131	3MED	MP		84	13	8	1.60000	2.14500	105.554	16.4851	3412.09	75.040	88.204	163.244	24.2998	69.1130
132	3MED	MP		85	13	8	.	.	.	.	.	75.040	22.806	97.846	17.7380	.
133	3MED	NT		83	13	6	1.55167	2.03833	117.176	18.7489	2476.89	109.760	28.560	138.320	28.5600	69.2135
134	3MED	NT		84	13	8	1.49500	1.90000	86.417	14.4549	3322.77	75.040	62.454	137.494	17.1318	69.0908
135	3MED	NT		85	13	8	.	.	.	.	.	75.040	22.582	97.622	15.7220	.
136	4HIGH	CH		83	13	6	1.66500	2.09167	110.082	16.6152	2761.61	170.240	28.560	198.800	30.8000	70.0676
137	4HIGH	CH		84	13	8	1.62500	1.95500	102.392	15.7626	3416.01	112.000	84.368	196.368	20.4386	69.6622
138	4HIGH	CH		85	13	8	.	.	.	.	.	112.000	26.264	138.264	20.7620	.
139	4HIGH	MP		83	13	6	1.63833	2.07167	102.135	15.6067	2765.05	170.240	28.560	198.800	30.8000	69.1885
140	4HIGH	MP		84	13	8	1.60000	2.12500	102.993	16.0706	3399.06	112.000	110.022	222.022	34.5506	70.2218
141	4HIGH	MP		85	13	8	.	.	.	.	.	112.000	29.610	141.610	30.0300	.
142	4HIGH	NT		83	13	6	1.63167	2.05333	108.582	16.6501	2511.31	170.240	28.747	198.987	30.8000	71.2262
143	4HIGH	NT		84	13	8	1.65500	2.02000	107.165	16.1551	3403.12	112.000	99.512	211.512	25.0138	71.2562
144	4HIGH	NT		85	13	8	.	.	.	.	.	112.000	31.640	143.640	24.7800	.
145	1ZERO	CH	AN	.	14	11	1.26286	1.83571	51.553	10.1158	2112.96	0.000	24.909	24.909	10.9159	66.6798
146	1ZERO	CH	KN	.	14	11	1.25429	1.84143	50.748	10.1092	2016.23	0.000	23.237	23.237	11.4240	66.9902
147	1ZERO	MP	AN	.	14	11	1.35714	1.93286	61.750	11.3190	2445.70	0.000	30.263	30.263	13.9542	66.9111
148	1ZERO	MP	KN	.	14	11	1.31714	2.06857	58.254	11.0517	2548.02	0.000	23.761	23.761	10.6797	67.1831
149	1ZERO	NT	AN	.	14	11	1.26000	1.51571	45.360	9.0273	1975.92	0.000	21.767	21.767	11.9809	68.0043
150	1ZERO	NT	KN	.	14	11	1.34571	1.77714	50.857	9.4201	1982.38	0.000	24.073	24.073	11.2387	67.2573
151	2LOW	CH	AN	.	14	11	1.57571	1.88000	100.079	15.8254	2869.73	46.735	41.053	87.788	12.6448	68.7570
152	2LOW	CH	KN	.	14	11	1.32714	1.88571	69.505	12.9392	2936.31	46.735	26.368	73.102	12.4799	67.5474
153	2LOW	MP	AN	.	14	11	1.53000	1.99714	89.572	14.2423	2970.97	46.735	37.017	83.752	15.0844	68.9453
154	2LOW	MP	KN	.	14	11	1.38286	1.96429	79.412	14.3558	3073.79	46.735	29.104	75.839	25.2865	67.5225
155	2LOW	NT	AN	.	14	11	1.39857	1.88143	77.583	13.7408	3023.01	46.735	33.337	80.072	14.3615	69.1987
156	2LOW	NT	KN	.	14	11	1.41714	1.87857	79.243	13.9446	2757.19	45.735	29.112	75.946	11.9280	68.9037
157	3MED	CH	AN	.	14	11	1.57571	1.86714	76.922	15.4127	3078.32	84.509	41.572	125.582	22.0579	68.8754
158	3MED	CH	KN	.	14	11	1.42000	1.95429	89.311	15.6345	3008.48	84.509	35.930	120.439	18.5991	68.3952
159	3MED	MP	AN	.	14	11	1.61143	2.22429	104.791	16.2350	3072.03	84.509	50.756	135.265	25.7529	68.7760
160	3MED	MP	KN	.	14	11	1.59000	2.03571	101.007	15.7111	3236.14	84.509	45.658	130.167	20.2964	69.1305
161	3MED	NT	AN	.	14	11	1.55571	2.01000	99.637	16.0162	3030.90	84.509	41.618	126.127	21.4897	69.5098
162	3MED	NT	KN	.	14	11	1.49286	1.90857	99.563	16.5742	2889.59	84.509	35.804	120.313	17.9821	69.7769
163	4HIGH	CH	AN	.	14	11	1.72857	1.98857	106.601	15.4647	3067.52	127.884	55.731	185.203	25.6307	70.0072
164	4HIGH	CH	KN	.	14	11	1.55571	2.03857	104.775	16.7914	3203.58	127.884	44.658	174.130	21.1334	69.6648
165	4HIGH	MP	AN	.	14	11	1.66857	2.11714	106.465	15.0572	2905.90	127.884	63.537	196.421	37.2746	70.2383

Table 2. Continued

OBS	FERT	TILL	SOURCE	YEAR	_TYPE_	_FREQ_	OATLN	GRAINN	KGNUP	MGOATL	KGGRAIN	FN	RSN	FNRSN	RSNDEEP	PH2O
166	4HIGH	MP	KN	.	14	11	1.56429	2.08714	98.786	15.7865	3348.78	127.884	48.5917	176.475	26.4931	69.3196
167	4HIGH	NT	AN	.	14	11	1.62571	2.04429	100.524	15.4617	3022.61	127.884	66.5718	194.455	28.4897	71.7968
168	4HIGH	NT	KN	.	14	11	1.66429	2.02429	115.020	17.2728	3019.23	127.884	44.4915	172.375	24.5239	70.6898
169	1ZERO	CH	AN	83	15	3	1.22667	1.89667	46.292	9.2630	1444.84	0.000	10.0800	10.080	8.5867	64.7089
170	1ZERO	CH	AN	84	15	4	1.29000	1.79000	55.498	10.7555	2614.05	0.000	41.1152	41.115	12.2948	68.1581
171	1ZERO	CH	AN	85	15	4	.	.	.	.	.	0.000	19.8240	19.824	11.2840	.
172	1ZERO	CH	KN	83	15	3	1.27333	1.88333	56.106	11.0266	1678.79	0.000	12.3200	12.320	7.0933	64.9313
173	1ZERO	CH	KN	84	15	4	1.24000	1.81000	46.729	9.4212	2269.31	0.000	36.9376	36.938	14.3920	68.5343
174	1ZERO	CH	KN	85	15	4	.	.	.	.	.	0.000	17.7240	17.724	11.7040	.
175	1ZERO	MP	AN	83	15	3	1.30000	1.92333	48.719	9.3816	1569.46	0.000	10.0800	10.080	8.5867	65.2456
176	1ZERO	MP	AN	84	15	4	1.40000	1.94000	71.523	12.7720	3102.88	0.000	53.2924	53.292	17.4020	68.1602
177	1ZERO	MP	AN	85	15	4	.	.	.	.	.	0.000	22.3720	22.372	14.5320	.
178	1ZERO	MP	KN	83	15	3	1.30000	1.97333	50.173	9.6684	1867.78	0.000	12.3200	12.320	7.0933	65.7483
179	1ZERO	MP	KN	84	15	4	1.33000	2.14000	64.314	12.0892	3058.21	0.000	37.9316	37.932	12.3732	68.2593
180	1ZERO	MP	KN	85	15	4	.	.	.	.	.	0.000	18.1720	18.172	11.6760	.
181	1ZERO	NT	AN	83	15	3	1.24667	1.85667	42.723	8.6390	1553.83	0.000	10.0800	10.080	8.5867	66.3824
182	1ZERO	NT	AN	84	15	4	1.27000	1.26000	47.338	9.3185	2292.48	0.000	34.3504	34.350	12.8156	69.2207
183	1ZERO	NT	AN	85	15	4	.	.	.	.	.	0.000	17.9480	17.948	13.6920	.
184	1ZERO	NT	KN	83	15	3	1.36667	1.77333	47.450	8.5937	1400.87	0.000	12.3200	12.320	7.0933	65.4315
185	1ZERO	NT	KN	84	15	4	1.33000	1.78000	53.412	10.0399	2418.50	0.000	35.1204	35.120	13.0984	68.6267
186	1ZERO	NT	KN	85	15	4	.	.	.	.	.	0.000	21.8400	21.840	12.4880	.
187	2LOW	CH	AN	83	15	3	1.66333	1.98667	113.594	17.0709	2429.76	72.800	14.5600	87.360	10.0800	68.9808
188	2LOW	CH	AN	84	15	4	1.51000	1.80000	89.943	14.8913	3197.96	36.960	80.1920	117.152	15.1172	68.5891
189	2LOW	CH	AN	85	15	4	.	.	.	.	.	36.960	21.7840	58.744	12.0960	.
190	2LOW	CH	KN	83	15	3	1.41667	1.94667	88.439	15.5607	2829.17	72.800	12.3200	85.120	8.9600	67.5905
191	2LOW	CH	KN	84	15	4	1.26000	1.84000	55.304	10.9730	3016.67	36.960	41.3196	78.280	13.9076	67.5150
192	2LOW	CH	KN	85	15	4	.	.	.	.	.	36.960	21.9520	58.912	13.6920	.
193	2LOW	MP	AN	83	15	3	1.55667	2.06000	97.889	14.4443	2356.66	72.800	14.5600	87.360	10.0800	69.2847
194	2LOW	MP	AN	84	15	4	1.51000	1.95000	85.413	14.1412	3431.70	36.960	63.3248	100.285	15.3580	68.6908
195	2LOW	MP	AN	85	15	4	.	.	.	.	.	36.960	27.5520	64.512	18.5640	.
196	2LOW	MP	KN	83	15	3	1.38667	1.97000	78.787	14.2020	2396.16	72.800	12.3200	85.120	8.9600	66.3471
197	2LOW	MP	KN	84	15	4	1.38000	1.96000	79.880	14.4711	3582.00	36.960	51.6992	88.659	49.0700	68.4040
198	2LOW	MP	KN	85	15	4	.	.	.	.	.	36.960	19.0960	56.056	13.7480	.
199	2LOW	NT	AN	83	15	3	1.43667	1.99000	88.760	15.2249	2516.74	72.800	14.5600	87.360	10.0800	68.4740
200	2LOW	NT	AN	84	15	4	1.37000	1.80000	69.200	12.6277	3402.71	36.960	57.7416	94.702	14.9940	69.7423
201	2LOW	NT	AN	85	15	4	.	.	.	.	.	36.960	23.0160	59.976	16.9400	.
202	2LOW	NT	KN	83	15	3	1.41333	1.91667	91.720	16.1326	2639.74	72.800	12.3200	85.120	8.9600	67.6477
203	2LOW	NT	KN	84	15	4	1.42000	1.85000	69.885	12.3036	2845.28	36.960	47.9696	84.930	11.9700	69.8457
204	2LOW	NT	KN	85	15	4	.	.	.	.	.	36.960	22.8480	59.808	14.1120	.
205	3MED	CH	AN	83	15	3	1.66333	2.11667	95.469	14.3268	2503.54	109.760	23.1467	132.907	32.1067	68.9190
206	3MED	CH	AN	84	15	4	1.51000	1.68000	98.012	16.2272	3509.41	75.040	72.6292	147.669	22.0472	68.8427
207	3MED	CH	AN	85	15	4	.	.	.	.	.	75.040	22.9600	98.000	14.5320	.
208	3MED	CH	KN	83	15	3	1.51333	2.02667	106.066	17.5310	2805.92	109.760	34.3467	144.107	24.2667	68.8254
209	3MED	CH	KN	84	15	4	1.35000	1.90000	76.745	14.2121	3160.39	75.040	49.4424	124.482	15.1956	68.0726
210	3MED	CH	KN	85	15	4	.	.	.	.	.	75.040	23.6040	98.644	17.7520	.
211	3MED	MP	AN	83	15	3	1.56000	2.15000	97.267	15.5716	2770.23	109.760	23.1467	132.907	32.4800	68.2107
212	3MED	MP	AN	84	15	4	1.65000	2.28000	110.435	16.7325	3298.38	75.040	98.0280	173.068	29.1284	69.1999
213	3MED	MP	AN	85	15	4	.	.	.	.	.	75.040	24.1920	99.232	17.3320	.
214	3MED	MP	KN	83	15	3	1.64333	2.07000	101.451	15.4756	2849.90	109.760	34.3467	144.107	24.2667	69.2698
215	3MED	MP	KN	84	15	4	1.55000	2.01000	100.674	16.2377	3525.81	75.040	78.3904	153.420	19.4712	69.0260
216	3MED	MP	KN	85	15	4	.	.	.	.	.	75.040	21.4200	96.460	18.1440	.
217	3MED	NT	AN	83	15	3	1.53667	2.05000	112.091	18.1999	2521.67	109.760	22.7733	132.533	32.8533	70.1725
218	3MED	NT	AN	84	15	4	1.57000	1.98000	90.246	14.3784	3412.82	75.040	73.9700	149.030	15.9208	69.0128
219	3MED	NT	AN	85	15	4	.	.	.	.	.	75.040	23.3800	98.420	18.5360	.
220	3MED	NT	KN	83	15	3	1.56667	2.02667	122.261	19.2979	2432.11	109.760	34.3467	144.107	24.2667	68.2544

Table 2. Continued

OBS	FERT	TILL	SOURCE	YEAR	_TYPE_	_FREQ_	OATLN	GRAINN	KGNUP	MGOATL	KGGRAIN	FN	RSN	FNRSN	RSNDEEP	PH2O
221	3MEO	NT	KN	84	15	4	1.42000	1.82000	82.539	14.5315	3232.71	75.04	50.918	125.958	18.3428	69.1688
222	3MED	NT	KN	85	15	4	.	.	.	.	.	75.04	21.784	96.824	12.9080	.
223	4HIGH	CH	AN	83	15	3	1.71333	2.10667	103.768	15.2554	2606.92	170.24	26.880	197.120	35.8400	70.1984
224	4HIGH	CH	AN	84	15	4	1.74000	1.90000	108.726	15.6216	3412.98	112.00	98.196	210.196	19.8324	69.8638
225	4HIGH	CH	AN	85	15	4	.	.	.	.	.	112.00	27.963	139.963	23.7720	.
226	4HIGH	CH	KN	83	15	3	1.61667	2.07667	116.396	17.9750	2916.30	170.24	30.240	200.480	25.7600	69.9369
227	4HIGH	CH	KN	84	15	4	1.51000	2.01000	96.058	15.9037	3419.04	112.00	70.540	182.540	21.0448	69.4607
228	4HIGH	CH	KN	85	15	4	.	.	.	.	.	112.00	24.565	136.565	17.7520	.
229	4HIGH	MP	AN	83	15	3	1.69000	2.07333	100.934	15.0217	2488.46	170.24	26.880	197.120	35.8400	70.4371
230	4HIGH	MP	AN	84	15	4	1.66000	2.15000	110.614	16.6587	3218.98	112.00	130.460	242.460	36.9292	70.0893
231	4HIGH	MP	AN	85	15	4	.	.	.	.	.	112.00	37.856	149.856	38.6960	.
232	4HIGH	MP	KN	83	15	3	1.59667	2.07000	103.336	16.1917	3041.65	170.24	30.240	200.480	25.7600	67.9399
233	4HIGH	MP	KN	84	15	4	1.54000	2.10000	95.373	15.4826	3579.14	112.00	89.583	201.583	32.1720	70.3543
234	4HIGH	MP	KN	85	15	4	.	.	.	.	.	112.00	21.364	133.364	21.3640	.
235	4HIGH	NT	AN	83	15	3	1.64667	2.07667	106.218	16.1490	2550.83	170.24	27.253	197.493	35.8400	71.6277
236	4HIGH	NT	AN	84	15	4	1.61000	2.02000	96.254	14.9463	3376.44	112.00	127.576	239.576	23.6628	71.9237
237	4HIGH	NT	AN	85	15	4	.	.	.	.	.	112.00	35.056	147.056	27.8040	.
238	4HIGH	NT	KN	83	15	3	1.61667	2.03000	110.945	17.1512	2471.79	170.24	30.240	200.480	25.7600	70.8246
239	4HIGH	NT	KN	84	15	4	1.70000	2.02000	118.075	17.3640	3429.80	112.00	71.448	183.448	26.3648	70.5887
240	4HIGH	NT	KN	85	15	4	.	.	.	.	.	112.00	28.224	140.224	21.7560	.

Table 3. Data summary, continuous corn, S.E. site.

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	TCTUP	MGSIL	MGCGRN	FN	RSN	FNRSN	RSNOEEP	GRAINN	STCVN
1				.	0	264	60.9166	21.5763	1.25153	84.224	17.7566	2.82115	81.073	38.8892	118.689	34.3156	1.51125	0.550CCO
2				83	1	72	60.9166	21.5763	1.73097	84.224	21.2753	3.90188	93.800	32.5500	126.350	59.6400	1.51125	0.550CCO
3				84	1	96	.	.	0.89196	.	15.1175	2.01061	75.600	44.5655	120.165	35.3645	.	.
4				85	1	96	.	.	.	.	.	.	77.000	36.3825	113.382	20.6045	.	.
5			AN	.	2	132	62.6194	20.4980	1.29177	84.913	18.0278	2.91185	81.073	41.7216	121.522	34.3065	1.50417	C.520833
6			KNIF	.	2	132	59.2138	22.6546	1.21130	83.534	17.4853	2.73046	81.073	36.0568	115.857	34.3246	1.51833	C.579167
7			AN	83	3	36	62.6194	20.4980	1.79616	84.913	21.6551	4.04882	93.800	38.7800	132.580	56.4200	1.50417	0.520833
8			AN	84	3	48	.	.	0.91348	.	15.3074	2.05912	75.600	49.4240	125.024	36.8247	.	.
9			AN	85	3	48	.	.	.	.	.	.	77.000	35.4900	112.490	20.7317	.	.
10			KNIF	83	3	36	59.2138	22.6546	1.66578	83.534	20.8955	3.75493	93.800	26.3200	120.120	62.8600	1.51833	0.579167
11			KNIF	84	3	48	.	.	0.87044	.	14.9277	1.96211	75.600	39.7070	115.307	33.9043	.	.
12			KNIF	85	3	48	.	.	.	.	.	.	77.000	37.2750	114.275	20.4773	.	.
13		CH		.	4	88	56.8746	21.2575	1.20526	79.671	18.0275	2.71685	81.073	36.6535	116.454	35.7444	1.57375	0.558750
14		MP		.	4	88	64.3883	22.5573	1.35124	88.853	18.3490	3.04591	81.073	38.3968	118.197	35.0063	1.47125	0.548750
15		TP		.	4	88	61.4867	20.9141	1.19810	84.147	16.8932	2.70070	81.073	41.6172	121.417	32.1961	1.48875	C.542500
16		CH		83	5	24	56.8746	21.2575	1.53927	79.671	19.5768	3.46976	93.800	32.5500	126.350	59.6400	1.57375	0.558750
17		CH		84	5	32	.	.	0.95475	.	16.8656	2.15216	75.600	41.0833	116.683	37.2109	.	.
18		CH		85	5	32	.	.	.	.	.	.	77.000	34.2755	111.275	22.3300	.	.
19		MP		83	5	24	64.3883	22.5573	1.90766	88.853	23.0741	4.30017	93.800	32.5500	126.350	59.6400	1.47125	0.548750
20		MP		84	5	32	.	.	0.93393	.	14.8052	2.10522	75.600	45.3575	120.958	35.0682	.	.
21		MP		85	5	32	.	.	.	.	.	.	77.000	34.3595	111.359	22.6275	.	.
22		TP		83	5	24	61.4867	20.9141	1.74597	84.147	21.1751	3.93569	93.800	32.5500	126.350	59.6400	1.48875	0.542500
23		TP		84	5	32	.	.	0.78719	.	13.6818	1.77446	75.600	47.2556	122.856	33.8142	.	.
24		TP		85	5	32	.	.	.	.	.	.	77.000	40.5125	117.512	16.8560	.	.
25		CH	AN	.	6	44	58.2877	18.3059	1.24811	78.167	17.7100	2.81343	81.073	39.5356	119.340	35.8613	1.58500	0.495000
26		CH	KNIF	.	6	44	55.4615	24.2092	1.16241	81.176	18.3450	2.62028	81.073	33.7874	113.987	35.6275	1.5625C	0.622500
27		MP	AN	.	6	44	67.8705	23.3598	1.41700	93.255	19.3320	3.19414	81.073	40.8624	120.662	34.4868	1.46750	0.552500
28		MP	KNIF	.	6	44	60.9061	21.7548	1.28549	84.451	17.3660	2.89769	81.073	35.9313	115.731	35.5258	1.47500	0.545000
29		TP	AN	.	6	44	61.6999	19.8282	1.21019	83.318	17.0415	2.72796	81.073	44.7628	124.563	32.5716	1.46CCO	0.515CCO
30		TP	KNIF	.	6	44	61.2736	22.0000	1.18600	84.976	16.7449	2.67344	81.073	38.4717	118.272	31.8206	1.51750	C.570CGO
31		CH	AN	83	7	12	58.2877	18.3059	1.57354	78.167	19.5082	3.54700	93.800	38.7800	132.580	56.4200	1.585CC	0.495C00
32		CH	AN	84	7	16	.	.	1.00404	.	16.3614	2.26326	75.600	46.5941	122.194	39.7712	.	.
33		CH	AN	85	7	16	.	.	.	.	.	.	77.000	32.8650	109.865	21.6720	.	.
34		CH	KNIF	83	7	12	55.4615	24.2092	1.50501	81.176	19.6453	3.39253	93.800	26.3200	120.120	62.8600	1.5625C	0.622500
35		CH	KNIF	84	7	16	.	.	0.90547	.	17.3697	2.04108	75.600	35.5726	111.173	34.6507	.	.
36		CH	KNIF	85	7	16	.	.	.	.	.	.	77.000	35.6860	112.686	22.9880	.	.
37		MP	AN	83	7	12	67.8705	23.3598	2.02494	93.255	24.1169	4.56452	93.800	38.7800	132.580	56.4200	1.4675C	0.5525CC
38		MP	AN	84	7	16	.	.	0.96105	.	15.7432	2.16636	75.600	48.5499	124.150	35.1239	.	.
39		MP	AN	85	7	16	.	.	.	.	.	.	77.000	34.2160	111.216	22.8830	.	.
40		MP	KNIF	83	7	12	60.9061	21.7548	1.79039	84.451	22.0312	4.03582	93.800	26.3200	120.120	62.8600	1.47500	0.545000
41		MP	KNIF	84	7	16	.	.	0.90681	.	13.8871	2.04408	75.600	42.1692	117.765	35.0124	.	.
42		MP	KNIF	85	7	16	.	.	.	.	.	.	77.000	34.5030	111.503	22.3720	.	.
43		TP	AN	83	7	12	61.6999	19.8282	1.79000	83.318	21.3403	4.03494	93.800	38.7800	132.580	56.4200	1.46C00	0.515000
44		TP	AN	84	7	16	.	.	0.77534	.	13.8179	1.74773	75.600	53.1279	128.728	35.5789	.	.
45		TP	AN	85	7	16	.	.	.	.	.	.	77.000	39.3890	116.389	17.6400	.	.
46		TP	KNIF	83	7	12	61.2736	22.0000	1.70194	84.976	21.0100	3.83644	93.800	26.3200	120.120	62.8600	1.5175C	C.570000
47		TP	KNIF	84	7	16	.	.	0.79905	.	13.5461	1.80119	75.600	41.3833	116.983	32.0495	.	.
48		TP	KNIF	85	7	16	.	.	.	.	.	.	77.000	41.6360	118.636	16.0720	.	.
49	1ZERO			.	8	66	29.3620	17.0520	0.84621	47.519	13.3262	1.90749	0.000	23.4541	23.454	22.6279	1.17833	0.493333
50	2LOW			.	8	66	51.1728	17.7247	1.15088	70.543	17.1049	2.59427	55.898	25.3574	79.789	27.3418	1.37833	0.448333

Table 3. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	TGTUP	MGSIL	MGCGRN	FN	RSN	FNRSN	RSNDEEP	GRAINK	STGVK
51	3MED			.	8	66	76.3328	23.6568	1.46423	102.026	19.5547	3.30061	112.611	46.5685	156.776	36.650	1.67667	0.585000
52	4HIGH			.	8	66	86.7987	27.8717	1.54481	116.807	21.0405	3.48224	155.782	60.1769	214.737	50.642	1.81167	0.673333
53	1ZERO			83	9	18	29.3620	17.0520	1.10522	47.519	16.3266	2.49135	0.000	22.4000	22.400	32.480	1.17833	0.493333
54	1ZERO			84	9	24	.	.	0.65195	.	11.0759	1.46959	0.000	27.2753	27.275	27.837	.	.
55	1ZERO			85	9	24	.	.	.	.	.	.	0.000	20.1600	20.160	12.493	.	.
56	2LOW			83	9	18	51.1728	17.7247	1.64545	70.543	20.9177	3.70911	70.560	26.0400	96.600	46.760	1.37833	0.448333
57	2LOW			84	9	24	.	.	0.77996	.	14.2452	1.75815	50.400	28.9767	79.377	30.699	.	.
58	2LOW			85	9	24	.	.	.	.	.	.	50.400	21.3967	71.797	14.275	.	.
59	3MED			83	9	18	76.3328	23.6568	2.03650	102.026	23.6101	4.59060	136.640	31.0800	167.720	59.920	1.67667	0.585000
60	3MED			84	9	24	.	.	1.03503	.	16.5132	2.33313	100.800	54.0932	154.893	37.996	.	.
61	3MED			85	9	24	.	.	.	.	.	.	106.400	46.7880	153.188	23.669	.	.
62	4HIGH			83	9	18	86.7987	27.8717	2.13670	116.807	24.2469	4.81645	168.000	50.6800	218.680	99.400	1.81167	0.673333
63	4HIGH			84	9	24	.	.	1.10090	.	18.6357	2.48159	151.200	67.9168	219.117	44.925	.	.
64	4HIGH			85	9	24	.	.	.	.	.	.	151.200	57.1853	208.385	31.981	.	.
65	1ZERO		AN	.	10	33	31.6238	17.5315	0.91054	50.337	13.7390	2.05249	0.000	24.3746	24.375	23.146	1.18667	0.493333
66	1ZERO		KNIF	.	10	33	27.1001	16.5724	0.78188	44.701	12.9134	1.76248	0.000	22.5337	22.534	22.110	1.17000	0.493333
67	2LOW		AN	.	10	33	54.6000	17.1955	1.19035	73.513	17.4001	2.68323	55.898	28.1116	82.544	27.938	1.40667	0.450000
68	2LOW		KNIF	.	10	33	47.7456	18.2539	1.11142	67.573	16.8097	2.50531	55.898	22.6031	77.035	26.746	1.35000	0.446667
69	3MED		AN	.	10	33	78.1549	21.6488	1.50863	101.975	19.8160	3.40068	112.611	45.2999	155.508	33.034	1.59667	0.523333
70	3MED		KNIF	.	10	33	74.5106	25.6647	1.41984	102.077	19.2935	3.20054	112.611	47.8371	158.045	40.267	1.75667	0.646667
71	4HIGH		AN	.	10	33	86.0987	25.6159	1.55756	113.829	21.1563	3.51098	155.782	69.1003	223.660	53.109	1.82667	0.616667
72	4HIGH		KNIF	.	10	33	87.4987	30.1276	1.53206	119.786	20.9247	3.45351	155.782	51.2534	205.813	48.176	1.79667	0.730000
73	1ZERO		AN	83	11	9	31.6238	17.5315	1.18159	50.337	17.0380	2.66349	0.000	24.0800	24.080	30.800	1.18667	0.493333
74	1ZERO		AN	84	11	12	.	.	0.70724	.	11.2647	1.59424	0.000	27.7657	27.766	29.565	.	.
75	1ZERO		AN	85	11	12	.	.	.	.	.	.	0.000	21.1307	21.131	12.899	.	.
76	1ZERO		KNIF	83	11	9	27.1001	16.5724	1.02886	44.701	15.6152	2.31920	0.000	20.7200	20.720	34.160	1.17000	0.493333
77	1ZERO		KNIF	84	11	12	.	.	0.59665	.	10.8871	1.34495	0.000	26.7848	26.785	26.109	.	.
78	1ZERO		KNIF	85	11	12	.	.	.	.	.	.	0.000	19.1893	19.189	12.087	.	.
79	2LOW		AN	83	11	9	54.6000	17.1955	1.71758	73.513	20.8775	3.87170	70.560	30.2400	100.800	47.600	1.40667	0.450000
80	2LOW		AN	84	11	12	.	.	0.79492	.	14.7919	1.79188	50.400	32.1897	82.590	31.270	.	.
81	2LOW		AN	85	11	12	.	.	.	.	.	.	50.400	22.9693	73.369	14.775	.	.
82	2LOW		KNIF	83	11	9	47.7456	18.2539	1.57332	67.573	20.9579	3.54652	70.560	21.8400	92.400	45.920	1.35000	0.446667
83	2LOW		KNIF	84	11	12	.	.	0.76499	.	13.6985	1.72441	50.400	25.7637	76.164	30.128	.	.
84	2LOW		KNIF	85	11	12	.	.	.	.	.	.	50.400	19.8240	70.224	13.776	.	.
85	3MED		AN	83	11	9	78.1549	21.6488	2.17143	101.975	24.6234	4.89475	136.640	31.3600	168.000	44.240	1.59667	0.523333
86	3MED		AN	84	11	12	.	.	1.01153	.	16.2104	2.28014	100.800	56.2324	157.032	37.869	.	.
87	3MED		AN	85	11	12	.	.	.	.	.	.	106.400	41.3373	147.737	22.596	.	.
88	3MED		KNIF	83	11	9	74.5106	25.6647	1.90158	102.077	22.5967	4.28645	136.640	30.8000	167.440	75.600	1.75667	0.646667
89	3MED		KNIF	84	11	12	.	.	1.05854	.	16.8160	2.38611	100.800	51.9540	152.754	38.124	.	.
90	3MED		KNIF	85	11	12	.	.	.	.	.	.	106.400	52.2387	158.639	24.743	.	.
91	4HIGH		AN	83	11	9	86.0987	25.6159	2.11402	113.829	24.0816	4.76534	168.000	69.4400	237.440	103.040	1.82667	0.616667
92	4HIGH		AN	84	11	12	.	.	1.14021	.	18.9624	2.57021	151.200	81.5080	232.708	48.594	.	.
93	4HIGH		AN	85	11	12	.	.	.	.	.	.	151.200	56.5227	207.723	32.657	.	.
94	4HIGH		KNIF	83	11	9	87.4987	30.1276	2.15937	119.786	24.4123	4.86756	168.000	31.9200	199.920	95.760	1.79667	0.730000
95	4HIGH		KNIF	84	11	12	.	.	1.06158	.	18.3090	2.39297	151.200	54.3256	205.526	41.256	.	.
96	4HIGH		KNIF	85	11	12	.	.	.	.	.	.	151.200	57.8480	209.048	31.304	.	.
97	1ZERO	CH		.	12	22	24.6124	13.6961	0.83305	39.255	13.0188	1.87782	0.000	20.9647	20.965	22.394	1.16000	0.435000
98	1ZERO	MP		.	12	22	39.7400	21.6317	1.05670	62.834	15.3266	2.38198	0.000	24.8114	24.811	23.667	1.20500	0.540000
99	1ZERO	TP		.	12	22	23.7337	15.8261	0.64887	40.469	11.6332	1.46266	0.000	24.5862	24.586	21.822	1.17000	0.505000
100	2LOW	CH		.	12	22	45.3833	17.8123	1.08627	64.606	17.0763	2.44861	55.898	25.0583	79.490	27.470	1.42500	0.460000

Table 3. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	TOTUP	MGSIL	MGCORN	FN	RSN	FNRSN	RSNDEEP	GRAINN	STCVN
101	2LOW	MP		.	12	22	59.3404	18.6884	1.29030	79.838	17.9506	2.90854	55.898	26.7120	81.144	30.1722	1.450	0.465
102	2LOW	TP		.	12	22	48.7946	16.6734	1.07609	67.185	16.2876	2.42566	55.898	24.3018	78.734	24.3830	1.260	0.420
103	3MED	CH		.	12	22	73.5248	23.2146	1.41993	98.623	19.9214	3.20074	112.611	42.0980	152.306	39.5377	1.760	0.605
104	3MED	MP		.	12	22	77.6117	22.9292	1.52319	102.693	19.4224	3.43350	112.611	45.9295	156.138	38.1119	1.600	0.550
105	3MED	TP		.	12	22	77.8618	24.8266	1.44959	104.762	19.3203	3.26760	112.611	51.6779	161.886	32.3014	1.670	0.600
106	4HIGH	CH		.	12	22	83.9779	30.3071	1.48180	116.202	22.0935	3.34022	155.782	58.4931	213.053	53.5752	1.950	0.735
107	4HIGH	MP		.	12	22	80.8613	26.9798	1.53478	110.048	20.6963	3.45964	155.782	56.1344	210.694	48.0738	1.630	0.640
108	4HIGH	TP		.	12	22	95.5569	26.3283	1.61785	124.172	20.3317	3.64688	155.782	65.9030	220.463	50.2779	1.855	0.645
109	1ZERO	CH		83	13	6	24.6124	13.6961	0.94622	39.255	14.5275	2.13294	0.000	22.4000	22.400	32.4800	1.160	0.435
110	1ZERO	CH		84	13	8	.	.	0.74817	.	11.8872	1.68649	0.000	24.7058	24.706	28.4620	.	.
111	1ZERO	CH		85	13	8	.	.	.	.	.	.	0.000	16.5060	16.506	11.2840	.	.
112	1ZERO	MP		83	13	6	39.7400	21.6317	1.46254	62.834	20.2715	3.29680	0.000	22.4000	22.400	32.4800	1.205	0.540
113	1ZERO	MP		84	13	8	.	.	0.75233	.	11.6180	1.69586	0.000	29.1424	29.142	28.0182	.	.
114	1ZERO	MP		85	13	8	.	.	.	.	.	.	0.000	21.6860	21.686	14.9100	.	.
115	1ZERO	TP		83	13	6	23.7337	15.8281	0.90690	40.469	14.1807	2.04430	0.000	22.4000	22.400	32.4800	1.170	0.505
116	1ZERO	TP		84	13	8	.	.	0.45535	.	9.7226	1.02642	0.000	27.9776	27.978	27.0312	.	.
117	1ZERO	TP		85	13	8	.	.	.	.	.	.	0.000	22.2880	22.288	11.2840	.	.
118	2LOW	CH		83	13	6	45.3833	17.8123	1.41070	64.606	19.2119	3.17994	70.560	26.0400	96.600	46.7600	1.425	0.460
119	2LOW	CH		84	13	8	.	.	0.84294	.	15.4746	1.90012	50.400	27.6318	78.032	31.1836	.	.
120	2LOW	CH		85	13	8	.	.	.	.	.	.	50.400	21.9940	72.394	14.1120	.	.
121	2LOW	MP		83	13	6	59.3404	18.6884	1.80884	79.838	22.1624	4.07740	70.560	26.0400	96.600	46.7600	1.450	0.465
122	2LOW	MP		84	13	8	.	.	0.90140	.	14.7918	2.03190	50.400	32.5360	82.936	33.5006	.	.
123	2LOW	MP		85	13	8	.	.	.	.	.	.	50.400	21.2240	71.624	18.5500	.	.
124	2LOW	TP		83	13	6	48.7946	16.6734	1.71682	67.185	21.3787	3.86999	70.560	26.0400	96.600	46.7600	1.260	0.420
125	2LOW	TP		84	13	8	.	.	0.59553	.	12.4693	1.34242	50.400	26.7624	77.162	27.4134	.	.
126	2LOW	TP		85	13	8	.	.	.	.	.	.	50.400	20.9720	71.372	10.1640	.	.
127	3MED	CH		83	13	6	73.5248	23.2146	1.88358	98.623	21.9220	4.24587	136.640	31.0800	167.720	59.9200	1.760	0.605
128	3MED	CH		84	13	8	.	.	1.07219	.	18.4209	2.41689	100.800	44.1910	144.991	41.4442	.	.
129	3MED	CH		85	13	8	.	.	.	.	.	.	106.400	45.5140	151.914	27.4400	.	.
130	3MED	MP		83	13	6	77.6117	22.9292	2.15216	102.693	24.7672	4.85131	136.640	31.0800	167.720	59.9200	1.600	0.550
131	3MED	MP		84	13	8	.	.	1.05145	.	15.4139	2.37014	100.800	55.6738	156.474	38.9018	.	.
132	3MED	MP		85	13	8	.	.	.	.	.	.	106.400	43.6100	150.010	26.4180	.	.
133	3MED	TP		83	13	6	77.8618	24.8266	2.07377	104.762	24.1410	4.67460	136.640	31.0800	167.720	59.9200	1.670	0.600
134	3MED	TP		84	13	8	.	.	0.98145	.	15.7048	2.21235	100.800	62.4148	163.215	33.6434	.	.
135	3MED	TP		85	13	8	.	.	.	.	.	.	106.400	51.2400	157.640	17.1500	.	.
136	4HIGH	CH		83	13	6	83.9779	30.3071	1.91660	116.202	22.6455	4.32031	168.000	50.6800	218.680	99.4000	1.950	0.735
137	4HIGH	CH		84	13	8	.	.	1.15571	.	21.6795	2.60515	151.200	67.8048	219.005	47.7540	.	.
138	4HIGH	CH		85	13	8	.	.	.	.	.	.	151.200	53.0880	204.288	36.4840	.	.
139	4HIGH	MP		83	13	6	80.8613	26.9798	2.20711	110.048	25.0952	4.97518	168.000	50.6800	218.680	99.4000	1.630	0.640
140	4HIGH	MP		84	13	8	.	.	1.03053	.	17.3971	2.32298	151.200	64.0780	215.278	39.8524	.	.
141	4HIGH	MP		85	13	8	.	.	.	.	.	.	151.200	50.9180	202.118	30.6320	.	.
142	4HIGH	TP		83	13	6	95.5569	26.3283	2.28638	124.172	25.0001	5.15386	168.000	50.6800	218.680	99.4000	1.855	0.645
143	4HIGH	TP		84	13	8	.	.	1.11645	.	16.8305	2.51664	151.200	71.8676	223.068	47.1688	.	.
144	4HIGH	TP		85	13	8	.	.	.	.	.	.	151.200	67.5500	218.750	28.8260	.	.
145	1ZERO	CH	AN	.	14	11	23.3840	13.3140	0.76445	37.548	11.9923	1.72320	0.000	22.4414	22.441	22.3630	1.220	0.430
146	1ZERO	CH	KNIF	.	14	11	25.8407	14.0782	0.90165	40.961	14.0453	2.03245	0.000	19.4880	19.488	22.4258	1.100	0.440
147	1ZERO	MP	AN	.	14	11	43.1698	23.4791	1.20410	68.232	16.5109	2.71423	0.000	25.4330	25.433	24.2726	1.210	0.570
148	1ZERO	MP	KNIF	.	14	11	36.3101	19.7842	0.90931	57.437	14.1424	2.04973	0.000	24.1898	24.190	23.0619	1.200	0.510
149	1ZERO	TP	AN	.	14	11	28.3177	15.8015	0.76305	45.231	12.7138	1.72004	0.000	25.2493	25.249	22.8010	1.130	0.480
150	1ZERO	TP	KNIF	.	14	11	19.1496	15.8547	0.53469	35.706	10.5526	1.20527	0.000	23.9232	23.923	20.8432	1.210	0.530

Table 3. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	TOTUP	MGSIL	MGCGRN	FN	RSN	FARSN	RSADEEP	GRAINA	STGVA
151	2LOW	CH	AN	.	14	11	48.9671	16.2030	1.14270	66.628	17.1016	2.57582	55.898	27.5666	81.999	28.4525	1.49	0.45
152	2LOW	CH	KNIF	.	14	11	41.7995	19.4215	1.02983	62.585	17.0510	2.32141	55.898	22.5501	76.982	26.4880	1.36	0.47
153	2LOW	MP	AN	.	14	11	68.8783	20.2176	1.41530	91.147	18.9833	3.19030	55.898	29.4269	~~83.859~~	31.2558	~~1.49~~	0.50
154	2LOW	MP	KNIF	.	14	11	49.8026	17.1593	1.16531	68.529	16.9179	2.62678	55.898	23.9971	78.429	29.0886	1.41	0.43
155	2LOW	TP	AN	.	14	11	45.9546	15.1660	1.01305	62.765	16.1152	2.28357	55.898	27.3414	81.773	24.1058	1.24	0.40
156	2LOW	TP	KNIF	.	14	11	51.6347	18.1808	1.13912	71.605	16.4601	2.56775	55.898	21.2621	75.694	24.6602	1.28	0.44
157	3MED	CH	AN	.	14	11	81.2659	19.8857	1.61028	103.391	21.1250	3.62983	112.611	40.5082	150.716	34.9384	1.61	0.50
158	3MED	CH	KNIF	.	14	11	65.7838	26.5435	1.22957	93.855	18.7178	2.77165	112.611	43.6878	153.896	44.1370	1.91	0.71
159	3MED	MP	AN	.	14	11	76.6031	24.3592	1.46891	103.073	19.0507	3.31116	112.611	45.4776	155.686	33.7837	1.61	0.57
160	3MED	MP	KNIF	.	14	11	78.6203	21.4992	1.57746	102.313	19.7942	3.55584	112.611	46.3814	156.589	42.4402	1.59	0.53
161	3MED	TP	AN	.	14	11	76.5958	20.7015	1.44669	99.462	19.2722	3.26106	112.611	49.9139	160.122	30.3800	1.57	0.50
162	3MED	TP	KNIF	.	14	11	79.1278	26.9516	1.45249	110.063	19.3685	3.27414	112.611	53.4419	163.650	34.2227	1.77	0.70
163	4HIGH	CH	AN	.	14	11	79.5337	23.8208	1.47501	105.101	20.6212	3.32489	155.782	67.6424	222.202	57.6912	2.02	0.60
164	4HIGH	CH	KNIF	.	14	11	88.4221	36.7934	1.48860	127.302	23.5659	3.35554	155.782	49.3438	203.904	49.4592	1.88	0.87
165	4HIGH	MP	AN	.	14	11	82.8309	25.3832	1.57970	110.570	22.7829	3.56088	155.782	63.1120	217.672	48.6349	1.56	0.57
166	4HIGH	MP	KNIF	.	14	11	78.8916	28.5764	1.48987	109.527	18.6096	3.35839	155.782	49.1568	203.717	47.5126	1.70	0.71
167	4HIGH	TP	AN	.	14	11	95.9314	27.6438	1.61797	125.815	20.0649	3.64717	155.782	76.5464	231.106	52.9995	1.90	0.68
168	4HIGH	TP	KNIF	.	14	11	95.1824	25.0129	1.61772	122.528	20.5985	3.64659	155.782	55.2597	209.820	47.5563	1.81	0.61
169	1ZERO	CH	AN	83	15	3	23.3840	13.3140	0.85031	37.548	13.7833	1.91672	0.000	24.0800	24.080	30.8000	1.22	0.43
170	1ZERO	CH	AN	84	15	4	.	.	0.70006	.	10.6491	1.57805	0.000	25.8356	25.836	30.0356	.	.
171	1ZERO	CH	AN	85	15	4	.	.	.	.	.	.	0.000	18.2280	18.228	10.4720	.	.
172	1ZERO	CH	KNIF	83	15	3	25.8407	14.0782	1.04214	40.961	15.2718	2.34915	0.000	20.7200	20.720	34.1600	1.10	0.44
173	1ZERO	CH	KNIF	84	15	4	.	.	0.79628	.	13.1254	1.79493	0.000	23.5760	23.576	26.8804	.	.
174	1ZERO	CH	KNIF	85	15	4	.	.	.	.	.	.	0.000	14.7840	14.784	12.0960	.	.
175	1ZERO	MP	AN	83	15	3	43.1698	23.4791	1.58274	68.232	21.3543	3.56775	0.000	24.0800	24.080	30.8000	1.21	0.57
176	1ZERO	MP	AN	84	15	4	.	.	0.92011	.	12.8783	2.07408	0.000	27.4344	27.434	28.3416	.	.
177	1ZERO	MP	AN	85	15	4	.	.	.	.	.	.	0.000	24.1080	24.108	16.9400	.	.
178	1ZERO	MP	KNIF	83	15	3	36.3101	19.7842	1.34234	57.437	19.1887	3.02584	0.000	20.7200	20.720	34.1600	1.20	0.51
179	1ZERO	MP	KNIF	84	15	4	.	.	0.58454	.	10.3577	1.31764	0.000	30.8504	30.850	27.6948	.	.
180	1ZERO	MP	KNIF	85	15	4	.	.	.	.	.	.	0.000	19.2640	19.264	12.8800	.	.
181	1ZERO	TP	AN	83	15	3	28.3177	15.8015	1.11172	45.231	15.9764	2.50599	0.000	24.0800	24.080	30.8000	1.13	0.48
182	1ZERO	TP	AN	84	15	4	.	.	0.50155	.	10.2669	1.13058	0.000	30.0272	30.027	30.3184	.	.
183	1ZERO	TP	AN	85	15	4	.	.	.	.	.	.	0.000	21.0560	21.056	11.2840	.	.
184	1ZERO	TP	KNIF	83	15	3	19.1496	15.8547	0.70209	35.706	12.3850	1.58261	0.000	20.7200	20.720	34.1600	1.21	0.53
185	1ZERO	TP	KNIF	84	15	4	.	.	0.40914	.	9.1783	0.92227	0.000	25.9280	25.928	23.7440	.	.
186	1ZERO	TP	KNIF	85	15	4	.	.	.	.	.	.	0.000	23.5200	23.520	11.2840	.	.
187	2LOW	CH	AN	83	15	3	48.9671	16.2030	1.45792	66.628	18.6059	3.28638	70.560	30.2400	100.800	47.6000	1.49	0.45
188	2LOW	CH	AN	84	15	4	.	.	0.90628	.	15.9734	2.04290	50.400	30.5844	80.984	33.2192	.	.
189	2LOW	CH	AN	85	15	4	.	.	.	.	.	.	50.400	23.2120	73.612	14.1120	.	.
190	2LOW	CH	KNIF	83	15	3	41.7995	19.4215	1.36348	62.585	19.8180	3.07349	70.560	21.8400	92.400	45.9200	1.36	0.47
191	2LOW	CH	KNIF	84	15	4	.	.	0.77960	.	14.9757	1.75734	50.400	24.6792	75.079	29.1480	.	.
192	2LOW	CH	KNIF	85	15	4	.	.	.	.	.	.	50.400	20.7760	71.176	14.1120	.	.
193	2LOW	MP	AN	83	15	3	68.8783	20.2176	2.05075	91.147	23.6830	4.62270	70.560	30.2400	100.800	47.6000	1.49	0.50
194	2LOW	MP	AN	84	15	4	.	.	0.93871	.	15.4586	2.11600	50.400	36.1592	86.559	34.9916	.	.
195	2LOW	MP	AN	85	15	4	.	.	.	.	.	.	50.400	22.2880	72.688	19.3480	.	.
196	2LOW	MP	KNIF	83	15	3	49.8026	17.1593	1.56693	68.529	20.6418	3.53210	70.560	21.8400	92.400	45.9200	1.41	0.43
197	2LOW	MP	KNIF	84	15	4	.	.	0.86469	.	14.1250	1.94780	50.400	28.9128	79.313	32.0096	.	.
198	2LOW	MP	KNIF	85	15	4	.	.	.	.	.	.	50.400	20.1600	70.560	17.7520	.	.
199	2LOW	TP	AN	83	15	3	45.9546	15.1660	1.64408	62.765	20.3437	3.70602	70.560	30.2400	100.800	47.6000	1.24	0.40
200	2LOW	TP	AN	84	15	4	.	.	0.53978	.	12.9438	1.21674	50.400	29.8256	80.226	25.6004	.	.

Table 3. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	TOTUP	MGSIL	MGCORN	FN	RSN	FNRSN	RSNDEEP	GRAINN	STOVN
201	2LOW	TP	AN	85	15	4	.	.	.	.	.	.	50.40	23.4080	73.808	10.884	.	.
202	2LOW	TP	KNIF	83	15	3	51.6347	18.1808	1.78956	71.605	22.4138	4.03396	70.56	21.8400	92.400	45.920	1.28	0.44
203	2LOW	TP	KNIF	84	15	4	.	.	0.65129	.	11.9948	1.46810	50.40	23.6992	74.099	29.226	.	.
204	2LOW	TP	KNIF	85	15	4	.	.	.	.	.	.	50.40	18.5360	68.936	9.464	.	.
205	3MED	CH	AN	83	15	3	81.2659	19.8857	2.23923	103.391	24.5281	5.04757	136.64	31.3600	168.000	44.240	1.61	0.50
206	3MED	CH	AN	84	15	4	.	.	1.13857	.	18.5726	2.56653	100.80	47.7904	148.590	42.210	.	.
207	3MED	CH	AN	85	15	4	.	.	.	.	.	.	106.40	37.8000	144.200	23.016	.	.
208	3MED	CH	KNIF	83	15	3	65.7838	26.5435	1.52792	93.855	19.3159	3.44418	136.64	30.8000	167.440	75.600	1.91	0.71
209	3MED	CH	KNIF	84	15	4	.	.	1.00581	.	18.2691	2.26725	100.80	40.5916	141.392	40.678	.	.
210	3MED	CH	KNIF	85	15	4	.	.	.	.	.	.	106.40	53.2280	159.628	31.864	.	.
211	3MED	MP	AN	83	15	3	76.6031	24.3592	2.11075	103.073	24.7613	4.75796	136.64	31.3600	168.000	44.240	1.61	0.57
212	3MED	MP	AN	84	15	4	.	.	0.98753	.	14.7678	2.22606	100.80	61.7820	162.582	36.523	.	.
213	3MED	MP	AN	85	15	4	.	.	.	.	.	.	106.40	36.2320	142.632	25.816	.	.
214	3MED	MP	KNIF	83	15	3	78.6203	21.4992	2.19358	102.313	24.7732	4.94467	136.64	30.8000	167.440	75.600	1.59	0.53
215	3MED	MP	KNIF	84	15	4	.	.	1.11537	.	16.0599	2.51423	100.80	49.5656	150.366	41.280	.	.
216	3MED	MP	KNIF	85	15	4	.	.	.	.	.	.	106.40	50.9880	157.388	27.020	.	.
217	3MED	TP	AN	83	15	3	76.5958	20.7015	2.16432	99.462	24.5809	4.87871	136.64	31.3600	168.000	44.240	1.57	0.50
218	3MED	TP	AN	84	15	4	.	.	0.90847	.	15.2906	2.04783	100.80	59.1248	159.925	34.874	.	.
219	3MED	TP	AN	85	15	4	.	.	.	.	.	.	106.40	49.9800	156.380	18.956	.	.
220	3MED	TP	KNIF	83	15	3	79.1278	28.9516	1.98323	110.063	23.7010	4.47050	136.64	30.8000	167.440	75.600	1.77	0.70
221	3MED	TP	KNIF	84	15	4	.	.	1.05444	.	16.1190	2.37687	100.80	65.7048	166.505	32.413	.	.
222	3MED	TP	KNIF	85	15	4	.	.	.	.	.	.	106.40	52.5000	158.900	15.344	.	.
223	4HIGH	CH	AN	83	15	3	79.5337	23.8208	1.74669	105.101	21.1155	3.93731	168.00	69.4400	237.440	103.040	2.02	0.60
224	4HIGH	CH	AN	84	15	4	.	.	1.27124	.	20.2504	2.86558	151.20	82.1660	233.366	53.620	.	.
225	4HIGH	CH	AN	85	15	4	.	.	.	.	.	.	151.20	52.2200	203.420	39.088	.	.
226	4HIGH	CH	KNIF	83	15	3	86.4221	38.7934	2.08650	127.302	24.1758	4.70330	168.00	31.9200	199.920	95.760	1.88	0.87
227	4HIGH	CH	KNIF	84	15	4	.	.	1.04018	.	23.1087	2.34473	151.20	53.4436	204.644	41.888	.	.
228	4HIGH	CH	KNIF	85	15	4	.	.	.	.	.	.	151.20	53.9560	205.156	33.880	.	.
229	4HIGH	MP	AN	83	15	3	82.8309	25.3832	2.35550	110.570	26.6692	5.30967	168.00	69.4400	237.440	103.040	1.56	0.57
230	4HIGH	MP	AN	84	15	4	.	.	0.99784	.	19.8682	2.24929	151.20	68.8240	220.024	40.639	.	.
231	4HIGH	MP	AN	85	15	4	.	.	.	.	.	.	151.20	54.2360	205.436	29.428	.	.
232	4HIGH	MP	KNIF	83	15	3	78.8916	28.5764	2.05872	109.527	23.5212	4.64068	168.00	31.9200	199.920	95.760	1.70	0.71
233	4HIGH	MP	KNIF	84	15	4	.	.	1.06322	.	14.9259	2.39667	151.20	59.3320	210.532	39.066	.	.
234	4HIGH	MP	KNIF	85	15	4	.	.	.	.	.	.	151.20	47.6000	198.800	31.836	.	.
235	4HIGH	TP	AN	83	15	3	95.9314	27.6438	2.23987	125.815	24.4600	5.04902	168.00	69.4400	237.440	103.040	1.90	0.68
236	4HIGH	TP	AN	84	15	4	.	.	1.15155	.	16.7686	2.59577	151.20	93.5340	244.734	51.523	.	.
237	4HIGH	TP	AN	85	15	4	.	.	.	.	.	.	151.20	63.1120	214.312	29.456	.	.
238	4HIGH	TP	KNIF	83	15	3	95.1824	25.0129	2.33289	122.528	25.5402	5.25869	168.00	31.9200	199.920	95.760	1.81	0.61
239	4HIGH	TP	KNIF	84	15	4	.	.	1.08134	.	16.8923	2.43751	151.20	50.2012	201.401	42.815	.	.
240	4HIGH	TP	KNIF	85	15	4	.	.	.	.	.	.	151.20	71.9880	223.188	28.156	.	.

Table 4. Data summary, corn-soybean rotation, S.E. site.

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	MGSIL	MGCORN	EN	ENRSN	RSN	RSNDEEP	GRAINN	STOVN
1				.	0	288	52.7899	24.4377	1.36213	21.4934	3.07045	64.587	69.328	24.5276	25.4022	157.750	57.2500
2				83	1	96	52.7899	24.4377	1.74015	24.5999	3.92256	109.760	.	.	.	157.750	57.2500
3				84	1	96	.	.	0.98411	18.3869	2.21833	84.000	113.983	29.9826	31.8045	.	.
4				85	1	96	.	.	.	.	.	0.000	18.293	18.2933	18.0853	.	.
5			AN	.	2	144	52.4181	22.6037	1.36453	21.6106	3.07586	64.587	67.438	23.6115	25.6767	158.000	53.6667
6			KNIF	.	2	144	53.1617	26.2717	1.35972	21.3762	3.06503	64.587	71.304	25.4853	25.1152	157.500	60.8333
7			AN	83	3	48	52.4181	22.6037	1.72451	24.3282	3.88732	109.760	.	.	.	158.000	53.6667
8			AN	84	3	48	.	.	1.00455	18.8930	2.26441	84.000	112.791	28.7915	32.6144	.	.
9			AN	85	3	48	.	.	.	.	.	0.000	17.961	17.9607	18.1084	.	.
10			KNIF	83	3	48	53.1617	26.2717	1.75578	24.8716	3.95780	109.760	.	.	.	157.500	60.8333
11			KNIF	84	3	48	.	.	0.96367	17.8808	2.17226	84.000	115.174	31.1738	30.9946	.	.
12			KNIF	85	3	48	.	.	.	.	.	0.000	18.659	18.6592	18.0600	.	.
13		MP		.	4	96	50.8377	29.2542	1.30014	21.6038	2.93071	64.587	78.328	26.6358	26.2683	157.500	64.2500
14		NT		.	4	96	55.6480	24.7802	1.41103	21.9704	3.18067	64.587	67.437	25.4369	25.4726	157.250	56.0000
15		TP		.	4	96	51.8841	19.2787	1.37522	20.9060	3.09996	64.587	63.905	21.9054	24.6281	158.500	51.5000
16		MP		83	5	32	50.8377	29.2542	1.67367	25.3731	3.77271	109.760	.	.	.	157.500	64.2500
17		MP		84	5	32	.	.	0.92660	17.8345	2.08871	84.000	112.709	28.7091	30.3870	.	.
18		MP		85	5	32	.	.	.	.	.	0.000	23.318	23.3184	19.6784	.	.
19		NT		83	5	32	55.6480	24.7802	1.85114	25.6984	4.17277	109.760	.	.	.	157.250	56.0000
20		NT		84	5	32	.	.	0.97091	18.2425	2.18858	84.000	118.830	34.8299	33.9143	.	.
21		NT		85	5	32	.	.	.	.	.	0.000	16.044	16.0440	17.0310	.	.
22		TP		83	5	32	51.8841	19.2787	1.69563	22.7282	3.82220	109.760	.	.	.	158.500	51.5000
23		TP		84	5	32	.	.	1.05481	19.0837	2.37771	84.000	110.409	26.4089	31.1122	.	.
24		TP		85	5	32	.	.	.	.	.	0.000	17.402	17.4020	18.1440	.	.
25		MP	AN	.	6	48	48.7010	25.7046	1.31758	21.0990	2.97003	64.587	73.639	25.6392	26.6616	150.000	57.2500
26		MP	KNIF	.	6	48	52.9744	32.8038	1.28269	21.3085	2.89138	64.587	83.798	27.7984	25.8095	165.000	71.2500
27		NT	AN	.	6	48	57.1536	22.2507	1.43241	22.0138	3.22887	64.587	66.413	24.4132	26.7785	159.500	52.2500
28		NT	KNIF	.	6	48	54.1423	27.3096	1.38965	21.9271	3.13248	64.587	68.461	26.4607	24.1668	155.000	59.7500
29		TP	AN	.	6	48	51.3997	19.8558	1.34360	20.9188	3.02868	64.587	63.036	21.0357	23.7132	164.500	51.5000
30		TP	KNIF	.	6	48	52.3685	18.7016	1.40684	20.8931	3.17123	64.587	64.775	22.7752	25.5430	152.500	51.5000
31		MP	AN	83	7	16	48.7010	25.7046	1.68576	25.3030	3.79996	109.760	.	.	.	150.000	57.2500
32		MP	AN	84	7	16	.	.	0.94940	18.4951	2.14010	84.000	111.509	27.5086	29.9138	.	.
33		MP	AN	85	7	16	.	.	.	.	.	0.000	23.147	23.1467	22.3253	.	.
34		MP	KNIF	83	7	16	52.9744	32.8038	1.66158	25.4432	3.74545	109.760	.	.	.	165.000	71.2500
35		MP	KNIF	84	7	16	.	.	0.90380	17.1739	2.03731	84.000	113.910	29.9096	30.8602	.	.
36		MP	KNIF	85	7	16	.	.	.	.	.	0.000	23.576	23.5760	15.7080	.	.
37		NT	AN	83	7	16	57.1536	22.2507	1.87128	25.2650	4.21817	109.760	.	.	.	159.500	52.2500
38		NT	AN	84	7	16	.	.	0.99353	18.7627	2.23958	84.000	118.294	34.2944	37.8350	.	.
39		NT	AN	85	7	16	.	.	.	.	.	0.000	14.532	14.5320	15.7220	.	.
40		NT	KNIF	83	7	16	54.1423	27.3096	1.83100	26.1318	4.12737	109.760	.	.	.	155.000	59.7500
41		NT	KNIF	84	7	16	.	.	0.94829	17.7223	2.13759	84.000	119.365	35.3654	29.9936	.	.
42		NT	KNIF	85	7	16	.	.	.	.	.	0.000	17.556	17.5560	18.3400	.	.
43		TP	AN	83	7	16	51.3997	19.8558	1.61649	22.4165	3.64382	109.760	.	.	.	164.500	51.5000
44		TP	AN	84	7	16	.	.	1.07071	19.4212	2.41354	84.000	108.571	24.5714	30.0944	.	.
45		TP	AN	85	7	16	.	.	.	.	.	0.000	17.500	17.5000	17.3320	.	.
46		TP	KNIF	83	7	16	52.3685	18.7016	1.77476	23.0399	4.00059	109.760	.	.	.	152.500	51.5000
47		TP	KNIF	84	7	16	.	.	1.03891	18.7463	2.34187	84.000	112.246	28.2464	32.1300	.	.
48		TP	KNIF	85	7	16	.	.	.	.	.	0.000	17.304	17.3040	18.9560	.	.
49	1ZERO			.	8	72	36.6142	19.9606	1.14861	19.2125	2.58914	0.000	24.303	24.3035	23.9487	133.833	50.1667
50	2LOW			.	8	72	49.9071	21.8674	1.37292	21.3909	3.09478	45.547	53.276	22.7304	22.9228	146.000	51.5000
51	3MED			.	8	72	59.7891	26.2259	1.43483	22.4664	3.23433	87.733	82.754	24.3196	25.0184	172.333	60.3333
52	4HIGH			.	8	72	64.9474	29.6969	1.49215	22.9038	3.36354	125.067	114.321	26.6691	29.5480	178.833	67.0000
53	1ZERO			83	9	24	36.6142	19.9606	1.43860	21.7196	3.24283	0.000	.	.	.	133.833	50.1667
54	1ZERO			84	9	24	.	.	0.85861	16.7054	1.93545	0.000	30.407	30.4071	32.7619	.	.
55	1ZERO			85	9	24	.	.	.	.	.	0.000	16.979	16.9792	13.3728	.	.
56	2LOW			83	9	24	49.9071	21.8674	1.78842	24.8435	4.03139	80.640	.	.	.	146.000	51.5000

Table 4. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	MGSIL	MGCORN	FN	FNRSN	RSN	RSNDEEP	GRAINN	STOVN
57	2LOW			84	9	24	.	.	0.95742	17.9382	2.15817	56.000	83.784	27.7844	28.8372	.	.
58	2LOW			85	9	24	.	.	.	.	.	0.000	16.666	16.6656	15.8256	.	.
59	3MED			83	9	24	59.6891	26.2259	1.81717	25.4259	4.09619	151.200	.	.	.	172.333	60.3333
60	3MED			84	9	24	.	.	1.05249	19.5068	2.37248	112.000	140.973	28.9725	30.8812	.	.
61	3MED			85	9	24	.	.	.	.	.	0.000	19.244	19.2436	18.6225	.	.
62	4HIGH			83	9	24	64.9494	29.6969	1.91639	26.4105	4.31984	207.200	.	.	.	178.833	67.0000
63	4HIGH			84	9	24	.	.	1.06791	19.3971	2.40724	168.000	200.767	32.7665	34.7377	.	.
64	4HIGH			85	9	24	.	.	.	.	.	0.000	20.017	20.0175	23.8865	.	.
65	1ZERO		AN	.	10	36	35.9920	18.4792	1.11612	18.7328	2.51590	0.000	22.282	22.2819	25.9158	141.000	48.0000
66	1ZERO		KNIF	.	10	36	37.2364	21.4419	1.18109	19.6923	2.66237	0.000	26.325	26.3251	21.9815	126.667	52.3333
67	2LOW		AN	.	10	36	49.7933	22.0831	1.39427	21.7789	3.14290	45.547	52.823	22.2778	24.2124	144.333	51.3333
68	2LOW		KNIF	.	10	36	50.0208	21.6517	1.35157	21.0029	3.04665	45.547	53.728	23.1830	21.6333	147.667	51.6667
69	3MED		AN	.	10	36	57.1145	23.1696	1.40638	22.5240	3.17021	87.733	81.122	25.1216	23.5181	169.000	54.3333
70	3MED		KNIF	.	10	36	62.2637	29.2821	1.46328	22.4087	3.29845	87.733	84.536	23.4447	26.6550	175.667	66.3333
71	4HIGH		AN	.	10	36	66.7726	26.6828	1.54134	23.4066	3.47443	125.067	108.543	24.5429	28.9585	177.667	61.0000
72	4HIGH		KNIF	.	10	36	63.1261	32.7110	1.44296	22.4010	3.25265	125.067	120.625	28.9887	30.1911	180.000	73.0000
73	1ZERO		AN	83	11	12	35.9920	18.4792	1.33789	20.6208	3.01582	0.000	.	.	.	141.000	48.0000
74	1ZERO		AN	84	11	12	.	.	0.89434	16.8447	2.01599	0.000	27.802	27.8021	36.4989	.	.
75	1ZERO		AN	85	11	12	.	.	.	.	.	0.000	15.658	15.6576	13.2160	.	.
76	1ZERO		KNIF	83	11	12	37.2364	21.4419	1.53931	22.8184	3.46984	0.000	.	.	.	126.667	52.3333
77	1ZERO		KNIF	84	11	12	.	.	0.82288	16.5662	1.85490	0.000	33.012	33.0120	29.0248	.	.
78	1ZERO		KNIF	85	11	12	.	.	.	.	.	0.000	18.301	18.3008	13.5296	.	.
79	2LOW		AN	83	11	12	49.7933	22.0831	1.80874	25.1341	4.07718	80.640	.	.	.	144.333	51.3333
80	2LOW		AN	84	11	12	.	.	0.97980	18.4236	2.20863	56.000	83.253	27.2533	30.1280	.	.
81	2LOW		AN	85	11	12	.	.	.	.	.	0.000	16.307	16.3072	17.1136	.	.
82	2LOW		KNIF	83	11	12	50.0208	21.6517	1.76811	24.5528	3.98559	80.640	.	.	.	147.667	51.6667
83	2LOW		KNIF	84	11	12	.	.	0.93503	17.4529	2.10770	56.000	84.315	28.3155	27.5464	.	.
84	2LOW		KNIF	85	11	12	.	.	.	.	.	0.000	17.024	17.0240	14.5376	.	.
85	3MED		AN	83	11	12	57.1145	23.1696	1.77230	24.9120	3.99504	151.200	.	.	.	169.000	54.3333
86	3MED		AN	84	11	12	.	.	1.04047	20.1360	2.34538	112.000	143.614	31.6139	29.5643	.	.
87	3MED		AN	85	11	12	.	.	.	.	.	0.000	18.629	18.6293	17.4720	.	.
88	3MED		KNIF	83	11	12	62.2637	29.2821	1.86204	25.9398	4.19733	151.200	.	.	.	175.667	66.3333
89	3MED		KNIF	84	11	12	.	.	1.06451	18.8776	2.39957	112.000	138.331	26.3312	32.1981	.	.
90	3MED		KNIF	85	11	12	.	.	.	.	.	0.000	19.981	19.9808	20.0032	.	.
91	4HIGH		AN	83	11	12	66.7726	26.6828	1.97912	26.6456	4.46124	207.200	.	.	.	177.667	61.0000
92	4HIGH		AN	84	11	12	.	.	1.10357	20.1676	2.48762	168.000	196.497	28.4965	34.2664	.	.
93	4HIGH		AN	85	11	12	.	.	.	.	.	0.000	20.589	20.5893	23.6507	.	.
94	4HIGH		KNIF	83	11	12	63.1261	32.7110	1.85366	26.1754	4.17844	207.200	.	.	.	180.000	73.0000
95	4HIGH		KNIF	84	11	12	.	.	1.03225	18.6266	2.32685	168.000	205.037	37.0365	35.2091	.	.
96	4HIGH		KNIF	85	11	12	.	.	.	.	.	0.000	19.331	19.3312	24.1696	.	.
97	1ZERO	MP		.	12	24	31.2149	22.0621	1.00428	18.8258	2.26381	0.000	27.151	27.1507	25.2056	131.000	55.0000
98	1ZERO	NT		.	12	24	43.1403	21.8938	1.26012	20.0360	2.84051	0.000	24.921	24.9214	25.1118	138.000	49.5000
99	1ZERO	TP		.	12	24	35.4874	15.9258	1.18142	18.7758	2.66309	0.000	21.550	21.5502	21.8428	132.500	46.0000
100	2LOW	MP		.	12	24	53.8045	30.9676	1.37928	21.9969	3.10910	45.547	60.512	23.1784	25.0264	153.500	66.5000
101	2LOW	NT		.	12	24	52.5246	19.5833	1.42231	22.0591	3.20610	45.547	51.820	23.8196	23.3786	144.500	45.5000
102	2LOW	TP		.	12	24	43.3920	15.9452	1.31718	20.1166	2.96912	45.547	49.305	21.3052	20.8894	140.000	42.5000
103	3MED	MP		.	12	24	56.0492	30.4053	1.40041	23.1780	3.15673	87.733	91.878	27.8784	24.7056	162.500	63.5000
104	3MED	NT		.	12	24	62.6519	27.2849	1.43130	22.0275	3.22638	87.733	80.923	24.9228	25.3316	178.000	63.5000
105	3MED	TP		.	12	24	60.3663	20.9874	1.47278	22.1937	3.31989	87.733	76.602	20.6024	24.9788	176.500	54.0000
106	4HIGH	MP		.	12	24	62.2822	33.5816	1.41658	22.4145	3.19319	125.067	123.915	27.9152	29.8064	183.000	72.0000
107	4HIGH	NT		.	12	24	64.2751	30.3526	1.53037	23.7593	3.44970	125.067	112.084	28.0840	28.0696	168.500	65.5000
108	4HIGH	TP		.	12	24	68.2907	25.1566	1.52950	22.5377	3.44772	125.067	108.164	24.1640	30.8014	185.000	63.5000
109	1ZERO	MP		83	13	8	31.2149	22.0621	1.25055	20.8862	2.81892	0.000	.	.	.	131.000	55.0000
110	1ZERO	MP		84	13	8	.	.	0.75802	16.7653	1.70869	0.000	30.758	30.7580	30.5564	.	.
111	1ZERO	MP		85	13	8	.	.	.	.	.	0.000	19.936	19.9360	14.5040	.	.
112	1ZERO	NT		83	13	8	43.1403	21.8938	1.64894	24.1130	3.71697	0.000	.	.	.	138.000	49.5000

Table 4. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	MGSIL	MGCORN	FN	FNRSN	RSN	RSNDEEP	GRAINN	STOVN
113	1ZERO	NT		84	13	8	.	.	0.87130	15.9589	1.96406	0.000	30.383	30.3828	37.7356	.	.
114	1ZERO	NT		85	13	8	.	.	.	.	.	0.000	19.460	19.4600	12.4880	.	.
115	1ZERO	TP		83	13	8	35.4874	15.0258	1.41631	20.1596	3.19259	0.000	.	.	.	132.5	46.0
116	1ZERO	TP		84	13	8	.	.	0.94652	17.3920	2.13360	0.000	30.080	30.0804	29.9936	.	.
117	1ZERO	TP		85	13	8	.	.	.	.	.	0.000	13.020	13.0200	13.6920	.	.
118	2LOW	MP		83	13	8	53.8045	30.9676	1.83335	26.7490	4.13265	80.640	.	.	.	153.5	66.5
119	2LOW	MP		84	13	8	.	.	0.92521	17.2448	2.08556	56.000	82.984	26.9836	28.6636	.	.
120	2LOW	MP		85	13	8	.	.	.	.	.	0.000	15.568	15.5680	17.7520	.	.
121	2LOW	NT		83	13	8	52.5246	19.5893	1.90533	25.8496	4.29492	80.640	.	.	.	144.5	45.5
122	2LOW	NT		84	13	8	.	.	0.93928	18.2685	2.11729	56.000	88.407	32.4072	31.8052	.	.
123	2LOW	NT		85	13	8	.	.	.	.	.	0.000	15.232	15.2320	14.9520	.	.
124	2LOW	TP		83	13	8	43.3920	15.0452	1.62659	21.9319	3.66659	80.640	.	.	.	140.0	42.5
125	2LOW	TP		84	13	8	.	.	1.00776	18.3014	2.27165	56.000	79.962	23.9624	26.0428	.	.
126	2LOW	TP		85	13	8	.	.	.	.	.	0.000	18.648	18.6480	15.7360	.	.
127	3MED	MP		83	13	8	56.0492	30.4053	1.80541	27.1623	4.06967	151.200	.	.	.	162.5	63.5
128	3MED	MP		84	13	8	.	.	0.99540	19.1937	2.24380	112.000	139.843	27.8432	28.7028	.	.
129	3MED	MP		85	13	8	.	.	.	.	.	0.000	27.925	27.9253	19.3760	.	.
130	3MED	NT		83	13	8	62.6519	27.2849	1.84906	25.2507	4.16806	151.200	.	.	.	178.0	63.5
131	3MED	NT		84	13	8	.	.	1.01355	18.8043	2.28469	112.000	148.714	36.7136	30.9232	.	.
132	3MED	NT		85	13	8	.	.	.	.	.	0.000	13.132	13.1320	19.7400	.	.
133	3MED	TP		83	13	8	60.3663	20.9874	1.79705	23.8649	4.05083	151.200	.	.	.	176.5	54.0
134	3MED	TP		84	13	8	.	.	1.14852	20.5225	2.58894	112.000	134.361	22.3608	33.0176	.	.
135	3MED	TP		85	13	8	.	.	.	.	.	0.000	18.844	18.8440	16.9400	.	.
136	4HIGH	MP		83	13	8	62.2822	33.5816	1.80537	26.6948	4.06959	207.200	.	.	.	183.0	72.0
137	4HIGH	MP		84	13	8	.	.	1.02778	18.1341	2.31678	168.000	197.252	29.2516	33.6252	.	.
138	4HIGH	MP		85	13	8	.	.	.	.	.	0.000	26.133	26.1333	24.7147	.	.
139	4HIGH	NT		83	13	8	64.2751	30.3526	2.00124	27.5803	4.51111	207.200	.	.	.	168.5	65.5
140	4HIGH	NT		84	13	8	.	.	1.05950	19.9383	2.38829	168.000	207.816	39.8160	35.1932	.	.
141	4HIGH	NT		85	13	8	.	.	.	.	.	0.000	16.352	16.3520	20.9440	.	.
142	4HIGH	TP		83	13	8	68.2907	25.1566	1.94255	24.9564	4.37881	207.200	.	.	.	185.0	63.5
143	4HIGH	TP		84	13	8	.	.	1.11644	20.1189	2.51664	168.000	197.232	29.2320	35.3948	.	.
144	4HIGH	TP		85	13	8	.	.	.	.	.	0.000	19.096	19.0960	26.2080	.	.
145	1ZERO	MP	AN	.	14	12	32.8790	21.1843	1.02196	18.7737	2.30365	0.000	24.633	24.6325	23.3221	137.0	53.0
146	1ZERO	MP	KNIF	.	14	12	29.5500	22.9399	0.98661	18.8778	2.22397	0.000	29.669	29.6688	27.0891	125.0	57.0
147	1ZERO	NT	AN	.	14	12	41.3317	18.5976	1.19089	19.1976	2.68445	0.000	22.445	22.4448	32.7376	145.0	47.0
148	1ZERO	NT	KNIF	.	14	12	44.9489	25.1900	1.32936	20.8744	2.99657	0.000	27.398	27.3980	17.4860	131.0	52.0
149	1ZERO	TP	AN	.	14	12	33.7647	15.6558	1.13551	18.2270	2.55962	0.000	20.356	20.3560	21.0392	141.0	44.0
150	1ZERO	TP	KNIF	.	14	12	37.2102	16.1957	1.22732	19.3246	2.76657	0.000	22.744	22.7444	22.6464	124.0	48.0
151	2LOW	MP	AN	.	14	12	46.9721	31.7912	1.36077	22.1358	3.06740	45.547	60.935	23.6021	30.1168	141.0	68.0
152	2LOW	MP	KNIF	.	14	12	60.6368	30.1441	1.39778	21.8579	3.15081	45.547	60.088	22.7547	19.9360	166.0	65.0
153	2LOW	NT	AN	.	14	12	57.2061	18.2102	1.50043	22.8202	3.38221	45.547	50.565	22.5652	21.3836	148.0	43.0
154	2LOW	NT	KNIF	.	14	12	47.8432	20.9685	1.34418	21.2979	3.03000	45.547	53.074	25.0740	25.3736	141.0	48.0
155	2LOW	TP	AN	.	14	12	45.2017	16.2480	1.32160	20.3806	2.97910	45.547	48.997	20.9972	22.6128	144.0	43.0
156	2LOW	TP	KNIF	.	14	12	41.5823	13.8424	1.31275	19.8527	2.95914	45.547	49.613	21.6132	19.1660	136.0	42.0
157	3MED	MP	AN	.	14	12	49.9235	23.2753	1.33954	23.2667	3.01953	87.733	85.039	29.0388	23.3604	154.0	51.0
158	3MED	MP	KNIF	.	14	12	62.1749	37.5353	1.46127	23.0893	3.29394	87.733	100.998	26.3312	26.4992	171.0	76.0
159	3MED	NT	AN	.	14	12	62.3139	24.6850	1.46078	21.9466	3.29282	87.733	82.345	26.3452	25.4744	173.0	59.0
160	3MED	NT	KNIF	.	14	12	62.9898	29.8848	1.40183	22.1084	3.15994	87.733	79.500	23.5004	25.1888	183.0	68.0
161	3MED	TP	AN	.	14	12	59.1061	21.5484	1.41884	22.3588	3.19828	87.733	75.981	19.9808	21.7196	180.0	53.0
162	3MED	TP	KNIF	.	14	12	61.6264	20.4263	1.52673	22.0285	3.44149	87.733	77.224	21.2240	28.2380	173.0	55.0
163	4HIGH	MP	AN	.	14	12	65.0287	26.5674	1.54805	23.4198	3.48955	125.067	108.522	24.5224	29.8760	168.0	57.0
164	4HIGH	MP	KNIF	.	14	12	59.5358	40.5959	1.28510	21.4091	2.89682	125.067	144.439	32.4389	29.7136	198.0	87.0
165	4HIGH	NT	AN	.	14	12	67.7629	27.5100	1.57753	24.0910	3.55601	125.067	110.298	26.2976	27.5184	172.0	60.0
166	4HIGH	NT	KNIF	.	14	12	60.7873	33.1952	1.48321	23.4276	3.34340	125.067	113.870	29.8704	28.6188	165.0	71.0
167	4HIGH	TP	AN	.	14	12	67.5263	25.9711	1.49844	22.7090	3.37772	125.067	106.809	22.8088	29.4812	193.0	66.0
168	4HIGH	TP	KNIF	.	14	12	69.0551	24.3420	1.56055	22.3664	3.51773	125.067	109.519	25.5192	32.1216	177.0	61.0

Table 4. Continued

OBS	FERT	TILL	SCUPLE	YEAR	TYPE	ECCD	GRAINUP	STOVUP	COBUP	MGSIL	MGCORN	EN	ENRSN	RSN	RSNDEEP	GRAINN	STOVN
169	1ZERO	MP	AN	83	15	4	32.8798	21.1843	1.25999	20.9385	2.84022	0.00	.	.	.	137	53
170	1ZERO	MP	AN	84	15	4	.	.	0.78392	16.6090	1.76708	0.00	29.893	29.8928	28.5432	.	.
171	1ZERO	MP	AN	85	15	4	.	.	.	.	.	0.00	14.112	14.1120	12.8800	.	.
172	1ZERO	MP	KNIF	83	15	4	29.5500	22.9399	1.24110	20.8339	2.79763	0.00	.	.	.	125	57
173	1ZERO	MP	KNIF	84	15	4	.	.	0.73212	16.9217	1.65030	0.00	31.623	31.6232	32.5696	.	.
174	1ZERO	MP	KNIF	85	15	4	.	.	.	.	.	0.00	25.760	25.7600	16.1280	.	.
175	1ZERO	NT	AN	83	15	4	41.3317	18.5976	1.49649	21.5575	3.37333	0.00	.	.	.	145	47
176	1ZERO	NT	AN	84	15	4	.	.	0.88529	16.8377	1.99557	0.00	26.970	26.9696	53.3792	.	.
177	1ZERO	NT	AN	85	15	4	.	.	.	.	.	0.00	17.920	17.9200	12.0960	.	.
178	1ZERO	NT	KNIF	83	15	4	44.9489	25.1900	1.80139	26.6686	4.06061	0.00	.	.	.	131	52
179	1ZERO	NT	KNIF	84	15	4	.	.	0.85732	15.0802	1.93254	0.00	33.796	33.7960	22.0920	.	.
180	1ZERO	NT	KNIF	85	15	4	.	.	.	.	.	0.00	21.000	21.0000	12.8800	.	.
181	1ZERO	TP	AN	83	15	4	33.7647	15.6558	1.25720	19.3665	2.83392	0.00	.	.	.	141	44
182	1ZERO	TP	AN	84	15	4	.	.	1.01383	17.0874	2.28532	0.00	26.544	26.5440	27.5744	.	.
183	1ZERO	TP	AN	85	15	4	.	.	.	.	.	0.00	14.168	14.1680	14.5040	.	.
184	1ZERO	TP	KNIF	83	15	4	37.2102	16.1957	1.57543	20.9526	3.55127	0.00	.	.	.	124	48
185	1ZERO	TP	KNIF	84	15	4	.	.	0.87921	17.6967	1.98187	0.00	33.617	33.6168	32.4128	.	.
186	1ZERO	TP	KNIF	85	15	4	.	.	.	.	.	0.00	11.872	11.8720	12.8800	.	.
187	2LOW	MP	AN	83	15	4	46.9721	31.7912	1.74896	26.3498	3.94244	80.64	.	.	.	141	68
188	2LOW	MP	AN	84	15	4	.	.	0.97259	17.9219	2.19236	56.00	82.499	26.4992	33.8632	.	.
189	2LOW	MP	AN	85	15	4	.	.	.	.	.	0.00	17.808	17.8080	22.6240	.	.
190	2LOW	MP	KNIF	83	15	4	60.6368	30.1441	1.91773	27.1481	4.32287	80.64	.	.	.	166	65
191	2LOW	MP	KNIF	84	15	4	.	.	0.87782	16.5677	1.97875	56.00	83.468	27.4680	23.4640	.	.
192	2LOW	MP	KNIF	85	15	4	.	.	.	.	.	0.00	13.328	13.3280	12.8800	.	.
193	2LOW	NT	AN	83	15	4	57.2061	18.2102	2.02927	26.3636	4.57429	80.64	.	.	.	148	43
194	2LOW	NT	AN	84	15	4	.	.	0.97160	19.2768	2.19013	56.00	86.794	30.7944	25.7992	.	.
195	2LOW	NT	AN	85	15	4	.	.	.	.	.	0.00	14.336	14.3360	16.9680	.	.
196	2LOW	NT	KNIF	83	15	4	47.8432	20.9685	1.78140	25.3356	4.01554	80.64	.	.	.	141	48
197	2LOW	NT	KNIF	84	15	4	.	.	0.90697	17.2603	2.04445	56.00	90.020	34.0200	37.8112	.	.
198	2LOW	NT	KNIF	85	15	4	.	.	.	.	.	0.00	16.128	16.1280	12.9360	.	.
199	2LOW	TP	AN	83	15	4	45.2017	16.2480	1.64798	22.6890	3.71480	80.64	.	.	.	144	43
200	2LOW	TP	AN	84	15	4	.	.	0.99523	18.0722	2.24340	56.00	80.466	24.4664	30.7216	.	.
201	2LOW	TP	AN	85	15	4	.	.	.	.	.	0.00	17.528	17.5280	14.5040	.	.
202	2LOW	TP	KNIF	83	15	4	41.5823	13.8424	1.60520	21.1747	3.61837	80.64	.	.	.	136	42
203	2LOW	TP	KNIF	84	15	4	.	.	1.02030	18.5307	2.29991	56.00	79.458	23.4584	21.3640	.	.
204	2LOW	TP	KNIF	85	15	4	.	.	.	.	.	0.00	19.768	19.7680	16.9680	.	.
205	3MED	MP	AN	83	15	4	49.9235	23.2753	1.70194	25.8545	3.83643	151.20	.	.	.	154	51
206	3MED	MP	AN	84	15	4	.	.	0.97714	20.6790	2.20263	112.00	143.478	31.4776	25.7208	.	.
207	3MED	MP	AN	85	15	4	.	.	.	.	.	0.00	26.600	26.6000	21.0000	.	.
208	3MED	MP	KNIF	83	15	4	62.1749	37.5353	1.90888	28.4700	4.30291	151.20	.	.	.	171	76
209	3MED	MP	KNIF	84	15	4	.	.	1.01167	17.7085	2.28497	112.00	136.209	24.2088	31.6848	.	.
210	3MED	MP	KNIF	85	15	4	.	.	.	.	.	0.00	30.576	30.5760	16.1280	.	.
211	3MED	NT	AN	83	15	4	62.3139	24.6850	1.89103	25.3226	4.26268	151.20	.	.	.	173	59
212	3MED	NT	AN	84	15	4	.	.	1.03052	18.5705	2.32296	112.00	153.378	41.3784	36.4448	.	.
213	3MED	NT	AN	85	15	4	.	.	.	.	.	0.00	11.312	11.3120	14.5040	.	.
214	3MED	NT	KNIF	83	15	4	62.9898	29.8848	1.80708	25.1787	4.07345	151.20	.	.	.	183	68
215	3MED	NT	KNIF	84	15	4	.	.	0.99657	19.0380	2.24643	112.00	144.049	32.0488	25.4016	.	.
216	3MED	NT	KNIF	85	15	4	.	.	.	.	.	0.00	14.952	14.9520	24.9760	.	.
217	3MED	TP	AN	83	15	4	59.1061	21.5494	1.72393	23.5590	3.88601	151.20	.	.	.	180	53
218	3MED	TP	AN	84	15	4	.	.	1.11375	21.1587	2.51056	112.00	133.986	21.9856	26.5272	.	.
219	3MED	TP	AN	85	15	4	.	.	.	.	.	0.00	17.976	17.9760	16.9120	.	.
220	3MED	TP	KNIF	83	15	4	61.6264	20.4263	1.87017	24.1708	4.21565	151.20	.	.	.	173	55
221	3MED	TP	KNIF	84	15	4	.	.	1.18329	19.8862	2.66733	112.00	134.736	22.7360	39.5080	.	.
222	3MED	TP	KNIF	85	15	4	.	.	.	.	.	0.00	19.712	19.7120	16.9680	.	.
223	4HIGH	MP	AN	83	15	4	65.0287	26.5674	2.03215	28.0690	4.58077	207.20	.	.	.	168	57
224	4HIGH	MP	AN	84	15	4	.	.	1.06396	18.7706	2.39833	168.00	190.165	22.1648	31.5280	.	.

Table 4. Continued

OBS	FERT	TILL	SOURCE	YEAR	TYPE	FREQ	GRAINUP	STOVUP	COBUP	MGSIL	MGCORN	FN	FNRSN	RSN	RSNDEEP	GRAINN	STOVN
225	4HIGH	MP	AN	85	15	4	.	.	.	.	.	0.0	26.880	26.8800	28.2240	.	.
226	4HIGH	MP	KNIF	83	15	4	59.5358	40.5959	1.57860	25.3206	3.55841	207.2	.	.	.	198	87
227	4HIGH	MP	KNIF	84	15	4	.	.	0.99160	17.4976	2.23523	168.0	204.338	36.3384	35.7224	.	.
228	4HIGH	MP	KNIF	85	15	4	.	.	.	.	.	0.0	24.640	24.6400	17.6960	.	.
229	4HIGH	NT	AN	83	15	4	67.7629	27.5100	2.06834	27.8163	4.66237	207.2	.	.	.	172	60
230	4HIGH	NT	AN	84	15	4	.	.	1.08672	20.3657	2.44964	168.0	206.035	38.0352	35.7168	.	.
231	4HIGH	NT	AN	85	15	4	.	.	.	.	.	0.0	14.560	14.5600	19.3200	.	.
232	4HIGH	NT	KNIF	83	15	4	60.7873	33.1952	1.93414	27.3443	4.35986	207.2	.	.	.	165	71
233	4HIGH	NT	KNIF	84	15	4	.	.	1.03229	19.5108	2.32693	168.0	209.597	41.5968	34.6696	.	.
234	4HIGH	NT	KNIF	85	15	4	.	.	.	.	.	0.0	18.144	18.1440	22.5680	.	.
235	4HIGH	TP	AN	83	15	4	67.5263	25.9711	1.83686	24.0515	4.14056	207.2	.	.	.	193	66
236	4HIGH	TP	AN	84	15	4	.	.	1.16003	21.3665	2.61488	168.0	193.290	25.2896	35.5544	.	.
237	4HIGH	TP	AN	85	15	4	.	.	.	.	.	0.0	20.328	20.3280	23.4080	.	.
238	4HIGH	TP	KNIF	83	15	4	69.0551	24.3420	2.04825	25.8613	4.61707	207.2	.	.	.	177	61
239	4HIGH	TP	KNIF	84	15	4	.	.	1.07286	18.8714	2.41839	168.0	201.174	33.1744	35.2352	.	.
240	4HIGH	TP	KNIF	85	15	4	.	.	.	.	.	0.0	17.864	17.8640	29.0080	.	.