Animal Manures and Urea as Nitrogen Sources
for
Corn Production
in
Quebec

by

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ABSTRACT

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Renewable Resources

Fresh (FC) and composted cow (CC) manures, hog manure (HM) and urea (U) were applied as N sources for corn (W 844) production on a Chicot soil (sandy clay loam) and a St Benoit soil (sandy loam) at rates of 60 to 240 kg N/ha.

More soil water was conserved by CC and FC manures than by HM. Soil organic matter and bulk density were not affected by manures over the three years of the experiment. Soil NO_3-N levels were significantly increased by N additions. An application of 240 kg manure-N/ha produced less NO_3-N in the soils that one of 180 kg urea-N/ha.

Significant correlations existed between corn dry-matter yields and N or P contents of corn ear leaves at silking. Dry-matter yields and N uptake were higher with HM than with CC or FC manures. Differences between surface spreading or incorporating of manure on corn dry-matter yields were not signifcant. Cumulative effects of the treatments on yields were higher on the sandy loam soil than on the sandy clay loam soil.

RESUME

Rongjing Xie

Ressources renouvelables

Du fumier de bovins frais (FC) et composté (CC), du fumier de porcs (HM) et de l'urée (U) furent appliqués comme sources d'azote pour la production de maïs (W844). Ces produits ont été appliqués à des taux de 60 à 240 kg N/ha sur un loam sablo-argileux Chicot et sur un loam sableux St Benoit.

L'humidité du sol était supérieure avec l'application du fumier composté qu'avec le fumier frais de bovins et le fumier de porcs. A court terme, la matière organique du sol et la densité apparente n'ont pas été affectées par les applications de fumier. Le contenu en nitrates (NO_3-N) du sol a été significativement augmenté par une augmentation des doses d'azote. Une dose de 240 kg N/ha venant du fumier de porc n'a pas augmenté le contenu en nitrate du sol autant que 180 kg N/ha venant de l'urée.

Des corrélations significatives ont été obtenues entre le rendement en matière sèche du maïs et la concentration en N et P dans les feuilles au niveau de l'épi. Le rendement en matière sèche et les prélèvements en azote étaient supérieurs avec le fumier de porcs qu'avec le fumier de bovins frais ou composté. Les rendements en matière sèche du maïs n'étaient pas très différents, que le fumier fut appliqué en surface ou

incorporé dans le sol. Les effets cumulatifs des différents traitements étaient supérieurs dans le cas du loam sableux que dans celui du loam sablo-argileux.

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FOREWORD

This thesis contains an overall introduction, three chapters, and ends with general conclusions. Chapter 1 is a review of literature. Chapter 2 discusses effects of manures or urea on soil properties and Chapter 3 presents effects of manures or urea on corn production.

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Introduction

Organic wastes have been used as soil amendments and sources of plant nutrients for many centuries. Research on use of barnyard manure to improve soil productivity decreased after World War II, when N fertilizers became abundant and inexpensive. In recent years, large amounts of manure have been produced by animal production units concentrated in feedlots and large poultry operations. Problems in disposing of this manure coupled with increased fertilizer costs have renewed interest in using organic wastes as nutrient sources for crop production.

There are numerous varieties of animal manures. Different manures have different compositions (Gilberstson et al. 1974; Peng and Pei 1979). Fresh manures contain various substances which could be toxic, such as ammonia, sulfides, soluble salts, and harmful organisms (Hong et al. 1982; Lund and Nissen 1983). For this reason, it may be necessary to aerate manures to remove toxic substances before putting manures to use. When applied to soils, variation in composition of manure can exert different effects on soil properties, and subsequently, nutrient uptake and crop growth can be affected.

Inorganic N fertilizers have been reported to increase soil acidity (Jaakkola 1978; Barnard and Folscher 1980) when applied alone in long-term monoculture without ameliorating management practices being adopted. Compared with inorganic fertilizers, manure can not only supply plants with necessary nutrients, but also improve soil physical properties, such as soil water retention capacity (Tiarks et al. 1974; Meek et al. 1982).

One of the problems with manure use is that manure can be a source of contaminants, such as NO_3-N, which can reach ground water or waterways by runoff or leaching (Young and Mutchler 1976; Bashkin and Kudeyarov 1983).

Thus it is hypothesized that various manures, compared with urea, may have different effects on soil physical parameters, such as water retention capacity and bulk density, and on chemical properties, such as NH_4- and NO_3-N levels and on organic matter contents. These soil properties, in turn, may influence crop yields.

Work has been done on the management of animal manures (Calvert 1979; Vanderholm 1979) and their influences on soil properties and crop growth in recent years (Evans et al. 1977; Higgins 1984). In Quebec, however, work on animal manures as soil amendments and crop nutrient sources has been inadequate to assess appropriate manure management practices. Therefore, the purposes of this project were to study:

1. The effect of manures on soil moisture content, organic-matter content and bulk density.
2. NH_4- and NO_3-N contents in soil profiles resulting from different application methods of manure-N.
3. Corn silage yield response to different kinds of manure and urea-N treatments.
4. Cumulative effects of different kinds of manure and urea-N on corn yields and nutrient uptake by corn.

Chapter 1

Literature Review

1.1 Manure as a nutrient source

In Quebec, the total livestock and poultry population was over 28 million in 1982, and in Canada, 116 million, according to Agriculture Canada (1983) (Table 1.1).

The estimated manure production in Quebec was 26 million tonnes, and in Canada 135 million tonnes annually. These quantities of manures contain approximately 129 and 710 thousand tonnes of N (Tables 1.2 and 1.3). In addition, it is estimated by the author, based on the average manure nutrient contents of different sources (Mathers et al. 1973; Gilbertson et al. 1974; Peng and Pei 1979), that manures also contain about 75, 150 and 23 thousand tonnes of P, K, and Ca, expressed as P_2O_5, K_2O, and CaO in Quebec, and 443, 887, and 133 thousand tonnes in Canada, respectively.

Besides plant nutrients, manures are sources of organic materials. Generally manures contain about 60% organic matter and 17.5% moisture as has been reported by Meek et al. (1982). Thus, it is estimated by the author, that in Quebec at least 10 million tonnes, and in Canada 80 million tonnes, of organic materials are excreted by animals annually, and are available for land application.

Table 1.1 Numbers of livestock and poultry on farms at July 1, 1978 and 1982 in Quebec and Canada (thousands)

Kind of animal	Quebec		Canada	
	1982	1978	1982	1978
Dairy cow	695	729	1,765	1,863
Heifer, beef cow	490	452	5,623	5,784
Steer or bull	98	89	1,874	2,123
Calf	365	275	3,790	3,583
Sow	320	257	1,047	835
Weaner (<20 kg)	1,145	746	3,279	2,459
Hog (20-90 kg)	1,860	1,337	5,475	4,080
Hen	3,858	3,810	24,096	23,377
Pullet	17,139	14,556	59,601	36,363
Turkey	1,942	2,340	8,718	11,049
Lamb	120	58	817	587
Total	28,032	24,649	116,083	92,102

Source : Agriculture Canada, Selected agricultural statistics Canada and the Provinces. 1983.

Table 1.2 Fresh manure production and manure total nitrogen content estimated for various types of livestock used to calculate total manure and nitrogen production

Kind of animal	Manure production ----- t/yr -----	Nitrogen content ---- kg/t -----
1 Dairy cow	16.6	3.8
1 Heifer, beef cow	10.3	5.4
1 Steer or bull	7.7	5.4
1 Calf	3.4	5.4
1 Sow	4.1	6.3
1 Weaner (<20 kg)	0.6	6.3
1 Hog (20-90 kg)	1.9	6.3
1 Hen	0.05	10.4
1 Turkey	0.09	10.4
1 Pullet	0.03	10.4
1 Lamb	0.5	7.1

Adopted from Culley and Barnett (1984).

Table 1.3 Estimated total manure production and nitrogen contained in manures in 1982

Kind of animal	Manure production		Nitrogen content	
	Quebec	Canada	Quebec	Canada
	-- million tonnes --		-- thousand tonnes --	
Dairy cow	11.5	29.3	44	111
Heifer, beef cow	5.0	57.9	27	313
Steer or bull	0.8	14.4	4	78
Calf	1.2	12.9	7	70
Sow	1.3	4.3	8	27
Weaner (<20 kg)	0.7	2.0	4	12
Hog (20-90 kg)	3.5	10.4	22	66
Hen	0.2	1.2	2	13
Pullet	0.5	1.8	5	19
Turkey	0.2	0.8	2	8
Lamb	0.1	0.4	4	3
Total	26.0	135.0	129	710

1.2 Effects of manure on soil properties and plant nutrition

1.2.1 Soil properties

After being incorporated into soil, manure has an effect on soil properties due to the various components it contains.

A comprehensive review of the literature by Khaleel et al. (1981) indicated that in general, soil organic matter has been increased by manure applications in a variety of conditions or climates. Without manure, large amounts of N, P, and K failed to prevent a diminution in soil organic matter under continuous corn (Jaiyebo and Bouldin 1967). Increased soil organic matter levels with added manures led to significant improvement of soil structure and decreased soil bulk density in Nebraska (Tiarks et al. 1974), in Texas (Unger and Stewart 1974) and reduced soil erosion in Uttar Pradesh, India (Chandra and De 1982) although runoff water quality after manure aplication was not improved in Texas, according to Mathers et al. (1977).

Increased soil moisture has been observed due to reduced soil surface and subsurface temperatures and decreased evaporation following the application of manures (Unger and Stewart 1974; Hornick 1982), and has resulted in more water intake by crops during the growing season (Meek et al. 1982).

Increased yields with manure applications were attributed to enhanced response of crop to nutrients or soil nutrition status (Cope et al. 1958; Carlson et al. 1961; Herron and Erhart 1965; Dubetz et al. 1975; Evans et al. 1977; Mathers and Stewart 1981; El-Attar et al. 1982), and in some cases , the decreased evaporation of water from soil due to manure application was the main cause of the substantially increased yields (Hall and Coker 1982; and Gupta et al. 1983).

Application of manures was observed to be effective in increasing soil microbial activities (Karpova and Petrova 1966) and crop nutrient levels (Bishop et al. 1962; Olsen et al. 1970; Swarup 1982). According to Swarup (1982), working with a calcareous, sandy loam soil at Karnal, India, additions of farmyard manure markedly increased levels of extractable Fe and Mn from a submerged sodic soil in comparison with the control and were more effective in reducing the decrease of available P than other treatments employed during the growth period of rice crops. Manure tended to increase soil pH and the contents of organic N, available P and exchangeable K, Ca and Mg, particularly at the higher application rates (Olsen et al. 1970). From Nova Scotia it was reported that application of manure at 70 t/ha to a clay loam soil every third year almost maintained initial levels of total soil N (Bishop et al. 1962).

1.2.2 Crop production and plant nutrition

Manure has direct and indirect effects on crop yield. Direct effects depend on the amount of nutrients it contains, and manure can substitute for mineral fertilizers in this aspect. An indirect effect of manure, as detailed earlier, is to improve the physical properties of the soil, to intensify microbiological and enzymatic soil activities, and to enrich the air above the soil with carbon dioxide (Karpova and Petrova 1966; Tiarks et al. 1974; Mazurak et al. 1977). Thus manure may increase crop yields more than expected on the basis of manure nutrient contents.

Many authors have noted increased crop yields with manures over control or inorganic fertilizers (Cope et al. 1958; Bishop et al. 1964; Black and White 1973; Dubetz et al. 1975; Kiver and Kiver 1976; Cheng 1982; Higgins 1984; Stomberg et al. 1984). Comparison among different manures and between manures and inorganic fertlizers indicated that liquid manure (liquid hog manure and liquid beef manure) resulted in slightly higher yields of corn than solid beef manure (Evans et al. 1977). According to Evans et al. (1977), working with a silt loam soil in Minnesota, yields associated with manures were higher than those with inorganic fertilizer, but in a short term experiment conducted in Quebec, increased yields with manure were not evident (Miller and MacKenzie 1978). Different climatic conditions and different soils involved in these experiments could account for the variable effects on crop yields.

Cumulative benefits of manure and N fertilizer may become apparent during the second application and increase with advancing years (Bishop et al. 1964; Dubetz et al. 1975). The residual effect of manures lasted 6-8 years depending on loading rate, variety of crops and climatic conditions (Cope et al. 1958; Kiver and Kiver 1976).

Manure must also have an influence on nutrient uptake by crops since it can improve soil fertility and raise yields of crops. A few examples illustrate a general trend.

According to Cheng (1982) in Quebec, the content of N, P, K, Ca, Mg, Cu, Fe, Mn and Zn in raspberry leaves from plots manured at 70 tonnes/ha were higher than those from plots manured at 35 tonnes/ha. From India, it was reported that with the application of 15 tonnes/ha farmyard manure to a wheat crop grown on an Aridisol soil with a sandy loam texture, grain yield increased from 1.40 to 1.92 tonnes/ha and Zn uptake increased from 48 to 79.9 g/ha (Srivastava and Sethi 1981). Studies in Iowa indicated that manure addition to subsoil resulted in substantially higher P uptake by maize, and K concentration in roots and shoots was consistently high and not as limiting as N and P according to Aina and Egolum (1980) from Iowa. Working with corn grown on a subsoil, Carlson et al. (1961) from North Dakota indicated that manure increased the ability of the plant to absorb P. Data obtained in Nova Scotia by Bishop et al. (1964) showed that N content of corn leaves was higher at the rate of 50 tonnes manure per hectare than that at the rate of 25 tonnes per hectare. In Ontario, Culley et al. (1981), working with sandy clay loam, obtained the same results as Bishop et al. (1964), but their work further pointed out that uptake of nutrients was not affected by time of application. Similarly, P, Ca and Mg contents of sweet-corn grain were about the same on control and waste-amended plots, although N contents of the grain on waste-amended plots were significantly higher than those on control plots (Hornick 1982). No significant change in uptake of trace elements was observed in the grain as a result of the amendments. As reported by Reddy et al. (1982), manure had no effect on Fe concentration and uptake by rice or wheat in any of the soil types researched in India.

1.3 Relative value of manure as fertilizer

Manure has numerous benefits for soils and crops. However, in most cases, it is thought of as a N source because N content is higher than other mineral nutrients (Heck 1931; Herron and Erhart 1965; Follett et al. 1981).

Research in Quebec has shown that 4 kg manure-N was approximately equivalent to 1 kg ammonium nitrate-N for corn production (Miller and MacKenzie 1978). As reported by Herron and Erhart (1965), each tonne of high quality manure was equivalent to 10 kg of N from ammonium nitrate as measured by equivalent grain sorghum yields over a 4 year period. Cope et al. (1958) pointed out that each 5 tonne application of manure was equivalent to 26 kg of commercial N for corn, and 28 kg for cotton.

According to Beauchamp (1983), with respect to corn grain yield and soil NO_3-N concentration, the availability of liquid cattle manure N (LCM) was appoximately one-half that of urea or anhydrous ammonia N. Comparison between application methods (surface vs. injection) showed injection of LCM resulted in LCM N being about 60% as available as inorganic fertilizer N, while LCM application to soil surface resulted in LCM N being approximately one-third as available as anhydrous ammonia N.

1.4 Efficiency of manure use

Loss of ammonia and soluble N from manure can reduce the effectiveness of manure as a source of N.

Work conducted in Ontario (Beauchamp et al. 1982; Beauchamp 1983) showed that one-half of the total N in manure was made of ammoniacal N, which may be subject to potential volatilization. Over periods of 6 or 7 days following manure surface application, between 24 and 33% of the ammoniacal N applied in liquid dairy cattle manure was lost by volatilization (Beauchamp et al. 1982). Similarly, Lauer et al. (1976) reported that from 17 to 316 kg N/ha can volatilize depending on the application rate and total ammoniacal N content of the manure. Between 10 and 75% of the ammoniacal-N may be lost from applied manure if it is not incorporated into the soil within a week or so following application (Beauchamp et al. 1978).

Besides ammoniacal N volatilization, soluble N contained in manure can be lost by runoff or leaching (Young and Mutcher 1976; Evans et al. 1977).

To reduce losses of N contained in manure, incorporating animal wastes into soil has been shown to be effective. In Minnesota, up to 20% of the N and 16% of the ortho-P in manure was carried away in spring runoff while no more than 3% of the N and 4% of the ortho-P were lost from manured fall-plowed plots (Young and Mutchler, 1976).

1.5 Manure as a source of NO_3-N contamination

Ground water NO_3-N content may be increased by manure application to the soil (Bashkin and Kudeyarov 1983). As noted by Evans et al. (1977), working on a silt loam soil at Morris, Minnesota, NO_3-N levels in soil treated with liquid beef manure were generally greater than those treated with liquid hog manure or solid beef manure. Soil treated with manures had higher NO_3-N levels than soil treated with ammonium nitrate. In Quebec (Miller and MacKenzie 1978), the total extractable NH_4- and NO_3-N in soil profiles was higher with ammonium nitrate and urea than with solid beef manure and liquid hog manure soon after their application. Slightly higher NH_4- and NO_3-N contents were found with solid beef manure later in the growing season. According to Phillips et al. (1981), however, pollution potential of manure was the same as that of chemical fertilizer.

The time of application of manure affected the NO_3-N content of the soil in Pennsylvania (Marriott et al. 1977), and of runoff water in Ontario (Phillips et al. 1981). Fall- (Marriott et al. 1977) and winter- (Phillips etal. 1981) applied manure resulted in higher soil or runoff water NO_3-N levels than spring-applied manure throughout most of the period. Therefore, spring application was "safe" as regards potential NO_3-N pollution.

1.6 Summary

Animal manure can be a source of crop nutrients, can improve soil physically, and can act as a source of NO_3-N, a potential contaminant to our environment.

Application of manures to agricultural land is a common manure management practice. Soil physical properties, such as water holding capacity, bulk density, and chemical properties, such as organic-matter content and levels of crop nutrients, have been improved by incorporating manures into soils. In return, the enhancement of soil properties leads to increases in crop production. Despite these studies, precise crop-manure response results are lacking. This is due to problems of predicting the value of manures in relation to their properties. Storage and handling influence N forms and quantities, as well as C/N ratios, and subsequent release of N of manure. In addition, soil properties may be changed in relation to kind of manures. Thus it seemed appropriate to study the following problems to propose the hypothesis that changes in handling procedure and methods of application would influence manure value for crop production, specifically:

1. Surface applied manures would act as mulches, increasing soil moisture content and increasing crop yield.
2. Composting manure would convert N to more resistant and non-available forms, thus, reduce N losses due to ammonia-N volatilization. When applied to soil, composted manure could result in less NO_3-N, compared with fresh manure.
3. Losses of ammonia-N would be more pronounced on surface applications and lead to low soil NO_3-N level, as compared with incorporation of manure.
4. Liquid hog manure should have more available N due to the higher NH_4-N content found in this manure compared with solid manure.

5. Due to changes in soil physical properties and due to nutrient content of manures, uptakes of nutrients other than N would be greater from soil amended with manures than from soil with inorganic fertilizer.

6. The effects of manure would be cumulative, whereas inorganic N effects would not be cumulative.

Chapter 2

Effect of manures and urea on soil bulk density, ammonium- and nitrate-N, and organic matter content

2.1 INTRODUCTION

Application of animal manures to agricultural land has been reported to result in higher levels of mineral N in the soil profile and improvement of soil properties.

Comparisons made among ammonium nitrate, solid beef manure, liquid beef manure, and liquid hog manure have indicated that soil NO_3-N levels from liquid beef manure were higher than those from liquid hog manure (Evans et al. 1977). Solid beef manure had the lowest soil NO_3-N levels, but all manure treatments resulted in higher NO_3-N levels than ammonium nitrate. The effects of ammonium nitrate, S-coated urea, liquid hog manure, hog manure plus straw and solid cow manure on total extractable NH_4- and NO_3-N to a depth of 1 m of soil were studied by Miller and MacKenzie (1978). They found cow manure and S-coated urea were potentially more serious as NO_3-N pollution hazards than ammonium nitrate and liquid hog manure, assuming mineral N in the soil profile as the source of ground water pollution. Leaching of NO_3-N below the root zone of corn grown on manured soil was recorded by Evans et al. (1977). Cooper et al. (1984) determined the distribution of NH_4-, NO_3-, NO_2- and total N to a depth of 6 m in a clay loam soil under the influence of cattle and poultry manures with the rates from 32 to 121 tonnes/ha. They found the recovery of applied N in the upper 6 m of the soil profile generally decreased with the increased manure N application, although the quantity of N present increased with increased N application. The primary inorganic N component in the soil profile was NO_3-N and the zone of maximum accumulation was between 2 and 2.5 m. Quisenberry et al (1981) suggested that if N losses by leaching are to be minimized, N additions of dairy wastewater to a sandy textured soil must be based on the same criteria as that used to determine N applications of mineral fertilizers.

Soil water holding capacity was significantly increased and soil bulk density was decreased by incorporation of digested or undigested sludges in the soil in the Netherlands (Hall and Coker 1982), by feedlot waste in Texas (Unger and Stewart 1974, and by farmyard manure associated with urea in western Rajasthani of Indian (Gupta et al 1983). The use-efficiency of soil moisture reserves was increased by manure applications in Alberta (Hoyt and Rice 1977). These increases were considered to be due to increased soil organic matter content and improved physical condition of the soil. Application of feedlot manure increased soil organic matter content and hydraulic conductivity at Bushland, Texas (Mathers and Stewart 1981). Soil organic matter and aggregation increased and evaporation decreased as feedlot waste application rates increased (Unger and Stewart 1974). For plots tilled 10 cm deep, the manure applications of 360 tonnes/ha increased the soil organic carbon content from 2% to 5% after 2 years and bulk density decreased from 1.05 g cm^{-3} to 0.90 g cm^{-3} in Nebraska (Tiarks et al. 1974). However, the most efficient manure rate was 22 tonnes/ha incorporated into the soil immediately after spreading for crop production. Higher manure rates more effectively improved soil physical properties but large N losses reduced the fertilizer efficiency of high manure rates (Mathers and Stewart 1981) and elsewhere resulted in risks of NO_3-N poisoning and base-imbalance in the soil (Ito and Miyazawa 1984). However, the effects of manure on soil properties decreased with increased depth of tillage (Tiarks et al. 1974) due to a dilution effect.

Although considerable work has been done on effects of manure applications to soil, comparison of effects of different kinds of manures on soil physical and chemical properties are limited. This study was an attempt to determine :

1. Soil moisture conservation, bulk density and organic matter content influenced by additions of cow and pig manures and by urea.
2. Soil NH_4- and NO_3-N contents as affected by manures and urea N sources.

2.2 MATERIALS AND METHODS

2.2.1 Field methods

2.2.1.1 Soils

Two soils, a St Benoit and a Chicot, described by Lajoie (1960), were selected on two sites (Table 2.1). Both sites were on the Macdonald College farm of McGill University, Ste Anne de Bellevue, Quebec. The two sites were under the same general climate conditions and the distance between them was 1 km.

2.2.1.2 Manures

Three kinds of manures were used, varying in chemical composition (Table 2.2). Fresh cow manure (FC) was collected from the Macdonald College farm. Composted cow manure (CC) was prepared by aerating fresh cow manure for two months before application. Composting was accomplished by piling fresh cow manure and turning it over every other day. Hog manure (HM) in liquid state was collected in a retaining tank from the hog facilities on the Macdonald College farm, and applied immediately.

2.2.1.3 Field experimental procedure

Research was initiated in 1982 and continued in 1983 and 1984. Only the experimental data collected in 1983 and 1984 are included in this discussion.

Twelve treatments were applied for each of the 3 years (Table 2.3). Each of the manures was applied at two levels, level 1 was 120 kg N/ha, and level 2 was 240 kg N/ha. The manure N rate of 240 kg N/ha of FC or HM was applied either on the surface (FC2S, HM2S) or incorporated into the soils (FC2, HM2). Urea (U) at rates of 60 (level 1), 120 (level 2),

Table 2.1 Characteristics of the experimental soils

Parameter		Soil series	
		Chicot	St Benoit
Parent material		Loamy sand over calcareous till	Sand over calcareous till
Particle size range (%)	clay	21	13
	silt	25	18
	sand	54	69
Texture		Sandy clay loam	Sandy loam
pH (soil:water=1:2)		7.0	5.3
Organic carbon (%)		2.33	2.34
Total-N (%)		0.23	0.19
C/N		10	12
Bray-2-P (kg P/ha)		286	176
Extractable K (kg K/ha)		198	110
Extractable Ca (kg Ca/ha)		2860	2283
Extractable Mg (kg Mg/ha)		633	290

Table 2.2 The properties of the manures used in the study in 1984

Parameter		Manure		
		CC[1]	FC[2]	HM[3]
Dry matter	(%)+	21.4	17.4	5.1
Organic matter	(%)*	81.1	85.9	67.1
Organic carbon	(%)*	46.7	50.9	52.8
Total-P	(%)*	1.13	1.06	2.32
K	(%)*	3.33	2.71	3.59
Ca	(%)*	3.53	2.24	2.79
Mg	(%)*	0.62	0.51	0.44
Ammonium-N	(%)*	1.10	1.53	1.15
Total-N	(%)*	2.2	2.0	2.50
C/N		21	25	21

+ on wet weight basis.
* based on dry matter .
1) composted cow manure .
2) fresh cow manure .
3) hog manure in liquid state .

Table 2.3 N application as related to treatments

Treatment	CC[1]	FC[2]	HM[3]	U[4]
	Kg N/Ha			
Ctrl	0	0	0	0
CC1	120	0	0	0
CC2	240	0	0	0
FC1	0	120	0	0
FC2	0	240	0	0
HM1	0	0	120	0
HM2	0	0	240	0
U1	0	0	0	60
U2	0	0	0	120
U3	0	0	0	180
FC2S	0	240*	0	0
HM2S	0	0	240*	0

* : Surface application.
1) Composted cow manure.
2) Fresh cow manure.
3) Liquid hog manure.
4) Urea.

and 180 (level 3) kg N/ha was applied for comparison with manures. A control treatment was included. Based on soil test values, in each of the 3 years, the Chicot soil was fertilized with 75 kg P_2O_5/ha as triple superphosphate, and 110 kg K_2O/ha applied as muriate of potash, the St Benoit soil with 145 kg P_2O_5/ha and 180 kg K_2O/ha. The field treatments were arranged in a randomized complete block design with four replications, using a treatment plot size of 3.0 X 5.0 m. Manures and urea were disked into the soils once they were applied, prior to sowing. For surface application treatments, manures were not disked.

Corn (Zea mays L.) CV W844 was sown June 16, 1983, and May 28, 1984. Plant populations were controlled at 60,000 plants/ha in 1983, and 80,000 plants/ha in 1984, and harvested for silage on September 26 and September 28 in 1983 and 1984 respectively.

2.2.1.4 Soil sampling methods

Soils were sampled once a month after seeding in 1983 at three depths, 0-20, 20-40, and 40-60 cm, for the St Benoit soil, and at two depths, 0-20, and 20-40 cm, for the Chicot soil during the growing season, and in 1984, at four depths, 0-10, 10-20, 20-40, and 40-60 cm, for the St Benoit soil and at three depths, 0-10, 10-20, and 20-40 cm, for the Chicot soil. Soil samples were taken with an auger, placed in cans, covered, and taken to the laboratory for determination of gravimetric moisture content, NH_4-N and NO_3-N.

Prior to application of manures and urea in 1984, soil samples were taken for the measurement of 1983 treatment residual effects on NO_3-N and NH_4-N contents.

Soil bulk density was measured in August, 1984 by taking an undisturbed core sample using an aluminum cylinder, 8.5 cm in diameter and 7.8 cm in height. The top 5 cm soil was removed and the cylinder was hammered into the soil, external soil removed, and the soil in the cylinder carefully removed for moisture content determination at 105°C. A subsample was taken when the soil was dried for the measurement of soil organic matter content.

2.2.2 Laboratory methods

From the auger soil samples of each depth, a 100-g subsample of soil was transported to the laboratory. A further subsample of 10-15 g fresh soil was shaken with 100 mL 1M KCl for one hour, filtered and analyzed for NH_4-N and NO_3-N according to the procedure suggested by O'Brien and Fiore (1962) and Kamphake et al. (1967), respectively. The rest of the soil was dried at 105°C for gravimetric moisture measurements.

Total soil N content was measured by using the semi-micro Kjeldahl method described by Bremner (1965). Soil pH was determined in a 1:2 soil - water ratio using a glass-calomel electrode (Peech 1965). Organic carbon was analyzed by employing the Walkley-Black procedure detailed by Allison (1965). Available P was determined by the Bray-2 method (Bray and Kurtz 1945). Exchangeable K, Ca and Mg were extracted with 1M NH_4OAc, and K was determined by flame photometer, Ca and Mg by atomic absorption (Hunter 1974). Soil texture was determined based on the procedure described by Bouyoucos (1951).

The NH_4-N content of wet (fresh) manures was determined in an 1M KCl extraction. The semi-micro Kjeldahl method (Bremner 1965) was used to determine total-N content of fresh manure samples (CC, FC and HM).

Manure samples were dried in the oven at 105°C. Organic C was analyzed by the method of Allison (1965). For the determination of P, K, Ca and Mg, the wet digestion method outlined by Thomas et al. (1967) was used. P was determined colorimetrically (Thomas et al. 1967), Ca and Mg by atomic absorption and K by flame photometer (Hunter 1974).

Duncan's multiple range test was employed to locate differences among the 12 treatments. Also, the treatments, CC1, CC2, FC1, FC2, HM1, HM2 were analysed statistically as a 3 X 2 factorial arrangement (Steel and Torrie 1980).

2.3 RESULTS

2.3.1 Soil water retention

Chicot Soil

In 1983, measurements made 61 days after sowing indicated the surface soil treated with FC2S and FC2, retained significantly more water than soil treated with CC2, HM1, HM2, U1, U2, U3 and HM2S. The treatment effect was not reflected 103 days after sowing (Table 2.4).

Table 2.4 Effect of manures or urea on moisture content of soils in 1983

	Chicot		St Benoit		
	Depth (cm)				
Treatment	0-20	20-40	0-20	20-40	40-60
	%				
	61 days after seeding				
Ctrl	16 abc[1]	14	16	11	9#
CC1	16 abc	14	18	12	12
CC2	15 bc	14	19	14	11
FC1	16 abc	15	18	12	11
FC2	17 a	14	18	14	10
HM1	14 d	14	17	11	7
HM2	15 cd	11	18	13	9
U1	15 cd	12	16	12	8
U2	15 cd	13	17	13	11
U3	15 cd	14	17	13	9
FC2S	17 a	14	19	13	9
HM2S	14 d	13	18	10	8
F	3.63**	1.37	1.68	0.61	2.07
CV(%)	7.4	13.6	12.6	29.1	20.6
	103 days after seeding				
Ctrl	19	14	16	14	13
CC1	19	14	16	12	10
CC2	20	15	17	15	10
FC1	19	14	16	13	10
FC2	21	15	16	12	12
HM1	20	15	14	13	11
HM2	18	19	14	13	13
U1	20	16	14	10	8
U2	19	16	16	12	10
U3	20	16	15	11	9
FC2S	21	15	17	15	10
HM2S	19	15	13	11	11
F	1.94	1.13	1.31	0.57	1.02
CV(%)	5.9	17.1	9.3	23.5	30.3

1) means in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

** : Significant at the level of 0.01 .

: in this thesis, means not followed by a letter in a column within a block in a table are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

In 1984, 30 days after seeding (June 27, 1984), the gravimetric water contents of soil treated with FC2S and FC2 were significantly higher than that of the control, U1, U2 and HM2S treatments at the depth of 0-10 cm. Differences among manures were not significant. At depths of 10-20, 20-40 cm, no significant differences were found (Tables 2.5, 2.6 and 2.7).

In measurements of the top 10 cm layer made 60 days after sowing (July 26, 1984), the FC2S and FC2 treatments had moisture contents of 23% and 22% which were significantly greater than other treatments with values of 20% or less (Table 2.5). At depths of 10-20 cm, the effects of the FC2S, and FC2 treatments resulted in moisture contents significantly higher than those of the control, CC1, FC1, HM2, U2 and HM2S treatments. At depths of 20-40 cm, little moisture content difference was found. The moisture content of the HM2S treatment was the lowest among the treatments through the soil profile. When analyzed as a factorial arrangement, the moisture content associated with FC manure treatments was significantly higher than that with CC manure treatments (Table 2.6). High manure application rates resulted in significantly more water in the soil.

Significant treatment or manure effects on soil water content were not detected at 90 days after seeding (August 28, 1984; Table 2.7).

At 125 days after seeding (October 4, 1984), at 0-10 cm, significantly higher moisture contents were found with the FC2S treatment compared with other treatments, except for the FC2 treatment (Tables 2.7 and 2.8). The FC2 treatment had a higher water content than

Table 2.5 Effect of manures or urea on moisture content of soils at 30 and 60 days after seeding in 1984

	Chicot			St Benoit			
	Depth (cm)						
Treatment	0-10	10-20	20-40	0-10	10-20	20-40	40-60
	%						
	30 days after seeding						
Ctrl	23 b[1]	25	21	24 cd	27 a	24 abc	19
CC1	24 ab	26	24	26 abc	27 a	25 abc	20
CC2	24 ab	27	22	27 a	28 a	24 abc	20
FC1	24 ab	26	22	25 abc	27 a	27 ab	22
FC2	26 a	27	22	26 abc	28 a	23 bc	19
HM1	24 ab	25	22	26 abc	27 a	20 c	17
HM2	24 ab	26	21	25 abc	27 a	25 abc	20
U1	22 b	25	21	23 d	24 b	21 c	19
U2	23 b	27	22	25 abc	26 a	21 c	17
U3	24 ab	27	24	25 abc	27 a	22 c	18
FC2S	26 a	28	24	27 a	28 a	28 a	23
HM2S	23 b	25	23	24 cd	26 a	23 bc	18
F	2.45*	2.05	1.22	2.52*	2.46*	3.01**	1.97
CV(%)	6.1	5.1	9.4	5.9	4.6	12.1	14.1
	60 days after seeding						
Ctrl	19 bc	20 cd	18	20	23	21	18
CC1	19 bc	20 cd	18	21	22	20	13
CC2	20 b	21 bc	19	22	23	20	20
FC1	19 bc	19 cd	19	21	22	16	12
FC2	22 a	23 ab	18	21	23	16	14
HM1	19 bc	21 bc	19	21	22	20	16
HM2	20 b	20 cd	18	18	20	16	13
U1	19 bc	21 bc	21	20	20	18	14
U2	19 bc	19 cd	18	21	21	16	11
U3	19 bc	21 bc	18	21	22	19	18
FC2S	23 a	26 a	18	23	24	20	15
HM2S	17 d	18 d	16	20	21	20	16
F	8.72**	5.31**	1.03	1.61	1.15	0.89	1.17
CV(%)	19.6	8.6	11.0	8.6	11.3	18.6	31.6

1) means in the same column with the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*, ** : significant at the levels of 0.05 and 0.01 respectively.

Table 2.6 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on gravimetric moisture content of soils at 30 and 60 days after seeding in 1984

Main effect	Chicot Soil			St Benoit Soil			
	Depth (cm)						
	0-10	10-20	20-40	0-10	10-20	20-40	40-60
	6/27/1984 (30 days after seeding)						
	probability						
CFH	0.5319	0.1684	0.3744	0.4821	0.0574	0.1232	0.1209
NR	0.0611	0.0608	0.4472	0.7311	0.3826	0.9578	0.8123
CV(%)	6.8	4.9	8.6	5.7	3.0	10.1	11.6
	%						
CC	24.3	26.3	22.7	26.1	27.5	24.1	20.5
FC	24.9	26.6	22.2	26.2	27.6	24.8	20.5
HM	24.0	25.4	21.3	25.4	26.6	22.3	18.3
N120	23.7	25.6	22.4	26.0	27.1	23.7	19.9
N240	25.1	26.6	21.8	25.8	27.4	23.8	19.7
	6/27/1984 (60 days ater seeding)						
	probability						
CFH	0.0449	0.6164	0.9877	0.5564	0.4029	0.2039	0.2832
NR	0.0053	0.0681	0.5138	0.8558	0.6966	0.4506	0.2563
CV(%)	5.6	8.5	14.1	8.9	9.3	22.9	26.6
	%						
CC	19.3b[1]	20.6	18.5	21.5	22.6	20.0	16.4
FC	20.8a	21.4	18.7	21.2	22.4	16.1	13.4
HM	19.8ab	20.7	18.6	20.5	21.3	18.3	14.1
N120	19.3b	20.2	19.0	21.1	22.3	18.8	13.7
N240	20.7a	21.6	18.3	21.0	21.9	17.5	15.6

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.7 Effect of manures or urea on moisture content of soils at 90 and 125 days after seeding in 1984

Treatment	Chicot			St Benoit			
	Depth (cm)						
	0-10	10-20	20-40	0-10	10-20	20-40	40-60
	%						
	90 days after seeding						
Ctrl	17	21	20	23 abc[1]	24 bcd	22	19
CC1	21	17	17	23 abc	24 bcd	21	15
CC2	24	24	19	25 a	25 ab	20	17
FC1	21	22	20	23 abc	23 bcde	17	12
FC2	23	23	20	25 a	24 bcd	20	16
HM1	21	22	21	22 bc	23 bcde	19	14
HM2	22	22	24	24 ab	22 def	18	15
U1	21	21	18	20 d	20 g	14	12
U2	21	22	21	22 bc	22 def	17	12
U3	22	22	23	22 bc	22 def	15	13
FC2S	23	24	18	25 a	26 a	27	18
HM2S	20	22	20	21 cd	21 f	15	12
F	1.29	1.15	0.63	4.89**	8.93**	1.48	1.81
CV(%)	15.0	15.1	23.8	6.4	4.6	30.4	26.2
	125 days after seeding						
Ctrl	22 bc	21	18	22 cde	23 ab	17	15
CC1	22 bc	22	17	26 abc	22 abcd	15	12
CC2	22 bc	21	22	27 ab	23 ab	15	10
FC1	22 bc	22	18	23 cde	19 d	13	9
FC2	24 ab	23	21	25 abcd	23 ab	16	12
HM1	22 bc	21	17	22 cde	22 abcd	12	11
HM2	21 bc	20	17	21 de	19 d	15	13
U1	20 c	21	20	20 e	19 d	12	9
U2	22 bc	21	21	22 cde	19 d	12	9
U3	22 bc	21	19	23 cde	21 bcd	11	11
FC2S	25 a	25	19	29 a	25 a	18	11
HM2S	22 bc	20	18	21 de	20 bcd	13	9
F	2.22*	1.57	1.00	3.87**	3.53**	1.14	1.55
CV(%)	7.3	10.4	18.7	12.3	10.3	29.7	27.1

1) means in the same column followed by the same letters are not significantly different at the level of 0.01 by Duncan's Multiple Range Test.

*, ** : significant at the levels of 0.05 and 0.01 rspectively.

Table 2.8 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on gravimetric moisture content of soils at 90 and 125 days after seeding in 1984

Main effect	Chicot Soil			St Benoit Soil			
	Depth (cm)						
	0-10	10-20	20-40	0-10	10-20	20-40	40-60
	90 days after seeding (8/28/1984)						
	probability						
CFH	0.4190	0.7543	0.4361	0.5416	0.0023	0.7585	0.5517
NR	0.0428	0.1913	0.5340	0.0145	0.5070	0.9431	0.2757
CV(%)	8.7	20.5	29.2	6.2	3.5	28.9	28.2
	%						
CC	22.6	20.9	18.4	23.9	24.2a[1]	20.3	16.4
FC	22.2	22.6	19.7	24.0	23.5a	18.7	13.9
HM	21.3	22.0	22.2	23.2	22.4b	18.3	14.2
N120	21.2b	20.6	19.3	22.9b	23.3	19.0	13.8
N240	22.9a	23.1	20.9	24.5a	23,5	19.2	15.7
	125 days after seeding (10/04/1984)						
	probability						
CFH	0.1658	0.1004	0.4315	0.0056	0.1493	0.7117	0.4090
NR	0.4253	0.8051	0.1831	0.5512	0.4354	0.4169	0.4512
CV(%)	6.5	6.9	25.0	10.3	11.1	28.2	19.6
	%						
CC	21.9	21.6	19.3	26.7a	22.7	15.0	11.0
FC	23.0	22.3	19.1	24.4ab	21.3	14.0	10.4
HM	21.7	20.6	16.6	21.9b	20.3	13.4	11.9
N120	22.0	21.4	17.0	24.0	21.0	13.5	10.8
N240	22.4	21.5	19.6	24.6	21.8	14.8	11.4

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

the U1 treatment, which had the lowest water content.

St Benoit soil

In 1983, measurements conducted 62 and 107 days after sowing showed no significant differences in water content among the treatments (Table 2.4).

In 1984, 30 days after seeding (June 27, 1984), moisture contents of the top 10 cm of soil associated with the FC2S and CC2 treatments were significantly higher than those of the control, U1, and HM2S treatments. At 10-20 cm, the U1 treatment had a significantly lower water content than other treatments. At a depth of 20-40 cm, significantly higher moisture contents with the FC2S treatment compared with the FC2, HM1, U1, U2, U3 and HM2S treatments were observed. At 40-60 cm, no treatment differences were detected (Tables 2.5 and 2.6).

At 60 days after seeding (July 26, 1984), only small differences were found among the treatments through the soil profile (Tables 2.5 and 2.6), while at 90 days after sowing (August 28, 1984), the CC2, FC2 and FC2S treatments had significantly higher moisture contents than the HM1, U1, U2, U3 and HM2S treatments in the top 10 cm layer (Table 2.7). Higher manure application rates resulted in significantly higher soil water contents than the lower rates at 90 days (Table 2.8). At 10-20 cm, the highest soil moisture content was found with the FC2S treatment, the lowest with the U2 treatment. CC or FC manure treatments had greater effects on conserving soil moisture than HM treatments. Differences among treatments were not detected at depths of 20-40 and 40-60 cm.

The last measurement was made 125 days after seeding, October 1, 1984; Table 2.7). At depths of 0-10 and 10-20 cm, the highest moisture content was found with the FC2S treatment, lower values with the HM2, U1 and HM2S treatments. Differences disappeared at soil depths of 20-40 and 40-60 cm. When analyzed as a factorial arrangement, CC manure treatments resulted in significantly higher soil moisture contents than HM treatments at the top 10 cm soil layer (Table 2.8).

2.3.2 Soil organic matter and soil bulk density

There was no significant treatment effect on soil organic matter content and soil bulk density for the soils sampled at a depth of 5-13 cm (Tables 2.9 and 2.10).

2.3.3 Ammonium- and nitrate-N

2.3.3.1 Chicot soil

Ammonium-N

Treatments with added manures (CC, FC, HM) and urea (U) had higher contents of NH_4-N in the first two months after application, compared with the control treatment (Tables 2.11 to 2.20). This trend gradually disappeared with time. Among the 3 measurements in 1983 and 5 in 1984, the only significant treatment effects on soil NH_4-N contents were found in June, 1984. At that time, the CC2 and FC2 treatments resulted in higher NH_4-N contents in the soil profile. For the top 40 cm soil, the

Table 2.9 Effect of manures or urea on soil organic matter content and bulk density in 1984

Treatment	Organic matter		Bulk densssity	
	Chicot	St Benoit	Chicot	St Benoit
	%		g/cm^3	
Ctrl	3.82	3.93	1.33	1.18
CC1	3.96	4.07	1.36	1.17
CC2	4.11	4.12	1.28	1.12
FC1	3.75	3.85	1.34	1.12
FC2	3.89	4.07	1.41	1.17
HM1	3.81	3.89	1.33	1.14
HM2	3.78	4.02	1.39	1.13
U1	3.90	3.56	1.34	1.22
U2	4.14	3.89	1.34	1.21
U3	3.86	3.92	1.34	1.14
FC2S	3.71	4.03	1.35	1.19
HM2S	3.60	4.03	1.35	1.17
F	0.38	0.56	1.31	0.51
CV(%)	13.0	10.1	4.3	7.9

Table 2.10 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on soil organic matter content and bulk density in 1984

Main effect	Organic matter		Bulk density	
	Chicot	St Benoit	Chicot	St Benoit
	probability			
CFH	0.5713	0.6286	0.0925	0.9705
NR	0.6761	0.3313	0.4483	1.0000
CV(%)	12.6	8.2	3.7	6.8
	%		g/cm³	
CC	4.04	4.09	1.32	1.14
FC	3.82	3.96	1.37	1.14
HM	3.80	3.95	1.36	1.13
N120	3.84	3.93	1.34	1.14
N240	3.92	4.07	1.36	1.14

Table 2.11 Effect of manures or urea on ammonium- and nitrate-N content of Chicot soil in 1983

Treatment	Ammonium-N		Nitrate-N	
	Depth (cm)			
	0-20	20-40	0-20	20-40
	mg N/kg dry soil			
	7/11/1983			
Ctrl	1.3	0.8	2.7 bc[1]	1.4
CC1	1.7	1.2	2.3 bc	1.2
CC2	2.0	1.2	2.4 bc	1.5
FC1	1.3	2.1	1.7 bc	1.5
FC2	2.9	1.6	1.2 c	1.1
HM1	1.6	1.2	2.5 bc	1.6
HM2	2.6	1.5	3.5 abc	2.4
U1	2.1	2.5	2.5 bc	1.4
U2	1.3	1.3	3.9 ab	2.0
U3	1.7	1.0	2.2 bc	0.8
FC2S	1.9	1.2	2.4 bc	1.7
HM2S	2.5	1.0	5.7 a	1.8
F	1.10	0.67	2.21*	0.98
CV (%)	53.6	88.1	58.0	54.7
	8/15/1983			
Ctrl	3.3	1.2	1.4	2.0
CC1	2.3	0.7	1.0	1.1
CC2	2.6	1.4	1.2	1.5
FC1	2.9	0.9	0.9	1.1
FC2	4.0	0.8	1.3	0.5
HM1	3.6	1.7	1.0	0.9
HM2	4.1	1.1	2.8	1.0
U1	4.0	2.8	1.4	1.4
U2	2.0	5.3	1.3	0.9
U3	3.3	1.7	1.6	1.5
FC2S	5.6	1.3	1.3	0.8
HM2S	2.6	0.9	1.0	1.0
F	0.48	0.85	0.91	1.77
CV(%)	85.5	70.2	76.5	51.8

1) means in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

* : significant at the level of 0.05.

Table 2.12 Effect and residual effect of manures or urea on ammonium- and nitrate-N content of Chicot soil in 1983 and 1984

Treatment	Ammonium-N		Nitrate-N	
	mg N/kg dry soil			
	9/30/1983			
	Depth (cm)			
	0-20	20-40	0-20	20-40
Ctrl	2.4	2.0	0.9	0.0
CC1	2.0	1.9	1.8	0.9
CC2	2.5	2.8	2.1	0.8
FC1	2.8	1.7	0.8	0.3
FC2	3.3	2.3	2.1	0.5
HM1	2.2	1.7	2.8	0.5
HM2	2.2	2.9	2.7	1.1
U1	1.8	2.1	3.1	1.6
U2	1.8	1.9	2.4	1.0
U3	2.0	2.3	4.7	1.7
FC2S	2.3	1.8	1.2	0.5
HM2S	2.3	1.4	2.7	0.6
F	1.27	1.00	1.82	1.60
CV(%)	31.8	43.2	70.2	99.3

Treatment	Residual effect of manures or urea applied in 1983 (5/18/1984)					
	Depth (cm)					
	0-10	10-20	20-40	0-10	10-20	20-40
Ctrl	0.4	0.5	0.4	4.8	6.9	2.8
CC1	0.4	0.6	0.4	5.1	5.4	3.3
CC2	0.4	0.5	0.4	4.5	5.0	3.2
FC1	0.4	0.4	0.3	4.4	6.8	2.9
FC2	0.4	0.4	0.5	3.9	4.6	2.9
HM1	0.4	0.4	0.3	4.3	5.4	2.6
HM2	0.4	0.4	0.6	5.5	6.9	3.5
U1	0.7	0.4	0.3	4.4	4.9	3.4
U2	0.5	0.4	0.3	6.4	7.4	3.7
U3	0.4	0.5	0.3	3.5	4.7	3.5
FC2S	0.5	0.8	0.4	4.0	4.6	2.5
HM2S	0.4	0.4	0.3	5.5	6.5	3.4
F	1.34	1.16	0.64	1.19	1.72	0.61
CV(%)	38.1	44.6	65.9	31.9	25.9	32.8

Table 2.13 Probability associated with the residual main effect of manures (CFH) and nitrogen rate (NR) on ammonium- and nitrate-N content of Chicot soil (5/26/1984)

	N content			N accumulation	
Main effect	Depth (cm)				
	0-10	10-20	20-40	0-20	0-40
Ammonium-N					
probability					
CFH	0.8125	0.1615	0.9665	0.3334	0.9514
NR	0.5069	0.4580	0.2087	0.6947	0.2238
CV(%)	17.0	20.7	75.4	14.6	40.4
	mg N/kg soil			kg N/ha	
CC	0.4	0.5	0.4	1.2	2.4
FC	0.4	0.4	0.4	1.1	2.3
HM	0.4	0.4	0.4	1.1	2.3
N120	0.4	0.5	0.3	1.1	2.1
N240	0.4	0.4	0.5	1.1	2.5
Nitrate-N					
probability					
CFH	0.6250	0.3857	0.6924	0.6399	0.7637
NR	0.6236	0.9591	0.5357	0.7613	0.9285
CV(%)	33.0	25.5	30.1	26.6	25.9
	mg N/kg soil			kg N/ha	
CC	5.2	4.8	3.3	13.0	22.1
FC	5.7	4.1	2.9	12.8	20.7
HM	6.1	4.9	3.0	14.4	22.8
N120	5.9	4.6	3.2	13.6	21.8
N240	5.5	4.6	3.2	13.2	22.0

Table 2.14 Effect of manures or urea on ammonium- and nitrate-N content of Chicot soil at 30 and 60 days after seeding in 1984

Treatment	Ammonium-N			Nitrate-N		
	Depth (cm)					
	0-10	10-20	20-40	0-10	10-20	20-40
	mg N/kg dry soil					
	30 days after seeding (6/27/1984)					
Ctrl	0.8	1.1 b	0.8	11.8 d	11.7	5.7 bc[1]
CC1	0.9	1.3 b	1.0	13.2 d	13.3	6.3 abc
CC2	2.3	3.0 a	2.4	13.3 d	14.7	7.5 abc
FC1	1.2	1.1 b	2.0	14.3 d	13.8	6.7 abc
FC2	2.5	2.8 a	1.6	12.7 d	9.3	6.4 abc
HM1	1.2	1.5 b	1.1	17.9 cd	14.3	8.9 a
HM2	1.4	1.3 b	0.8	28.5 ab	15.5	9.1 a
U1	1.6	0.8 b	0.6	19.1 bcd	15.7	7.4 abc
U2	0.8	1.0 b	0.9	24.4 abc	16.9	7.7 ab
U3	1.8	1.4 b	1.1	28.1 ab	15.3	8.4 ab
FC2S	1.5	1.2 b	1.0	8.5 d	8.8	4.6 c
HM2S	1.0	1.1 b	0.9	32.3 a	17.8	8.1 ab
F	1.54	4.04**	1.28	5.88**	1.37	2.21*
CV(%)	63.5	47.2	79.1	34.4	34.4	25.0
	60 days after seeding (7/26/1984)					
Ctrl	4.2	4.4	4.3	10.7 d	11.6 c	12.5
CC1	5.0	5.1	5.7	14.7 cd	16.1 bc	14.3
CC2	7.8	11.1	4.8	22.2 bcd	14.3 bc	17.4
FC1	5.1	5.8	6.3	20.2 bcd	18.0 bc	16.0
FC2	3.4	4.3	4.8	15.8 cd	13.9 bc	16.8
HM1	3.7	4.4	3.2	22.8 bcd	15.7 bc	14.3
HM2	4.7	5.3	5.7	43.9 a	29.2 a	22.3
U1	2.6	3.6	2.9	19.9 bcd	17.2 bc	14.3
U2	4.7	4.2	4.2	22.5 bcd	18.1 bc	18.2
U3	4.2	4.2	2.9	36.4 ab	23.9 ab	21.5
FC2S	2.9	2.2	2.3	13.7 cd	12.9 bc	17.4
HM2S	4.6	5.2	4.1	30.4 abc	22.6 abc	19.8
F	0.68	0.78	0.94	2.91**	2.15*	1.36
CV (%)	73.3	97.1	59.9	50.3	39.3	29.6

1) means in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multilple Range Test.

*,** : significant at the levels of 0.05 and 0.01 respectively.

Table 2.15 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on ammonium- and nitrate-N content of Chicot soil at 30 and 60 days after seeding in 1984

Main effect	Ammonium-N			Nitrate-N		
	Depth (cm)					
	0-10	10-20	20-40	0-10	10-20	20-40
	30 days after seeding (6/27/1984)					
	probability					
CFH	0.3193	0.2377	0.3739	0.0272	0.3956	0.0483
NR	0.0083	0.0093	0.6718	0.3344	0.7689	0.6545
CV(%)	48.6	46.2	85.2	44.7	36.9	26.0
	mg N/kg soil					
CC	1.6	2.1	1.7	13.3 b	14.0	6.9 b[1]
FC	1.9	2.0	1.8	13.5 b	11.5	6.6 b
HM	1.3	1.4	1.0	23.2 a	14.9	9.0 a
N120	1.1b	1.3 b	1.4	15.1	13.2	7.3
N240	2.0a	2.3 a	1.6	18.2	13.8	7.7
	60 days after seeding (7/26/1984)					
	Probability					
CFH	0.5059	0.5702	0.7329	0.0080	0.0601	0.4882
NR	0.6785	0.5327	0.9877	0.0561	0.3213	0.0352
CV(%)	85.0	112.1	58.6	40.9	34.2	25.0
	mg N/kg soil					
CC	6.4	8.1	5.3	18.4 b	15.2	15.9
FC	4.2	5.0	5.6	18.0 b	16.0	16.4
HM	4.2	4.9	4.4	33.3 a	22.4	18.3
N120	4.6	5.1	5.1	19.2	16.6	14.9 b
N240	5.3	6.9	5.1	27.3	19.1	18.8 a

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.16 Effect of manures or urea on quantity of ammonium- and nitrate-N of Chicot soil at 30 and 60 days after seeding in 1984

Treatment	Ammonium-N		Nitrate-N	
	Depth (cm)			
	0-20	0-40	0-20	0-40
	kg N/ha			
30 days after seeding (6/27/1984)				
Ctrl	2 b	5 c	31 ef	47 ef[1]
CC1	3 b	6 bc	35 def	52 def
CC2	7 a	13 a	37 cdef	57 bcdef
FC1	3 b	9 abc	37 cdef	55 cdef
FC2	7 a	11 ab	29 ef	46 ef
HM1	4 b	7 bc	42 bcdef	67 abcde
HM2	3 b	6 bc	57 ab	82 ab
U1	3 b	5 c	45 abcde	66 abcde
U2	2 b	5 c	54 abcd	75 abcd
U3	4 b	7 bc	56 abc	80 abc
FC2S	4 b	6 bc	23 f	35 f
HM2S	3 b	5 bc	65 a	87 a
F	3.25**	2.17*	4.60**	4.42**
CV(%)	46.1	54.0	28.8	24.8
60 days after seeeding (7/26/1984)				
Ctrl	11	23	29 d	64 c
CC1	13	29	40 bcd	80 bc
CC2	25	38	47 bcd	96 bc
FC1	14	32	50 bcd	94 bc
FC2	10	23	39 cd	85 bc
HM1	11	20	50 bcd	90 bc
HM2	13	29	95 a	157 a
U1	8	17	48 bcd	83 bc
U2	12	23	53 bcd	103 abc
U3	11	19	78 ab	138 ab
FC2S	7	13	35 cd	83 bc
HM2S	13	24	69 abc	124 ab
F	0.75	0.78	2.68*	2.37*
CV(%)	84.6	64.0	44.1	34.4

1) means within the soil in the same cullume followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*,** : significant at the levels of 0.05 and 0.01, respectively.

Table 2.17 Probability associated with the main effect of nitrogen rate (NR) and manures (CFH) on quantity of ammonium- and nitrate-N of Chicot soil at 30 and 60 days after seeding in 1984

Main effect	Ammonium-N		Nitrate-N	
	Depth (cm)			
	0-20	0-40	0-20	0-40
	30 days after seeding (6/27/1983)			
	probability			
CFH	0.1849	0.2464	0.0802	0.0403
NR	0.0021	0.1227	0.6211	0.5895
CV(%)	38.2	55.9	37.2	29.7
	kg N/ha			
CC	5	10	36	55 b[1]
FC	5	10	33	51 b
HM	4	6	49	74 a
N120	3 b	7	38	58
N240	6 a	10	41	62
	60 days after seeding (7/26/1984)			
	probability			
CFH	0.5399	0.6284	0.0156	0.0332
NR	0.5803	0.6812	0.1113	0.0420
CV(%)	99.3	68.4	36.8	27.1
	kg N/ha			
CC	19	34	44 b	88 b
FC	12	28	44 b	90 b
HM	12	24	72 a	123 a
N120	17	27	47	88 b
N240	16	30	60	113 a

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.18 Effect of manures or urea on ammonium- and nitrate-N content of Chicot soil at 90 and 125 days after seeding in 1984

Treatment	Ammonium-N			Nitrate-N		
	Depth (cm)					
	0-10	10-20	20-40	0-10	10-20	20-40
	mg N/kg dry soil					
	90 days after seeding (8/28/1984)					
Ctrl	2.7	2.3	2.3	6.8 b[1]	6.5	6.2 abcd
CC1	4.5	7.1	1.9	6.0 b	7.9	4.0 bcd
CC2	2.6	2.5	2.0	7.3 b	7.1	5.3 bcd
FC1	4.5	4.7	3.8	9.7 b	9.0	7.8 abc
FC2	2.7	2.4	2.5	10.8 b	6.4	4.8 bcd
HM1	2.4	2.2	2.1	10.3 b	7.3	6.4 abcd
HM2	5.7	3.0	3.1	11.2 b	8.4	4.3 bcd
U1	2.0	2.0	2.0	7.8 b	5.7	5.0 bcd
U2	2.2	2.7	2.9	23.5 a	13.6	9.7 ab
U3	2.3	3.0	2.0	6.3 b	4.1	3.4 cd
FC2S	3.7	3.6	2.4	5.3 b	5.0	1.6 d
HM2S	3.6	3.8	3.5	15.8 ab	19.2	11.3 a
F	1.01	0.85	0.59	2.70*	2.06	2.35*
CV (%)	70.8	95.2	66.5	62.5	69.9	61.1
	125 days after seeding (10/04/1984)					
Ctrl	1.5	2.0	1.6	3.4 e	3.4 b	0.5
CC1	1.6	2.2	2.1	4.6 de	4.6 b	0.9
CC2	2.2	2.3	3.0	7.9 bcd	7.4 ab	1.8
FC1	2.1	2.1	1.8	6.9 bcde	6.2 b	1.2
FC2	3.9	1.9	2.0	9.6 abc	7.4 ab	4.4
HM1	1.6	2.1	2.1	5.1 de	4.5 b	1.4
HM2	2.8	2.1	1.7	8.2 bcd	6.5 b	2.6
U1	1.6	1.8	1.7	3.6 e	3.3 b	3.0
U2	2.2	1.8	1.8	8.2 bcd	7.1 ab	3.5
U3	2.2	1.6	1.3	5.6 cde	5.4 b	1.8
FC2S	6.4	4.2	1.5	10.2 ab	7.6 ab	2.6
HM2S	2.8	2.2	1.7	13.3 a	11.0 a	4.9
F	1.23	1.15	1.58	5.29**	2.67*	1.58
CV (%)	97.8	56.4	36.3	35.6	42.9	92.8

1) means in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*,** : Significant at the levels of 0.05 and 0.01 respectively.

Table 2.19 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on ammonium- and nitrate-N content of Chicot soil at 90 and 125 days after seeding in 1984

	Ammonium-N			Nitrate-N		
	Depth (cm)					
Main effect	0-10	10-20	20-40	0-10	10-20	20-40
90 days after seeding (8/28/1984)						
probability						
CFH	0.9396	0.5520	0.3349	0.1542	0.9737	0.5696
NR	0.8955	0.2289	0.9857	0.5491	0.5235	0.3156
CV(%)	85.2	108.6	61.3	47.1	39.5	56.4
mg N/kg soil						
CC	3.5	4.8	1.9	6.7	7.5	4.6
FC	3.6	3.6	3.1	10.3	7.7	6.3
HM	4.0	2.6	2.6	10.7	7.8	5.4
N120	3.8	4.7	2.6	8.7	8.1	6.1
N240	3.6	2.7	2.6	9.8	7.3	4.8
125 days after seeding (10/04/1984)						
probability						
CFH	0.3567	0.7696	0.1767	0.2310	0.4136	0.5770
NR	0.0798	0.9005	0.5611	0.0071	0.0256	0.1377
CV(%)	64.1	32.3	35.8	33.9	32.4	136.0
mg N/kg soil						
CC	1.9	2.3	2.5	6.2	6.0	1.3
FC	3.0	2.0	1.9	8.3	6.8	2.8
HM	2.2	2.3	1.9	6.7	5.5	2.0
N120	1.8	2.2	2.0	5.5 b[1]	5.1 b	1.1
N240	2.9	2.1	2.2	8.6 a	7.1 a	2.9

[1] means followed by the different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.20 Effect of manures or urea on quantity of ammonium- and nitrate-N of Chicot soil at 90 and 125 days after seeding in 1984

Treatment	Ammonium-N		Nitrate-N	
	Depth (cm)			
	0-20	0-40	0-20	0-40
	kg N/ha			
	90 days after seeding (8/28/1984)			
Ctrl	7	13	17 b	35 b[1]
CC1	15	20	18 b	29 b
CC2	7	12	19 b	33 b
FC1	12	23	25 b	46 b
FC2	7	14	22 b	35 b
HM1	6	12	23 b	41 b
HM2	11	20	25 b	37 b
U1	5	11	18 b	31 b
U2	7	15	48 a	75 a
U3	7	13	13 b	23 b
FC2S	10	16	13 b	18 b
HM2S	10	19	46 a	77 a
F	0.86	0.75	4.06**	4.22**
CV(%)	77.3	59.4	47.3	44.8
	125 days after seeding (4/10/1984)			
Ctrl	5	9	9 d	10 d
CC1	5	11	12 cd	14 cd
CC2	6	14	20 bc	25 bcd
FC1	6	11	17 bcd	20 bcd
FC2	8	13	22 abc	34 ab
HM1	5	11	12 cd	16 cd
HM2	6	11	19 bcd	26 bcd
U1	4	9	9 d	17 bcd
U2	5	10	20 bc	30 abc
U3	5	9	14 bcd	19 bcd
FC2S	14	18	23 ab	30 abc
HM2S	7	11	32 a	45 a
F	1.80	1.33	4.37**	3.36**
CV(%)	61.2	39.7	36.3	44.5

1) means within the soil in the same culumn followed by the same letters are not significantly different at the level of 0.01 by Duncan's Multiple Range Test.

** : significant at the levels of 0.05 and 0.01, respectively.

CC2 and FC2 treatments had values of more than 13 and 11 kg NH_4-N/ha respectively, while other treatments had values which varied from less than 9 to less than 5 kg NH_4-N/ha (Table 2.16).

Nitrate-N

In 1983, the only significant treatment effect on NO_3-N content was detected in July at a depth of 0-20 cm. Of the 12 treatments, the HM2S resulted in significantly higher NO_3-N contents than the other treatments, except for the HM2 and U2. The FC1 and FC2 treatments had lower NO_3-N values. NO_3-N contents in general were lower in August (silking stage) than in July or September (Tables 2.11 and 2.12).

In 1984, residual effects of manures or urea applied in previous years on soil NO_3-N content were not significant (Tables 2.12 and 2.13). Treatment effects were reflected in NO_3-N contents measured one month after seeding (June 27, 1984). NO_3-N contents of 32.3, 28.1 and 28.5 mg/kg soil for the HM2S, U3 and HM2 treatments, respectively, were significanly greater than those for the control, CC1, CC2, FC1, FC2, HM1 and FC2S treatments at 0-10 cm depths. At 10-20 cm depths, no differences were observed among the treatments. Significantly higher NO_3-N contents than the control and FC2S treatments at 20-40 cm were observed with the HM1 and HM2 treatments (Table 2.14). For the top 40 cm soil, the accumulations of NO_3-N for the HM2S, HM2, U3 and U2 treatments were aproximately 87, 82, 79 and 75 kg/ha, respectively, while those for other treatments were less than 70 kg NO_3-N/ha (Table 2.16). HM treatments had significantly higher NO_3-N content or accumulations than

CC and FC manure treatments at depths of 0-10 and 20-40 cm and in the top 40 cm soil respectively (Tables 2.15, 2.16 and 2.17).

At 60 days after seeding (July 26, 1984), NO_3-N contents of HM2 and U3 treatments were significantly higher than those of the control, CC1, FC2, and FC2S at depths of 0-10 cm, and that of the control at depths of 20-40 cm (Table 2.14). Values of approximately 157, 138, and 124 kg NO_3-N/ha for the HM2, U3, and HM2S treatments, respectively, were much greater than those for the control (Table 2.16). HM treatments resulted in higher NO_3-N contents at 0-10 cm and more NO_3-N in the soil profile, compared with CC, or FC manure treatments. Higher manure application rates resulted in higher contents or accumulations of NO_3-N in the soil (Tables 2.15, 2.16 and 2.17).

At 90 days after sowing (August 28, 1984), the only significantly higher NO_3-N content at 0-10 cm was found with the U2 treatment, which was not significantly higher than the other treatments, except for the HM2S treatment. Treatment effects were not significant at 10-20 cm. At 20-40 cm depths, the U2 and HM2S treatments had significantly higher NO_3-N contents than the U3 and FC2S treatments (Table 2.18). Thus significantly more accumulation of NO_3-N was found with the U2 and HM2S treatments in the soil profile, compared with other treatments (Table 2.20). Differences among manures and between manure application rates were not significant (Tables 2.19, 2.20 and 2.21).

At 125 days after seeding (October 4, 1984), significantly higher NO_3-N contents at 0-10 cm were observed with the HM2S, FC2S, FC2, CC2, HM2 and U2 treatments, compared with the control and U1 treatment. At

Table 2.21 Probability associated with the main effect of nitrogen rate (NR) and manures (CFH) on quantity of ammonium- and nitrate-N of Chicot soil at 90 and 125 days after seeding in 1984

Main effect	Ammonium-N 0-20	Ammonium-N 0-40	Nitrate-N 0-20	Nitrate-N 0-40
		Depth (cm)		
90 days after seeding (8/28/1984)				
		probability		
CFH	0.8611	0.9155	0.2816	0.2087
NR	0.4182	0.5118	0.9269	0.4609
CV(%)	90.7	65.3	33.4	29.1
		kg N/ha		
CC	11	16	19	31
FC	9	18	23	39
HM	9	16	24	41
N120	11	18	22	39
N240	8	15	22	35
125 days after seeding (10/04/1984)				
		probability		
CFH	0.5530	0.5819	0.3109	0.4014
NR	0.1073	0.1500	0.0101	0.0301
CV(%)	34.5	26.5	31.8	51.5
		kg N/ha		
CC	6	13	16	20
FC	7	12	20	27
HM	6	11	16	21
N120	5	11	14 b	17 b[1]
N240	7	13	20 a	29 a

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

10-20 cm, only the HM2S treatment had significantly higher NO_3-N contents in comparison with the control. At 20-40 cm, no significant treatment differences were observed (Table 2.18). Different manures showed no significant effect on NO_3-N content of the soil (Table 2.19). The HM2S, HM2, FC2S and U2 treatments resulted in much more NO_3-N accumulation than the control treatment in the top 40 cm soil (Table 2.20). Higher manure application rates gave significantly more NO_3-N in the soil profile (Table 2.21).

2.3.3.2 St Benoit soil

Ammonium-N

NH_4-N content of the soil was not affected consistantly by treatments. In 1983, significant differences were detected one month after treatment applications at depths of 40-60 cm where the HM1 and U3 treatments had higher NH_4-N levels than the control, CC1, CC2, FC1, FC2, U1 and HM2S treatments. No residual effect of manures or urea applied in the previous years on NH_4-N content measured in 1984 was significant (Tables 2.22, 2.23 and 2.24).

The significant treatment effects on NH_4-N content in 1984 were observed the first month after treatment applications (Table 2.25). The U3 treatment had a very high NH_4-N content at depths of 0-10 cm, compared with other treatments. At 10-20 cm, significantly higher NH_4-N contents were observed with the CC2 and U3 treatments, compared with the control, CC1, FC2, HM1, U1, U2 and HM2S treatments. The HM2 treatment had a high NH_4-N content but was not greatly different from the control.

Table 2.22 Effect of manures or urea on ammonium- and nitrate-N content of St Benoit soil in 1983

Treatment	Ammonium-N			Nitrate-N		
	Depth (cm)					
	0-20	20-40	40-60	0-20	20-40	40-60
	mg N/kg dry soil					
	7/13/1983					
Ctrl	1.4	1.0	0.8 c	10.2 bc	9.2 bc[1]	5.0
CC1	1.9	1.2	0.8 c	13.7 bc	12.3 bc	7.7
CC2	2.3	0.7	0.7 c	11.4 bc	8.5 c	7.7
FC1	1.4	0.8	0.7 c	10.7 bc	9.9 bc	6.2
FC2	2.4	1.6	0.8 c	16.1 b	14.2 abc	7.1
HM1	3.3	6.1	2.8 a	22.9 a	19.7 a	14.0
HM2	3.2	0.8	1.9 abc	10.3 bc	8.7 c	7.9
U1	1.4	0.8	0.8 c	7.8 c	7.5 c	7.5
U2	6.0	2.3	2.2 abc	12.9 ab	12.0 bc	7.9
U3	14.5	5.2	2.5 ab	16.8 ab	11.7 bc	8.8
FC2S	1.5	1.4	0.6 c	15.2 b	11.9 bc	6.6
HM2S	5.3	6.9	1.2 bc	14.9 b	15.8 ab	5.8
F	1.37	1.51	2.56*	3.59**	2.78*	1.76
CV (%)	172.8	155.4	77.1	31.2	35.4	59.2
	8/16/1983					
Ctrl	1.2	1.2	0.7	3.7 c	3.2 c	4.2 bc
CC1	1.2	0.7	0.5	3.5 c	3.8 c	4.0 c
CC2	1.9	1.4	0.7	4.2 c	4.2 c	4.6 bc
FC1	1.5	0.9	0.7	4.6 c	3.9 c	4.0 c
FC2	1.4	0.8	1.1	4.2 c	4.1 c	3.9 c
HM1	2.5	1.7	0.6	6.2 c	5.3 c	4.5 bc
HM2	1.8	1.1	1.5	18.1 ab	10.3 ab	10.3 a
U1	1.9	2.8	0.6	5.0 c	3.9 c	3.9 c
U2	3.0	5.3	2.7	25.9 a	14.9 a	8.6 ab
U3	1.4	1.7	0.8	27.4 a	11.2 ab	5.8 bc
FC2S	1.7	1.3	1.0	4.1 c	4.2 c	4.7 bc
HM2S	1.7	0.9	2.1	13.1 bc	8.4 bc	4.3 bc
F	0.79	1.10	1.33	8.19**	5.85**	2.32*
CV (%)	66.9	151.1	108.1	62.9	48.9	51.4

1) means in the same column followed the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*, ** : significant at the levels of 0.05 and 0.01 respectively.

Table 2.23 Effect and residual effect of manures or urea on ammonium- and nitrate-N content of St Benoit soil in 1983 and 1984

Treatment	Ammonium-N			Nitrate-N		
	Depth (cm)					
	0-20	20-40	40-60	0-20	20-40	40-60
	mg N/kg dry soil					
	9/30/1983					
Ctrl	1.9	1.0	0.9	3.7 c	2.0 b	1.5 b[1]
CC1	2.2	1.3	2.3	4.9 c	3.4 b	2.3 b
CC2	2.5	1.5	1.2	6.3 c	4.4 b	3.3 b
FC1	3.7	1.2	1.1	5.1 c	2.5 b	2.7 b
FC2	2.3	1.4	1.1	5.9 c	4.4 b	2.8 b
HM1	2.7	1.4	1.2	8.4 bc	5.4 b	3.5 b
HM2	2.2	1.5	0.9	13.3 abc	8.0 b	5.3 b
U1	1.6	1.2	0.8	8.0 c	4.9 b	2.5 b
U2	2.5	1.7	1.2	20.0 ab	11.0 b	5.6 b
U3	3.7	1.3	1.2	24.0 a	22.1 a	11.3 a
FC2S	2.0	1.2	0.7	6.0 c	3.1 b	2.3 b
HM2S	2.3	1.1	1.5	10.1 bc	7.3 b	4.8 b
F	0.97	0.34	0.64	2.94**	2.59*	3.28**
CV (%)	52.9	48.9	89.6	77.1	105.0	73.0

	Residual effect of manures or urea applied in 1983 (4/27/1984)							
	Depth (cm)							
	0-10	10-20	20-40	40-60	0-10	10-20	20-40	40-60
Ctrl	3.8	1.3	4.1	2.4	4.4	4.6	3.8	2.8
CC1	2.7	2.2	2.8	2.1	2.9	3.7	3.1	2.4
CC2	4.0	2.8	2.5	2.5	4.5	5.4	4.4	3.2
FC1	3.0	2.6	2.3	2.3	3.2	4.1	3.1	2.1
FC2	2.6	2.5	1.9	1.7	3.2	4.1	2.3	1.6
HM1	3.0	2.7	2.5	2.0	4.0	4.3	6.1	2.8
HM2	2.9	2.3	2.7	4.9	3.2	6.0	4.8	4.9
U1	2.6	2.2	2.6	2.4	2.5	4.1	3.1	3.1
U2	3.1	2.9	2.4	2.6	4.7	5.7	3.4	2.8
U3	2.9	2.7	2.0	2.1	3.1	5.3	4.7	2.8
FC2S	3.6	3.8	2.7	2.1	3.7	5.5	4.9	3.3
HM2S	2.2	2.7	2.1	2.0	3.6	4.4	3.0	1.8
F	1.28	0.83	0.88	1.10	1.17	0.47	1.33	1.19
CV (%)	31.2	48.0	48.7	58.0	35.8	46.1	47.7	51.4

1) means in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*,** : significant at the levels of 0.05 and 0.01 respectively.

Table 2.24 Probability associated with residual main effect of nitrogen rate (NR) and manures (CFH) applied in 1983 on quantity of ammonium- and nitrate-N of St Benoit soil (4/28/1984)

Main effect	N content				N accumulation	
	Depth (cm)					
	0-10	10-20	20-40	40-60	0-20	0-60
	Ammonium-N					
	probability					
CFH	0.4862	0.9857	0.3165	0.3372	0.6995	0.3887
NR	0.5501	0.9704	0.7380	0.2710	0.6799	0.4488
CV(%)	33.0	22.6	33.4	73.72	25.9	37.3
	mg N/kg soil				kg N/ha	
CC	3.4	2.5	2.6	2.3	6.5	18.6
FC	2.9	2.5	2.1	2.0	5.9	15.9
HM	2.8	2.5	2.5	3.2	6.0	20.3
N120	2.9	2.5	2.5	2.1	5.9	17.4
N240	3.2	2.6	2.3	2.9	6.3	19.1
	Nitrate-N					
	probability					
CFH	0.6669	0.6125	0.0069	0.0831	0.6050	0.0509
NR	0.5831	0.1973	0.6924	0.2614	0.2469	0.4677
CV(%)	32.1	43.6	35.3	56.1	34.9	36.6
	mg N/kg soil				kg N/ha	
CC	3.7	4.5	3.7b[1]	2.8	9.2	25.3
FC	3.2	4.1	2.7b	1.8	8.1	19.3
HM	3.7	5.0	5.5a	3.8	9.7	32.3
N120	3.4	4.0	3.8	3.0	8.2	24.2
N240	3.7	5.1	3.8	3.0	9.8	26.5

1) means with the same letters in the same column within the same block are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.25 Effect of manures or urea on ammonium- and nitrate-N content of St Benoit soil at 30 and 60 days after seeding in 1984

Treatment	Ammonium-N				Nitrate-N			
	Depth (cm)							
	0-10	10-20	20-40	40-60	0-10	10-20	20-40	40-60
	mg N/kg dry soil							
30 days after seeding (6/27/1984)								
Ctrl	4.5b[1]	4.1b	4.0	4.1	24.8d	24.8e	24.7	11.8
CC1	6.4b	4.4b	3.7	4.2	39.9cd	34.4de	16.9	17.4
CC2	12.8b	19.4a	9.7	11.6	64.8bcd	53.6bcd	21.3	15.9
FC1	13.8b	9.0ab	10.3	6.8	64.4bcd	43.30de	28.6	14.4
FC2	7.9b	4.0b	4.8	3.0	49.0cd	53.1bcd	23.0	14.8
HM1	9.3b	4.4b	4.0	3.6	69.2bc	32.2de	20.5	14.7
HM2	15.7b	17.2ab	9.0	6.6	110.3a	62.9abc	23.5	19.0
U1	7.5b	3.4b	3.4	1.8	67.8bc	46.1bcde	18.5	11.4
U2	20.6b	5.5b	3.3	3.0	91.4ab	59.1abcd	19.1	12.9
U3	50.3a	21.0a	9.1	8.8	116.5a	84.5a	25.3	21.7
FC2S	8.3b	9.1ab	8.1	7.2	55.3bcd	44.1cde	28.2	15.3
HM2S	9.9b	5.7b	5.1	4.8	79.3abc	72.3ab	40.0	17.7
F	4.34**	2.36*	1.06	2.00	4.48**	4.11**	0.65	1.50
CV (%)	84.9	93.0	87.9	73.0	36.7	32.6	63.4	30.6
60 days after seeding (7/26/1984)								
Ctrl	2.6	2.9	3.0	2.7	15.6d	13.9d	13.5	13.2
CC1	5.2	6.6	3.1	2.6	21.4cd	14.0d	11.2	10.1
CC2	5.9	2.9	4.2	3.1	29.8bcd	24.1abcd	16.5	13.8
FC1	5.1	3.7	3.2	4.6	53.4ab	27.0abcd	18.0	11.6
FC2	3.8	4.1	2.2	2.5	58.9a	38.9ab	17.5	15.5
HM1	3.2	2.6	2.6	2.1	39.9abcd	21.9bcd	13.9	10.4
HM2	3.2	4.8	1.5	1.4	68.3a	31.0abcd	16.1	12.7
U1	2.3	3.3	2.2	1.9	29.0bcd	18.0bcd	17.4	11.8
U2	4.0	4.1	3.0	2.1	58.7a	27.3abcd	16.0	12.3
U3	4.5	3.4	2.3	4.1	45.0abc	17.3cd	12.2	14.9
FC2S	4.0	2.8	2.0	2.3	43.9abcd	35.8abc	20.1	13.1
HM2S	2.7	3.0	2.0	1.8	39.6abcd	43.1a	20.7	18.0
F	0.68	0.84	0.45	0.92	3.45**	2.34*	0.83	1.32
CV (%)	71.6	67.7	82.5	75.3	41.3	48.8	40.2	52.5

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1) means in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*,** : Significant at the levels of 0.05 and 0.01 respectively.

For the top 60 cm of soil, levels of 105, 88, 75 kg NH_4-N/ha with the U3, CC2 and HM2 treatments, respectively, were significantly greater than those with the control, CC1, FC2, HM1 and U1 treatments. Different manures did not have different effects on NH_4-N contents or accumulations in the soil profile to a depth of 60 cm (Tables 2.26, 2.27 and 2.28). Measurements in July (July 26, 1984), August (August 28, 1984) and October (October 4, 1984) indicated that soil NH_4-N status was not significantly affected by treatments (Tables 2.24 to 2.32).

Nitrate-N

In 1983, at the first sampling (July 13, 1983), at 0-20, 20-40 cm sampling depths, NO_3-N associated with the HM1 treatment was significantly higher than that found with other treatments, except for the U2 and U3 treatments at 0-20 cm and the FC2 and HM2S at 20-40 cm (Table 2.22). At depths of 40-60 cm, there were no significant differences. At the second sampling (August 16, 1983), the HM2, U2 and U3 treatments resulted in higher NO_3-N contents at depths of 0-20 and 20-40 cm, compared with the other treatments, except for the HM2S treatment. Significantly higher NO_3-N content at 40-60 cm depths than other treatments except U2 was found with the HM2 treatment, indicating leaching of NO_3-N from HM into the soil profile (Table 2.22). By the end of the growing season (September 30, 1983), the U3 treatment had resulted in significantly higher NO_3-N content in the soil profile than had the other treatments. The HM2 and HM2S treatments had slightly higher NO_3-N contents but were not significantly different from the control (Table 2.23).

Table 2.26 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on ammonium- and nitrate-N content of St Benoit soil at 30 and 60 days after seeding in 1984

Main effect	Ammonium-N				Nitrate-N			
	Depth (cm)							
	0-10	10-20	20-40	40-60	0-10	10-20	20-40	40-60
	30 days after seeding (6/27/1984)							
	probability							
CFH	0.7071	0.5715	0.9505	0.4335	0.0292	0.8460	0.2665	0.5243
NR	0.4257	0.0994	0.5372	0.2999	0.1501	0.0081	0.8479	0.5511
CV(%)	63.5	109.5	101.3	84.7	41.0	32.5	35.5	26.8
	mg N/kg soil							
CC	9.6	11.9	6.7	7.9	52.4b[1]	44.0	19.1	16.6
FC	10.9	6.5	7.6	4.9	56.7b	48.2	25.8	14.6
HM	12.5	10.8	6.5	5.1	89.7a	49.7	22.0	16.9
N120	9.8	5.9	6.0	4.9	57.8	37.0 b	22.0	15.5
N240	12.1	13.5	7.8	7.1	74.7	56.5 a	22.6	16.6
	60 days after seeding (7/26/1984)							
	probability							
CFH	0.4602	0.7567	0.5121	0.2430	0.0004	0.0033	0.2939	0.2007
NR	0.8871	0.7732	0.7897	0.3822	0.0172	0.0019	0.2614	0.0684
CV(%)	78.6	76.2	99.0	77.2	28.48	25.8	31.5	59.4
	mg N/kg soil							
CC	5.6	4.8	3.7	2.8	25.6 b	19.0 b	13.9	11.9
FC	4.5	3.9	2.7	3.5	56.1 a	33.0 a	17.8	18.6
HM	3.2	3.7	2.0	1.7	54.1 a	26.5 a	15.0	11.6
N120	4.5	4.3	3.0	3.1	38.2 b	21.0 b	14.4	10.7
N240	4.3	3.9	2.7	2.3	52.3 a	31.3 a	16.7	17.3

[1] means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.27 Effect of manures or urea on quantity of ammonium- and nitrate-N of St Benoit soil at 30 and 60 days after seeding in 1984

Treatment	Ammonium-N		Nitrate-N	
	Depth (cm)			
	0-20	0-60	0-20	0-60
	kg N/ha			
	30 days after seeding (6/27/1984)			
Ctrl	10 b	28 de	54 e	144 c[1]
CC1	12 b	31 de	82 de	166 c
CC2	36 b	89 ab	130 bcd	222 bc
FC1	25 b	67 abcd	118 cd	223 bc
FC2	13 b	32 de	113 cde	206 bc
HM1	15 b	34 de	118 cd	206 bc
HM2	37 b	75 abc	189 ab	294 ab
U1	12 b	25 e	125 cd	198 bc
U2	28 b	44 cde	165 abc	243 ab
U3	77 a	105 a	220 a	341 a
FC2S	19 b	57 bcde	109 cde	216 bc
HM2S	17 b	41 cde	167 abc	308 ab
F	4.73**	4.39**	5.93**	2.49*
CV (%)	67.9	46.4	28.33	30.34
	60 days after seeding (7/26/1984)			
Ctrl	6	20	33 c	99 cd
CC1	13	27	39 c	91 d
CC2	10	28	59 bc	134 bcd
FC1	10	29	88 ab	160 abcd
FC2	9	20	107 a	214 a
HM1	6	18	67 abc	127 bcd
HM2	9	16	108 a	179 ab
U1	6	16	51 bc	123 bcd
U2	9	22	93 ab	163 abcd
U3	9	25	67 abc	134 bcd
FC2S	7	18	88 ab	169 abc
HM2S	6	16	92 ab	187 ab
F	0.69	0.60	3.36**	2.59*
CV (%)	59.3	58.1	37.2	30.7

1) means within the soil in the same column followed by the same letters are not significantly different at the level of 0.01 by Duncan's Multiple Range Test.

*,** : significant at the levels of 0.05 and 0.01, respectively.

Table 2.28 Probability associated with the main effect of nitrogen rate (NR) and manures (CFH) on quantity of ammonium- and nitrate-N of St Benoit soil at 30 and 60 days after seeding in 1984

Main effect	Ammonium-N		Nitrate-N	
	Depth (cm)			
	0-20	0-60	0-20	0-60
30 days after seeding (6/27/1984)				
	probability			
CFH	0.6257	0.7524	0.0978	0.1634
NR	0.0697	0.0746	0.0385	0.0701
CV(%)	62.2	49.8	31.8	23.4
	kg N/ha			
CC	24	60	106	194
FC	19	50	115	215
HM	26	54	158	256
N120	17	44	105 b[1]	198
N240	28	65	144 a	241
60 days after seeding (7/26/1984)				
	probability			
CFH	0.4655	0.4254	0.0001	0.0030
NR	0.7947	0.6242	0.0013	0.0040
CV(%)	64.0	70.8	21.4	23.6
	kg N/ha			
CC	11	27	49 b	113 b
FC	9	25	97 a	187 a
HM	8	17	88 a	153 a
N120	10	25	65 b	126 b
N240	9	21	91 a	175 a

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.29 Effect of manures or urea on ammonium- and nitrate N content of St Benoit soil at 90 and 125 days after seeding in 1984

Treatment	Ammonium-N				Nitrate-N			
	Depth (cm)							
	0-10	10-20	20-40	40-60	0-10	10-20	20-40	40-60
	mg N/kg dry soil							
	90 days after seeding (8/28/1984)							
Ctrl	5.1	4.8	2.8	3.2	5.3 b	3.7 d	3.3 c[1]	5.0
CC1	4.9	6.7	4.6	2.4	6.8 b	6.8 d	5.8 c	4.2
CC2	8.0	8.9	3.1	4.9	4.4 b	4.1 d	3.0 c	3.0
FC1	8.4	8.0	4.9	4.6	6.8 b	8.8 cd	4.9 c	4.8
FC2	8.7	7.1	4.9	3.6	16.4 b	18.1 bcd	13.8 ab	8.4
HM1	3.4	5.0	3.0	2.3	15.1 b	10.0 cd	6.3 c	6.2
HM2	5.6	4.5	4.4	3.9	36.0.ab	35.8 ab	14.5 a	11.4
U1	7.0	4.2	2.9	3.0	6.6 b	8.9 cd	6.3 c	8.6
U2	6.7	7.8	3.1	2.8	37.7 ab	18.6 bcd	7.5 bc	7.8
U3	7.0	9.0	4.9	4.5	61.6 a	57.6 a	8.8 abc	6.0
FC2S	5.2	6.2	3.8	3.1	9.7 b	11.7 bcd	6.0 c	9.8
HM2S	4.9	4.9	2.3	4.6	52.3 a	34.4 abc	6.0 c	7.5
F	0.92	1.18	1.08	1.02	3.73**	4.28**	2.83*	1.78
CV (%)	55.0	49.6	49.7	50.8	96.5	87.0	60.9	54.0
	125 days after seeding (10/04/1984)							
Ctrl	3.6	5.0	2.2	1.2	1.7 b	1.5 b	0.6 b	0.4 e
CC1	4.1	5.7	2.5	1.2	10.8 b	4.2 b	1.2 b	0.6 de
CC2	5.4	5.8	2.4	0.7	7.5 b	5.2 b	1.6 b	0,8 cde
FC1	4.2	5.8	2.4	1.2	9.1 b	6.6 b	1.9 b	1.1 cde
FC2	3.8	4.8	2.6	2.1	23.5 b	13.2 b	6.4 ab	3.7 ab
HM1	3.3	5.1	2.2	0.9	16.7 b	14.0 b	3.3 b	1.5 cde
HM2	2.9	4.2	2.2	1.2	9.2 b	21.7 b	6.0 ab	2.5 bc
U1	3.4	3.7	1.6	1.6	2.5 b	4.4 b	1.4 b	0.6 de
U2	3.9	4.0	1.9	1.5	6.0 b	7.0 b	2.0 b	1.2 cde
U3	3.3	4.8	2.3	1.1	49.6 a	63.4 a	9.3 a	2.4 bcd
FC2S	6.2	5.8	2.8	1.3	16.6 b	10.9 b	5.5 ab	2.1 bcde
HM2S	2.8	2.6	2.9	1.6	16.2 b	20.8 b	10.5 a	5.1 a
F	1.70	1.51	0.61	1.24	3.97**	3.40**	3.76**	6.62**
CV(%)	39.55	33.90	39.95	50.00	91.51	125.83	82.82	60.12

1) means in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*,** : significant at the levels of 0.05 and 0.01 respectively.

Table 2.30 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on ammonium- and nitrate-N content of St Benoit soil at 90 and 125 days after seeding in 1984

Main effect	Ammonium-N				Nitrate-N			
	Depth (cm)							
	0-10	10-20	20-40	40-60	0-10	10-20	20-40	40-60
	90 days after seeding (8/28/1984)							
	probability							
CFH	0.1039	0.1090	0.4899	0.5444	0.0008	0.0017	0.0604	0.0509
NR	0.2197	0.8216	0.9670	0.1557	0.0159	0.0038	0.0321	0.1402
CV(%)	54.7	43.7	52.7	48.8	59.0	55.9	61.5	61.9
	mg N/kg soil							
CC	6.4	7.8	3.8	3.7	5.6 c[1]	5.4 b	4.4	3.5
FC	8.6	7.5	4.9	4.1	11.6 b	13.5 b	9.3	6.6
HM	4.5	4.8	3.7	3.1	25.6 a	22.9 a	10.4	8.8
N120	5.6	6.6	4.2	3.1	9.6 b	8.5 b	5.6 b	5.1
N240	7.4	6.8	4.1	4.2	18.9 a	19.4 a	10.4 a	7.6
	125 days after seeding (10/04/1984)							
	probability							
CFH	0.1263	0.6190	0.8289	0.1563	0.2431	0.0540	0.0263	0.0033
NR	0.7956	0.4775	0.9326	0.4402	0.7165	0.2255	0.0172	0.0023
CV(%)	38.8	39.9	39.0	61.48	63.1	91.4	66.7	49.9
	mg N/kg soil							
CC	4.7	5.7	2.4	1.0	9.2	4.7	1.4 b	0.7 b
FC	4.0	5.3	2.5	1.7	16.3	9.9	4.1 a	2.4 a
HM	3.1	4.7	2.2	1.0	12.9	17.9	4.6 a	2.0 a
N120	3.9	5.5	2.4	1.1	12.2	8.3	2.2 b	1.1 b
N240	4.0	4.9	2.4	1.3	13.4	13.4	4.6 a	2.3 a

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 2.31 Effect of manures or urea on quantity of ammonium- and nitrate-N of St Benoit soil after 90 and 125 days after seeding in 1984

Treatment	Ammonium-N		Nitrate-N	
	Depth (cm)			
	0-20	0-60	0-20	0-60
	kg N/ha			
90 days after seeding (8/28/1984)				
Ctrl	11	26	10 d	30 de[1]
CC1	13	30	15 d	40 de
CC2	19	39	9 d	24 e
FC1	18	42	17 d	41 de
FC2	17	38	38 cd	93 bcde
HM1	10	22	28 cd	58 cde
HM2	11	32	79 abc	143 ab
U1	12	27	17 d	54 de
U2	16	31	61 bcd	99 bcd
U3	18	41	132 a	168 a
FC2S	13	30	24 cd	63 cde
HM2S	11	28	95 ab	128 abc
F	1.12	1.09	4.43**	4.62**
CV (%)	45.2	37.8	85.7	56.2
125 days after seeding (10/04/1984)				
Ctrl	10 abcd	18	4 b	6 c
CC1	11 abc	20	16 b	21 bc
CC2	12 ab	20	14 b	20 bc
FC1	11 abc	20	17 b	25 bc
FC2	10 abcd	21	40 b	65 bc
HM1	9 bcd	17	34 b	46 bc
HM2	8 cd	6	35 b	56 bc
U1	8 cd	16	8 b	13 c
U2	9 bcd	17	14 b	22 bc
U3	9 bcd	17	126 a	154 a
FC2S	13 a	23	30 b	49 bc
HM2S	6 d	17	41 b	79 b
F	2.41*	1.46	4.09**	4.77**
CV (%)	27.1	20.3	101.0	80.9

1) means within the soil in the same column followed by the same letters are not significantly different at the level of 0.01 by Duncan's Multiple Range Test.

*,** : significant at the levels of 0.05 and 0.01, respectively.

Table 2.32 Probability associated with the main effect of nitrogen rate (NR) and manures (CFH) on quantity of ammonium- and nitrate-N of St Benoit soil after 90 and 125 days after seeding in 1984

	Ammonium-N		Nitrate-N	
	Depth (cm)			
Main effect	0-20	0-60	0-20	0-60
	90 days after seeding (8/28/1984)			
	probability			
CFH	0.0573	0.1294	0.0008	0.0067
NR	0.3588	0.3314	0.0058	0.0168
CV(%)	40.2	35.4	54.9	55.0
	kg N/ha			
CC	16	34	12 b	32 b[1]
FC	18	40	28 b	67 ab
HM	10	27	53 a	101 a
N120	14	31	20 b	46 b
N240	16	36	42 a	87 a
	125 days after seeding (10/04/1984)			
	probability			
CFH	0.1925	0.1484	0.0417	0.0071
NR	0.6690	0.9313	0.2268	0.0329
CV(%)	30.1	21.0	53.9	44.4
	kg N/ha			
CC	12	20	15 b	20 b
FC	10	21	29 ab	45 a
HM	9	17	34 a	51 a
N120	11	19	22	30 b
N240	10	19	30	47 a

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

The residual effect of the treatments on soil NO_3-N contents and NO_3-N accumulations in the soil profile measured after the winter were not significant (Tables 2.23 and 2.24).

In 1984, treatment effects were reflected in soil NO_3-N contents (Tables 2.24-2.32). One month after treatment applications (June 27, 1984), the U3 treatment had the highest NO_3-N content at 116 mg N/kg soil at 0-10 cm depths, followed by the HM2, U2, HM2S, HM1 and U1 treatments with values of 110, 91, 79, 69 and 68 mg NO_3-N/kg soil, respectively. These values were significantly more than that of the control, which had 25 mg NO_3-N/kg soil. The same tendency was observed at 10-20 cm. There was no evidence suggesting significant treatment effects on NO_3-N contents at depths of 20-40 and 40-60 cm (Table 2.25). Significantly more NO_3-N accumulation in the entire soil profile was found with the U3, HM2S, HM2 and U2 treatments, compared with the control (Table 2.27). The NO_3-N content associated with the HM treatment was significantly higher than contents of CC and FC manure treatments in the top 10 cm soil (Table 2.26). Higher manure application rates resulted in more NO_3-N accumulation in the top 20 cm of soil (Table 2.28).

Sampling conducted in July (July 26, 1984; Table 2.25) indicated significantly higher NO_3-N contents were found with the HM2, FC2, U2, FC1 and U3 treatments at 0-10 cm depths, and with the HM2S, FC2 and FC2S treatments at 10-20 cm, compared with the control at each depth. At depths of 20-40 and 40-60 cm, treatment effects remained non-significant (Table 2.25). A significantly greater NO_3-N accumulation over the control in the entire soil profile was noted with the FC2, HM2S, and HM2 treatments (Table 2.27). Among the three manure sources, HM and FC manures gave significantly higher NO_3-N contents in the upper soil layers and in the entire soil profile than did CC manure. Higher manure application rates resulted in higher NO_3-N accumulations (Table 2.26 and 2.28).

Three months after treatment applications (August 28, 1984), significantly higher NO_3-N contents over the control were associated with the U3 and HM2S treatments at the 0-10 cm layer, with the U3, HM2 and HM2S at the 10-20 cm layer (Table 2.29), and with the HM2 and FC2 at the 20-40 cm layer. NO_3-N contents of 40-60 cm soil depths were not significantly affected by treatments (Table 2.29). The highest NO_3-N accumulation in the top 20 cm soil was with the U3, followed by the HM2S and HM2 treatments, and the control had the lowest NO_3-N accumulation, but was not significantly lower than the CC, FC, HM1, U1, U2 and FC2S treatment. In the top 60 cm soil, significantly higher NO_3-N accumulation than the control was found with the HM2, HM2S and U3 treatments (Table 2.31). Comparison among the manures indicated significantly higher NO_3-N contents or accumulations were found with HM treatments. Higher manure application rates resulted in higher NO_3-N contents or accumulations in the soil profile (Tables 2.30 and 2.32).

By the end of the growing season (October 4, 1984) at depths of 0-10 and 10-20 cm, only the U3 treatment had significantly higher NO_3-N contents or accumulations compared with the control. At 20-40 cm, higher

NO_3-N contents were associated with the HM2S, FC2, HM2 and U3 treatments. The highest NO_3-N accumulation in the soil profile was with the U3 treatment, followed by the HM2S treatment. The lowest NO_3-N content was found with the control (Tables 2.29, 2.31). HM and FC manure treatments resulted in higher NO_3-N contents or accumulations at the lower depths, compared to CC manure, and higher manure application rates resulted in significantly higher NO_3-N acccumulations (Tables 2.30 and 2.32).

2.4 DISCUSSION

2.4.1 Soil water retention, organic matter content and bulk density

The effects of CC and FC treatments on conservation of soil water were greater than HM and U treatments. This was probably due to higher contents of straw bedding, or of organic matter in CC or FC manures than in HM. Thus CC and FC manures would have had a greater mulching effect. This is consistent with results of Unger and Stewart (1974), who observed larger reductions in evaporation at higher rates of feedlot waste. In the field increased effective moisture content with added manure has been noted by Hoyt and Rice (1977). On the other hand, lower moisture contents associated with HM plots could also be attributed to the greater crop growth extracting more water.

Also, high soil water retention resulting from manure application has been related to changes of soil conditions, such as decreased bulk density and increased organic matter content (Khaleel et al. 1981). In the experiment reported here, however, soil organic matter and soil bulk density were not significantly different among the treatments. This was probably due to low loading rates of manure, and a sampling depth of 5-13 cm, which would not have picked up all the applied manure. Assuming applied organic matter decomposition at the rate of 40 to 50% during the first year of application, 10 to 20% the second year, and 5% the third year (Pratt et al. 1976), no more than 20 tonnes/ha of applied organic matter during the three years remained in the 20 cm tilled surface soil at the time of sampling, or less than 1% of the soil. Thus the impact of manures on soil organic matter and bulk density would be expected to be minimal. On the other hand, manures were disked into the soils to a depths of 15 cm, and experimental plots were ploughed to 20 cm every fall. Thus the effects of manures on soil properties may have decreased with increased depth of tillage as noted by Tiark et al. (1974) due to a dillution effect.

2.4.2 Soil mineral N

Soil NH_4-N levels were affected by soil texture. For example, on the Chicot soil with a finer texture, higher NH_4-N was found with higher application rates of cow manure (CC2 and FC2), compared with HM or urea, while on the St Benoit soil with a coarser texture, treatments of higher rates of composted cow manure (CC2), hog manure (HM2) and the highest rate of urea (U3) resulted in significantly greater quantities of NH_4-N in the soil profile than with fresh cow manure (FC). This effect was attributed to the more rapid decomposition of manures or hydrolysis of urea in the coarser textured soil than in the finer textured soil. Treatment effects on soil NH_4-N disappeared one month after manure or urea application, indicating most of the N was converted to NO_3-N, as noted in other studies (Quisenberry et al. 1981). Also, ammonia volatilization from the applied manures or urea could have contributed to NH_4-N loss (Chin and Kroontje 1962; Elliott et al. 1971; Lauer et al. 1976; and Makarov and Gerashenko 1981).

Fresh cow manure spread on soil surfaces (FC2S) gave slightly lower soil NO_3-N contents than cow manure incorporated into soil (FC2) at both research sites, indicating that volatilization of ammonia N contained in the manure may have occurred (Elliott et al. 1971; Lauer et al. 1976; Beauchamp et al. 1978; Beauchamp et al. 1982; Hutchinson et al. 1982; Beauchamp 1983).

The residual effects of manures or urea applied in 1983 on soil NO_3-N content in 1984 were not significant. For example, on St Benoit soil, among the treatments, significantly different NO_3-N contents detected in September of 1983 were not evident in the spring of 1984 in spite of the higher NO_3-N contents found in the spring of 1984. The higher NO_3-N contents after the winter season were attributed to mineralization of organic N and nitrification of NH_4-N during the fall and winter seasons (Campbell and Biederbeck 1982; Malhi and Nyborg 1983).

Soil with finer texture may have increased the adsorption of NH_4-N because of larger adorption capacity. Nitrification, thus, may have been delayed. Delayed nitrification was evidenced by the fact that a relatively high accumulation of NO_3-N in the soil profiles occurred one and two months after treatment applications to the St Benoit and the Chicot soil, respectively.

On the Chicot soil, significantly more NO_3-N in the soil profile was associated with the HM2S treatment late in the growing season, compared with the treatments of cow manure left on the soil surface (FC2S) and hog manure incorporated into the soil (HM2) probably due to greater nitrification and less denitrification in the HM2S plot than in the FC2S and HM2 plots. On the St Benoit soil, however, this phenomena was less evident. These observations revealed that to increase N for crop utilization, manure in solid state should be incorporated into the soils, while manures in liquid state could be spread on the surface of soils with finer textures.

Soils with urea at more than 120 kg N/ha had equivalent or greater NO_3-N levels to manures at higher N application rates. For example, NO_3-N accumulation in the St Benoit soil with the U3 treatment was as much as 2 to 3 times those of other treatments, measured at the end of the growing season (October 4, 1984). This was not consistent with the findings of Evans et al. (1977), who indicated that soil with beef manure was consistently higher in NO_3-N content than soil with solid beef manure, liquid hog manure and ammonium nitrate fertilizer.

Higher manure application rates gave significantly more NO_3-N in both soils than the lower rates at the end of growing season. Lower application rates, thus, would be preferred, considering NO_3-N as a potential ground water pollutant (Ito and Miyazawa 1984).

Table 2.33 Precipitation recorded at La Station de Ste Anne de Bellevue, Service de la meteorologie, Ste Anne de Bellevue, Quebec.

1983		1984	
Period	Precipitation (mm)	Period	Precipitation (mm)
15/06-13/07	45.4	1/01-26/04	177.0
14/07-16/08	71.7	27/04-18/05	64.9
17/08-30/09	97.8	19/05-28/05	36.4
1/10-31/12	312.1	29/05-27/06	110.3
		28/06-26/07	85.2
		27/07-28/08	114.0
		29/08- 4/10	61.1
Total	527.0		648.9

Leaching of NO_3-N from the various treatments and nitrification of NH_4-N were obvious through the growing season in the St Benoit soil, where only in the upper layers was the soil NO_3-N content significantly affected by the treatments in the early season. With the increase in cumulative precipitation with time (Table 2.33), soil NO_3-N content of deeper soil layers varied with the treatments. More NO_3-N was found at lower depths in U or HM plots than in the control, and CC, or FC manure plots, perhaps due to less organic matter contained in the hog manure used in this research and to the fact that there was no addition of organic material to the urea plots.

NO_3-N leaching problems have been recognized by many people (Adriano et al. 1971; Evans et al. 1977; Lembke and Thorne 1980; Cooper et al. 1984). Thus to reduce the pollution potential and to limit N losses by leaching, it was suggested that N application rates of animal wastes be based on the same criteria as those used to determine N additions of mineral fertilizers (Quisenberry et al. 1981).

2.5 CONCLUSIONS

Soil moisture was significantly higher following applications of semi-solid CC and FC, especially when it was applied on the soil surface, compared with the control, HM or U treatments. Soil organic matter contents and bulk densities at the depth of 5-13 cm were affected little by the treatments, probably due to the low manure application rates.

Manure or urea additions increased soil NH_4-N content only briefly after treatment application, but soil NO_3-N contents or accumulations were increased by application of manures or urea. Obvious NO_3-N leaching was observed on both soils. On the St Benoit soil, urea applied at the rate of 180 kg N/ha was found to have a greater potential for NO_3-N accumulation than liquid hog manure or cow manure at the rate of 240 kg N/ha. Manures ranked in decreasing order as to NO_3-N accumulation were as follows: HM > FC > CC. Higher N levels with the St Benoit soil, compared with the Chicot soil, indicated N applied to the coarser texture soil had greater potential to increase NO_3-N level and possible pollution of ground water than N applied to the finer texture soil.

Experimental data also suggested that liquid manure should be spread on the surface of soils with finer textures in order to avoid N losses. For coarser textured soils, either incorporation or surface application could be adopted for manure management.

PREFACE TO CHAPTER 3

In Chapter 2, the effects of animal manures or urea on soil mineral N, soil water retention capacity, bulk density and organic matter content were discussed. Thus, it seemed logical to discuss the impact of these properties on plant growth. In Chapter 3, crop yields, N uptake and cumulative effect of manures and urea on dry-matter yields and nutrient uptake will be discussed.

Chapter 3

Effect of manures or urea on corn dry matter yields and nutrient uptake

3.1 INTRODUCTION

Experiments have shown that manures can be more effective than inorganic fertilizers in increasing crop yields (Cope et al. 1958, Bishop et al. 1964, Dubetz et al. 1975). Growth and dry matter yields of corn and ryegrass increased linearly with increasing farmyard manure (FYM) application rates up to 200 t FYM/ha with, however, a simultaneous deficiency in Ca and Mg (Evans et al. 1977; Ito and Miyazawa 1984). Manure applications of 22 t/ha annually supplied sufficient elements for maximum crop yields on a Pullman loam soil (Mathers and Stewart 1981). In other studies, however, manure resulted in lower crop yields than inorganic fertilizers (Hoyt and Rice 1977; Miller and MacKenzie 1978).

Comparisons made among manures have indicated that yields with beef manure were higher than with hog manure, and liquid manures were more effective than solid manures although reasons for these differences were not clear (Evans et al. 1977; Miller and MacKenzie 1978).

Different manures have different properties (Loehr 1974; Peng and Pei 1979). The process of manure storage or composting has been indicated to be accompanied by great N losses (Vanderholm 1975), but composted manure normally has a C/N ratio of about 15/1 (Singley et al.

1975; Stombaugh and White 1975), indicating that no problems should be encountered with plant N deficiencies when the composts are added to soil. Thus differently treated manures may be expected to have different effects on crop growth, when they are applied at the same N levels. Crop nutrition status can be reflected in the analysis of the composition of plant tissue.

For evaluating soil fertility and estimating corn yields, nutrient compositions of ear leaf of corn have been related to yields. Tyner (1946) proposed critical nutrient concentrations of 2.90% N, 0.295% P and 1.30% K on a 6.6% moisture basis for the 6th leaf from the plant base selected at silking. Melsted et al. (1969) considered 3.0% N, 0.25% P and 1.90% K, 0.40% Ca and 0.25% Mg for the ear leaf at tasselling. However, for a given percentage of N in the leaf, yields may vary markedly among experiments, even when leaves from the same hybrid at the same stage of physiological development are selected for sampling (Viets et al. 1954). However, ear leaf studies can indicate potential nutrient deficiencies, or nutrient interactions that are not evident otherwise.

Thus, based on information in the literature, it was decided that the objectives of this research were to study :

1. Nutrient concentrations of ear leaf as affected by different N sources and rates.
2. Dry-matter yields and N uptake by corn grown on plots amended with various manures or urea.
3. Cumulative effects of manures or urea on dry-matter yields and nutrient uptake.

3.2 MATERIALS AND METHODS

3.2.1 Field arrangement

Chicot soil and St Benoit soil, fresh (FC) and composted solid cow (CC) manure, liquid hog manure (HM) and urea (U) as N sources, were used. The characteristics of the soils, and manures and the experimental methods were described in Chapter 2 (Tables 2.1, 2.2 and 2.3).

3.2.2 Sampling procedure

Plant samples were taken on July 16 and August 17, 1983, and June 16 and July 16, 1984. Two plants selected at random from the side rows of each plot were sampled for total N content and dry matter accumulation determinations. In 1984, at the silking stage, a dozen corn ear leaves from the two side rows of each plot were taken for leaf composition analysis. For computing the final dry matter yields (DMY) and nutrient uptake, plants from the centre 3 m of the centre two rows in each plot were harvested using a mechanical forage chopper.

3.2.3 Laboratory analysis

Corn tissue samples were oven-dried at 80°C, and ground in a stainless-steel Wiley mill to pass a 0.2 mm mesh sieve prior to digestion. The wet digestion method outlined by Thomas et al. (1967) was used. N and P were determined colorimetrically (Thomas et al. 1967), K by flame photometer (Thomas et al. 1967), and Ca and Mg by atomic absorption (Hunter 1974).

Duncan's multiple range test was employed to locate differences among the 12 treatments. Further, the CC1, CC2, FC1, FC2, HM1, and HM2 treatment results were analysed statistically as a 3 X 2 factorial experiment (Steel and Torrie 1980).

To discuss the cumulative effect of manures or urea on DMY or nutrient uptake, the effect coefficient of treatment (ECT) was defined as follows:

$$ECT = P_{rt} / P_{rc}$$

where P_{rt} was DMY or nutrient uptake from each treatment in each replicate, P_{rc} was DMY or nutrient uptake from the control plot within each replicate. The advantages of introducing ECT were to control the yield variations among years and sites due to variations in weather, plant population, seeding date, and management practices. The values of ECT are dimensionless.

3.3 RESULTS

3.3.1 Ear-leaf composition

The ear-leaf N content ranged from 2.38% to 2.94% for corn grown on the Chicot soil, and from 2.93% to 3.34% for corn grown on the St Benoit soil (Table 3.1). Leaf N contents associated with the U2 and HM2S treatments on the Chicot soil were significantly higher than those from the control, FC2S, CC1 and FC1 treatments. There was no significant treatment effect on corn ear leaf N content on the St Benoit soil.

Significantly higher P levels of ear leaves were noted with the HM2, HM1, HM2S, U2, FC1, FC2 and FC2S treatments on the Chicot soil over the control, and with the HM2S, FC2S, CC2, FC2 and HM1 treatments over the control on the St Benoit soil (Table 3.1).

Lowest K contents were found with the U1 treatment on the Chicot soil, and with the HM2 treatment on the St Benoit soil (Table 3.1). On the Chicot soil, ear leaf K contents associated with the CC2 and FC2S treatments were significantly higher than those associated with the control, U2, U3 and U1 treatments, while on the St Benoit soil, no significant difference was found between any of the manured or urea-N treatments and the control. However, ear leaf K contents of corn receiving the CC1, FC1 treatments were significantly higher than those of the HM2, U1, U2, U3 and HM2S treatment on the St Benoit soil.

Leaf Ca contents were generally not affected by the treatments (Table 3.1). Significantly higher leaf Mg contents were found with the U2, U1 and HM2S treatments, compared with the FC2, HM2, HM2S treatments on the Chicot soil. Treatments had no significant effect on corn ear leaf Mg levels on the St Benoit soil.

Comparison among manures indicated that on the Chicot soil, HM treatments resulted in significantly higher leaf P contents than CC or

Table 3.1 Effect of manures or urea-N on composition of corn ear leaf at silking stage in 1984

Treatment	N	P	K	Ca	Mg
			%		
			Chicot soil		
Ctrl	2.40 c[1]	0.32 e	1.85 bc	0.79	0.37 abcd
CC1	2.60 bc	0.35 bcde	1.91 abc	0.56	0.36 bcde
CC2	2.77 ab	0.35 bcde	2.08 a	0.65	0.36 bcde
FC1	2.62 bc	0.36 abcd	1.96 abc	0.69	0.35 cdef
FC2	2.77 ab	0.36 abcd	2.00 ab	0.63	0.32 ef
HM1	2.78 ab	0.38 ab	1.90 abc	0.81	0.37 abcd
HM2	2.84 ab	0.39 a	1.95 abc	0.62	0.34 def
U1	2.75 ab	0.33 de	1.75 c	0.67	0.39 ab
U2	2.94 a	0.37 abcd	1.80 bc	0.87	0.40 a
U3	2.83 ab	0.34 cde	1.86 bc	0.73	0.37 abcd
FC2S	2.38 c	0.36 abcd	2.09 a	0.52	0.31 f
HM2S	2.92 a	0.38 ab	1.93 abc	0.63	0.38 abc
F	4.09**	3.18**	2.42*	1.18	4.74**
CV (%)	6.6	6.3	6.8	28.1	7.0
			St Benoit soil		
Ctrl	2.93	0.29 d	2.20 abcd	0.74	0.19
CC1	3.01	0.30 bcd	2.32 a	0.64	0.18
CC2	3.26	0.32 ab	2.20 abcd	0.70	0.20
FC1	3.11	0.30 bcd	2.32 a	0.65	0.18
FC2	3.30	0.32 ab	2.31 ab	0.66	0.18
HM1	3.23	0.32 ab	2.22 abcd	0.82	0.19
HM2	3.22	0.31 abcd	2.11 d	0.83	0.21
U1	3.10	0.30 bcd	2.16 cd	0.79	0.21
U2	3.18	0.30 bcd	2.12 d	0.83	0.18
U3	3.14	0.30 bcd	2.17 bcd	0.74	0.17
FC2S	3.31	0.33 a	2.30 abc	0.66	0.19
HM2S	3.34	0.33 a	2.14 d	0.82	0.20
F	1.26	3.09**	3.10**	1.99	1.10
CV (%)	7.1	5.3	4.1	14.8	11.8

1) means of the same soil in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range test.

*,** : significant at the levels of 0.05 and 0.01 respectively.

FC manure treatments (Table 3.2). Corn receiving higher manure application rates was higher in ear leaf N and Mg contents. On the St Benoit soil, FC manure treatments were more effective in raising leaf K content than HM treatments, while significantly higher leaf Ca levels were found with HM treatments, compared with CC or FC manure treatments.

By correlating final DMY with nutrient contents of corn ear leaves, it was shown that significant partial correlations existed between DMY and N content of corn ear leaves on the Chicot soil (r=0.58, p=0.0001), and P content of corn ear leaves on both the Chicot soil (r=0.38, p=0.0077) and the St Benoit soil (r=0.52, p=0.0002).

3.3.2 N uptake by corn

In the following sections, the word "corn" refers to total corn above the ground.

Chicot Soil

In 1983, corn grown on the CC1 and U3 plots had significantly higher N contents measured 26 days after sowing, compared with that on the control, CC2 and FC2 plots (Table 3.3). The N contents of corn determined 61 days after sowing in 1983 were not significantly different among manure or urea plots, but a significantly higher N content was noted with the U2 treatment, compared with the control. By harvest time in 1983, corn N contents associated with the U2 and HM2S treatments significantly exceeded those of the control and CC1, FC1, FC2 and FC2S

Table 3.2 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on corn ear leaf composition at silking stage in 1984

Main effect	N	P	K	Ca	Mg
			Chicot soil		
			probability		
CFH	0.1737	0.0081	0.6383	0.4622	0.0748
NR	0.0419	0.3725	0.2089	0.4911	0.0436
CV (%)	5.2	4.9	7.8	25.9	5.9
			%		
CC	2.68	0.35b	1.99	0.60	0.36
FC	2.69	0.36b	1.98	0.71	0.35
HM	2.81	0.38a	1.92	0.71	0.35
N120	2.66b^1	0.36	1.92	0.68	0.36a
N240	2.79a	0.37	2.01	0.63	0.34b
			St Benoit soil		
			probability		
CFH	0.5983	0.6678	0.0231	0.0156	0.1118
NR	0.0873	0.1249	0.0520	0.5519	0.1267
CV (%)	6.1	4.4	4.3	15.9	10.0
			%		
CC	3.13	0.31	2.26ab	0.67b	0.19
FC	3.21	0.32	2.32a	0.65b	0.18
HM	3.23	0.31	2.17b	0.83a	0.20
N120	3.12	0.31	2.29	0.70	0.18
N240	3.26	0.32	2.21	0.73	0.20

1) means follwed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

Table 3.3 Effect of manures or urea on N content of corn during 1983 and 1984

Treatment	Chicot soil			St Benoit soil		
	%					
	Days after seeding (1983)					
	26	61	97	27	61	97
Ctrl	3.14 bc[1]	1.72 b	1.41 bc	3.22 b	2.04 c	1.36 d
CC1	3.63 a	1.88 ab	1.35 c	3.39 ab	2.24 bc	1.70 bc
CC2	3.12 bc	1.82 ab	1.53 abc	3.13 b	2.20 bc	1.66 bc
FC1	3.32 abc	1.88 ab	1.38 c	3.68 a	2.25 bc	1.63 bc
FC2	2.89 c	1.93 ab	1.36 c	3.39 ab	2.18 bc	1.55 c
HM1	3.28 abc	2.02 ab	1.53 abc	3.46 ab	2.35 ab	1.80 ab
HM2	3.20 abc	2.36 ab	1.57 abc	3.71 a	2.36 ab	1.80 ab
U1	3.21 abc	1.99 ab	1.56 abc	3.33 ab	2.33 ab	1.70 bc
U2	3.24 abc	2.55 a	1.63 a	3.38 ab	2.36 ab	1.74 abc
U3	3.65 a	2.25 ab	1.58 abc	3.41 ab	2.50 a	1.93 a
FC2S	3.24 abc	1.96 ab	1.41 bc	3.22 b	2.21 bc	1.58 c
HM2S	3.56 ab	2.24 ab	1.63 a	3.72 a	2.36 ab	1.84 ab
F	2.66*	3.88**	2.96**	2.13*	2.79*	5.72**
CV (%)	8.4	12.5	8.2	7.8	6.3	7.5
	Days after seeding (1984)					
	40	69	120	40	69	120
Ctrl	3.05	1.29 d	0.92	2.78 d	1.51 d	0.94
CC1	3.09	1.31 d	1.01	2.79 d	1.66 cd	1.14
CC2	3.25	1.44 cd	1.07	2.94 abcd	2.15 ab	1.14
FC1	3.15	1.35 d	0.99	2.93 abcd	2.03 abc	1.16
FC2	3.10	1.46 bcd	1.05	3.15 a	2.13 ab	1.16
HM1	3.29	1.36 d	1.11	2.97 abcd	2.05 abc	1.28
HM2	3.34	1.60 abc	1.11	2.82 cd	2.24 a	1.27
U1	3.26	1.34 d	1.05	2.86 bcd	1.77 bcd	1.02
U2	3.53	1.70 a	1.09	2.81 cd	2.05 abc	1.23
U3	3.22	1.42 cd	1.32	2.86 bcd	2.00 abc	1.16
FC2S	3.01	1.37 d	1.05	3.06 abc	1.98 abc	1.10
HM2S	3.43	1.66 ab	1.12	3.10 ab	1.99 abc	1.18
F	1.40	3.84**	1.80	2.50*	2.78*	1.48
CV (%)	8.2	9.9	13.3	5.6	12.9	12.8

1) means of the same year in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*, ** : significant at the level of 0.05 and 0.01 respectively.

treatments (Table 3.3).

In 1984, there were no significant differences in N contents among treatments, analyzed 40 days after sowing (Table 3.3). Treatment effects on corn N content became apparent two months after sowing as indicated by significantly higher N contents of corn from the U2, HM2S and HM2 treatments compared to those from the control, CC1, FC1, HM1, U1 and FC2S treatments. No significant treatment effects on final corn N content were detected. The differences between the FC2 and FC2S and between the FM2 and HM2S were small, indicating that manure application methods had no effect on corn N content. However, significantly higher N content was noted with the HM2S treatment than with the FC2S treatment at 70 days after planting, indicating HM was more effective than FC manure when they both were applied on the soil surface.

Final N uptake values by corn were significantly affected by the treatments. In 1983, the highest N uptake was from the HM2S plots, the lowest from the FC2S. The N uptakes of greater than 215 kg N/ha for the HM2S, U2, U3, CC2 and HM2 treatments, were significantly more than those for the control, CC1, FC1, FC2 and FC2S treatments, which were less than 171 kg N/ha (Table 3.4). In 1984, the highest N uptake was 210 kg N/ha with the U3 plots, and the lowest 108 kg N/ha with the control. N uptakes from all manured or urea applied plots except for the FC2S plot were significantly higher than the control, and N uptake from the U3 plot was much higher than that from the CC1, FC1, FC2, U1 and FC2S treatments.

Table 3.4 Effect of manures or urea on N uptake by corn

Treatment	Chicot soil			St Benoit soil		
	kg/ha					
	Days after seeding (1983)					
	26	61	97	26	61	97
Ctrl	9.8	128	152 de[1]	4.5 d	111 c	119 c
CC1	10.2	140	171 cde	5.6 bcd	154 ab	193 ab
CC2	10.0	126	216 ab	7.1 ab	154 ab	191 ab
FC1	8.6	143	167 cde	7.5 abcd	139 bc	174 ab
FC2	7.6	139	164 cde	6.5 abcd	145 b	192 ab
HM1	8.9	182	188 bcd	8.9 ab	186 a	188 ab
HM2	10.4	180	215 ab	10.0 a	160 ab	214 a
U1	10.0	142	199 abc	5.1 cd	141 cd	157 b
U2	11.3	189	223 ab	6.7 abcd	142 bc	173 ab
U3	9.0	175	217 ab	7.2 abcd	170 ab	192 ab
FC2S	7.5	168	143 e	5.4 bcd	137 bc	169 b
HM2S	12.9	186	234 a	8.3 abc	186 a	195 a
F	1.75	1.83	5.35**	2.27*	4.44**	3.75**
CV (%)	23.7	24.1	13.9	30.5	13.4	13.9
	Days after seeding (1984)					
	40	69	120	40	69	120
Ctrl	23.3	79	108 d	5.8 c	76 de	92 d
CC1	27.8	79	149 bc	7.0 c	70 e	144 bc
CC2	30.8	131	176 abc	6.8 c	84 de	172 abc
FC1	23.8	100	154 bc	6.5 c	95 cde	172 abc
FC2	21.4	122	152 bc	9.2 bc	145 ab	182 ab
HM1	30.2	98	187 ab	7.9 bc	128 abc	161 abc
HM2	39.7	114	184 ab	14.2 a	155 a	205 a
U1	31.1	97	165 bc	7.0 c	99 cde	130 cd
U2	34.7	125	175 abc	7.9 bc	111 bcd	161 abc
U3	26.8	111	210 a	6.4 c	109 bcde	142 bc
FC2S	18.7	94	135 cd	9.0 bc	131 abc	165 abc
HM2S	30.7	112	182 ab	12.8 ab	155 a	190 ab
F	1.69	0.93	4.72**	2.66*	5.71**	3.92**
CV (%)	32.1	33.3	15.1	38.3	22.0	17.4

1) means of the same year in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Mutiple Range Test.

*,** : significant at the levels of 0.05 and 0.01 respectively.

St Benoit Soil

Corn N content associated with the control was consistently lowest of all treatments in the two years (Table 3.3). In 1983, significantly higher N contents than that of the control were found with the FC1, HM2 and HM2S treatments at 26 days after sowing, with the HM1, HM2, U1, U2, U3 and HM2S treatments at 61 days after sowing, and with all manure or urea treatments at 97 days. In 1984, a comparison with the control showed that N contents were higher with the FC2, FC2S and HM2S treatments at 40 days after sowing in 1984, and with all other treatments, except for the CC1 and U1 treatments, at 69 days after seeding. At the last sampling (97 days after sowing) in 1983, N contents associated with the FC2 and FC2S were exceeded by those with the U3, HM2S, HM1 and HM2 treatments. However, final analyses made in 1984 showed no significant treatment effects on corn N content (Table 3.3).

As with corn N content, the lowest N uptake was found with the control and the highest with HM in the six estimations made in the two years. A comparison made 69 days after sowing in 1984 indicated N uptake among the three manure N sources was significantly different with highest N uptake from HM plots and lowest from CC manure plots (Table 3.5). The final N uptake ranged from 119 to 214 kg N/ha in 1983 and from 92 to 205 kg N/ha in 1984. Differences among the manures on final N uptake were not significant though HM tended to provide more N for corn plants than CC or FC manures. The high manure application rates resulted in significantly higher N uptake (Tables 3.4 and 3.6) compared to the lower application rates.

Table 3.5 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on accumulation of corn dry matter (CDM) and nitrogen content (NC) and uptake (NUP) in 1984

	Days after seeding					
Main effect	40			69		
	CDM	NC	NUP	CDM	NC	NUP
	Chicot soil					
	probability					
CFH	0.0626	0.2754	0.0234	0.7098	0.2439	0.9013
NR	0.4563	0.5833	0.3145	0.1737	0.0059	0.0309
	St Benoit soil					
	probability					
CFH	0.0532	0.1395	0.0701	0.0024	0.3501	0.0001
NR	0.0678	0.3232	0.0560	0.1441	0.0746	0.0024

Table 3.6 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on final yield (Y in 1983 and 1984 and nutrient uptake by corn in 198

	Y		Uptake				
Main effect	1983	1984	N	P	K	Ca	Mg
			Chicot soil				
			probability				
CFH	0.0872	0.5773	0.0818	0.5781	0.2375	0.2753	0.0930
NR	0.0621	0.5304	0.4011	0.5523	0.0733	0.7360	0.1594
CV (%)	9.3	13.1	14.6	16.6	14.1	31.6	21.5
	t/ha		kg/ha				
CC	13.4	15.6	162	43	204	81	36
FC	12.0	14.9	153	43	192	63	33
HM	13.0	16.0	185	46	180	79	42
N120	12.3	15.2	161	43	181	73	35
N240	13.3	15.8	171	45	202	76	40
			St Benoit soil				
			probability				
CFH	0.8866	0.3634	0.2125	0.5481	0.0193	0.1522	0.3680
NR	0.1025	0.0127	0.0282	0.0609	0.0007	0.0136	0.0129
CV (%)	14.0	13.0	18.4	18.5	12.6	17.5	16.4
	t/ha		kg/ha				
CC	11.5	13.9	158	26	242ab[1]	51	23
FC	11.6	15.3	177	28	275a	55	24
HM	11.2	14.4	183	28	225b	62	25
N120	10.8	13.4b	159b	25	220b	56b	22b
N240	12.0	15.6a	187a	29	274a	62a	26a

1) means followed by different letters in the same column within the same block are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

3.3.3 Nutrient balance

On the Chicot soil, it was found that N uptake from the control, CC1, FC1, HM1, U1 and U2 treatment plots exceeded N added (Table 3.7). Negative values of P, K and Ca balances were found with the U plots (U1, U2 and U3). For Mg, positive values with cow manures at higher application rates (CC2, FC2) were noted.

On the St Benoit soil, the same trends as on the Chicot soil were observed with N, K, Ca and Mg balances. Added P could accumulate in the soil with some treatments, especially with HM due to a positive P balance.

3.3.4 Corn dry matter yields

Only the final total DMY in each year will be discussed.

Chicot Soil

Corn dry matter yields on Chicot soil ranged from 10.1 to 14.4 t/ha in 1983, and from 11.8 to 16.6 t/ha in 1984 (Table 3.8). Yields associated with the HM2S, CC2, HM2, U2 and U3 treatments were significantly higher than those with the control and FC2S treatments in 1983. In 1984, all treatments except for the FC2 and FC2S treatment had significantly higher yields than the control, which had the lowest yields. Yield differences among manures were not significant (Tables 3.6 and 3.8).

Table 3.7 Balance of nutrients added in manures & fertilizers and removed by corn in 1984

Treatment	N	P	K	Ca	Mg
	kg/ha				
	Chicot soil				
Ctrl	-108	1	-50	-61	- 30[1]
CC1	- 29	53	82	110	- 1
CC2	64	113	238	306	31[2]
FC1	- 34	52	72	72	- 2
FC2	88	118	215	204	28
HM1	- 67	102	92	59	- 15
HM2	56	204	246	184	- 7
U1	-105	- 7	- 65	- 76	- 42
U2	- 55	- 5	- 80	- 93	- 46
U3	30	- 7	- 97	- 80	- 42
FC2S	105	116	231	207	31
HM2S	58	210	229	185	- 2
	St Benoit soil				
Ctrl	- 92	45	13	- 40	- 16
CC1	- 24	102	123	146	14
CC2	64	159	235	328	43
FC1	- 52	100	49	82	18
FC2	58	162	187	210	36
HM1	- 41	150	130	80	- 1
HM2	35	255	233	199	13
U1	- 70	39	- 19	- 52	- 21
U2	- 41	40	- 36	- 71	- 23
U3	38	40	- 34	- 54	- 19
FC2S	75	162	186	213	- 35
HM2S	50	255	217	182	15

1) negative value means nutrient uptake exceeded nutrient added.

2) positive value means nutrient added was more than nutrient uptake.

Table 3.8 Effect of manures or urea on accumulation of corn dry matter yield

Treatment	Chicot soil			St Benoit soil		
	t/ha					
	Days after seeding (1983)					
	26	61	97	26	61	97
Ctrl	0.31	7.5	10.8 de[1]	0.14	5.5 d	8.9 d
CC1	0.28	7.4	12.7 abcd	0.17	6.9 abc	11.4 abc
CC2	0.32	7.0	14.2 ab	0.23	7.0 abc	11.5 ab
FC1	0.26	7.5	12.0 cde	0.21	6.2 cd	10.7 abcd
FC2	0.26	7.4	12.1 bcde	0.20	6.7 c	12.4 a
HM1	0.27	9.0	12.3 bcd	0.26	8.0 a	10.4 abcd
HM2	0.33	7.6	13.7 abc	0.27	6.7 c	12.0 ab
U1	0.32	7.1	12.8 abcd	0.16	6.0 cd	9.2 cd
U2	0.35	7.5	13.7 abc	0.20	6.0 cd	10.0 bcd
U3	0.24	7.8	13.6 abc	0.21	6.8 bc	9.9 bcd
FC2S	0.24	6.6	10.1 e	0.17	6.3 cd	10.8 abcd
HM2S	0.36	8.3	14.4 a	0.22	7.9 ab	10.7 abcd
F	1.71	0.80	4.35**	1.62	4.00**	2.45*
CV (%)	21.5	18.2	10.0	30.4	11.1	12.7
	Days after seeding (1984)					
	40	69	120	40	69	120
Ctrl	0.75	6.6	11.8 c	0.21 c	5.1 bcd	9.7 e
CC1	0.91	6.0	14.7 ab	0.25 bc	4.3 cd	12.7 cd
CC2	0.94	9.1	16.4 a	0.23 bc	3.9 d	15.1 abc
FC1	0.75	7.6	15.5 ab	0.22 c	4.7 bcd	14.9 abc
FC2	0.69	8.4	14.3 abc	0.29 bc	6.8 ab	15.6 ab
HM1	0.92	7.2	15.4 ab	0.27 bc	6.4 abc	12.7 cd
HM2	1.20	7.0	16.6 a	0.50 a	7.0 ab	16.1 a
U1	0.96	7.5	15.7 ab	0.25 bc	5.6 bcd	12.7 cd
U2	0.99	7.4	16.0 a	0.28 bc	5.4 bcd	13.2 bcd
U3	0.81	7.9	16.2 a	0.23 bc	5.4 bcd	12.3 d
FC2S	0.61	6.9	12.9 bc	0.29 bc	6.7 ab	14.9 abc
HM2S	0.90	7.0	16.3 a	0.41 ab	7.9 a	16.2 a
F	1.28	0.46	2.83*	2.43*	3.08**	6.03**
CV (%)	32.1	32.6	11.6	38.8	23.7	11.4

1) means of the same year in the same column followed by the same letters are not significantly different at the level of 0.05 by Duncan's Multiple Range Test.

*, ** : significant at the levels of 0.05 and 0.01 respectively.

St Benoit Soil

The control had consistently lowest yields of all treatments in both 1983 and 1984. The highest yields were with the FC2 treatment in 1983 and with the HM2S treatment in 1984. The yields associated with the FC2, HM2, CC2 and CC1 treatments were significantly higher than that of the control in 1983. The effects of manures or urea were more obvious in 1984, as indicated by significantly higher yields from all manured or urea treated plots compared to the control. Yields from urea treatments were exceeded by those from the FC2 treatment in 1983, and the HM2S and HM2 treatments in 1984. In terms of DMY, the effect of manures incorporated into the soil was not significantly different from that of manures left on the soil surface. Plots receiving higher manure application rates yielded significantly more dry matter than lower manure application rates. Differences among the manures were not significant when analyzed as a factorial experiment (Tables 3.6 and 3.8).

3.3.5 Cumulative effects

Treatment effects as expressed by effect coefficients of treatments (ECT) on DMY and nutrient uptake were found to be greater in 1984 compared with 1983 (Tables 3.9, 3.10 and 3.11). On the Chicot soil, the average ECT of all treatments of 1.29 for DMY of 1984 was significantly higher than that of 1.18 for 1983. A larger difference of ECT for DMY between 1984 and 1983 was noticed on the St Benoit soil, compared with that of the Chicot soil (Table 3.11).

Table 3.9 Comparison of effect coefficients of treatment of dry matter yield (DMY) and nutrient uptake on the Chicot soil in 1983 and 1984

Year	Treatment	DMY	Uptake				
			N	P	K	Ca	Mg
1983	Ctrl	1.00ef	1.00gh	1.00d	1.00	1.00	1.00def[1]
1983	CC1	1.18abcde	1.12efgh	1.03cd	1.31	0.85	0.98def
1983	CC2	1.32abcd	1.44bcdef	1.36abcd	1.49	1.28	1.17bcdef
1983	FC1	1.12cdef	1.11efgh	1.15bcd	1.11	0.71	0.88f
1983	FC2	1.12cdef	1.09fgh	1.18bcd	1.21	1.04	0.88f
1983	HM1	1.14bcdef	1.24defgh	1.00d	1.38	1.19	1.10cdef
1983	HM2	1.27abcd	1.43bcdef	1.08bcd	1.39	1.49	1.10cdef
1983	U1	1.19abcde	1.32cdefg	1.09bcd	1.19	1.24	1.12cdef
1983	U2	1.28abcd	1.47bcde	1.12bcd	1.29	1.21	1.14bcdef
1983	U3	1.26abcd	1.45bcdef	1.01d	1.08	0.96	1.05cdef
1983	FC2S	0.93f	0.95h	1.00d	1.28	0.89	0.91ef
1983	HM2S	1.34abcd	1.55bcd	1.39abcd	1.56	1.15	1.34abcde
1984	Ctrl	1.00ef	1.00gh	1.00d	1.00	1.00	1.00def
1984	CC1	1.25abcd	1.40bcdef	1.36abcd	1.42	1.54	1.19bcdef
1984	CC2	1.38ab	1.64abc	1.41abcd	1.60	1.39	1.22abcdef
1984	FC1	1.32abcd	1.45bcdef	1.47ab	1.35	1.11	1.11cdef
1984	FC2	1.22abcde	1.41bcdef	1.35abcd	1.47	1.25	1.11cdef
1984	HM1	1.31abcd	1.53bcd	1.36abcd	1.25	1.39	1.19bcdef
1984	HM2	1.41a	1.71ab	1.62a	1.40	1.46	1.62a
1984	U1	1.34abcd	1.55bcd	1.26abcd	1.15	1.53	1.46abc
1984	U2	1.36abc	1.64abc	1.21abcd	1.27	1.69	1.56ab
1984	U3	1.38ab	1.94a	1.26abcd	1.42	1.58	1.42abcd
1984	FC2S	1.09def	1.24defgh	1.44abc	1.39	1.02	0.98def
1984	HM2S	1.39a	1.71ab	1.41abcd	1.53	1.55	1.49abc
F		3.28**	5.28**	2.21**	1.18	1.21	2.68**
CV (%)		12.1	16.0	20.0	23.5	39.0	22.1

1) means in the same column followed various letters are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

* : significant at the level of 0.05.

** : significant at the level of 0.01.

Table 3.10 Comparison of effect coefficients of treatment of dry matter yield (DMY) and nutrient uptake on the St Benoit soil in 1983 and 1984

Year	Treatment	DMY	Uptake				
			N	P	K	Ca	Mg
1983	Ctrl	1.00g	1.00g	1.00cd	1.00h	1.00e	1.00c
1983	CC1	1.32cdef	1.63cdef	1.66a	1.49 defg	1.46 bcde	1.54abc
1983	CC2	1.32cdef	1.60cdef	1.51abc	1.77abcd	1.53abcde	1.50abc
1983	FC1	1.24efg	1.48def	1.44abcd	1.75abcde	1.12de	1.35abc
1983	FC2	1.41abcde	1.61cdef	1.44abcd	1.92abc	1.32cde	1.45abc
1983	HM1	1.20efg	1.58cdef	1.1abcd	1.55cdef	1.60abcde	1.59ab
1983	HM2	1.36bcde	1.79bcde	1.39abcd	1.59cdef	2.01ab	1.68ab
1983	U1	1.05fg	1.32fg	1.13bcd	1.20fgh	1.27cde	1.18bc
1983	U2	1.14efg	1.46def	0.97d	1.15gh	1.88abc	1.56ab
1983	U3	1.13efg	1.60cdef	1.22abcd	1.20fgh	1.56abcde	1.29bc
1983	FC2S	1.23efg	1.41ef	1.36abcd	1.66bcde	1.13de	1.28bc
1983	HM2S	1.22efg	1.64cdef	1.35abcd	1.46defg	1.27cde	1.43abc
1984	Ctrl	1.00g	1.00g	1.00cd	1.00h	1.00e	1.00c
1984	CC1	1.31cdef	1.59cdef	1.26abcd	1.52cdefg	1.13de	1.27bc
1984	CC2	1.58abc	1.91abcd	1.47abcd	2.04ab	1.42bcde	1.59ab
1984	FC1	1.55abcd	1.90abcd	1.50abc	1.92abc	1.31cde	1.51abc
1984	FC2	1.62ab	2.00abc	1.53ab	2.13a	1.45bcde	1.59ab
1984	HM1	1.32cdef	1.76bcde	1.29abcd	1.40defg	1.33bcde	1.38abc
1984	HM2	1.69a	2.28a	1.73a	1.91abc	1.74abcd	1.89a
1984	U1	1.32cdef	1.44ef	1.30abcd	1.24fgh	1.30cde	1.35abc
1984	U2	1.37bcde	1.77bcdef	1.29abcd	1.36efgh	1.76abcd	1.45abc
1984	U3	1.27defg	1.57cdef	1.29abcd	1.35efgh	1.35bcde	1.22bc
1984	FC2S	1.56abcd	1.83bcde	1.58ab	2.11a	1.39bcde	1.67ab
1984	HM2S	1.67a	2.10ab	1.72a	2.02ab	2.14a	1.69ab
F		5.02**	5.00**	1.92*	8.37**	2.23**	1.83*
CV (%)		13.5	16.3	22.3	15.4	28.0	22.3

1) means in the same column followed various letters are significantly different at the level of 0.05 by Duncan's Multiple Range Test.

* : significant at the level of 0.05.

** : significant at the level of 0.01.

Table 3.11 Combined effect of manures and urea effect coefficients of dry matter yield (DMY) and uptake of nutrients in 1983 and 1984[1]

Parameter	Effect coefficient 1983	Effect coefficient 1984	F values	CV (%)
		Chicot soil		
DMY	1.18 b[2]	1.29 a	14.28**	11.5
N	1.26 b	1.53 a	36.45**	15.2
P	1.12 b	1.35 a	20.66**	20.0
K	1.27	1.35	1.75	22.5
Ca	1.09 b	1.38 a	9.45**	37.6
Mg	1.05 b	1.28 a	18.57**	21.8
		St Benoit Soil		
DMY	1.22 b	1.44 a	35.32**	13.7
N	1.51 b	1.76 a	21.32**	16.4
P	1.31	1.41	2.58	22.2
K	1.48 b	1.67 a	13.78**	15.8
Ca	1.43	1.44	0.03	28.7
Mg	1.40	1.47	0.99	21.9

1) means are expressed by effect coefficient of treatments.

2) means on the same row followed by different letters are significantly different by Duncan's Multiple Range Test at the level of 0.05.

** : significant at the lelvel of 0.01.

The ECT of N uptake by corn from the Chicot soil in 1983 was 1.26 which was significantly exceeded by that in 1984 with the value of 1.53 (Table 3.11). Similarly, on the Chicot soil, cumulative effects of treatments were also reflected by larger ECT values in 1984 compared to 1983 for P, Ca, and Mg uptake. No significant cumulative effect was detected with K uptake, although a slightly larger ECT was noted in 1984, compared with that in 1983. On the St Benoit soil, significantly larger ECTs of N and K uptake were associated with 1984 in the two years. Slightly higher ECTs of P, Ca and Mg uptake were observed in 1984, compared with those in 1983 (Table 3.11).

Table 3.12 shows the various effect coefficients of manure and urea for DMY and nutrient uptake. On the Chicot soil, effect coefficients of manures were not different from those of urea for DMY and uptake of K and Ca. The ECT value for manure was larger than that of urea for P uptake while the reverse was true for Mg uptake. On the St Benoit soil, manure generally had significantly higher effect coefficients for DMY and uptake of N, P and K, The differences of effect coefficients between manure and urea for uptakes of Ca and Mg were not pronounced.

Comparisons of ECT values among the manures indicated that the manures had significant cumulative effects (as noted by greater ECT values in 1984 compared with 1983) on DMY, N, P and Mg uptake on the Chicot soil, and on DMY and N uptake on the St Benoit soil (Tables 3.13 and 3.14). On the Chicot soil, the differences of ECTs between 1984 and 1983 were 0.12, 0.30, 0.30 and 0.22 for DMY, N, P, Mg uptake, respectively, and on the St Benoit soil, the differences were 0.20 for

Table 3.12 Effect of manure or urea on the effect coefficeints of dry matter yield (DMY) and uptake of nutrients in 1983 and 1984[1]

	Effect coefficient					
Parameter	1983		1984		F values	CV (%)
	Manure	Urea	Manure	Urea		
Chicot soil						
DMY	1.19 c[2]	1.24 bc	1.31 ab	1.36 a	4.29**	12.2
N	1.24 c	1.41 bc	1.52 bc	1.71 a	10.51**	17.6
P	1.13 b	1.07 b	1.43 a	1.24 b	7.35**	20.7
K	1.32	1.18	1.41	1.28	1.63	22.9
Ca	1.09 b	1.14 b	1.36 ab	1.60 a	3.33*	38.8
Mg	1.02 c	1.10 bc	1.24 b	1.48 a	8.30**	23.1
St Benoit Soil						
DMY	1.30 b	1.11 c	1.51 a	1.32 b	12.32**	14.4
N	1.61 b	1.46 b	1.91 a	1.59 b	8.36**	16.9
P	1.46 a	1.11 b	1.46 a	1.29 ab	4.84**	21.7
K	1.68 a	1.18 b	1.82 a	1.32 b	17.75**	18.1
Ca	1.51	1.57	1.40	1.47	0.45	30.8
Mg	1.52	1.34	1.54	1.34	1.63	23.0

1) means are expressed by effect coefficient of treatments.

2) means on the same row followed by different letters are significantly different by Duncan's Multiple Range Test at the level of 0.05.

* : significant at the level of 0.05.

** : significant at the lelvel of 0.01.

Table 3.13 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) and the effect coefficients of manures on dry matter yield (DMY) and uptake of nutrients by corn from Chicot soil[1]

		Uptake				
Main effect	DMY	N	P	K	Ca	Mg
	probability					
YR	0.0053	0.0001	0.0009	0.2502	0.0692	0.0020
CFH	0.1544	0.0085	0.9680	0.2484	0.1290	0.0128
NR	0.1336	0.0521	0.1867	0.1474	0.1980	0.1212
CV (%)	11.7	14.9	21.8	21.2	40.0	20.7
	effect coefficients of manures					
1983	1.19 b	1.24 b	1.13 b	1.32	1.09	1.02 b[2]
1984	1.31 a	1.54 a	1.43 a	1.41	1.36	1.24 a
CC	1.28	1.40 ab	1.29	1.46	1.27	1.14 ab
FC	1.19	1.26 b	1.29	1.28	1.03	0.99 b
HM	1.28	1.51 a	1.27	1.35	1.38	1.25 a
N120	1.22	1.32 b	1.23	1.30	1.13	1.08
N240	1.28	1.45 a	1.34	1.43	1.32	1.18

1) means are expressed as the effect coefficients of manures.
2) means followed by different letters within the same block are significantly different by Duncan's Multiple Range Test at the level of 0.05.

Table 3.14 Probability associated with the main effect of manures (CFH) and nitrogen rate (NR) on the effect coefficients of manures of dry matter yield (DMY) and uptake of nutrients by corn from St Benoit soil[1]

Main effect	DMY	Uptake				
		N	P	K	Ca	Mg
	probability					
YR	0.0010	0.0010	0.9519	0.0862	0.3440	0.8205
CFH	0.5560	0.2449	0.9140	0.0082	0.0287	0.2374
NR	0.0041	0.0170	0.2903	0.0010	0.0300	0.0471
CV (%)	14.0	16.2	23.4	15.8	27.0	19.9
	effect coefficient of manures					
1983	1.31 b[2]	1.61 b	1.46	1.68	1.40	1.52
1984	1.51 a	1.91 a	1.46	1.82	1.51	1.54
CC	1.38	1.68	1.48	1.71 b	1.39 b	1.48
FC	1.45	1.75	1.48	1.93 a	1.30 b	1.47
HM	1.39	1.85	1.43	1.61 b	1.67 a	1.64
N120	1.32 b	1.66 b	1.41	1.61 b	1.32 b	1.44 b
N240	1.50 a	1.86 a	1.51	1.89 a	1.59 a	1.62 a

1) means are expressed as the effect coefficients of manures.
2) means followed by different letters within the same block are significantly different by Duncan's Multiple Range Test at the level of 0.05.

dry matter yield, and 0.36 for N uptake.

3.4 DISCUSSION

3.4.1 Corn ear leaf composition

The significant correlations between DMY and N of corn ear leaves on the Chicot soil, and P content of corn ear leaves on both the Chicot and the St Benoit soil probably mean that N and P were deficient although this deficiency could not be determined in the case of P (Tyner, 1946; Krantz and Chandler, 1951; Bennett et al. 1953; Viets et al. 1954).

On the Chicot soil, corn ear leaves had a range of N content from 2.38 to 2.94% which showed "sufficient" or "high" N levels according to the classification system of Jones (1967). However, these values were somewhat below the critical level of 2.9% found by Tyner (1946). P, K, Ca and Mg contents of ear leaves were all above the critical levels proposed by Tyner (1946) and Melsted et al.(1969); indicating the soil was probably not deficient in these elements.

Treatment effects on ear leaf composition were not consistent between soils. On the St Benoit soil, N applications did not affect N contents of ear leaves, most likely because the soil had high extractable NH_4- and NO_3-N before silking (Chapter 2), indicating that N levels of the soil were not a limiting factor for corn production.

The non-significant treatment effect on the Ca content of the ear leaf on both the Chicot soil and St Benoit soil could have been due to the high Ca contents in the soils, 2860 and 2283 kg exchangeable Ca/ha for the Chicot and the St Benoit soils respectively. The Ca applied from the manures, ranging from 130 to 380 kg/ha, was only a small fraction of the Ca contained in the soil and was considerably higher than that removed by the corn crop (data were not presented here). Mg contents of ear leaves on the St Benoit soil below the proposed critical level (Melsted et al. 1969) could be due to low available Mg of the soil and the low Mg added from the manures (21-68 kg/ha) although the initial extractable Mg levels of the soil was reasonably high (290 kg/ha).

3.4.2 N uptake and corn dry-matter yields

N uptake by corn exceeded the applied N in the plots with lower N application rates. In the long term, this could lead to a decrease in N uptake and crop yields. Thus in order to avoid the appearance of N deficiency, moderately higher N application rates should be recommended.

Increased corn yields and N uptake by manure applications have been reported by Dilz et al. (1984) from the Netherlands, Lembke and Thorne (1980) from Illinois, and Evans et al. (1977) from Minnesota, and by the others (Cope et al. 1958, Dubetz et al. 1975, and Sugihara et al. 1979). In this research, manure applications enhanced both DMY and N uptake by corn on both soils. The treatment effects of manures on the St Benoit soil were more significant than those on the Chicot soil, probably due to the reduced available N in the Chicot soil and improved moisture supplement in the St Benoit soil (Chapter 2).

Different manures (CC, FC, HM) had similar effects on DMY, which was similar to previous findings (Miller and MacKenzie 1978), or on N uptake. Increased manure N application rates, however, improved DMY and N uptake, especially on the St Benoit soil, where higher manure application rates, compared with the lower application rates, resulted in an increase of 20% in DMY, and an increase of 17% in N uptake, suggesting manures were more effective for corn production on the St Benoit soil, which was a coarser textured soil with lower pH values and lower available P and K than the Chicot soil.

Although DMY increased with increasing rates of manure application, high application rates could have resulted in an imbalance of nutrients and more N losses (Lauer et al. 1976; Sugihara et al. 1979; Phillips et al. 1981). Mathers and Stewart (1981) found that the most efficient manure rate was 22 tonnes/ha incorporated immediately into the soil after spreading. In the experiment reported here the manure application rates ranged from 5 to 12 tonnes/ha on a dry weight base and little danger of unbalanced nutrient supplement was shown. With respect to DMY, the optimum rate of N application was 120-240 kg N/ha for manure-N, and 0-60 kg N/ha for urea-N.

3.4.3 Cumulative effects

The experiment showed that ECT in 1984 compared with 1983 was larger with the coarser textured soil than with the finer textured soil. This greater cumulative effect could be due to greater improvement in plant nutrient levels, such as available N levels (Chapter 2), or in physical properties or chemical properties of the coarser textured soils compared to those of the finer textured soil (Olsen et al. 1970; Dubetz et al. 1975; Mazurak et al. 1977; Meek et al. 1979; Chandra and De 1982).

Some work has been published on manure cumulative effects on corn yields (Cope et al. 1958; Evans et al. 1977; Kiver and Kiver 1976; Turchin et al. 1972). By analyzing the published data of Dubetz et al. (1975), it was found, in the short term, that treatments of manure plus inorganic N had the highest cumulative effect on corn grain yields, inorganic N had the medium effect, and manure the lowest effect. The differences in cumulative effects among manures were not obvious, based on the data of Evans et al. (1977), and the results of this experiment reported here provide further evidence of similarity among the manures applied on the both soils as to yield increases, and in addition, it was shown that manure had larger ECT values than urea on the coarse textured soil, compared with the fine textured soil.

3.5 CONCLUSIONS

Significant positive correlations existed between DMY and N or P contents of corn ear leaves, indicating soil deficiencies in N and possibly P.

No difference was found due to manure spreading techniques, perhaps due to compensating effects of increased N volatilization and of improved soil moisture levels with surface applied manures.

Dry matter yields were unaffected by different manures. Hog manure was more effective in supplying corn with N than cow manure (CC, FC). This may have related to the higher moisture content of HM, and thus more efficient penetration of inorganic N compounds into the soil.

Higher manure application rates increased DMY and N uptake.

Cumulative effects of manure or urea on yields were more pronounced with the coarser textured soil than with the finer textured soil. On the coarser textured soil, larger ECT values were noted with manure compared with urea for DMY, and uptakes of N, P and K. This may have been a result of the improved P and K supplements with manure, and the longer term effects of organic N found with manures.

GENERAL CONCLUSIONS

Cow manures (CC, FC) showed a greater potential for conserving soil water than liquid hog manure or urea.

In the short-term, soil organic matter content and soil bulk densities at the depth of 5-13 cm were not significantly affected by the manure or urea applications.

Manures applied at 240 kg N/ha had less potential for polluting groundwater than urea applied at 180 kg N/ha. Among the manures, liquid hog manure accumulated more NO_3-N in the soil profiles than FC or CC manure. Coarse textured soil had a higher NO_3-N content, probably due to the rapid decomposition and nitrification of applied N in manures and urea than fine textured soil.

Optimum N application rates were 60 kg N/ha for urea-N, and 120-240 kg N/ha for manure-N. Thus 1 kg of urea-N was approximately equal to 2 to 4 kg of manure-N.

Manure application may have to be accompanied with application of certain nutrients, such as Mg.

Liquid hog manure was slightly more effective in increasing corn silage yields than semi-solid cow manures.

Both manures and urea had a cumulative effect on corn dry matter yields and nutrient uptake. The cumulative effect associated with coarse textured soil was larger than that with fine textured soil, and larger effect coefficients were noted with manure on the coarse textured soil, compared with urea, perhaps due to the greater improvement of the soil water and available N, and possibly other nutrient supplements such as P or K.

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