USE OF NBPT-DCD FORMULATED UREA TO REDUCE N_2O EMISSIONS AND N LOSSES FROM FALL BANDED FERTILIZER

by

ERYN WILLIAMSON

A Thesis

Submitted to the Faculty of Graduate Studies of

The University of Manitoba

in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

Department of Soil Science

University of Manitoba

Winnipeg, Manitoba

ABSTRACT

A two-year field study and two incubation studies were conducted to evaluate incorporating urea with a urease and nitrification inhibitor to reduce N_2O and N losses from fall banded fertilizer. In each year of the field experiment, five fertilizer treatments (fall banded NBPT-DCD urea, conventional urea, calcium nitrate, spring banded conventional urea and control) were applied at three sites. The effect of incorporating urease and nitrification inhibitors with urea was not consistent in our studies. The application of fall banded NBPT and DCD did not result in greater agronomic performance. Moreover, the addition of inhibitors to urea did not reduce nitrous oxide emissions in the field. The addition of inhibitors resulted in significantly less cumulative nitrous oxide emissions compared to conventional urea in only one of two laboratory experiments. In conditions where fertilizer was not generally susceptible to large losses, the effects of urease and nitrification inhibitors may not be evident.

ACKNOWLEDGMENTS

I would like to thank AgroEnviro Consulting Services, Agriculture and Agri-Food Canada, Cargill Ltd., Mosaic, Saskferco, Western Co-operative Fertilizers Limited, and Agrotain International for the generous financial support to make this project possible.

I am grateful to my advisory committee, Dr. Don Flaten, Mario Tenuta, and Kim Ominski, for the opportunity to work with them as a graduate student. I would like to sincerely thank my advisor, Dr. Don Flaten, for most of all your patience and understanding during the long and often challenging past years.

Thank you to Dr. Cindy Grant and Guy Lafond for the technical support. Thank you to Vern Klassen, Manitoba Zero Tillage Farmers Association, and Jim Halford for generously providing land for the field experiment. To Dale Boskwick, Dana Rankin, and Harmony Koiter, thank you for the hours spent collecting soil and nitrous oxide samples. I could not have completed this project without your hard work. I also cannot thank Dr. Darshani Kumaragamage enough for all the support, both technical and personal. Your encouragement, especially during my first year, is truly appreciated.

Finally, thank you to my friends and family for your unwavering support throughout these past years. In particular, I would like to thank my father for the many hours spent helping me in the field, the late nights analyzing data, and most of all, the dinnertime conversation about nitrous oxide emissions and urease and nitrification inhibitors. Your encouragement and willingness to listen to my ideas helped me tremendously throughout the years. I am also incredibly grateful for the support of my husband. Thank you for everything from collecting soil samples early Saturday mornings to your continual motivation. I could not have completed this project without your love and support.

FOREWORD

This thesis has been prepared in the manuscript format in adherence with the guidelines established by the Department of Soil Science at the University of Manitoba. Chapters were written in manuscript style following the format of the "Canadian Journal of Soil Science".

The field experiment was established in the fall of 2005 under the charge of Dr. Darshani Kumaragamage. All field measurements collected at the Oak Bluff site from the fall of 2005 to April 2006 were analyzed by Dr. Kumaragamage. The field sites located at the Manitoba Zero-Till Research Associated Farm and the Halford Farm were established and field measurements collected under the supervision of Drs. Cindy Grant and Guy Lafonde, respectively.

The laboratory experiment A was established by Dale Boskwick as an Agroecology research project. Dale completed the experiment set-up and nitrous oxide monitoring for the first 28 days of the experiment.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

1.0 INTRODUCTION

Nitrogen is the most limiting macronutrient for crops, and the ability to support a crop's N requirements is facilitated by industrial nitrogen fixation, a process central to synthetic fertilizer production. The granular form of urea is the major type of synthetic nitrogen fertilizer used worldwide (Yeomans 1991). In the Canadian context, it is also the form most commonly used in Western Canada (Agriculture and Agri-Food Canada 2004). The high N content, coupled with the ease in which it can be stored and transported as well as its low corrosive properties, has resulted in increased use (Yeomans 1991). In the western Canadian Prairies, urea fertilizer is commonly applied in the fall rather than the spring in order to balance the annual workload, reduce seedbed disturbance by reducing spring tillage, and to take advantage of lower cost fertilizer. Fertilizer applied in the fall, however, is generally less efficient compared to fertilizer applied in the spring (Aulakh and Rennie 1984; Malhi and Nyborg 1990a; Malhi and Nyborg 1992b). There is a risk of loss through immobilization, leaching, and denitrification over winter and during the spring thaw period following application of nitrate and nitrate forming fertilizers, such as urea, in the fall (Aulakh and Rennie 1984).

Once applied to the soil, urea is quickly hydrolyzed to ammonium (NH_4^+) and carbamate (NH_2COOH) by urease, an enzyme commonly found in soil. Urease is found both free and bound to soil colloids and is remarkably stable in conditions not conducive for most free enzymes. This is suggested to be the result of its adsorption onto clay colloids and immobilization within organic matter (Pettit et al. 1976). Urease activity is highest in moist soil and activity decreases as soil moisture contents reach wilting point (Sommer et al. 2004). Urea hydrolysis follows Michaelis-Menten kinetics as urease activity increases with increasing urea concentration to a point of saturation (Sommer et al. 2004). Urease activity also increases with increasing temperature, and can be described by the Arrhenius equation and corresponds to a Q_{10} value of approximately 2 (Moyo et al. 1989).

Following urea hydrolysis, NH_4^+ is oxidized to nitrate (NO_3^-) during a two-step nitrification process where NH_4^+ is oxidized to nitrite (NO_2^-) then further oxidation produces nitrate (Bremner 1997) as microorganisms derive energy needed for metabolic activities. In soils, chemoautotrophic microorganisms such as *Nitrosomonas spp., Nitrosospira spp.* are believed to be predominantly responsible for the oxidation of ammonium to nitrite (Blackmer et al. 1980). Chemoautotrophic bacteria belonging to the genus *Nitrobacter* sp. are largely responsible for the oxidation of NO_2^- to NO_3^- (Bremner 1997).

Fall application prolongs the period in which fertilizer is subject to transformation prior to plant uptake which can result in considerable losses compared to spring application when fertilizer is applied closer to when it is utilized by the plant. Hydrolysis and nitrification are reduced at lower temperatures (Aulakh and Rennie 1984; Moyo et al. 1989); however, soil microorganism activity continues at lower temperatures due to the adaptation to local environments (Pelletier et al. 1999), which can result in nitrification of urea in the fall and over winter. Urease was still active at -5ºC in chernozemic and luvisolic soils in a laboratory study (Monreal et al. 1986). Delaying fertilizer application to later in the fall has also been shown to increase yield and the percent of fertilizer recovered (Malhi and Nyborg 1990a; Tiessen et al. 2005).

Sub-surface banding has consistently increased fertilizer efficiency compared to broadcast or incorporated fertilizer (Malhi and Nyborg 1984; Malhi and Nyborg 1985; Malhi and Nyborg 1988; Malhi and Nyborg 1990b; Malhi and Nyborg 1992a). Band application decreases fertilizer contact with the soil and, therefore, lowers contact with soil microorganisms responsible for hydrolysis and nitrification. Applying fertilizer in a band also creates a toxic environment by increasing soil pH, ammonia concentration and osmotic pressure within the urea band (Malhi and Nyborg 1984). Decreasing pH gradients can develop surrounding the band, and nitrification can be suppressed. Concentrations of NO_3^- are generally greatest at the edges and decrease inwards reflecting the changes in pH and nitrification activity (Pang et al. 1973).

Following nitrification in the fall and winter, fertilizer can be subject to loss through denitrification in the spring (Bremner 1997). Nitrous oxide (N_2O), a potent greenhouse gas, is an obligatory intermediate byproduct of the denitrification process (Bremner 1997). Denitrification occurs when oxygen is limited and is, therefore, not restricted to the spring; however, conditions are conducive during spring thaw. Substantial production of N_2O has occurred during thawing in soil. Although the top layer of soil may be thawing, soil is often frozen at depth which impedes drainage and creates water saturated conditions and anaerobic conditions at the soil surface (Nyborg et al. 1997). Nitrous oxide may also be physically released during the thawing process as trapped gas is released (Burton and Beauchamp 1994). Organic matter may also become available for denitrification when subjecting microbes to freezing and thawing (Wagner-Riddle and Thurtell 1998; Christenson and Tiedje 1990). The ratio of N_2O:N_2 from biological denitrification has also increased with decreasing soil temperatures resulting in increased production of N_2O at thaw (Tenuta and Sparling 2011). Denitrification during spring is considered to be a dominant process in N loss of fall-applied fertilizer (Malhi and Nyborg 1985).

Nitrous oxide is also emitted during nitrification as a by-product of the oxidation of NH_4^- and NO_2^- under aerobic conditions (Blackmer et al 1980; Snyder et al. 2007). Although denitrification has generally been considered the dominant process of N_2O production, especially when fertilizer is applied in the fall, substantial N_2O emissions have evolved in aerobic conditions, suggesting that nitrification can also contribute to gaseous nitrogen loss (Blackmer et al. 1980).

Delaying the conversion of urea during the fall period can reduce losses during winter and spring thaw by lowering the amount of NO_3^- available for denitrification. Aside from methods of application that reduce transformation, such as sub-surface banding, inhibitors also have potential in slowing the transformation of urea. Urease inhibitors slow urea hydrolysis by either obstructing the activity of the urease enzyme or interfering with the metabolism of the soil microorganisms responsible for urease production (Yeomans 1991). Compounds can inhibit the activity of the urease enzyme by either forming bonds with atoms at the active sites or through competition with urea for active sites on the urease enzyme (Yeomans 1991). Delaying hydrolysis can reduce ammonia volatilization from surface applied fertilizer as well as reduce seedling toxicity when fertilizer is applied with the seed by lowering the concentration of NH_3 at the point of application as there is opportunity for the source to infiltrate the soil, whether at depth into the soil or away from the seed (Rawluk et al. 2001). Of the many urease inhibitors, N-(n-butyl) thiophosphoric triamide (NBPT) has been effective at reducing NH_3

volatilization and seedling toxicity by inhibiting the conversion of urea to ammonium by competing with urea for active sites on the urease enzyme complex (Yeomans 1991).

Nitrification inhibitors also reduce transformation of urea fertilizer, and they have reduced nitrous oxide emissions from fertilizer (Amberger 1989). Nitrification inhibitors interfere with the transformation of NH_4^+ to NO_3^- through several mechanisms. Compounds can inhibit nitrification by creating unfavourable environmental conditions or by stimulating the growth of microorganisms that compete with those responsible for nitrification. Nitrification can be further inhibited by compounds that interfere with NH_3, hydroxylamine, and nitrite oxidation (Hauck 1980). The nitrification inhibitor dicyandiamide (DCD) slows the conversion of ammonium to nitrate by inhibiting the first stage of nitrification, the oxidation of ammonium to nitrite (Amberger 1989). Apparent nitrification of urea granules containing 50 and 100 g DCD kg^{-1} was reduced 23 and 41 % respectively in comparison with urea where no DCD was added (Singh and Beauchamp 1987).

Nitrogen is vulnerable to loss as ammonia when fertilizer is applied close to the soil surface and reducing soil air interaction by applying fertilizer at depth reduces volatilization. Conditions which promote rapid transformation yet restrict fertilizer movement into the soil, such as increased evaporation through high wind and temperatures and low moisture, increase potential losses (Malhi et al. 2001; Rawluk et al. 2001). Higher moisture contents provide increased surface area for NH_3 adsorption and increases the rate of nitrification resulting in reduced volatilization (Prasad 1976). Ammonia volatilization is nearly eliminated by sub-surface application, as this reduces fertilizer and atmosphere interaction. Banding urea increased N recovery in bromegrass compared to application via broadcast due to reduced volatilization (Malhi et al. 1995).

In summary, delaying the transformation of urea applied in the fall by sub-surface banding and incorporating inhibitors can reduce the concentration of NO_3^- in the soil over winter and during spring, thus reducing loss due to denitrification events during spring thaw. The current study was a two year field trial which built on previous work that measured a reduction in nitrate concentrations and increased nitrogen use efficiency with the use of the urease inhibitor NBPT and nitrification inhibitor DCD when urea was banded in the fall (Tiessen et al. 2005). The main objectives of this project were to measure N_2O emissions as well as the efficiency of N fertilizer use and crop yield of a spring annual crop to determine the potential of a urea incorporated with a double inhibitor to reduce N_2O emissions and increase fertilizer efficiency when applied in the fall. Two incubation studies simulating fall fertilization were also conducted to measure the effect of soil moisture content and type of nitrogen fertilizer on N_2O emissions.

1.1 References

Agriculture and Agri-Foods Canada. 2004. Fertilizer and pesticide management in Canada.

Amberger, A. 1989. Research on dicyandiamide as a nitrification inhibitor and future outlook. Commun. in Soil Sci. Plant. Anal. **20**: 1933-1955.

Aulakh, M.S. and Rennie, D. A. 1984. Transformations of fall-applied nitrogen-15-labelled fertilizers. Soil Sci. Am. J. **48**: 1184-1189.

Blackmer, A. M., Bremner, J. M. and Schmidtz, E. L. 1980. Production of nitrous oxide by ammonia-oxidizing chemoautotrophic microorganisms in soil. Appl. Environ. Microbiol. **40**: 1060-1066.

Bremner, J. M. 1997. Sources of nitrous oxide in soils. Nutr. Cycling Agroecosyst. **49**: 7-16.

Hauck, R. D. 1980. Mode of action of nitrification inhibitors. Pages 19-32 *in* Nitrification inhibitors-potentials and limitations. Amer.Soc.Agron. Special Publication 38.

Malhi, S. S. and Nyborg, M. 1979. Nitrate formation during winter from fall-applied urea. Soil Biol. Biochem. **11**: 439-441.

Malhi, S. S. and Nyborg, M. 1984. Inhibiting nitrification and increasing yield of barley by band placement of thiourea with fall-applied urea. Plant Soil. **77**: 193-206.

Malhi, S. S. and Nyborg, M. 1985. Methods of placement for increasing the efficiency of n fertilizers applied in the fall. Agron. J. **77**: 27-32.

Malhi, S. S. and Nyborg, M. 1988. Control of nitrification of fertilizer nitrogen: effect of inhibitors, banding and nesting. Plant Soil **107**: 245-250.

Malhi, S. S. and Nyborg, M. 1990a. Efficiency of fall-applied urea for barley: influence of date of application. Fert. Res. **22**: 141-145.

Malhi, S. S. and Nyborg, M. 1990b. Evaluation of methods of placement for fall-applied urea under zero-tillage. Soil TillageRes. **15**:383-389.

Malhi, S. S. and Nyborg, M. 1992a. Placement of urea fertilizer under zero and conventional tillage for barley. Soil TillageRes. **23**: 193-197.

Malhi, S. S. and Nyborg, M. 1992b. Recovery of nitrogen by spring barley from ammonium nitrate, urea and sulphur-coated urea as affected by time and method of application. Fert. Res. **32**: 19-25.

Malhi, S. S., Nyborg, M. and Harapiak, J . T. 1995. Recovery of ^{15}N-labelled fertilizers applied to bromegrass on a thin black chernozem soil. Can. J. Soil Sci. **75**: 539-542.

Malhi, S.S., Grant, C. A., Johnston, A. M. and Gill K. S. 2001. Nitrogen fertilization management for no-till cereal production in the Canadian Great Plains: a review. Soil TillageRes **60**: 101-122.

Malhi, S.S., Oliver, E., Mayerle, G., Kruger, G. and Gill, K.S. 2003. Improving Effectiveness of Seedrow-Placed Urea with Urease Inhibitor and Polymer Coating for Durum Wheat and Canola. Commun. In Soil Sci. Plant. Anal. **34**: 1709-1727.

Monreal, C., McGill, W. B. and Nyborg, M. 1986. Spatial heterogeneity of substrates: effects on hydrolysis, immobilization and nitrification of urea-N. Can. J. Soil Sci. **66**: 499-511.

Moyo, C. C., Kissel, D. E. and Cabrera, M.L. 1989. Temperature effects on soil urease activity. Soil Bio. Biochem. **21:** 935-938.

Nyborg, M., Laidlaw, J. W., Solberg, E. D., and Malhi, S. S. 1997. Denitrification and nitrous oxide emissions from a black chernozemic soils during spring thaw in Alberta. Can. J. Soil Sci. **77**: 153-160.

Pang, P. C., Hedlin, R. A. and Cho, C.M. 1973. Transformation and movement of band-applied urea, ammonium sulfate and ammonium hydroxide during incubation in several Manitoba soils. Can. J. Soil Sci. **53**: 331-341.

Pelletier, F., Prévost, D., Laliberté, G. and van Bochove, E. 1999. Seasonal response of denitrifiers to temperature in a Quebec cropped soil. Can. J. Soil Sci. **79**: 551-556.

Pettit, N. M., Smith, R. J., Freedman, R. B. and Burns, R. G. 1976. Soil urease: activity, stability and kinetic properties. Soil Bio. Biochem. **8**: 479-484.

Prasad, M. 1976. Gaseous loss of ammonia from sulfur-coated urea, ammonium sulfate, and urea applied to calcareous soil (pH 7.3). Soil Sci. Soc. Am. J. **40**: 130-134.

Rawluk, C. D. L., Grant, C. A. and Racz, G., J. 2001. Ammonia volatilization from soils fertilized with urea and varying rate of urease inhibitor NBPT. Can. J. Soil Sci. **81**: 239-246.

Sommer, S. G., Schjoerring, J. K. and Denmear, O. T. 2004. Ammonia emission from mineral fertilizers and fertilized crops. Adv. Agron. **82**: 558-622.

Tenuta, M. and Sparling, B. 2011. A laboratory study of soil conditions affecting emissions of nitrous oxide from packed cores subjected to freezing and thawing. Can J. Soil Sci. **91**: 223-233.

Tiessen, K. H. D., Flaten, D. N., Grant, C. A., Karamanos, R. E. and Entz, M. H. 2005. Efficiency of fall-banded urea for spring wheat production in Manitoba: influence of application date, landscape position and fertilizer additives. Can J. Soil Sci. **85**: 649-666.

Wagner-Riddle, C. and Thurtell, G. W. 1998. Nitrous oxide emissions from agricultural fields during winter and spring thaw as affected by management practices. Nutr. Cycling Agroecosyst **52**: 151-163.

Yeomans, J. C. 1991. Inhibition of nitrogen transformations in soil: Potentials and limitations for agriculture. Trends in Soil Sci. **1**: 127-158.

2.0 EFFECT OF NITROGEN FERTILIZER INHIBITORS AND TIMING OF APPLICATION ON FERTILIZER USE EFFICIENCY

2.1 Abstract

A two year field study was conducted to evaluate incorporating urea with a urease and nitrification inhibitor to reduce N losses from fall banded fertilizer. Four replicates of five treatments were applied at each site in a randomized complete block design. Treatments consisted of nitrogen fertilizer applied as fall banded NBPT-DCD formulated urea (SuperU®), fall banded conventional urea, fall banded calcium nitrate, and spring banded conventional urea and a control where no nitrogen fertilizer was added. After fertilizer application, ammonia volatilization from the fall banded treatments and the control was monitored until four weeks after application. Grain and straw yields were calculated at midseason and physiological maturity. Total N uptake and fertilizer nitrogen use efficiency were determined from plant samples collected at midseason and maturity. Ammonium-N and nitrate plus nitrite-N were measured in soil throughout the sampling period. In our study, agronomic performance of spring wheat was generally not affected by timing of urea application and the use of inhibitors. The fall banded urea treatments produced similar yields and nitrogen content as the spring banded conventional urea at all site years except for Oak Bluff 2006/07, demonstrating little loss of fall-applied fertilizer at most sites.

2.2 Introduction

To overcome time and cost constraints and to maintain spring seedbed quality, nitrogen fertilizer is often applied in the fall rather than spring in the western Canadian prairies (Aulakh and Rennie 1984; Malhi and Nyborg 1990). Fall fertilization, however, often results in inferior performance compared to when applied in the spring due to immobilization and over-winter losses of N (Malhi and Nyborg 1979; Malhi and Nyborg 1990). Although not a loss from the soil system, immobilization of fertilizer following application in the fall can lower the efficiency of fertilizer during the following growing season. A field study in Saskatchewan found up to 20% of fall applied nitrogen fertilizer was immobilized by the following spring (Aulakh and Rennie 1986). Fertilizer is also much more vulnerable to losses through leaching and denitrification following nitrification. Therefore, considerable losses from fall applied urea can occur when fertilizer is subject to nitrification during the fall period prior to plant uptake (Malhi and Nyborg 1990). For example, only 51 to 54% of fall applied fertilizer N was found as mineral N at time of seeding on stubble fields and 61% on fallow fields in Saskatchewan demonstrating that immobilization and/or denitrification were dominant processes reducing fertilizer efficiency (Aulakh and Rennie 1984). Malhi and Nyborg (1990) found increased recovery of mineral N in soil when fertilizer was applied later in the fall period suggesting that immobilization and N losses decrease when fertilizer is applied closer to soil freezing and plant uptake.

Urea is the most common form of synthetic nitrogen fertilizer applied in western Canada (Agriculture and Agri-Food Canada 2004). Upon application, urea is quickly hydrolyzed to ammonia and carbon dioxide by the urease enzyme. Ammonia is vulnerable to volatilization and loss depends on the rate and method of application, with higher rates and methods of application exposing fertilizer to the atmosphere, resulting in increased loss (Fenn and Hossner 1985). Ammonia volatilization is generally less from fine-textured soils than coarse-textured soils, as fine-textured soils have greater ability to retain added ammonium from the soil solution (Malhi et al. 2001). The risk of volatilization is greater in high pH soils and soils with low buffering capacity due to the limited supply of hydrogen ion and, therefore, the lower proportion of fertilizer found in the more stable ammonium form (Fenn and Hossner 1985). Banding fertilizer below the surface significantly reduces ammonia volatilization by reducing fertilizer contact with the atmosphere.

Following urea hydrolysis, ammonia is oxidized to nitrate during the nitrification process. Fall fertilization increases the time during which fertilizer is subject to transformation, and, therefore, potential loss prior to plant uptake. Significant losses can occur during the early spring as conditions are often favourable for the reduction of nitrate formed during the previous fall, with denitrification during spring considered to be the dominant process in N loss of fall-applied fertilizer (Malhi and Nyborg 1985). Fall fertilizer application often results in lower yields and nitrogen content of the agricultural crop compared to spring-applied (Malhi and Nyborg 1984). Experiments conducted in Alberta demonstrated that fall banded urea produced lower grain yields than spring banded urea at eight of ten locations and lower N uptake at all locations due to nitrification in the fall and denitrification during the wet period during spring thaw (Malhi and Nyborg 1984).

Urease and nitrification inhibitors slow the transformation of fertilizer and can increase grain yield and nitrogen uptake through reducing fertilizer loss. For example, n-butyl thiophosphoric triamide (NBPT), a urease inhibitor, slows hydrolysis by competing with urease enzymes for active sites on the urease enzyme complex (Yeomans 1991). The addition of NBPT significantly reduces ammonia volatilization from surface applied urea (Rawluk et al. 2001). Dicyandiamide (DCD), a nitrification inhibitor, slows the conversion of ammonium to nitrate by inhibiting the first stage of nitrification, the oxidation of ammonium to nitrite (Amberger 1989). As a result, adding nitrification inhibitors with fall applied urea has increased grain yield and nitrogen uptake. In southern Ontario, incorporation of DCD into 2-g urea granules applied in the fall increased winter wheat grain yield over that without DCD, and grain yields were similar to those obtained when the crop was fertilized in the spring (Yadvinder-Singh and Beauchamp 1988). In another study, the addition of the fertilizer additives NBPT and DCD reduced nitrification of fall banded urea (Tiessen et al. 2006). Grain yield and N uptake were, however, similar from the fall banded urea treatments with and without inhibitors at three of four sites (Tiessen et al. 2005). The present field study builds upon previous studies examining the use of the urease and nitrification inhibitors NBPT and DCD on soil transformations and yield and nitrogen uptake of a spring annual crop. In addition, this study also formed the basis for investigating the use of a double inhibitor with banded urea to reduce ammonia volatilization and nitrous oxide emissions (please refer to Chapter 3).

2.3 Materials and Methods

2.3.1 Experimental Design and Treatments

Field sites were located near Oak Bluff, MB, at the Manitoba Zero-Till Research Association Farm near Brandon, MB, and near Indian Head, SK. Selected soil characteristics are listed in Table 2.1. Prior to plot establishment, soil samples were collected to 120 cm at Oak Bluff and Brandon and 90 cm at Indian Head for site characterization. Samples were refrigerated at 2°C, dried for a minimum of 24 hours, ground to pass through a 2 mm sieve using a high-speed soil grinding mill.

Table 2.1. Selected properties of soils at research sites.

Characteristics	Depth (cm)	Oak Bluff	Oak Bluff	Brandon	Brandon	Indian Head	Indian Head
		Fall 2005	Fall 2006	Fall 2005	Fall 2006	Fall 2005	Fall 2006
Soil Series		Red River - Osborne Clay	Red River - Osborne Clay	Newdale Clay Loam	Newdale Clay Loam	Oxbow Loam	Oxbow Loam
Soil texture	0-15	clay	clay	clay loam	clay loam	loam	loam
pH	0-15	7.6	8.2	7.3	6.7	7.0	7.2
Organic Matter (g kg^{-1})	0-15	52.3	33.0	47.0	50.0	19.0	22.0
Water soluble NO_3 - N (kg ha^{-1})^z	0-60	30.0	37.0	10.0	52.0	6.0	16.0
Water soluble SO_4 - S (kg ha^{-1})^z	0-60	50.0	160+	160+	160+	30.0	44.0
Olsen Extractable P (kg ha^{-1})^z	0-15	29.0	6.3	19.0	42.0	26.0	14.0

^{Z} Assumed bulk density of 1.33 g cm^{-3}.

Four replicates of five treatments were applied at each site in a randomized complete block design. Treatments consisted of nitrogen fertilizer applied as fall banded NBPT-DCD formulated urea (SuperU®), fall banded conventional urea, fall banded calcium nitrate, and spring banded conventional urea and a control where no nitrogen fertilizer was added. The fall banded calcium nitrate treatment was included as an indicator of the degree to which denitrification was the dominant process responsible for N_2O emissions. During the first year, fall treatments were applied on October 13, 2005 at Oak Bluff, October 14, 2005 at Brandon, and October 11, 2005 at Indian Head. Fertilizer was applied for the second year on October 6, 2006 at Oak Bluff, October 12, 2006 at Brandon, and October 3, 2006 at Indian Head. Fertilizer was applied at a rate of 80 kg N ha^{-1} at Oak Bluff and 60 kg N ha^{-1} at the Brandon and Indian Head sites. The spring banded conventional urea treatment was sidebanded at all sites, 2 to 5 cm beside the seed. Plots were 1.7 m wide and 5 m long at Oak Bluff, 1 m wide and 5 m long at Brandon, and 4 m wide and 11 m long at Indian Head. The fertilizer was fall or spring banded at a depth of 7.5 cm with 20 cm spacing at Oak Bluff, a depth of 5 cm with 20 cm spacing at Brandon, and a depth of 7.5 cm and 30 cm spacing at Indian Head. Following application, bands were staked to permit accurate sampling of soil and placement of ammonia monitoring chambers.

General weather conditions for Winnipeg, Brandon, and Indian Head, including mean monthly air temperatures and total monthly precipitation, were obtained from Environment Canada's archived weather data and presented in Table 2.2. In year one, precipitation was generally below average at the Oak Bluff and Indian Head sites. Precipitation was greater in year two at the Oak Bluff site compared to year one with greater precipitation during the spring period. Precipitation was near average both site years at the Brandon site.

Table 2.2. Air temperature and precipitation and Oak Bluff, Brandon, and Indian Head [z]

	Oak Bluff			Brandon			Indian Head		
	Air temperature °C								
	Average	**2005/06**	**2006/07**	**Average**	**2005/06**	**2006/07**	**Average**	**2005/06**	**2006/07**
October	5.3	6.9	3.5	4.4	5.3	2.1	4.6	4.4	1.2
November	-5.3	-2.9	-4.6	-6.1	-4.0	-1.0	-5.4	-3.8	-6.3
December	-14.4	-9.1	-9.7	-14.9	-9.5	-4.9	-13.1	-9.6	-10.2
January	-17.8	-7.4	-16.0	-18.0	-7.2	-15.1	-16.2	-6.4	-13.1
February	-13.6	-16.0	-18.8	-13.8	-14.9	-12.8	-12.3	-12.9	-17.7
March	-6.1	-6.1	-5.1	-6.4	-6.5	-5.2	-5.4	-6.5	-3.4
April	4.0	9.4	4.2	3.5	8.2	4.1	4.0	7.3	3.4
May	12.0	12.0	12.2	11.4	11.6	10.8	11.4	11.2	9.6
June	17.0	18.2	17.3	16.1	17.2	16.3	16.1	16.0	15.0
July	19.5	21.5	21.3	18.4	19.9	20.6	18.4	17.9	19.9
August	18.5	19.8	17.6	17.5	18.9	16.5	17.5	17.4	15.5
September	12.3	13.6	13.2	11.4	12.1	11.9	11.4	11.6	11.1
	Precipitation (mm)								
	Average	**2005/06**	**2006/07**	**Average**	**2005/06**	**2006/07**	**Average**	**2005/06**	**2006/07**
October	36.0	18.5	11.0	27.7	21.4	15.0	24.3	6.6	23.5
November	25.0	43.0	17.5	17.7	34.1	38.8	17.4	34.9	60.3
December	18.5	24.5	36.0	19.2	27.6	22.0	25.3	24.7	11.8
January	19.7	25.5	11.5	18.0	12.2	11.4	19.7	13.1	6.3
February	14.9	5.0	19.0	14.1	13.2	30.4	16.2	6.3	23.0
March	21.5	36.5	57.7	22.2	33.4	57.8	24.1	10.6	23.7
April	31.9	16.5	15.9	31.0	46.2	4.6	24.6	73.2	8.8
May	58.8	44.5	72.5	52.7	41.0	84.4	55.7	39.0	46.0
June	89.5	29.0	123.0	74.4	81.6	80.8	78.9	80.4	46.2
July	70.6	10.5	60.5	75.8	7.8	51.4	67.1	4.4	50.6
August	75.1	52.0	24.5	69.2	76.4	49.2	52.7	11.6	62.8
September	52.3	41.5	30.0	49.9	74.6	19.6	39.5	54.8	24.0
Total	513.8	347.0	479.1	471.9	469.5	465.4	445.5	359.6	387.0

[z] Source: nearby Environment Canada weather stations in Winnipeg, Brandon, and Indian Head www.weatheroffice.gc.ca.

2.3.2 Crop Measurements

Canadian Western Red Spring wheat (*Triticum aestivum* L. cv. AC Superb) was grown as a test crop on all sites. All wheat was seeded to a depth of 2.5 cm and row spacing was 20 cm at Oak Bluff and Brandon, and 30 cm at Indian Head. At Oak Bluff, the wheat was seeded using a 1.8 m wide plot-scale air seeder with Flexi-Coil openers, at Brandon with a 3-pt hitch air seeder equipped with SEED-HAWK hoe openers, and at Indian Head with a Conservapak® seeder. All sites were seeded at a rate of 134 kg ha^{-1}. In year one, sites were seeded between May 10 and May 17, 2006. In year two, the Oak

Bluff and Indian Head sites were seeded on May 10 and May 8, 2007 respectively. Wet weather caused a delay in seeding at Brandon until June 5, 2007. At all sites, phosphorus fertilizer was applied to all plots as monoammonium phosphate at a rate of 30 kg P_2O_5 ha^{-1}.

Pesticides were applied at recommended rates to control weeds and diseases. At Oak Bluff in the first year glyphosate, as Roundup was applied on May 12 at a rate of 0.75 L ha^{-1} using a bicycle sprayer. Herbicides clopyralid as Curtail M, clodinafop-propargyl as Horizon, and Score adjuvant were applied using a CO_2 backpack sprayer at a rate of 2 L ha^{-1}, 0.29 L ha^{-1}, and 1 L per 100 L spray solution respectively. In the second year on May 9, 2007, glyphosate as Credit and 2, 4-D was applied with a CO_2 backpack sprayer at a rate of 0.75 L ha^{-1} and 0.58 L ha^{-1}, respectively. Clopyralid as Curtail M (2 L ha^{-1}), clodinafop-propargyl as Horizon (0.29 L ha^{-1}), and the adjuvant Score (1 L 100 L^{-1} spray solution) were applied June 15, 2007 using the CO_2 backpack sprayer. In both years at heading stage, the fungicide Folicur and Agral 90 were applied at a rate of 0.29 L ha^{-1} and 1.25 L 1000 L^{-1} spray solution respectively.

At Brandon in the first year, glyphosate as Factor was applied on April 28, 2006 at a rate of 2.47 L ha^{-1}. Glyphosate as Roundup WeatherMax and 2,4-D Amine 500 were applied on May 21, 2006 using a bicycle sprayer at a rate of 1.7 L ha^{-1} and 0.84 L ha^{-1} respectively. Tralkoxydim as Achieve liquid (0.49 L ha^{-1}), fluroxypyr as Prestige A (0.79 L ha^{-1}), clopyralid as Prestige B (2 L ha^{-1}), and Turbocharge at a rate of 0.5% were applied on June 12, 2006 with a tractor sprayer. In the second year, glyphosate as Roundup Transorb (1.2 L ha^{-1}) was applied May 8, 2007. With a tractor sprayer, tralkoxydim as Achieve (0.49 L ha^{-1}), fluroxypyr as Prestige A (0.79 L ha^{-1}), clopyralid as Prestige B (2 L ha^{-1}), and Turbocharge (0.5%) were applied on June 28, 2007.

Glyphosate (0.75 L ha^{-1}) was applied as Roundup on all plots the first year in Indian Head September 22, 2005 and May 8, 2006. Tralkoxydim as Achieve (0.5 L ha^{-1}) and fluroxypyr as Attain (0.6 L ha^{-1}) were applied June 7, 2006. The second year, glyphosate as Roundup was applied at a rate of 0.75 L ha^{-1} May 5, 2007. On June 5, 2007, tralkoxydim as Achieve (0.5 L ha^{-1}) and fluroxypyr as Attain (0.6 L ha^{-1}) were applied.

At midseason (50% heading) two one-metre rows of above ground plant biomass were hand harvested. Midseason plant samples were dried at a temperature between 35°C and 40°C to a constant weight and dry matter biomass (kg ha^{-1}) was calculated, adjusted to 0% moisture content. At physiological maturity, two three-metre rows at Oak Bluff were hand harvested; plots were harvested at Brandon using a Hege plot combine and at Indian Head with a MF300 combine. Above ground plant samples were dried, threshed, and grain and straw yields (adjusted to 0% moisture content) were calculated.

2.3.3 Ammonia Volatilization

After fertilizer application, ammonia volatilization from the fall banded treatments and the control was monitored until four weeks after application. At seeding, the control and spring banded treatment were also monitored for four weeks. Trap chambers consisting of PVC tubes 20 cm long and 15 cm diameter were inserted to a depth of 5 cm centred over a fertilizer band. Foam disks saturated with a glycerol-phosphoric acid solution were placed inside the PVC tubes roughly 10 cm from the soil surface and at the top of the chamber. The base disk absorbed ammonia from the soil surface while the top disk prevented the absorption of any ammonia from the air outside the chambers. The chambers were also covered with a roof. The disks were removed and the base disk extracted using a 0.5 M KCl solution 7, 14, 21, and 28 days after application. Fresh disks replaced those that were removed. The extract was analyzed for ammonium by a Technicon Autoanalyzer II Single-Channel Colorimeter by automated phenate method (Greenberg et al. 1998).

2.3.4 Ammonium and Nitrite + Nitrate N in Soil

Ammonium-N and nitrate plus nitrite-N were measured in soil throughout the sampling period. Soil was sampled (0-30 cm) 1, 2, and 3 weeks after fertilizer application in the fall and 1, 2, 3, and 4 weeks after planting, using JMC “Backsaver” soil probes and Dutch augers. Five random sub-samples per plot were collected between fertilizer bands, at distances greater than 4 cm from bands. Samples were also taken from each of two bands per plot; for each band, five sub-samples were taken in a “W” pattern with one centered on the band and two additional sub-samples at 2 cm and 4 cm away from each side of the fertilizer band. At planting and at harvest, two sub-samples per plot were collected to 120 cm at Oak Bluff and Brandon and 90 cm at Indian Head. Sub-samples from each respective plot, depth, and band zone were mixed and composited. Samples were stored at a temperature of 2^{o}C, then dried for a minimum of 24 hours and ground to pass through a 2 mm sieve. Ground soil samples were extracted by shaking 5 g of soil with 25 mL of 2 M KCl solution for 30 minutes. The solution was centrifuged for 1 minute 30 seconds at 2800 rpm and 10 mL was extracted by pipette. The concentration of combined NO_3^- + NO_2^- in the extracts was determined using a Technicon Autoanalyzer II Single-Channel Colorimeter by automated cadmium reduction method (Greenberg et al. 1998). Ammonium-N was determined by automated phenate colorimetric method using the same Technicon Autoanlyzer II (Greenberg et al. 1998). Apparent recovered fertilizer N in soil was determined by subtracting the total inorganic N in the control plots from the total inorganic N in the fertilized plots.

2.3.5 Crop Nitrogen Use Efficiency

Total N uptake and fertilizer nitrogen use efficiency were determined from plant samples collected at midseason and maturity. Plant samples were dried and ground with a Wiley mill to pass through a 2 mm sieve and samples were analyzed for total N using a Leco CNS Combustion Analyzer. Total above ground N uptake was calculated on a dry matter basis for midseason samples (above plant biomass x % N content/100) and harvest ([grain yield x % grain N] + [straw yield x % straw N]/100). Fertilizer nitrogen use efficiency was calculated on a dry matter basis for midseason and harvest samples (fertilized total above ground N uptake – control total above ground N uptake/fertilizer applied x 100). Apparent total recovered fertilizer in the plant and soil (0-120 cm at Oak Bluff and Brandon and 0-90 cm at Indian Head) was also calculated (Total above ground N uptake + Total inorganic N/fertilizer applied).

2.3.6 Statistical Analysis

Statistical analyses were performed using the mixed procedure of the Statistical Analysis System (SAS) (SAS 9.1.3). The data were tested for normality and skewness using the Univariate function of SAS. A randomized complete block design ANOVA model was used. Due to interactions between site years and treatments, all data were analyzed and presented separately for each site year. Least significant difference (LSD) tests were used to compare the fertilizer treatment means. A probability level (α) of 0.05 was used as the significance threshold for all data. Single degree of freedom contrasts were also performed on all data.

2.4 Results and Discussion

2.4.1 Ammonia Volatilization

Ammonia volatilization was small (<3 %) at all site years except for Indian Head in 2005/06 (Table 2.3). Ammonia loss from the fall banded conventional urea treatment at Indian Head in 2005/06 equalled 18 % of applied fertilizer, but was not significantly greater than for the other fertilizer treatments according to Proc MIXED ANOVA. However, single degree of freedom contrasts showed a significant difference between the fall and spring banded conventional urea at this site (Table 2.3). The large coefficient of variation and the inconsistent differences between fall and spring conventional urea treatments suggest that the greater ammonia volatilization from the fall treatment was likely the result of inconsistent coverage of the fall-banded fertilizer. Substantial ammonia volatilization from N fertilizer exposed to the atmosphere has been reported. For example, total NH_3 loss from surface applied conventional urea ranged from 5.8 % to 38.9 % of N applied, dependent on soil type (Watson et al. 1994). In that study, volatilization was highly correlated with pH-KCl and titratable acidity (TA) and these two soil properties explained 95 % of the variation between soils, indicating large ammonia loss from high pH and low TA soils (Watson et al. 1994). Incomplete band coverage could, therefore, result in substantial ammonia volatilization from the high pH Indian Head soil (Table 2.1). Significantly greater volatilization was also observed from the spring banded conventional urea treatment than from the fall banded conventional urea at Brandon 2006/07, which may also be the result of incomplete soil coverage.

Table 2.3 Effect of fertilizer form, additives and timing of application on cumulative ammonia volatilization.

		Oak Bluff, MB		Brandon, MB		Indian Head, SK	
		Fall 2005-Spring 2006	Fall 2006-Spring 2007	Fall 2005-Spring 2006	Fall 2006-Spring 2007	Fall 2005-Spring 2006	Fall 2006-Spring 2007
Treatment		**Cumulative ammonia emissions from fertilizer (% of applied)**					
Fall Banded NBPT-DCD Urea		0.08	0.03	0.07	0.1b[z]	0.96	-0.01
Fall Banded Conventional Urea		0.01	0.04	1.16	0.04b	18.12	0.01
Fall Banded Calcium Nitrate		0.03	0.05	0.01	-0.01b	0.16	0.01
Spring Banded Conventional Urea		0.03	-0.18	1.59	2.22a	1.13	-0.005
ANOVA	***df***	***P>F***					
Treatment	4	0.57	0.27	0.10	0.01	0.09	0.89
Block	3	0.16	0.87	0.68	0.21	0.41	0.28
C.V. (%)		191	1207	170	220	236	3015
Contrasts		***P>F***					
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.20	0.91	0.31	0.91	0.04	0.58
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.31	0.90	0.96	0.85	0.91	0.54
Fall Conv. Urea vs. Fall Ca Nitrate		0.76	0.99	0.30	0.94	0.03	0.94
Fall Conv. Urea vs. Spring Conv. Urea		0.62	0.11	0.19	0.006	0.04	0.66
FallNBPT-DCDUrea vs. Spring Conv. Urea		0.40	0.13	0.03	0.007	0.98	0.91

[z]Mean values within the same column followed by the same lower case letter are not significantly different at p≤0.05.

2.4.2 Transformation of Urea Fertilizer during the Fall Period

Soil was sampled at regular intervals to determine the transformation of the banded fertilizer throughout the fall period. At the last fall sampling period at two of the six site years, fall banded NBPT-DCD urea had significantly greater soil ammonium N compared to the fall banded conventional urea treatment, suggesting that the inhibitors slowed nitrification of the fertilizer N (Table 2.4). Previous studies in Manitoba have also demonstrated that the addition of NBPT and DCD to urea significantly reduced nitrification (Tiessen et al. 2006). Of the other site years, ammonium N was similar for the two fall banded urea treatments except for Brandon 2006/07 where the concentration of NH_4^+-N in the fall banded conventional urea treatment was significantly greater than in the fall banded NBPT-DCD urea treatment, opposite to what had been expected. The reason for the latter difference is not known. The concentration of soil nitrite plus nitrate N in the fall fertilizer treatments was significantly greater in the fall banded calcium nitrate treatments compared to the other fertilizer treatments at three of the six site years. With the nitrogen applied in the nitrate form, it would be expected that this treatment would have significantly greater soil nitrite and nitrate N.

At the Oak Bluff and Indian Head sites in 2005/06, the concentration of recovered inorganic N at the last fall sampling period was greater in the inhibitor treated urea than in the conventional urea treatment, similar to the trend observed for ammonium-N concentrations. Some of these greater concentrations of inorganic N for the inhibitor treated urea treatments may have been due to retardation of urea hydrolysis by NBPT. The concentrations of recovered inorganic N were much more variable than those reported by Tiessen et al. (2006). In the experiment conducted by Tiessen et al., the recovered inorganic N in the urea treatment with inhibitors at the final sampling period in the fall ranged from 111 kg ha^{-1} to 117 kg ha^{-1} compared to 50 kg ha^{-1} to 142 kg ha^{-1} in the present study. The apparent recovered fertilizer N ranged from 24 kg ha^{-1} in the fall banded conventional urea treatment at Oak Bluff 2006/07 to 72 kg ha^{-1} in the fall banded NBPT-DCD urea at Oak Bluff 2005/06, which represents 30 and 90% of the fertilizer applied, respectively. The apparent recovered fertilizer N was similar for all treatments, except at Indian Head 2006 where the apparent recovered fertilizer N was significantly greater in the fall banded calcium nitrate treatment than the urea fertilizer treatments.

Given that the recovery of N from the calcium nitrate treatment was at least as great as from the urea treatments, we can deduce that denitrification was not a major loss mechanism during the fall period. Therefore, the low and variable apparent recovered fertilizer N was likely due to a combination of sampling variability, immobilization during the fall period, and retardation of urea hydrolysis by NBPT. In a field study in northern Alberta, recovery of ^{15}N as total-N was 14 to 24% higher than ^{15}N as NH_4^+-N plus NO_3-N during the fall period indicating that significant quantities of fall applied fertilizer was immobilized into the organic fraction (Heaney and Nyborg 1988). Conversely, in a field study in Saskatchewan, at time of freezing nearly all of the fertilizer could be accounted for in the urea treatment and 90% of KNO_3 applied (Aulakh and Rennie 1984). Therefore, the extent to which fall-applied fertilizer is immobilized prior to freeze-up appears to vary substantially within the Prairies.

Table 2.4a. Effect of fertilizer form, inhibitors and timing of application on recovered soil inorganic N at the final fall sampling period prior to freeze-up (0-30 cm depth) for the Oak Bluff site.

		2005/06				2006/07			
Site and Treatment		**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**	**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**
Oak Bluff					kg ha^{-1}				
Control		33b[z]	36b	69c	-	19	50b	69	-
Fall Banded NBPT-DCD Urea		63a	79a	142a	72	41	64b	105	35
Fall Banded Conventional Urea		37b	71a	109b	39	39	54b	93	24
Fall Banded Calcium Nitrate		38b	95a	133ab	64	17	106a	123	53
Spring Banded Conventional Urea		-	-	-	-	-	-	-	-
ANOVA	***df***				***P>F***				
Trt	4	0.05	0.01	0.01	0.15	0.08	0.03	0.16	0.55
Block	3	0.38	0.41	0.22	0.06	0.53	0.53	0.60	0.80
C.V. (%)		40	41	32	53	58	44	34	85
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.14	0.003	0.001	-	0.14	0.10	0.06	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.03	0.61	0.06	0.07	0.88	0.56	0.61	0.68
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.03	0.27	0.61	0.97	0.05	0.03	0.42	0.51
Fall Ca Nitrate vs. Fall Conv. Urea		0.91	0.12	0.15	0.09	0.06	0.01	0.20	0.30

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$

Table 2.4b. Effect of fertilizer form, inhibitors and timing of application on recovered soil inorganic N at the final fall sampling period prior to freeze-up (0-30 cm depth) for the Brandon site.

		2005/06				2006/07			
Site and Treatment		**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**	**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**
Brandon					kg ha^{-1}				
Control		18	6b	24b	-	15b	33	48	-
Fall Banded NBPT-DCD Urea		17	32a	50a	26	23b	52	75	27
Fall Banded Conventional Urea		16	50a	66a	42	41a	58	98	51
Fall Banded Calcium Nitrate		15	39a	54a	30	14b	73	87	39
Spring Banded Conventional Urea		-	-	-	-	-	-	-	-
ANOVA	***df***				***P>F***				
Trt	4	0.15	0.02	0.03	0.51	0.02	0.27	0.21	0.66
Block	3	0.40	0.61	0.63	0.76	0.56	0.28	0.50	0.20
C.V. (%)		13	68	44	54	61	53	45	98
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.09	0.004	0.01	-	0.09	0.10	0.07	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.42	0.14	0.19	0.28	0.03	0.78	0.33	0.38
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.11	0.57	0.74	0.78	0.29	0.30	0.61	0.64
Fall Ca Nitrate vs. Fall Conv. Urea		0.37	0.34	0.31	0.41	0.01	0.44	0.63	0.67

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$

Table 2.4c. Effect of fertilizer form, inhibitors and timing of application on recovered soil inorganic N at the final fall sampling period prior to freeze-up (0-30 cm depth) for the Indian Head site.

		2005/06				2006/07			
Site and Treatment		**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**	**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**
Indian Head					**kg ha^{-1}**				
Control		7d	23c	30c	-	12c	12b	24c	-
Fall Banded NBPT-DCD Urea		39a	31b	71a	41	42a	22b	64b	40b
Fall Banded Conventional Urea		30b	31b	61b	30	32ab	21b	53bc	28b
Fall Banded Calcium Nitrate		9cd	47a	55b	25	17bc	92a	109a	85a
Spring Banded Conventional Urea		-	-	-	-	-	-	-	-
ANOVA	***df***				***P>F***				
Trt	4	0.0001	0.0003	0.0002	0.11	0.03	0.0002	0.0030	0.05
Block	3	0.17	0.05	0.13	0.51	0.38	0.51	0.61	0.71
C.V. (%)		73	31	32	32	61	98	59	65
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.0003	0.001	0.0001	-	0.03	0.01	0.003	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.04	0.90	0.09	0.16	0.25	0.95	0.48	0.56
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.0001	0.0008	0.02	0.05	0.02	0.0002	0.02	0.05
Fall Ca Nitrate vs. Fall Conv. Urea		0.001	0.001	0.32	0.40	0.14	0.0002	0.01	0.02

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \le 0.05$

2.4.3 Total Recovered N in the Soil at Planting

Soil samples to 120 cm at Oak Bluff and Brandon, MB and to 90 cm at Indian Head, SK immediately prior to planting, revealed that urea fertilization significantly increased ammonium N concentrations over those for the control or calcium nitrate treatment at only one site year, Indian Head in 2006/07 (Table 2.5). At this site year, however, the ammonium concentrations for fall banded NBPT-DCD urea and conventional urea were similar. According to the ANOVA, concentrations of nitrite plus nitrate were increased by fall nitrogen fertilization at three of six site years, but these increases were more frequent for conventional urea treatments (three of six) than for NBPT-DCD urea (one of six) or calcium nitrate (one of six).

Fertilization increased the concentrations of total inorganic N two of six site years, at Brandon in 2005/06 and Indian Head in 2006/07. For these two site years, the concentrations of total inorganic N for NBPT-DCD urea and conventional urea were similar. There were, however, no statistically significant differences in the apparent recovered fertilizer N between fertilizer treatments. Variability among replicates for this measurement was very high, with CVs ranging from 69-132%. However, the lack of significantly lower recovered fertilizer N from the fall banded calcium nitrate treatment compared to the urea treatments may also suggest that there was little loss due to denitrification during the spring thaw period (Table 2.5). Conditions during the fall and spring period at most site years were not excessively wet and, therefore, not favourable for denitrification of fertilizer N (Table 2.2). Under wet conditions, significant losses have occurred due to denitrification events in the spring with as much as 70% of fertilizer lost during the thaw period (Röver et al. 1998).

Table 2.5a. Effect of fertilizer form, additives and timing of application on recovered soil and fertilizer inorganic N (0-120 cm) at planting at Oak Bluff.

		2005/06				2006/07			
Site and Treatment		**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**	**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**
Oak Bluff					kg ha^{-1}				
Control		86[z]	86	172	-	75	79	154	-
Fall Banded NBPT-DCD Urea		79	131	210	37	88	93	181	28
Fall Banded Conventional Urea		84	138	222	50	83	96	179	25
Fall Banded Calcium Nitrate		86	131	217	45	83	101	175	30
Spring Banded Conventional Urea		-	-	-	-	-	-	-	-
ANOVA	***df***				***P>F***				
Trt	4	0.48	0.17	0.26	0.90	0.60	0.70	0.72	0.98
Block	3	0.001	0.001	0.003	0.15	0.90	0.12	0.66	0.30
C.V. (%)		15	51	31	98	15	33	19	132
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.53	0.04	0.06	-	0.24	0.29	0.28	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.32	0.76	0.64	0.67	0.62	0.88	0.94	0.94
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.18	0.98	0.77	0.79	0.60	0.68	0.81	0.92
Fall Ca Nitrate vs. Fall Conv. Urea		0.70	0.78	0.86	0.87	0.97	0.79	0.87	0.86

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 2.5b. Effect of fertilizer form, additives and timing of application on recovered soil and fertilizer inorganic N (0-120 cm) at planting at Brandon.

Site and Treatment		2005/06				2006/07			
		NH_4^+-N	NO_2^-+NO_3^--N	Total inorganic N	Apparent recovered fertilizer N	NH_4^+-N	NO_2^-+NO_3^--N	Total inorganic N	Apparent recovered fertilizer N
Brandon		**kg ha^{-1}**							
Control		104	41c	145c	-	50	73	124	-
Fall Banded NBPT-DCD Urea		106	99a	204a	59	51	111	162	38
Fall Banded Conventional Urea		79	80ab	181ab	36	60	135	195	71
Fall Banded Calcium Nitrate		97	65bc	162bc	21	55	107	162	39
Spring Banded Conventional Urea		-	-	-	-	-	-	-	-
ANOVA	**df**				***P>F***				
Trt	4	0.76	0.04	0.02	0.15	0.19	0.07	0.08	0.44
Block	3	0.03	0.001	0.001	0.42	0.81	0.32	0.39	0.74
C.V. (%)		15	59	27	78	13	33	25	69
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.71	0.02	0.02	-	0.24	0.02	0.03	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.66	0.29	0.18	0.26	0.07	0.26	0.18	0.27
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.34	0.08	0.03	0.06	0.36	0.85	0.98	0.98
Fall Ca Nitrate vs. Fall Conv. Urea		0.59	0.43	0.26	0.34	0.29	0.20	0.19	0.28

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 2.5c. Effect of fertilizer form, additives and timing of application on recovered soil and fertilizer inorganic N (0-90 cm) at planting at Indian Head.

Site and Treatment		2005/06				2006/07			
		NH_4^+-N	NO_2^-+NO_3^--N	Total inorganic N	Apparent recovered fertilizer N	NH_4^+-N	NO_2^-+NO_3^--N	Total inorganic N	Apparent recovered fertilizer N
Indian Head					kg ha^{-1}				
Control		50	94b	144	-	30b	41b	71c	-
Fall Banded NBPT-DCD Urea		49	101b	149	5	67a	79b	146ab	75
Fall Banded Conventional Urea		63	129a	192	48	65a	139a	204a	133
Fall Banded Calcium Nitrate		55	137a	191	47	26b	108b	134bc	63
Spring Banded Conventional Urea		-	-	-	-	-	-	-	-
ANOVA	**df**				***P>F***				
Trt	4	0.76	0.04	0.10	0.21	0.02	0.02	0.02	0.27
Block	3	0.30	0.99	0.54	0.25	0.17	0.19	0.13	0.29
C.V. (%)		37	22	21	121	65	55	52	72
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.67	0.04	0.09	-	0.20	0.02	0.03	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.34	0.08	0.08	0.13	0.90	0.04	0.16	0.21
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.68	0.04	0.09	0.14	0.01	0.98	0.18	0.78
Fall Ca Nitrate vs. Fall Conv. Urea		0.58	0.63	0.96	0.97	0.01	0.04	0.01	0.14

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

2.4.4 Midseason: Biomass and N Uptake

At midseason, fertilizer increased the midseason yield of above ground plant biomass all only one site year, Indian Head 2006/07, according to the ANOVA (Table 2.6). However, single degree of freedom contrasts showed another significant increase in midseason yield in the fertilizer treatments above the control, at Indian Head in 2005/06. Fertilization increased nitrogen uptake at three of six site years. Nitrogen uptake from fall banded NBPT-DCD urea and fall banded conventional urea was similar, except at Indian Head 2006/07 where fall banded NBPT-DCD urea had greater N uptake. At this site, nitrogen uptake from the fall banded NBPT-DCD urea was also significantly greater than from the spring banded conventional urea but similar to that from fall banded calcium nitrate. The inconsistent benefits of adding NBPT-DCD inhibitors to urea on midseason biomass and N uptake are similar to those found by Tiessen et al. (2005) who found significantly greater biomass and nitrogen uptake at only one individual site year and no differences when data from all field sites were combined. Nitrogen uptake from the fall banded calcium nitrate treatment was similar to that of the spring banded conventional urea treatment at four of six sites (Table 2.6). Nitrogen uptake in the fall banded calcium nitrate was the greatest of all fertilized treatments at Indian Head in 2006/07 and smallest of all fertilized treatments at Oak Bluff in 2006/07. The smaller N uptake from the calcium nitrate treatment at Oak Bluff 2006/07 is probably due to N loss during the early spring. Due to the depressional location of the site, field conditions at Oak Bluff in 2006/07 were saturated throughout the thaw period, likely resulting in substantial denitrification of the fall-applied nitrate fertilizer, even though sampling variability within this site may have masked these losses in the soil N measurements (Table 2.5).

Table 2.6. Effect of fertilizer form, additives and timing of application on above ground biomass and N uptake of spring wheat at heading.

Site and Treatment		2005/06 Above ground biomass	2005/06 N uptake	2006/07 Above ground biomass	2006/07 N uptake
Oak Bluff			kg ha^{-1}		
Control		5886	109	2744	39b[z]
Fall Banded NBPT-DCD Urea		4782	118	3413	56ab
Fall Banded Conventional Urea		6202	140	3463	58a
Fall Banded Calcium Nitrate		5207	118	2669	44b
Spring Banded Conventional Urea		5651	120	4006	59a
ANOVA	***df***		***P>F***		
Trt	4	0.65	0.71	0.07	0.05
Block	3	0.88	1.00	0.87	0.52
C.V. (%)		23	22	23	24
Contrasts			***P>F***		
Fertilized treatments vs. control		0.60	0.40	0.10	0.02
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.29	0.69	0.92	0.85
Spring Conv. Urea vs. Fall Conv. Urea		0.68	0.99	0.26	0.81
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.40	0.91	0.22	0.67
Fall Ca Nitrate vs. Fall Conv. Urea		0.18	0.33	0.11	0.08
Brandon			kg ha^{-1}		
Control		2566	36	1882	35
Fall Banded NBPT-DCD Urea		2740	35	1789	38
Fall Banded Conventional Urea		2604	37	1736	39
Fall Banded Calcium Nitrate		2652	36	1816	38
Spring Banded Conventional Urea		2901	39	1771	41
ANOVA	***df***		***P>F***		
Trt	4	0.85	0.85	0.92	0.54
Block	3	0.12	0.01	0.75	0.74
C.V. (%)		18	19	11	12
Contrasts			***P>F***		
Fertilized treatments vs. control		0.56	0.87	0.43	0.16
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.69	0.68	0.75	0.71
Spring Conv. Urea vs. Fall Conv. Urea		0.39	0.53	0.83	0.61
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.63	0.31	0.92	0.38
Fall Ca Nitrate vs. Fall Conv. Urea		0.89	0.84	0.63	0.84
Indian Head			kg ha^{-1}		
Control		2924	55b	3375b	48c
Fall Banded NBPT-DCD Urea		3461	79a	4905a	95a
Fall Banded Conventional Urea		3498	88a	4314a	83b
Fall Banded Calcium Nitrate		3486	89a	4405a	94a
Spring Banded Conventional Urea		3240	88a	4610a	84b
ANOVA	***df***		***P>F***		
Trt	4	0.05	0.03	0.02	0.0001
Block	3	0.03	0.71	0.0161	0.0036
C.V. (%)		12	22	16	24
Contrasts			***P>F***		
Fertilized treatments vs. control		0.01	0.0021	0.0002	0.0001
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.83	0.42	0.06	0.02
Spring Conv. Urea vs. Fall Conv. Urea		0.21	0.96	0.31	0.83
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.28	0.40	0.31	0.03
Fall Ca Nitrate vs. Fall Conv. Urea		0.95	0.88	0.75	0.04

[z] Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

2.4.5 Harvest: Straw Yield, Grain Yield and Total N Uptake

At maturity, fertilization increased straw yield three of six site years, all in 2006/07 (Table 2.7). However, the addition of inhibitors to fall banded urea did not increase straw yield in any site year compared to conventional urea. Conversely, straw yield for the fall banded conventional urea was greater than for fall banded NBPT-DCD urea at Brandon, 2006/07. Timing of application did not have a significant effect on straw yield as spring banded conventional urea did not produce greater yields than fall banded conventional urea at any site year. Timing of application also had little effect on straw yield in the study by Tiessen et al. (2005) who found spring banded N produced significantly higher straw yield than early fall banded conventional urea in only one site year.

Nitrogen fertilizer significantly increased grain yield at four of six site years (Table 2.7). According to ANOVA, grain yields were similar for the fall banded NBPT-DCD urea and fall banded conventional urea at all responsive sites. However, contrasts revealed that adding NBPT-DCD to fall banded urea increased grain yield at Indian Head in 2006/07. Fall conventional urea produced grain yields that were similar to calcium nitrate at all site-years. However, fall banded NBPT-DCD urea increased grain yields over the fall banded calcium nitrate treatment at three of the site years where a fertilizer response was observed. At Oak Bluff 2006/07 the fall banded NBPT-DCD urea had greater yields than the spring banded conventional urea. Although the reason for the poor performance of spring urea at this site is uncertain, wet conditions during seeding may have resulted in a poor quality seedbed, causing inadequate separation of the fertilizer and seed, resulting in urea toxicity. For all other site years, both fall banded urea treatments had similar yields to the spring banded conventional urea. The similar yields for the spring and fall banded urea treatments at all but one site is consistent with observations of Hultgreen and Leduc (2003) who found spring banded N fertilizer significantly increased wheat grain yield over that of fall banded at only one of eleven site years. Also, on a Stockton fine sandy loam soil under conventional tillage, Grant et al. (2001) recorded several cases where fall banded urea ammonium nitrate (UAN) and urea produced greater grain yields than spring banded UAN and urea. Under wet conditions, however, fall application can result in smaller yields than when fertilizer is applied in the spring. Malhi and Nyborg (1992) found barley grain yielded considerably more with spring application than fall application of urea at three of four sites and this difference was attributed primarily to denitrification of the fall applied fertilizer.

Analysis of variance showed significant fertilization effects on total N uptake at four of six site years (Table 2.7). According to single degree of freedom contrasts, the addition of inhibitors to fall banded urea increased total N uptake of the crop at only one of six site years, Indian Head 2006/07. Fall banded conventional urea and fall banded calcium nitrate had similar N uptake at all but one responsive site. Fall banded NBPT-DCD urea, however, increased N uptake over the calcium nitrate treatment at two of six site years.

Apparent uptake of fertilizer N was similar for all treatments, except at Indian Head 2006/07, where uptake of fall banded NBPT-DCD urea was greater than from fall banded calcium nitrate and spring banded urea. Conversely, single degree of freedom contrasts revealed significantly less apparent recovered fertilizer N from the fall banded calcium nitrate compared to the fall banded conventional urea at Brandon 2005/06.

However, fertilizer N uptake from fall banded NBPT-DCD urea was not greater than from fall banded conventional urea at any site year.

In our study, the performance of spring banded conventional urea and fall banded calcium nitrate were similar in all site years. Setting aside the anomalous results at Oak Bluff 2006/07 where both of these treatments performed poorly for different reasons, the fall applied treatments in our study were not particularly susceptible to substantial overwinter losses and timing of fertilizer application was not a dominant factor for crop response. Although fall applied fertilizer is susceptible to denitrification, other research has demonstrated that this form of loss is only substantial under saturated conditions. For example, the apparent recovery of fall applied potassium nitrate on a zero-tilled and conventional tilled field was 98.1 and 102.1 % respectively in a field study in Alberta demonstrating little apparent fall and early spring loss under dry conditions (Malhi et al. 1996). Under relatively dry conditions, such as those found at all of ours sites except for Oak Bluff in the spring of 2007, fall applied nitrogen fertilizer may be reasonable stable and not vulnerable to substantial loss, decreasing the need for urease and nitrification inhibitors.

Table 2.7a. Effect of fertilizer form, additives and timing of application on yield and N uptake of spring wheat at maturity at Oak Bluff.

Site and Treatment		**2005/06**				**2006/07**			
		Straw yield	**Grain yield**	**Total N uptake**	**Apparent Fertilizer N Uptake**	**Straw yield**	**Grain yield**	**Total N uptake**	**Apparent Fertilizer N Uptake**
Oak Bluff		**kg ha^{-1}**							
Control		4773[†]	4222	110	-	2782c	2145c	70b	-
Fall Banded NBPT-DCD Urea		5171	4506	136	26	3967a	3015a	103a	34a
Fall Banded Conventional Urea		5098	4700	133	23	3859ab	2728ab	96ab	27ab
Fall Banded Calcium Nitrate		4888	4446	126	16	3185bc	2494bc	84b	15bc
Spring Banded Conventional Urea		4880	4454	129	19	3250cb	2529c	83b	13c
ANOVA	***df***	***P>F***							
Trt	4	0.86	0.82	0.40	0.56	0.02	0.02	0.003	0.02
Block	3	0.55	0.66	0.61	0.0003	0.17	0.6	0.63	0.001
Contrasts		***P>F***							
Fertilized treatments vs. Control		0.76	0.96	0.08	-	0.009	0.009	0.002	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.86	0.63	0.80	0.68	0.74	0.22	0.33	0.26
Spring Conv. Urea vs. Fall Conv. Urea		0.61	0.54	0.80	0.61	0.08	0.39	0.07	0.04
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.50	0.90	0.61	0.93	0.04	0.05	0.01	0.006
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.51	0.88	0.46	0.25	0.03	0.04	0.02	0.009
Fall Ca Nitrate vs. Fall Conv. Urea		0.62	0.53	0.63	0.45	0.06	0.31	0.1	0.06

[z]Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 2.7b. Effect of fertilizer form, additives and timing of application on yield and N uptake of spring wheat at maturity at Brandon.

Site and Treatment		2005/06				2006/07			
		Straw yield	Grain yield	Total N uptake	Apparent Fertilizer N Uptake	Straw yield	Grain yield	Total N uptake	Apparent Fertilizer N Uptake
Brandon					kg ha^{-1}				
Control		2263	1649c	53c	-	2714b	2053	78	-
Fall Banded NBPT-DCD Urea		2164	3136a	80a	27	2947b	2282	94	16
Fall Banded Conventional Urea		3336	3007ab	87a	34	3922a	2130	103	24
Fall Banded Calcium Nitrate		2485	2620b	70ab	17	2978b	2196	93	15
Spring Banded Conventional Urea		2132	2958ab	74ab	21	3497ab	2179	93	14
ANOVA	***df***				***P>F***				
Trt	4	0.62	<0.001	0.001	0.14	0.05	0.76	0.28	0.46
Block	3	0.90	0.0095	0.04	0.47	0.50	0.48	0.93	0.42
Contrasts					***P>F***				
Fertilized treatments vs. control		0.7	<0.0001	0.0002	-	0.06	0.32	0.06	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.20	0.55	0.24	0.29	0.03	0.41	0.42	0.14
Spring Conv. Urea vs. Fall Conv. Urea		0.19	0.82	0.05	0.09	0.29	0.79	0.33	0.29
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.97	0.41	0.39	0.44	0.17	0.57	0.85	0.62
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.71	0.0301	0.14	0.19	0.94	0.63	0.9	0.59
Fall Ca Nitrate vs. Fall Conv. Urea		0.34	0.09	0.02	0.03	0.03	0.72	0.36	0.31

[z]Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 2.7c. Effect of fertilizer form, additives and timing of application on yield and N uptake of spring wheat at maturity at Indian Head.

Site and Treatment		2005/06				2006/07			
		Straw yield	Grain yield	Total N uptake	Apparent Fertilizer N Uptake	Straw yield	Grain yield	Total N uptake	Apparent Fertilizer N Uptake
Indian Head		kg ha^{-1}							
Control		2141	2206b	71c	-	2346c	1087c	41c	-
Fall Banded NBPT-DCD Urea		2044	2738a	85b	14	3894a	1822a	73a	33
Fall Banded Conventional Urea		2265	2788a	88ab	17	3530ab	1678ab	65b	24
Fall Banded Calcium Nitrate		2332	2922a	96a	25	3277b	1608b	69ab	28
Spring Banded Conventional Urea		1834	2792a	89ab	18	3609ab	1796a	69ab	29
ANOVA	***df***	***P>F***							
Trt	4	0.58	0.0002	0.0004	0.10	0.0004	<0.0001	<0.0001	0.16
Block	3	0.07	0.66	0.04	0.05	0.0063	0.0040	0.0025	0.13
Contrasts		***P>F***							
Fertilized treatments vs. control		0.93	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.51	0.65	0.43	0.45	0.16	0.05*	0.02*	0.03
Spring Conv. Urea vs. Fall Conv. Urea		0.21	0.97	0.77	0.78	0.75	0.09	0.17	0.21
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.53	0.62	0.29	0.31	0.27	0.71	0.22	0.26
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.39	0.11	0.01	0.02	0.03	0.0066	0.14	0.17
Fall Ca Nitrate vs. Fall Conv. Urea		0.84	0.23	0.06	0.07	0.32	0.31	0.27	0.32

^{z}Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

2.4.6 Harvest: Apparent Fertilizer N Use Efficiency and Total Recovered Fertilizer N in Soil and Plant

According to the ANOVA, fertilizer nitrogen use efficiency (NUE) was similar for fertilized treatments at all site years except for Oak Bluff 2006/07 (Table 2.8). During this site year, fall banded NBPT-DCD had significantly greater NUE than all other fertilizer treatments with the exception of fall banded conventional urea. During this site year, both fall banded urea treatments had significantly greater NUE than the spring banded conventional urea treatment. As previously mentioned, poor seedbed quality during spring 2006/07 may have resulted in low NUE for spring banded urea due to seedling toxicity. Contrast analyses revealed that the NUE for fall banded NBPT-DCD urea was greater than for fall banded conventional urea at Indian Head 2006/07; and greater for calcium nitrate than for fall banded conventional urea at Brandon in 2005/06. The results are consistent with the study by Tiessen et al. (2005) which found increased nitrogen use efficiency for NBPT-DCD urea compared to conventional urea at only site. The increased NUE in Tiessen's study, however, was in low landscape positions under wet conditions, conditions which were not similar to those at Indian Head.

Although the timing of application for conventional urea did not have a statistically significant effect on fertilizer nitrogen use efficiency except at Oak Bluff 2006/07, at five of six site years fall banded NBPT-DCD had numerically higher nitrogen use efficiency than the spring banded conventional urea treatment (Table 2.8). Nitrogen use efficiency was also numerically higher from the fall banded conventional urea compared to spring banded urea at four of six site years and NUE from fall banded calcium nitrate was numerically higher than from spring banded urea at two site years.

Table 2.8. Effect of fertilizer form, additives, and timing of application on urea fertilizer use efficiency of spring wheat at maturity.

Site and Treatment		2005/06 Fertilizer NUE		2006/07 Fertilizer NUE	
Oak Bluff		**% of applied**	**% of spring**	**% of applied**	**% of spring**
Fall Banded NBPT-DCD Urea		33	138	42a	263a
Fall Banded Conventional Urea		28	119	34ab	213ab
Fall Banded Calcium Nitrate		20	84	18bc	113bc
Spring Banded Conventional Urea		24	100	16c	100c
ANOVA	***df***		***P>F***		
Trt	4	0.82		0.02	
Block	3	0.001		0.001	
C.V. (%)		141		70	
Contrasts			***P>F***		
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.76		0.26	
Spring Conv. Urea vs. Fall Conv. Urea		0.76		0.04	
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.55		0.006	
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.39		0.009	
Fall Ca Nitrate vs. Fall Conv. Urea		0.57		0.06	
Brandon					
Fall Banded NBPT-DCD Urea		44	125	27	112
Fall Banded Conventional Urea		57	160	40	170
Fall Banded Calcium Nitrate		29	81	24	103
Spring Banded Conventional Urea		35	100	24	100
ANOVA	***df***		***P>F***		
Trt	4	0.14		0.80	
Block	3	0.47		0.55	
C.V. (%)		42		85	
Contrasts			***P>F***		
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.29		0.49	
Spring Conv. Urea vs. Fall Conv. Urea		0.09		0.41	
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.44		0.88	
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.19		0.91	
Fall Ca Nitrate vs. Fall Conv. Urea		0.03		0.42	
Indian Head					
Fall Banded NBPT-DCD Urea		23	77	56	113
Fall Banded Conventional Urea		28	94	43	85
Fall Banded Calcium Nitrate		41	137	48	96
Spring Banded Conventional Urea		30	100	50	100
ANOVA	***df***		***P>F***		
Trt	4	0.10		0.15	
Block	3	0.05		0.12	
C.V. (%)		42		19	
Contrasts			***P>F***		
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.45		0.03	
Spring Conv. Urea vs. Fall Conv. Urea		0.78		0.21	
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.31		0.27	
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.02		0.16	
Fall Ca Nitrate vs. Fall Conv. Urea		0.07		0.32	

[z]Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

As mentioned previously, these results indicate that losses of fall banded were generally small under the conditions of this experiment. Fertilization, fertilizer form, additives and timing did not have a significant effect on the residual inorganic N in soil at maturity for any site year, according to the ANOVA (Table 2.9). The contrast analyses, however, found significantly more total ammonium N, total inorganic N, and apparent recovered fertilizer N in the fall banded calcium nitrate treatment compared to the fall banded conventional urea treatment at Indian Head 2006/07. The reasons for the unexpected recovery of more ammonium N in the calcium nitrate treatment are not known.

At all but two site years, fertilizer source and timing of application did not have a significant effect on the apparent recovery of fertilizer N in the soil plus the aboveground portion of the crop (Table 2.10). According to the ANOVA and contrast analyses, at Oak Bluff 2006/07, the fall banded conventional urea treatment produced a higher recovery than the spring banded conventional urea treatment; both fall banded urea treatments produced higher recoveries than fall banded calcium nitrate at this site. In addition, contrast analyses revealed that the recovery of fertilizer N was greater for fall calcium nitrate than for fall conventional urea at Indian Head 2006/07. Nitrogen recovery by plants generally increases when application is delayed closer to the active growth period of the plant. Nitrogen recovery, therefore, is generally higher when fertilizer is applied in the spring (Malhi et al. 1995). The modest precipitation throughout the field seasons in the present study (Table 2.2) probably minimized losses of N through denitrification and leaching and, therefore, minimized differences in efficiency of recovery between treatments at most site years. In addition, the high coefficients of variation (30 – 146%) in these data made it difficult to detect significant differences among treatments.

Table 2.9a. Effect of fertilizer form, additives and timing on the apparent recovered residual soil inorganic N in soil (0-120 cm) at maturity at Oak Bluff.

		2005/06				2006/07			
Site and Treatment		**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**	**NH_4^+-N**	**NO_2^-+NO_3^--N**	**Total inorganic N**	**Apparent recovered fertilizer N**
Oak Bluff					kg ha^{-1}				
Control		135[z]	57	193	-	119	27	147	-
Fall Banded NBPT-DCD Urea		119	89	208	16	125	34	159	12
Fall Banded Conventional Urea		120	97	217	24	131	42	172	25
Fall Banded Calcium Nitrate		120	70	189	-3	114	31	145	-2
Spring Banded Conventional Urea		138	81	220	27	115	32	148	1
ANOVA	***df***				***P>F***				
Trt	4	0.55	0.10	0.24	0.35	0.73	0.17	0.27	0.26
Block	3	0.04	0.0008	<0.0001	0.53	0.03	0.005	0.002	0.07
C.V. (%)		21	44	24	157	19	34	19	279
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.36	0.03	0.23	-	0.87	0.12	0.42	-
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.95	0.57	0.60	0.63	0.69	0.20	0.36	0.39
Fall Conv. Urea vs. Spring Conv. Urea		0.25	0.29	0.85	0.88	0.28	0.11	0.09	0.12
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.97	0.21	0.24	0.31	0.44	0.49	0.30	0.32
Fall Ca Nitrate vs. Fall Conv. Urea		0.97	0.08	0.10	0.15	0.25	0.06	0.06	0.08

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 2.9b. Effect of fertilizer form, additives and timing on the apparent recovered residual soil inorganic N in soil (0-120 cm) at maturity at Brandon.

		2005/06				2006/07			
Site and Treatment		**NH_4^+-N**	**NO_2^- $+NO_3^-$-N**	**Total inorganic N**	**Apparent recovered fertilizer N**	**NH_4^+-N**	**NO_2^- $+NO_3^-$-N**	**Total inorganic N**	**Apparent recovered fertilizer N**
Brandon					kg ha^{-1}				
Control		109	23	132	-	96	41	137	-
Fall Banded NBPT-DCD Urea		103	21	124	-8	94	62	157	20
Fall Banded Conventional Urea		115	21	137	5	101	59	160	23
Fall Banded Calcium Nitrate		110	25	135	3	103	70	173	36
Spring Banded Conventional Urea		107	21	128	-4	104	45	149	13
ANOVA	***df***				***P>F***				
Trt	4	0.60	0.76	0.70	0.61	0.47	0.52	0.59	0.81
Block	3	0.43	0.48	0.44	0.14	0.07	0.34	0.24	0.44
C.V. (%)		9	23	10	1628	10	48	21	143
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.94	0.87	0.90	-	0.37	0.24	0.22	-
FallNBPT-DCDUreavs.FallConv.Urea		0.13	0.96	0.23	0.27	0.31	0.86	0.89	0.90
Fall Conv. Urea vs. Spring Conv. Urea		0.23	0.93	0.39	0.43	0.62	0.48	0.65	0.69
Fall NBPT-DCDUreavs.Fall CaNitrate		0.39	0.29	0.28	0.32	0.20	0.67	0.47	0.52
Fall Ca Nitrate vs. Fall Conv. Urea		0.48	0.32	0.89	0.90	0.76	0.55	0.56	0.60

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 2.9c. Effect of fertilizer form, additives and timing on the apparent recovered residual soil inorganic N in soil (0-90 cm) at maturity at Indian Head.

		2005/06				2006/07			
Site and Treatment		**NH_4^+-N**	**NO_2^- $+NO_3^-$-N**	**Total inorganic N**	**Apparent recovered fertilizer N**	**NH_4^+-N**	**NO_2^- $+NO_3^-$-N**	**Total inorganic N**	**Apparent recovered fertilizer N**
Indian Head					kg ha^{-1}				
Control		61	19	81	-	26	13	39	-
Fall Banded NBPT-DCD Urea		61	17	78	-3	30	16	46	7
Fall Banded Conventional Urea		50	30	80	-1	24	18	43	4
Fall Banded Calcium Nitrate		57	36	92	12	35	24	59	20
Spring Banded Conventional Urea		60	22	82	1	33	19	52	13
ANOVA	***df***				***P>F***				
Trt	4	0.54	0.64	0.93	0.88	0.17	0.38	0.10	0.16
Block	3	0.23	0.25	0.31	0.19	0.39	0.27	0.49	0.01
C.V. (%)		19	78	29	1182	24	44	24	138
Contrasts					***P>F***				
Fertilized treatments vs. Control		0.44	0.53	0.87	-	0.25	0.16	0.08	-
FallNBPT-DCDUreavs.FallConv.Urea		0.17	0.37	0.92	0.92	0.28	0.69	0.68	0.67
Fall Conv. Urea vs. Spring Conv. Urea		0.21	0.56	0.93	0.94	0.07	0.96	0.22	0.21
Fall NBPT-DCD Ureavs.FallCaNitrate		0.59	0.20	0.44	0.48	0.27	0.17	0.09	0.09
Fall Ca Nitrate vs. Fall Conv. Urea		0.38	0.69	0.50	0.54	0.04	0.31	0.04	0.04

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth. Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \le 0.05$.

Table 2.10. Effect of fertilizer form, additives and timing on the apparent recovered fertilizer N and overall efficiency of recovered fertilizer N in the aboveground portion of the spring wheat (grain and straw) and soil (0-120 cm Oak Bluff and Brandon, MB 0-90 cm Indian Head, SK) at maturity.

Site and Treatment		**2005/06**	**2006/07**
Oak Bluff		**Efficiency of recovered fertilizer N in soil and plant (%)**	
Fall Banded NBPT-DCD Urea		52[z]	58ab
Fall Banded Conventional Urea		59	66a
Fall Banded Calcium Nitrate		16	15c
Spring Banded Conventional Urea		68	24bc
ANOVA	***df***	***P>F***	
Trt	4	0.26	0.04
Block	3	0.04	0.01
C.V. (%)		100	102
Contrasts		***P>F***	
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.81	0.67
Spring Conv. Urea vs. Fall Conv. Urea		0.73	0.04
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.56	0.07
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.19	0.03
Fall Ca Nitrate vs. Fall Conv. Urea		0.13	0.02
Brandon			
Fall Banded NBPT-DCD Urea		31	60
Fall Banded Conventional Urea		64	79
Fall Banded Calcium Nitrate		34	85
Spring Banded Conventional Urea		28	45
ANOVA	***df***	***P>F***	
Trt	4	0.37	0.88
Block	3	0.16	0.56
C.V. (%)		88	104
Contrasts		***P>F***	
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.17	0.74
Spring Conv. Urea vs. Fall Conv. Urea		0.13	0.56
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.90	0.80
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.90	0.66
Fall Ca Nitrate vs. Fall Conv. Urea		0.20	0.91
Indian Head			
Fall Banded NBPT-DCD Urea		19	73
Fall Banded Conventional Urea		27	61
Fall Banded Calcium Nitrate		60	82
Spring Banded Conventional Urea		31	72
ANOVA	***df***	***P>F***	
Trt	4	0.66	0.18
Block	3	0.22	0.002
C.V. (%)		146	30
Contrasts		***P>F***	
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.82	0.20
Spring Conv. Urea vs. Fall Conv. Urea		0.90	0.23
Fall NBPT-DCD Urea vs. Spring Conv. Urea		0.72	0.93
Fall NBPT-DCD Urea vs. Fall Ca Nitrate		0.26	0.31
Fall Ca Nitrate vs. Fall Conv. Urea		0.36	0.04

[z] Assumed bulk density of 1.24 g cm^{-3} for 0-15 cm and 1.33 g cm^{-3} 15-30 cm depth Mean values within the same site year and column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Overall, there was little agronomic benefit to apparent recovered fertilizer from the addition of the urease and nitrification inhibitors. The relatively high FUE from the fall banded calcium nitrate treatment at half the site years also indicates that denitrification may not consistently cause large losses of fall applied nitrogen fertilizer under Prairie conditions. Furthermore, at maturity, fertilizer did not appear to move below the root zone as the majority of the fertilizer N was found in the 0-60 cm depth demonstrating that leaching did not contribute significantly to N loss in these medium to fine textured soils. Due to evidence for small overall losses at most sites, the remainder of the fertilizer applied was likely immobilized. Under these conditions, delaying nitrification may not result in increased apparent recovered fertilizer N.

2.5 Conclusions

In this study, agronomic performance of spring wheat was generally not affected by timing of application and the use of inhibitors. The fall banded urea treatments produced similar yields and nitrogen content as the spring banded conventional urea at all site years except for Oak Bluff 2006/07, demonstrating little loss of fall-applied fertilizer at most sites. At Oak Bluff 2006/07, the lower efficiency of recovered fertilizer N in the fall banded calcium nitrate treatment indicated that denitrification likely occurred due to the saturated conditions during spring at this site. The efficiency of the N fertilizer was likely reduced mainly through immobilization because sub-surface banding the fertilizer nearly eliminated ammonia volatilization and there was little evidence that fertilizer was lost as nitrous oxide or leaching. Under these conditions, there was little agronomic difference between fall and spring banded fertilizer. With little denitrification of fall banded urea fertilizer, the use of urease and nitrification inhibitors to prevent fertilizer loss during denitrification events of the spring thaw period may show little benefits in most situations. However under certain conditions, the use of urease and nitrification inhibitors have effectively increased yield and N uptake and decreased nitrogen loss. When urea is broadcasted without incorporation, for example, the addition of urease and/or nitrification inhibitors has slowed fertilizer hydrolysis and nitrification allowing the fertilizer to move at depth reducing contact with the atmosphere and N loss. Furthermore, broadcasting N fertilizer with the urease inhibitor NBPT has been shown to reduce total ammonia loss by up to 88 % throughout the duration of a field study (Rawluk et al. 2001). The addition of the nitrification inhibitor DCD to broadcasted urea also increased the N content of winter wheat compared to broadcasted conventional urea (Rao and Popham 1999). The addition of inhibitors has also been beneficial under wet conditions. Under conditions favourable for leaching, there was evidence of slowed nitrification and increased N uptake (Rao and Popham 1999). Slowing of nitrification with the addition of NBPT and DCD has also been beneficial with early fall banded urea applied in depressional areas (Tiessen et al. 2006). Due to the relatively late dates of fall application, well-drained landscape positions and lack of excessive moisture at most site years in the present study, however, the addition of the urease inhibitor NBPT and nitrification inhibitor DCD demonstrated little agronomic advantage over conventional urea.

2.6 References

Agriculture and Agri-Food Canada. 2004. Fertilizer and pesticide management in Canada. Available at: http://dsp-psd.pwgsc.gc.ca/Collection/Statcan/21-021-M/21-021-MIE2004002.pdf.

Amberger, A. 1989. Research on dicyandiamide as a nitrification inhibitor and future outlook. Commun. in Soil Sci. Plant. Anal. **20**: 1933-1955.

Aulakh, M. S. and Rennie, D. A. 1984. Transformations of fall-applied nitrogen-15-labelled fertilizers. Soil Sci. Soc. Am. J. **48**: 1184-1189.

Aluakh, M.S. and Rennie, D. A. 1986. Nitrogen transformations with special reference to gaseous N losses from zero-tilled soils of Saskatchewan, Canada. Soil Tillage Res. **7**: 157-171.

Fenn, L. B. and Hossner, L. R. 1985. Ammonia volatilization from ammonium or ammonium-forming nitrogen fertilizers. Adv. Soil Sci. **1**: 123-169.

Grant, C. A., Brown, K. R., Racz, G. J. and Bailey, L. D. 2001. Influence of source, timing, and placement of nitrogen on grain yield and nitrogen removal of durum wheat under reduced- and conventional- tillage management. Can. J. Plant Sci. **81**: 17-27.

Greenberg, A. E., Clesceri, L. S., Eaton, A. D. and Franson, M. A. H. 1998. Standard Methods for the Examination of Water and Wastewater. **20 ed.** American Public Health Association.

Heany, D. J. and Nyborg, M. 1988. Overwinter transformations of nitrate derived from soil and ^{15}N-labeled potassium nitrate. Soil Sci. Soc. Am. J. **52**: 667-671.

Hultgreen, G. and Leduc, P. 2003. The Effect of Nitrogen Fertilizer Placement, Formulation, Timing, and Rate on Greenhouse Gas Emissions and Agronomic Performance: Saskatchewan Department of Agriculture and Food. Final Report Project No. 5300G, ADF# 19990028 – Regina, Saskatchewan, Canada.

Malhi, S.S., Grant, C. A., Johnston, A. M. and Gill K. S. 2001. Nitrogen fertilization management for no-till cereal production in the Canadian Great Plains: a review. Soil Tillage Res. **60**: 101-122.

Malhi, S. S., Nyborg, M, and Solberg, E. D. 1996. Influence of source, method of placement and simulated rainfall on the recovery of ^{15}N-labelled fertilizers under zero tillage. Can. J. Soil. Sci. **76**: 93-100.

Malhi, S. S., Nyborg, M. and Harapiak, J. T. 1995. Recovery of ^{15}N-labelled fertilizers applied to bromegrass on a thin black chernozem soil. Can J. Soil Sci. **75**: 539-542.

Malhi, S. S. and Nyborg, M. 1990. Efficiency of fall-applied urea for barley: influence of date of application. Fert. Res **22**: 141-145.

Malhi, S.S. and Nyborg, M. 1985. Methods of placement for increasing the efficiency of n fertilizers applied in the fall. Agron. J. **77**: 27-32.

Malhi, S. S. and Nyborg, M. 1984. Inhibiting nitrification and increasing yield of barley by band placement of thiourea with fall-applied urea. Plant. Soil **77**: 193-206.

Malhi, S. S. and Nyborg, M. 1979. Increasing the efficiency of fall-applied urea fertilizer by placing in big pellets or in nests. Plant. Soil **52**: 461-465.

Tiessen, K. H. D., Flaten, D. N., Bullock, P. R., Burton, D. L., Grant, C. A. and Karamanos, R. E. 2006. Transformation of fall-banded urea: application date, landscape position, and fertilizer additives effects. Agron. J. **98**: 1460-1470.

Tiessen, K. H. D., Flaten, D. N., Grant, C. A., Karamanos, R. E. and Entz, M. H. 2005. Efficiency of fall-banded urea for spring wheat production in Manitoba: Influence of application date, landscape position and fertilizer additives. Can. J. Soil Sci. **85**: 649-666.

Tiessen, K. H. D. 2003. Efficiency of fall-banded urea fertilizer in Manitoba: Effect of application date, landscape position and fertilizer additives. MSc. Thesis, University of Manitoba, Winnipeg, MB, Canada, pp. 413.

Rao, S.C. and Popham, T. W. 1999. Urea placement and nitrification inhibitor effects on growth and nitrogen accumulation by no-till winter wheat. Crop Science **39**: 1115-1119.

Rawluk, C. D. L., Grant, C. A. and Racz, G., J. 2001. Ammonia volatilization from soils fertilized with urea and varying rate of urease inhibitor NBPT. Can. J. Soil Sci. **81**: 239-246.

Röver, M., Heinemeyer, O. and Kaiser, E-A. 1998. Microbial induced nitrous oxide emissions from an arable soil during winter. Soil Bio. Biochem. **30**: 1859-1865.

Watson, C. J., Miller, H., Poland, P., Kilpatrick, D. J., Allen, M. D., Garrett, M. K., and Christianson, C. B. 1994. Soil Properties and the ability of the urease inhibitor *N*-(n-butyl) thosphosphoric triamide (nBTPT) to reduce ammonia volatilization from surface-applied urea. Soil Biol. Biochem. **26**: 1165-1171.

Yadvinder-Singh and Beauchamp, E.G. 1988. Response of winter wheat to fall-applied large urea granules with dicyandiamide. Can J. Soil Sci. **68**: 133-142.

Yeomans, J. C. 1991. Inhibition of nitrogen transformations in soil: Potentials and limitations for agriculture. Trends in Soil Sci. **1**: 127-158.

3.0 THE EFFECT OF NITROGEN FERTILIZER ADDITIVES AND APPLICATION TIMING ON NITROUS OXIDE EMISSIONS FROM SOIL

3.1 Abstract

A two year field study was conducted to evaluate incorporating urea with a urease and nitrification inhibitor to reduce nitrous oxide from fall banded fertilizer. The study was conducted at three sites in the Canadian Prairies, near Winnipeg, MB, Brandon, MB and Indian Head, SK, using vented static chambers. Nitrous oxide monitoring began following fertilizer application and continued until freeze-up. Sampling resumed at spring thaw and continued until four weeks after planting. Yearly cumulative emissions of nitrous oxide emissions from fertilizer treatments were very low and not significantly different from emissions from unfertilized control treatments. Cumulative yearly emissions of N_2O were similar from all treatments, including the control, at five of six site years. As a result, yearly cumulative emissions were also unaffected by fertilizer source, timing or the addition of inhibitors.

3.2 Introduction

The atmospheric concentration of nitrous oxide has steadily increased at a rate of 0.2 to 0.3% yr^{-1} since the beginning of industrialization and this increase is primarily due to agricultural activities (IPCCa 2007; IPCCb 2007) with synthetic fertilizers responsible for 24% to 35% of cropland nitrous oxide emissions in North America (Snyder et al. 2009). Nitrous oxide, with a global warming potential approximately 300 times that of carbon dioxide, contributes not only to climate change; it is also a major source of ozone-depleting nitric oxide and nitrogen dioxide in the stratosphere (IPCCa 2007). Nitrogen is generally the most limiting of the plant macronutrients in agricultural systems and synthetic production of nitrogen fertilizer has facilitated expanding food production for an increasing global population. The continued increase in synthetic fertilizer use for global food production results in potentially substantial N_2O losses to the atmosphere.

Nitrous oxide is emitted through both the nitrification and denitrification processes of the nitrogen cycle. During the nitrification process, where ammonia is biologically oxidized to nitrate by chemoautotrophic bacteria ubiquitous to the soil environment, nitrous oxide is emitted when hydroxylamine is hydrolyzed (Subbarao et al. 2006). N_2O is also an obligatory intermediate byproduct of the denitrification process as NO_3^- is reduced (Bremner 1997). Nitrification occurs under aerobic conditions while denitrification is an anaerobic process. The dominant process responsible for nitrous oxide emissions is, therefore, related to the oxygen status of the soil. Under aerobic conditions, the addition of ammoniacal N can cause a much larger emission of nitrous oxide than from the equivalent addition of nitrate; however, at higher moisture contents, the reverse is true (Aulakh et al. 1984). The pattern of nitrous oxide emitted is also governed by temperature, soil available N and water-soluble organic C (Lemke et al. 1998). The ability for nitrous oxide to be emitted at low temperatures is inconsistent, with studies demonstrating both few emissions (Lemke et al. 1998) as well as significant emissions (Malhi and Nyborg 1979; Röver et al. 1998) at temperatures close to freezing, although production may continue throughout the winter period at deep depths (Burton and Beauchamp 1994).

Fertilizer induced nitrous oxide emissions will vary with form and rate of fertilizer applied. Nitrous oxide emissions have been shown to increase as the rate of application increases. Increasing the rate of fertilizer applied from 75 kg ha^{-1} to 450 kg ha^{-1} resulted in an average 2.87 kg ha^{-1} greater fertilizer induced emissions of N_2O-N from anhydrous ammonia (Breitenbeck and Bremner 1986). Nitrous oxide production was greater from urea than ammonium sulphate, ammonium nitrate, and calcium nitrate under aerobic conditions where nitrification dominated (Tenuta and Beauchamp 2003). Nitrous oxide emissions from nitrate based fertilizers may exceed those of ammoniacal forms with the difference increasing with increased saturated conditions (Snyder et al. 2009). Emissions may be elevated from nitrification of ammoniacal fertilizers when oxygen is not limited, while vulnerability to denitrification events intensifies with increased fertilizer found in the nitrate form, whether nitrate is applied directly or through the transformation of ammoniacal forms of fertilizer (Subbarao et al. 2006).

In the Canadian Prairies, urea fertilizer is often applied in the fall and fertilizer efficiency is generally less than when fertilizer is applied in the spring (Aulakh and Rennie 1984; Malhi and Nyborg 1990; Malhi and Nyborg 1992). One series of processes responsible for reduced efficiency of ammoniacal fertilizer applied in the fall is nitrification in the fall and subsequent denitrification the following spring. As much as 70% of the fall-applied fertilizer applied can be lost during the thaw period, resulting in significant emissions of N_2O during this period (Röver et al. 1998). Several processes have been identified responsible for emissions of N_2O during soil thawing including the physical release of trapped gas accumulated at depth (Burton and Beauchamp 1994), increased carbon availability from microorganisms or detritus made available during the freeze thaw cycle (Wagner-Riddle and Thurtell 1998; Christenson and Tiedje 1990), and an increased ratio of N_2O:N_2 from biological denitrification with decreasing soil temperatures (Tenuta and Sparling 2011).

Fertilizer efficiency has consistently increased when fertilizer is placed in bands or nests in comparison to broadcast and incorporated (Malhi and Nyborg 1984; Malhi and Nyborg 1985; Malhi and Nyborg 1990b; Malhi et al. 2001). Banding of fall-applied N fertilizer has increased N recovery, yield and N uptake the following spring, demonstrating reduced loss compared to fall broadcast and incorporation (Malhi and Nyboorg 1985). Higher recovery is the result of reduced nitrification in the fall and subsequent losses during the spring thaw as fertilizer contact with soil and soil microorganisms is decreased and a toxic environment is created due to high pH and osmotic pressure within the band (Malhi and Nyborg 1984).

Inhibitors have the ability to delay the transformation of fertilizer after application resulting in increased fertilizer remaining in the ammoniacal form, a form less susceptible to leaching and denitrification losses. Urease inhibitors slow urea hydrolysis, retaining the fertilizer in the urea form (Rawluk et al. 2001) by either obstructing the activity of the urease enzyme or interfering with the metabolism of the soil microorganisms responsible for urease production (Yeomans 1991). N-(n-butyl) thiophosphoric triamide (NBPT) slows hydrolysis by converting to its oxon analog N-(n-butyl) phosphoric triamide (NBPTO) and competing with urea for active sites on the urease enzyme complex (Yeomans 1991). The delay of nitrification prior to crop uptake can reduce nitrous oxide emissions directly by reducing loss due to nitrification as well as reducing NO_3^- substrate available for denitrification (McTaggart et al. 1997). Several synthetic compounds have been identified as nitrification inhibitors, which suppress the activities of nitrifiers in the soil. Of the compounds, nitrapyrin (N-Serve©) and dicyandiamide (DCD) have gained considerable use (Subbarao et al. 2006). Dicyandiamide is highly water soluble, has high nitrogen content, and, unlike nitrapyrin, is non-volatile (Subbarao et al. 2006). Therefore, DCD is well suited to application with granular urea fertilizer. Dicyandiamide inhibits the first stage of nitrification, the oxidation of ammonium to nitrite (Amberger 1989). Dicyandiamide can persist in the soil for an average of one to three months, and its persistence is dependent on temperature, water content, organic matter, and the pH of the soil (Amberger 1989). Decomposition will proceed more rapidly at higher temperatures, increased moisture content, and in soils high in organic matter (Subbarao et al. 2006). Fall banded urea with a urease and nitrification inhibitor has demonstrated reduced nitrification in comparison to conventional urea (Tiessen 2005); however, nitrous oxide emissions from double inhibited urea applied in the fall have not been investigated. The objective of this field study was to investigate the effect of adding a urease and nitrification inhibitor with urea banded in the fall on nitrous oxide emissions with the hypthothesis that nitrous oxide emissions will be lowered by the addition of inhibitors.

3.3 Materials and Methods

3.3.1 Experimental Design and Treatments

Two years of field trial sites were located near Oak Bluff, MB, at the Zero-Till Research Farm near Brandon, MB and near Indian Head, SK. Select soil properties are given in Table 3.1. Four replicates of five treatments were applied at each site in a randomized complete block design.

Table 3.1. Selected properties of soils at research sites.

Characteristics	Depth (cm)	Oak Bluff	Oak Bluff	Brandon	Brandon	Indian Head	Indian Head
		Fall 2005	Fall 2006	Fall 2005	Fall 2006	Fall 2005	Fall 2006
Soil Series		Red River - Osborne Clay	Red River - Osborne Clay	Newdale Clay Loam	Newdale Clay Loam	Oxbow Loam	Oxbow Loam
Soil texture	0-15	clay	clay	clay loam	clay loam	loam	loam
pH	0-15	7.6	8.2	7.3	6.7	7.0	7.2
Organic Matter ($g\ kg^{-1}$)	0-15	52.3	33.0	47.0	50.0	19.0	22.0
Water soluble NO_3 - N ($kg\ ha^{-1}$)^z	0-60	30.0	37.0	10.0	52.0	6.0	16.0
Water soluble SO_4 - S ($kg\ ha^{-1}$)^z	0-60	50.0	160+	160+	160+	30.0	44.0
Olsen Extractable P ($kg\ ha^{-1}$)^z	0-15	29.0	6.3	19.0	42.0	26.0	14.0

^{Z} Assumed bulk density of 1.33 $g\ cm^{-3}$.

General weather conditions for Winnipeg, Brandon, and Indian Head, including mean monthly air temperatures and total monthly precipitation, were obtained from Environment Canada's archived weather data (Table 3.2). Precipitation was generally below average at the Oak Bluff and Indian Head sites in year one. Precipitation was greater in year two at the Oak Bluff site compared to year one with greater precipitation during the spring period. Precipitation was near average both site years at the Brandon site.

Table 3.2. Air temperature and precipitation at Oak Bluff, Brandon and Indian Head.[z]

	Oak Bluff			Brandon			Indian Head		
	Air temperature °C								
	Average	2005/06	2006/07	Average	2005/06	2006/07	Average	2005/06	2006/07
October	5.3	6.9	3.5	4.4	5.3	2.1	4.6	4.4	1.2
November	-5.3	-2.9	-4.6	-6.1	-4.0	-1.0	-5.4	-3.8	-6.3
December	-14.4	-9.1	-9.7	-14.9	-9.5	-4.9	-13.1	-9.6	-10.2
January	-17.8	-7.4	-16.0	-18.0	-7.2	-15.1	-16.2	-6.4	-13.1
February	-13.6	-16.0	-18.8	-13.8	-14.9	-12.8	-12.3	-12.9	-17.7
March	-6.1	-6.1	-5.1	-6.4	-6.5	-5.2	-5.4	-6.5	-3.4
April	4.0	9.4	4.2	3.5	8.2	4.1	4.0	7.3	3.4
May	12.0	12.0	12.2	11.4	11.6	10.8	11.4	11.2	9.6
June	17.0	18.2	17.3	16.1	17.2	16.3	16.1	16.0	15.0
July	19.5	21.5	21.3	18.4	19.9	20.6	18.4	17.9	19.9
August	18.5	19.8	17.6	17.5	18.9	16.5	17.5	17.4	15.5
September	12.3	13.6	13.2	11.4	12.1	11.9	11.4	11.6	11.1
	Precipitation (mm)								
	Average	2005/06	2006/07	Average	2005/06	2006/07	Average	2005/06	2006/07
October	36.0	18.5	11.0	27.7	21.4	15.0	24.3	6.6	23.5
November	25.0	43.0	17.5	17.7	34.1	38.8	17.4	34.9	60.3
December	18.5	24.5	36.0	19.2	27.6	22.0	25.3	24.7	11.8
January	19.7	25.5	11.5	18.0	12.2	11.4	19.7	13.1	6.3
February	14.9	5.0	19.0	14.1	13.2	30.4	16.2	6.3	23.0
March	21.5	36.5	57.7	22.2	33.4	57.8	24.1	10.6	23.7
April	31.9	16.5	15.9	31.0	46.2	4.6	24.6	73.2	8.8
May	58.8	44.5	72.5	52.7	41.0	84.4	55.7	39.0	46.0
June	89.5	29.0	123.0	74.4	81.6	80.8	78.9	80.4	46.2
July	70.6	10.5	60.5	75.8	7.8	51.4	67.1	4.4	50.6
August	75.1	52.0	24.5	69.2	76.4	49.2	52.7	11.6	62.8
September	52.3	41.5	30.0	49.9	74.6	19.6	39.5	54.8	24.0
Total	513.8	347.0	479.1	471.9	469.5	465.4	445.5	359.6	387.0

[z] Source: nearby Environment Canada weather stations in Winnipeg, Brandon, and Indian Head www.weatheroffice.gc.ca.

The study was conducted using Canadian Western Red Spring wheat (*Triticum aestivum* L. cv. AC Superb) seeded at a rate of 134 kg ha^{-1}. Treatments consisted of nitrogen fertilizer applied as fall banded NBPT-DCD formulated urea (SuperU®), fall banded conventional urea, fall banded calcium nitrate, spring banded conventional urea and a control where no nitrogen fertilizer was added. Fertilizer was applied at a rate of 80 kg N ha^{-1} at Oak Bluff, MB and 60 kg N ha^{-1} at Brandon, MB and Indian Head, SK. The fertilizer was banded at a depth of 7.5 cm with 20 cm spacing at Oak Bluff, a depth of 5 cm with 20 cm spacing at Brandon, and a depth of 7.5 cm and 30 cm spacing at Indian Head. At Oak Bluff, fertilizer was applied using a 1.8 m wide plot-scale air seeder with Flexi-Coil openers, at Brandon with a 3-pt hitch air seeder equipped with SEED-HAWK hoe openers, and at Indian Head with a Conservapak® seeder. Fall fertilizer treatments were applied during the first season on October 13, 2005 at Oak Bluff, October 14, 2005 at Brandon, and October 11, 2005 at Indian Head; during the second season fertilizer was applied on October 6, 2006 at Oak Bluff, October 12, 2006 at Brandon, and October 3, 2006 at Indian Head. Subsequent to application, band locations were marked with stakes to permit precise sampling of soil and placement of gas monitoring chambers.

3.3.2 Nitrous oxide monitoring

Following fertilizer application, rectangular static vented chambers (0.0120 m^3) were inserted into the soil surface on each plot to a depth of 5 cm centered over a fertilizer band. Oak Bluff and Brandon chambers were 40 cm in length, 20 cm in width and 15 cm in height. Indian Head chambers were 27 cm in length and 30 cm in width due to the wider band spacing at this site. During the first season, nitrous oxide monitoring began October 14, October 16, and October 12, 2005 and during the second season, on October 9, October 13 and October 4 at Oak Bluff, Brandon and Indian Head respectively and continued until freeze-up. Sampling resumed at spring thaw and continued until four weeks after planting. Nitrous oxide sampling was conducted up to three times per week. At time of sampling, lids fitted with rubber septums were placed onto the chambers and secured with bricks in year one. The lids were secured using elastic bands in year two to reduce the risk of chamber failure. Sampling began immediately after placing the lids on the chambers and at intervals of 15, 30, and 45 minutes afterwards. To sample, an empty syringe was inserted into the septum, and a 10-mL air sample was collected from the chamber headspace and injected into an evacuated

6-mL Exetainer® vial (Labco Limited, Buckinghamshire, UK). The samples were analyzed by automated gas chromatograph (Varian 3800, Mississauga, ON). Soil temperature at 2.5 cm and 7.5 cm depths was recorded at each sampling period and soil samples (0-15 cm) were taken from each plot weekly to determine the soil gravimetric moisture content.

3.3.3 Soil Ammonium and Nitrate N

Soil was sampled (0-30 cm) weekly from on and between the fertilizer bands using JMC "Backsaver" soil probed and Dutch augers. In the fall, samples were collected until three weeks after fertilizer application. Following planting, soil was sampled until four weeks after planting. Two fertilizer bands were sampled per plot with five samples collected from each band and composited. Soil was collected in a W pattern directly from the band, 2 cm and 4 cm on either side of the band. In addition, five soil samples were collected between the fertilizer bands from each plot and composited. All samples were refrigerated until air dried at 40 °C, then ground to pass through a 2 mm sieve. Soil ammonium, nitrite and nitrate N was extracted by shaking 5 g of ground soil with 25 mL of 2 M KCl solution for 30 minutes. The solution was centrifuged for one minute 30 seconds at 2800 rpm and 10 mL was extracted by pipette. The concentrations of (NO_3^- + NO_2^-) and NH_4^+ in the extract were determined by automated cadmium reduction method and automated phenate colorimetric method, respectively, using a Technicon Autoanalyzer II Single-Channel Colorimeter (Greenberg et al. 1998).

3.3.4 Data and Statistical Analysis

Nitrous oxide flux rates were calculating using the concentration of gas, the molecular mass of nitrogen, the chamber area and volume, the air temperature at the time of sampling and atmospheric pressure. The flux rate of nitrogen was determined using a linear regression plot of the mass of gas per area (µg-N_2O m^{-2}) versus time. This was calculated by converting the mass of gas in the chamber (g N_2O) to the mass of gas per chamber area (µg- N_2O m^{-2}). Data filtering of the fluxes was carried out by examining the R^2 of the regression line for N_2O production. If a point was inconsistent with other points, resulting in an R^2 value lower than 0.9, and this erratic pattern mirrored that of CO_2, the point was removed. Points were not removed simply because the mass of gas per area was very low, as this was considered to be the result of natural background variation. A minimum of three or four points were used to calculate the regression line for N_2O production within each chamber. Regression tests ($\alpha = 0.05$) were performed to determine the minimum calculated rate of nitrous oxide production that was significantly different from 0. Approximately 120 chamber fluxes were used for these tests. The minimum measurable nitrous oxide flux significantly different from zero was 0.0022 (µg-N_2O m^{-2} s^{-1}). The cumulative N_2O emissions throughout the sampling period were calculated by the summation of daily estimates of emissions by linear interpolation between sampling dates. Statistical analyses were performed using the Proc Mixed procedure of the Statistical Analysis System (SAS) (SAS 9.1.3). The data was tested for normality and skewness using the Univariate function of SAS. The majority of the nitrous oxide and yield data was normally distributed and transformation was not necessary. A randomized complete block design was used for the ANOVA. The least significant difference (LSD) test was used to compare the fertilizer treatment means and single degree of freedom contrasts were also performed on all data. A probability level (α) of 0.05 was used as the significance threshold. Associations between N_2O production and soil parameters including soil temperature at a depth of 7.5 cm, soil (NO_3^- + NO_2^-) and NH_4^+, and volumetric moisture content were determined using Spearman rank correlation analysis.

3.4 Results and Discussion

3.4.1 Daily Pattern of N_2O Emissions

Nitrous oxide emissions were low throughout the study from all treatments, with production below the minimum measurable nitrous oxide flux on most sampling days (data not presented). In the fall, following fertilization, daily N_2O emissions from the conventional urea treatment periodically increased above background levels at Oak Bluff 2005/06 and 2006/07 and at Brandon 2005/06. Fall fertilization did not increase daily N_2O emissions from any treatments at Indian Head in either fall period. Fall banded NBPT-DCD urea did not increase daily N_2O emissions above those for the control at any of the six site years. Apart from one sampling day at Oak Bluff 2006/07 and Brandon 2005/06, calcium nitrate did not increase N_2O emissions during the fall period, suggesting that nitrification was the dominant source of nitrous oxide emissions. Although N_2O emissions are highly episodic, other studies have shown that fertilization generally results in elevated N_2O emissions above background levels. Emissions were elevated within a week following fertilization of a field study in Montana and continued for more than ten weeks when fertilizer was applied in the fall (Dusenbury et al. 2008). The reasons for the low frequency of significant daily emissions from fall fertilization in our study are not known.

During the spring period prior to planting, the number of sampling days with measurable emissions of N_2O increased for most fall banded fertilizer treatments. One exception to this trend was at Oak Bluff, where the fall banded calcium nitrate treatment did not increase emissions during the spring thaw period of 2005/06. However, increased emissions from the ammoniacal fertilizers at this site suggest that nitrous oxide emissions were more likely from nitrification than from denitrification. All fall banded treatments emitted N_2O above background levels during the second spring at Oak Bluff and Brandon, suggesting that denitrification events were a significant source of N_2O during the second spring thaw period. Greater precipitation during the second field season may explain the increased emissions from the treatments (Table 3.2); in addition, the Oak Bluff site was located in a poorly drained landscape position for the second year. In studies in Montana, Dusenbury et al. (2008) also found elevated nitrous oxide emissions from soil with greater average moisture contents. Significant year to year variation in N_2O emissions was also observed in a Manitoba field study, with elevated rates of N_2O emissions during the spring from fall applied fertilizer and highest emissions during the wettest site year (Burton et al. 2008).

At all site years, the spring banded conventional urea treatment increased nitrous oxide emission above background levels following application. This is consistent with previous studies in the prairies which showed increased N_2O emissions following fertilizer application in the spring (Lemke et al. 1999). In our studies, soil moisture contents were not excessive after planting and nitrous oxide emissions from the fall banded calcium nitrate treatment did not increase during this period suggesting that nitrification was the major source of nitrous oxide from the spring banded conventional urea treatment. Under aerobic conditions, most N_2O evolved from soil amended with ammoniacal N fertilizer can be produced by nitrifying microorganisms during the nitrification process (Blackmer et al. 1980).

Nitrous oxide flux responded to changes in soil temperature, volumetric moisture content, and inorganic N anions (Table 3.3). Nitrous oxide emissions were positively correlated with soil temperature at three of six site years and negatively correlated with soil temperature at one site year. However, the effect of volumetric moisture content and ammonium N and nitrite + nitrate N was even less consistent as a significantly negative correlation between ammonium N and nitrous oxide flux was observed at only one of six sites, and a positive correlation between nitrite + nitrate N was observed at two of the six site years. A significantly negative correlation between volumetric moisture content and nitrous oxide flux was observed at three of six site years and a significantly positive correlation was observed two of six site years. The balance and intensity of nitrification and denitrification is regulated by the oxygen availability in the soil, with nitrification dominating in soils below 60% water filled pore space (Linn and Doran 1984). At higher moisture contents, nitrification is restricted as soil pores are increasingly filled with water and the diffusion of oxygen into the soil is limited (Subbarao et al. 2006). Under these conditions, denitrification is the dominant process in which microorganisms gain energy using nitrogen as a terminal electron acceptor. A negative correlation between volumetric moisture and nitrous oxide emissions during three of six site years suggest that nitrification was a dominant source of N_2O in these cases while a positive correlation suggests that denitrification was the dominant source of nitrous oxide emissions at two site years.

Table 3.3. Spearman rank correlation analysis (r values) for N_2O flux and soil parameters.

	n	Soil Temperature	NH_4^+	$NO_2^- + NO_3^-$	Volumetric Moisture Content
Oak Bluff, MB Fall 2005-Spring	511	0.491***	-	0.095*	-0.381***
Oak Bluf, MB Fall 2006-Spring	380	0.191**	0.074	-0.066	0.200***
Brandon, MB Fall 2005- Spring	247	-0.117	0.049	-0.012	-0.021
Brandon, MB Fall 2006-Spring	440	-0.118**	-0.001	0.066	0.137**
Indian Head, SK Fall 2005-Spring	304	0.214***	0.029	0.159**	-0.267***
Indian Head, SK Fall 2006-Spring	292	0.106	0.029	0.009	-0.248***

*, **, *** Significant at P<0.05, 0.001, and 0.0001 respectively.

Nitrous oxide emissions were spatially and temporally variable throughout the sampling periods. This was similar to a study examining nitrous oxide emissions from irrigation fields in Southern Alberta, which also found high variability within treatments (Ellert and Janzen 2008). Timing and location of nitrous oxide production is influenced by several soil parameters including temperature, aeration status of the soil, N availability, and presence of microbial population. The heterogeneity of soil at the field scale results in localized production due, for example, to changes in the oxygen status of the soil, availability of substrate for microbial activity, and changes in temperature. Microsite production can occur as limited diffusion in tortuous soils can create anaerobic conditions. Variability within the landscape results in the interaction of the parameters with nitrous oxide production. Moisture regimes mediated by landscape position, for example, are controlling factors as lower oxygen status and increased concentrations of nitrate are found in footslope and depressional areas (Izaurralde et al. 2004).

3.4.2 Seasonal and Yearly Cumulative Emissions of N_2O

Total cumulative emissions ranged from -0.028 to 0.294 kg N_2O-N ha^{-1} for the entire sampling period (Table 3.4). Nitrous oxide emissions were not affected by soil type, soil characteristics, and climate with relatively small emissions at all six site years. Previous work in the Northern Great Plains region also measured emissions which were lower than expected from the international literature (Hultgreen and Leduc 2003; Dusenbury et al. 2008; Burton et al. 2008; Engel et al. 2010). In a Manitoba field study, average cumulative N_2O emissions were 0.82 and 0.21 kg N ha^{-1} at Winnipeg and Brandon field sites respectively (Burton et al. 2008).

Cumulative yearly emissions of N_2O were similar from all treatments, including the control, at five of six site years. The only effect of fertilization on yearly emissions was at Indian Head 2006/07, where emissions from the fall calcium nitrate treatment were smaller than all other treatments (Table 3.4). Yearly emissions from fall banded NBPT-DCD urea were not significantly different from those emitted by fall banded conventional urea, spring banded conventional urea or the control at any site year. However, the temporal and spatial variability within treatments were large and may have obscured some possible treatment effects. Part of this variability may be the result of chamber size and number, as well as their location relative to the fertilizer bands. In a study comparing nitrous oxide measurements from chambers of various sizes, coefficients of variation decreased with increasing chamber radius as the chamber encompassed more productive areas and inherent variability was reduced (Kaiser et al. 1996). Variability within smaller chambers, such as those used in the present study, may result in the lack of measured treatment effects. In other field studies where N fertilization increased N_2O emissions, the addition of inhibitors reduced the emissions significantly (Snyder et al. 2009, Yeomans 1991). Other research has demonstrated that

Table 3.4a. Seasonal and yearly average cumulative nitrous oxide emissions at Oak Bluff.

		2005/06				2006/07			
Site and Treatment		**Fall**	**Spring Pre-Seeding**	**Post-Seeding**	**Total**	**Fall 2006**	**Spring Pre-Seeding**	**Post-Seeding**	**Total**
Oak Bluff		**Average Cumulative Flux (kg N_2O-N ha^{-1})**							
Control		0.010	0.024	0.067	0.102	0.008	0.083	0.033	0.124
Fall Banded NBPT-DCD Urea		-0.028	0.034	0.075	0.080	0.004	0.167	0.028	0.199
Fall Banded Conventional Urea		0.020	0.044	0.049	0.113	0.204	0.163	0.048	0.203
Fall Banded Calcium Nitrate		0.009	0.009	0.066	0.084	0.019	0.089	0.005	0.113
Spring Banded Conventional Urea		-0.012	0.023	0.178	0.189	0.007	0.069	0.178	0.254
ANOVA	***df***	***Pr>F***							
Trt	4	0.35	0.41	0.06	0.39	0.34	0.16	0.07	0.49
Block	3	0.49	0.82	0.65	0.56	0.18	0.47	0.67	0.78
C.V. (%)		60349	89	79	72	96	64	159	64
Contrasts		***Pr>F***							
Fertilized treatments vs. Control		0.52	0.83	0.47	0.75	0.83	0.32	0.49	0.38
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.08	0.56	0.54	0.60	0.06	0.93	0.73	0.86
Spring Conv. Urea vs. Fall Conv. Urea		0.23	0.26	0.01	0.22	0.16	0.07	0.04	0.44
Fall Ca Nitrate vs. Fall NBPT-DCD Urea		0.16	0.19	0.82	0.97	0.75	0.12	0.70	0.34
Fall Ca Nitrate vs. Fall Conv. Urea		0.68	0.07	0.70	0.63	0.11	0.14	0.47	0.45

[z] Mean values within the same column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 3.4b. Seasonal and yearly average cumulative nitrous oxide emissions at Brandon.

		2005/06				2006/07			
Site and Treatment		**Fall**	**Spring Pre-Seeding**	**Post-Seeding**	**Total**	**Fall 2006**	**Spring Pre-Seeding**	**Post-Seeding**	**Total**
Brandon		**Average Cumulative Flux (kg N_2O-N ha^{-1})**							
Control		0.004	-0.005	-0.0001b[z]	-0.001	0.006	0.153	0.019	0.177
Fall Banded NBPT-DCD Urea		0.012	0.085	0.001b	0.098	-0.001	0.205	0.009	0.212
Fall Banded Conventional Urea		0.024	0.029	0.001b	0.055	0.003	0.073	0.009	0.085
Fall Banded Calcium Nitrate		0.013	0.060	0.002b	0.075	0.005	0.268	0.021	0.294
Spring Banded Conventional Urea		0.003	0.014	0.008a	0.025	0.001	0.102	0.012	0.114
ANOVA	***df***	***Pr>F***							
Trt	4	0.16	0.60	0.01	0.50	0.24	0.33	0.69	0.65
Block	3	0.69	0.73	0.07	0.73	0.66	0.33	0.13	0.35
C.V. (%)		113	213	198	156	165	111	113	84
Contrasts		***Pr>F***							
Fertilized treatments vs. Control		0.21	0.30	0.02	0.19	0.16	0.59	0.47	0.62
FallNBPT-DCDUrea vs. Fall Conv. Urea		0.19	0.38	0.94	0.47	0.22	0.22	0.95	0.19
Spring Conv. Urea vs. Fall Conv. Urea		0.03	0.80	0.01	0.63	0.57	0.93	0.83	0.75
Fall Ca Nitrate vs. Fall NBPT-DCD Urea		0.98	0.69	0.78	0.70	0.08	0.72	0.27	0.55
Fall Ca Nitrate vs. Fall Conv Urea		0.19	0.61	0.72	0.74	0.54	0.12	0.30	0.51

[z] Mean values within the same column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Table 3.4c. Seasonal and yearly average cumulative nitrous oxide emissions at Indian Head.

Site and Treatment		2005/06 Fall	2005/06 Spring Pre-Seeding	2005/06 Post-Seeding	2005/06 Total	2006/07 Fall 2006	2006/07 Spring Pre-Seeding	2006/07 Post-Seeding	2006/07 Total
Indian Head		**Average Cumulative Flux (kg N_2O-N ha^{-1})**							
Control		-0.009	-0.032	0.032	-0.001	0.004	0.185a	0.009	0.198a
Fall Banded NBPT-DCD Urea		-0.028	0.090	0.030	0.117	0.001	0.171a	0.027	0.199a
Fall Banded Conventional Urea		0.000	0.013	0.102	0.115	-0.001	0.152a	0.001	0.153a
Fall Banded Calcium Nitrate		0.002	-0.015	0.044	0.028	0.003	-0.069b	0.038	-0.028b
Spring Banded Conventional Urea		0.002	0.001	0.038	0.041	0.001	0.023b	0.107	0.130a
ANOVA	***df***	***Pr>F***							
Trt	4	0.53	0.59	0.57	0.40	0.75	0.001	0.08	0.04
Block	3	0.36	0.14	0.21	0.54	0.36	0.0004	0.76	0.01
C.V. (%)		583	832	145	169	302	169	151	112
Contrasts		***Pr>F***							
Fertilized treatments vs. Control		0.12	0.45	0.60	0.20	0.37	0.01	0.23	0.14
Fall NBPT-DCD Urea vs. Fall Conv. Urea		0.72	0.32	0.16	0.97	0.66	0.71	0.49	0.49
Spring Conv. Urea vs. Fall Conv. Urea		0.81	0.88	0.21	0.33	0.65	0.02	0.01	0.74
Fall Ca Nitrate vs. Fall NBPT-DCD Urea		0.54	0.19	0.81	0.24	0.59	0.0004	0.57	0.01
Fall Ca Nitrate vs. Fall Conv. Urea		0.79	0.71	0.24	0.25	0.33	0.001	0.22	0.02

[z] Mean values within the same column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

DCD applied to an imperfectly drained clay loam soil significantly reduced nitrous oxide emissions from urea by 58% (McTaggart et al. 1997).

Part of the explanation for a lack of effect of inhibitors on nitrous oxide emission may be low emissions of nitrous oxide from denitrification in our study. The application of calcium nitrate did not significantly increase nitrous oxide emissions during any site year (Table 3.4). Conversely, as mentioned earlier, emissions from the fall banded calcium nitrate treatment were significantly lower than other fertilized treatments or the control at Indian Head 2006/07. The application of nitrate based fertilizer ought to increase N_2O emissions when conditions are conducive for denitrification because 100% of the fertilizer N is in the nitrate form and immediately available. The lack of any significant increase in nitrous oxide emissions from the fall banded calcium nitrate compared to the spring banded conventional urea indicates that either denitrification was not the dominant process responsible for the release of nitrous oxide or that most of any denitrification that occurred resulted in complete reduction of nitrate to N_2.

Although nitrous oxide fluxes from all treatments were small in magnitude, the majority of annual emissions occurred during the spring thaw, with as much as 99 % of the yearly cumulative nitrous oxide emitted during the thaw period (Table 3.4). The maximum nitrous oxide emitted during this period was 0.268 kg N_2O-N ha^{-1} from the fall banded calcium nitrate treatment at Brandon 2006/07. The proportion of N_2O lost from fall fertilized treatments during the spring thaw period varied over treatment and site year; however, these proportions are generally consistent with previous studies as nitrous oxide measurements are often greatest during soil thawing (Röver et al. 1998; Dusenbury et al. 2008). In southern Ontario, for example, up to 75 % of emissions over a 28 month period occurred during spring thaw (Wagner-Riddle et al. 1997).

Yearly cumulative nitrous oxide emissions from fall banded conventional urea were similar to the spring banded conventional urea treatment. Increased time between fertilizer application and plant uptake has the potential to increase potential emissions, resulting in greater fertilizer induced nitrous oxide emissions from fertilizer applied in the fall compared to fertilizer applied in the spring (Hultgreen and Leduc 2003). However, no such differences were observed in our study.

During the post-seeding period, however, emissions from spring banded conventional urea were greater than from fall banded conventional urea at four of six site years, according to single degree of freedom contrasts (Table 3.4). The significantly greater emission from the spring banded conventional urea treatment during the post-seeding period coupled with the similar total emissions adds to the evidence that nitrification was the dominant process responsible for nitrous oxide emissions. Therefore, under the relatively dry conditions at most site years in our study, where nitrification was the major source of N_2O and where denitrification played a minor role, timing of fertilizer N banding had little influence on yearly cumulative nitrous oxide emissions.

3.5 Conclusions

Yearly cumulative emissions of nitrous oxide emissions from fertilizer treatments were very low and not significantly different from emissions from unfertilized control treatments. As a result, yearly cumulative emissions were also unaffected by fertilizer source, timing or the addition of inhibitors. Emissions from fall banded double inhibited urea were similar to those from fall banded conventional urea and fall banded calcium nitrate. None of the fall banded fertilizer treatments produced greater N_2O emissions than the control or spring banded conventional urea treatments. The small emissions of N_2O and lack of significant differences among treatments suggests that conditions were not generally favourable for N_2O production from fertilizer. In particular, the lack of significantly greater N_2O emissions from the fall banded calcium nitrate treatment, compared to all other treatments indicates that the fertilizer was not vulnerable to partial denitrification during the fall, winter and spring period.

From a seasonal perspective, nitrous oxide emissions from the spring banded conventional urea treatment was significantly greater than from the fall banded conventional urea during the post-seeding period at four of six site years while there were no significant differences between the fall banded calcium nitrate and conventional urea treatments at five of six site years, indicating that nitrification was likely the major source of N_2O. As a result, delayed nitrification from the fall banded NBPT-DCD urea produced N_2O losses that were similar to the fall and spring banded conventional urea.

3.6 References

Amberger, A. 1989. Research on dicyandiamide as a nitrification inhibitor and future outlook. Commun. In Soil Sci. Plant. Anal. **20**: 1933-1955.

Aulakh, M.S. and Rennie, D. A. 1984. Transformations of fall-applied nitrogen-15-labelled fertilizers. Soil Sci. Am. J. **48**: 1184-1189.

Aulakh, M. S., Rennie, D. A., and Paul, E. A. 1984. Acetylene and N-serve effects upon N_2O emissions from NH_4^+ and NO_3^- treated soils under aerobic and anaerobic conditions. Soil Biol. Biochem. **16**: 351-356.

Aulakh, M.S. and Rennie, D. A. 1986. Nitrogen transformations with special reference to gaseous N losses from zero-tilled soils of Saskatchewan, Canada. Soil Tillage Res **7**: 157-171.

Blackmer, A. M., Bremner, J. M and Schmidt, E. L. 1980. Production of nitrous oxide by ammonia-oxidizing chemoautotrophic microorganisms in soil. Appl. Environ. Microbiol. **40**: 1060-1066.

Burton, D.L. and Beachamp, E. G. 1994. Profile nitrous oxide and carbon dioxide concentrations in soil subject to freezing. Soil Sci. Soc. of Amer. J. **58**: 115-122.

Burton, D. L., Xinhui Li and Grant, C. A. 2008. Influence of fertilizer nitrogen source and management practice on N_2O emissions from two black chernozemic soils. Can. J. Soil. Sci. **88**: 219-227.

Breitenbeck, G. A. and Bremner, J. M. 1986. Effects of rate and depth of fertilizer placement on emission of nitrous oxide from soil fertilized with anhydrous ammonia. Biol Fertil. Soils **2**: 201-204.

Bremner, J. M. 1997. Sources of nitrous oxide in soils. Nutr. Cycling Agroecosyst. **49**: 7-16.

Christensen, S and Tiedge J. M. 1990. Brief and vigorous N_2O production by soil at spring thaw. J. of Soil Sci **41**: 1-4.

Dusenbury, M. P., Engel, R. E., Miller, P. R., Lemke, R. L. and Wallander, R. 2008. Nitrous oxide emissions from a northern great plains soil as influenced by nitrogen management and cropping systems. J. Environ. Qual. **37**: 542-550.

Elert, B.H. and Janzen, H.H. 2008. Nitrous oxide, carbon dioxide and methane emissions from irrigated cropping systems as influenced by legumes, manure and fertilizer. Can J. Soil Sci. **88**: 207-217.

Engel, R., Liang, D.L, Wallander, R and Bembenek. 2010. Influence of urea placement on nitrous oxide production from a silt loam soil. J. Environ. Qual. **39:** 115-125.

Greenberg, A. E., Clesceri, L. S., Eaton, A. D. and Franson, M. A. H. 1998. Standard methods for the examination of water and wastewater. **20 ed.** American Public Health Association.

Guiraud, G and Marol, C. 1992. Influence of temperature on mineralization kinetics with a nitrification inhibitor (mixture of dicyandiamide and ammonium thiosulphate). Bio. Fertil. Soils **13**:1-5.

Hultgreen, G. and Leduc, P. 2003. The effect of nitrogen fertilizer placement, formulation, timing, and rate on greenhouse gas emissions and agronomic performance. Final Report, Project No. 5300G, ADF#19990028, Saskatchewan Department of Agriculture and Food, Regina, SK.

IPCC 2007a. Climate change 2007: The physical science basis. International panel on climate change. Available at: http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

IPCC 2007b. Climate change 2007: synthesis report. International panel on climate change. Available at: http://www.ipcc.ch/ipccreports/ar4-syr.htm.

Izaurralde, R. C., Lemke, R. L., Goddard, T. W. McConkey, B., and Zwang, Z. 2004. Nitrous oxide emissions from agricultural toposequences in Alberta and Saskatchewan. Soil Sci. Soc. Amer. J. **68**: 1285- 1294.

Kaiser, E. A., Munch, J. C. and Heinemeyer, O. 1996. Importance of soil cover box area for the determination of N_20 emissions from arable soils. Plant Soil **181**: 185-192.

Ladha, J.K., Pathak, H., Krupnik, T. J., Six, J. and van Kessel, C. 2005. Efficiency of nitrogen fertilizer in cereal production: retrospects and prospects. Adv. Agron. **87**: 85-156.

Lemke, R. L, Izaurralde, R. C, and Nyborg, M. 1998. Seasonal distribution of nitrous oxide emissions in the Parkland region. Soil Sci. Soc. of Amer. J. **62**:1320-1326.

Linn, D. M. and Doran, J. W. 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. Soil Sci. Soc. of Amer. J. **48**: 1267-1272.

McTaggart, I. P., Clayton, H., Parker, J. and Swan, L. 1997. Nitrous oxide emissions from grassland and spring barley, following N fertiliser application with and without nitrification inhibitors. Bio. Fertil. Soil. **2**: 173-179.

Malhi, S. S. and Nyborg, M. 1979. Nitrate formation during winter from fall-applied urea. Soil Biol. Biochem. **11**: 439-441.

Malhi, S. S. and Nyborg, M. 1984. Inhibiting nitrification and increasing yield of barley by band placement of thiourea with fall-applied urea. Plant Soil **77**: 193-206.

Malhi, S. S. and Nyborg, M. 1985. Methods of placement for increasing the efficiency of N fertilizers applied in the fall. Agron. J. **77**: 27-32.

Malhi, S. S. and Nyborg, M. 1990a. Efficiency of fall-applied urea for barley: influence of date of application. Fert. Res **22**: 141-145.

Malhi, S. S. and Nyborg, M. 1992b. Recovery of nitrogen by spring barley from ammonium nitrate, urea and sulphur-coated urea as affected by time and method of application. Fert. Res. **32**: 19-25.

Malhi, S.S., Grant, C. A., Johnston, A. M. and Gill K. S. 2001. Nitrogen fertilization management for no-till cereal production in the Canadian Great Plains: a review. Soil Tillage Res. **60**: 101-122.

Snyder, C. S., Bruulsema, T. W. Jensen, T. L. and Fixen, P.E. 2009. Review of greenhouse has emissions from crop production systems and fertilizer management effects. Agri. Ecosyst. Environ. **133**: 247-266.

Subbarao, G.V., Ito, O., Sahrawat, K. L., Berry, W. L., Nakahara, K., Ishikawa, T., Watanabe, T., Suenaga, K., Rondon, M. and Rao, I. M. 2006. Scope and strategies for regulation of nitrification in agricultural systems- challenges and opportunities. Critical Rev. Plant Sci. **25**: 303-335.

Rawluk, C. D. L., Grant, C. A. and Racz, G. J. 2001. Ammonia volatilization from soils fertilized with urea and varying rate of urease inhibitor NBPT. Can. J. Soil Sci. **81**: 239-246.

Röver, M., Heinemeyer, O. and Kaiser, E-A. 1998. Microbial induced nitrous oxide emissions from an arable soil during winter. Soil Bio. Biochem. **30**: 1859-1865.

Tenuta, M. and Beauchamp, E. G. 2003. Nitrous oxide production from granular nitrogen fertilizers applied to a silt loam soil. Can J. Soil Sci. **83**: 521-532.

Tiessen, K. H. D., Flaten, D. N., Grant, C. A., Karamanos, R. E. and Entz, M. H. 2005. Efficiency of fall-banded urea for spring wheat production in Manitoba: influence of application date, landscape position and fertilizer additives. Can J. Soil Sci. **85**: 649-666.

Wagner-Riddle, C., Thurtell, G. W., Kidd, G. K., Beauchamp, E. G. and Sweetman, R. 1997. Estimates of nitrous oxide emissions from agricultural fields over 28 months**.** Can. J. Soil Sci. **77**: 135–144.

Wagner-Riddle, C. and Thurtell, G. W. 1998. Nitrous oxide emissions from agricultural fields during winter and spring thaw as affected by management practices. Nutr. Cycling Agroecosyst. **52**: 151-163.

Yeomans, J. C. 1991. Inhibition of nitrogen transformations in soil: Potentials and limitations for agriculture. Trends in Soil Sci **1**: 127-158.

4.0 EFFECT OF NBPT, DCD AND SOIL MOISTURE CONTENT ON NITROUS OXIDE EMISSIONS FROM UREA UNDER LABORATORY CONDITIONS

4.1 Abstract

Two incubation studies simulating fall fertilization were carried out with the objective to investigate N_2O emissions from soil amended with conventional urea fertilizer and urea with the urease and nitrification inhibitors NBPT and DCD alone and in combination. In experiment A, the soil was subjected to a freeze thaw cycle under a moisture content of 50% water filled pore space (WFPS). In experiment B, the soil was subjected to a freeze thaw cycle under two moisture contents, 50 and 70% WFPS, to simulate wet and dry spring conditions with the objective to examine the effect of different moisture regimes on N_2O emissions from the fertilizer treatments during simulated spring thaw. In experiment A, the fertilizer treatments consisted of banded NBPT-DCD formulated urea (SuperU®), conventional urea, calcium nitrate, and a control where no fertilizer was added. In experiment B, treatments included five fertilizer treatments: banded NBPT-DCD (SuperU®) formulated urea, NBPT (Agrotain®) formulated urea, conventional urea, calcium nitrate, and a control where no fertilizer was added. The initial moisture content of all jars in Experiment B was 50% WFPS until just before freezing. However, immediately prior to freezing, the moisture content of half the jars was increased and maintained at 70% WFPS for the remainder of the experiment. In experiment A and B, the double inhibitor treatment produced significantly fewer emissions of N_2O than conventional urea from the 50 % WFPS soils. However, N_2O emissions were greatest from the inhibitor treatments at the greater moisture content in Experiment B.

4.2 Introduction

Nitrous oxide emissions from nitrogen fertilizer contribute to the increase in atmospheric N_2O concentration and resulting global warming as nitrous oxide is a potent greenhouse gas (IPCCa 2007; IPCCb 2007). Processes of N_2O loss from soil following application of ammonium forming fertilizer are through nitrification and denitrification. Nitrification is an aerobic process carried out mainly by autotrophic bacteria where ammonia N is oxidized to nitrate N whereas denitrification is the reduction of nitrate N primarily by facultative heterotrophic bacteria under anaerobic conditions (Beauchamp 1997). Nitrous oxide is emitted through hydrolysis of hydroxylamine during oxidation of ammonia N to nitrite N and the reduction of nitrate-N into N_2O (Subbarao et al. 2006). These two processes are regulated by several edaphic factors including soil moisture and associated soil aeration, ammonium and nitrate concentration, carbon supply and pH. Nitrous oxide emissions are typically thought to be the result of denitritification with losses due to nitrification rarely exceeding 2% of the total N nitrified (Subbarao et al. 2006). However, other studies have demonstrated the amounts of N_2O evolved from ammonium treated soils to be higher than soils treated with nitrate, demonstrating that most of N_2O derived from ammoniacal fertilizers is generated by nitrifying microorganisms (Blackmer et al. 1980).

Both nitrification and denitrification can occur simultaneously in agricultural soils, but the dominance of each is dependent on soil moisture content (Linn and Doran 1984). In experiments with silty clay loam soils, aerobic respiration and nitrification increased with increasing soil moisture content to a maximum of 60% water filled pore space (WFPS) while anaerobic denitrification was insignificant below 60% WFPS and increased to a maximum at saturation (Linn and Doran 1984). Highly episodic emissions have also been observed following wetting and drying of soil. Rapid microbial response and production of N_2O occurred within minutes of soil wetting as both nitrifying and denitrifying populations can remain viable in dry soil (Davidson 1992).

Of concern in temperate climates is N_2O emitted during soil freezing and thawing during spring, especially when nitrogen fertilizer is applied in the fall. Several processes are suggested as responsible for the bursts of N_2O during thaw, including the increased carbon availability for denitrifiers following freezing and thawing (Christensen and Tiedje 1990), increased nitrate availability for denitrification following enhanced nitrification, the alteration of pore structures during freeze thaw resulting in reduced oxygen supply (Edwards and Killham 1986), the physical release of trapped gas accumulated below the frozen layer in the soil profile (Burton and Beauchamp 1994), and an increased ratio of N_2O:N from biological denitrification with decreasing temperature (Tenuta and Sparling 2011). An observed increase in N_2O emissions following thaw has been attributed to the creation of conditions for denitrification through the accumulation of nitrate in unfrozen water together with increased carbon availability (Müller et al. 2002). This saturated water layer appeared to be a critical condition for emissions during spring thaw in a field experiment in Alberta where 23 and 33 kg of added KNO_3^- applied in the fall was apparently denitrified during two spring thaw periods, respectively (Nyborg et al. 1997).

The addition of urease and nitrification inhibitors to fall applied fertilizer may be a strategy to reduce nitrous oxide emissions. Maintaining the fertilizer in the ammoniacal form may reduce denitrification losses during freezing and thawing in spring. Urease activity in soil can be inhibited by two types of urease inhibitors, compounds which interfere with urease-producing soil microorganisms and compounds which interfere with the urease enzyme itself (Yeomans 1991). The urease inhibitor n-butyl thiophosphoric triamide (NBPT) slows the conversion of urea by competing with urea for active sites on the urease enzyme complex (Yeomans 1991). NBPT itself does not actively inhibit hydrolysis, but must first convert to its oxon analog N-(n-butyl) phosphoric triamide (BNPO) to be effective. Several compounds have been identified as nitrification inhibitors through restricting either the oxidation of ammonia to hydroxylamine and hydroxylamine to nitrite or the inhibition of nitrite oxidation (Hauck 1980). The nitrification inhibitor dicyandiamide (DCD) inhibits the first stage of nitrification, the oxidation of ammonia to nitrite by aerobic autotrophic bacteria (Yeomans 1991). Dicyandiamide is microbially mineralized with slower decomposition in anaerobic conditions and is more effective in coarse textured soils low in organic matter (Yeomans 1991). By slowing the formation of nitrate, adding DCD to urea decreased N_2O emissions in sandy loam and clay loam soils (Vallejo et al. 2001).

Two incubation studies simulating fall fertilization were carried out with the objective to investigate N_2O emissions from soil amended with conventional urea fertilizer and urea with the urease and nitrification inhibitors NBPT and DCD alone and in combination. In experiment A, the soil was subjected to a freeze thaw cycle under a moisture content of 50% WFPS. In experiment B, the soil was subjected to a freeze thaw cycle under two moisture contents, 50 and 70% WFPS, to simulate wet and dry spring conditions with the objective to examine the effect of different moisture regimes on N_2O emissions from the fertilizer treatments during simulated spring thaw.

4.3 Material and Methods

4.3.1 Soil Preparation

Table 4.1. Selected soil characteristics.

Characteristics	Experiment A	Experiment B
Soil Series	Oxbow loam	Oxbow loam
Soil texture	loam	loam
pH	7.0	7.2
Organic Matter (g kg^{-1})	19.0	22.0
Water soluble NO_3-N (mg kg^{-1})^z	2.4^z	4.9
Water soluble SO_4-S (mg kg^{-1})^z	7.8	12.0
Olsen Extractable P (mg kg^{-1})^z	19.8	10.8

^{z} Depth of soil 0 - 15cm. Values expressed as ppm.

Surface soil was collected (0-15 cm) from the Halford Farm, south of Indian Head, SK (50°24'58" N 103°34'48" W). Soil was thoroughly combined and sieved to pass through a 2 cm sieve. In experiment A, the fertilizer treatments consisted of banded NBPT-DCD formulated urea (SuperU®), conventional urea, calcium nitrate, and a control where no fertilizer was added. The soil moisture content was 50% WFPS throughout the entire experiment. In experiment B, treatments included five fertilizer treatments and two moisture contents. The fertilizer treatments included banded NBPT-DCD (SuperU®) formulated urea, NBPT (Agrotain®) formulated urea, conventional urea, calcium nitrate, and a control where no fertilizer was added. The initial moisture content of all jars was 50% WFPS until just before freeze. However, immediately prior to freezing, the moisture content of half the jars was increased and maintained at 70% WFPS for the remainder of the experiment. All treatments were replicated four times in both experiments. Fertilizer was applied as granules in a band at a rate of 160 mg N kg^{-1} (160 kg N ha^{-1}) with 348 mg of urea or 1032 mg of calcium nitrate added to each jar.

In experiment A, two complete sets of jars were treated. One set of jars was analyzed for ammonium and nitrite + nitrate in soil at thaw and one set of jars was used to measure nitrous oxide emissions throughout the experiment, and was also analyzed for ammonium and nitrite + nitrate at final soil sampling. In experiment B, three sets of jars were treated. Two sets of jars were analyzed for ammonium, nitrite and nitrate in soil during the incubation period, one at freeze and one at thaw, and the third set of jars was used to measure nitrous oxide emissions throughout the experiment and inorganic nitrogen content at final soil sampling.

To prepare for incubation, 1.5 L mason jars were packed with moist soil to a bulk density of 1.2 g cm^{-3}. The amount of soil added was equivalent to 1.4 kg of air dry soil in Experiment A and 1.2 kg of air dry soil in Experiment B. For jar set-up, each mason jar was packed with half the soil after which the fertilizer band was applied and covered with the remaining soil. In experiment A, mason jars were packed with 700 g of soil, fertilizer bands were applied, and the remaining 700 g of soil was added. Then, 252 mL of distilled water was added to each jar and the soil was packed to a bulk density of 1.2 g cm^{-3}. In experiment B, mason jars were packed by adding and thoroughly combining 87.5 mL of water and 600 g of soil, which was then packed into the jar to a bulk density of 1.2 g cm^{-3}. Fertilizer was added in a band and the remaining moistened soil was added and soil also was packed to a bulk density of 1.2 g cm^{-3}. The methodology was modified for experiment B to reduce water ponding problems experienced in experiment A. The jars were covered with perforated parafilm to minimize moisture loss and provide aeration. The initial lower moisture content of 50% was sufficiently low to ensure nitrification of the fertilizer. In experiment A, the jars were incubated at +15 ºC for four weeks, frozen at -10 °C for 17 weeks, thawed and incubated at +15 °C for four weeks. In experiment B, the jars were incubated at +15 ºC for seven days, then frozen at -10 ºC for seven days and thawed and incubated at +15 ºC for two weeks. The shorter incubation period prior to freeze in experiment B was to more accurately reflect the cumulative heat units experienced in the field experiment prior to freezing. Two extra incubation jars were packed with Ibuttons® to record soil temperature throughout the sampling period.

4.3.2 Measurement of Nitrous Oxide Fluxes

In each experiment, one set of mason jars was sampled for N_2O emissions. To sample, the mason jars were removed from the incubator, the air in the jar was displaced with an empty pop can and replaced with laboratory air and then closed with lids fitted with rubber septums. The jars were replaced in the incubator for two hours. At time of sampling, a syringe was inserted into the septum and the air within the jar was mixed for approximately ten seconds. A 5 mL air sample was collected from the headspace and injected into an evacuated 3 mL Exetainer® vial (Labco Limited, Buckinghamshire, UK). The samples were analyzed for N_2O by automated gas chromatography (Varian 3800, Mississauga, ON). In experiment A, nitrous oxide was measured a total of 26 times and nitrous oxide was measured a total of 13 times in experiment B.

4.3.3 Soil Ammonium, Nitrite and Nitrate N

Soil was sampled for soil ammonium, nitrite and nitrate N using a destructive sampling method. In experiment A, one set of jars was sampled at thaw and the nitrous oxide sampling jars were sampled at the end of the incubation. In experiment B, one set of jars was sampled before freezing, another set was sampled once the soil temperature increased to +15 ºC following thaw and the nitrous oxide sampling jars were sampled at the end of the incubation. Soil ammonium, nitrite and nitrate N were extracted by shaking 5 g of wet soil with 25 mL of 2 M KCl solution for 30 minutes. The solution was centrifuged for one minute 30 seconds at 2800 rpm and 10 mL was extracted by pipette. The concentration of NO_3^-, NO_2^- and NH_4^+ in the extract was determined using a Technicon Autoanalyzer II Single-Channel Colorimeter by automated cadmium reduction method for NO_3^- and NO_2^- and automated phenate colorimetric method for NH_4^+ (Greenberg et al. 1998). In this method, all nitrate in the extract is reduced to nitrite with a cadmium reduction column and the value of NO_3-N + NO_2-N is measured. In experiment B, NO_2-N was also measured by analyzing the extract without the reducing step, and NO_3-N was determined by subtracting the NO_2-N from the value of NO_3-N + NO_2-N. Gravimetric moisture content was determined on all samples at time of sampling and the nitrogen concentration was adjusted to account for the moisture content.

4.3.4 Data and Statistical Analysis

The accumulated rates of N_2O production per kg of dry soil per hour were calculating by determining the volume of atmosphere in the incubation jar, the concentration of gas in the sample and the total mass of N_2O-N in the incubation jar. The volume of atmosphere in the incubation jar was established by subtracting the volume of soil and water in the jar from the total volume of the incubation jar. The total mass of N_2O-N in the incubation jar was found by adding the mass of N_2O-N in the atmosphere of the incubation jar and the mass of N_2O-N dissolved in solution. The cumulative N_2O emissions throughout the sampling period were calculated by the summation of daily estimates of emissions by linear interpolation between sampling dates.

Statistical analysis was performed using the Proc Mixed procedure of the Statistical Analysis System (SAS; SAS 9.1.3). The data was tested for normality and skewness using the Univariate function of SAS. A randomized complete block design model was used for ANOVA. The protected least significant difference (LSD) test was used to compare the fertilizer treatment means and moisture. The LSD test with repeated measures was used to compare cumulative fertilizer treatments means on individual sampling days.

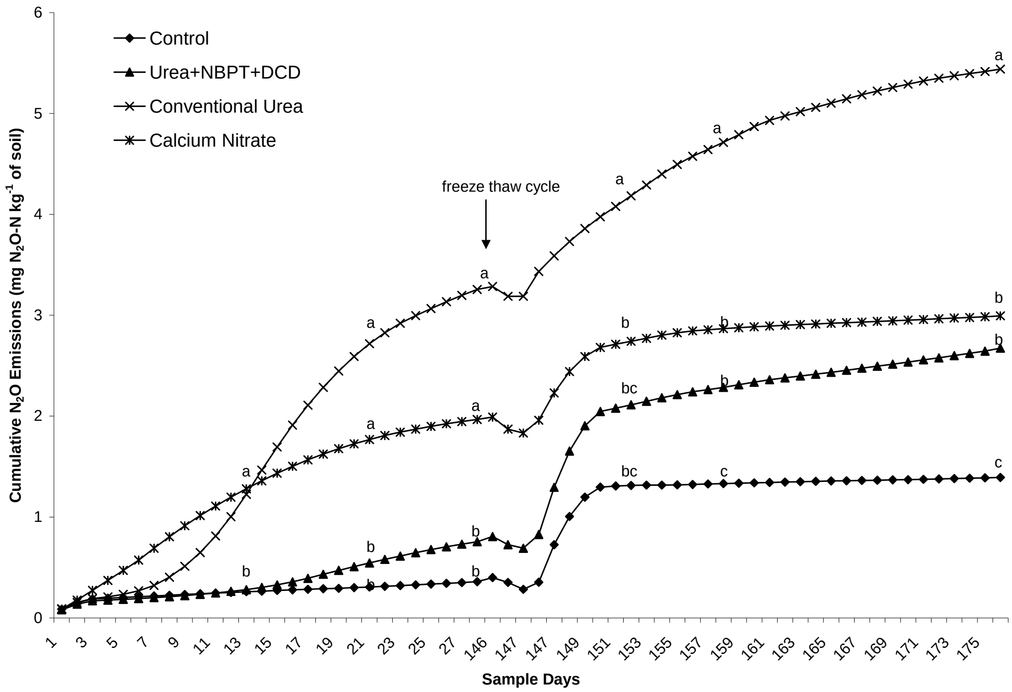
4.4 Results and Discussion

4.4.1 Experiment A

4.4.1.1 Nitrous Oxide Emissions before Freeze

During the first week of the experiment, nitrous oxide emissions were similar from all urea treatments, including the control (Figure 4.1). However, as of day 13, the conventional urea and calcium nitrate treatments had emitted significantly more nitrous oxide than the control and the NBPT-DCD urea, a trend that continued for the duration of the incubation study. Cumulative emissions from the calcium nitrate treatment steadily increased from the very beginning of the incubation period, suggesting that the denitrification process was responsible for a substantial portion of the nitrous oxide emitted during the study. Soil water content is often identified as a dominant factor controlling the denitrification process as it directly affects soil aeration. As an anaerobic process, denitrification is usually negligible in well aerated soils, and generally increases above 60% WFPS (Linn and Doran 1984; Maag and Vinther 1999). Therefore, at 50% WFPS, we had expected nitrification to be responsible for most of the N_2O emissions. One reason for increased denitrification at the lower moisture content could be the method in which water was added to the incubation jars. All water was added to the jars after the soil had been packed, which caused saturation and further compaction of the surface soil. Oxygen exchange between the soil and atmosphere could, therefore, have been limited by the saturated conditions at the soil surface.

Figure 4.1. Effect of fertilizer form and inhibitors on cumulative nitrous oxide emissions for Experiment A.



Mean values within the same sampling time followed by the same lower case letter are not significantly different at $p \leq 0.05$.

The rate of N_2O emissions from the conventional urea treatment did not increase above the control until approximately day ten, after which the rate increased significantly to exceed the rate of emission for calcium nitrate. During the third week, the faster rates of emission and larger cumulative emissions from the urea treatment, compared to the calcium nitrate treatment indicate nitrification was increasingly responsible for N_2O emissions. Before nitrifying, urea must first hydrolyze; therefore, it would be expected that emissions from the urea fertilizer would be delayed following fertilization. Additionally, more favourable conditions for nitrification may have been produced as the added water percolated into the soil and oxygen diffusion increased.

During the pre-freeze period, emissions from NBPT-DCD urea were significantly smaller than those from calcium nitrate and conventional urea, and emissions were similar to the control. The small emissions from NBPT-DCD indicate that urea hydrolysis and nitrification were delayed by the inhibitors.

The majority of cumulative N_2O emissions occurred before freeze from all fertilizer treatments (Table 4.2). Emissions were greatest during this period from the conventional urea followed by the calcium nitrate. The large emissions from both calcium nitrate and urea indicate that both nitrification and denitrification were probably occurring simultaneously prior to freezing. Although soil aeration was adequate for nitrification of urea, the presence of micro-sites where oxygen was limited likely produced conditions that were favourable for denitrification. N-(n-butyl) thiophosphoric triamide -Dicyandiamide and the control emitted similar amounts of nitrous oxide revealing that nitrous oxide emissions were reduced by the urease and nitrification inhibitors.

Table 4.2. Effect of fertilizer form and inhibitors on cumulative nitrous oxide emissions for Experiment A.

Treatment		Cumulative nitrous oxide emissions: Before Freeze 1-7 days	Before Freeze 8-28 days	During Thaw	After Thaw	Total
		mg N_2O-N kg^{-1} of soil				
Control		0.22c	0.14c	0.95	0.08b	1.39c
NBPT-DCD Urea		0.20c	0.56bc	1.32	0.60ab	2.67bc
Conventional Urea		0.32b	2.93a	0.82	1.36a	5.44a
Calcium Nitrate		0.69a	1.28b	0.75	0.28b	2.99b
ANOVA	***df***	***P>F***				
Trt	3	<0.0001	<0.0001	0.20	0.02	0.002
Block	3	0.36	0.47	0.05	0.52	0.18
C.V.		65	97	51	114	57

Mean values within the same column followed by the same lower case letter are not significantly different at $p \leq 0.05$.

4.4.1.2 Nitrous Oxide Emissions and Soil Analysis during and after Thaw

During thaw on the first sampling period (day 147), negative nitrous oxide emissions were measured from all treatments (Figure 4.1). The reasons for these negative emissions are not known. During the second sampling period, immediately following thaw, (day 147 to day 151), the rate of emissions increased from all treatments including the control, which may be attributed to an increase in carbon availability during the thaw period (Figure 4.1). At thaw, increased microbial activity and denitrification may occur due to the release of organic carbon from plant and microbial detritus (Christensen and Tiedje 1990).

As of day 148 of the incubation study, cumulative N_2O emissions became significantly greater from conventional urea than calcium nitrate. Within five days after thaw, cumulative emissions from calcium nitrate appeared to level off suggesting that denitrification was no longer the dominant process for emitting N_2O.

Soil was analyzed to determine the transformation of the fertilizer throughout the incubation study. After thaw, the concentration of total ammonium N in the soil was similar for the urea, calcium nitrate and control treatments (Table 4.3). However, high variability between reps, especially in the control treatment, may have masked any fertilizer effects. The concentration of soil ammonium N was significantly greater for NBPT-DCD urea compared to the conventional urea. Fertilization increased the concentration of soil nitrite + nitrate N after thaw, and the concentration was significantly lower for NBPT-DCD urea than for conventional urea, indicating that inhibitors slowed urea hydrolysis and nitrification. Limited availability of nitrate for denitrification may also have lowered nitrous oxide emissions from the inhibitor treatment before freeze (Table 4.2). Fertilization significantly increased the total concentration of soil inorganic N, and the concentration was similar among all fertilizer treatments. Similar and high concentrations of recovered fertilizer (average of 64 % among treatments) indicate that denitrification losses were not substantial (Table 4.4).

Table 4.3. Effect of fertilizer form and inhibitors on total recovered soil inorganic N for Experiment A.

After Thaw				
Treatment and Moisture		**NH_4^+-N**	**NO_2^-+ NO_3^--N**	**Inorganic N**
			mg kg^{-1}	
Control		2b	21c^z	23b
NBPT-DCD Urea		50a	72b	123a
Conventional Urea		15b	119a	134a
Calcium Nitrate		3b	127a	130a
ANOVA	***df***		***P>F***	
Fertilizer Trt	3	0.005	0.002	0.008
Block	3	0.21	0.47	0.91
C.V. (%)		134	52	47
End of Sampling				
Control		1	26c	27b
NBPT-DCD Urea		17	116b	133a
Conventional Urea		1	158a	159a
Calcium Nitrate		1	143a	144a
ANOVA	***df***		***P>F***	
Fertilizer Trt	3	0.11	<0.0001	<0.0001
Block	3	0.42	0.54	0.64
C.V. (%)		233	48	48

^{z}Mean values within the same column followed by the same letter are not significantly different at $p \leq 0.05$.

Cumulative nitrous oxide emissions from the NBPT-DCD urea treatment were similar to the control from the beginning of the incubation study up to day 157 after which the NBPT-DCD urea emitted significantly greater emissions than the control. Therefore, it appears that hydrolysis and nitrification were delayed by the inhibitors for the majority of the study.

Total cumulative nitrous oxide emissions during the entire study were largest from the conventional urea (Table 4.2). N-(n-butyl) thiophosphoric triamide - Dicyandiamide urea had similar total cumulative emissions to both the control and calcium nitrate, and the calcium nitrate treatment emitted more total cumulative emissions than the control. While greater emissions from the conventional urea treatment compared to calcium nitrate demonstrates that nitrous oxide was being emitted by nitrification, greater emissions from the calcium nitrate compared to the control shows that denitrification was also responsible for N_2O emissions. As denitrification occurs in conditions where oxygen is limited, increased emissions from the conventional urea compared to the calcium nitrate demonstrates that, at 50% water filled pore space (WFPS), the majority of nitrous oxide emissions were emitted as the result of nitrification. This is similar to study by Stevens et al. (1997) who found nitrification to be the dominant N_2O producing process at 50% WFPS. Lower total cumulative nitrous oxide emission from the NBPT-DCD urea compared to the conventional urea suggests that N_2O emissions were reduced by the inhibitors.

At the end of the study, there were no significant differences in soil ammonium N among treatments (Table 4.3). Although the concentration of soil ammonium N was numerically higher in the NBPT-DCD urea treatment than the other fertilizer treatments, large variability once again may have concealed a fertilizer treatment effect as this trend was supported by a significantly smaller concentration of soil nitrite + nitrate N for the NBPT-DCD urea compared to conventional urea and calcium nitrate, indicating that nitrification was reduced by the urease and nitrification inhibitors. At the end of the experiment, apparent total recovered fertilizer averaged 74 % and was similar among fertilizer treatments (Table 4.4). Similar recovered fertilizer from calcium nitrate and urea indicates that denitrification losses were not significant and that large cumulative nitrous oxide emissions from the conventional urea were likely the result of nitrification (Table 4.2).

Table 4.4. Effect of fertilizer form and inhibitors on apparent total recovered fertilizer for Experiment A.

At Thaw		Apparent Total Fertilizer Recovered	% of Applied
Fertilizer Treatment		**mg kg^{-1} of soil**	
NBPT-DCD		98.2	61
Conventional Urea		111.2	70
Calcium Nitrate		96.5	60
ANOVA	***df***	***P>F***	
Fertilizer	2	0.90	
Block	3	0.99	
C.V. (%)		30	

End of Sampling			
NBPT-DCD		105.8	66
Conventional Urea		131.7	82
Calcium Nitrate		116.9	72
ANOVA	***df***	***P>F***	
Fertilizer	2	0.24	
Block	3	0.63	
C.V. (%)		17	

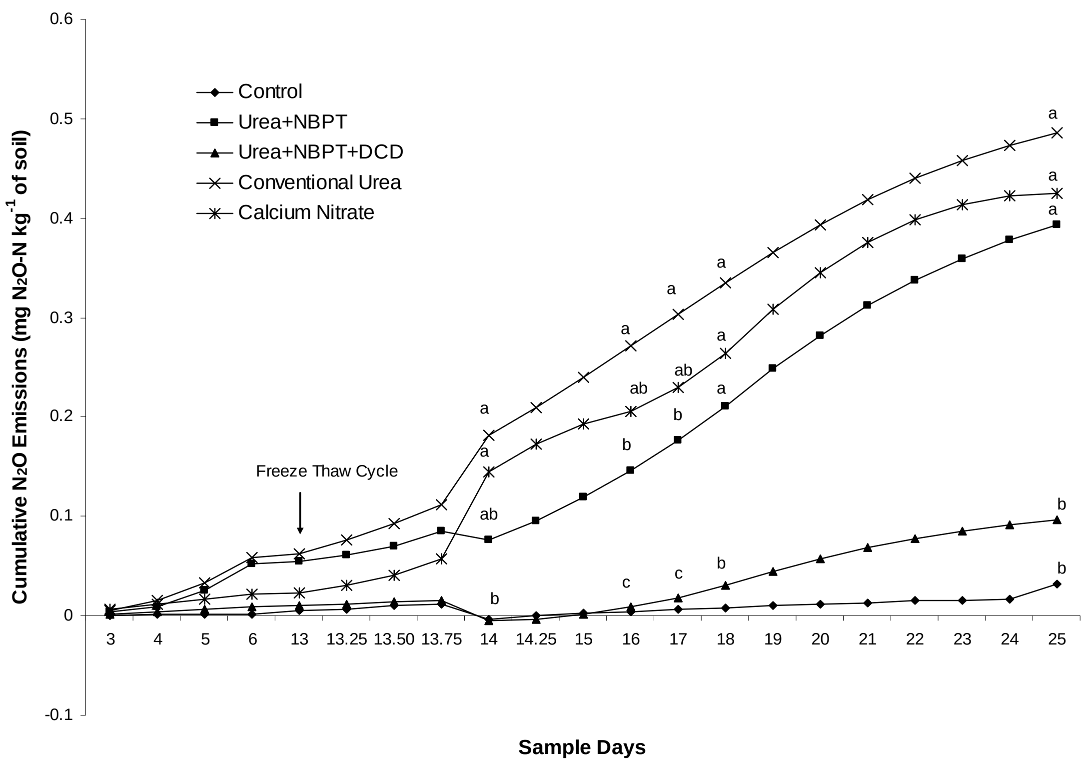
[z]Mean values within the same column followed by the same letter are not significantly different at $p \leq 0.05$.

4.4.2 Experiment B

4.4.2.1 Nitrous Oxide Emissions and Soil Inorganic N before Freeze

Before the soil was frozen, N_2O emissions were small from all fertilizer treatments, with no significant differences between treatments on individual sampling dates (Figures 4.2 and 4.3). Differences among fertilizer treatments on individual sampling days were not observed until after thaw. This is unlike experiment A where significant differences between fertilizer treatments occurred before freeze. However, in Experiment A, no significant differences in N_2O emission were measured within the first week of incubation. Therefore, the difference in the length of incubation prior to soil freezing can help to account for the differences between the two experiments.

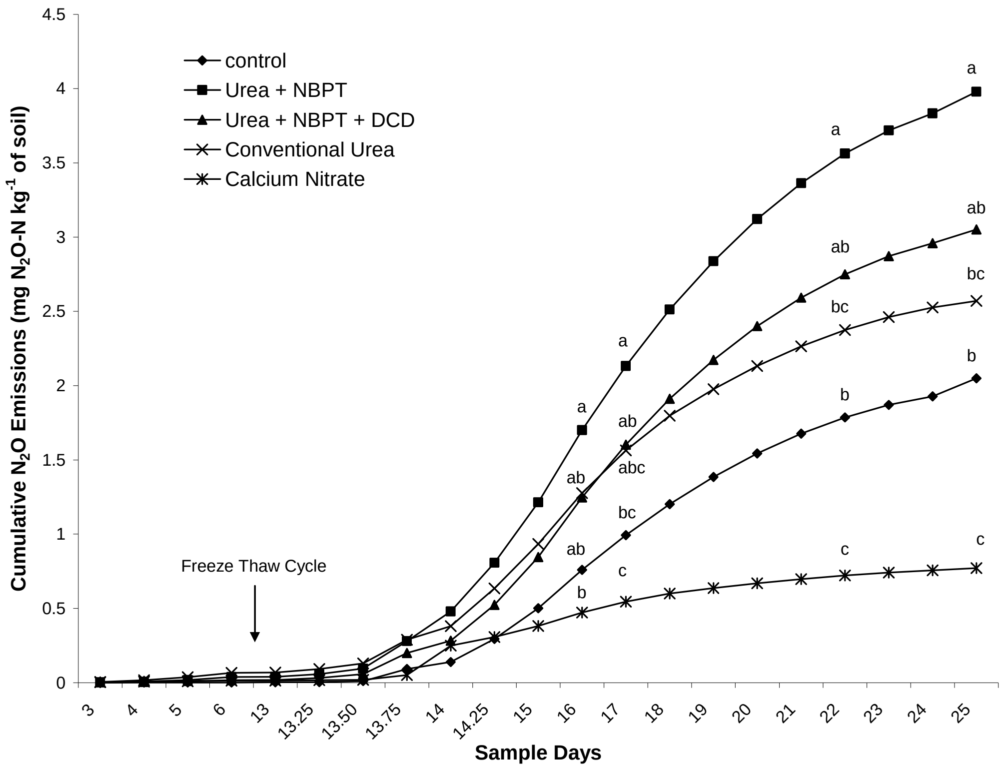
Figure 4.2. Effect of fertilizer sources and inhibitors on cumulative nitrous oxide emissions from soil at 50% water filled pore space for Experiment B.



Mean values within the same sampling time followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Cumulative emissions were greater from the conventional urea treatment than from NBPT or from NBPT-DCD urea before freeze (Table 4.5). N-(n-butyl) thiophosphoric triamide -Dicyandiamide urea also emitted significantly less N_2O than the NBPT urea during this period suggesting that each of the inhibitors helped to reduced N_2O production.

Figure 4.3. Effect of fertilizer sources and inhibitors on cumulative nitrous oxide emissions from soil at 50 % water filled pore space before freeze and 70% water filled pore space following thaw for Experiment B.



Mean values within the same sampling time followed by the same lower case letter are not significantly different at $p \leq 0.05$.

Fertilization increased soil ammonium above the control in all urea fertilizer treatments (Table 4.6). Before freeze, total inorganic nitrogen was similar among all fertilizer treatments. Both NBPT and conventional urea had greater concentrations of nitrite N than the control; NBPT-DCD urea, however, did not. Greater concentrations of nitrite N in the urease inhibitor and conventional urea than in the NBPT-Urea, calcium nitrate and control treatments confirm that nitrification was slowed by the DCD in the double inhibited treatment. Although ammonium-N concentrations were numerically lower for conventional urea compared to NBPT or NBPT-DCD urea, the differences were not significant due to a large C.V. and/or little or no effect of inhibitors on nitrification or urea hydrolysis at the time of sampling. At the end of the first week of incubation, the apparent recovered fertilizer was similar among treatments with an average of 79 %.

Table 4.5. Effect of fertilizer source and moisture content on cumulative nitrous oxide emissions for Experiment B.

Treatment			Before Freeze		During Thaw	After Thaw	Total
Fertilizer	Post Thaw Moisture				mg N_2O-N kg^{-1} soil		
Control			0.002c[z]			0.79	
NBPT Urea			0.05b			1.52	
NBPT + DCD Urea			0.01c			1.15	
Conventional Urea			0.06a			0.94	
Calcium Nitrate			0.02c			0.31	
	50					0.17b	0.29b
	70					1.71a	2.48a
Control	50				0.0006a		0.03b
NBPT Urea					0.07a		0.39a
NBPT + DCD Urea					-0.007a		0.10b
Conventional Urea					0.18a		0.49a
Calcium Nitrate					0.17a		0.43a
Control	70				0.50c		2.05bc
NBPT Urea					1.18a		3.98a
NBPT + DCD Urea					0.83b		3.05ab
Conventional Urea					0.87ab		2.57b
Calcium Nitrate					0.37c		0.77c
ANOVA		***df***	***P>F***	***df***		***P>F***	
Fertilizer		4	<0.0001	4	0.01	0.11	0.03
Moisture		0	-	1	0.0003	0.002	0.0004
Fertilizer x Moisture		-	-	4	0.0054	0.07	0.03
Block		3	0.04	6	0.0017	0.0001	0.02
C.V. (%)			106		115	135	122

z Fertilizer treatments means followed by similar lower case within a column are not significantly different. Moisture content means followed by similar upper case letters are not significantly different within a sampling period.

Table 4.6. Effect of fertilizer source and moisture content on inorganic soil N for Experiment B.

Before Freeze					
Treatment		NH_4^+-N	NO_2^--N	NO_3^--N	Inorganic N
Fertilizer			mg kg^{-1}		
Control		1b	0.54c	89c	90b
NBPT Urea		105a	7.11a	124b	235a
NBPT + Urea		91a	0.92c	111bc	203a
Conventional Urea		74a	4.31b	120b	199a
Calcium Nitrate		4b	0.55c	221a	226a
ANOVA	***df***		***P>F***		
Fertilizer	4	<0.0001	<0.0001	<0.0001	<0.0001
Moisture	-	-	-	-	-
Fertilizer x Moisture	-	-	-	-	-
Block	3	0.12	0.79	0.55	0.75
C.V. (%)		98	128	41	36
After Thaw					
Treatment		NH_4^+-N	NO_2^--N	NO_3^--N	Inorganic N
Fertilizer			mg kg^{-1}		
Control		4.35b	0.42b	82.50d	87.27b
NBPT Urea		117.22a	1.45a	136.31b	254.98a
NBPT + Urea		121.09a	0.57a	106.31c	227.97a
Conventional Urea		109.05a	1.66a	110.88c	221.58a
Calcium Nitrate		4.17b	0.39c	204.55a	209.11a
ANOVA	***df***		***P>F***		
Fertilizer	4	<0.0001	<0.0001	<0.0001	<0.0001
Moisture	1	0.29	0.24	0.77	0.75
Fertilizer x Moisture	4	0.68	0.10	0.52	0.37
Block	6	0.91	0.58	0.06	0.68
C.V. (%)		91	82	38	39
End of Sampling					
Treatment		NH_4^+-N	NO_2^--N	NO_3^--N	Inorganic N
Fertilizer			mg kg^{-1}		
Control		2b	0.41	94b	97b
NBPT Urea		2b	0.37	228a	231a
NBPT + Urea		27a	0.34	213a	240a
Conventional Urea		1b	0.31	233a	234a
Calcium Nitrate		1b	0.36	231a	233a
ANOVA	***df***		***P>F***		
Fertilizer	4	<0.0001	0.40	<0.0001	<0.0001
Moisture	1	0.56	0.16	0.70	0.65
Fertilizer x Moisture	4	0.77	0.36	0.14	0.16
Block	6	0.16	0.30	0.34	0.33
C.V. (%)		178	31	27	27

[z] Mean values within the same sampling time followed by the same lower case letter are not significantly different at $p \leq 0.05$.

4.4.2.2 Nitrous Oxide Emissions and Soil Inorganic N during and after Thaw

After thawing, the soil showed an increase in N_2O emissions when the moisture content was increased to 70% WFPS. Wetter soil emitted up to approximately 10 times more N_2O than the drier soil. For example, at the end of the thaw period, cumulative emissions from the fertilizer treatments ranged from -0.007 mg N_2O-N kg^{-1} soil to 0.18 mg N_2O-N kg^{-1} soil at 50 % WFPS and 0.37 mg N_2O-N kg^{-1} soil to 1.18 mg N_2O-N kg^{-1} soil at 70% WFPS (Table 4.5). Following soil thaw, N_2O production did not increase until the soil temperature returned to 15 ºC at least 12 hours after thaw (Figures 4.2 and 4.3), which is similar to a study by Christensen and Tiedje (1990) who found N_2O production began five to ten hours after thaw. Significant differences among fertilizer treatments were observed from the wetter soil (Table 4.5). N-(n-butyl) thiophosphoric triamide urea, NBPT + DCD urea, and conventional urea emitted significantly greater N_2O emissions compared to calcium nitrate and control. All fertilizer treatments at 50 % WFPS had similar emission to the control during this period. After thaw, all fertilizer treatments had similar and high concentrations of recovered fertilizer (average of 88 % among treatments).

Cumulative emissions of N_2O were greater at 70% WFPS than at 50% WFPS during and after thaw (Table 4.5). Greater nitrous oxide emissions have been observed with increasing moisture content in several other studies (Maag and Vinther 1999; Wrage et al. 2004). In a laboratory study emissions were up to 11 times higher when water was added to increase the moisture content to 90% WFPS than from soil where no water was added (Kopenen et al. 2004). Cumulative emissions from the calcium nitrate treatment were not significantly greater at 70% WFPS than at 50% WFPS. After thaw, total inorganic N was similar among fertilizer and moisture treatments (Table 4.6). Concentrations of nitrate N in the soil were greater for calcium nitrate than NBPT, NBPT + DCD and conventional urea indicating that denitrification was not the dominant process responsible for N_2O emissions under both moisture conditions.

The majority of emissions occurred after the thaw period. This is contrary to experiment A where the majority of emissions occurred prior to freeze. This is likely due to the short incubation period prior to freezing for Experiment B (7 d) compared to Experiment A (28 d). Unlike during thaw, there were no significant differences among all fertilizer treatments according to ANOVA (Table 4.5); however, a significant moisture effect for all fertilizer treatments was observed. Following thaw to the end of the incubation study, differences in cumulative nitrous oxide emissions among fertilizer treatments were observed at both moisture contents on individual sampling days when analyzed as repeated measures (Figures 4.2 and 4.3). Other studies have observed greater N_2O emissions from urea fertilizer with and without nitrification inhibitors at higher WFPS contents with the increase in emissions attributed to increased rates of denitrification (Vallejo et al. 2001).

At 50% WFPS, conventional urea, calcium nitrate, and NBPT urea emitted significantly more cumulative N_2O than the NBPT-DCD urea and control treatments (Figure 4.2). Nitrous oxide emissions from all treatments were much greater in Experiment A than Experiment B (Figures 4.1 and 4.2). Total cumulative N_2O emissions ranged from 1.4 mg N_2O-N kg^{-1} of soil to 5.4 mg N_2O-N kg^{-1} of soil in Experiment A while emissions ranged from 0.03 mg N_2O-N kg^{-1} of soil to 0.5 mg N_2O-N kg^{-1} of soil in Experiment B. Reasons for this include the longer duration of incubation as well of freezing as the duration of freezing has increased nitrous oxide emissions (Teepe et al. 2004). Nitrous Oxide emissions from the NBPT-DCD urea and control treatments were similar throughout the study. The increased rate of N_2O emission for the conventional urea and calcium nitrate treatments as of day 14 suggests that denitrification was responsible for the majority of emissions on this sampling day. This would be expected as favourable conditions for denitrification, including the accumulation of nitrate in unfrozen water and increased carbon availability generally occur during the thaw period (Müller et al. 2002). Following thaw, the rate of increase in cumulative emissions of N_2O was generally similar for the NBPT- urea, conventional, and calcium nitrate fertilizer treatments. Similar rates of emissions from the two urea treatments and the calcium nitrate demonstrate that emissions were probably the result of denitrification. Throughout the incubation study, however, concentrations of nitrate N in the soil did not vary significantly (Table 4.6). Decreasing concentrations of nitrate N, especially in the calcium nitrate treatment, would be expected if substantial emissions of N_2O from denitrification had occurred.

At 70 % WFPS, the greatest nitrous oxide emissions were emitted by the NBPT urea, NBPT-DCD urea, and conventional urea, respectively, during the after thaw period (Figure 4.3). Emission from the calcium nitrate was smallest among all fertilizer treatments, including the control, suggesting that conditions may have been favourable for the complete reduction of nitrate to N_2. However, the concentration of nitrate N was significantly greater in the calcium nitrate treatment compared to all other fertilizer treatments during the after thaw period. Therefore, relatively small emissions from calcium nitrate were not the result complete denitrification (Table 4.6). Alternatively, greater emissions from the urea treatments compared to the calcium nitrate suggest that the nitrification process was responsible for substantial emissions.

At the end of the sampling period, cumulative N_2O emissions from the drier soil were significantly greater from the NBPT urea, conventional urea and calcium nitrate compared to the NBPT+DCD urea and control (Table 4.5). For the wetter soil, urea fertilizer treatments emitted more N_2O than calcium nitrate (Table 4.5). At 70 % WFPS, the NBPT urea and NBPT+DCD urea emitted the greatest N_2O and calcium nitrate the smallest. However, emissions from the control were also large with the control also emitting more N_2O than calcium nitrate. This is similar to the Indian Head field experiment where N_2O emissions from the fall banded calcium nitrate were significantly smaller than emissions from all other treatments (Chapter 3). The reasons for smaller emissions are not known.

At the end of the sampling period, NBPT-DCD had significantly greater concentrations of ammonium N than all other treatments at both moisture levels (Table 4.6). At both moisture contents, fertilization increased the concentration of soil nitrate N and total inorganic N compared to the control. There were, however, no significant differences in soil nitrate N and total inorganic N among the fertilizer treatments. The soil data do not explain the greater cumulative emissions observed from NBPT and NBPT+DCD urea treatments compared to calcium nitrate at the greater moisture content. Similar and substantial concentrations of soil nitrate N among the fertilizer treatments indicate that the smaller cumulative emission from calcium nitrate was not the result of the complete reduction of nitrate to N_2, while significantly greater soil ammonium N in the NBPT+DCD urea suggests that nitrification was not responsible for the substantial

N_2O emissions from NBPT+DCD. At the end of sampling, apparent recovered fertilizer was similar among treatments with an average of 82 % indicating that N losses were not substantial throughout the incubation study (Table 4.6).

Table 4.7. Effect of fertilizer source and moisture content on apparent total recovered fertilizer for Experiment B.

Treatment		Before Freeze			After Thaw		End of Sampling	
Fertilizer	Moisture	Apparent Total Fertilizer Recovered	% of Applied		Apparent Total Fertilizer Recovered	% of Applied	Apparent Total Fertilizer Recovered	% of Applied
					mg kg^{-1}			
NBPT Urea		145.3	91		167.7	105	131.1	82
NBPT + DCD Urea		113.2	71		140.7	88	140.2	88
Conventional Urea		108.5	68		134.3	84	128.6	80
Calcium Nitrate		135.2	85		121.8	76	121.3	76
	50				139.2	87	111.9	70
	70				143.1	89	148.7	93
ANOVA		***df***	***P>F***	***df***		***P>F***		
Fertilizer		3	0.47	3	0.52		0.57	
Moisture		0	-	1	0.87		0.02	
Fertilizer x Moisture		0	-	3	0.34		0.53	
Block		3	0.71	6	0.39		0.63	
C.V. (%)			41		43		27	

[z] Mean values within the same sampling time followed by the same lower case letter are not significantly different at $p \leq 0.05$.

4.5 Conclusions

In experiment A and B, the double inhibitor treatment produced significantly fewer emissions of N_2O than conventional urea from the soils at 50 % WFPS. However in Experiment B, N_2O emissions were greatest from the inhibitor treatments at the greater moisture content. The addition of both urease and nitrification inhibitors, NBPT and DCD, respectively, significantly increased the soil ammonium concentration at the end of the sampling period in Experiment B. Cumulative emissions from calcium nitrate were small in both studies, and soil nitrate N and total inorganic N were similar at the end of sampling for all fertilizer treatments in both studies. It appears that, in conditions simulating a drier spring, the addition of urease and nitrification inhibitors delayed fertilizer transformation and reduced nitrous oxide emissions. However, inhibitors did not reduce N_2O emissions under wet conditions where nitrate might be vulnerable to denitrification loss. High concentrations of soil nitrate N and small cumulative emissions from calcium nitrate suggest the denitrification losses were not substantial in either study. Under conditions where soil nitrate N is not susceptible to denitrification losses, the effectiveness of urease and nitrification inhibitors may not be evident.

4.6 References

Beachamp, E. G. 1997. Nitrous oxide emissions from agricultural soils. Can J. Soil Sci. **77**: 113-123.

Blackmer, A. M., Bremner, J. M. and Schmidt, E. L. 1980. Production of nitrous oxide by ammonia-oxidizing chemoautotrophic microorgansisms in soil. Appl. Environ. Microbiol. **40**: 1060-1066.

Burton, D.L. and Beachamp, E. G. 1994. Profile nitrous oxide and carbon dioxide concentrations in soil subject to freezing. Soil Sci. Soc. of Amer. J. **58**: 115-122.

Christensen, S and Tiedje, J. M. 1990. Brief and vigorous N_2O production by soil during spring thaw. J. of Soil Sci. **41**: 1-4.

Davidson, E. A. 1992. Sources of nitric oxide and nitrous oxide following wetting of dry soil. Soil Sci. Soc. Am. J. **56**: 95-102.

Edwards, A.C., Killham, K. 1986. The effect of freeze/thaw of gaseous nitrogen loss from upland soils. Soil Use Manage. **2**: 86-91.

Greenberg, A. E., Clesceri, L. S., Eaton, A. D. and Franson, M. A. H. 1998. Standard Methods for the Examination of Water and Wastewater. **20 ed.** American Public Health Association.

Hauck R. D. 1980. Mode of action of nitrification inhibitors. In *Nitrification inhibitors-potentials and limitations.* ASA special publication number 38.

IPCC 2007a. Climate change 2007: The physical science basis. International panel on climate change. Available at: http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

IPCC 2007b. Climate change 2007: synthesis report. International panel on climate change. Available at: http://www.ipcc.ch/ipccreports/ar4-syr.htm.

Koponen, H. T., Flöjt, L. and Martikainen, P. J. 2004. Nitrous oxide emissions from agricultural soils at low temperatures: a laboratory microcosm study. Soil Biol. & Biochem. **36**: 757-766.

Linn, D. M. and Doran, J. W. 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. Soil Sci. Soc. Am. J. **48**: 1267-1272.

Maag, M and Vinther, F. P. 1999. Effect of temperature and water on gaseous emissions
from soils treated with animal slurry. Soil Sci. Soc. Am. J. **63**: 858-865.

Malhi, S. S. and Nyborg, M. 1983. Release of mineral N from soils: influence of inhibitors of nitrification. Soil Biol. Biochem. **15**: 581-585.

Müller, C., Martin, M., Stevens, R. J., Laughlin, R. J., Kammann, C., Ottow, J. C. G. and Jäger, H. J. 2002. Processes leading to N_2O emissions in grassland soil during freezing and thawing. Soil Biol. Biochem. **34**: 1325-1331.

Nyborg, M., Laidlaw, J. W., Solberg, E. D., and Malhi, S. S. 1997. Denitrification and nitrous oxide emissions from a black chernozemic soils during spring thaw in Alberta. Can. J. Soil Sci. **77**: 153-160.

Röver, M., Heinemyer, O. and Kaiser, E.A. 1998. Microbial induced nitrous oxide emissions from an arable soil during winter. Soil Biol. Biochem. **30**: 1859-1865.

Stevens, R. J., Laughlin, R. J., Burns, L.C., Arah, J. R., M. and Hood, R. C. 1997. Measuring the contribution of nitrification and denitrification to the flux of nitrous oxide from soil. Soil Biol. Biochem. **29**: 139-151.

Subbarao, G. V., Ito, O., Sahrawat, K. L., Berry, W. L., Nakahara, K., Ishikawa, T., Watanabe, T., Suenaga, K., Rondon, M. and Roa, I. M. 2006. Scope and strategies for regulation of nitrification in agricultural systems-challenges and opportunities. Critical Rev. Plant Sci. **25**: 303-335.

Teepe, R., Vor, R.A., Beese, F. and Ludwig, B. 2004. Emissions of N_2O from soils during cycles of freezing and thawing and the effects of soil water, texture and duration of freezing. Eur. J. Soil Sci. **55**: 357-365.

Tenuta, M. and Sparling, B. 2011.A laboratory study of soil conditions affecting emissions of nitrous oxide from packed cores subjected to freezing and thawing. Can J. Soil Sci. **91**: 223-233.

Vallejo, A., Diez, J. A., López-Valdivia, L., M., Gascó, A and Jiménez, C. 2001. Nitrous oxide emission and denitrification nitrogen losses from soils treated with isobutylenediurea and urea plus dicyandiamide. Biol Fertil Soils. **34**: 248-257.

Wrage, N., Velthof, G. L., Laanbroek, H., J. and Oenema., O. 2004. Nitrous oxide production in grassland soils: assessing the contribution of nitrifier denitrification. Soil Biol. Biochem. **36**: 229-236.

Yeomans, J. C. 1991. Inhibition of nitrogen transformations in soil: Potentials and limitations for agriculture. Trends in Soil Sci. **1**: 127-158.

5.0 OVERALL SYNTHESIS

The use of nitrogen fertilizer is associated with the increase in atmospheric concentrations of N_2O, a powerful greenhouse gas. Fertilizer management practices which are assumed to increase emissions of N_2O include the fall application of nitrogen fertilizer, a practice common in the Canadian Prairies. Gaseous losses of fertilizer N are also associated with a decrease in nitrogen availability to the crop, resulting in poorer yield and nitrogen uptake. In fertilized soils, N_2O is emitted both during nitrification and denitrification, with denitrification thought to be responsible for the majority of gaseous loss of fall applied N fertilizer. Both processes are influenced by several factors, most notably soil moisture, with greater nitrous oxide emissions largely associated with the denitrification of fertilizer under wetter conditions. Of special concern with the fall application of N fertilizer is nitrogen loss during denitrification at spring thaw.

Adding urease and nitrification inhibitors with urea fertilizer has shown potential to decrease N_2O emissions and increase the agronomic performance of fall applied N by delaying the transformation of urea to nitrate and, therefore, reducing the amount of fertilizer found in the form susceptible to loss under saturated conditions. Determining the extent to which agricultural practices, such as the use of urease and nitrification inhibitors, contribute to a decrease in nitrous oxide emissions and increase in agronomic performance is important for future management strategies. The objectives of the present studies were to investigate the effect of the urease and nitrification inhibitors, NBPT and DCD, with urea banded in the fall on 1) soil transformations and agronomic performance of a spring annual crop 2) nitrous oxide emissions under field conditions 3) nitrous oxide emissions following freeze thaw cycles simulating wet and dry spring conditions.

In the field experiment, little connection was observed between total cumulative nitrous oxide emissions and agronomic performance as measured by yield, N uptake and apparent nitrogen use efficiency. Agronomic performance of spring wheat was generally not affected by fertilizer form and timing of application (Chapter 2). Fall banded NBPT and DCD incorporated urea increased total N uptake compared to fall banded conventional urea at only one of six site years; however, this was not reflected in an increase in grain yield. Apparent efficiency of recovered fertilizer in plant and soil was similar among all fertilizer treatments at five of six site years (average of 52 % applied fertilizer N among treatments). However, at Oak Bluff 2006/07, fall banded NBPT-DCD had greater apparent recovered fertilizer efficiency compared to fall banded calcium nitrate and spring banded conventional urea. Grain yield, apparent N uptake, and nitrogen use efficiency were similar between fall banded and spring banded fertilizer at five of six site years. However, at Oak Bluff in 2006/07, grain yield and N uptake were significantly lower in both fall banded calcium nitrate and spring banded conventional urea compared to fall banded NBPT-DCD urea. At this same site year, nitrous oxide emission from fall banded calcium nitrate was not significantly greater than fall banded NBPT-DCD urea. Fertilization, fertilizer form and timing of application also did not affect total cumulative nitrous oxide emissions, with similar emissions from all treatments at five of six site years (Chapter 3).

Similar agronomic performance and total cumulative nitrous oxide emissions among fertilizer treatments indicate that nitrate was generally stable and not susceptible to large losses. Nitrous oxide emissions from fall applied fertilizer have generally been associated with denitrification, especially during spring thaw. However, in the field and laboratory studies, denitrification losses were generally small. Significant nitrate loss was not observed in the field experiment from the fall banded fertilizer treatments as agronomic performance and cumulative nitrous oxide emissions were similar between fall banded calcium nitrate and spring banded conventional urea. Also, in the laboratory experiments, calcium nitrate did not emit more N_2O than conventional urea, even at the greater moisture content. At the end of sampling, soil nitrate N and apparent recovered fertilizer N were similar among all fertilizer treatments and generally large in both the field and laboratory experiments indicating that N losses from denitrification were not substantial or different among treatments.

Throughout all the experiments, N_2O emissions from calcium nitrate were similar to or less than emissions from urea treatments. Therefore, nitrification appears to be the dominant process responsible for N_2O emissions in our studies. In the field experiment, spring banded conventional urea emitted similar total cumulative emissions to fall banded calcium nitrate and fall banded conventional urea. In laboratory experiment A and the wetter soil of experiment B, conventional urea emitted more N_2O than calcium nitrate, indicating that nitrification was responsible for significant N_2O emissions (Chapter 4). Therefore, agricultural management practices focused on reducing denitrification losses alone may have little effect on total emissions of N_2O. Also, spring application of N fertilizer may be of little benefit for reducing the risk of N_2O emissions during thaw if there are similar emissions from nitrification of the spring and fall applied fertilizer.

The effect of incorporating urease and nitrification inhibitors with urea was not consistent in our studies. The application of fall banded NBPT and DCD did not result in greater agronomic performance as measured by grain yield, N uptake and recovered fertilizer efficiency in the field experiments (Chapter 2). Moreover, the addition of inhibitors to urea did not reduce nitrous oxide emissions in the field, as cumulative nitrous oxide emissions were similar among all fertilizer treatments including the control (Chapter 3). While the addition of inhibitors resulted in significant less cumulative nitrous oxide emissions compared to conventional urea in one of two laboratory experiments (experiment A), NBPT urea and NBPT-DCD urea emitted significantly greater N_2O emissions compared to conventional urea at 70 % WFPS in experiment B (Chapter 4). In conditions such as the present studies where fertilizer was not generally susceptible to large losses, the effects of urease and nitrification inhibitors may not be evident. Further evaluation under a larger range of moisture conditions and greater nitrous oxide emissions may demonstrate more clearly the effect of urease and nitrification inhibitors on N_2O emissions.

Spatial and temporal variability in N_2O emissions and soil N data within treatments was large in both the field and laboratory experiments, which may have obscured any fertilizer treatment effects. In the field experiment, N_2O emissions and soil N data varied spatially at all scales from among the sites to replicates within each site. Nitrous oxide and soil N also varied between site years at each individual site. Although more frequently sampled compared to the field experiment, spatial variability was also large among replicates in the laboratory experiments. Efforts to reduce site and treatment variability may reveal fertilizer effects not observed in the current studies. Increasing the frequency of N_2O emissions sampling, size of the static vented chambers, number of chambers per plot, and number of replicates for each fertilizer treatment can help to reduce spatial and temporal variability at each site. Increasing the number of soil samples collected from each treatment and increasing replicates can also improve variability in soil N data. Increasing the number of sites can also reduce variability among sites.

Management practices which aim to reduce nitrous oxide emissions during denitrification may have little impact on total nitrogen losses during nitrification. Therefore, further evaluation of nitrous oxide emitted during nitrification is needed before management practices to reduce nitrous oxide emissions are structured around limiting loss from denitrification.

APPENDIX A:

SUPPLEMENTARY TABLES FOR CHAPTER 2.0

Table A.1. Ammonia Volatilization Fall 2005

Oak Bluff MB	Rep	Week 1	Week 2	Week 3	Week 4
Treatment		Ammonia Volatilization (mg kg^{-1})			
Control	1	0.0132		0.0170	0.0191
Fall Banded NBPT+DCD Urea	1	0.0141	0.0286	0.0217	0.0095
Fall Banded Conventional Urea	1	0.0191	0.0175	0.0265	0.0106
Fall Banded Calcium Nitrate	1	0.0148	0.0223	0.0154	0.0106
Control	2	0.0198		0.0159	0.0136
Fall Banded NBPT+DCD Urea	2	0.0588	0.0726	0.0911	0.0721
Fall Banded Conventional Urea	2	0.0302	0.0127	0.0143	0.0254
Fall Banded Calcium Nitrate	2	0.0265	0.0170	0.0223	0.0180
Control	3	0.0199		0.0171	0.0144
Fall Banded NBPT+DCD Urea	3	0.0212	0.0117	0.0191	0.0132
Fall Banded Conventional Urea	3	0.0170	0.0159	0.0291	0.0122
Fall Banded Calcium Nitrate	3	0.0290		0.0238	0.0217
Control	4	0.0205		0.0197	0.0190
Fall Banded NBPT+DCD Urea	4	0.0191	0.0260	0.0254	0.0286
Fall Banded Conventional Urea	4	0.0154	0.0244	0.0260	0.0164
Fall Banded Calcium Nitrate	4	0.0220		0.0360	0.0196
Indian Head SK					
Control	1	0.0387	0.0217	0.0244	0.0318
Fall Banded NBPT+DCD Urea	1	0.0382	0.1797	0.2385	0.3720
Fall Banded Conventional Urea	1	0.1060	0.1367	0.0567	0.0482
Fall Banded Calcium Nitrate	1	0.0318	0.0148	0.0244	0.0286
Control	2	0.0413	0.0318	0.0286	0.0768
Fall Banded NBPT+DCD Urea	2	0.0466	0.0768	0.3439	0.7483
Fall Banded Conventional Urea	2	4.4399	13.3953	3.3052	1.2406
Fall Banded Calcium Nitrate	2	0.0350	0.0180	0.0350	0.0228
Control	3	0.0334	0.0244	0.0223	0.0223
Fall Banded NBPT+DCD Urea	3	0.0392	0.0371	0.0302	0.0223
Fall Banded Conventional Urea	3	1.3964	12.1076	5.8675	1.4573
Fall Banded Calcium Nitrate	3	0.0397	0.1887	0.0657	0.1537
Control	4	0.0350		0.0279	0.0207
Fall Banded NBPT+DCD Urea	4	0.0694	0.0594	0.1595	0.2496
Fall Banded Conventional Urea	4	0.1532	0.1097	0.1357	0.0530
Fall Banded Calcium Nitrate	4	0.0774	0.0620	0.0514	0.0498

Table A.1 (cont'd.). Ammonia Volatilization Fall 2005

Brandon MB	Rep	Day 1	Day 3	Day 10	Day 17	Day 24
		Ammonia Volatilization (mg kg^{-1})				
Control	1	0.0150	0.0237	0.0199	0.0156	0.0312
Fall Banded NBPT+DCD Urea	1	0.0165	0.0267	0.0268	0.0222	0.0457
Fall Banded Conventional Urea	1	0.0128	0.0244	0.0185	0.0199	0.0241
Fall Banded Calcium Nitrate	1	0.0241	0.0375	0.0205	0.0152	0.0188
Control	2	0.0157	0.0225	0.0166	0.0126	0.0147
Fall Banded NBPT+DCD Urea	2	0.0155	0.0270	0.0278	0.0154	0.0169
Fall Banded Conventional Urea	2	0.0223	0.3266	1.4552	0.7930	0.2097
Fall Banded Calcium Nitrate	2	0.0188	0.0223	0.0162	0.0213	0.0181
Control	3	0.0164	0.0250	0.0200	0.0147	0.0285
Fall Banded NBPT+DCD Urea	3	0.0112	0.0271	0.0410	0.0774	0.0538
Fall Banded Conventional Urea	3	0.0221	0.0300	0.0390	0.0266	0.0371
Fall Banded Calcium Nitrate	3	0.0158	0.0263	0.0123	0.0218	0.0313
Control	4	0.0138	0.0328	0.0196	0.0155	0.0195
Fall Banded NBPT+DCD Urea	4	0.0179	0.0209	0.0199	0.0268	0.0279
Fall Banded Conventional Urea	4	0.0217	0.0261	0.0308	0.0260	0.0232
Fall Banded Calcium Nitrate	4	0.0234	0.0266	0.0156	0.0187	0.0163

Table A.2. Ammonia Volatilization Spring 2006

Oak Bluff MB	Rep	Week 1	Week 2	Week 3	Week 4
Treatment		Ammonia Volatilization (mg kg^{-1})			
Control	1	0.1011	0.0692	0.0630	0.0779
Spring Banded Conventional Urea	1	0.0760	0.1020	0.0629	0.0335
Control	2	0.0375	0.0725	0.0615	0.0677
Spring Banded Conventional Urea	2	0.0736	0.1727	0.0648	0.0488
Control	3	0.0583	0.0713	0.0464	0.0176
Spring Banded Conventional Urea	3	0.0512	0.0880	0.0646	0.0295
Control	4	0.0816	0.0669	0.0542	0.0235
Spring Banded Conventional Urea	4	0.0288	0.0950	0.0655	0.0332
Brandon MB					
Control	1	0.0529	0.0849	0.0552	0.0864
Spring Banded Conventional Urea	1	0.4371	0.2345	0.0774	0.1496
Control	2	0.0611	0.0689	0.0613	0.0968
Spring Banded Conventional Urea	2	0.5203	0.5946	0.0944	0.1106
Control	3	0.0876	0.0933	0.0511	0.0963
Spring Banded Conventional Urea	3	0.9999	0.9327	0.2392	0.3279
Control	4	0.1032	0.1716	0.0634	0.0773
Spring Banded Conventional Urea	4	2.4639	0.3244	0.0792	0.0928
Indian Head SK					
Control	1	0.0624	0.3468	0.0614	0.0482
Spring Banded Conventional Urea	1				
Control	2	0.1395	0.1235	0.1737	0.0496
Spring Banded Conventional Urea	2				
Control	3	0.1111	0.1743	0.0731	0.0300
Spring Banded Conventional Urea	3				
Control	4	0.0960	0.1386	0.0631	0.0497
Spring Banded Conventional Urea	4				

Table A.3. Ammonia Volatilization Fall 2006

Oak Bluff MB	Rep	Week 1	Week 2	Week 3	Week 4
Treatment		Ammonia Volatilization (mg kg^{-1})			
Control	1	0.0725	0.0499	0.0404	0.0412
Fall Banded NBPT+DCD Urea	1	0.1153	0.0737	0.0239	NM
Fall Banded Conventional Urea	1	0.0437	0.0934	0.0201	0.0247
Fall Banded Calcium Nitrate	1	0.0603	0.0518	0.0337	0.0353
Control	2	0.0486	0.0432	0.0301	0.0270
Fall Banded NBPT+DCD Urea	2	0.0628	0.0899	0.0250	0.0278
Fall Banded Conventional Urea	2	0.0943	0.0995	0.0358	0.0240
Fall Banded Calcium Nitrate	2	0.0364	0.1289	0.0276	0.0250
Control	3	0.0339	0.1020	0.0252	0.0328
Fall Banded NBPT+DCD Urea	3	0.0499	0.0724	0.0275	0.0378
Fall Banded Conventional Urea	3	0.1123	0.0956	0.0288	0.0420
Fall Banded Calcium Nitrate	3	0.0819	0.1343	0.0349	0.0403
Control	4	0.0574	0.1026	0.0256	0.0270
Fall Banded NBPT+DCD Urea	4	0.0375	0.1096	0.0304	0.0334
Fall Banded Conventional Urea	4	0.0550	0.787	0.0204	0.0352
Fall Banded Calcium Nitrate	4	0.0891	0.0807	0.0241	0.0261
Indian Head SK					
Control	1	0.0826	0.0516	0.0140	0.0163
Fall Banded NBPT+DCD Urea	1	0.0942	0.0411	0.0119	0.0140
Fall Banded Conventional Urea	1	0.0616	0.0395	0.0149	0.0173
Fall Banded Calcium Nitrate	1	0.0842	0.0545	0.0125	0.0146
Control	2	0.0740	0.0726	0.0101	0.0110
Fall Banded NBPT+DCD Urea	2	0.0920	0.0700	0.0150	0.0139
Fall Banded Conventional Urea	2	0.0839	0.0458	0.0152	0.0115
Fall Banded Calcium Nitrate	2	0.0740	0.0458	0.0121	0.0091
Control	3	0.0413	0.0407	0.0147	0.0109
Fall Banded NBPT+DCD Urea	3	0.0557	0.0373	0.0104	0.0137
Fall Banded Conventional Urea	3	0.0703	0.0665	0.0117	0.0110
Fall Banded Calcium Nitrate	3	0.0433	0.0631	0.0139	0.0111
Control	4	0.0862	0.0443	0.0096	0.0209
Fall Banded NBPT+DCD Urea	4	0.0471	0.0297	0.0116	0.0120
Fall Banded Conventional Urea	4	0.0578	0.0685	0.0203	0.0159
Fall Banded Calcium Nitrate	4	0.0910	0.0662	0.0090	0.0126

Table A.3 (cont'd.). Ammonia Volatilization Fall 2006

Brandon MB	Rep	Day 1	Day 3	Day 17	Day 24	Day 31
Treatment		Ammonia Volatilization (mg kg^{-1})				
Control	1	0.0238	0.0327	0.0200	0.0212	0.0207
Fall Banded NBPT+DCD Urea	1	0.0591	0.0504	0.0459	0.1015	0.1012
Fall Banded Conventional Urea	1	0.0688	0.0641	0.0238	0.0440	0.0285
Fall Banded Calcium Nitrate	1	0.0470	0.0509	0.0242	0.0273	0.0521
Control	2	0.0497	0.0678	0.0246	0.0270	0.0275
Fall Banded NBPT+DCD Urea	2	0.0541	0.0520	0.0226	0.0279	0.0648
Fall Banded Conventional Urea	2	0.1139	0.0582	0.0150	0.0213	0.0441
Fall Banded Calcium Nitrate	2	0.0495	0.0312	0.0179	0.0404	0.0780
Control	3	0.0851	0.0616	0.0264	0.0299	0.0938
Fall Banded NBPT+DCD Urea	3	0.0488	0.0461	0.0249	0.0265	0.0277
Fall Banded Conventional Urea	3	0.0606	0.0705	0.0246	0.0275	0.0291
Fall Banded Calcium Nitrate	3	0.0927	0.0590	0.0233	0.0295	0.0355
Control	4	0.0429	0.0487	0.0374	0.0585	0.0784
Fall Banded NBPT+DCD Urea	4	0.0389	0.0274	0.0660	0.1216	0.1288
Fall Banded Conventional Urea	4	0.0644	0.0526	0.0323	0.0838	0.0392
Fall Banded Calcium Nitrate	4	0.0446	0.0428	0.0252	0.0262	0.0549

Table A.4. Ammonia Volatilization Spring 2007.

Oak Bluff MB	Rep	Week 1	Week 2	Week 3	Week 4
Treatment		Ammonia Volatilization (mg kg^{-1})			
Control	1	0.1441	0.0706	0.0210	0.0229
Spring Banded Conventional Urea	1	0.0632	0.1201	0.0261	0.0294
Control	2	0.6579	0.0755	0.0085	0.0276
Spring Banded Conventional Urea	2	0.1697	0.0668	0.0233	0.0303
Control	3	0.2017	0.1275	0.0247	0.0199
Spring Banded Conventional Urea	3	0.1213	0.0691	0.0069	0.0355
Control	4	0.0817	0.0758	0.0100	0.0569
Spring Banded Conventional Urea	4	0.1258	0.1084	0.0207	0.0313
Brandon MB					
Control	1	0.1622	0.1145	0.1102	NM
Spring Banded Conventional Urea	1	3.0050	0.2075	0.1033	0.0704
Control	2	0.0853	0.0538	0.0653	0.0976
Spring Banded Conventional Urea	2	1.2387	0.1014	0.1065	0.1250
Control	3	0.0719	0.0475	0.0933	0.1040
Spring Banded Conventional Urea	3	0.2777	0.1232	0.0860	0.0556
Control	4	0.0437	0.0531	0.0439	0.1272
Spring Banded Conventional Urea	4	0.8509	0.0789	0.1423	0.1341
Indian Head SK					
Control	1	0.0282	0.0330	0.0372	0.0403
Spring Banded Conventional Urea	1	0.0280	0.0434	0.0175	0.0305
Control	2	0.0260	0.0362	0.0272	0.0233
Spring Banded Conventional Urea	2	0.0220	0.0337	0.0297	0.0239
Control	3	0.0223	0.0362	0.0208	0.0218
Spring Banded Conventional Urea	3	0.0243	0.0357	0.0258	0.0262
Control	4	0.0226	0.0764	0.0229	0.0244
Spring Banded Conventional Urea	4	0.0228	0.0559	0.0283	0.0333

Table A.5. Concentrations of ammonium and nitrate in soil one week after fertilizer application in the fall at Oak Bluff.

				2005			
Site and treatment				1 week after fertilizer application			
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
				mg kg^{-1}			
Control	1	12.20		12.20	8.60		8.60
Fall Banded NBPT-DCD Urea	1	16.05	30.35	23.20	10.65	20.65	15.65
Fall Banded Conventional Urea	1	15.55	18.65	17.10	8.65	18.55	13.60
Fall Banded Calcium Nitrate	1	18.20	7.75	13.00	9.55	29.00	19.30
Spring Banded Conventional Urea	1						
Control	2	6.65		6.65	6.60		6.60
Fall Banded NBPT-DCD Urea	2	8.50	24.30	16.40	7.65	13.75	10.70
Fall Banded Conventional Urea	2	7.20	23.10	15.15	5.40	10.50	7.95
Fall Banded Calcium Nitrate	2	9.30	8.15	8.75	5.95	20.95	13.45
Spring Banded Conventional Urea	2						
Control	3	13.10		13.10	9.20		9.20
Fall Banded NBPT-DCD Urea	3	8.15	27.05	17.60	10.15	15.50	12.85
Fall Banded Conventional Urea	3	16.30	8.25	12.30	11.95	8.65	10.30
Fall Banded Calcium Nitrate	3	11.95	6.70	9.35	12.10	26.00	19.05
Spring Banded Conventional Urea	3						
Control	4	6.60		6.60	8.85		8.85
Fall Banded NBPT-DCD Urea	4	6.80	38.05	22.45	9.90	22.15	16.05
Fall Banded Conventional Urea	4	7.90	53.05	30.50	9.40	31.15	20.30
Fall Banded Calcium Nitrate	4	6.30	7.85	7.10	18.75	36.10	27.45
Spring Banded Conventional Urea	4						

Table A.6. Concentrations of ammonium and nitrate in soil two weeks after fertilizer application in the fall at Oak Bluff.

		2005					
Site and treatment		2 weeks after fertilizer application					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	8.75		8.75	8.65		8.65
Fall Banded NBPT-DCD Urea	1	7.95	28.80	18.40	8.45	21.00	14.75
Fall Banded Conventional Urea	1	7.85	28.15	18.00	9.65	17.05	13.35
Fall Banded Calcium Nitrate	1	5.45	12.65	9.05	13.85	39.15	26.50
Spring Banded Conventional Urea	1						
Control	2	11.55		11.55	6.85		6.85
Fall Banded NBPT-DCD Urea	2	9.70	25.20	17.45	15.05	28.80	22.00
Fall Banded Conventional Urea	2	6.40	18.85	12.65	7.45	16.15	11.80
Fall Banded Calcium Nitrate	2	8.65	5.65	7.15	19.25	28.60	23.95
Spring Banded Conventional Urea	2						
Control	3	8.05		8.05	7.00		7.00
Fall Banded NBPT-DCD Urea	3	16.25	29.15	22.70	12.80	30.75	21.80
Fall Banded Conventional Urea	3	10.35	14.65	12.50	12.45	17.60	15.05
Fall Banded Calcium Nitrate	3	5.95	5.40	5.70	15.90	34.35	25.15
Spring Banded Conventional Urea	3						
Control	4	6.25		6.25	10.50		10.50
Fall Banded NBPT-DCD Urea	4	7.30	20.85	14.10	8.40	18.40	13.40
Fall Banded Conventional Urea	4	6.35	31.50	18.95	12.25	30.80	21.55
Fall Banded Calcium Nitrate	4	9.75	4.90	7.35	16.50	31.55	24.05
Spring Banded Conventional Urea	4						

Table A.7. Concentrations of ammonium and nitrate in soil three weeks after fertilizer application in the fall at Oak Bluff.

		2005					
Site and treatment		3 weeks after fertilizer application					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	9.25		9.25	9.15		9.15
Fall Banded NBPT-DCD Urea	1	22.75	25.15	23.95	11.45	18.10	14.80
Fall Banded Conventional Urea	1	5.80	21.90	13.85	21.05	17.75	19.40
Fall Banded Calcium Nitrate	1	8.30	5.50	6.90	13.60	40.65	27.15
Spring Banded Conventional Urea	1						
Control	2	7.25		7.25	9.95		9.95
Fall Banded NBPT-DCD Urea	2	6.30	29.95	18.15	11.15	37.60	24.40
Fall Banded Conventional Urea	2	5.10	15.40	10.25	18.40	37.85	28.15
Fall Banded Calcium Nitrate	2	19.30	6.10	12.70	11.80	29.80	20.80
Spring Banded Conventional Urea	2						
Control	3	8.50		8.50	9.50		9.50
Fall Banded NBPT-DCD Urea	3	14.00	14.00	14.00	14.05	43.50	28.80
Fall Banded Conventional Urea	3	6.90	9.15	8.05	8.75	20.80	14.80
Fall Banded Calcium Nitrate	3	15.95	8.05	12.00	18.45	37.70	28.10
Spring Banded Conventional Urea	3						
Control	4	10.15		10.15	9.20		9.20
Fall Banded NBPT-DCD Urea	4	6.15	13.90	10.05	8.75	20.60	14.70
Fall Banded Conventional Urea	4	5.10	9.00	7.05	8.55	16.70	12.65
Fall Banded Calcium Nitrate	4	12.50	5.05	8.80	15.80	31.60	23.70
Spring Banded Conventional Urea	4						

Table A.8. Concentrations of ammonium and nitrate after fertilizer application in the fall at Brandon.

		2005					
Site and treatment		1 week after fertilizer application		2 weeks after fertilizer application		3 weeks after fertilizer application	
Brandon	Rep	Average NH_4 concentration	Average NO_3 concentration	Average NH_4 concentration	Average NO_3 concentration	Average NH_4 concentration	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.80	3.30	3.90	0.80	4.55	1.15
Fall Banded NBPT-DCD Urea	1	7.00	8.05	3.80	6.50	5.20	11.30
Fall Banded Conventional Urea	1	3.00	1.30	4.25	7.75	4.10	15.95
Fall Banded Calcium Nitrate	1	2.90	21.50	3.25	8.30	4.20	8.05
Spring Banded Conventional Urea	1						
Control	2	3.45	1.00	3.50	1.45	5.10	0.65
Fall Banded NBPT-DCD Urea	2	14.40	10.50	11.40	8.30	4.00	3.65
Fall Banded Conventional Urea	2	5.40	6.90	6.90	9.55	5.00	16.55
Fall Banded Calcium Nitrate	2	3.65	13.50	3.10	4.60	4.00	3.30
Spring Banded Conventional Urea	2						
Control	3	7.50	8.30	3.35	1.85	4.80	1.70
Fall Banded NBPT-DCD Urea	3	3.00	0.90	10.05	14.05	3.70	8.80
Fall Banded Conventional Urea	3	5.30	10.30	3.50	3.15	3.95	10.55
Fall Banded Calcium Nitrate	3	3.00	15.30	2.80	6.55	3.50	11.70
Spring Banded Conventional Urea	3						
Control	4	3.10	0.65	3.15	0.95	4.85	2.30
Fall Banded NBPT-DCD Urea	4	4.40	5.10	9.55	9.40	5.40	10.00
Fall Banded Conventional Urea	4	3.45	2.70	5.85	9.40	4.00	9.35
Fall Banded Calcium Nitrate	4	3.50	11.15	3.15	9.50	3.95	17.60
Spring Banded Conventional Urea	4						

Table A.9. Concentrations of ammonium and nitrate in soil one week after fertilizer application at Indian Head.

		2005					
Site and treatment		1 week after fertilizer application					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.20		4.20	6.65		6.65
Fall Banded NBPT-DCD Urea	1	4.25	14.90	7.80	11.75	4.40	9.30
Fall Banded Conventional Urea	1	3.35	32.05	12.90	5.30	4.90	5.15
Fall Banded Calcium Nitrate	1	3.65	6.85	4.70	4.10	16.45	8.20
Spring Banded Conventional Urea	1						
Control	2	6.80		6.80	8.10		8.10
Fall Banded NBPT-DCD Urea	2	4.30	15.70	8.10	10.85	5.90	9.20
Fall Banded Conventional Urea	2	4.00	14.15	7.40	8.30	5.65	7.40
Fall Banded Calcium Nitrate	2	4.60	6.70	5.30	5.55	27.75	12.95
Spring Banded Conventional Urea	2						
Control	3	4.30		4.30	8.00		8.00
Fall Banded NBPT-DCD Urea	3	4.30	7.05	5.20	6.30	8.10	6.90
Fall Banded Conventional Urea	3	4.40	24.55	11.10	9.60	7.35	8.85
Fall Banded Calcium Nitrate	3	4.15	5.95	4.75	13.05	33.05	19.70
Spring Banded Conventional Urea	3						
Control	4	6.30		6.30	7.65		7.65
Fall Banded NBPT-DCD Urea	4	5.80	13.75	8.45	8.20	6.85	7.75
Fall Banded Conventional Urea	4	3.45	32.35	13.10	7.50	6.65	7.20
Fall Banded Calcium Nitrate	4	2.90	5.05	3.60	9.85	54.65	24.80
Spring Banded Conventional Urea	4						

Table A.10. Concentrations of ammonium and nitrate in soil two weeks after fertilizer application at Indian Head.

		2005					
Site and treatment		2 weeks after fertilizer application					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	2.15		2.15	16.55		16.55
Fall Banded NBPT-DCD Urea	1	2.55	10.15	5.10	10.80	6.40	9.35
Fall Banded Conventional Urea	1	3.10	17.10	7.75	10.80	9.80	10.45
Fall Banded Calcium Nitrate	1	2.95	5.60	3.85	12.10	35.75	20.00
Spring Banded Conventional Urea	1						
Control	2	3.05		3.05	9.15		9.15
Fall Banded NBPT-DCD Urea	2	3.65	16.60	7.95	10.40	11.30	10.70
Fall Banded Conventional Urea	2	3.50	25.60	10.85	8.20	8.00	8.15
Fall Banded Calcium Nitrate	2	3.50	4.50	3.85	11.45	28.35	17.10
Spring Banded Conventional Urea	2						
Control	3	2.70		2.70	12.75		12.75
Fall Banded NBPT-DCD Urea	3	4.70	12.60	7.35	13.20	8.15	11.50
Fall Banded Conventional Urea	3	4.20	12.00	6.80	18.80	9.05	15.55
Fall Banded Calcium Nitrate	3	3.85	4.95	4.20	13.60	20.75	16.00
Spring Banded Conventional Urea	3						
Control	4	2.10		2.10	12.95		12.95
Fall Banded NBPT-DCD Urea	4	2.55	26.05	10.40	14.85	21.20	16.95
Fall Banded Conventional Urea	4	1.95	12.55	5.50	14.90	12.15	14.00
Fall Banded Calcium Nitrate	4	1.55	4.65	2.60	23.30	41.40	29.35
Spring Banded Conventional Urea	4						

Table A.11. Concentrations of ammonium and nitrate in soil three weeks after fertilizer application at Indian Head.

		2005					
Site and treatment		3 weeks after fertilizer application					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	1.45		1.45	6.15		6.15
Fall Banded NBPT-DCD Urea	1	1.25	24.80	9.10	8.60	7.65	8.30
Fall Banded Conventional Urea	1	1.60	19.35	7.50	4.90	12.10	7.30
Fall Banded Calcium Nitrate	1	2.15	2.30	2.20	7.10	26.25	13.50
Spring Banded Conventional Urea	1						
Control	2	1.85		1.85	5.20		5.20
Fall Banded NBPT-DCD Urea	2	3.50	26.50	11.15	7.20	8.80	7.75
Fall Banded Conventional Urea	2	4.75	20.00	9.85	7.15	7.75	7.35
Fall Banded Calcium Nitrate	2	1.65	3.95	2.40	7.00	11.20	8.40
Spring Banded Conventional Urea	2						
Control	3	1.95		1.95	6.00		6.00
Fall Banded NBPT-DCD Urea	3	1.70	21.05	8.15	6.05	13.30	8.45
Fall Banded Conventional Urea	3	1.55	9.25	4.10	6.70	10.60	8.00
Fall Banded Calcium Nitrate	3	2.50	2.95	2.65	8.45	21.65	12.85
Spring Banded Conventional Urea	3						
Control	4	2.00		2.00	7.10		7.10
Fall Banded NBPT-DCD Urea	4	1.40	36.00	12.95	6.35	12.50	8.40
Fall Banded Conventional Urea	4	1.65	25.95	9.75	7.05	15.40	9.85
Fall Banded Calcium Nitrate	4	1.65	1.85	1.70	10.25	21.90	14.15
Spring Banded Conventional Urea	4						

Table A.12. Concentrations of ammonium and nitrate in soil at spring thaw at Oak Bluff.

		2006					
Site and treatment		Spring thaw					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		$mg\ kg^{-1}$					
Control	1	5.15		5.15	44.20		44.20
Fall Banded NBPT-DCD Urea	1	6.65	11.70	9.20	111.05	34.40	72.75
Fall Banded Conventional Urea	1	5.00	4.80	4.90	35.45	46.85	41.15
Fall Banded Calcium Nitrate	1	5.25	5.35	5.30	47.80	34.90	41.35
Spring Banded Conventional Urea	1	6.10		6.10	17.50		17.50
Control	2	6.85		6.85	26.40		26.40
Fall Banded NBPT-DCD Urea	2	12.00	6.35	9.20	107.45	29.20	68.35
Fall Banded Conventional Urea	2	8.00	6.60	7.30	112.00	30.95	71.50
Fall Banded Calcium Nitrate	2	8.15	5.05	6.60	44.00	40.10	42.05
Spring Banded Conventional Urea	2	4.75		4.75	32.55		32.55
Control	3	6.90		6.90	27.45		27.45
Fall Banded NBPT-DCD Urea	3	5.45	4.85	5.15	23.60	37.60	30.60
Fall Banded Conventional Urea	3	5.95	6.10	6.05	16.25	22.95	19.60
Fall Banded Calcium Nitrate	3	5.20	4.95	5.10	19.80	21.20	20.50
Spring Banded Conventional Urea	3	6.05		6.05	6.15		6.15
Control	4	6.95		6.95	12.90		12.90
Fall Banded NBPT-DCD Urea	4	6.25	5.65	5.95	17.10	28.10	22.60
Fall Banded Conventional Urea	4	5.95	6.30	6.15	40.40	54.45	47.45
Fall Banded Calcium Nitrate	4	4.65	5.95	5.30	22.85	21.05	21.95
Spring Banded Conventional Urea	4	8.20		8.20	12.20		12.20

Table A.13. Concentrations of ammonium and nitrate in soil at planting at Oak Bluff.

				2006			
Site and treatment				planting			
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
				mg kg^{-1}			
Control	1	2.80		2.80	21.45		21.45
Fall Banded NBPT-DCD Urea	1	4.40	3.10	3.75	27.80	33.75	30.80
Fall Banded Conventional Urea	1	3.35	2.95	3.15	23.80	34.20	29.00
Fall Banded Calcium Nitrate	1	3.50	3.05	3.30	33.60	21.10	27.35
Spring Banded Conventional Urea	1	3.60		3.60	13.55		13.55
Control	2	3.10		3.10	4.15		4.15
Fall Banded NBPT-DCD Urea	2	2.55	2.90	2.75	25.05	32.25	28.65
Fall Banded Conventional Urea	2	3.55	2.15	2.85	12.25	15.10	13.70
Fall Banded Calcium Nitrate	2	3.05	2.80	2.95	35.25	9.75	22.50
Spring Banded Conventional Urea	2	4.45		4.45	3.05		3.05
Control	3	2.70		2.70	2.15		2.15
Fall Banded NBPT-DCD Urea	3	2.70	2.45	2.60	2.80	3.55	3.20
Fall Banded Conventional Urea	3	3.25	2.10	2.70	4.50	1.95	3.25
Fall Banded Calcium Nitrate	3	2.75	2.70	2.75	12.00	4.15	8.10
Spring Banded Conventional Urea	3	2.75		2.75	1.05		1.05
Control	4	3.40		3.40	5.20		5.20
Fall Banded NBPT-DCD Urea	4	3.40	2.05	2.75	7.35	3.45	5.40
Fall Banded Conventional Urea	4	4.85	2.70	3.80	10.45	20.80	15.65
Fall Banded Calcium Nitrate	4	3.40	3.60	3.50	7.65	5.35	6.50
Spring Banded Conventional Urea	4	3.00		3.00	7.40		7.40

Table A.14. Concentrations of ammonium and nitrate in soil one week after planting at Oak Bluff.

		2006					
Site and treatment		1 week after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
				mg kg^{-1}			
Control	1	5.90		5.90	5.80		5.80
Fall Banded NBPT-DCD Urea	1	4.45	3.60	4.05	21.95	31.75	26.85
Fall Banded Conventional Urea	1	3.20	530.00	4.25	166.75	17.90	17.35
Fall Banded Calcium Nitrate	1	4.30	6.10	5.20	2.50	25.80	14.15
Spring Banded Conventional Urea	1	3.15	12.70	7.95	4.70	35.80	20.25
Control	2	3.65		3.65	5.00		5.00
Fall Banded NBPT-DCD Urea	2	4.25	4.15	4.20	24.95	33.25	29.10
Fall Banded Conventional Urea	2	5.65	4.80	5.25	28.00	22.10	25.05
Fall Banded Calcium Nitrate	2	5.30	4.35	4.85	19.10	18.40	18.75
Spring Banded Conventional Urea	2	3.85	13.85	8.85	9.30	24.15	16.75
Control	3	5.05		5.05	15.70		15.70
Fall Banded NBPT-DCD Urea	3	5.70	4.10	4.90	24.40	27.55	26.00
Fall Banded Conventional Urea	3	4.80	4.45	4.65	24.90	15.90	20.40
Fall Banded Calcium Nitrate	3	7.70	5.60	6.65	35.05	21.05	28.05
Spring Banded Conventional Urea	3	5.05	5.60	5.35	12.35	12.55	12.45
Control	4	4.50		4.50	16.05		16.05
Fall Banded NBPT-DCD Urea	4	4.95	5.25	5.10	9.05	19.60	14.35
Fall Banded Conventional Urea	4	4.00	3.95	4.00	12.25	11.25	11.75
Fall Banded Calcium Nitrate	4	4.60	5.20	4.90	27.05	22.05	24.55
Spring Banded Conventional Urea	4	4.75	17.00	10.90	20.50	31.30	25.90

Table A.15. Concentrations of ammonium and nitrate in soil two weeks after planting at Oak Bluff.

		2006					
Site and treatment		2 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.80		3.80	17.20		17.20
Fall Banded NBPT-DCD Urea	1	3.95	4.20	4.10	32.25	34.90	33.60
Fall Banded Conventional Urea	1	3.10	3.20	3.15	42.05	43.45	42.75
Fall Banded Calcium Nitrate	1	3.80	4.00	3.90	31.05	25.35	28.20
Spring Banded Conventional Urea	1	3.15	5.65	4.40	18.50	38.40	28.45
Control	2	4.80		4.80	17.50		17.50
Fall Banded NBPT-DCD Urea	2	3.70	4.10	3.90	41.15	39.30	40.25
Fall Banded Conventional Urea	2	3.30	3.20	3.25	31.60	38.40	35.00
Fall Banded Calcium Nitrate	2	3.40	3.35	3.40	22.00	21.45	21.75
Spring Banded Conventional Urea	2	4.35	7.25	5.80	24.15	54.90	39.55
Control	3	3.05		3.05	12.15		12.15
Fall Banded NBPT-DCD Urea	3	3.40	2.70	3.05	40.20	30.00	35.10
Fall Banded Conventional Urea	3	3.95	3.40	3.70	27.15	23.20	25.20
Fall Banded Calcium Nitrate	3	5.20	3.05	4.15	29.00	22.45	25.75
Spring Banded Conventional Urea	3	3.00	2.95	3.00	15.40	9.25	12.35
Control	4	3.35		3.35	14.60		14.60
Fall Banded NBPT-DCD Urea	4	6.55	4.65	5.60	15.65	36.45	26.05
Fall Banded Conventional Urea	4	3.35	3.05	3.20	33.80	28.95	31.40
Fall Banded Calcium Nitrate	4	3.40	3.05	3.25	23.60	22.05	22.85
Spring Banded Conventional Urea	4	3.35	4.30	3.85	18.85	20.30	19.60

Table A.16. Concentrations of ammonium and nitrate in soil three weeks after planting at Oak Bluff.

		2006					
Site and treatment		3 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.50		3.50	25.10		25.10
Fall Banded NBPT-DCD Urea	1	4.25	4.25	4.25	29.00	38.90	33.95
Fall Banded Conventional Urea	1	3.55	4.35	3.95	39.10	44.10	41.60
Fall Banded Calcium Nitrate	1	3.75	5.45	4.60	22.40	29.70	26.05
Spring Banded Conventional Urea	1	4.00	3.00	3.50	25.00	54.35	39.70
Control	2	3.85		3.85	19.80		19.80
Fall Banded NBPT-DCD Urea	2	4.00	4.30	4.15	36.40	35.25	35.85
Fall Banded Conventional Urea	2	4.30	3.25	3.80	36.90	33.80	35.35
Fall Banded Calcium Nitrate	2	3.95	4.40	4.20	23.45	30.75	27.10
Spring Banded Conventional Urea	2	4.90	4.00	4.45	22.20	54.45	38.35
Control	3	3.25		3.25	16.50		16.50
Fall Banded NBPT-DCD Urea	3	3.60	3.85	3.75	31.10	28.50	29.80
Fall Banded Conventional Urea	3	4.45	4.15	4.30	27.30	26.70	26.75
Fall Banded Calcium Nitrate	3	3.80	4.55	4.20	32.45	29.70	31.10
Spring Banded Conventional Urea	3	3.95	4.80	4.40	16.85	22.90	19.90
Control	4	4.35		4.35	14.20		14.20
Fall Banded NBPT-DCD Urea	4	4.05	3.90	4.00	24.70	24.90	24.80
Fall Banded Conventional Urea	4	3.80	4.85	4.35	28.40	26.25	27.35
Fall Banded Calcium Nitrate	4	3.60	5.45	4.55	28.05	21.30	24.70
Spring Banded Conventional Urea	4	3.90	4.05	4.00	22.55	25.30	23.95

Table A.17. Concentrations of ammonium and nitrate in soil four weeks after planting at Oak Bluff.

		2006					
Site and treatment		4 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	12.00		12.00	22.75		22.75
Fall Banded NBPT-DCD Urea	1	6.85	6.80	6.85	34.70	32.60	33.65
Fall Banded Conventional Urea	1	19.40	6.90	13.15	36.90	49.85	43.40
Fall Banded Calcium Nitrate	1	9.55	9.70	9.65	21.60	25.15	23.40
Spring Banded Conventional Urea	1	12.40	7.75	10.10	25.95	42.05	34.00
Control	2	7.90		7.90	23.80		23.80
Fall Banded NBPT-DCD Urea	2	12.75	8.60	10.70	37.80	43.55	40.70
Fall Banded Conventional Urea	2	9.40	7.55	8.50	38.10	41.40	39.75
Fall Banded Calcium Nitrate	2	7.45	7.25	7.35	24.55	29.20	26.90
Spring Banded Conventional Urea	2	8.25	11.70	10.00	34.55	51.25	42.90
Control	3	8.45		8.45	18.45		18.45
Fall Banded NBPT-DCD Urea	3	8.80	6.70	7.75	26.45	26.45	26.45
Fall Banded Conventional Urea	3	8.10	8.00	8.05	20.95	23.05	22.00
Fall Banded Calcium Nitrate	3	8.05	6.95	7.50	32.05	30.15	31.10
Spring Banded Conventional Urea	3	8.25	8.15	8.20	16.10	14.45	15.30
Control	4	9.65		9.65	14.90		14.90
Fall Banded NBPT-DCD Urea	4	6.70	8.00	7.35	25.10	25.60	25.35
Fall Banded Conventional Urea	4	14.30	12.15	13.25	21.20	18.85	20.05
Fall Banded Calcium Nitrate	4	6.25	6.85	6.55	22.10	19.15	20.65
Spring Banded Conventional Urea	4	9.50	11.00	10.25	33.25	27.30	30.30

Table A.18. Concentrations of ammonium and nitrate in soil at spring thaw at Brandon.

		2006					
Site and treatment		Spring thaw					
Brandon	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	6.25		6.25	3.75		3.75
Fall Banded NBPT-DCD Urea	1	6.50	7.50	7.00	8.75	15.85	12.30
Fall Banded Conventional Urea	1	6.60	6.00	6.30	7.30	9.05	8.20
Fall Banded Calcium Nitrate	1	5.85	4.90	5.40	7.70	2.70	5.20
Spring Banded Conventional Urea	1	7.00		7.00	2.10		2.10
Control	2	5.60		5.60	2.40		2.40
Fall Banded NBPT-DCD Urea	2	9.45	6.90	8.20	4.35	8.65	6.50
Fall Banded Conventional Urea	2	5.30	6.05	5.70	9.60	12.40	11.00
Fall Banded Calcium Nitrate	2	5.25	7.80	6.55	12.65	9.20	10.95
Spring Banded Conventional Urea	2	5.85		5.85	1.15		1.15
Control	3	6.10		6.10	2.15		2.15
Fall Banded NBPT-DCD Urea	3	6.00	7.40	6.70	12.45	11.50	12.00
Fall Banded Conventional Urea	3	5.95	6.80	6.40	3.40	4.85	4.15
Fall Banded Calcium Nitrate	3	8.20	7.70	7.95	5.00	5.30	5.15
Spring Banded Conventional Urea	3	6.50		6.50	2.60		2.60
Control	4	5.80		5.80	1.45		1.45
Fall Banded NBPT-DCD Urea	4	6.00	6.75	6.40	8.95	15.40	12.20
Fall Banded Conventional Urea	4	7.30	5.80	6.55	7.65	1.75	4.70
Fall Banded Calcium Nitrate	4	6.90	7.45	7.20	8.15	8.40	8.30
Spring Banded Conventional Urea	4	5.95		5.95	1.55		1.55

Table A.19. Concentrations of ammonium and nitrate in soil at planting at Brandon.

		2006					
Site and treatment		planting					
Brandon	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.95		3.95	1.85		1.85
Fall Banded NBPT-DCD Urea	1	3.80	3.65	3.75	5.00	8.80	6.90
Fall Banded Conventional Urea	1	3.30	3.75	3.55	14.65	11.70	13.20
Fall Banded Calcium Nitrate	1	4.15	6.55	5.35	2.80	4.45	3.65
Spring Banded Conventional Urea	1	5.80		5.80	3.55		3.55
Control	2	6.85		6.85	5.75		5.75
Fall Banded NBPT-DCD Urea	2	3.75	3.55	3.65	4.70	6.65	5.70
Fall Banded Conventional Urea	2	4.45	4.50	4.50	6.90	3.70	5.30
Fall Banded Calcium Nitrate	2	5.65	4.40	5.05	13.50	15.25	14.40
Spring Banded Conventional Urea	2	3.70		3.70	2.85		2.85
Control	3	3.80		3.80	2.75		2.75
Fall Banded NBPT-DCD Urea	3	4.30	4.90	4.60	15.60	13.55	14.60
Fall Banded Conventional Urea	3	4.40	3.90	4.15	7.90	12.95	10.45
Fall Banded Calcium Nitrate	3	4.00	3.25	3.65	5.65	7.80	6.75
Spring Banded Conventional Urea	3	5.20		5.20	2.00		2.00
Control	4	3.90		3.90	2.50		2.50
Fall Banded NBPT-DCD Urea	4	3.15	3.85	3.50	8.20	6.30	7.25
Fall Banded Conventional Urea	4	3.05	3.90	3.50	10.95	9.90	10.45
Fall Banded Calcium Nitrate	4	3.50	4.00	3.75	8.50	8.75	8.65
Spring Banded Conventional Urea	4	3.40	0.00	3.40	2.10	0.00	2.10

Table A.20. Concentrations of ammonium and nitrate in soil one week after planting at Brandon.

		2006					
Site and treatment		1 week after planting					
Brandon	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	5.30		5.30	3.60		3.60
Fall Banded NBPT-DCD Urea	1	4.90	5.25	5.10	13.50	19.25	16.40
Fall Banded Conventional Urea	1	4.60	6.40	5.50	12.35	12.00	12.20
Fall Banded Calcium Nitrate	1	5.65	4.40	5.05	10.05	7.10	8.60
Spring Banded Conventional Urea	1	5.05	15.30	10.20	4.50	15.85	10.20
Control	2	4.00		4.00	2.90		2.90
Fall Banded NBPT-DCD Urea	2	5.30	5.00	4.70	4.45	4.60	0.00
Fall Banded Conventional Urea	2	4.80	6.15	5.50	13.55	4.50	9.05
Fall Banded Calcium Nitrate	2	5.30	5.35	5.35	8.75	10.80	9.80
Spring Banded Conventional Urea	2	4.10	5.50	8.15	4.25	19.60	11.95
Control	3	4.45		4.45	4.80		4.80
Fall Banded NBPT-DCD Urea	3	5.70	15.30	10.55	6.95	12.15	9.55
Fall Banded Conventional Urea	3	6.35	5.65	6.00	8.15	9.55	8.85
Fall Banded Calcium Nitrate	3	4.10	5.50	4.80	3.35	6.00	4.70
Spring Banded Conventional Urea	3	4.65	12.95	8.80	3.00	14.45	8.75
Control	4	4.30		4.30	3.60		3.60
Fall Banded NBPT-DCD Urea	4	4.20	5.05	4.65	7.50	13.10	10.30
Fall Banded Conventional Urea	4	4.75	4.25	4.50	5.10	3.95	4.55
Fall Banded Calcium Nitrate	4	5.00	3.85	4.45	10.80	8.90	9.85
Spring Banded Conventional Urea	4	4.75	7.65	6.20	2.60	15.90	9.25

Table A.21. Concentrations of ammonium and nitrate in soil two weeks after planting at Brandon.

		2006					
Site and treatment		2 weeks after planting					
Brandon	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	5.00		5.00	5.00		5.00
Fall Banded NBPT-DCD Urea	1	4.05	4.65	4.60	6.40	20.50	13.45
Fall Banded Conventional Urea	1	4.65	4.30	4.50	13.95	13.35	13.65
Fall Banded Calcium Nitrate	1	4.00	3.30	3.65	2.90	4.70	3.80
Spring Banded Conventional Urea	1	3.70	4.30	4.00	5.05	15.55	10.30
Control	2	4.35		4.35	8.05		8.05
Fall Banded NBPT-DCD Urea	2	4.85	4.50	4.70	8.00	15.55	11.80
Fall Banded Conventional Urea	2	5.00	4.50	4.75	10.85	13.55	12.20
Fall Banded Calcium Nitrate	2	4.75	5.15	4.95	17.80	18.60	18.20
Spring Banded Conventional Urea	2	4.65	9.00	6.85	6.25	21.20	13.75
Control	3	4.20		4.20	3.35		3.35
Fall Banded NBPT-DCD Urea	3	4.75	3.50	4.15	16.25	15.60	15.95
Fall Banded Conventional Urea	3	3.05	4.05	3.55	8.40	6.05	7.25
Fall Banded Calcium Nitrate	3	4.50	3.45	4.00	5.70	6.75	6.25
Spring Banded Conventional Urea	3	3.65	12.25	7.95	4.50	31.35	17.95
Control	4	3.85		3.85	7.65		7.65
Fall Banded NBPT-DCD Urea	4	4.15	4.50	4.35	11.95	15.25	13.60
Fall Banded Conventional Urea	4	3.85	3.95	3.90	14.70	13.10	13.90
Fall Banded Calcium Nitrate	4	3.85	3.95	3.90	21.40	11.00	16.20
Spring Banded Conventional Urea	4	3.10	8.75	5.95	3.25	27.30	15.30

Table A.22. Concentrations of ammonium and nitrate in soil three weeks after planting at Brandon.

		2006					
Site and treatment		3 weeks after planting					
Brandon	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.30		3.30	6.30		6.30
Fall Banded NBPT-DCD Urea	1	3.35	3.85	3.60	13.25	18.15	15.70
Fall Banded Conventional Urea	1	3.45	2.70	3.10	11.30	18.40	14.85
Fall Banded Calcium Nitrate	1	3.20	3.75	3.50	4.10	7.40	5.75
Spring Banded Conventional Urea	1	2.95	3.40	3.20	8.95	24.80	16.90
Control	2	3.80		3.80	4.65		4.65
Fall Banded NBPT-DCD Urea	2	4.05	3.45	3.75	7.85	10.85	9.35
Fall Banded Conventional Urea	2	4.05	4.35	4.20	15.60	14.15	14.90
Fall Banded Calcium Nitrate	2	3.50	3.60	3.55	14.45	20.15	0.00
Spring Banded Conventional Urea	2	3.85	5.05	4.45	3.55	44.20	23.90
Control	3	3.40		3.40	6.70		6.70
Fall Banded NBPT-DCD Urea	3	3.85	2.95	3.40	17.95	10.45	14.20
Fall Banded Conventional Urea	3	3.10	3.00	3.05	8.70	7.35	8.05
Fall Banded Calcium Nitrate	3	3.30	3.25	3.30	14.50	14.15	14.35
Spring Banded Conventional Urea	3	3.40	4.15	3.80	5.55	31.50	18.55
Control	4	3.05		3.05	7.95		7.95
Fall Banded NBPT-DCD Urea	4	3.15	3.05	3.10	22.15	14.50	18.35
Fall Banded Conventional Urea	4	3.15	3.25	3.20	5.40	17.50	11.45
Fall Banded Calcium Nitrate	4	3.30	3.25	3.30	14.30	7.55	10.95
Spring Banded Conventional Urea	4	2.80	2.85	2.85	10.70	20.00	15.35

Table A.23. Concentrations of ammonium and nitrate in soil four weeks after planting at Brandon.

		2006					
Site and treatment		4 weeks after planting					
Brandon	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.80		4.80	5.75		5.75
Fall Banded NBPT-DCD Urea	1	5.30	6.00	5.65	16.00	13.45	14.75
Fall Banded Conventional Urea	1	5.15	8.00	6.60	17.40	7.65	12.55
Fall Banded Calcium Nitrate	1	7.25	4.90	6.10	4.60	3.25	3.95
Spring Banded Conventional Urea	1	5.55	6.75	6.15	8.25	4.55	6.40
Control	2	4.20		4.20	4.45		4.45
Fall Banded NBPT-DCD Urea	2	5.35	4.55	4.95	7.55	6.90	7.25
Fall Banded Conventional Urea	2	4.95	5.95	5.45	8.55	17.00	12.80
Fall Banded Calcium Nitrate	2	6.50	6.35	6.45	7.35	8.95	8.15
Spring Banded Conventional Urea	2	4.00	5.95	5.00	9.30	30.35	19.85
Control	3	6.30		6.30	2.45		2.45
Fall Banded NBPT-DCD Urea	3	5.50	5.30	5.40	13.60	12.40	13.00
Fall Banded Conventional Urea	3	5.65	5.10	5.40	13.40	7.15	10.30
Fall Banded Calcium Nitrate	3	5.25	5.80	5.55	10.15	20.90	15.55
Spring Banded Conventional Urea	3	4.75	6.55	5.65	13.95	34.00	24.00
Control	4	5.40		50.40	3.90		3.90
Fall Banded NBPT-DCD Urea	4	5.90	4.90	5.40	6.45	4.50	5.50
Fall Banded Conventional Urea	4	4.50	5.55	5.05	4.45	4.95	4.70
Fall Banded Calcium Nitrate	4	4.95	5.75	5.35	9.10	6.80	7.95
Spring Banded Conventional Urea	4	4.30	5.20	4.75	6.50	28.50	17.50

Table A.24. Concentrations of ammonium and nitrate in soil at spring thaw at Indian Head.

		2006					
Site and treatment		Spring thaw					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	6.55		6.55	2.65		2.65
Fall Banded NBPT-DCD Urea	1	10.90	6.35	9.40	5.60	2.25	4.50
Fall Banded Conventional Urea	1	7.20	5.10	6.50	4.10	6.30	4.85
Fall Banded Calcium Nitrate	1	7.35	5.20	6.65	3.50	2.45	3.15
Spring Banded Conventional Urea	1						
Control	2	5.65		5.65	5.30		5.30
Fall Banded NBPT-DCD Urea	2	15.15	24.30	18.20	6.60	11.25	8.15
Fall Banded Conventional Urea	2	8.95	5.55	7.80	8.85	12.25	10.00
Fall Banded Calcium Nitrate	2	7.80	5.30	6.95	9.45	5.75	8.20
Spring Banded Conventional Urea	2						
Control	3	9.15		9.15	5.85		5.85
Fall Banded NBPT-DCD Urea	3	11.95	11.75	11.90	11.05	10.65	10.90
Fall Banded Conventional Urea	3	7.95	17.05	11.00	13.25	15.85	14.10
Fall Banded Calcium Nitrate	3	7.70	5.30	6.90	9.60	7.55	8.90
Spring Banded Conventional Urea	3						
Control	4	10.95		10.95	6.80		6.80
Fall Banded NBPT-DCD Urea	4	9.50	12.95	10.65	7.70	7.65	7.70
Fall Banded Conventional Urea	4	8.05	5.50	7.20	7.35	4.80	6.50
Fall Banded Calcium Nitrate	4	6.95	6.15	6.70	7.10	5.35	6.50
Spring Banded Conventional Urea	4						

Table A.25. Concentrations of ammonium and nitrate in soil at planting at Indian Head.

		2006					
Site and treatment		planting					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.20		4.20	7.75		7.75
Fall Banded NBPT-DCD Urea	1	3.25	6.40	4.30	6.10	24.25	12.15
Fall Banded Conventional Urea	1	4.80	7.05	5.55	10.00	10.70	10.25
Fall Banded Calcium Nitrate	1	3.25	4.05	3.50	3.75	4.55	4.00
Spring Banded Conventional Urea	1						
Control	2	4.20		4.20	7.20		7.20
Fall Banded NBPT-DCD Urea	2	4.90	9.40	6.40	10.55	15.10	12.05
Fall Banded Conventional Urea	2	2.85	5.35	3.70	10.65	22.45	14.60
Fall Banded Calcium Nitrate	2	4.50	9.75	6.25	10.75	15.70	12.40
Spring Banded Conventional Urea	2						
Control	3	6.20		6.20	7.95		7.95
Fall Banded NBPT-DCD Urea	3	3.10	11.30	5.85	16.75	19.40	17.65
Fall Banded Conventional Urea	3	4.40	6.10	4.95	17.40	19.80	18.20
Fall Banded Calcium Nitrate	3	4.10	5.65	4.60	16.65	15.80	16.35
Spring Banded Conventional Urea	3						
Control	4	3.50		3.50	8.30		8.30
Fall Banded NBPT-DCD Urea	4	3.45	8.90	5.25	12.45	16.90	13.95
Fall Banded Conventional Urea	4	2.80	5.20	3.60	9.70	14.65	11.35
Fall Banded Calcium Nitrate	4	2.85	2.90	2.85	14.90	17.75	15.85
Spring Banded Conventional Urea	4						

Table A.26. Concentrations of ammonium and nitrate in soil one week after planting at Indian Head.

				2006			
Site and treatment				1 week after planting			
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
				mg kg^{-1}			
Control	1	3.15		3.15	7.45		7.45
Fall Banded NBPT-DCD Urea	1	3.20	9.10	5.15	5.00	16.70	8.90
Fall Banded Conventional Urea	1	4.95	9.55	6.50	11.50	11.30	11.45
Fall Banded Calcium Nitrate	1	4.45	3.65	4.20	8.20	7.35	7.90
Spring Banded Conventional Urea	1	3.20	23.90	10.10	6.05	6.30	6.15
Control	2	4.20		4.20	13.75		13.75
Fall Banded NBPT-DCD Urea	2	7.15	6.30	6.85	13.00	14.40	13.45
Fall Banded Conventional Urea	2	7.10	8.40	7.55	17.20	14.55	16.30
Fall Banded Calcium Nitrate	2	4.00	7.05	5.00	13.40	10.40	12.40
Spring Banded Conventional Urea	2	4.65	14.05	7.80	9.40	6.95	8.60
Control	3	4.05		4.05	7.10		7.10
Fall Banded NBPT-DCD Urea	3	5.75	3.60	5.05	18.75	16.30	17.95
Fall Banded Conventional Urea	3	4.15	4.35	4.20	13.90	11.25	13.00
Fall Banded Calcium Nitrate	3	3.65	4.00	3.75	18.85	16.90	18.20
Spring Banded Conventional Urea	3	4.45	12.70	7.20	7.30	6.55	7.05
Control	4	3.75		3.75	9.75		9.75
Fall Banded NBPT-DCD Urea	4	3.75	6.00	4.50	10.40	13.30	11.35
Fall Banded Conventional Urea	4	4.55	6.65	5.25	14.55	11.90	13.65
Fall Banded Calcium Nitrate	4	3.10	6.15	4.10	10.65	10.10	10.45
Spring Banded Conventional Urea	4	3.95	80.80	29.55	8.75	10.95	9.50

Table A.27. Concentrations of ammonium and nitrate in soil two weeks after planting at Indian Head.

		2006					
Site and treatment		2 weeks after planting					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.85		3.85	9.20		9.20
Fall Banded NBPT-DCD Urea	1	3.75	3.25	3.60	6.95	10.85	8.25
Fall Banded Conventional Urea	1	3.65	13.75	7.00	8.25	12.75	9.75
Fall Banded Calcium Nitrate	1	3.75	4.60	4.05	5.40	9.45	6.75
Spring Banded Conventional Urea	1	3.60	47.35	18.20	5.35	13.35	8.00
Control	2	8.25		8.25	9.10		9.10
Fall Banded NBPT-DCD Urea	2	5.20	6.60	5.65	10.55	17.30	12.80
Fall Banded Conventional Urea	2	4.85	4.60	4.75	15.95	14.65	15.50
Fall Banded Calcium Nitrate	2	3.60	9.60	5.60	12.40	17.35	14.05
Spring Banded Conventional Urea	2	4.05	29.85	12.65	6.15	9.20	7.15
Control	3	4.95		4.95	10.45		10.45
Fall Banded NBPT-DCD Urea	3	3.75	2.80	3.45	14.55	12.60	13.90
Fall Banded Conventional Urea	3	3.75	4.15	3.90	13.50	9.75	12.25
Fall Banded Calcium Nitrate	3	4.30	4.30	4.30	16.35	12.80	15.15
Spring Banded Conventional Urea	3	5.70	5.20	5.55	8.10	8.65	8.30
Control	4	5.15		5.15	15.05		15.05
Fall Banded NBPT-DCD Urea	4	3.80	6.70	4.75	8.80	13.35	10.30
Fall Banded Conventional Urea	4	3.20	4.50	3.65	9.40	14.15	11.00
Fall Banded Calcium Nitrate	4	3.20	5.85	4.10	13.65	12.75	13.35
Spring Banded Conventional Urea	4	5.70	10.45	7.30	9.20	10.95	9.80

Table A.28. Concentrations of ammonium and nitrate in soil three weeks after planting at Indian Head.

		2006					
Site and treatment		3 weeks after planting					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	2.90		2.90	11.85		11.85
Fall Banded NBPT-DCD Urea	1	3.70	9.10	5.50	11.55	11.85	11.65
Fall Banded Conventional Urea	1	4.65	6.05	5.10	16.95	14.10	16.00
Fall Banded Calcium Nitrate	1	3.30	2.90	3.15	9.10	10.60	9.60
Spring Banded Conventional Urea	1	3.60	31.40	12.85	8.80	17.85	11.80
Control	2	3.20		3.20	11.80		11.80
Fall Banded NBPT-DCD Urea	2	3.20	10.00	5.45	13.15	18.90	15.05
Fall Banded Conventional Urea	2	3.55	7.65	4.90	19.10	12.65	16.95
Fall Banded Calcium Nitrate	2	4.75	4.90	4.80	13.10	11.50	12.55
Spring Banded Conventional Urea	2	3.30	24.65	10.40	7.70	14.30	9.90
Control	3	3.15		3.15	11.25		11.25
Fall Banded NBPT-DCD Urea	3	3.25	4.30	3.60	17.40	14.95	16.60
Fall Banded Conventional Urea	3	3.85	3.90	3.85	23.05	13.50	19.85
Fall Banded Calcium Nitrate	3	4.05	4.00	4.05	17.90	20.25	18.70
Spring Banded Conventional Urea	3	7.15	15.25	9.85	10.15	15.90	12.05
Control	4	3.25		3.25	11.95		11.95
Fall Banded NBPT-DCD Urea	4	3.50	4.20	3.75	17.90	16.60	17.45
Fall Banded Conventional Urea	4	3.00	4.30	3.45	14.95	10.60	13.50
Fall Banded Calcium Nitrate	4	1.85	4.20	2.65	19.40	9.00	15.95
Spring Banded Conventional Urea	4	3.90	27.00	11.60	14.75	19.85	16.45

Table A.29. Concentrations of ammonium and nitrate in soil 4 weeks after planting at Indian Head.

		2006					
Site and treatment		4 weeks after planting					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	2.50		2.50	6.80		6.80
Fall Banded NBPT-DCD Urea	1	3.00	4.15	3.40	8.25	20.75	12.40
Fall Banded Conventional Urea	1	3.95	3.60	3.85	8.95	10.40	9.45
Fall Banded Calcium Nitrate	1	3.55	3.00	3.35	6.75	6.50	6.65
Spring Banded Conventional Urea	1	3.60	15.55	7.60	8.00	25.60	13.85
Control	2	3.25		3.25	10.85		10.85
Fall Banded NBPT-DCD Urea	2	5.90	5.60	5.80	16.15	15.00	15.75
Fall Banded Conventional Urea	2	4.25	3.90	4.15	13.35	14.60	13.75
Fall Banded Calcium Nitrate	2	3.10	4.20	3.45	12.95	7.25	11.05
Spring Banded Conventional Urea	2	4.20	7.95	5.45	7.05	18.85	11.00
Control	3	3.05		3.05	10.50		10.50
Fall Banded NBPT-DCD Urea	3	3.55	4.05	3.70	15.05	12.75	14.30
Fall Banded Conventional Urea	3	4.15	3.95	4.10	21.80	15.05	19.55
Fall Banded Calcium Nitrate	3	3.35	4.05	3.60	16.90	17.50	17.10
Spring Banded Conventional Urea	3	3.25	4.15	3.55	11.45	12.05	11.65
Control	4	3.20		3.20	11.15		11.15
Fall Banded NBPT-DCD Urea	4	3.95	3.45	3.80	9.35	7.30	8.65
Fall Banded Conventional Urea	4	3.30	3.75	3.45	11.60	10.00	11.05
Fall Banded Calcium Nitrate	4	2.15	1.85	2.05	16.55	9.45	14.20
Spring Banded Conventional Urea	4	3.20	18.65	8.35	15.45	21.20	17.35

Table A.30. Concentrations of ammonium and nitrate in soil one week after fertilizer application in the fall at Oak Bluff.

		2006					
Site and treatment		1 week after fertilizer application					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.80		4.80	23.85		23.85
Fall Banded NBPT-DCD Urea	1	5.05	21.25	13.15	9.30	9.90	9.60
Fall Banded Conventional Urea	1	6.25	20.85	13.55	5.60	15.35	10.50
Fall Banded Calcium Nitrate	1	7.20	5.00	6.10	47.95	14.70	31.35
Spring Banded Conventional Urea	1						
Control	2	5.20		5.20	5.00		5.00
Fall Banded NBPT-DCD Urea	2	6.10	6.95	6.55	10.85	11.70	11.30
Fall Banded Conventional Urea	2	4.70	29.60	17.15	5.70	16.15	10.95
Fall Banded Calcium Nitrate	2	6.30	5.45	5.90	8.10	28.15	18.15
Spring Banded Conventional Urea	2						
Control	3	6.65		6.65	11.00		11.00
Fall Banded NBPT-DCD Urea	3	6.45	16.55	11.50	8.25	18.85	13.55
Fall Banded Conventional Urea	3	6.80	28.15	17.50	16.20	16.05	16.15
Fall Banded Calcium Nitrate	3	9.70	6.10	7.90	30.60	32.15	31.40
Spring Banded Conventional Urea	3						
Control	4	5.35		5.35	8.10		8.10
Fall Banded NBPT-DCD Urea	4	5.65	11.10	8.40	11.65	16.35	14.00
Fall Banded Conventional Urea	4	6.60	5.90	6.25	16.00	8.70	12.35
Fall Banded Calcium Nitrate	4	5.50	6.15	5.85	12.30	38.10	25.20
Spring Banded Conventional Urea	4						

Table A.31. Concentrations of ammonium and nitrate in soil two weeks after fertilizer application in the fall at Oak Bluff.

		2006					
Site and treatment		2 weeks after fertilizer application					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.00		4.00	18.90		18.90
Fall Banded NBPT-DCD Urea	1	4.60	20.75	12.70	13.75	21.40	17.60
Fall Banded Conventional Urea	1	4.80	18.20	11.50	14.90	18.20	16.55
Fall Banded Calcium Nitrate	1	4.70	3.70	4.20	18.65	19.50	19.10
Spring Banded Conventional Urea	1						
Control	2	5.00		5.00	7.30		7.30
Fall Banded NBPT-DCD Urea	2	4.90	9.45	7.20	17.85	23.20	20.55
Fall Banded Conventional Urea	2	10.00	19.05	14.55	16.40	30.05	23.25
Fall Banded Calcium Nitrate	2	5.00	5.10	5.05	12.50	23.80	18.15
Spring Banded Conventional Urea	2						
Control	3	4.80		4.80	12.90		12.90
Fall Banded NBPT-DCD Urea	3	4.60	19.80	12.20	9.50	22.50	16.00
Fall Banded Conventional Urea	3	6.90	10.55	8.75	11.10	16.20	13.65
Fall Banded Calcium Nitrate	3	4.70	4.95	4.85	13.50	34.40	23.95
Spring Banded Conventional Urea	3						
Control	4	5.10		5.10	17.80		17.80
Fall Banded NBPT-DCD Urea	4	9.10	16.05	12.60	12.25	16.25	14.25
Fall Banded Conventional Urea	4	4.85	6.90	5.90	10.80	13.85	12.35
Fall Banded Calcium Nitrate	4	6.55	5.00	5.80	20.55	36.60	28.60
Spring Banded Conventional Urea	4						

Table A.32. Concentrations of ammonium and nitrate in soil three weeks after fertilizer application in the fall at Oak Bluff.

		2006					
Site and treatment		3 weeks after fertilizer application					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.75		3.75	13.50		13.50
Fall Banded NBPT-DCD Urea	1	10.45	27.10	18.80	15.60	26.60	21.10
Fall Banded Conventional Urea	1	4.00	19.80	11.90	13.15	22.20	17.70
Fall Banded Calcium Nitrate	1	3.80	3.95	3.90	23.50	19.00	21.25
Spring Banded Conventional Urea	1						
Control	2	5.50		5.50	10.00		10.00
Fall Banded NBPT-DCD Urea	2	4.70	6.40	5.55	12.35	20.75	16.55
Fall Banded Conventional Urea	2	4.65	13.90	9.30	10.35	19.85	15.10
Fall Banded Calcium Nitrate	2	4.95	3.65	4.30	10.30	24.30	17.30
Spring Banded Conventional Urea	2						
Control	3	5.35		5.35	13.30		13.30
Fall Banded NBPT-DCD Urea	3	4.80	12.55	8.70	10.10	14.75	12.45
Fall Banded Conventional Urea	3	5.00	25.75	15.40	10.10	14.70	12.40
Fall Banded Calcium Nitrate	3	4.70	4.65	4.70	20.85	44.05	32.45
Spring Banded Conventional Urea	3						
Control	4	5.40		5.40	16.15		16.15
Fall Banded NBPT-DCD Urea	4	5.20	14.65	9.95	9.80	24.20	17.00
Fall Banded Conventional Urea	4	4.45	4.95	4.70	10.05	13.20	11.65
Fall Banded Calcium Nitrate	4	5.10	5.50	5.30	22.50	57.25	39.90
Spring Banded Conventional Urea	4						

Table A.33. Concentrations of ammonium and nitrate after fertilizer application in the fall at Brandon.

		2006					
Site and treatment		1 week after fertilizer application		2 weeks after fertilizer application		3 weeks after fertilizer application	
Brandon	Rep	Average NH_4 concentration	Average NO_3 concentration	Average NH_4 concentration	Average NO_3 concentration	Average NH_4 concentration	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.05	3.35	3.25	6.80	3.90	3.20
Fall Banded NBPT-DCD Urea	1	7.75	12.80	14.05	9.75	5.20	10.95
Fall Banded Conventional Urea	1	23.85	14.45	11.70	15.05	17.30	18.20
Fall Banded Calcium Nitrate	1	4.55	20.50	2.75	20.40	3.35	7.20
Spring Banded Conventional Urea	1						
Control	2	3.75	3.65	3.15	4.60	4.15	20.00
Fall Banded NBPT-DCD Urea	2	8.60	9.50	5.20	12.25	7.20	17.70
Fall Banded Conventional Urea	2	5.95	11.25	29.85	13.40	6.20	9.55
Fall Banded Calcium Nitrate	2	3.60	24.45	4.60	27.80	3.45	27.90
Spring Banded Conventional Urea	2						
Control	3	4.30	7.90	3.35	4.60	3.50	5.80
Fall Banded NBPT-DCD Urea	3	5.65	7.90	9.15	19.80	7.45	14.55
Fall Banded Conventional Urea	3	11.45	10.45	5.30	10.35	11.45	15.95
Fall Banded Calcium Nitrate	3	3.65	26.70	2.95	21.85	3.85	28.45
Spring Banded Conventional Urea	3						
Control	4	4.20	6.60	3.80	4.55	3.80	5.80
Fall Banded NBPT-DCD Urea	4	13.30	9.25	19.05	18.45	3.95	11.80
Fall Banded Conventional Urea	4	5.45	13.35	17.35	17.20	7.85	16.85
Fall Banded Calcium Nitrate	4	3.95	38.20	3.10	10.40	4.20	11.05
Spring Banded Conventional Urea	4						

Table A.34. Concentrations of ammonium and nitrate in soil one week after fertilizer application in the fall at Indian Head.

		2006					
Site and treatment		1 week after fertilizer application					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.00		4.00	3.90		3.90
Fall Banded NBPT-DCD Urea	1	3.80	25.40	11.00	3.40	4.30	3.70
Fall Banded Conventional Urea	1	2.85	49.90	18.55	2.20	5.00	3.15
Fall Banded Calcium Nitrate	1	3.20	8.35	4.90	2.60	55.80	20.35
Spring Banded Conventional Urea	1	0.00					
Control	2	2.30		2.30			3.80
Fall Banded NBPT-DCD Urea	2	3.25	40.75	15.75	4.45	6.30	5.05
Fall Banded Conventional Urea	2	2.70	39.75	15.05	3.30	7.10	4.55
Fall Banded Calcium Nitrate	2	3.05	6.25	4.10	10.30	51.55	24.05
Spring Banded Conventional Urea	2	0.00	0.00	0.00	0.00	0.00	0.00
Control	3	2.50	0.00	2.50	2.55	0.00	2.55
Fall Banded NBPT-DCD Urea	3	3.10	22.80	9.65	2.75	5.85	3.80
Fall Banded Conventional Urea	3	2.90	27.60	11.15	3.75	5.10	4.20
Fall Banded Calcium Nitrate	3	4.25	5.95	4.80	4.55	43.80	17.65
Spring Banded Conventional Urea	3						
Control	4	3.45		3.45	3.10		3.10
Fall Banded NBPT-DCD Urea	4	15.90	29.30	20.35	4.70	3.60	4.35
Fall Banded Conventional Urea	4	3.40	35.40	14.05	3.50	6.55	4.50
Fall Banded Calcium Nitrate	4	3.25	5.40	3.95	2.35	40.75	15.15
Spring Banded Conventional Urea	4						

Table A.35. Concentrations of ammonium and nitrate in soil two weeks after fertilizer application in the fall at Indian Head.

		2006					
Site and treatment		2 weeks after fertilizer application					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.60		3.60	3.35		3.35
Fall Banded NBPT-DCD Urea	1	4.45	26.45	11.80	3.40	4.35	3.70
Fall Banded Conventional Urea	1	3.05	32.85	13.00	3.05	5.40	3.85
Fall Banded Calcium Nitrate	1	3.40	6.60	4.45	4.00	48.80	18.95
Spring Banded Conventional Urea	1						
Control	2	2.55		2.55	4.70		4.70
Fall Banded NBPT-DCD Urea	2	4.10	45.60	17.95	4.95	5.80	5.25
Fall Banded Conventional Urea	2	7.15	28.80	14.35	7.10	8.55	7.60
Fall Banded Calcium Nitrate	2	3.50	9.10	5.35	3.95	72.15	26.70
Spring Banded Conventional Urea	2						
Control	3	2.55		2.55	2.30		2.30
Fall Banded NBPT-DCD Urea	3	23.65	8.25	18.50	7.50	7.75	7.60
Fall Banded Conventional Urea	3	3.15	31.75	12.70	3.65	9.30	5.55
Fall Banded Calcium Nitrate	3	4.10	6.20	4.80	4.40	53.35	20.70
Spring Banded Conventional Urea	3						
Control	4	3.50		3.50	3.80		3.80
Fall Banded NBPT-DCD Urea	4	2.95	38.70	14.85	3.45	5.00	3.95
Fall Banded Conventional Urea	4	4.75	45.05	18.20	3.65	7.35	4.90
Fall Banded Calcium Nitrate	4	3.50	7.35	4.80	12.75	45.75	23.75
Spring Banded Conventional Urea	4						

Table A.36. Concentrations of ammonium and nitrate in soil three weeks after fertilizer application in the fall at Indian Head.

		2006					
Site and treatment		3 weeks after fertilizer application					
Indian Head	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.85		3.85	3.85		3.85
Fall Banded NBPT-DCD Urea	1	8.10	34.45	16.90	5.25	5.10	5.20
Fall Banded Conventional Urea	1	4.15	7.45	5.25	3.00	4.95	3.65
Fall Banded Calcium Nitrate	1	2.20	6.35	3.60	11.10	33.90	18.70
Spring Banded Conventional Urea	1						
Control	2	2.25		2.25	3.50		3.50
Fall Banded NBPT-DCD Urea	2	3.20	13.15	6.50	3.95	5.85	4.60
Fall Banded Conventional Urea	2	4.60	13.15	7.45	3.35	8.80	5.15
Fall Banded Calcium Nitrate	2	4.10	7.30	5.15	19.35	68.00	35.55
Spring Banded Conventional Urea	2						
Control	3	2.55		2.55	2.10		2.10
Fall Banded NBPT-DCD Urea	3	3.30	13.15	6.60	5.75	9.90	7.15
Fall Banded Conventional Urea	3	3.85	13.15	6.95	5.20	9.30	6.55
Fall Banded Calcium Nitrate	3	5.05	6.55	5.55	10.45	33.10	18.00
Spring Banded Conventional Urea	3						
Control	4	3.85		3.85	3.50		3.50
Fall Banded NBPT-DCD Urea	4	4.50	34.55	14.50	5.60	6.65	5.95
Fall Banded Conventional Urea	4	2.95	35.00	13.65	4.55	11.00	6.70
Fall Banded Calcium Nitrate	4	2.35	7.20	3.95	9.70	53.25	24.20
Spring Banded Conventional Urea	4						

Table A.37. Concentrations of ammonium and nitrate in soil at spring thaw at Oak Bluff.

		2007					
Site and treatment		Spring thaw					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.10		4.10	8.15		8.15
Fall Banded NBPT-DCD Urea	1	8.95	26.80	17.90	9.60	18.20	13.90
Fall Banded Conventional Urea	1	3.35	22.40	12.90	6.30	17.90	12.10
Fall Banded Calcium Nitrate	1	3.95	2.40	3.20	7.80	10.25	9.05
Spring Banded Conventional Urea	1						
Control	2	6.00		6.00	8.30		8.30
Fall Banded NBPT-DCD Urea	2	8.00	31.50	19.75	6.25	11.60	8.95
Fall Banded Conventional Urea	2	20.30	9.95	15.15	8.50	8.75	8.65
Fall Banded Calcium Nitrate	2	4.85	3.90	4.40	5.95	6.50	6.25
Spring Banded Conventional Urea	2						
Control	3	5.20		5.20	6.00		6.00
Fall Banded NBPT-DCD Urea	3	5.05	6.60	5.85	8.20	7.35	7.80
Fall Banded Conventional Urea	3	6.40	15.50	10.95	7.50	7.70	7.60
Fall Banded Calcium Nitrate	3	4.70	4.75	4.75	8.00	6.85	7.45
Spring Banded Conventional Urea	3						
Control	4	3.90		3.90	6.65		6.65
Fall Banded NBPT-DCD Urea	4	4.75	4.90	4.85	6.70	6.60	6.65
Fall Banded Conventional Urea	4	7.05	37.80	22.45	10.40	18.05	14.25
Fall Banded Calcium Nitrate	4	5.35	4.25	4.80	7.85	10.50	9.20
Spring Banded Conventional Urea	4						

Table A.38. Concentrations of ammonium and nitrate in soil 1 week after planting at Oak Bluff.

		2007					
Site and treatment		1 week after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	5.20		5.20	17.90		17.90
Fall Banded NBPT-DCD Urea	1	7.30	5.75	6.55	24.60	15.75	20.20
Fall Banded Conventional Urea	1	5.90	5.15	5.55	11.35	19.50	15.45
Fall Banded Calcium Nitrate	1	5.65	8.20	6.95	11.00	12.55	11.80
Spring Banded Conventional Urea	1	6.95	6.75	6.85	10.25	12.85	11.55
Control	2	7.40		7.40	9.15		9.15
Fall Banded NBPT-DCD Urea	2	6.75	5.70	6.25	12.60	17.75	15.20
Fall Banded Conventional Urea	2	6.95	6.40	6.70	22.65	15.65	19.15
Fall Banded Calcium Nitrate	2	8.10	6.95	7.55	10.10	8.85	9.50
Spring Banded Conventional Urea	2	19.45	27.75	23.60	17.75	22.00	19.90
Control	3	6.05		6.05	8.70		8.70
Fall Banded NBPT-DCD Urea	3	7.85	9.25	8.55	16.55	12.40	14.50
Fall Banded Conventional Urea	3	6.65	5.65	6.15	11.80	11.05	11.45
Fall Banded Calcium Nitrate	3	10.00	6.55	8.30	14.75	15.30	15.05
Spring Banded Conventional Urea	3	7.45	26.35	16.90	10.40	18.85	14.65
Control	4	6.80		6.80	8.35		8.35
Fall Banded NBPT-DCD Urea	4	7.30	5.55	6.45	10.40	11.65	11.05
Fall Banded Conventional Urea	4	6.95	13.05	10.00	14.60	17.30	15.95
Fall Banded Calcium Nitrate	4	5.75	7.30	6.55	11.50	9.30	10.40
Spring Banded Conventional Urea	4	7.30	8.20	7.75	16.85	16.85	16.85

Table A.39. Concentrations of ammonium and nitrate in soil 2 weeks after planting at Oak Bluff.

		2007					
Site and treatment		2 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	2.85		2.85	8.60		8.60
Fall Banded NBPT-DCD Urea	1	4.10	3.35	3.75	11.65	9.55	10.60
Fall Banded Conventional Urea	1	3.50	3.80	3.65	6.90	7.95	7.45
Fall Banded Calcium Nitrate	1	3.75	3.00	3.40	11.30	10.65	11.00
Spring Banded Conventional Urea	1	3.45	4.60	4.05	10.15	24.30	17.25
Control	2	3.20		3.20	8.70		8.70
Fall Banded NBPT-DCD Urea	2	3.50	3.65	3.60	12.80	18.60	15.70
Fall Banded Conventional Urea	2	3.60	3.65	3.65	8.85	21.30	15.10
Fall Banded Calcium Nitrate	2	4.00	3.40	3.70	8.70	7.80	8.25
Spring Banded Conventional Urea	2	3.65	13.20	8.45	22.55	27.65	25.10
Control	3	3.55		3.55	9.55		9.55
Fall Banded NBPT-DCD Urea	3	3.50	3.95	3.75	14.50	23.35	18.95
Fall Banded Conventional Urea	3	3.80	3.45	3.65	20.85	15.30	18.10
Fall Banded Calcium Nitrate	3	3.80	3.50	3.65	13.35	15.05	14.20
Spring Banded Conventional Urea	3	3.40	3.40	3.40	11.75	11.60	11.70
Control	4	3.45		3.45	15.60		15.60
Fall Banded NBPT-DCD Urea	4	3.85	4.25	4.05	14.20	26.45	20.35
Fall Banded Conventional Urea	4	4.85	4.15	4.50	18.80	19.75	19.30
Fall Banded Calcium Nitrate	4	3.85	3.75	3.80	9.70	10.35	10.05
Spring Banded Conventional Urea	4	4.25	7.30	5.80	19.85	31.30	25.60

Table A.40. Concentrations of ammonium and nitrate in soil 3 weeks after planting at Oak Bluff.

		2007					
Site and treatment		3 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	3.40		3.40	7.35		7.35
Fall Banded NBPT-DCD Urea	1						
Fall Banded Conventional Urea	1	3.10	3.75	3.45	11.85	13.60	12.75
Fall Banded Calcium Nitrate	1	3.40	3.30	3.35	10.85	8.35	9.60
Spring Banded Conventional Urea	1	4.15	2.95	3.55	17.85	22.30	20.10
Control	2	2.90		2.90	5.75		5.75
Fall Banded NBPT-DCD Urea	2	2.55	3.70	3.15	8.65	11.30	10.00
Fall Banded Conventional Urea	2	5.00	3.10	4.05	31.70	21.40	26.55
Fall Banded Calcium Nitrate	2	3.75	3.75	3.75	7.65	7.25	7.45
Spring Banded Conventional Urea	2	2.85	5.55	4.20	12.95	15.50	14.25
Control	3	4.45		4.45	9.15		9.15
Fall Banded NBPT-DCD Urea	3	3.65	4.00	3.85	13.45	15.50	14.50
Fall Banded Conventional Urea	3	3.50	3.90	3.70	13.20	17.30	15.25
Fall Banded Calcium Nitrate	3	3.00	3.15	3.10	11.30	11.85	11.60
Spring Banded Conventional Urea	3	3.85	14.60	9.25	15.85	61.70	38.80
Control	4	3.70		3.70	8.90		8.90
Fall Banded NBPT-DCD Urea	4	4.60	4.75	4.70	16.00	15.45	15.75
Fall Banded Conventional Urea	4	4.20	5.05	4.65	9.00	12.30	10.65
Fall Banded Calcium Nitrate	4	3.85	4.00	3.95	6.20	6.65	6.45
Spring Banded Conventional Urea	4	3.65	3.95	3.80	13.30	15.55	14.45

Table A.41. Concentrations of ammonium and nitrate in soil 4 weeks after planting at Oak Bluff.

		2007					
Site and treatment		4 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	2.85		2.85	10.60		10.60
Fall Banded NBPT-DCD Urea	1	3.05	3.45	3.25	5.05	7.50	6.30
Fall Banded Conventional Urea	1	3.15	2.90	3.05	4.75	8.85	6.80
Fall Banded Calcium Nitrate	1	2.55	3.50	3.05	5.90	5.65	5.80
Spring Banded Conventional Urea	1	2.90	3.95	3.45	9.70	16.05	12.90
Control	2	3.25		3.25	4.10		4.10
Fall Banded NBPT-DCD Urea	2	3.20		3.20	10.30		10.30
Fall Banded Conventional Urea	2	2.90	3.80	3.35	11.45	9.15	10.30
Fall Banded Calcium Nitrate	2	3.90	3.90	3.90	4.35	4.60	4.50
Spring Banded Conventional Urea	2	2.75	4.35	3.55	9.15	16.55	12.85
Control	3	3.30		3.30	6.15		6.15
Fall Banded NBPT-DCD Urea	3	4.25	3.75	4.00	9.60	8.85	9.25
Fall Banded Conventional Urea	3	4.15	4.30	4.25	10.15	9.60	9.90
Fall Banded Calcium Nitrate	3	3.90	3.60	3.75	7.40	6.85	7.15
Spring Banded Conventional Urea	3	3.90	3.85	3.90	6.80	4.60	5.70
Control	4	3.40		3.40	5.90		5.90
Fall Banded NBPT-DCD Urea	4	4.10	4.40	4.25	9.70	6.60	8.15
Fall Banded Conventional Urea	4	3.95	3.90	3.95	5.45	7.15	6.30
Fall Banded Calcium Nitrate	4	3.40	4.25	3.85	3.75	3.00	3.40
Spring Banded Conventional Urea	4	2.85	7.15	5.00	13.05	23.90	18.50

Table A.42. Concentrations of ammonium and nitrate in soil at spring thaw at Brandon.

		2007					
Site and treatment		Spring thaw					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1	4.80		4.80	8.30		8.30
Fall Banded NBPT-DCD Urea	1	5.15	5.20	5.20	14.80	10.30	12.55
Fall Banded Conventional Urea	1	5.75	38.65	22.20	9.75	25.45	17.60
Fall Banded Calcium Nitrate	1	4.65	5.25	4.95	15.05	19.70	17.40
Spring Banded Conventional Urea	1	5.40		5.40	7.10		7.10
Control	2	4.90		4.90	5.00		5.00
Fall Banded NBPT-DCD Urea	2	4.35	15.60	10.00	9.15	18.85	14.00
Fall Banded Conventional Urea	2	4.60	12.75	8.70	19.25	18.50	18.90
Fall Banded Calcium Nitrate	2	5.05	5.40	5.25	21.60	30.45	26.05
Spring Banded Conventional Urea	2	7.75		7.75	19.25		19.25
Control	3	4.00		4.00	5.65		5.65
Fall Banded NBPT-DCD Urea	3	3.80	4.10	3.95	10.25	8.70	9.50
Fall Banded Conventional Urea	3	3.85	9.40	6.65	13.00	23.30	18.15
Fall Banded Calcium Nitrate	3	3.70	5.75	4.75	12.85	19.75	16.30
Spring Banded Conventional Urea	3	3.90		3.90	8.10		8.10
Control	4	4.35		4.35	15.65		15.65
Fall Banded NBPT-DCD Urea	4	4.60	6.40	5.50	26.15	40.80	33.50
Fall Banded Conventional Urea	4	4.90	4.55	4.75	10.90	16.35	13.65
Fall Banded Calcium Nitrate	4	4.30	4.85	4.60	8.05	20.50	14.30
Spring Banded Conventional Urea	4	4.60		4.60	6.50		6.50

Table A.43. Concentrations of ammonium and nitrate 1 and 2 weeks after planting at Brandon.

		2007			
Site and treatment		1 week after planting		2 weeks after planting	
Brandon	Rep	Average NH_4 concentration	Average NO_3 concentration	Average NH_4 concentration	Average NO_3 concentration
		mg kg^{-1}			
Control	1	3.80	7.50	4.85	8.05
Fall Banded NBPT-DCD Urea	1	3.00	16.65	3.05	8.50
Fall Banded Conventional Urea	1	3.45	9.00	2.60	8.20
Fall Banded Calcium Nitrate	1	3.35	11.45	3.35	9.40
Spring Banded Conventional Urea	1	8.90	18.50	3.30	25.90
Control	2	4.00	7.00	4.65	3.60
Fall Banded NBPT-DCD Urea	2	2.90	14.50	3.15	14.75
Fall Banded Conventional Urea	2	4.20	30.50	3.40	17.05
Fall Banded Calcium Nitrate	2	2.85	14.85	3.10	22.15
Spring Banded Conventional Urea	2	11.40	31.35	6.50	32.55
Control	3	5.45	12.85	5.25	12.40
Fall Banded NBPT-DCD Urea	3	3.15	12.65	3.10	18.80
Fall Banded Conventional Urea	3	4.80	13.70	3.10	14.05
Fall Banded Calcium Nitrate	3	2.90	13.75	3.05	7.95
Spring Banded Conventional Urea	3	6.05	20.15	2.90	11.65
Control	4	4.90	5.15	5.35	4.75
Fall Banded NBPT-DCD Urea	4	2.85	14.75	3.35	15.05
Fall Banded Conventional Urea	4	2.35	14.05	2.55	13.25
Fall Banded Calcium Nitrate	4	3.55	12.90	3.00	10.60
Spring Banded Conventional Urea	4	10.55	21.85	12.50	35.90

Table A.44. Concentrations of ammonium and nitrate 3 and 4 weeks after planting at Brandon.

		2007			
Site and treatment		3 weeks after planting		4 weeks after planting	
Brandon	Rep	Average NH_4 concentration	Average NO_3 concentration	Average NH_4 concentration	Average NO_3 concentration
		mg kg^{-1}			
Control	1	6.05	5.05	5.50	2.65
Fall Banded NBPT-DCD Urea	1	3.60	8.45	2.95	10.80
Fall Banded Conventional Urea	1	3.40	9.75	2.90	5.60
Fall Banded Calcium Nitrate	1	3.35	5.30	2.75	4.65
Spring Banded Conventional Urea	1	4.50	24.30	2.70	10.35
Control	2	8.20	3.55	4.45	2.00
Fall Banded NBPT-DCD Urea	2	3.65	5.55	3.15	3.40
Fall Banded Conventional Urea	2	5.20	13.60	3.30	5.15
Fall Banded Calcium Nitrate	2	3.85	6.50	3.45	5.25
Spring Banded Conventional Urea	2	4.60	9.70	3.30	5.85
Control	3	7.95	9.10	4.60	2.05
Fall Banded NBPT-DCD Urea	3	3.70	3.35	2.95	2.80
Fall Banded Conventional Urea	3	3.75	5.00	3.30	3.55
Fall Banded Calcium Nitrate	3	3.70	4.95	4.55	3.15
Spring Banded Conventional Urea	3	5.30	21.75	3.45	10.35
Control	4	6.80	3.00	4.95	1.65
Fall Banded NBPT-DCD Urea	4	4.75	8.30	3.00	3.50
Fall Banded Conventional Urea	4	2.85	6.25	2.45	3.75
Fall Banded Calcium Nitrate	4	4.15	8.35	3.15	3.55
Spring Banded Conventional Urea	4	5.00	7.20	3.55	13.10

Table A.45. Concentrations of ammonium and nitrate at thaw at Indian Head.

		2007	
		Spring thaw	
Indian Head	Rep	Average NH_4 concentration outbound	Average NO_3 concentration outbound
		mg kg^{-1}	
Control	1	1.95	4.50
Fall Banded NBPT-DCD Urea	1	1.95	6.00
Fall Banded Conventional Urea	1	2.25	4.95
Fall Banded Calcium Nitrate	1	2.15	10.05
Spring Banded Conventional Urea	1	1.70	3.05
Control	2	2.40	2.65
Fall Banded NBPT-DCD Urea	2	2.00	4.55
Fall Banded Conventional Urea	2	1.85	3.60
Fall Banded Calcium Nitrate	2	2.00	10.65
Spring Banded Conventional Urea	2	2.05	2.05
Control	3	2.45	3.35
Fall Banded NBPT-DCD Urea	3	5.00	12.15
Fall Banded Conventional Urea	3	2.10	3.75
Fall Banded Calcium Nitrate	3	1.85	2.40
Spring Banded Conventional Urea	3	2.65	5.95
Control	4	2.95	4.30
Fall Banded NBPT-DCD Urea	4	2.30	4.95
Fall Banded Conventional Urea	4	2.25	7.40
Fall Banded Calcium Nitrate	4	1.90	7.60
Spring Banded Conventional Urea	4	2.55	3.15

Table A.46. Concentrations of ammonium and nitrate in soil 1 week after planting at Indian Head.

		2007					
Site and treatment		1 week after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1						
Fall Banded NBPT-DCD Urea	1	12.25	20.70	15.05	8.95	17.35	11.75
Fall Banded Conventional Urea	1	2.10	5.40	3.20	8.85	24.70	14.15
Fall Banded Calcium Nitrate	1	2.60	9.65	4.95	13.85	11.60	13.10
Spring Banded Conventional Urea	1	2.00		2.00	4.50		4.50
Control	2						
Fall Banded NBPT-DCD Urea	2	15.20	2.20	10.85	10.85	5.60	9.10
Fall Banded Conventional Urea	2	1.90	5.50	3.10	6.95	17.35	10.40
Fall Banded Calcium Nitrate	2	2.00	2.80	2.25	10.75	18.30	13.25
Spring Banded Conventional Urea	2	1.55	14.85	6.00	4.15	9.20	5.85
Control	3						
Fall Banded NBPT-DCD Urea	3	2.65	4.50	3.25	11.75	15.90	13.15
Fall Banded Conventional Urea	3	1.75	2.20	1.90	7.85	11.95	9.20
Fall Banded Calcium Nitrate	3	8.00	2.85	6.30	9.10	8.95	9.05
Spring Banded Conventional Urea	3	1.55	71.05	24.70	4.30	14.15	7.60
Control	4						
Fall Banded NBPT-DCD Urea	4	2.15	17.30	7.20	6.95	14.15	9.35
Fall Banded Conventional Urea	4	1.80	5.55	3.05	5.45	17.95	9.60
Fall Banded Calcium Nitrate	4	1.70	3.65	2.35	7.40	7.95	7.60
Spring Banded Conventional Urea	4	2.20	43.40	15.95	5.20	11.75	7.40

Table A.47. Concentrations of ammonium and nitrate in soil 2 weeks after planting at Indian Head.

		2007					
Site and treatment		2 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1						
Fall Banded NBPT-DCD Urea	1	7.95	26.55	14.15	11.50	14.75	12.60
Fall Banded Conventional Urea	1	3.70	4.75	4.05	8.20	14.45	10.30
Fall Banded Calcium Nitrate	1	4.85	2.90	4.20	10.35	10.65	10.45
Spring Banded Conventional Urea	1	3.20	31.45	12.60	5.25	12.30	7.60
Control	2						
Fall Banded NBPT-DCD Urea	2	8.55	5.95	7.70	12.75	8.75	11.40
Fall Banded Conventional Urea	2	2.50	3.30	2.75	7.35	14.75	9.80
Fall Banded Calcium Nitrate	2	4.05	3.15	3.75	10.00	14.90	11.65
Spring Banded Conventional Urea	2	2.25	5.80	3.45	3.65	8.40	5.25
Control	3						
Fall Banded NBPT-DCD Urea	3	2.95	3.95	3.30	9.15	22.05	13.45
Fall Banded Conventional Urea	3	1.90	2.95	2.25	6.40	9.50	7.45
Fall Banded Calcium Nitrate	3	3.50	3.10	3.35	11.40	10.70	11.15
Spring Banded Conventional Urea	3	2.20	16.50	6.95	5.00	12.20	7.40
Control	4						
Fall Banded NBPT-DCD Urea	4	3.05	8.90	5.00	8.80	14.65	10.75
Fall Banded Conventional Urea	4	2.80	5.75	3.80	7.50	22.40	12.45
Fall Banded Calcium Nitrate	4	2.55	3.65	2.90	4.25	11.00	6.50
Spring Banded Conventional Urea	4	6.75	4.90	6.15	11.90	6.45	10.10

Table A.48. Concentrations of ammonium and nitrate in soil 3 weeks after planting at Indian Head.

		2007					
Site and treatment		3 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1						
Fall Banded NBPT-DCD Urea	1	4.55	8.25	5.80	8.00	14.60	10.20
Fall Banded Conventional Urea	1	2.40	2.95	2.60	5.35	12.55	7.75
Fall Banded Calcium Nitrate	1	2.15	3.50	2.60	4.80	7.20	5.60
Spring Banded Conventional Urea	1	2.40	30.90	11.90	3.85	15.40	7.70
Control	2						
Fall Banded NBPT-DCD Urea	2	2.95	2.50	2.80	8.10	3.65	6.60
Fall Banded Conventional Urea	2	3.15	3.00	3.10	5.20	8.25	6.20
Fall Banded Calcium Nitrate	2	2.15	2.65	2.30	4.30	4.40	4.35
Spring Banded Conventional Urea	2	2.05	8.40	4.15	2.30	11.30	5.30
Control	3						
Fall Banded NBPT-DCD Urea	3	3.25	3.95	3.50	5.55	4.30	5.15
Fall Banded Conventional Urea	3	2.15	2.45	2.25	2.85	1.80	2.50
Fall Banded Calcium Nitrate	3	2.45	3.05	2.65	3.50	4.25	3.75
Spring Banded Conventional Urea	3	2.05	9.85	4.65	3.15	25.45	10.60
Control	4						
Fall Banded NBPT-DCD Urea	4	2.70	8.95	4.80	4.00	9.20	5.75
Fall Banded Conventional Urea	4	3.55	2.45	3.20	6.75	2.45	5.30
Fall Banded Calcium Nitrate	4	4.35	2.30	3.65	4.10	4.30	4.15
Spring Banded Conventional Urea	4	2.95	12.70	6.20	4.95	18.80	9.55

Table A.49. Concentrations of ammonium and nitrate in soil 4 weeks after planting at Indian Head.

		2007					
Site and treatment		4 weeks after planting					
Oak Bluff	Rep	Concentration NH_4 outband	Concentration NH_4 inband	Average NH_4 concentration	Concentration NO_3 outband	Concentration NO_3 inband	Average NO_3 concentration
		mg kg^{-1}					
Control	1						
Fall Banded NBPT-DCD Urea	1	2.50	7.10	4.05	9.55	12.70	10.60
Fall Banded Conventional Urea	1	2.25	2.55	2.35	3.35	11.60	6.10
Fall Banded Calcium Nitrate	1	1.90	1.90	1.90	4.30	2.35	3.65
Spring Banded Conventional Urea	1	1.95	12.20	5.35	7.10	20.00	11.40
Control	2						
Fall Banded NBPT-DCD Urea	2	2.10	2.20	2.15	3.30	3.60	3.40
Fall Banded Conventional Urea	2	1.60	3.35	2.20	3.75	7.75	5.10
Fall Banded Calcium Nitrate	2	1.65	2.15	1.80	3.00	3.10	3.05
Spring Banded Conventional Urea	2	1.95	5.10	3.00	10.10	10.95	10.40
Control	3						
Fall Banded NBPT-DCD Urea	3	2.25	2.35	2.30	5.55	4.15	5.10
Fall Banded Conventional Urea	3	1.95	2.10	2.00	3.10	4.90	3.70
Fall Banded Calcium Nitrate	3	2.70	3.10	2.85	2.60	3.75	3.00
Spring Banded Conventional Urea	3	1.60	3.55	2.25	5.35	22.95	11.20
Control	4						
Fall Banded NBPT-DCD Urea	4	2.30	3.65	2.75	4.65	10.00	6.45
Fall Banded Conventional Urea	4	0.00	3.10	1.05	0.00	4.85	1.60
Fall Banded Calcium Nitrate	4	1.95	2.15	2.00	3.00	3.85	3.30
Spring Banded Conventional Urea	4	1.90	9.45	4.40	4.75	15.40	8.30

Table A.50. Concentrations of ammonium and nitrate at planting at Oak Bluff.

			2006	
Site and Treatment			At planting	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		30-60	7.20	2.45
Control	1	60-90	6.00	0.90
		90-120	6.85	14.60
		30-60	6.35	2.55
Fall Banded NBPT-DCD Urea	1	60-90	7.05	1.05
		90-120	5.55	4.90
		30-60	7.25	8.00
Fall Banded Conventional Urea	1	60-90	5.85	15.65
		90-120	8.80	7.25
		30-60	7.05	7.20
Fall Banded Calcium Nitrate	1	60-90	5.60	3.30
		90-120	7.70	17.50
		30-60	7.85	2.00
Spring Banded Conventional Urea	1	60-90	5.85	1.05
		90-120	7.25	3.80
		30-60	4.65	12.10
Control	2	60-90	5.30	2.90
		90-120	5.60	1.95
		30-60	5.20	21.50
Fall Banded NBPT-DCD Urea	2	60-90	6.05	4.25
		90-120	5.25	2.30
		30-60	5.05	16.75
Fall Banded Conventional Urea	2	60-90	5.15	4.10
		90-120	6.10	2.65
		30-60	5.40	11.25
Fall Banded Calcium Nitrate	2	60-90	4.65	2.60
		90-120	5.65	2.20
		30-60	12.55	23.45
Spring Banded Conventional Urea	2	60-90	12.30	11.75
		90-120	5.10	3.85

Table A.50 (cont'd). Concentrations of ammonium and nitrate at planting at Oak Bluff.

			2006	
Site and Treatment			At planting	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		30-60	7.50	0.85
Control	3	60-90	6.10	1.35
		90-120	11.55	5.65
		30-60	6.30	0.85
Fall Banded NBPT-DCD Urea	3	60-90	4.55	1.60
		90-120	8.85	11.45
		30-60	7.55	0.75
Fall Banded Conventional Urea	3	60-90	4.85	1.15
		90-120	7.20	11.45
		30-60	6.60	2.25
Fall Banded Calcium Nitrate	3	60-90	6.15	1.60
		90-120	11.80	6.35
		30-60	5.80	1.30
Spring Banded Conventional Urea	3	60-90	8.10	1.00
		90-120	10.95	3.40
		30-60	5.55	7.55
Control	4	60-90	4.50	3.05
		90-120	5.15	2.35
		30-60	5.30	10.80
Fall Banded NBPT-DCD Urea	4	60-90	4.05	2.80
		90-120	4.80	1.85
		30-60	6.90	7.70
Fall Banded Conventional Urea	4	60-90	3.85	2.50
		90-120	5.40	1.80
		30-60	5.20	10.85
Fall Banded Calcium Nitrate	4	60-90	5.20	3.35
		90-120	4.95	1.70
		30-60	4.75	7.30
Spring Banded Conventional Urea	4	60-90	4.55	2.75
		90-120	4.55	2.20

Table A.51. Concentrations of ammonium and nitrate at planting at Brandon.

			2006	
Site and Treatment			At planting	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-15	7.55	5.80
		15-30	7.20	1.45
		30-60	4.50	0.95
		60-90	7.15	0.85
		90-120		
Fall Banded NBPT-DCD Urea	1	0-15	7.20	10.50
		15-30	7.35	2.70
		30-60	8.20	1.75
		60-90	6.75	2.50
		90-120	6.05	0.85
Fall Banded Conventional Urea	1	0-15	6.70	5.50
		15-30	6.40	1.10
		30-60	6.55	1.15
		60-90	4.05	0.75
		90-120	4.95	0.60
Fall Banded Calcium Nitrate	1	0-15	9.80	5.25
		15-30	6.35	2.15
		30-60	3.15	1.15
		60-90	3.80	0.90
		90-120	4.35	0.60
Spring Banded Conventional Urea	1	0-15	6.80	3.10
		15-30	5.85	1.40
		30-60	5.10	1.30
		60-90	4.90	0.90
		90-120	4.60	0.60

Table A.51 (cont'd) Concentrations of ammonium and nitrate at planting at Brandon.

			2006	
Site and Treatment			At planting	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	2	0-15	8.30	8.35
		15-30	7.60	1.60
		30-60	6.25	1.20
		60-90	5.95	4.75
		90-120	4.75	1.35
Fall Banded NBPT-DCD Urea	2	0-15	9.50	33.60
		15-30	5.60	7.85
		30-60	3.25	1.75
		60-90	4.80	1.50
		90-120	3.30	1.50
Fall Banded Conventional Urea	2	0-15	8.15	27.55
		15-30	6.30	7.15
		30-60	4.25	1.60
		60-90	6.55	0.90
		90-120	5.75	0.70
Fall Banded Calcium Nitrate	2	0-15	8.50	15.50
		15-30	5.60	4.95
		30-60	3.95	1.80
		60-90	4.40	1.40
		90-120	4.15	1.15
Spring Banded Conventional Urea	2	0-15	7.90	4.65
		15-30	6.45	0.80
		30-60	5.40	0.70
		60-90	4.45	0.60
		90-120	4.50	0.70

Table A.51 (cont'd) Concentrations of ammonium and nitrate at planting at Brandon.

		2006		
Site and Treatment		At planting		
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-15	5.95	4.40
		15-30	5.40	3.25
Control	3	30-60	3.40	1.15
		60-90	4.30	1.20
		90-120	3.75	1.05
		0-15	7.30	9.10
		15-30	6.15	5.15
Fall Banded NBPT-DCD Urea	3	30-60	3.40	1.00
		60-90	4.65	1.55
		90-120	3.15	1.25
		0-15	6.05	11.40
		15-30	6.05	3.40
Fall Banded Conventional Urea	3	30-60	3.15	1.15
		60-90	4.65	0.75
		90-120	4.40	0.65
		0-15	8.05	5.25
		15-30	5.95	1.20
Fall Banded Calcium Nitrate	3	30-60	3.20	0.85
		60-90	2.95	0.55
		90-120	4.50	0.75
		0-15	6.35	7.65
		15-30	5.25	2.35
Spring Banded Conventional Urea	3	30-60	4.05	1.00
		60-90	5.65	2.50
		90-120	3.85	1.00

Table A.51 (cont'd) Concentrations of ammonium and nitrate at planting at Brandon.

			2006	
Site and Treatment			At planting	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-15	8.35	2.55
		15-30	4.80	0.80
Control	4	30-60	3.95	0.80
		60-90	4.15	0.45
		90-120	4.65	0.65
		0-15	6.65	11.85
		15-30	5.90	6.80
Fall Banded NBPT-DCD Urea	4	30-60	3.50	1.10
		60-90	6.80	0.90
		90-120		
		0-15	6.65	10.15
		15-30	3.35	5.05
Fall Banded Conventional Urea	4	30-60	3.15	1.15
		60-90	2.75	1.30
		90-120	5.55	1.35
		0-15	7.25	14.70
		15-30	4.35	6.80
Fall Banded Calcium Nitrate	4	30-60	3.00	1.45
		60-90	1.70	0.95
		90-120	5.75	1.10
		0-15	8.80	1.75
		15-30	5.60	0.75
Spring Banded Conventional Urea	4	30-60	3.80	0.70
		60-90	4.15	0.45
		90-120	4.90	0.40

Table A.52. Concentrations of ammonium and nitrate at planting at Indian Head.

			2006	
Site and Treatment			At planting	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-30	4.65	11.75
Control	1	30-60	3.3	7.6
		60-90	4.4	7.95
		0-30	4.95	7.35
Fall Banded NBPT-DCD Urea	1	30-60	2.60	4.65
		60-90	2.70	5.35
		0-30	4.55	9.90
Fall Banded Conventional Urea	1	30-60	2.85	15.70
		60-90	3.40	9.05
		0-30	3.60	14.75
Fall Banded Calcium Nitrate	1	30-60	3.55	14.75
		60-90	4.05	8.65
		0-30	6.15	12.10
Spring Banded Conventional Urea	1	30-60	3.45	11.00
		60-90	4.65	8.20
		0-30	6.15	9.40
Control	2	30-60	2.95	6.65
		60-90	3.85	5.50
		0-30	6.80	13.10
Fall Banded NBPT-DCD Urea	2	30-60	3.90	7.50
		60-90	6.00	10.50
		0-30	5.85	15.65
Fall Banded Conventional Urea	2	30-60	3.35	7.50
		60-90	3.75	8.65
		0-30	3.40	11.15
Fall Banded Calcium Nitrate	2	30-60	2.55	14.55
		60-90	3.05	8.50
		0-30	4.15	6.20
Spring Banded Conventional Urea	2	30-60	3.00	10.30
		60-90	3.20	9.40

Table A.52 (cont'd) Concentrations of ammonium and nitrate at planting at Indian Head.

Site and Treatment			2006 At planting	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-30	7.70	18.05
Control	3	30-60	3.35	3.95
		60-90	3.45	7.60
		0-30	3.55	12.55
Fall Banded NBPT-DCD Urea	3	30-60	6.50	6.35
		60-90	4.30	9.95
		0-30	7.40	17.30
Fall Banded Conventional Urea	3	30-60	6.20	4.65
		60-90	4.00	6.90
		0-30	18.85	22.50
Fall Banded Calcium Nitrate	3	30-60	3.75	6.30
		60-90	4.15	4.40
		0-30	3.30	9.65
Spring Banded Conventional Urea	3	30-60	1.65	2.60
		60-90	2.65	7.45
		0-30	5.20	7.90
Control	4	30-60	2.50	4.45
		60-90	4.00	5.10
		0-30	3.15	11.90
Fall Banded NBPT-DCD Urea	4	30-60	2.40	4.65
		60-90	2.90	9.40
		0-30	16.40	20.10
Fall Banded Conventional Urea	4	30-60	3.55	8.70
		60-90	3.05	8.65
		0-30	3.35	14.60
Fall Banded Calcium Nitrate	4	30-60	1.80	10.05
		60-90	3.85	9.90
		0-30	4.30	13.00
Spring Banded Conventional Urea	4	30-60	5.45	6.90
		60-90	3.95	5.10

Table A.53. Concentrations of ammonium and nitrate at maturity at Oak Bluff.

			2006	
Site and Treatment			At maturity	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-30	9.40	8.10
		30-60	9.30	2.30
		60-90	7.05	1.55
		90-120	9.00	1.20
Fall Banded NBPT-DCD Urea	1	0-30	10.35	11.80
		30-60	7.35	4.30
		60-90	5.60	1.50
		90-120	7.80	1.45
Fall Banded Conventional Urea	1	0-30	7.75	10.60
		30-60	7.50	5.00
		60-90	6.80	4.60
		90-120	7.30	1.75
Fall Banded Calcium Nitrate	1	0-30	7.90	8.20
		30-60	12.20	4.10
		60-90	6.20	1.90
		90-120	6.35	1.55
Spring Banded Conventional Urea	1	0-30	8.95	6.15
		30-60	6.50	5.55
		60-90	6.50	2.25
		90-120	6.45	1.85
Control	2	0-30	14.95	9.90
		30-60	16.20	4.55
		60-90	8.30	2.15
		90-120	8.70	1.55
Fall Banded NBPT-DCD Urea	2	0-30	6.75	25.55
		30-60	8.80	11.80
		60-90	7.10	5.70
		90-120	8.55	2.10
Fall Banded Conventional Urea	2	0-30	9.15	29.95
		30-60	13.80	6.00
		60-90	5.95	2.55
		90-120	6.60	1.85
Fall Banded Calcium Nitrate	2	0-30	8.05	15.15
		30-60	10.30	6.10
		60-90	5.35	2.80
		90-120	9.45	1.35
Spring Banded Conventional Urea	2	0-30	12.50	17.35
		30-60	15.50	9.95
		60-90	9.50	3.60
		90-120	13.20	1.50

Table A.53 (cont'd) Concentrations of ammonium and nitrate at maturity at Oak Bluff.

Site and Treatment			2006 At maturity	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-30	7.05	7.20
		30-60	7.80	4.05
		60-90	4.65	2.00
		90-120	8.35	1.30
Fall Banded NBPT-DCD Urea	3	0-30	7.30	9.20
		30-60	6.40	4.20
		60-90	7.45	2.65
		90-120	11.00	1.65
Fall Banded Conventional Urea	3	0-30	7.15	12.70
		30-60	4.45	3.15
		60-90	4.90	1.80
		90-120	9.60	1.75
Fall Banded Calcium Nitrate	3	0-30	7.75	8.55
		30-60	5.95	3.35
		60-90	6.15	2.10
		90-120	7.05	1.95
Spring Banded Conventional Urea	3	0-30	9.45	7.75
		30-60	11.20	4.35
		60-90	9.35	3.10
		90-120	7.60	2.20
Control	4	0-30	7.25	8.55
		30-60	9.75	1.95
		60-90	5.20	1.55
		90-120	5.95	1.50
Fall Banded NBPT-DCD Urea	4	0-30	9.30	5.70
		30-60	5.00	1.95
		60-90	4.65	1.40
		90-120	8.85	1.45
Fall Banded Conventional Urea	4	0-30	8.35	11.65
		30-60	6.85	3.90
		60-90	5.05	1.70
		90-120	12.00	1.70
Fall Banded Calcium Nitrate	4	0-30	8.05	8.70
		30-60	8.70	3.15
		60-90	5.15	2.00
		90-120	8.00	1.40
Spring Banded Conventional Urea	4	0-30	12.45	8.85
		30-60	5.35	2.80
		60-90	0.34	6.20
		90-120	6.90	1.45

Table A.54. Concentrations of ammonium and nitrate at maturity at Brandon.

			2006	
Site and Treatment			At maturity	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-15	7.80	6.70
		15-30	7.25	1.45
Control	1	30-60	4.50	1.85
		60-90	6.35	1.35
		90-120	5.20	0.70
		0-15	7.65	5.75
		15-30	7.25	1.05
Fall Banded NBPT-DCD Urea	1	30-60	4.85	1.15
		60-90	5.45	1.55
		90-120	5.30	1.50
		0-15	5.75	2.85
		15-30	6.35	0.85
Fall Banded Conventional Urea	1	30-60	4.70	0.85
		60-90	5.20	0.80
		90-120	4.45	0.65
		0-15	11.95	8.55
		15-30	5.65	1.35
Fall Banded Calcium Nitrate	1	30-60	3.65	1.05
		60-90	5.70	1.85
		90-120	5.15	0.80
		0-15	6.45	2.50
		15-30	6.25	1.20
Spring Banded Conventional Urea	1	30-60	3.70	0.95
		60-90	6.00	0.75
		90-120	5.35	0.65

Table A.54 (cont'd) Concentrations of ammonium and nitrate at maturity at Brandon.

			2006	
Site and Treatment			At maturity	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-15	5.55	3.00
		15-30	6.10	1.00
Control	2	30-60	3.40	0.85
		60-90	6.15	1.80
		90-120	3.55	0.80
		0-15	6.40	2.40
		15-30	4.95	1.05
Fall Banded NBPT-DCD Urea	2	30-60	3.50	1.25
		60-90	5.30	0.55
		90-120	5.30	1.40
		0-15	7.35	3.40
		15-30	6.05	0.95
Fall Banded Conventional Urea	2	30-60	3.90	1.00
		60-90	7.65	1.65
		90-120	5.20	0.95
		0-15	7.25	4.55
		15-30	6.70	0.80
Fall Banded Calcium Nitrate	2	30-60	4.30	0.80
		60-90	6.30	0.95
		90-120	4.35	1.20
		0-15	7.20	4.15
		15-30	6.25	1.00
Spring Banded Conventional Urea	2	30-60	4.60	1.10
		60-90	4.50	0.70
		90-120	4.90	1.25

Table A.54 (cont'd) Concentrations of ammonium and nitrate at maturity at Brandon.

			2006	
Site and Treatment			At maturity	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-15	7.05	2.15
		15-30	6.45	1.15
Control	3	30-60	3.75	1.00
		60-90	6.40	0.85
		90-120	4.65	0.90
		0-15	7.25	2.75
		15-30	6.15	1.40
Fall Banded NBPT-DCD Urea	3	30-60	3.10	0.85
		60-90	3.35	0.75
		90-120	3.35	0.80
		0-15	9.50	3.50
		15-30	6.35	1.20
Fall Banded Conventional Urea	3	30-60	4.60	1.05
		60-90	5.15	1.25
		90-120	6.60	0.95
		0-15	6.95	1.85
		15-30	6.05	1.15
Fall Banded Calcium Nitrate	3	30-60	3.95	0.75
		60-90	5.65	1.25
		90-120	6.25	1.05
		0-15	8.00	4.55
		15-30	6.80	1.35
Spring Banded Conventional Urea	3	30-60	2.95	0.75
		60-90	5.20	1.20
		90-120	4.90	1.80

Table A.54 (cont'd) Concentrations of ammonium and nitrate at maturity at Brandon.

			2006	
Site and Treatment			At maturity	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
		0-15	6.55	3.10
		15-30	6.10	1.25
Control	4	30-60	4.50	1.00
		60-90	6.20	1.30
		90-120	4.70	1.25
		0-15	7.35	3.85
		15-30	5.85	1.40
Fall Banded NBPT-DCD Urea	4	30-60	3.00	0.75
		60-90	4.55	0.75
		90-120	6.00	0.80
		0-15	7.30	5.15
		15-30	5.80	1.20
Fall Banded Conventional Urea	4	30-60	3.85	1.00
		60-90	6.95	1.20
		90-120	5.65	1.25
		0-15	5.40	4.55
		15-30	5.45	1.20
Fall Banded Calcium Nitrate	4	30-60	3.45	1.05
		60-90	4.85	2.10
		90-120	3.80	1.50
		0-15	4.90	3.70
		15-30	6.00	1.20
Spring Banded Conventional Urea	4	30-60	5.00	0.70
		60-90	5.75	0.95
		90-120	5.05	1.15

Table A.55. Concentrations of ammonium and nitrate at maturity at Indian Head.

			2006	
Site and Treatment			At maturity	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-15	3.30	3.05
		15-30	3.30	0.70
		30-60	2.10	0.65
		60-90	3.50	2.75
Fall Banded NBPT-DCD Urea	1	0-15	2.90	1.45
		15-30	2.75	0.50
		30-60	3.00	0.60
		60-90	3.55	0.60
Fall Banded Conventional Urea	1	0-15	2.60	1.30
		15-30	2.60	0.45
		30-60	2.15	0.55
		60-90	2.55	1.05
Fall Banded Calcium Nitrate	1	0-15	4.60	2.05
		15-30	2.75	0.50
		30-60	2.55	0.70
		60-90	3.65	0.70
Spring Banded Conventional Urea	1	0-15	3.05	3.50
		15-30	4.10	0.65
		30-60	5.10	0.80
		60-90	5.70	4.30
Control	2	0-15	3.70	1.95
		15-30	3.40	0.45
		30-60	3.85	0.65
		60-90	2.30	0.50
Fall Banded NBPT-DCD Urea	2	0-15	5.25	2.35
		15-30	3.35	0.80
		30-60	3.35	0.75
		60-90	5.50	2.75
Fall Banded Conventional Urea	2	0-15	2.80	2.20
		15-30	3.65	0.80
		30-60	3.90	0.75
		60-90	4.30	2.95
Fall Banded Calcium Nitrate	2	0-15	2.90	1.85
		15-30	4.30	0.50
		30-60	3.70	0.65
		60-90	4.55	2.15
Spring Banded Conventional Urea	2	0-15	2.95	3.60
		15-30	5.60	0.80
		30-60	4.20	0.65
		60-90	3.05	3.75

Table A.55. (cont'd) Concentrations of ammonium and nitrate at maturity at Indian Head.

			2006	
Site and Treatment			At maturity	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-15	3.80	1.45
		15-30	5.25	0.60
		30-60	7.35	1.00
		60-90	5.75	4.20
Fall Banded NBPT-DCD Urea	3	0-15	3.15	1.65
		15-30	5.70	0.80
		30-60	5.60	2.45
		60-90	4.70	4.60
Fall Banded Conventional Urea	3	0-15	2.90	4.50
		15-30	2.40	1.05
		30-60	3.25	1.45
		60-90	3.80	2.15
Fall Banded Calcium Nitrate	3	0-15	3.80	2.60
		15-30	4.15	1.15
		30-60	3.35	1.85
		60-90	3.95	4.30
Spring Banded Conventional Urea	3	0-15	3.50	3.15
		15-30	3.70	1.00
		30-60	3.10	0.90
		60-90	4.40	3.40
Control	4	0-15	3.40	0.90
		15-30	3.35	1.20
		30-60	4.15	0.50
		60-90	4.55	4.55
Fall Banded NBPT-DCD Urea	4	0-15	2.70	1.20
		15-30	3.15	0.70
		30-60	3.95	0.75
		60-90	3.80	0.75
Fall Banded Conventional Urea	4	0-15	2.30	1.80
		15-30	3.10	0.80
		30-60	4.20	5.50
		60-90	4.80	10.25
Fall Banded Calcium Nitrate	4	0-15	2.85	1.90
		15-30	3.30	5.45
		30-60	3.20	8.90
		60-90	4.60	9.55
Spring Banded Conventional Urea	4	0-15	2.85	0.85
		15-30	2.85	0.45
		30-60	3.30	0.90
		60-90	3.90	1.00

Table A.56. Concentrations of ammonium and nitrate at planting at Oak Bluff.

			2007	
Site and Treatment			At planting	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-30	3.75	11.35
		30-60	4.40	7.60
		60-90	3.15	3.95
		90-120	4.30	1.55
Fall Banded NBPT-DCD Urea	1	0-30	9.25	30.35
		30-60	4.60	6.90
		60-90	5.95	2.75
		90-120	7.90	1.15
Fall Banded Conventional Urea	1	0-30	4.45	18.80
		30-60	5.20	7.95
		60-90	5.90	3.05
		90-120	5.25	0.85
Fall Banded Calcium Nitrate	1	0-30	5.50	11.30
		30-60	4.70	10.40
		60-90	4.65	7.35
		90-120	2.85	3.40
Spring Banded Conventional Urea	1	0-30	4.10	6.90
		30-60	4.65	4.80
		60-90	4.80	2.85
		90-120	5.40	3.15
Control	2	0-30	4.75	8.75
		30-60	5.05	5.40
		60-90	7.50	2.95
		90-120	5.10	1.20
Fall Banded NBPT-DCD Urea	2	0-30	4.75	10.80
		30-60	5.05	9.65
		60-90	5.25	5.20
		90-120	4.60	2.75
Fall Banded Conventional Urea	2	0-30	4.55	10.20
		30-60	6.50	4.15
		60-90	5.50	1.85
		90-120	4.90	0.95
Fall Banded Calcium Nitrate	2	0-30	5.30	6.45
		30-60	7.05	5.15
		60-90	5.70	2.65
		90-120	6.45	1.00
Spring Banded Conventional Urea	2	0-30	5.50	6.30
		30-60	6.35	3.50
		60-90	6.15	2.10
		90-120	5.65	1.20

Table A.56 (cont'd). Concentrations of ammonium and nitrate at planting at Oak Bluff.

			2007	
Site and Treatment			At planting	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-30	5.45	10.50
		30-60	5.85	3.85
		60-90	5.35	2.30
		90-120	4.90	1.30
Fall Banded NBPT-DCD Urea	3	0-30	5.40	5.95
		30-60	4.55	1.50
		60-90	5.10	2.65
		90-120	5.90	1.80
Fall Banded Conventional Urea	3	0-30	4.50	14.60
		30-60	4.65	5.45
		60-90	4.55	2.35
		90-120	4.25	1.60
Fall Banded Calcium Nitrate	3	0-30	5.30	17.90
		30-60	6.20	6.85
		60-90	5.80	3.20
		90-120	4.75	1.45
Spring Banded Conventional Urea	3	0-30	5.15	8.10
		30-60	5.30	5.40
		60-90	5.00	2.60
		90-120	4.55	1.50
Control	4	0-30	4.30	11.95
		30-60	4.45	4.80
		60-90	4.85	3.15
		90-120	3.75	1.35
Fall Banded NBPT-DCD Urea	4	0-30	5.15	7.10
		30-60	6.25	3.95
		60-90	5.05	2.50
		90-120	6.25	1.55
Fall Banded Conventional Urea	4	0-30	6.50	16.75
		30-60	5.60	6.40
		60-90	6.05	3.00
		90-120	7.40	1.75
Fall Banded Calcium Nitrate	4	0-30	5.05	11.75
		30-60	5.20	8.50
		60-90	5.10	4.45
		90-120	5.80	3.05
Spring Banded Conventional Urea	4	0-30	4.75	14.75
		30-60	6.05	5.40
		60-90	6.35	2.65
		90-120	5.70	1.55

Table A.57. Concentrations of ammonium and nitrate at planting at Brandon.

			2007	
Site and Treatment			At planting	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-30	4.35	4.15
		30-60	2.45	8.05
		60-90	4.10	3.30
		90-120	2.60	1.35
Fall Banded NBPT-DCD Urea	1	0-30	3.35	11.10
		30-60	2.15	10.70
		60-90	3.25	2.40
		90-120	4.25	1.70
Fall Banded Conventional Urea	1	0-30	3.30	13.05
		30-60	2.85	9.90
		60-90	3.80	2.10
		90-120	3.35	1.95
Fall Banded Calcium Nitrate	1	0-30	3.55	9.15
		30-60	3.00	6.65
		60-90	4.05	3.05
		90-120	2.95	2.75
Spring Banded Conventional Urea	1	0-30	3.50	10.80
		30-60	2.80	3.80
		60-90	4.60	1.50
		90-120	3.45	1.45
Control	2	0-30	4.00	5.70
		30-60	2.65	5.35
		60-90	2.60	2.30
		90-120	3.05	1.60
Fall Banded NBPT-DCD Urea	2	0-30	3.50	7.25
		30-60	2.95	6.40
		60-90	3.15	2.05
		90-120	3.55	1.55
Fall Banded Conventional Urea	2	0-30	4.20	12.35
		30-60	3.50	10.10
		60-90	4.70	6.55
		90-120	2.35	2.05
Fall Banded Calcium Nitrate	2	0-30	4.25	20.80
		30-60	4.80	5.20
		60-90	4.80	8.30
		90-120	3.50	3.85
Spring Banded Conventional Urea	2	0-30	4.95	10.60
		30-60	3.30	5.70
		60-90	3.75	5.25
		90-120	3.35	2.10

Table A.57 (cont'd). Concentrations of ammonium and nitrate at planting at Brandon.

			2007	
Site and Treatment			At planting	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-30	4.95	8.25
		30-60	2.55	8.20
		60-90	3.00	3.50
		90-120	3.30	1.90
Fall Banded NBPT-DCD Urea	3	0-30	3.40	14.95
		30-60	2.85	12.10
		60-90	3.30	2.25
		90-120	3.35	1.85
Fall Banded Conventional Urea	3	0-30	3.65	20.15
		30-60	3.25	17.25
		60-90	4.25	5.35
		90-120	5.80	3.25
Fall Banded Calcium Nitrate	3	0-30	3.35	13.75
		30-60	2.60	6.60
		60-90	3.30	3.40
		90-120	2.50	1.80
Spring Banded Conventional Urea	3	0-30	4.60	4.35
		30-60	2.55	4.90
		60-90	3.00	3.35
		90-120	2.90	2.15
Control	4	0-30	3.55	5.70
		30-60	2.35	9.15
		60-90	3.50	4.00
		90-120	3.15	3.20
Fall Banded NBPT-DCD Urea	4	0-30	3.55	13.85
		30-60	3.15	18.95
		60-90	3.80	5.00
		90-120	2.65	3.20
Fall Banded Conventional Urea	4	0-30	4.20	15.90
		30-60	4.05	12.40
		60-90	5.10	3.95
		90-120	3.85	3.45
Fall Banded Calcium Nitrate	4	0-30	4.55	13.60
		30-60	3.40	6.70
		60-90	3.25	3.00
		90-120	2.95	2.95
Spring Banded Conventional Urea	4	0-30	5.10	5.95
		30-60	3.15	6.25
		60-90	3.60	1.95
		90-120	3.65	1.60

Table A.58. Concentrations of ammonium and nitrate at planting at Indian Head.

			2007	
Site and Treatment			At planting	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-15	2.20	5.05
		15-30	1.70	3.05
		30-60	1.55	1.95
		60-90	2.15	1.10
Fall Banded NBPT-DCD Urea	1	0-15	3.20	4.65
		15-30	2.00	4.00
		30-60	1.70	1.05
		60-90	1.55	0.80
Fall Banded Conventional Urea	1	0-15	17.15	30.70
		15-30	1.55	2.80
		30-60	1.40	0.90
		60-90	1.70	0.60
Fall Banded Calcium Nitrate	1	0-15	2.50	11.05
		15-30	2.05	28.45
		30-60	1.45	5.40
		60-90	1.80	0.70
Spring Banded Conventional Urea	1	0-15	2.20	4.80
		15-30	2.00	3.65
		30-60	0.90	1.90
		60-90	1.45	0.55
Control	2	0-15	2.15	2.55
		15-30	2.25	3.80
		30-60	1.90	3.30
		60-90	1.60	3.85
Fall Banded NBPT-DCD Urea	2	0-15	18.55	16.20
		15-30	3.25	7.35
		30-60	1.75	3.70
		60-90	2.50	1.65
Fall Banded Conventional Urea	2	0-15	18.00	35.35
		15-30	2.20	11.40
		30-60	1.85	3.15
		60-90	2.20	0.90
Fall Banded Calcium Nitrate	2	0-15	2.25	5.10
		15-30	2.15	13.95
		30-60	1.65	7.55
		60-90	1.95	0.90
Spring Banded Conventional Urea	2	0-15	1.95	3.30
		15-30	2.00	3.10
		30-60	1.55	3.00
		60-90	1.90	1.65

Table A.58 (cont'd). Concentrations of ammonium and nitrate at planting at Indian Head.

			2007	
Site and Treatment			At planting	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-15	2.55	4.10
		15-30	1.55	2.45
		30-60	1.55	1.70
		60-90	1.05	0.80
Fall Banded NBPT-DCD Urea	3	0-15	2.10	5.10
		15-30	2.00	4.40
		30-60	1.90	3.00
		60-90	1.55	0.70
Fall Banded Conventional Urea	3	0-15	2.65	13.70
		15-30	1.45	5.50
		30-60	1.50	1.90
		60-90	1.25	2.35
Fall Banded Calcium Nitrate	3	0-15	1.40	5.60
		15-30	0.00	0.00
		30-60	2.10	8.00
		60-90	1.40	2.40
Spring Banded Conventional Urea	3	0-15	1.30	3.85
		15-30	1.40	3.35
		30-60	1.35	2.95
		60-90	2.60	0.95
Control	4	0-15	2.40	2.80
		15-30	1.90	3.25
		30-60	2.45	1.50
		60-90	1.90	1.50
Fall Banded NBPT-DCD Urea	4	0-15	22.50	20.20
		15-30	2.00	5.55
		30-60	2.00	3.50
		60-90	1.50	0.85
Fall Banded Conventional Urea	4	0-15	7.55	19.60
		15-30	2.75	11.65
		30-60	2.25	2.65
		60-90	2.45	1.95
Fall Banded Calcium Nitrate	4	0-15	1.60	5.30
		15-30	1.40	14.35
		30-60	1.55	2.85
		60-90	1.65	1.10
Spring Banded Conventional Urea	4	0-15	2.20	6.55
		15-30	2.30	2.25
		30-60	2.00	1.35
		60-90	1.60	0.90

Table A.59. Concentrations of ammonium and nitrate at maturity at Oak Bluff.

			2007	
Site and Treatment			At maturity	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-30	4.75	2.40
		30-60	4.70	1.45
		60-90	12.60	1.15
		90-120	8.00	0.80
Fall Banded NBPT-DCD Urea	1	0-30	10.60	2.00
		30-60	4.75	1.50
		60-90	5.30	1.45
		90-120	8.70	0.85
Fall Banded Conventional Urea	1	0-30	5.25	2.70
		30-60	4.25	1.65
		60-90	4.65	1.00
		90-120	8.80	1.30
Fall Banded Calcium Nitrate	1	0-30	4.75	2.80
		30-60	4.50	1.70
		60-90	5.20	1.75
		90-120	4.05	1.25
Spring Banded Conventional Urea	1	0-30	4.15	2.60
		30-60	8.20	1.00
		60-90	4.80	0.75
		90-120	12.60	0.90
Control	2	0-30	5.15	2.15
		30-60	3.80	1.70
		60-90	12.60	1.25
		90-120	6.00	1.30
Fall Banded NBPT-DCD Urea	2	0-30	5.10	3.70
		30-60	6.55	1.05
		60-90	9.25	1.65
		90-120	5.00	2.15
Fall Banded Conventional Urea	2	0-30	12.60	3.05
		30-60	5.20	2.45
		60-90	7.05	0.95
		90-120	9.65	2.15
Fall Banded Calcium Nitrate	2	0-30	7.85	2.30
		30-60	7.35	1.05
		60-90	9.25	0.95
		90-120	8.55	1.25
Spring Banded Conventional Urea	2	0-30	4.45	3.50
		30-60	4.70	2.15
		60-90	6.10	1.45
		90-120	6.40	2.70

Table A.59 (cont'd). Concentrations of ammonium and nitrate at maturity at Oak Bluff.

			2007	
Site and Treatment			At maturity	
Oak Bluff	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-30	6.40	2.10
		30-60	12.60	1.65
		60-90	7.50	0.80
		90-120	7.85	0.75
Fall Banded NBPT-DCD Urea	3	0-30	8.85	5.50
		30-60	10.20	1.70
		60-90	10.55	1.65
		90-120	9.90	2.20
Fall Banded Conventional Urea	3	0-30	8.95	5.80
		30-60	8.55	1.60
		60-90	8.40	2.15
		90-120	7.70	3.70
Fall Banded Calcium Nitrate	3	0-30	6.25	2.40
		30-60	7.60	1.75
		60-90	7.75	1.30
		90-120	10.95	1.75
Spring Banded Conventional Urea	3	0-30	7.55	2.75
		30-60	8.50	1.10
		60-90	9.80	0.90
		90-120	7.85	0.90
Control	4	0-30	7.85	5.60
		30-60	8.10	1.60
		60-90	7.10	1.60
		90-120	8.05	2.15
Fall Banded NBPT-DCD Urea	4	0-30	10.80	4.95
		30-60	6.60	1.65
		60-90	8.10	1.40
		90-120	7.95	1.85
Fall Banded Conventional Urea	4	0-30	9.90	7.80
		30-60	10.60	3.00
		60-90	10.55	1.45
		90-120	12.60	2.60
Fall Banded Calcium Nitrate	4	0-30	7.95	5.80
		30-60	8.65	1.65
		60-90	8.85	1.55
		90-120	8.05	2.35
Spring Banded Conventional Urea	4	0-30	9.70	6.75
		30-60	8.50	2.80
		60-90	7.80	1.40
		90-120	7.70	1.90

Table A.60. Concentrations of ammonium and nitrate at maturity at Brandon.

			2007	
Site and Treatment			At maturity	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-30	11.20	3.70
		30-60	4.35	0.85
		60-90	3.35	0.65
		90-120	2.90	0.30
Fall Banded NBPT-DCD Urea	1	0-30	10.85	7.95
		30-60	4.00	0.80
		60-90	4.40	0.65
		90-120	2.95	0.40
Fall Banded Conventional Urea	1	0-30	10.50	6.05
		30-60	5.30	1.15
		60-90	5.05	1.90
		90-120	2.75	0.45
Fall Banded Calcium Nitrate	1	0-30	11.75	13.60
		30-60	4.55	1.60
		60-90	6.10	1.15
		90-120	4.70	0.30
Spring Banded Conventional Urea	1	0-30	10.65	6.65
		30-60	4.75	1.00
		60-90	5.05	0.85
		90-120	3.30	0.10
Control	2	0-30	10.10	12.70
		30-60	4.85	0.75
		60-90	4.90	0.70
		90-120	4.55	0.35
Fall Banded NBPT-DCD Urea	2	0-30	9.25	6.60
		30-60	4.65	0.70
		60-90	4.35	0.50
		90-120	4.65	0.45
Fall Banded Conventional Urea	2	0-30	12.10	16.50
		30-60	5.30	0.85
		60-90	5.05	1.60
		90-120	4.25	0.30
Fall Banded Calcium Nitrate	2	0-30	12.15	12.30
		30-60	5.40	1.40
		60-90	6.45	4.45
		90-120	5.00	0.25
Spring Banded Conventional Urea	2	0-30	10.55	8.95
		30-60	5.35	0.90
		60-90	4.00	1.15
		90-120	5.25	0.25

Table A.60 (cont'd). Concentrations of ammonium and nitrate at maturity at Brandon.

			2007	
Site and Treatment			At maturity	
Brandon	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-30	11.50	9.10
		30-60	5.05	0.90
		60-90	7.75	1.10
		90-120	5.40	0.30
Fall Banded NBPT-DCD Urea	3	0-30	11.30	9.75
		30-60	4.55	3.60
		60-90	4.40	2.35
		90-120	4.80	0.35
Fall Banded Conventional Urea	3	0-30	12.55	7.45
		30-60	3.95	0.80
		60-90	6.50	0.85
		90-120	5.05	0.20
Fall Banded Calcium Nitrate	3	0-30	12.45	21.80
		30-60	4.55	4.30
		60-90	5.50	2.70
		90-120	4.90	0.30
Spring Banded Conventional Urea	3	0-30	15.55	9.25
		30-60	5.05	1.00
		60-90	4.40	0.90
		90-120	5.30	0.45
Control	4	0-30	10.35	8.25
		30-60	4.75	1.00
		60-90	4.20	1.70
		90-120	4.05	0.40
Fall Banded NBPT-DCD Urea	4	0-30	15.35	20.00
		30-60	4.30	8.80
		60-90	4.35	1.80
		90-120	3.55	0.30
Fall Banded Conventional Urea	4	0-30	12.50	19.50
		30-60	4.70	2.55
		60-90	4.10	1.15
		90-120	4.05	0.35
Fall Banded Calcium Nitrate	4	0-30	9.50	7.85
		30-60	3.90	0.85
		60-90	4.35	0.35
		90-120	5.10	0.35
Spring Banded Conventional Urea	4	0-30	11.40	13.75
		30-60	6.15	1.20
		60-90	6.10	0.85
		90-120	4.75	0.30

Table A.61. Concentrations of ammonium and nitrate at maturity at Indian Head.

			2007	
Site and Treatment			At maturity	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	1	0-15		
		15-30	2.10	0.50
		30-60	0.00	0.00
		60-90	1.80	0.55
Fall Banded NBPT-DCD Urea	1	0-15	2.30	2.00
		15-30	2.20	0.50
		30-60	2.10	0.50
		60-90	1.80	1.35
Fall Banded Conventional Urea	1	0-15		
		15-30	1.90	0.50
		30-60	1.35	0.50
		60-90	1.35	1.00
Fall Banded Calcium Nitrate	1	0-15	1.65	2.55
		15-30	1.85	0.40
		30-60	1.60	0.35
		60-90	0.00	0.00
Spring Banded Conventional Urea	1	0-15	2.15	2.45
		15-30	1.55	0.50
		30-60	1.35	0.50
		60-90	1.95	2.00
Control	2	0-15	1.90	2.50
		15-30	2.15	3.50
		30-60	2.05	0.50
		60-90	1.50	0.50
Fall Banded NBPT-DCD Urea	2	0-15	2.15	2.00
		15-30		
		30-60		
		60-90	2.55	2.00
Fall Banded Conventional Urea	2	0-15	0.00	0.00
		15-30	2.10	7.35
		30-60	1.70	0.45
		60-90		
Fall Banded Calcium Nitrate	2	0-15	2.80	1.50
		15-30	2.95	0.50
		30-60	2.25	1.00
		60-90	2.25	1.50
Spring Banded Conventional Urea	2	0-15	2.20	3.50
		15-30	2.45	0.50
		30-60	2.35	0.50
		60-90	2.25	1.50

Table A.61 (cont'd). Concentrations of ammonium and nitrate at maturity at Indian Head.

			2007	
Site and Treatment			At maturity	
Indian Head	Rep	Depth (cm)	Average NH_4 concentration	Average NO_3 concentration
			mg kg^{-1}	
Control	3	0-15	1.75	1.40
		15-30	1.90	0.50
		30-60	2.05	0.55
		60-90	1.90	0.55
Fall Banded NBPT-DCD Urea	3	0-15	2.15	0.90
		15-30	2.15	0.45
		30-60	2.30	0.90
		60-90	1.90	0.55
Fall Banded Conventional Urea	3	0-15	1.55	3.00
		15-30	1.80	0.50
		30-60	1.80	0.50
		60-90	1.90	0.50
Fall Banded Calcium Nitrate	3	0-15	2.35	1.85
		15-30	2.45	0.45
		30-60	3.45	1.30
		60-90	2.35	1.20
Spring Banded Conventional Urea	3	0-15	1.65	1.15
		15-30	1.45	0.40
		30-60	1.90	0.40
		60-90	2.45	0.50
Control	4	0-15	2.00	0.80
		15-30		
		30-60	2.25	0.30
		60-90	2.15	0.90
Fall Banded NBPT-DCD Urea	4	0-15	1.65	3.10
		15-30	2.40	0.45
		30-60		
		60-90	2.80	0.65
Fall Banded Conventional Urea	4	0-15	2.40	1.40
		15-30	2.60	0.40
		30-60	2.25	0.75
		60-90	2.50	2.40
Fall Banded Calcium Nitrate	4	0-15	2.30	3.45
		15-30	2.10	0.60
		30-60	1.60	0.45
		60-90	1.80	1.40
Spring Banded Conventional Urea	4	0-15	4.20	3.40
		15-30	2.30	0.55
		30-60	2.40	0.45
		60-90	2.00	1.20

Table A.62. Crop measurement and nitrogen efficiency at heading at Oak Bluff.

Site and Treatment		2005/06				2006/07			
Oak Bluff	Rep	% Nitrogen	Above ground biomass	N uptake	Apparent Fertilizer NUE	% Nitrogen	Above ground biomass	N uptake	Apparent Fertilizer NUE
			kg ha^{-1}		% of applied		kg ha^{-1}		% of applied
Control	1	1.89	5997	113		1.20	3713	45	
Fall Banded NBPT-DCD Urea	1	2.22	2292	51	-78.09	1.54	3787	58	25.42
Fall Banded Conventional Urea	1	2.38	7532	179	82.40	1.54	2475	38	-8.35
Fall Banded Calcium Nitrate	1	2.14	7161	153	49.88	2.17	2030	44	-0.95
Spring Banded Conventional Urea	1	2.55	4240	108	-6.54	1.66	3911	65	25.42
Control	2	1.93	5872	113		1.34	2450	33	
Fall Banded NBPT-DCD Urea	2	2.43	5909	144	37.82	1.72	3341	57	30.77
Fall Banded Conventional Urea	2	2.58	3900	101	-15.91	2.01	3539	71	47.72
Fall Banded Calcium Nitrate	2	2.31	4209	97	-20.12	1.33	3143	42	11.28
Spring Banded Conventional Urea	2	2.17	6407	139	32.13	1.40	3292	46	16.79
Control	3	1.97	5664	112		1.51	2426	37	
Fall Banded NBPT-DCD Urea	3	2.82	4932	139	34.38	1.44	2772	40	4.22
Fall Banded Conventional Urea	3	2.11	6837	144	40.86	1.57	3267	51	18.30
Fall Banded Calcium Nitrate	3	2.50	4473	112	0.30	1.62	2921	47	13.18
Spring Banded Conventional Urea	3	1.95	5742	112	0.50	1.35	4282	58	26.55
Control	4	1.61	6011	97		1.79	2277	41	
Fall Banded NBPT-DCD Urea	4	2.29	5996	137	50.68	1.84	3614	67	32.27
Fall Banded Conventional Urea	4	2.06	6539	144	47.42	1.52	4430	68	33.42
Fall Banded Calcium Nitrate	4	2.21	4986	110	16.77	1.62	2475	40	-0.95
Spring Banded Conventional Urea	4	1.96	6217	122	31.35	1.50	4381	66	31.16

Table A.63. Crop measurement and nitrogen efficiency at heading at Brandon.

Site and Treatment		2005/06				2006/07			
Brandon	Rep	% Nitrogen	Above ground biomass	N uptake	Apparent Fertilizer NUE	% Nitrogen	Above ground biomass	N uptake	Apparent Fertilizer NUE
			kg ha^{-1}		% of applied		kg ha^{-1}		% of applied
Control	1	1.45	3238	46.94		1.97	1965	39	
Fall Banded NBPT-DCD Urea	1	1.40	2598	36.37	-17.63	1.97	1723	34	-7.94
Fall Banded Conventional Urea	1	1.80	2525	45.45	-2.49	2.22	1890	42	5.61
Fall Banded Calcium Nitrate	1	1.18	3013	35.55	-18.99	1.95	1875	36	-3.57
Spring Banded Conventional Urea	1	1.14	3860	44.00	-4.90	2.66	1723	46	11.92
Control	2	1.53	2415	36.95		1.97	1463	29	
Fall Banded NBPT-DCD Urea	2	1.24	2805	34.78	-3.61	2.09	1925	40	19.20
Fall Banded Conventional Urea	2	1.23	3538	43.51	10.94	2.37	1555	37	13.53
Fall Banded Calcium Nitrate	2	1.70	2608	44.33	12.30	2.25	2070	47	29.63
Spring Banded Conventional Urea	2	1.43	2523	36.07	-1.46	2.25	1803	41	19.64
Control	3	1.41	2468	34.79		1.79	2253	40	
Fall Banded NBPT-DCD Urea	3	1.46	2673	39.02	7.04	2.04	1935	39	-1.54
Fall Banded Conventional Urea	3	1.42	2338	33.19	-2.67	2.10	1890	40	-1.15
Fall Banded Calcium Nitrate	3	1.17	3055	35.74	1.59	2.18	1665	36	-6.71
Spring Banded Conventional Urea	3	1.70	2815	47.86	21.77	2.14	1608	34	-9.82
Control	4	1.24	2145	26.60		1.70	1848	31	
Fall Banded NBPT-DCD Urea	4	1.07	2885	30.87	7.12	2.34	1573	37	9.04
Fall Banded Conventional Urea	4	1.24	2015	24.99	-2.69	2.30	1610	37	9.29
Fall Banded Calcium Nitrate	4	1.48	1933	28.60	3.34	2.02	1653	33	3.21
Spring Banded Conventional Urea	4	1.19	2405	28.62	3.37	2.14	1953	42	17.45

Table A.64. Crop measurement and nitrogen efficiency at heading at Indian Head.

Site and Treatment		2005/06				2006/07			
Indian Head	Rep	% Nitrogen	Above ground biomass	N uptake	Apparent Fertilizer NUE	% Nitrogen	Above ground biomass	N uptake	Apparent Fertilizer NUE
			kg ha^{-1}		% of applied		kg ha^{-1}		% of applied
Control	1	2.02	2805	57		1.46	3855	56	
Fall Banded NBPT-DCD Urea	1	1.73	3330	58	1.58	2.19	4692	103	77.55
Fall Banded Conventional Urea	1	2.74	3461	95	63.63	1.89	4232	80	39.63
Fall Banded Calcium Nitrate	1	2.70	3445	93	60.58	1.96	4659	91	58.73
Spring Banded Conventional Urea	1	2.79	2953	82	42.86	1.81	5052	92	59.06
Control	2	1.91	3281	63		1.50	2969	45	
Fall Banded NBPT-DCD Urea	2	2.46	3871	95	54.29	1.80	5069	91	77.55
Fall Banded Conventional Urea	2	2.82	3527	99	61.32	1.85	4856	90	75.13
Fall Banded Calcium Nitrate	2	2.46	3330	82	32.09	2.18	3970	86	69.73
Spring Banded Conventional Urea	2	2.68	3428	92	48.70	1.69	4150	70	42.72
Control	3	2.15	2297	49		1.30	2936	38	
Fall Banded NBPT-DCD Urea	3	2.35	2707	64	23.72	2.02	4035	82	72.21
Fall Banded Conventional Urea	3	2.62	3478	91	69.56	1.92	3593	69	51.48
Fall Banded Calcium Nitrate	3	2.40	3445	83	55.50	2.02	4314	87	81.67
Spring Banded Conventional Urea	3	3.14	3937	100	85.11	1.96	4249	83	74.86
Control	4	1.60	3314	53		1.45	3740	54	
Fall Banded NBPT-DCD Urea	4	2.56	3937	101	79.62	1.83	5823	107	87.67
Fall Banded Conventional Urea	4	1.87	3527	66	21.56	2.02	4577	93	64.25
Fall Banded Calcium Nitrate	4	2.66	3724	99	76.72	2.34	4675	110	92.51
Spring Banded Conventional Urea	4	2.34	3527	66	21.56	1.81	4987	90	60.63

APPENDIX B:

SUPPLEMENTARY TABLES FOR CHAPTER 3.0

Table B.1. Concentrations of nitrous oxide emitted at Oak Bluff during fall 2005.

Site and treatment			Fall 2005			
Oak Bluff	Rep	Time	Date			
			Oct. 14	Oct. 17	Oct. 19	Oct.21
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.356	0.370	0.361	0.380
		15	0.367	0.366	0.369	0.371
		30	0.361	0.359	0.381	0.378
		45	0.370	0.369	0.379	0.370
Fall Banded NBPT-DCD Urea	1	0	0.367	0.367	0.377	0.380
		15	0.364	0.365	0.382	0.369
		30	0.370	0.370	0.369	0.371
		45	0.368	0.367	0.378	0.363
Fall Banded Conventional Urea	1	0	0.362	0.378	0.366	0.357
		15	0.367	0.365	0.405	0.369
		30	0.369	0.373	0.397	0.373
		45	0.366	0.366	0.428	0.374
Fall Banded Calcium Nitrate	1	0	0.372	0.371	0.370	0.372
		15	0.364	0.353	0.379	0.372
		30	0.372	0.360	0.384	0.388
		45	0.373	0.365	0.390	0.381
Spring Banded Conventional Urea	1	0	0.364	0.372	0.364	0.369
		15	0.368	0.362	0.371	0.366
		30	0.372	0.359	0.380	0.370
		45	0.362	0.363	0.376	0.373
Control	2	0	0.371	0.374	0.370	0.376
		15	0.368	0.358	0.369	0.376
		30	0.372	0.362	0.374	0.368
		45	0.362	0.361	0.376	0.382
Fall Banded NBPT-DCD Urea	2	0	0.377	0.372	0.368	0.378
		15	0.370	0.366	0.371	0.373
		30	0.362	0.368	0.371	0.395
		45	0.357	0.367	0.377	0.366
Fall Banded Conventional Urea	2	0	0.369	0.364	0.371	0.367
		15	0.368	0.365	0.382	0.375
		30	0.378	0.360	0.385	0.367
		45	0.364	0.365	0.381	0.361
Fall Banded Calcium Nitrate	2	0	0.365	0.367	0.371	0.356
		15	0.366	0.356	0.373	0.366
		30	0.367	0.369	0.393	0.377
		45	0.365	0.358	0.389	0.361
Spring Banded Conventional Urea	2	0	0.369	0.370	0.371	0.366
		15	0.369	0.370	0.374	0.365
		30	0.374	0.366	0.373	0.375
		45	0.364	0.370	0.374	0.371

Table B.1 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during fall 2005.

Site and treatment			Fall 2005			
Oak Bluff	Rep	Time	Date			
			Oct. 14	Oct. 17	Oct. 19	Oct. 21
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.367	0.365	0.369	0.362
		15	0.366	0.351	0.367	0.374
		30	0.374	0.371	0.375	0.369
		45	0.358	0.366	0.380	0.370
Fall Banded NBPT-DCD Urea	3	0	0.366	0.371	0.369	0.372
		15	0.371	0.365	0.382	0.381
		30	0.366	0.366	0.384	0.350
		45	0.362	0.366	0.405	0.375
Fall Banded Conventional Urea	3	0	0.365	0.362	0.373	0.369
		15	0.365	0.355	0.387	0.368
		30	0.370	0.353	0.356	0.372
		45	0.359	0.359	0.406	0.355
Fall Banded Calcium Nitrate	3	0	0.366	0.366	0.371	0.375
		15	0.364	0.363	0.363	0.372
		30	0.368	0.367	0.364	0.360
		45	0.361	0.352	0.372	0.374
Spring Banded Conventional Urea	3	0	0.368	0.367	0.372	0.369
		15	0.361	0.361	0.369	0.376
		30	0.366	0.372	0.371	0.367
		45	0.360	0.340	0.375	0.373
Control	4	0	0.364	0.368	0.372	0.374
		15	0.367	0.357	0.374	0.370
		30	0.376	0.361	0.377	0.374
		45	0.358	0.364	0.373	0.374
Fall Banded NBPT-DCD Urea	4	0	0.368	0.365	0.370	0.375
		15	0.369	0.366	0.374	0.360
		30	0.360	0.356	0.382	0.368
		45	0.368	0.348	0.375	0.344
Fall Banded Conventional Urea	4	0	0.368	0.364	0.368	0.379
		15	0.360	0.375	0.449	0.391
		30	0.364	0.361	0.506	0.393
		45	0.363	0.362	0.545	0.403
Fall Banded Calcium Nitrate	4	0	0.369	0.364	0.367	0.372
		15	0.367	0.346	0.383	0.375
		30	0.370	0.354	0.393	0.380
		45	0.363	0.350	0.401	0.372
Spring Banded Conventional Urea	4	0	0.373	0.371	0.364	0.371
		15	0.359	0.366	0.371	0.348
		30	0.366	0.356	0.374	0.373
		45	0.365	0.369	0.378	0.371

Table B.1 (cont'd) Concentrations of nitrous oxide emitted at Oak Bluff during fall 2005.

Site and treatment			Fall 2005			
Oak Bluff	Rep	Time	Date			
			Oct. 24	Oct. 26	Oct. 28	Oct. 31
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.360		0.356	0.373
		15	0.358	0.370	0.357	0.371
		30	0.365	0.361	0.369	0.376
		45	0.367	0.357	0.378	0.374
Fall Banded NBPT-DCD Urea	1	0	0.345	0.364	0.352	0.376
		15	0.369	0.373	0.376	0.381
		30	0.379	0.370	0.389	0.379
		45	0.382		0.388	0.380
Fall Banded Conventional Urea	1	0	0.363	0.365	0.353	0.379
		15	0.384	0.388	0.374	0.407
		30	0.380	0.373	0.389	0.400
		45	0.381		0.384	0.407
Fall Banded Calcium Nitrate	1	0	0.362	0.362	0.354	0.371
		15	0.376	0.365	0.364	0.374
		30	0.369	0.374	0.370	0.381
		45	0.371	0.364	0.372	0.374
Spring Banded Conventional Urea	1	0	0.359	0.358	0.350	0.378
		15	0.328	0.360	0.357	0.376
		30	0.355		0.372	0.378
		45	0.360	0.361	0.383	0.378
Control	2	0	0.363	0.361	0.356	0.370
		15	0.365	0.363	0.369	0.380
		30	0.367	0.355	0.371	0.372
		45	0.362	0.360	0.378	0.383
Fall Banded NBPT-DCD Urea	2	0	0.352	0.358	0.349	0.385
		15	0.361	0.369	0.357	0.378
		30	0.364	0.363	0.368	0.379
		45	0.370	0.360	0.373	0.384
Fall Banded Conventional Urea	2	0	0.361	0.362	0.362	0.380
		15	0.365	0.374	0.364	0.396
		30	0.369	0.361	0.378	0.397
		45	0.364	0.366	0.366	0.417
Fall Banded Calcium Nitrate	2	0	0.353	0.364	0.354	0.371
		15	0.375	0.365	0.364	0.371
		30	0.354	0.362	0.375	0.379
		45	0.359	0.358	0.370	0.371
Spring Banded Conventional Urea	2	0	0.369	0.357	0.360	0.374
		15	0.357	0.366	0.358	0.380
		30	0.361	0.363	0.371	0.372
		45	0.357	0.362	0.375	0.376

Table B.1 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during fall 2005.

Site and treatment			Fall 2005			
Oak Bluff	Rep	Time	Date			
			Oct. 24	Oct. 26	Oct. 28	Oct. 31
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.356	0.357	0.367	0.379
		15	0.359	0.360	0.372	0.380
		30	0.355	0.362	0.383	0.377
		45	0.362	0.363	0.379	0.383
Fall Banded NBPT-DCD Urea	3	0	0.363	0.355	0.376	0.379
		15	0.453	0.358	0.384	0.383
		30	0.420	0.358	0.383	0.389
		45	0.412	0.377	0.385	0.401
Fall Banded Conventional Urea	3	0	0.365	0.358	0.371	0.380
		15	0.369	0.362	0.366	0.385
		30	0.376	0.358	0.370	0.386
		45	0.371	0.365	0.377	0.381
Fall Banded Calcium Nitrate	3	0	0.355	0.359	0.374	0.384
		15	0.358	0.379	0.371	0.380
		30	0.367	0.374	0.370	0.382
		45	0.364	0.375	0.371	0.380
Spring Banded Conventional Urea	3	0	0.366	0.358	0.377	0.375
		15	0.364	0.363	0.373	0.381
		30	0.359	0.355	0.379	0.378
		45	0.359	0.356	0.374	
Control	4	0	0.359	0.362	0.379	0.372
		15	0.361	0.361	0.374	0.386
		30	0.364	0.368	0.377	0.380
		45	0.362	0.364	0.371	0.383
Fall Banded NBPT-DCD Urea	4	0	0.362	0.380	0.372	0.386
		15	0.362	0.388	0.377	0.381
		30	0.370	0.350	0.378	0.383
		45	0.363	0.364	0.384	0.373
Fall Banded Conventional Urea	4	0	0.361	0.358	0.367	0.380
		15	0.406	0.366	0.379	0.421
		30	0.424	0.384	0.384	0.443
		45	0.399	0.424	0.381	0.414
Fall Banded Calcium Nitrate	4	0	0.365	0.350	0.371	0.377
		15	0.363	0.437	0.373	0.387
		30	0.366	0.362	0.381	0.383
		45	0.363	0.367	0.371	0.378
Spring Banded Conventional Urea	4	0	0.355	0.359	0.371	0.381
		15	0.358	0.365	0.379	0.379
		30	0.366	0.431	0.371	0.374
		45	0.364	0.367	0.374	0.378

Table B.1 (cont'd) Concentrations of nitrous oxide emitted at Oak Bluff during fall 2005.

Site and treatment			Fall 2005			
Oak Bluff	Rep	Time	Date			
			Nov. 4	Nov. 7	Nov. 10	Nov. 14
			µL N_2O L^{-1}			
Control	1	0	0.357	0.353	0.375	0.371
		15	0.412	0.348	0.377	0.374
		30	0.441	0.348	0.377	0.374
		45	0.425	0.351	0.376	0.377
Fall Banded NBPT-DCD Urea	1	0	0.350	0.346	0.380	0.379
		15	0.357	0.353	0.378	0.382
		30	0.353	0.351	0.380	0.378
		45	0.362	0.352	0.382	0.371
Fall Banded Conventional Urea	1	0	0.355	0.347	0.383	0.380
		15	0.355	0.357	0.435	0.384
		30	0.351	0.354	0.419	0.378
		45	0.345	0.363	0.426	
Fall Banded Calcium Nitrate	1	0	0.347	0.357	0.379	0.381
		15	0.364	0.352	0.375	0.378
		30	0.360	0.346	0.374	0.381
		45	0.354	0.349	0.378	0.378
Spring Banded Conventional Urea	1	0	0.354	0.355	0.381	0.384
		15	0.394	0.347	0.377	0.379
		30	0.398	0.354	0.366	0.374
		45	0.397	0.347	0.378	0.377
Control	2	0	0.357	0.344	0.378	0.387
		15	0.382	0.350	0.376	0.381
		30	0.388	0.353	0.375	0.388
		45	0.388	0.350	0.372	0.376
Fall Banded NBPT-DCD Urea	2	0	0.345	0.344	0.370	0.385
		15	0.362	0.356	0.375	0.379
		30	0.346	0.365	0.378	0.375
		45	0.362	0.358	0.379	0.382
Fall Banded Conventional Urea	2	0	0.347	0.349	0.383	0.381
		15	0.369	0.350	0.378	0.380
		30	0.357	0.354	0.384	0.386
		45	0.360	0.366	0.379	0.382
Fall Banded Calcium Nitrate	2	0	0.358	0.347	0.384	0.379
		15	0.346	0.353	0.373	0.379
		30	0.347	0.347	0.378	0.380
		45	0.351	0.363	0.374	0.374
Spring Banded Conventional Urea	2	0	0.351	0.346	0.384	0.382
		15	0.368	0.350	0.383	0.373
		30	0.368	0.351	0.377	0.383
		45	0.358	0.354	0.376	0.375

Table B.1 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during fall 2005.

Site and treatment			Fall 2005			
Oak Bluff	Rep	Time	Date			
			Nov. 4	Nov. 7	Nov. 10	Nov. 14
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.352	0.368	0.382	0.369
		15	0.348	0.370	0.379	0.368
		30	0.352	0.378	0.378	0.376
		45	0.352	0.381	0.385	0.371
Fall Banded NBPT-DCD Urea	3	0	0.350	0.375	0.378	0.365
		15	0.350	0.376	0.378	0.371
		30	0.354	0.386	0.379	0.364
		45	0.354	0.378	0.374	0.364
Fall Banded Conventional Urea	3	0	0.352	0.371	0.380	0.370
		15	0.352	0.370	0.390	0.379
		30	0.351	0.376	0.399	0.367
		45	0.377	0.376	0.401	0.376
Fall Banded Calcium Nitrate	3	0	0.352	0.376	0.376	0.377
		15	0.370	0.373	0.372	0.368
		30	0.375	0.382	0.374	0.370
		45	0.352	0.389	0.372	0.372
Spring Banded Conventional Urea	3	0	0.348	0.378	0.374	0.368
		15	0.348	0.378	0.376	0.369
		30	0.356	0.380	0.378	0.372
		45	0.347	0.378	0.377	0.366
Control	4	0	0.349	0.373	0.384	0.370
		15	0.348	0.375	0.371	0.365
		30	0.355	0.380	0.376	0.374
		45	0.345	0.368	0.374	0.362
Fall Banded NBPT-DCD Urea	4	0	0.381	0.375	0.389	0.371
		15	0.409	0.374	0.376	0.364
		30	0.346	0.383	0.382	0.370
		45	0.349	0.378	0.373	0.362
Fall Banded Conventional Urea	4	0	0.349	0.376	0.384	0.368
		15	0.355	0.400	0.386	0.366
		30	0.415	0.437	0.400	0.370
		45	0.353	0.448	0.372	0.366
Fall Banded Calcium Nitrate	4	0	0.355	0.370	0.375	0.369
		15	0.400	0.380	0.378	0.367
		30	0.358	0.380	0.384	0.366
		45	0.350	0.377	0.378	0.369
Spring Banded Conventional Urea	4	0	0.353	0.373	0.378	0.368
		15	0.354	0.369	0.378	0.376
		30	0.353	0.381	0.375	0.369
		45	0.439	0.382	0.373	0.368

Table B.2. Concentrations of nitrous oxide emitted at Brandon during fall 2005.

Site and treatment			Fall 2005			
Brandon	Rep	Time	Date			
			Oct. 16	Oct. 18	Oct. 21	Oct. 25
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.336	0.334	0.330	0.336
		15	0.336	0.338	0.333	0.330
		30	0.341	0.314	0.326	0.330
		45	0.341	0.321	0.338	0.330
Fall Banded NBPT-DCD Urea	1	0	0.336	0.333	0.326	0.334
		15	0.334	0.339	0.330	0.328
		30	0.343	0.339	0.334	0.337
		45	0.341	0.305	0.336	0.336
Fall Banded Conventional Urea	1	0	0.335	0.338	0.329	0.334
		15	0.337	0.349	0.314	0.348
		30	0.346	0.348	0.333	0.342
		45	0.332	0.347	0.336	0.352
Fall Banded Calcium Nitrate	1	0	0.337	0.333	0.331	0.333
		15	0.312	0.332	0.325	0.331
		30	0.336	0.363	0.338	0.336
		45	0.311	0.363	0.315	0.346
Spring Banded Conventional Urea	1	0	0.337	0.336	0.331	0.335
		15	0.334	0.333	0.330	0.329
		30	0.332	0.337	0.331	0.338
		45	0.336	0.345	0.325	0.336
Control	2	0	0.331	0.336	0.330	0.333
		15	0.333	0.334	0.328	0.346
		30	0.333	0.340	0.334	0.353
		45	0.315	0.323	0.332	0.354
Fall Banded NBPT-DCD Urea	2	0	0.298	0.339	0.297	0.343
		15	0.332	0.337	0.317	0.349
		30	0.336	0.328	0.307	0.354
		45	0.332	0.312	0.338	0.367
Fall Banded Conventional Urea	2	0	0.339	0.335	0.330	0.342
		15	0.324	0.332	0.319	0.337
		30	0.330	0.311	0.336	0.338
		45	0.332	0.332	0.326	0.344
Fall Banded Calcium Nitrate	2	0	0.325	0.320	0.324	0.331
		15	0.345	0.333	0.338	0.336
		30	0.329	0.329	0.321	0.342
		45	0.338	0.332	0.337	0.341
Spring Banded Conventional Urea	2	0	0.334	0.336	0.331	0.337
		15	0.308	0.298	0.322	0.326
		30	0.335	0.334	0.324	0.332
		45	0.304	0.333	0.306	0.330

Table B.2 (cont'd). Concentrations of nitrous oxide emitted at Brandon during fall 2005.

Site and treatment			Fall 2005			
Brandon	Rep	Time	Date			
			Oct. 16	Oct. 18	Oct. 21	Oct. 25
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.335	0.329	0.336	0.331
		15	0.326	0.319	0.326	0.322
		30	0.336	0.310	0.335	0.322
		45	0.340	0.339	0.330	0.310
Fall Banded NBPT-DCD Urea	3	0	0.334	0.331	0.334	0.309
		15	0.340	0.338	0.330	0.331
		30	0.339	0.336	0.327	0.339
		45	0.336	0.331	0.329	0.317
Fall Banded Conventional Urea	3	0	0.328	0.336	0.337	0.339
		15	0.310	0.329	0.333	0.367
		30	0.346	0.342	0.346	0.370
		45	0.319	0.334	0.346	
Fall Banded Calcium Nitrate	3	0	0.329	0.339	0.342	0.332
		15	0.325	0.326	0.331	0.319
		30	0.338	0.340	0.333	0.338
		45	0.330	0.337	0.328	0.349
Spring Banded Conventional Urea	3	0	0.335	0.335	0.331	0.342
		15	0.335	0.325	0.326	0.333
		30	0.328	0.328	0.332	0.313
		45	0.331	0.335	0.330	0.331
Control	4	0	0.303	0.335	0.335	0.334
		15	0.335	0.336	0.324	0.332
		30	0.335	0.338	0.336	0.320
		45	0.333	0.320	0.329	0.307
Fall Banded NBPT-DCD Urea	4	0	0.316	0.336	0.333	0.310
		15	0.335	0.334	0.339	0.332
		30	0.331	0.334	0.330	0.338
		45	0.333	0.327	0.333	0.339
Fall Banded Conventional Urea	4	0	0.331	0.325	0.331	0.334
		15	0.335	0.339	0.338	0.337
		30	0.336	0.351	0.340	0.351
		45	0.329	0.350	0.332	0.386
Fall Banded Calcium Nitrate	4	0	0.332	0.331	0.328	0.318
		15	0.288	0.340	0.328	0.332
		30	0.332	0.338	0.335	0.347
		45	0.303	0.330	0.332	0.329
Spring Banded Conventional Urea	4	0	0.330	0.339	0.326	0.329
		15	0.310	0.328	0.328	0.324
		30	0.338	0.328	0.329	0.330
		45	0.336	0.336	0.329	0.321

Table B.2 (cont'd). Concentrations of nitrous oxide emitted at Brandon during fall 2005.

Site and treatment			Fall 2005	
Brandon	Rep	Time	Date	
			Nov. 1	Nov. 7
			μL N_2O L^{-1}	
Control	1	0	0.332	0.357
		15	0.347	0.367
		30	0.341	0.364
		45	0.330	0.356
Fall Banded NBPT-DCD Urea	1	0	0.335	0.356
		15	0.340	0.358
		30	0.338	0.367
		45	0.339	0.361
Fall Banded Conventional Urea	1	0	0.337	0.357
		15	0.347	0.357
		30	0.344	0.356
		45	0.343	0.371
Fall Banded Calcium Nitrate	1	0	0.337	0.343
		15	0.367	0.406
		30	0.359	0.418
		45	0.356	0.449
Spring Banded Conventional Urea	1	0	0.340	0.353
		15	0.345	0.362
		30	0.335	0.362
		45	0.341	0.369
Control	2	0	0.333	0.355
		15	0.339	0.353
		30	0.338	0.363
		45	0.338	0.369
Fall Banded NBPT-DCD Urea	2	0	0.333	0.356
		15	0.346	0.368
		30	0.338	0.348
		45	0.343	0.369
Fall Banded Conventional Urea	2	0	0.339	0.354
		15	0.358	0.410
		30	0.356	0.413
		45	0.352	0.423
Fall Banded Calcium Nitrate	2	0	0.339	0.354
		15	0.348	0.361
		30	0.347	0.373
		45	0.340	0.371
Spring Banded Conventional Urea	2	0	0.339	0.357
		15	0.334	0.362
		30	0.337	0.362
		45	0.337	0.359

Table B.2 (cont'd). Concentrations of nitrous oxide emitted at Brandon during fall 2005.

Site and treatment			Fall 2005	
Brandon	Rep	Time	Date	
			Nov. 1	Nov. 7
			$\mu L\ N_2O\ L^{-1}$	
Control	3	0	1.99	0.329
		15	2.04	0.343
		30	2.08	0.341
		45	1.86	0.344
Fall Banded NBPT-DCD Urea	3	0	1.84	0.343
		15	2.00	0.352
		30	1.88	0.374
		45	1.84	0.380
Fall Banded Conventional Urea	3	0	1.82	0.343
		15	1.82	0.340
		30	1.85	0.342
		45	1.81	0.347
Fall Banded Calcium Nitrate	3	0	1.87	0.347
		15	1.84	0.341
		30	1.85	0.343
		45	1.82	0.344
Spring Banded Conventional Urea	3	0	1.81	0.334
		15	1.85	0.336
		30	1.83	0.334
		45	1.84	0.347
Control	4	0	1.80	0.342
		15	1.81	0.367
		30	1.89	0.364
		45	1.84	0.374
Fall Banded NBPT-DCD Urea	4	0	1.79	0.340
		15	1.84	0.364
		30	1.85	0.341
		45	1.85	0.327
Fall Banded Conventional Urea	4	0	1.84	0.339
		15	2.03	0.343
		30	1.82	0.348
		45	1.90	0.351
Fall Banded Calcium Nitrate	4	0	1.92	0.338
		15	2.04	0.340
		30	1.89	0.342
		45	1.86	0.341
Spring Banded Conventional Urea	4	0	1.89	0.349
		15	2.01	0.343
		30	1.77	0.352
		45	2.02	0.359

Table B.3. Concentrations of nitrous oxide emitted at Indian Head during fall 2005.

Site and treatment			Fall 2005			
Indian Head	Rep	Time	Date			
			Oct. 12	Oct. 14	Oct. 17	Oct. 19
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.322	0.376	0.374	0.369
		15	0.315	0.367	0.377	0.367
		30	0.322	0.376	0.375	0.359
		45	0.324	0.370	0.375	0.359
Fall Banded NBPT-DCD Urea	1	0	0.321	0.378	0.373	0.379
		15	0.314	0.378	0.366	0.382
		30	0.324	0.371	0.378	0.376
		45	0.316	0.371	0.364	0.363
Fall Banded Conventional Urea	1	0	0.316	0.377	0.381	0.378
		15	0.314	0.368	0.374	0.374
		30	0.332	0.371	0.381	0.388
		45	0.309	0.375	0.374	0.368
Fall Banded Calcium Nitrate	1	0	0.328	0.369	0.370	0.367
		15	0.333	0.367	0.376	0.374
		30	0.316	0.373	0.388	0.380
		45	0.321	0.365	0.377	0.369
Spring Banded Conventional		0			0.373	0.384
Urea	1		0.329	0.375		
		15	0.317	0.369	0.361	0.377
		30	0.313	0.377	0.370	0.381
		45	0.319	0.369	0.358	0.376
Control	2	0	0.316	0.371	0.374	0.378
		15	0.275	0.364	0.375	0.381
		30	0.315	0.533	0.377	0.384
		45	0.316	0.372	0.382	0.365
Fall Banded NBPT-DCD Urea	2	0	0.321	0.373	0.373	0.386
		15	0.323	0.371	0.375	0.381
		30	0.320	0.369	0.367	0.381
		45	0.315	0.369	0.348	0.375
Fall Banded Conventional Urea	2	0	0.325	0.370	0.379	0.378
		15	0.326	0.369	0.364	0.380
		30	0.327	0.369	0.374	0.383
		45	0.324	0.369	0.375	0.366
Fall Banded Calcium Nitrate	2	0	0.317	0.376	0.376	0.381
		15	0.318	0.375	0.365	0.375
		30	0.318	0.372	0.381	0.375
		45	0.318	0.369	0.380	0.361
Spring Banded Conventional		0			0.379	0.367
Urea	2		0.327	0.383		
		15	0.323	0.369	0.374	0.372
		30	0.326	0.372	0.374	0.371
		45	0.323	0.366	0.383	0.368

Table B.3 (cont'd). Concentrations of nitrous oxide emitted at Indian Head during fall 2005.

Site and treatment			Fall 2005			
Indian Head	Rep	Time	Date			
			Oct. 12	Oct. 14	Oct. 17	Oct. 19
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.322	0.373	0.384	0.375
		15	0.315	0.364	0.375	0.368
		30	0.332	0.370	0.379	0.377
		45	0.308	0.365	0.376	0.358
Fall Banded NBPT-DCD Urea	3	0	0.318	0.365	0.379	0.356
		15	0.315	0.373	0.369	0.363
		30	0.332	0.368	0.388	0.365
		45	0.319	0.373	0.361	0.372
Fall Banded Conventional Urea	3	0	0.331	0.376	0.383	0.368
		15	0.319	0.371	0.368	0.370
		30	0.325	0.373	0.380	0.372
		45	0.313	0.371	0.374	0.358
Fall Banded Calcium Nitrate	3	0	0.324	0.373	0.379	0.376
		15	0.321	0.370	0.384	0.332
		30	0.321	0.369	0.388	0.374
		45	0.319	0.367	0.369	0.371
Spring Banded Conventional		0			0.375	0.367
Urea	3		0.310	0.380		
		15	0.320	0.367	0.380	0.340
		30	0.315	0.373	0.383	0.361
		45	0.323	0.370	0.370	0.366
Control	4	0	0.322	0.378	0.380	0.341
		15	0.319	0.364	0.384	0.347
		30	0.318	0.366	0.386	0.370
		45	0.320	0.371	0.377	0.365
Fall Banded NBPT-DCD Urea	4	0	0.323	0.374	0.375	0.374
		15	0.322	0.372	0.385	0.373
		30	0.328	0.371	0.379	0.370
		45	0.328	0.366	0.376	0.372
Fall Banded Conventional Urea	4	0	0.324	0.368	0.376	0.369
		15	0.311	0.372	0.376	0.365
		30	0.331	0.368	0.385	0.360
		45	0.330	0.365	0.379	0.361
Fall Banded Calcium Nitrate	4	0	0.313	0.372	0.374	0.371
		15	0.325	0.372	0.390	0.371
		30	0.325	0.365	0.376	0.364
		45	0.320	0.369	0.384	0.371
Spring Banded Conventional		0			0.382	0.359
Urea	4		0.324	0.377		
		15	0.319	0.369	0.378	0.364
		30	0.317	0.368	0.381	0.374
		45	0.318	0.366	0.378	0.378

Table B.3 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during fall 2005.

Site and treatment			Fall 2005			
Indian Head	Rep	Time	Date			
			Oct. 21	Oct. 24	Oct. 27	Oct. 31
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.372	0.366	0.370	0.358
		15	0.368	0.373	0.375	0.355
		30	0.369	0.359	0.363	0.360
		45	0.366	0.365	0.369	0.364
Fall Banded NBPT-DCD Urea	1	0	0.366	0.328	0.362	0.364
		15	0.365	0.363	0.364	0.375
		30	0.374	0.366	0.363	0.366
		45	0.368	0.367	0.365	0.351
Fall Banded Conventional Urea	1	0	0.367	0.360	0.364	0.356
		15	0.359	0.368	0.368	0.377
		30	0.372	0.361	0.374	0.370
		45	0.368	0.356	0.372	0.371
Fall Banded Calcium Nitrate	1	0	0.365	0.362	0.363	0.366
		15	0.359	0.362	0.367	0.356
		30	0.373	0.364	0.363	0.365
		45	0.368	0.368	0.367	0.378
Spring Banded Conventional Urea	1	0	0.373	0.360	0.364	0.372
		15	0.361	0.367	0.368	0.372
		30	0.363	0.367	0.351	0.372
		45	0.367	0.371	0.356	0.354
Control	2	0	0.368	0.363	0.366	0.363
		15	0.364	0.365	0.365	0.358
		30	0.370	0.360	0.363	
		45	0.371	0.359	0.363	0.360
Fall Banded NBPT-DCD Urea	2	0	0.361	0.363	0.368	0.363
		15	0.366	0.368	0.361	0.359
		30	0.368	0.369	0.370	0.359
		45	0.371	0.359	0.364	0.354
Fall Banded Conventional Urea	2	0	0.372	0.368	0.362	0.365
		15	0.374	0.367	0.362	0.361
		30	0.366	0.358	0.355	0.357
		45	0.370	0.366	0.362	0.371
Fall Banded Calcium Nitrate	2	0	0.363	0.371	0.368	0.359
		15	0.371	0.374	0.358	0.362
		30	0.376	0.361	0.368	0.358
		45	0.367	0.366	0.364	0.373
Spring Banded Conventional Urea	2	0	0.367	0.369	0.370	0.365
		15	0.361	0.368	0.365	0.354
		30	0.372	0.371	0.364	0.360
		45	0.371	0.365	0.359	0.363

Table B.3 (cont'd). Concentrations of nitrous oxide emitted at Indian Head during fall 2005.

Site and treatment			Fall 2005			
Indian Head	Rep	Time	Date			
			Oct. 21	Oct. 24	Oct. 27	Oct. 31
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.377	0.366	0.355	0.355
		15	0.368	0.352	0.368	0.347
		30	0.361	0.362	0.359	0.355
		45	0.359	0.356	0.361	0.354
Fall Banded NBPT-DCD Urea	3	0	0.370	0.358	0.359	0.360
		15	0.364	0.361	0.357	0.349
		30	0.370	0.358	0.358	0.349
		45	0.359	0.367	0.368	0.367
Fall Banded Conventional Urea	3	0	0.376	0.362	0.357	0.349
		15	0.360	0.357	0.360	0.364
		30	0.366	0.364	0.357	0.379
		45	0.364	0.360	0.370	0.351
Fall Banded Calcium Nitrate	3	0	0.367	0.360	0.367	0.354
		15	0.374	0.352	0.365	0.350
		30	0.365	0.369	0.367	0.367
		45	0.364	0.364	0.360	0.354
Spring Banded Conventional Urea	3	0	0.362	0.356	0.360	0.358
		15	0.381	0.363	0.364	0.360
		30	0.361	0.357	0.359	0.377
		45	0.381	0.363	0.376	0.379
Control	4	0	0.365	0.356	0.359	0.351
		15	0.365	0.367	0.360	0.359
		30	0.362	0.361	0.367	0.358
		45	0.365	0.364	0.357	0.353
Fall Banded NBPT-DCD Urea	4	0	0.369	0.359	0.369	0.353
		15	0.371	0.371	0.371	0.364
		30	0.360	0.375	0.364	0.360
		45	0.370	0.362	0.364	0.355
Fall Banded Conventional Urea	4	0	0.366	0.371	0.351	0.345
		15	0.359	0.358	0.359	0.370
		30	0.369	0.358	0.357	0.358
		45	0.363	0.367	0.360	0.357
Fall Banded Calcium Nitrate	4	0	0.370	0.358	0.352	0.372
		15	0.364	0.367	0.367	0.353
		30	0.364	0.364	0.359	0.327
		45	0.368	0.360	0.371	0.358
Spring Banded Conventional Urea	4	0	0.384	0.362	0.353	0.355
		15	0.362	0.369	0.360	0.353
		30	0.362	0.360	0.369	0.367
		45	0.358	0.360		0.362

Table B.3 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during fall 2005.

Site and treatment			Fall 2005	
Indian Head	Rep	Time	Date	
			Nov. 4	Nov. 22
			$\mu L\ N_2O\ L^{-1}$	
Control	1	0	0.354	0.370
		15	0.361	0.363
		30	0.366	0.349
		45	0.368	0.381
Fall Banded NBPT-DCD Urea	1	0	0.359	0.351
		15	0.375	0.375
		30	0.368	0.370
		45	0.367	0.366
Fall Banded Conventional Urea	1	0	0.373	0.365
		15	0.364	0.374
		30	0.323	0.365
		45	0.310	0.374
Fall Banded Calcium Nitrate	1	0	0.361	0.369
		15	0.359	0.373
		30	0.372	0.373
		45	0.323	0.367
Spring Banded Conventional Urea	1	0	0.351	0.377
		15	0.363	0.368
		30	0.365	0.373
		45	0.366	0.367
Control	2	0	0.349	0.364
		15	0.365	0.380
		30	0.367	0.382
		45	0.352	0.366
Fall Banded NBPT-DCD Urea	2	0	0.358	0.348
		15	0.381	0.372
		30	0.362	0.378
		45	0.362	0.374
Fall Banded Conventional Urea	2	0	0.368	0.379
		15	0.363	0.374
		30	0.369	0.377
		45	0.336	0.366
Fall Banded Calcium Nitrate	2	0	0.358	0.369
		15	0.360	0.371
		30	0.361	0.378
		45	0.371	0.373
Spring Banded Conventional Urea	2	0	0.356	0.365
		15	0.359	0.377
		30	0.365	0.369
		45	0.325	0.387

Table B.3 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during fall 2005.

Site and treatment			Fall 2005	
Indian Head	Rep	Time	Date	
			Nov. 4	Nov. 22
			$\mu L\ N_2O\ L^{-1}$	
Control	3	0	0.360	0.373
		15	0.359	0.369
		30	0.365	0.366
		45	0.352	0.360
Fall Banded NBPT-DCD Urea	3	0	0.360	0.369
		15	0.363	0.370
		30	0.351	0.368
		45	0.362	0.364
Fall Banded Conventional Urea	3	0	0.356	0.371
		15	0.363	0.369
		30	0.344	0.367
		45	0.364	0.369
Fall Banded Calcium Nitrate	3	0	0.364	0.372
		15	0.362	0.371
		30	0.365	0.363
		45	0.362	0.365
Spring Banded Conventional Urea	3	0	0.356	0.377
		15	0.355	0.370
		30	0.349	0.372
		45	0.374	0.365
Control	4	0	0.365	0.365
		15	0.357	0.365
		30	0.349	0.371
		45	0.370	0.365
Fall Banded NBPT-DCD Urea	4	0	0.352	0.365
		15	0.357	0.368
		30	0.376	0.365
		45	0.357	0.366
Fall Banded Conventional Urea	4	0	0.357	0.375
		15	0.363	0.366
		30	0.357	0.365
		45	0.355	0.358
Fall Banded Calcium Nitrate	4	0	0.368	0.370
		15	0.357	0.375
		30	0.377	0.365
		45	0.354	0.371
Spring Banded Conventional Urea	4	0	0.361	0.364
		15	0.363	0.366
		30	0.356	0.362
		45	0.365	0.360

Table B.4. Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			April 6	April 10	April 12	April 18
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.384	0.385	0.385	0.381
		15	0.392	0.398	0.378	0.384
		30	0.391	0.396	0.384	0.374
		45	0.392	0.397	0.380	0.374
Fall Banded NBPT-DCD Urea	1	0	0.390	0.398	0.382	0.377
		15	0.446	0.478	0.378	0.418
		30	0.418	0.481	0.386	0.443
		45	0.424	0.471	0.401	0.440
Fall Banded Conventional Urea	1	0	0.386	0.396	0.383	0.370
		15	0.386	0.438	0.387	0.409
		30	0.387	0.439	0.398	0.407
		45	0.386	0.424	0.377	0.400
Fall Banded Calcium Nitrate	1	0	0.382	0.392	0.390	0.368
		15	0.383	0.399	0.382	0.377
		30	0.380	0.391	0.385	0.363
		45	0.387	0.410	0.386	0.376
Spring Banded Conventional		0	0.382			
Urea	1			0.393	0.381	0.369
		15	0.417	0.413	0.379	0.374
		30	0.419	0.428	0.385	0.376
		45	0.418	0.419	0.377	0.381
Control	2	0	0.383	0.399	0.383	0.378
		15	0.377	0.395	0.377	0.385
		30	0.387	0.399	0.381	0.388
		45	0.376	0.391	0.377	0.393
Fall Banded NBPT-DCD Urea	2	0	0.389	0.393	0.386	0.372
		15	0.384	0.399	0.382	0.375
		30	0.397	0.405	0.377	0.374
		45	0.391	0.393	0.369	0.372
Fall Banded Conventional Urea	2	0	0.398	0.396	0.386	0.383
		15	0.383	0.406	0.374	0.380
		30	0.399	0.404	0.381	0.376
		45	0.387	0.401	0.414	0.380
Fall Banded Calcium Nitrate	2	0	0.387	0.397	0.381	0.374
		15	0.381	0.408	0.383	0.367
		30	0.390	0.435	0.388	0.375
		45	0.385	0.438	0.393	0.373
Spring Banded Conventional		0	0.382			
Urea	2			0.391	0.389	0.373
		15	0.398	0.428	0.376	0.456
		30	0.394	0.422	0.380	0.482
		45	0.396	0.409	0.371	0.501

Table B.4 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			April 6	April 10	April 12	April 18
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.382	0.399	0.377	0.373
		15	0.388	0.434	0.378	0.377
		30	0.388	0.392	0.378	0.388
		45	0.395	0.623	0.371	0.383
Fall Banded NBPT-DCD Urea	3	0	0.388	0.399	0.375	0.374
		15	0.393	0.537	0.393	0.424
		30	0.391	0.598	0.373	0.432
		45	0.390	0.584	0.371	0.434
Fall Banded Conventional Urea	3	0	0.386	0.400	0.386	0.368
		15	0.391	0.399	0.373	0.427
		30	0.393	0.402	0.371	0.457
		45	0.403	0.397	0.378	0.475
Fall Banded Calcium Nitrate	3	0	0.391	0.399	0.384	0.378
		15	0.385	0.399	0.382	0.382
		30	0.391	0.390	0.377	0.396
		45	0.386	0.390	0.372	0.383
Spring Banded Conventional Urea	3	0	0.385	0.403	0.387	0.369
		15	0.394	0.586	0.386	0.375
		30	0.399	0.439	0.371	0.384
		45	0.399	0.442	0.379	0.380
Control	4	0	0.395	0.402	0.381	0.379
		15	0.390	0.413	0.378	0.407
		30	0.392	0.394	0.383	0.434
		45	0.389	0.395	0.375	0.400
Fall Banded NBPT-DCD Urea	4	0	0.387	0.402	0.375	0.370
		15	0.387	0.423	0.376	0.417
		30	0.391	0.424	0.372	0.417
		45	0.380	0.412	0.369	0.427
Fall Banded Conventional Urea	4	0	0.392	0.400	0.385	0.381
		15	0.396	0.624	0.381	0.421
		30	0.449	0.736	0.372	0.437
		45	0.464	0.770	0.372	0.469
Fall Banded Calcium Nitrate	4	0	0.389	0.403	0.376	0.376
		15	0.447	0.419	0.384	0.387
		30	0.390	0.419	0.383	0.386
		45	0.399	0.412	0.373	0.382
Spring Banded Conventional Urea	4	0	0.386	0.402	0.383	0.376
		15	0.393	0.486	0.384	0.396
		30	0.394	0.498	0.370	0.417
		45	0.393	0.505	0.378	0.425

Table B.4 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			April 25	May 3	May 8	May 10
			µL N_2O L^{-1}			
Control	1	0	0.374	0.377	0.337	0.334
		15	0.402	0.385	0.354	0.333
		30	0.408	0.388	0.347	0.344
		45	0.434	0.382	0.346	0.352
Fall Banded NBPT-DCD Urea	1	0	0.366	0.385	0.339	0.337
		15	0.391	0.403	0.377	0.342
		30	0.390	0.401	0.390	0.346
		45	0.388	0.399	0.377	0.364
Fall Banded Conventional Urea	1	0	0.371	0.387	0.339	0.348
		15	0.401	0.381	0.341	0.334
		30	0.426	0.386	0.351	0.341
		45	0.428	0.380	0.366	0.338
Fall Banded Calcium Nitrate	1	0	0.367	0.385	0.343	0.343
		15	0.372	0.381	0.356	0.340
		30	0.382	0.384	0.346	0.346
		45	0.369	0.388	0.348	0.342
Spring Banded Conventional Urea	1	0	0.373	0.385	0.343	0.346
		15	0.379	0.386	0.358	0.346
		30	0.378	0.388	0.369	0.361
		45	0.375	0.391	0.354	0.335
Control	2	0	0.372	0.388	0.343	0.338
		15	0.378	0.379	0.334	0.326
		30	0.374	0.391	0.340	0.338
		45	0.375	0.384	0.324	0.336
Fall Banded NBPT-DCD Urea	2	0	0.373	0.388	0.340	0.345
		15	0.369	0.388	0.342	0.340
		30	0.379	0.386	0.342	0.351
		45	0.371	0.381	0.336	0.349
Fall Banded Conventional Urea	2	0	0.377	0.390	0.355	0.345
		15	0.381	0.374	0.345	0.341
		30	0.389	0.389	0.354	0.346
		45	0.376	0.373	0.343	0.335
Fall Banded Calcium Nitrate	2	0	0.375	0.398	0.340	0.343
		15	0.384	0.373	0.333	0.329
		30	0.393	0.394	0.345	0.356
		45	0.385	0.382	0.327	0.342
Spring Banded Conventional Urea	2	0	0.371	0.383	0.338	0.346
		15	0.388	0.378	0.351	0.338
		30	0.383	0.389	0.362	0.343
		45	0.391	0.370	0.354	0.353

Table B.4 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			April 25	May 3	May 8	May 10
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.382	0.392	0.344	0.345
		15	0.380	0.383	0.338	0.343
		30	0.383	0.386	0.341	0.345
		45	0.379	0.392	0.338	0.336
Fall Banded NBPT-DCD Urea	3	0	0.385	0.373	0.337	0.342
		15	0.390	0.380	0.341	0.345
		30	0.403	0.390	0.359	0.344
		45	0.400	0.395	0.360	0.341
Fall Banded Conventional Urea	3	0	0.377	0.381	0.342	0.335
		15	0.369	0.384	0.346	0.346
		30	0.375	0.386	0.340	0.341
		45	0.378	0.383	0.334	0.340
Fall Banded Calcium Nitrate	3	0	0.383	0.385	0.339	0.352
		15	0.384	0.387	0.338	0.343
		30	0.375	0.388	0.331	0.347
		45	0.375	0.388	0.330	0.339
Spring Banded Conventional Urea	3	0	0.377	0.387	0.330	0.346
		15	0.380	0.378	0.344	0.342
		30	0.374	0.390	0.353	0.339
		45	0.374	0.391	0.352	0.343
Control	4	0	0.386	0.385	0.333	0.325
		15	0.407	0.379	0.343	0.344
		30	0.383	0.389	0.349	0.336
		45	0.410	0.383	0.331	0.345
Fall Banded NBPT-DCD Urea	4	0	0.378	0.383	0.339	0.348
		15	0.375	0.381	0.342	0.340
		30	0.377	0.395	0.358	0.350
		45	0.383	0.384	0.336	0.332
Fall Banded Conventional Urea	4	0	0.391	0.387	0.341	0.351
		15	0.374	0.380	0.346	0.351
		30	0.379	0.393	0.353	0.354
		45	0.371	0.380	0.345	0.347
Fall Banded Calcium Nitrate	4	0	0.389	0.390	0.341	0.347
		15	0.376	0.385	0.333	0.348
		30	0.377	0.384	0.321	0.340
		45	0.384	0.385	0.330	0.346
Spring Banded Conventional Urea	4	0	0.386	0.384	0.340	0.343
		15	0.368	0.383	0.333	0.339
		30	0.381	0.390	0.344	0.350
		45	0.380	0.381	0.331	0.346

Table B.4 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			May 17	May 19	May 22	May 24
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.365	0.354	0.363	0.369
		15	0.367	0.351	0.358	0.379
		30	0.370	0.352	0.365	0.391
		45	0.360	0.352	0.369	0.383
Fall Banded NBPT-DCD Urea	1	0	0.352	0.349	0.363	0.367
		15	0.355	0.366	0.381	0.385
		30	0.362	0.362	0.384	0.393
		45	0.363	0.368	0.366	0.395
Fall Banded Conventional Urea	1	0	0.387	0.345	0.376	0.371
		15	0.360	0.361	0.362	0.387
		30	0.349	0.351	0.373	0.393
		45	0.359	0.356	0.365	0.400
Fall Banded Calcium Nitrate	1	0	0.360	0.346	0.346	0.361
		15	0.364	0.359	0.362	0.366
		30	0.377	0.361	0.359	0.378
		45	0.361	0.355	0.344	0.390
Spring Banded Conventional Urea	1	0	0.382	0.354	0.365	0.368
		15	0.365	0.396	0.373	0.456
		30	0.377	0.367	0.388	0.473
		45	0.356	0.393	0.386	0.452
Control	2	0		0.352	0.359	0.370
		15		0.348	0.358	0.379
		30		0.350	0.362	0.384
		45		0.354	0.358	0.377
Fall Banded NBPT-DCD Urea	2	0	0.358	0.351	0.359	0.370
		15	0.361	0.348	0.368	0.380
		30	0.370	0.360	0.359	0.372
		45	0.359	0.354	0.367	0.374
Fall Banded Conventional Urea	2	0	0.365	0.338	0.368	0.376
		15	0.354	0.375	0.359	0.388
		30	0.361	0.379	0.367	0.404
		45	0.353	0.362	0.358	0.412
Fall Banded Calcium Nitrate	2	0	0.357	0.357	0.356	0.368
		15	0.353	0.358	0.362	0.404
		30	0.353	0.377	0.369	0.403
		45	0.350	0.348	0.358	0.401
Spring Banded Conventional Urea	2	0	0.359	0.352	0.362	0.375
		15	0.364	0.386	0.372	0.500
		30	0.366	0.388	0.372	0.648
		45	0.361	0.380	0.361	0.696

Table B.4 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			May 17	May 19	May 22	May 24
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.358	0.358	0.358	0.365
		15	0.365	0.362	0.353	0.382
		30	0.360	0.382	0.376	0.413
		45	0.346	0.703	0.377	0.428
Fall Banded NBPT-DCD Urea	3	0	0.363	0.346	0.361	0.371
		15	0.363	0.349	0.370	0.371
		30	0.354	0.376	0.399	0.378
		45	0.354	16.070	0.388	0.381
Fall Banded Conventional Urea	3	0	0.362	0.353	0.359	0.369
		15	0.360	0.362	0.361	0.371
		30	0.360	4.400	0.377	0.392
		45	0.354	0.538	0.381	0.382
Fall Banded Calcium Nitrate	3	0	0.354	0.353	0.367	0.375
		15	0.356	0.359	0.349	0.367
		30	0.361	0.363	0.386	0.393
		45	0.357	0.359	0.380	0.402
Spring Banded Conventional Urea	3	0	0.362	0.342	0.365	0.361
		15	0.354	0.356	0.358	0.384
		30	0.361	0.377	0.373	0.437
		45	0.349	0.351	0.379	0.419
Control	4	0	0.364	0.354	0.365	0.372
		15	0.357	0.355	0.354	0.371
		30	0.358	0.395	0.387	0.381
		45	0.358	0.340	0.373	0.382
Fall Banded NBPT-DCD Urea	4	0	0.359	0.351	0.360	0.375
		15	0.366	0.362	0.377	0.466
		30	0.368	0.383	0.395	0.495
		45	0.356	0.362	0.398	0.501
Fall Banded Conventional Urea	4	0	0.363	0.347	0.370	0.371
		15	0.350	0.352	0.359	0.397
		30	0.361	0.363	0.385	0.402
		45	0.352	0.347	0.384	0.403
Fall Banded Calcium Nitrate	4	0	0.363	0.349	0.358	0.370
		15	0.351	0.350	0.357	0.395
		30	0.363	0.377	0.386	0.423
		45	0.358	0.365	0.386	0.417
Spring Banded Conventional Urea	4	0	0.371	0.370	0.356	0.370
		15	0.369	0.394	0.373	0.617
		30	0.347	0.404	0.409	0.902
		45	0.356	0.403	0.405	1.077

Table B.4 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			May 26	May 29	May 31	June 2
			µL N_2O L^{-1}			
Control	1	0	0.342	0.376	0.336	0.359
		15	0.351	0.383	0.357	0.375
		30	0.340	0.377	0.356	0.403
		45	0.345	0.378	0.355	0.406
Fall Banded NBPT-DCD Urea	1	0	0.349	0.365	0.350	0.360
		15	0.354	0.368	0.355	0.377
		30	0.365	0.369	0.349	0.382
		45	0.356	0.378	0.343	0.379
Fall Banded Conventional Urea	1	0	0.337	0.365	0.345	0.354
		15	0.367	0.390	0.349	0.375
		30	0.368	0.383	0.348	0.373
		45	0.358	0.397	0.345	0.388
Fall Banded Calcium Nitrate	1	0	0.339	0.370	0.351	0.358
		15	0.344	0.378	0.351	0.402
		30	0.356	0.368	0.345	0.393
		45	0.354	0.373	0.353	0.408
Spring Banded Conventional Urea	1	0	0.352	0.358	0.343	0.359
		15	0.431	0.440	0.364	0.442
		30	0.462	0.440	0.371	0.462
		45	0.471	0.397	0.356	0.487
Control	2	0	0.344	0.370	0.347	0.363
		15	0.353	0.372	0.350	0.374
		30	0.355	0.364	0.342	0.381
		45	0.348	0.367	0.348	0.390
Fall Banded NBPT-DCD Urea	2	0	0.341	0.365	0.339	0.353
		15	0.357	0.361	0.341	0.379
		30	0.346	0.379	0.348	0.373
		45	0.344	0.375	0.345	0.380
Fall Banded Conventional Urea	2	0	0.345	0.365	0.346	0.361
		15	0.342	0.372	0.348	0.373
		30	0.362	0.383	0.349	0.379
		45	0.342	0.391	0.356	0.409
Fall Banded Calcium Nitrate	2	0	0.341	0.370	0.350	0.359
		15	0.361	0.391	0.356	0.404
		30	0.379	0.391	0.354	0.416
		45	0.373	0.376	0.350	0.434
Spring Banded Conventional Urea	2	0	0.341	0.364	0.340	0.370
		15	0.422	0.368	0.351	0.384
		30	0.451	0.379	0.355	0.390
		45	0.429	0.388	0.356	0.442

Table B.4 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006			
Oak Bluff	Rep	Time	Date			
			May 26	May 29	May 31	June 2
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.363	0.343	0.344	0.363
		15	0.370	0.353	0.356	0.413
		30	0.384	0.344	0.353	0.433
		45	0.398	0.345	0.362	0.434
Fall Banded NBPT-DCD Urea	3	0	0.355	0.347	0.348	0.367
		15	0.368	0.360	0.362	0.391
		30	0.367	0.361	0.367	0.381
		45	0.359	0.356	0.371	0.391
Fall Banded Conventional Urea	3	0	0.345	0.353	0.354	0.365
		15	0.359	0.356	0.367	0.404
		30	0.365	0.358	0.359	0.414
		45	0.373	0.352	0.367	0.431
Fall Banded Calcium Nitrate	3	0	0.345	0.345	0.351	0.353
		15	0.386	0.358	0.346	0.372
		30	0.380	0.350	0.354	0.376
		45	0.384	0.348	0.354	0.395
Spring Banded Conventional Urea	3	0	0.353	0.353	0.345	0.371
		15	0.385	0.358	0.353	0.386
		30	0.371	0.363	0.343	0.380
		45	0.365	0.347	0.351	0.395
Control	4	0	0.354	0.353	0.348	0.371
		15	0.353	0.355	0.347	0.369
		30	0.362	0.362	0.348	0.378
		45	0.367	0.361	0.351	0.393
Fall Banded NBPT-DCD Urea	4	0	0.354	0.341	0.362	0.367
		15	0.386	0.367	0.353	0.383
		30	0.374	0.367	0.363	0.386
		45	0.385	0.380	0.350	0.389
Fall Banded Conventional Urea	4	0	0.354	0.353	0.351	0.364
		15	0.372	0.367	0.354	0.369
		30	0.375	0.368	0.360	0.378
		45	0.377	0.374	0.358	0.388
Fall Banded Calcium Nitrate	4	0	0.350	0.357	0.343	0.359
		15	0.377	0.354	0.362	0.411
		30	0.376	0.349	0.355	0.446
		45	0.381	0.351	0.352	0.455
Spring Banded Conventional Urea	4	0	0.363	0.354	0.345	0.366
		15	0.444	0.411	0.360	0.485
		30	0.467	0.393	0.360	0.482
		45	0.446	0.410	0.366	0.549

Table B.4 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006	
Oak Bluff	Rep	Time	Date	
			June 7	June 12
			$\mu L\ N_2O\ L^{-1}$	
Control	1	0	0.343	0.379
		15	0.346	0.379
		30	0.341	0.378
		45	0.345	0.366
Fall Banded NBPT-DCD Urea	1	0	0.343	0.367
		15	0.340	0.364
		30	0.359	0.381
		45	0.348	0.372
Fall Banded Conventional Urea	1	0	0.351	0.365
		15	0.341	0.371
		30	0.355	0.389
		45	0.346	0.383
Fall Banded Calcium Nitrate	1	0	0.342	0.367
		15	0.351	0.384
		30	0.345	0.385
		45	0.356	0.381
Spring Banded Conventional Urea	1	0	0.344	0.370
		15	0.362	0.382
		30	0.370	0.379
		45	0.361	0.386
Control	2	0	0.348	0.368
		15	0.344	0.376
		30	0.344	0.379
		45	0.350	0.384
Fall Banded NBPT-DCD Urea	2	0	0.357	0.367
		15	0.337	0.363
		30	0.352	0.376
		45	0.350	0.368
Fall Banded Conventional Urea	2	0	0.349	0.365
		15	0.343	0.370
		30	0.348	0.388
		45	0.346	0.369
Fall Banded Calcium Nitrate	2	0	0.347	0.380
		15	0.347	0.376
		30	0.343	0.382
		45	0.345	0.380
Spring Banded Conventional Urea	2	0	0.346	0.375
		15	0.352	0.364
		30	0.345	0.388
		45	0.348	0.368

Table B.4 (cont'd). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2006.

Site and treatment			Spring 2006	
Oak Bluff	Rep	Time	Date	
			June 7	June 12
			$\mu L\ N_2O\ L^{-1}$	
Control	3	0	0.353	0.370
		15	0.351	0.379
		30	0.370	0.410
		45	0.360	0.400
Fall Banded NBPT-DCD Urea	3	0	0.350	0.369
		15	0.349	0.368
		30	0.352	0.382
		45	0.335	0.385
Fall Banded Conventional Urea	3	0	0.340	0.369
		15	0.356	0.369
		30	0.347	0.376
		45	0.350	0.369
Fall Banded Calcium Nitrate	3	0	0.353	0.362
		15	0.349	0.362
		30	0.353	0.367
		45	0.345	0.363
Spring Banded Conventional Urea	3	0	0.351	0.363
		15	0.349	0.371
		30	0.350	0.394
		45	0.351	0.401
Control	4	0	0.363	0.368
		15	0.342	0.366
		30	0.351	0.368
		45	0.345	0.366
Fall Banded NBPT-DCD Urea	4	0	0.359	0.364
		15	0.367	0.382
		30	0.360	0.367
		45	0.370	0.376
Fall Banded Conventional Urea	4	0	0.347	0.360
		15	0.347	0.366
		30	0.353	0.383
		45	0.360	0.374
Fall Banded Calcium Nitrate	4	0	0.351	0.366
		15	0.352	0.373
		30	0.361	0.393
		45	0.353	0.385
Spring Banded Conventional Urea	4	0	0.351	0.363
		15	0.354	0.379
		30	0.361	0.383
		45	0.348	0.371

Table B.5. Concentrations of nitrous oxide emitted at Brandon during spring 2006.

Site and treatment			Spring 2006			
Brandon	Rep	Time	Date			
			April 5	April 12	April 18	April 24
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.346	0.358	0.349	0.341
		15	0.361	0.341	0.353	0.352
		30	0.353	0.346	0.348	0.344
		45	0.348	0.343	0.345	0.358
Fall Banded NBPT-DCD Urea	1	0	0.342	0.345	0.353	0.340
		15	0.389	0.371	0.348	0.342
		30	0.382	0.363	0.352	0.353
		45	0.372	0.359	0.347	0.346
Fall Banded Conventional Urea	1	0	0.357	0.355	0.345	0.341
		15	0.430	0.378	0.359	0.355
		30	0.425	0.376	0.362	0.357
		45	0.419	0.383	0.353	0.353
Fall Banded Calcium Nitrate	1	0	0.356	0.352	0.351	0.347
		15	0.462	0.435	0.358	0.355
		30	0.502	0.470	0.368	0.366
		45	0.525	0.457	0.349	0.366
Spring Banded Conventional Urea	1	0	0.350	0.348	0.350	0.347
		15	0.347	0.353	0.348	0.338
		30	0.345	0.351	0.347	0.352
		45	0.356	0.343	0.348	0.356
Control	2	0	0.353	0.357	0.352	0.341
		15	0.360	0.352	0.348	0.344
		30	0.368	0.355	0.351	0.338
		45	0.366	0.343	0.338	0.347
Fall Banded NBPT-DCD Urea	2	0	0.351	0.354	0.353	0.345
		15	0.506	0.403	0.351	0.347
		30	0.458	0.420	0.354	0.340
		45	0.442	0.419	0.344	0.366
Fall Banded Conventional Urea	2	0	0.381	0.350	0.352	0.342
		15	0.782	0.367	0.352	0.355
		30	0.764	0.372	0.352	0.338
		45	0.775	0.365	0.349	0.357
Fall Banded Calcium Nitrate	2	0	0.369	0.344	0.362	0.340
		15	0.442	0.345	0.352	0.352
		30	0.409	0.365	0.347	0.334
		45	0.406	0.347	0.348	0.343
Spring Banded Conventional Urea	2	0	0.351	0.349	0.351	0.338
		15	0.354	0.339	0.337	0.344
		30	0.353	0.352	0.349	0.349
		45	0.343	0.344	0.346	0.344

Table B.5 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2006.

Site and treatment			Spring 2006			
Brandon	Rep	Time	Date			
			April 5	April 12	April 18	April 24
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.348	0.344	0.348	0.337
		15	0.349	0.349	0.348	0.350
		30	0.349	0.350	0.340	0.335
		45	0.354	0.345	0.344	0.341
Fall Banded NBPT-DCD Urea	3	0	0.341	0.365	0.344	0.347
		15	0.529	0.494	0.349	0.354
		30	0.595	0.438	0.349	0.348
		45	0.639	0.505	0.354	0.346
Fall Banded Conventional Urea	3	0	0.360	0.357	0.340	0.348
		15	0.460	0.371	0.351	0.356
		30	0.415	0.379	0.349	0.350
		45	0.400	0.386	0.338	0.355
Fall Banded Calcium Nitrate	3	0	0.342	0.347	0.352	0.343
		15	0.368	0.347	0.367	0.350
		30	0.389	0.362	0.365	0.351
		45	0.378	0.354	0.350	0.346
Spring Banded Conventional Urea	3	0	0.347	0.345	0.343	0.341
		15	0.349	0.345	0.340	0.351
		30	0.346	0.358	0.350	0.346
		45	0.354	0.341	0.346	0.338
Control	4	0	0.349	0.348	0.348	0.347
		15	0.350	0.344	0.333	0.352
		30	0.356	0.355	0.350	0.343
		45	0.350	0.346	0.340	0.344
Fall Banded NBPT-DCD Urea	4	0	0.344	0.356	0.364	0.346
		15	0.448	0.555	0.364	0.367
		30	0.523	0.577	0.349	0.362
		45	0.527	0.563	0.367	0.357
Fall Banded Conventional Urea	4	0	0.369	0.362	0.351	0.340
		15	0.606	0.436	0.363	0.366
		30	0.567	0.473	0.357	0.346
		45	0.505	0.429	0.347	0.362
Fall Banded Calcium Nitrate	4	0	0.356	0.343	0.357	0.346
		15	0.572	0.368	0.358	0.346
		30	0.573	0.372	0.376	0.358
		45	0.491	0.359	0.358	0.352
Spring Banded Conventional Urea	4	0	0.353	0.351	0.339	0.340
		15	0.358	0.335	0.343	0.342
		30	0.371	0.352	0.354	0.340
		45	0.371	0.345	0.350	0.341

Table B.5 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2006.

Site and treatment			Spring 2006			
Brandon	Rep	Time	Date			
			May 2	May 8	May 15	May 17
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.342	0.351	0.348	0.345
		15	0.346	0.358	0.346	0.343
		30	0.350	0.351	0.348	0.357
		45	0.344	0.363	0.350	0.344
Fall Banded NBPT-DCD Urea	1	0	0.346	0.362	0.357	0.346
		15	0.345	0.363	0.355	0.356
		30	0.342	0.361	0.352	0.359
		45	0.349	0.368	0.346	0.341
Fall Banded Conventional Urea	1	0	0.357	0.355	0.346	0.352
		15	0.351	0.359	0.355	0.361
		30	0.357	0.357	0.341	0.362
		45	0.352	0.380	0.349	0.351
Fall Banded Calcium Nitrate	1	0	0.342	0.347	0.357	0.349
		15	0.351	0.362	0.349	0.441
		30	0.340	0.345	0.351	0.478
		45	0.350	0.362	0.349	0.429
Spring Banded Conventional Urea	1	0	0.345	0.349	0.349	0.346
		15	0.356	0.359	0.356	0.350
		30	0.350	0.350	0.342	0.362
		45	0.356	0.355	0.354	0.344
Control	2	0	0.346	0.352	0.348	0.352
		15	0.348	0.357	0.359	0.349
		30	0.349	0.349	0.346	0.354
		45	0.352	0.365	0.357	0.340
Fall Banded NBPT-DCD Urea	2	0	0.347	0.340	0.349	0.350
		15	0.353	0.359	0.353	0.361
		30	0.349	0.361	0.357	0.355
		45	0.354	0.366	0.361	0.362
Fall Banded Conventional Urea	2	0	0.346	0.351	0.345	0.347
		15	0.360	0.359	0.355	0.349
		30	0.349	0.351	0.346	0.356
		45	0.355	0.361	0.354	0.352
Fall Banded Calcium Nitrate	2	0	0.352	0.351	0.349	0.336
		15	0.354	0.358	0.350	0.353
		30	0.348	0.349	0.347	0.353
		45	0.355	0.364	0.342	0.349
Spring Banded Conventional Urea	2	0	0.346	0.348	0.356	0.344
		15	0.350	0.357	0.350	0.357
		30	0.349	0.355	0.335	0.356
		45	0.350	0.363	0.348	0.353

Table B.5 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2006.

Site and treatment			Spring 2006			
Brandon	Rep	Time	Date			
			May 2	May 8	May 15	May 17
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.351	0.352	0.336	0.340
		15	0.353	0.351	0.349	0.354
		30	0.346	0.354	0.349	0.348
		45	0.351	0.348	0.345	0.354
Fall Banded NBPT-DCD Urea	3	0	0.349	0.356	0.342	0.344
		15	0.357	0.367	0.350	0.334
		30	0.352	0.357	0.347	0.353
		45	0.349	0.354	0.360	0.347
Fall Banded Conventional Urea	3	0	0.347	0.354	0.351	0.345
		15	0.352	0.373	0.348	0.370
		30	0.340	0.375	0.341	0.390
		45	0.350		0.338	0.378
Fall Banded Calcium Nitrate	3	0	0.349	0.340	0.335	0.342
		15	0.354	0.355	0.353	0.348
		30	0.349	0.348	0.341	0.357
		45	0.345	0.350	0.351	0.355
Spring Banded Conventional Urea	3	0	0.344	0.350	0.337	0.342
		15	0.352	0.353	0.339	0.342
		30	0.344	0.361	0.345	0.352
		45	0.357	0.354	0.345	0.347
Control	4	0	0.346	0.348	0.347	0.345
		15	0.351	0.355	0.352	0.351
		30	0.338	0.360	0.338	0.346
		45	0.351	0.358	0.344	0.345
Fall Banded NBPT-DCD Urea	4	0	0.333	0.351	0.346	0.343
		15	0.350	0.369	0.350	0.351
		30	0.344	0.379	0.354	0.344
		45	0.358	0.383	0.359	0.350
Fall Banded Conventional Urea	4	0	0.341	0.343	0.350	0.342
		15	0.353	0.370	0.351	0.342
		30	0.348	0.367	0.346	0.353
		45	0.357	0.376	0.375	0.362
Fall Banded Calcium Nitrate	4	0	0.339	0.351	0.347	0.336
		15	0.346	0.361	0.347	0.353
		30	0.343	0.362	0.349	0.349
		45	0.342	0.366	0.356	0.357
Spring Banded Conventional Urea	4	0	0.348	0.346	0.343	0.345
		15	0.355	0.355	0.352	0.345
		30	0.340	0.363	0.341	0.350
		45	0.357	0.358	0.348	0.339

Table B.5 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2006.

Site and treatment			Spring 2006	
Brandon	Rep	Time	Date	
			May 19	May 22
			$\mu L\ N_2O\ L^{-1}$	
Control	1	0	0.350	0.363
		15	0.353	0.363
		30	0.349	0.366
		45	0.353	0.368
Fall Banded NBPT-DCD Urea	1	0	0.356	0.359
		15	0.360	0.357
		30	0.362	0.357
		45	0.367	0.357
Fall Banded Conventional Urea	1	0	0.347	0.367
		15	0.373	0.355
		30	0.368	0.363
		45	0.366	0.360
Fall Banded Calcium Nitrate	1	0	0.348	0.349
		15	0.388	0.356
		30	0.409	0.359
		45	0.406	0.361
Spring Banded Conventional Urea	1	0	0.352	0.363
		15	0.384	0.386
		30	0.408	0.395
		45	0.403	0.374
Control	2	0	0.352	0.350
		15	0.347	0.353
		30	0.349	0.358
		45	0.337	0.360
Fall Banded NBPT-DCD Urea	2	0	0.355	0.348
		15	0.348	0.352
		30	0.348	0.354
		45	0.351	0.361
Fall Banded Conventional Urea	2	0	0.355	0.358
		15	0.359	0.358
		30	0.364	0.359
		45	0.354	0.351
Fall Banded Calcium Nitrate	2	0	0.356	0.369
		15	0.362	0.356
		30	0.345	0.358
		45	0.357	0.364
Spring Banded Conventional Urea	2	0	0.356	0.355
		15	0.368	0.366
		30	0.379	0.369
		45	0.374	0.361

Table B.5 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2006.

Site and treatment			Spring 2006	
Brandon	Rep	Time	Date	
			May 19	May 22
			$\mu L\ N_2O\ L^{-1}$	
Control	3	0	0.343	
		15	0.355	0.348
		30	0.352	0.360
		45	0.346	0.370
Fall Banded NBPT-DCD Urea	3	0	0.350	
		15	0.355	0.358
		30	0.352	0.356
		45	0.357	0.367
Fall Banded Conventional Urea	3	0	0.345	
		15	0.347	0.359
		30	0.365	0.359
		45	0.363	0.367
Fall Banded Calcium Nitrate	3	0	0.348	
		15	0.365	0.359
		30	0.368	0.370
		45	0.342	0.369
Spring Banded Conventional Urea	3	0	0.353	
		15	0.360	0.361
		30	0.361	0.367
		45	0.363	0.365
Control	4	0	0.352	
		15	0.358	0.357
		30	0.354	0.361
		45	0.366	0.366
Fall Banded NBPT-DCD Urea	4	0	0.350	
		15	0.364	0.356
		30	0.349	0.365
		45	0.355	0.363
Fall Banded Conventional Urea	4	0	0.357	
		15	0.352	0.345
		30	0.355	0.367
		45	0.352	0.360
Fall Banded Calcium Nitrate	4	0	0.351	
		15	0.352	0.352
		30	0.352	0.363
		45	0.358	0.359
Spring Banded Conventional Urea	4	0	0.345	
		15	0.393	0.382
		30	0.396	0.382
		45	0.397	0.382

Table B.6. Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006			
Indian Head	Rep	Time	Date			
			April 5	April 10	April 12	May 5
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.374	0.342	0.344	0.364
		15	0.391	0.370	0.369	0.370
		30	0.386	0.365	0.359	0.363
		45	0.386	0.377	0.385	0.369
Fall Banded NBPT-DCD Urea	1	0	0.367	0.352	0.355	0.355
		15	0.367	0.372	0.379	0.367
		30	0.372	0.373	0.386	0.368
		45	0.364	0.373	0.372	0.374
Fall Banded Conventional Urea	1	0	0.367	0.343	0.351	0.368
		15	0.371	0.380	0.398	0.373
		30	0.361	0.390	0.414	0.377
		45	0.373	0.414	0.374	0.378
Fall Banded Calcium Nitrate	1	0	0.365	0.354	0.341	0.367
		15	0.460	0.364	0.375	0.364
		30	0.471	0.368	0.385	0.371
		45	0.509	0.373	0.370	0.369
Spring Banded Conventional		0				
Urea	1		0.366	0.345	0.342	0.374
		15	0.379	0.349	0.361	0.369
		30	0.367	0.350	0.382	0.369
		45	0.358	0.355	0.366	0.374
Control	2	0				
		15				
		30				
		45				
Fall Banded NBPT-DCD Urea	2	0	0.372	0.352	0.348	0.362
		15	0.384	0.357	0.397	0.386
		30	0.384	0.361	0.400	0.383
		45	0.403	0.359	0.358	0.378
Fall Banded Conventional Urea	2	0	0.371	0.347	0.349	0.368
		15	0.383	0.371	0.404	0.390
		30	0.372	0.372	0.384	0.404
		45	0.379	0.395	0.372	0.389
Fall Banded Calcium Nitrate	2	0	0.375	0.338	0.346	0.357
		15	0.388	0.361	0.371	0.375
		30	0.385	0.356	0.362	0.378
		45	0.384	0.373	0.359	0.385
Spring Banded Conventional		0				
Urea	2		0.376	0.343	0.341	0.364
		15	0.374	0.348	0.355	0.361
		30	0.366	0.348	0.384	0.367
		45	0.364	0.365	0.363	0.367

Table B.6 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006			
Indian Head	Rep	Time	Date			
			April 5	April 10	April 12	May 5
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.361	0.355	0.341	0.362
		15	0.369	0.354	0.359	0.379
		30	0.363	0.360	0.377	0.367
		45	0.371	0.361	0.364	0.374
Fall Banded NBPT-DCD Urea	3	0	0.368	0.351	0.349	0.363
		15	0.380	0.376	0.395	0.419
		30	0.366	0.411	0.388	0.416
		45	0.374	0.404	0.417	0.421
Fall Banded Conventional Urea	3	0	0.370	0.347	0.352	0.362
		15	0.365	0.376	0.395	0.372
		30	0.371	0.363	0.429	0.371
		45	0.379	0.373	0.412	0.376
Fall Banded Calcium Nitrate	3	0	0.365	0.347	0.346	0.372
		15	0.375	0.361	0.354	0.375
		30	0.363	0.344	0.353	0.367
		45	0.376	0.346	0.349	0.366
Spring Banded Conventional Urea	3	0	0.366	0.353	0.352	0.361
		15	0.362	0.357	0.384	0.370
		30	0.373	0.362	0.404	0.369
		45	0.379	0.365	0.401	0.365
Control	4	0	0.367	0.342	0.344	0.374
		15	0.374	0.356	0.359	0.369
		30	0.379	0.353	0.383	0.366
		45	0.371	0.369	0.345	0.366
Fall Banded NBPT-DCD Urea	4	0	0.358	0.349	0.358	0.368
		15	0.541	0.406	0.463	0.398
		30	0.641	0.451	0.514	0.396
		45	0.732	0.482	0.485	0.396
Fall Banded Conventional Urea	4	0	0.376	0.347	0.382	0.376
		15	0.365	0.466	0.347	0.381
		30	0.356	0.403	0.366	0.374
		45	0.362	0.388	0.373	0.368
Fall Banded Calcium Nitrate	4	0	0.376	0.349		0.377
		15	0.397	0.366		0.376
		30	0.416	0.371		0.366
		45	0.410	0.370		0.366
Spring Banded Conventional Urea	4	0	0.351	0.347	0.362	0.368
		15	0.384	0.364	0.355	0.380
		30	0.368	0.351	0.355	0.368
		45	0.366	0.349	0.446	0.379

Table B.6 (cont'd). Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006			
Indian Head	Rep	Time	Date			
			May 10	May 12	May 15	May 17
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.366	0.361	0.363	0.382
		15	0.370	0.379	0.512	0.373
		30	0.368	0.379	0.379	0.367
		45	0.369	0.357	0.382	0.360
Fall Banded NBPT-DCD Urea	1	0	0.366	0.367	0.380	0.368
		15	0.369	0.368	0.371	0.375
		30	0.383	0.366	0.386	0.372
		45	0.369	0.346	0.382	0.368
Fall Banded Conventional Urea	1	0	0.366	0.371	0.374	0.381
		15	0.383	0.370	0.386	0.395
		30	0.368	0.369	0.389	0.396
		45	0.378	0.350	0.374	0.380
Fall Banded Calcium Nitrate	1	0	0.365	0.367	0.370	0.375
		15	0.364	0.370	0.375	0.372
		30	0.369	0.376	0.393	0.359
		45	0.369	0.345	0.374	0.362
Spring Banded Conventional Urea	1	0	0.375	0.361	0.366	0.368
		15	0.358	0.373	0.377	0.380
		30	0.374	0.365	0.371	0.358
		45	0.366	0.337	0.369	0.365
Control	2	0				0.371
		15				0.357
		30				0.361
		45				0.351
Fall Banded NBPT-DCD Urea	2	0	0.363	0.366	0.375	0.376
		15	0.369	0.379	0.380	0.361
		30	0.366	0.361	0.389	0.374
		45	0.360	0.350	0.399	0.358
Fall Banded Conventional Urea	2	0	0.372	0.365	0.362	0.366
		15	0.383	0.403	0.396	0.494
		30	0.397	0.384	0.415	0.547
		45	0.378	0.393	0.423	0.492
Fall Banded Calcium Nitrate	2	0	0.364	0.349	0.364	0.376
		15	0.371	0.369	0.385	0.364
		30	0.373	0.338	0.386	0.380
		45	0.367	0.351	0.523	0.386
Spring Banded Conventional Urea	2	0	0.363	0.359	0.364	0.383
		15	0.367	0.365	0.378	0.351
		30	0.364	0.332	0.364	0.368
		45	0.369	0.336	0.368	0.347

Table B.6 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006			
Indian Head	Rep	Time	Date			
			May 10	May 12	May 15	May 17
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.363	0.324	0.382	0.354
		15	0.372	0.364	0.375	0.346
		30	0.369	0.369	0.379	0.367
		45	0.373	0.368	0.395	0.367
Fall Banded NBPT-DCD Urea	3	0	0.360	0.339	0.376	0.342
		15	0.376	0.394	0.405	0.379
		30	0.363	0.418	0.393	0.409
		45	0.371	0.443	0.447	0.403
Fall Banded Conventional Urea	3	0	0.359	0.360	0.381	0.353
		15	0.382	0.396	0.413	0.358
		30	0.375	0.404	0.403	0.371
		45	0.379	0.378	0.423	0.389
Fall Banded Calcium Nitrate	3	0	0.366	0.340	0.377	0.347
		15	0.371	0.367	0.374	0.357
		30	0.369	0.367	0.377	0.369
		45	0.373	0.376	0.379	0.376
Spring Banded Conventional Urea	3	0	0.362	0.358	0.380	0.340
		15	0.364	0.354	0.379	0.361
		30	0.366	0.370	0.403	0.360
		45	0.361	0.364	0.375	0.360
Control	4	0	0.369	0.354	0.380	0.329
		15	0.371	0.382	0.379	0.367
		30	0.363	0.369	0.404	0.359
		45	0.378	0.372	0.427	0.366
Fall Banded NBPT-DCD Urea	4	0	0.362	0.363	0.374	0.320
		15	0.365	0.374	0.383	0.381
		30	0.360	0.383	0.383	0.370
		45	0.374	0.374	0.384	0.373
Fall Banded Conventional Urea	4	0	0.365	0.362	0.358	0.341
		15	0.378	0.386	0.398	0.444
		30	0.380	0.400	0.476	0.491
		45	0.373	0.406	0.449	0.519
Fall Banded Calcium Nitrate	4	0	0.361	0.364	0.369	0.331
		15	0.359	0.360	0.392	0.384
		30	0.365	0.360	0.395	0.400
		45	0.363	0.371	0.423	0.404
Spring Banded Conventional Urea	4	0	0.372	0.356	0.369	0.331
		15	0.372	0.376	0.410	0.351
		30	0.369	0.376	0.477	0.434
		45	0.366	0.379	0.494	0.410

Table B.6 (cont'd). Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006			
Indian Head	Rep	Time	Date			
			May 19	May 23	May 25	May 31
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.353	0.346	0.364	0.360
		15	0.360	0.361	0.376	0.358
		30	0.346	0.370	0.400	0.352
		45	0.358	0.368	0.404	0.362
Fall Banded NBPT-DCD Urea	1	0	0.358	0.349	0.356	0.355
		15	0.375	0.348	0.379	0.364
		30	0.366	0.365	0.397	0.360
		45	0.355	0.364	0.380	0.347
Fall Banded Conventional Urea	1	0	0.364	0.352	0.371	0.348
		15	0.399	0.354	0.397	0.348
		30	0.360	0.393	0.408	0.353
		45	0.416	0.379	0.381	0.353
Fall Banded Calcium Nitrate	1	0	0.355	0.350	0.367	0.355
		15	0.360	0.360	0.373	0.364
		30	0.358	0.362	0.396	0.372
		45	0.369	0.383	0.403	0.363
Spring Banded Conventional Urea	1	0	0.349	0.343	0.357	0.343
		15	0.370	0.368	0.383	0.358
		30	0.357	0.367	0.400	0.350
		45	0.371	0.391	0.403	0.352
Control	2	0	0.355	0.345	0.363	0.348
		15	0.393	0.357	0.369	0.368
		30	0.387	0.355	0.372	0.366
		45	0.419	0.369	0.369	0.362
Fall Banded NBPT-DCD Urea	2	0	0.354	0.366	0.369	0.339
		15	0.392	0.358	0.378	0.371
		30	0.362	0.372	0.386	0.368
		45	0.383	0.380	0.389	0.369
Fall Banded Conventional Urea	2	0	0.357	0.360	0.366	0.352
		15	0.409	0.377	0.477	0.397
		30	0.397	0.425	0.581	0.391
		45	0.440	0.487	0.523	0.395
Fall Banded Calcium Nitrate	2	0	0.356	0.343	0.356	0.339
		15	0.389	0.366	0.385	0.357
		30	0.372	0.363	0.404	0.375
		45	0.395	0.397	0.412	0.383
Spring Banded Conventional Urea	2	0	0.359	0.349	0.357	0.343
		15	0.356	0.370	0.378	0.365
		30	0.354	0.361	0.397	0.373
		45	0.362	0.375	0.432	0.363

Table B.6 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006			
Indian Head	Rep	Time	Date			
			May 19	May 23	May 25	May 31
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.352	0.373	0.342	0.348
		15	0.364	0.371	0.377	0.376
		30	0.374	0.383	0.391	0.378
		45	0.380	0.387	0.403	0.394
Fall Banded NBPT-DCD Urea	3	0	0.351	0.367	0.350	0.350
		15	0.368	0.399	0.368	0.369
		30	0.370	0.384	0.388	0.393
		45	0.371	0.422	0.384	0.365
Fall Banded Conventional Urea	3	0	0.338	0.354	0.339	0.341
		15	0.371	0.374	0.383	0.384
		30	0.366	0.391	0.419	0.383
		45	0.370	0.417	0.424	0.406
Fall Banded Calcium Nitrate	3	0	0.351	0.369	0.343	0.356
		15	0.371	0.369	0.360	0.363
		30	0.389	0.378	0.375	0.369
		45	0.394	0.391	0.371	0.374
Spring Banded Conventional Urea	3	0	0.342	0.376	0.333	0.350
		15	0.367	0.382	0.371	0.376
		30	0.362	0.370	0.383	0.361
		45	0.369	0.386	0.381	0.392
Control	4	0	0.351	0.373	0.338	0.352
		15	0.376	0.389	0.378	0.366
		30	0.385	0.397	0.382	0.373
		45	0.376	0.418	0.410	0.386
Fall Banded NBPT-DCD Urea	4	0	0.342	0.361	0.332	0.339
		15	0.364	0.380	0.364	0.353
		30	0.356	0.369	0.367	0.356
		45	0.352	0.383	0.383	0.369
Fall Banded Conventional Urea	4	0	0.361	0.374	0.352	0.351
		15	0.375	0.421	0.543	0.438
		30	0.373	0.437	0.347	0.476
		45	0.379	0.420	0.727	0.535
Fall Banded Calcium Nitrate	4	0	0.349	0.366	0.344	0.353
		15	0.361	0.388	0.408	0.381
		30	0.368	0.391	0.441	0.386
		45	0.362	0.422	0.478	0.387
Spring Banded Conventional Urea	4	0	0.342	0.366	0.343	0.342
		15	0.425	0.490	0.568	0.419
		30	0.397	0.588	0.759	0.382
		45	0.425	0.656	0.991	0.388

Table B.6 (cont'd). Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006	
Indian Head	Rep	Time	Date	
			June 2	June 5
			$\mu L\ N_2O\ L^{-1}$	
Control	1	0	0.357	0.369
		15	0.355	0.374
		30	0.360	0.367
		45	0.378	0.383
Fall Banded NBPT-DCD Urea	1	0	0.358	0.361
		15	0.356	0.371
		30	0.357	0.361
		45	0.369	0.373
Fall Banded Conventional Urea	1	0	0.375	0.363
		15	0.368	0.366
		30	0.370	0.356
		45	0.369	0.375
Fall Banded Calcium Nitrate	1	0	0.361	0.364
		15	0.364	0.377
		30	0.363	0.394
		45	0.364	0.395
Spring Banded Conventional Urea	1	0	0.366	0.362
		15	0.356	0.357
		30	0.377	0.366
		45	0.369	0.375
Control	2	0	0.360	0.357
		15	0.369	0.368
		30	0.356	0.364
		45	0.367	0.357
Fall Banded NBPT-DCD Urea	2	0	0.351	0.363
		15	0.364	0.374
		30	0.352	0.371
		45	0.367	0.372
Fall Banded Conventional Urea	2	0	0.364	0.365
		15	0.363	0.382
		30	0.375	0.370
		45	0.372	0.375
Fall Banded Calcium Nitrate	2	0	0.369	0.364
		15	0.356	0.379
		30	0.376	0.364
		45	0.370	0.385
Spring Banded Conventional Urea	2	0	0.361	0.363
		15	0.360	0.377
		30	0.367	0.364
		45	0.367	0.379

Table B.6 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2006.

Site and treatment			Spring 2006	
Indian Head	Rep	Time	Date	
			June 2	June 5
			$\mu L\ N_2O\ L^{-1}$	
Control	3	0	0.375	0.354
		15	0.365	0.370
		30	0.377	0.390
		45	0.369	0.368
Fall Banded NBPT-DCD Urea	3	0	0.356	0.355
		15	0.380	0.384
		30	0.361	0.380
		45	0.367	0.371
Fall Banded Conventional Urea	3	0	0.358	0.360
		15	0.371	0.370
		30	0.388	0.374
		45	0.382	0.375
Fall Banded Calcium Nitrate	3	0	0.362	0.358
		15	0.363	0.364
		30	0.371	0.371
		45	0.366	0.377
Spring Banded Conventional Urea	3	0	0.359	0.371
		15	0.374	0.372
		30	0.373	0.373
		45	0.381	0.371
Control	4	0	0.346	0.359
		15	0.378	0.371
		30	0.375	0.362
		45	0.389	0.372
Fall Banded NBPT-DCD Urea	4	0	0.361	0.357
		15	0.372	0.366
		30	0.369	0.353
		45	0.365	0.368
Fall Banded Conventional Urea	4	0	0.371	0.355
		15	0.378	0.411
		30	0.382	0.446
		45	0.385	0.440
Fall Banded Calcium Nitrate	4	0	0.355	0.366
		15	0.360	0.382
		30	0.355	0.380
		45	0.366	0.384
Spring Banded Conventional Urea	4	0	0.367	0.352
		15	0.390	0.470
		30	0.392	0.468
		45	0.394	0.487

Table B.7. Concentrations of nitrous oxide emitted at Oak Bluff during fall 2006.

Site and treatment			Fall 2006			
Oak Bluff	Rep	Time	Date			
			Oct. 9	Oct. 11	Oct. 14	Oct. 18
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.342	0.343	0.347	0.346
		15	0.355	0.340	0.349	0.351
		30	0.350	0.348	0.349	0.355
		45	0.364	0.352	0.334	0.354
Fall Banded NBPT-DCD Urea	1	0	0.353	0.340	0.353	0.382
		15	0.348	0.343	0.346	0.344
		30	0.354	0.350	0.343	0.350
		45	0.353	0.349	0.330	0.352
Fall Banded Conventional Urea	1	0	0.354	0.343	0.348	0.350
		15	0.362	0.338	0.357	0.352
		30	0.369	0.346	0.344	0.364
		45	0.381	0.351	0.336	0.365
Fall Banded Calcium Nitrate	1	0	0.342	0.346	0.345	0.350
		15	0.350	0.344	0.355	0.350
		30	0.355	0.346	0.347	0.351
		45	0.354	0.347	0.324	0.343
Spring Banded Conventional Urea	1	0	0.347	0.342	0.344	0.346
		15	0.355	0.349	0.349	0.352
		30	0.362	0.354	0.348	0.355
		45	0.370	0.356	0.339	0.362
Control	2	0	0.348	0.342	0.348	0.350
		15	0.349	0.342	0.348	0.396
		30	0.352	0.347	0.324	0.348
		45	0.352	0.346	0.352	0.348
Fall Banded NBPT-DCD Urea	2	0	0.350	0.347	0.342	0.349
		15	0.345	0.352	0.345	0.347
		30	0.354	0.348	0.322	0.357
		45	0.345	0.348	0.324	0.352
Fall Banded Conventional Urea	2	0	0.351	0.342	0.347	0.345
		15	0.383	0.352	0.348	0.344
		30	0.393	0.349	0.321	0.345
		45	0.389	0.356	0.320	0.350
Fall Banded Calcium Nitrate	2	0	0.349	0.342	0.346	0.348
		15	0.343	0.350	0.354	0.366
		30	0.356	0.353	0.327	0.356
		45	0.345	0.362	0.328	0.364
Spring Banded Conventional Urea	2	0	0.340	0.344	0.347	0.358
		15	0.343	0.351	0.344	0.365
		30	0.353	0.347	0.338	0.349
		45	0.352	0.353	0.332	0.355

Table B.7 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during fall 2006.

Site and treatment			Fall 2006			
Oak Bluff	Rep	Time	Date			
			Oct. 9	Oct. 11	Oct. 14	Oct. 18
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.360	0.346	0.318	0.358
		15	0.364	0.345	0.345	0.355
		30	0.364	0.345	0.339	0.358
		45	0.360	0.339	0.351	0.357
Fall Banded NBPT-DCD Urea	3	0	0.356	0.349	0.327	0.356
		15	0.372	0.348	0.368	0.359
		30	0.371	0.350	0.369	0.370
		45	0.378	0.354	0.367	0.363
Fall Banded Conventional Urea	3	0	0.351	0.349	0.321	0.358
		15	0.371	0.350	0.347	0.363
		30	0.382	0.344	0.348	0.367
		45	0.371	0.348	0.350	0.362
Fall Banded Calcium Nitrate	3	0	0.357	0.346	0.355	0.361
		15	0.363	0.350	0.354	0.356
		30	0.371	0.356	0.346	0.361
		45	0.369	0.349	0.346	0.351
Spring Banded Conventional Urea	3	0	0.354	0.358	0.319	0.355
		15	0.360	0.352	0.356	0.362
		30	0.365	0.353	0.339	0.363
		45	0.359	0.353	0.346	0.361
Control	4	0	0.359	0.345	0.315	0.354
		15	0.360	0.348	0.347	0.347
		30	0.351	0.356	0.339	0.353
		45	0.349	0.353	0.347	0.349
Fall Banded NBPT-DCD Urea	4	0	0.358	0.343	0.362	0.349
		15	0.347	0.344	0.343	0.358
		30	0.352	0.356	0.346	0.355
		45	0.342	0.349	0.345	0.358
Fall Banded Conventional Urea	4	0	0.349	0.345	0.341	0.356
		15	0.357	0.345	0.341	0.371
		30	0.363	0.355	0.355	0.363
		45	0.361	0.356	0.354	0.365
Fall Banded Calcium Nitrate	4	0	0.357	0.342	0.342	0.352
		15	0.357	0.348	0.344	0.356
		30	0.357	0.354	0.349	0.355
		45	0.358	0.353	0.711	0.352
Spring Banded Conventional Urea	4	0	0.357	0.343	0.341	0.353
		15	0.353	0.352	0.346	0.354
		30	0.357	0.349	0.422	0.357
		45	0.350	0.356	0.348	0.355

Table B.7 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during fall 2006.

Site and treatment			Fall 2006			
Oak Bluff	Rep	Time	Date			
			Oct. 20	Oct. 26	Oct. 27	Nov. 8
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.351	0.340	0.354	0.358
		15	0.357	0.344	0.359	0.359
		30	0.357	0.347	0.365	0.360
		45	0.353	0.354	0.363	0.360
Fall Banded NBPT-DCD Urea	1	0	0.365	0.342	0.347	0.350
		15	0.361	0.351	0.358	0.361
		30	0.353	0.351	0.356	0.369
		45	0.356	0.356	0.357	0.375
Fall Banded Conventional Urea	1	0	0.352	0.345	0.349	0.351
		15	0.364	0.340	0.362	0.363
		30	0.379	0.342	0.358	0.382
		45	0.380	0.349	0.357	0.383
Fall Banded Calcium Nitrate	1	0	0.362	0.338	0.349	0.352
		15	0.357	0.348	0.350	0.365
		30	0.356	0.349	0.363	0.358
		45	0.359	0.354	0.355	0.359
Spring Banded Conventional Urea	1	0	0.344	0.344	0.359	0.356
		15	0.365	0.354	0.360	0.359
		30	0.362	0.362	0.362	0.378
		45	0.360	0.365	0.363	0.375
Control	2	0	0.346	0.340	0.347	0.359
		15	0.352	0.342	0.348	0.354
		30	0.355	0.342	0.353	0.347
		45	0.349	0.334	0.359	0.366
Fall Banded NBPT-DCD Urea	2	0	0.355	0.338	0.356	0.347
		15	0.356	0.344	0.361	0.343
		30	0.355	0.349	0.356	0.358
		45	0.363	0.346	0.356	0.357
Fall Banded Conventional Urea	2	0	0.363	0.334	0.359	0.349
		15	0.355	0.348	0.360	0.366
		30	0.351	0.341	0.362	0.397
		45	0.358	0.355	0.365	0.400
Fall Banded Calcium Nitrate	2	0	0.353	0.347	0.350	0.340
		15	0.358	0.347	0.361	0.357
		30	0.357	0.357	0.357	0.354
		45	0.364	0.351	0.358	0.368
Spring Banded Conventional Urea	2	0	0.352	0.338	0.358	0.355
		15	0.355	0.355	0.352	0.345
		30	0.347	0.346	0.351	0.369
		45	0.348	0.342	0.349	0.369

Table B.7 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during fall 2006.

Site and treatment			Fall 2006			
Oak Bluff	Rep	Time	Date			
			Oct. 20	Oct. 26	Oct. 27	Nov. 8
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.346	0.342	0.355	0.343
		15	0.350	0.350	0.354	0.358
		30	0.343	0.342	0.356	0.367
		45	0.344	0.360	0.355	0.361
Fall Banded NBPT-DCD Urea	3	0	0.349	0.343	0.357	0.349
		15	0.348	0.352	0.358	0.350
		30	0.348	0.349	0.358	0.364
		45	0.358	0.361	0.354	0.365
Fall Banded Conventional Urea	3	0	0.340	0.343	0.350	0.348
		15	0.381	0.363	0.353	0.358
		30	0.368	0.368	0.352	0.380
		45	0.375	0.374	0.355	0.378
Fall Banded Calcium Nitrate	3	0	0.343	0.339	0.353	0.345
		15	0.354	0.360	0.352	0.351
		30	0.350	0.346	0.348	0.358
		45	0.354	0.356	0.354	0.377
Spring Banded Conventional Urea	3	0	0.355	0.349	0.354	0.348
		15	0.357	0.357	0.352	0.344
		30	0.348	0.364	0.358	0.371
		45	0.359	0.373	0.356	0.362
Control	4	0	0.357	0.339	0.349	0.354
		15	0.352	0.345	0.349	0.351
		30	0.348	0.345	0.354	0.354
		45	0.348	0.351	0.352	0.359
Fall Banded NBPT-DCD Urea	4	0	0.343	0.337	0.353	0.352
		15	0.361	0.347	0.352	0.359
		30	0.365	0.353	0.355	0.359
		45	0.353	0.355	0.349	0.363
Fall Banded Conventional Urea	4	0	0.355	0.346	0.352	0.366
		15	0.343	0.354	0.356	0.353
		30	0.339	0.362	0.352	0.370
		45	0.356	0.360	1.751	0.361
Fall Banded Calcium Nitrate	4	0	0.345	0.341	0.358	0.355
		15	0.339	0.349	0.350	0.350
		30	0.343	0.359	0.356	0.349
		45	0.343	0.360	0.355	0.352
Spring Banded Conventional Urea	4	0	0.353	0.339	0.349	0.359
		15	0.352	0.349	0.351	0.343
		30	0.345	0.349	0.352	0.358
		45	0.354	0.352	0.348	0.350

Table B.8. Concentrations of nitrous oxide emitted at Brandon during fall 2006.

Site and treatment			Fall 2006			
Brandon	Rep	Time	Date			
			Oct. 13	Oct. 15	Oct. 19	Oct. 23
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.342	0.353	0.352	0.344
		15	0.334	0.362	0.373	0.351
		30	0.341	0.358	0.360	0.347
		45	0.336	0.364	0.365	0.352
Fall Banded NBPT-DCD Urea	1	0	0.347	0.364	0.361	0.344
		15	0.346	0.371	0.351	0.354
		30	0.352	0.368	0.369	0.348
		45	0.339	0.354	0.358	0.352
Fall Banded Conventional Urea	1	0	0.338	0.355	0.352	0.349
		15	0.342	0.356	0.373	0.349
		30	0.343	0.361	0.360	0.353
		45	0.354	0.363	0.364	0.358
Fall Banded Calcium Nitrate	1	0	0.363	0.353	0.359	0.348
		15	0.340	0.348	0.364	0.352
		30	0.342	0.359	0.359	0.350
		45	0.339	0.348	0.361	0.356
Spring Banded Conventional Urea	1	0	0.344	0.351	0.367	0.345
		15	0.349	0.361	0.355	0.354
		30	0.339	0.352	0.375	0.353
		45	0.341	0.364	0.358	0.354
Control	2	0	0.348	0.357	0.352	0.346
		15	0.342	0.351	0.358	0.354
		30	0.362	0.364	0.350	0.350
		45	0.331	0.350	0.361	0.350
Fall Banded NBPT-DCD Urea	2	0	0.348	0.354	0.355	0.354
		15	0.345	0.361	0.374	0.347
		30	0.343	0.355	0.358	0.354
		45	0.336	0.360	0.362	0.355
Fall Banded Conventional Urea	2	0	0.351	0.344	0.350	0.353
		15	0.341	0.367	0.362	0.353
		30	0.355	0.350	0.358	0.350
		45	0.347	0.355	0.359	0.346
Fall Banded Calcium Nitrate	2	0	0.345	0.349	0.363	0.344
		15	0.340	0.358	0.372	0.355
		30	0.344	0.369	0.364	0.354
		45	0.349	0.371	0.360	0.355
Spring Banded Conventional Urea	2	0	0.344	0.349	0.358	0.351
		15	0.341	0.345	0.354	0.350
		30	0.357	0.351	0.360	0.351
		45	0.337	0.372	0.355	0.350

Table B.8 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during fall 2006.

Site and treatment			Fall 2006			
Brandon	Rep	Time	Date			
			Oct. 13	Oct. 15	Oct. 19	Oct. 23
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.342	0.354	0.346	0.346
		15	0.340	0.351	0.355	0.353
		30	0.353	0.360	0.357	0.350
		45	0.344	0.371	0.372	0.359
Fall Banded NBPT-DCD Urea	3	0	0.341	0.357	0.344	0.347
		15	0.339	0.348	0.351	0.346
		30	0.339	0.350	0.350	0.355
		45	0.338	0.364	0.353	0.347
Fall Banded Conventional Urea	3	0	0.342	0.366	0.351	0.346
		15	0.342	0.348	0.352	0.347
		30	0.343	0.365	0.348	0.345
		45	0.338	0.370	0.349	0.344
Fall Banded Calcium Nitrate	3	0	0.330	0.355	0.351	0.344
		15	0.346	0.366	0.351	0.342
		30	0.343	0.355	0.351	0.350
		45	0.359	0.369	0.354	0.347
Spring Banded Conventional Urea	3	0	0.367	0.351	0.347	0.341
		15	0.341	0.355	0.355	0.342
		30	0.347	0.350	0.349	0.347
		45	0.333	0.329	0.349	0.349
Control	4	0	0.342	0.368	0.349	0.340
		15	0.348	0.368	0.352	0.344
		30	0.350	0.363	0.350	0.349
		45	0.336	0.357	0.352	0.347
Fall Banded NBPT-DCD Urea	4	0	0.380	0.339	0.346	0.339
		15	0.339	0.370	0.343	0.356
		30	0.350	0.365	0.352	0.348
		45	0.337	0.352	0.350	0.345
Fall Banded Conventional Urea	4	0	0.357	0.374	0.351	0.341
		15	0.341	0.356	0.348	0.343
		30	0.344	0.358	0.350	0.346
		45	0.340	0.367	0.357	0.350
Fall Banded Calcium Nitrate	4	0	0.344	0.350	0.349	0.342
		15	0.342	0.366	0.351	0.342
		30	0.334	0.359	0.347	0.348
		45	0.344	0.374	0.353	0.354
Spring Banded Conventional Urea	4	0	0.339	0.364	0.345	0.344
		15	0.359	0.364	0.351	0.339
		30	0.345	0.352	0.345	0.346
		45	0.345	0.364	0.352	0.343

Table B.8 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during fall 2006.

Site and treatment		Fall 2006	
Brandon	Rep	Time	Date
			Oct. 26
			μL N_2O L^{-1}
Control	1	0	0.351
		15	0.346
		30	0.350
		45	0.349
Fall Banded NBPT-DCD Urea	1	0	0.353
		15	0.344
		30	0.350
		45	0.344
Fall Banded Conventional Urea	1	0	0.346
		15	0.351
		30	0.353
		45	0.347
Fall Banded Calcium Nitrate	1	0	0.347
		15	0.349
		30	0.348
		45	0.347
Spring Banded Conventional Urea	1	0	0.346
		15	0.349
		30	0.351
		45	0.347
Control	2	0	0.347
		15	0.342
		30	0.346
		45	0.350
Fall Banded NBPT-DCD Urea	2	0	0.453
		15	0.404
		30	0.385
		45	0.370
Fall Banded Conventional Urea	2	0	0.343
		15	0.351
		30	0.346
		45	0.354
Fall Banded Calcium Nitrate	2	0	0.346
		15	0.350
		30	0.355
		45	0.360
Spring Banded Conventional Urea	2	0	0.346
		15	0.353
		30	0.352
		45	0.349

Table B.8 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during fall 2006.

Site and treatment			Fall 2006
Brandon	Rep	Time	Date
			Oct. 26
			µL N_2O L^{-1}
Control	3	0	0.339
		15	0.348
		30	0.348
		45	0.374
Fall Banded NBPT-DCD Urea	3	0	0.350
		15	0.345
		30	0.351
		45	0.343
Fall Banded Conventional Urea	3	0	0.340
		15	0.340
		30	0.353
		45	0.354
Fall Banded Calcium Nitrate	3	0	0.355
		15	0.335
		30	0.359
		45	0.341
Spring Banded Conventional Urea	3	0	0.343
		15	0.359
		30	0.356
		45	0.360
Control	4	0	0.339
		15	0.345
		30	0.342
		45	0.366
Fall Banded NBPT-DCD Urea	4	0	0.352
		15	0.343
		30	0.355
		45	0.354
Fall Banded Conventional Urea	4	0	0.335
		15	0.356
		30	0.343
		45	0.340
Fall Banded Calcium Nitrate	4	0	0.338
		15	0.346
		30	0.358
		45	0.359
Spring Banded Conventional Urea	4	0	0.337
		15	0.354
		30	0.355
		45	0.345

Table B.9. Concentrations of nitrous oxide emitted at Indian Head during fall 2006.

Site and treatment			Fall 2006			
Indian Head	Rep	Time	Date			
			Oct. 4	Oct. 6	Oct. 9	Oct. 12
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.343	0.358	0.358	0.345
		15	0.359	0.349	0.349	0.340
		30	0.361	0.359	0.357	0.353
		45	0.353	0.366	0.354	0.348
Fall Banded NBPT-DCD Urea	1	0	0.345	0.357	0.345	0.344
		15	0.356	0.359	0.364	0.352
		30	0.369	0.364	0.356	0.354
		45	0.361	0.366	0.357	0.350
Fall Banded Conventional Urea	1	0	0.352	0.359	0.343	0.350
		15	0.353	0.355	0.352	0.348
		30	0.362	0.364	0.358	0.349
		45	0.353	0.362	0.355	0.360
Fall Banded Calcium Nitrate	1	0	0.350	0.350	0.348	0.344
		15	0.356	0.360	0.354	0.346
		30	0.356	0.348	0.354	0.351
		45	0.353	0.358	0.361	0.322
Spring Banded Conventional Urea	1	0	0.350	0.357	0.363	0.349
		15	0.357	0.358	0.362	0.341
		30	0.361	0.362	0.351	0.361
		45	0.361	0.360	0.367	0.350
Control	2	0	0.351	0.359	0.349	0.364
		15	0.355	0.352	0.350	0.346
		30	0.358	0.360	0.356	0.352
		45	0.359	0.358	0.363	0.362
Fall Banded NBPT-DCD Urea	2	0	0.354	0.361	0.354	0.348
		15	0.352	0.364	0.357	0.348
		30	0.356	0.364	0.349	0.362
		45	0.356	0.361	0.380	0.366
Fall Banded Conventional Urea	2	0	0.358	0.355	0.351	0.350
		15	0.357	0.358	0.351	0.341
		30	0.355	0.360	0.349	0.346
		45	0.353	0.363	0.365	0.352
Fall Banded Calcium Nitrate	2	0	0.355	0.361	0.348	0.345
		15	0.352	0.351	0.351	0.355
		30	0.356	0.357	0.352	0.344
		45	0.357	0.367	0.362	0.356
Spring Banded Conventional Urea	2	0	0.362	0.360	0.345	0.348
		15	0.354	0.352	0.358	0.348
		30	0.352	0.358	0.359	0.343
		45	0.355	0.358	0.358	0.341

Table B.9 (cont'd.). Concentrations of nitrous oxide emitted at Indian during fall 2006.

Site and treatment			Fall 2006			
Indian Head	Rep	Time	Date			
			Oct. 4	Oct. 6	Oct. 9	Oct. 12
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.354	0.357	0.353	0.346
		15	0.357	0.361	0.352	0.340
		30	0.358	0.364	0.342	0.346
		45	0.355	0.356	0.345	0.352
Fall Banded NBPT-DCD Urea	3	0	0.354	0.360	0.357	0.354
		15	0.356	0.356	0.367	0.352
		30	0.351	0.361	0.355	0.341
		45	0.362	0.366	0.351	0.335
Fall Banded Conventional Urea	3	0	0.357	0.350	0.352	0.351
		15	0.360	0.356	0.352	0.336
		30	0.360	0.355	0.369	0.345
		45	0.357	0.360	0.366	0.353
Fall Banded Calcium Nitrate	3	0	0.353	0.350	0.348	0.342
		15	0.357	0.356	0.366	0.332
		30	0.355	0.363	0.348	0.335
		45	0.360	0.364	0.358	0.354
Spring Banded Conventional Urea	3	0	0.359	0.357	0.353	0.352
		15	0.359	0.356	0.348	0.342
		30	0.359	0.356	0.353	0.340
		45	0.347	0.358	0.341	0.337
Control	4	0	0.358	0.359	0.350	0.338
		15	0.347	0.354	0.351	0.339
		30	0.359	0.357	0.354	0.333
		45	0.356	0.365	0.357	0.338
Fall Banded NBPT-DCD Urea	4	0	0.357	0.355	0.349	0.351
		15	0.349	0.363	0.369	0.338
		30	0.363	0.360	0.342	0.336
		45	0.355	0.359	0.360	0.332
Fall Banded Conventional Urea	4	0	0.362	0.350	0.352	0.358
		15	0.356	0.362	0.351	0.341
		30	0.360	0.364	0.351	0.343
		45	0.353	0.366	0.369	0.341
Fall Banded Calcium Nitrate	4	0	0.355	0.357	0.361	0.335
		15	0.354	0.362	0.353	0.348
		30	0.366	0.366	0.354	0.348
		45	0.362	0.352	0.364	0.360
Spring Banded Conventional Urea	4	0	0.356	0.358	0.360	0.344
		15	0.359	0.360	0.357	0.338
		30	0.369	0.360	0.358	0.366
		45	0.367	0.373	0.361	0.333

Table B.9 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during fall 2006.

Site and treatment			Fall 2006			
Indian Head	Rep	Time	Date			
			Oct. 14	Oct. 16	Oct. 18	Oct. 26
			μL N_2O L^{-1}			
Control	1	0	0.337	0.352	0.345	0.347
		15	0.344	0.339	0.352	0.349
		30	0.338	0.348	0.363	0.353
		45	0.338	0.358	0.351	0.345
Fall Banded NBPT-DCD Urea	1	0	0.335	0.359	0.348	0.358
		15	0.340	0.342	0.272	0.345
		30	0.334	0.351	0.343	0.353
		45	0.351	0.335	0.351	0.357
Fall Banded Conventional Urea	1	0	0.334	0.364	0.354	0.355
		15	0.332	0.349	0.349	0.350
		30	0.335	0.359	0.354	0.352
		45	0.342	0.359	0.342	0.350
Fall Banded Calcium Nitrate	1	0	0.326	0.358	0.358	0.345
		15	0.337	0.372	0.353	0.349
		30	0.324	0.340	0.343	0.346
		45	0.353	0.353	0.350	0.342
Spring Banded Conventional Urea	1	0	0.331	0.354	0.362	0.355
		15	0.334	0.325	0.349	0.353
		30	0.334	0.340	0.345	0.351
		45	0.357	0.353	0.345	0.351
Control	2	0	0.347	0.361	0.359	0.349
		15	0.324	0.339	0.362	0.348
		30	0.365	0.350	0.354	0.345
		45	0.344	0.363	0.342	0.345
Fall Banded NBPT-DCD Urea	2	0	0.338	0.387	0.360	0.352
		15	0.336	0.338	0.361	0.350
		30	0.335	0.363	0.353	0.351
		45	0.344	0.351	0.341	0.344
Fall Banded Conventional Urea	2	0	0.331	0.340	0.360	0.345
		15	0.338	0.370	0.356	0.352
		30	0.335	0.333	0.347	0.352
		45	0.349	0.349	0.351	0.349
Fall Banded Calcium Nitrate	2	0	0.334	0.361	0.344	0.346
		15	0.328	0.329	0.348	0.346
		30	0.349	0.330	0.360	0.346
		45	0.344	0.361	0.344	0.351
Spring Banded Conventional Urea	2	0	0.332	0.359	0.358	0.348
		15	0.323	0.346	0.352	0.346
		30	0.343	0.346	0.351	0.339
		45	0.345	0.360	0.370	0.342

Table B.9 (cont'd.). Concentrations of nitrous oxide emitted at Indian during fall 2006.

Site and treatment			Fall 2006			
Indian Head	Rep	Time	Date			
			Oct. 14	Oct. 16	Oct. 18	Oct. 26
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.334	0.343	0.341	0.341
		15	0.326	0.349	0.357	0.343
		30	0.349	0.349	0.348	0.346
		45	0.354	0.352	0.348	0.344
Fall Banded NBPT-DCD Urea	3	0	0.363	0.342	0.344	0.346
		15	0.337	0.349	0.359	0.341
		30	0.360	0.356	0.342	0.347
		45	0.359	0.345	0.347	0.341
Fall Banded Conventional Urea	3	0	0.353	0.358	0.344	0.347
		15	0.365	0.351	0.352	0.351
		30	0.369	0.346	0.344	0.353
		45	0.355	0.348	0.347	0.355
Fall Banded Calcium Nitrate	3	0	0.344	0.360	0.365	0.345
		15	0.339	0.362	0.344	0.340
		30	0.348	0.353	0.350	0.350
		45	0.354	0.359	0.354	0.344
Spring Banded Conventional Urea	3	0	0.362	0.360	0.352	0.343
		15	0.332	0.351	0.359	0.344
		30	0.358	0.346	0.355	0.348
		45	0.356	0.348	0.357	0.342
Control	4	0	0.341	0.356	0.346	0.343
		15	0.345	0.345	0.341	0.345
		30	0.363	0.349	0.349	0.345
		45	0.361	0.351	0.347	0.354
Fall Banded NBPT-DCD Urea	4	0	0.347	0.347	0.349	0.340
		15	0.360	0.355	0.341	0.344
		30	0.347	0.359	0.353	0.339
		45	0.345	0.342	0.347	0.342
Fall Banded Conventional Urea	4	0	0.348	0.359	0.344	0.338
		15	0.361	0.351	0.367	0.349
		30	0.346	0.355	0.346	0.350
		45	0.349	0.349	0.337	0.355
Fall Banded Calcium Nitrate	4	0	0.342	0.366	0.350	0.342
		15	0.345	0.344	0.359	0.342
		30	0.361	0.356	0.350	0.347
		45	0.352	0.351	0.347	0.352
Spring Banded Conventional Urea	4	0	0.347	0.346	0.343	0.340
		15	0.362	0.353	0.349	0.353
		30	0.347	0.346	0.347	0.349
		45	0.358	0.338	0.353	0.353

Table B.10. Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			Mar. 25	Mar. 27	April 9	April 14
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.377	0.361	0.349	0.354
		15	0.544	0.370	0.366	0.355
		30	0.657	0.360	0.379	0.359
		45	0.761	0.372	0.377	0.347
Fall Banded NBPT-DCD Urea	1	0	0.378	0.388	0.353	0.366
		15	0.375	0.364	0.359	0.358
		30	0.391	0.409	0.388	0.351
		45	0.385	0.378	0.390	0.352
Fall Banded Conventional Urea	1	0	0.383	0.365	0.354	0.361
		15	0.382	0.366	0.359	0.360
		30	0.388	0.492	0.362	0.350
		45	0.384	0.379	0.359	0.355
Fall Banded Calcium Nitrate	1	0	0.378	0.373	0.351	0.366
		15	0.541	0.362	0.355	0.357
		30	0.651	0.369	0.360	0.356
		45	0.767	0.367	0.356	0.351
Spring Banded Conventional Urea	1	0	0.390	0.396	0.351	0.363
		15	0.422	0.485	0.367	0.356
		30	0.457	0.400	0.386	0.350
		45	0.476	0.409	0.400	0.347
Control	2	0	0.382	0.437	0.351	0.359
		15	0.386	0.389	0.353	0.357
		30	0.381	0.704	0.359	0.350
		45	0.387	0.398	0.355	0.362
Fall Banded NBPT-DCD Urea	2	0	0.384	0.421	0.349	0.366
		15	0.410	0.444	0.352	0.360
		30	0.443	0.404	0.356	0.361
		45	0.460	0.372	0.363	0.354
Fall Banded Conventional Urea	2	0	0.379	0.431	0.352	0.362
		15	0.379	0.652	0.363	0.352
		30	0.385	0.448	0.366	0.352
		45	0.386	0.483	0.365	0.350
Fall Banded Calcium Nitrate	2	0	0.382	0.422	0.352	0.355
		15	0.382	0.371	0.357	0.348
		30	0.381	0.458	0.360	0.349
		45	0.397	0.393	0.361	0.348
Spring Banded Conventional Urea	2	0	0.384	0.604	0.352	0.363
		15	0.380	0.386	0.360	0.358
		30	0.384	0.415	0.351	0.354
		45	0.387	0.586	0.360	0.356

Table B.10 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			Mar. 25	Mar. 27	April 9	April 14
			μL N_2O L^{-1}			
Control	3	0	0.399	0.379	0.362	0.354
		15	0.476	0.365	0.360	0.355
		30	0.521	0.365	0.361	0.349
		45	0.557	0.406	0.358	0.345
Fall Banded NBPT-DCD Urea	3	0	0.395	0.362	0.358	0.348
		15	0.580	0.362	0.357	0.357
		30	0.748	0.401	0.354	0.359
		45	0.879	0.373	0.351	0.348
Fall Banded Conventional Urea	3	0	0.384	0.364	0.354	0.350
		15	0.381	0.367	0.364	0.358
		30	0.382	0.368	0.357	0.355
		45	0.386	0.370	0.359	0.347
Fall Banded Calcium Nitrate	3	0	0.388	0.356	0.355	0.348
		15	0.412	0.369	0.362	0.351
		30	0.445	0.372	0.361	0.358
		45	0.472	0.374	0.361	0.357
Spring Banded Conventional Urea	3	0	0.391	0.370	0.357	0.357
		15	0.457	0.732	0.360	0.351
		30	0.495	0.370	0.359	0.347
		45	0.535	0.371	0.361	0.345
Control	4	0	0.381	0.451	0.364	0.350
		15	0.386	0.370	0.355	0.354
		30	0.385	0.384	0.360	0.349
		45	0.380	0.376	0.354	0.352
Fall Banded NBPT-DCD Urea	4	0	0.379	0.375	0.359	0.353
		15	0.375	1.424	0.357	0.347
		30	0.376	0.382	0.358	0.351
		45	0.382	0.388	0.360	0.348
Fall Banded Conventional Urea	4	0	0.382	0.408	0.360	0.346
		15	0.475	0.385	0.357	0.346
		30	0.581	0.368	0.362	0.350
		45	0.651	0.499	0.366	0.347
Fall Banded Calcium Nitrate	4	0	0.380	0.379	0.367	0.347
		15	0.457	0.383	0.358	0.350
		30	0.466	0.481	0.362	0.350
		45	0.467	0.375	0.365	0.347
Spring Banded Conventional Urea	4	0	0.388	0.369	0.362	0.354
		15	0.683	0.451	0.359	0.353
		30	0.614	0.375	0.352	0.347
		45	0.664	1.122	0.367	0.345

Table B.10 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			April 18	April 23	April 27	May 2
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.360	0.358	0.375	0.348
		15	0.349	0.435	0.466	0.370
		30	0.355	0.482	0.501	0.358
		45	0.350	0.516	0.517	0.362
Fall Banded NBPT-DCD Urea	1	0	0.437	0.351	0.375	0.352
		15	0.435	0.394	0.433	0.375
		30	0.398	0.420	0.454	0.392
		45	0.544	0.425	0.451	0.389
Fall Banded Conventional Urea	1	0	0.356	0.359	0.370	0.355
		15	0.367	0.453	0.445	0.352
		30	0.423	0.429	0.448	0.357
		45	0.359	0.436	0.464	0.363
Fall Banded Calcium Nitrate	1	0	0.365	0.357	0.369	0.355
		15	0.359	0.381	0.376	0.359
		30	0.353	0.397	0.383	0.359
		45	0.350	0.410	0.379	0.355
Spring Banded Conventional Urea	1	0	0.708	0.347	0.374	0.358
		15	0.434	0.393	0.364	0.367
		30	0.455	0.401	0.365	0.363
		45	0.372	0.401	0.391	0.360
Control	2	0	0.398	0.358	0.376	0.359
		15	0.825	0.371	0.381	0.360
		30	0.463	0.385	0.387	0.355
		45	0.364	0.377	0.378	0.353
Fall Banded NBPT-DCD Urea	2	0	0.569	0.359	0.375	0.352
		15	0.387	0.491	0.534	0.401
		30	0.512	0.685	0.544	0.416
		45	0.537	0.741	0.538	0.440
Fall Banded Conventional Urea	2	0	1.060	0.375	0.463	0.359
		15	0.503	0.650	0.469	0.489
		30	0.612	0.705	0.413	0.495
		45	0.393	0.639	0.384	0.498
Fall Banded Calcium Nitrate	2	0	0.578	0.366	0.378	0.356
		15	0.602	0.407	0.396	0.381
		30	0.425	0.422	0.397	0.399
		45	0.902	0.410	0.406	0.404
Spring Banded Conventional Urea	2	0	0.435	0.358	0.368	0.354
		15	0.363	0.386	0.369	0.361
		30	0.775	0.403	0.359	0.357
		45	0.473	0.414	0.366	0.362

Table B.10 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			April 18	April 23	April 27	May 2
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.479	0.364	0.364	0.354
		15	0.514	0.402	0.420	0.375
		30	0.477	0.427	0.438	0.353
		45	0.382	0.462	0.445	0.356
Fall Banded NBPT-DCD Urea	3	0	0.404	0.363	0.371	0.358
		15	0.361	0.538	0.406	0.360
		30	0.481	0.671	0.439	0.391
		45	0.450	0.769	0.481	0.391
Fall Banded Conventional Urea	3	0	0.353	0.359	0.368	0.358
		15	0.357	0.489	0.392	0.373
		30	0.355	0.579	0.381	0.367
		45	0.353	0.630	0.387	0.372
Fall Banded Calcium Nitrate	3	0	0.353	0.364	0.358	0.357
		15	0.359	0.412	0.482	0.365
		30	0.361	0.461	0.564	0.446
		45	0.366	0.504	0.576	0.480
Spring Banded Conventional Urea	3	0	0.446	0.354	0.368	0.357
		15	0.423	0.438	0.387	0.346
		30	1.178	0.506	0.383	0.384
		45	0.756	0.559	0.385	0.378
Control	4	0	0.517	0.391	0.363	0.358
		15	0.549	0.393	0.361	0.376
		30	0.475	0.428	0.364	0.359
		45	0.576	0.445	0.373	0.360
Fall Banded NBPT-DCD Urea	4	0	0.543	0.363	0.379	0.353
		15	0.462	0.554	0.428	0.440
		30	1.586	0.653	0.443	0.442
		45	1.034	0.774	0.453	0.410
Fall Banded Conventional Urea	4	0	0.551	0.370	0.368	0.354
		15	0.679	0.656	0.417	0.402
		30	0.572	0.813	0.431	0.491
		45	0.399	0.901	0.405	0.498
Fall Banded Calcium Nitrate	4	0	1.464	0.357	0.370	0.360
		15	0.859	0.437	0.405	0.468
		30	0.538	0.488	0.395	0.410
		45	0.582	0.519	0.384	0.408
Spring Banded Conventional Urea	4	0	0.529	0.361	0.370	0.359
		15	0.401	0.380	0.415	0.405
		30	0.504	0.384	0.444	0.368
		45	0.458	0.390	0.478	0.381

Table B.10 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			May 9	May 15	May 22	May 25
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.359	0.350	0.375	0.372
		15	0.391	0.345	0.374	0.372
		30	0.406	0.353	0.370	0.368
		45	0.411	0.351	0.379	0.373
Fall Banded NBPT-DCD Urea	1	0	0.361	0.347	0.370	0.377
		15	0.374	0.353	0.368	0.375
		30	0.387	0.367	0.370	0.376
		45	0.384	0.358	0.383	0.386
Fall Banded Conventional Urea	1	0	0.365	0.352	0.379	0.369
		15	0.368	0.354	0.375	0.386
		30	0.369	0.356	0.378	0.382
		45	0.371	0.363	0.378	0.380
Fall Banded Calcium Nitrate	1	0	0.357	0.354	0.366	0.392
		15	0.375	0.354	0.377	0.378
		30	0.391	0.354	0.383	0.393
		45	0.396	0.356	0.376	0.379
Spring Banded Conventional Urea	1	0	0.361	0.342	0.366	0.384
		15	0.380	0.365	0.433	0.651
		30	0.386	0.370	0.476	0.791
		45	0.392	0.366	0.517	0.877
Control	2	0		0.346	0.377	0.375
		15	0.369	0.353	0.387	0.362
		30	0.369	0.360	0.397	0.372
		45	0.378	0.359	0.400	0.375
Fall Banded NBPT-DCD Urea	2	0	0.359	0.337	0.375	0.377
		15	0.400	0.351	0.382	0.373
		30	0.413	0.362	0.385	0.373
		45	0.439	0.356	0.383	0.394
Fall Banded Conventional Urea	2	0	0.363	0.347	0.375	0.373
		15	0.436	0.359	0.412	0.404
		30	0.511	0.379	0.443	0.447
		45	0.512	0.358	0.471	0.443
Fall Banded Calcium Nitrate	2	0	0.358	0.349	0.368	0.391
		15	0.382	0.358	0.376	0.372
		30	0.383	0.357	0.382	0.387
		45	0.381	0.358	0.387	0.373
Spring Banded Conventional Urea	2	0	0.358	0.347	0.374	0.369
		15	0.366	0.351	0.374	0.390
		30	0.370	0.361	0.382	0.382
		45	0.377	0.355	0.383	0.381

Table B.10 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			May 9	May 15	May 22	May 25
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.344	0.357	0.381	0.376
		15	0.364	0.360	0.392	0.370
		30	0.368	0.357	0.388	0.373
		45	0.367	0.360	0.389	0.385
Fall Banded NBPT-DCD Urea	3	0	0.345	0.356	0.387	0.383
		15	0.365	0.362	0.382	0.378
		30	0.363	0.351	0.390	0.375
		45	0.381	0.358	0.378	0.368
Fall Banded Conventional Urea	3	0	0.345	0.360	0.374	0.391
		15	0.381	0.359	0.390	0.379
		30	0.412	0.353	0.382	0.388
		45	0.419	0.361	0.388	0.361
Fall Banded Calcium Nitrate	3	0	0.354	0.348	0.378	0.375
		15	0.377	0.355	0.380	0.371
		30	0.394	0.343	0.369	0.373
		45	0.407	0.349	0.375	0.379
Spring Banded Conventional Urea	3	0	0.344	0.355	0.376	0.369
		15	0.369	0.350	0.390	0.407
		30	0.389	0.353	0.398	0.417
		45	0.400	0.354	0.397	0.438
Control	4	0	0.346	0.359	0.376	0.366
		15	0.359	0.354	0.381	0.384
		30	0.376	0.357	0.388	0.366
		45	0.374	0.351	0.381	0.378
Fall Banded NBPT-DCD Urea	4	0	0.355	0.361	0.375	0.385
		15	0.381	0.376	0.399	0.385
		30	0.417	0.365	0.402	0.400
		45	0.421	0.359	0.407	0.411
Fall Banded Conventional Urea	4	0	0.356	0.355	0.373	0.368
		15	0.366	0.352	0.384	0.365
		30	0.376	0.352	0.390	0.393
		45	0.356	0.358	0.394	0.391
Fall Banded Calcium Nitrate	4	0	0.349	0.365	0.377	0.375
		15	0.361	0.357	0.389	0.371
		30	0.364	0.347	0.376	0.374
		45	0.375	0.359	0.376	0.371
Spring Banded Conventional Urea	4	0	0.351	0.356	0.385	0.398
		15	0.367	0.363	0.494	0.732
		30	0.378	0.373	0.557	0.981
		45	0.385	0.373	0.595	1.120

Table B.10 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			May 30	June 2	June 8	June 11
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.376	0.380	0.371	0.373
		15	0.375	0.389	0.374	0.379
		30	0.374	0.375	0.378	0.379
		45	0.369	0.375	0.367	0.376
Fall Banded NBPT-DCD Urea	1	0	0.365	0.374	0.374	0.379
		15	0.373	0.379	0.378	0.381
		30	0.363	0.378	0.387	0.396
		45	0.366	0.371	0.383	0.390
Fall Banded Conventional Urea	1	0	0.371	0.372		0.378
		15	0.359	0.445	0.367	0.382
		30	0.381	0.380	0.373	0.387
		45	0.367	0.377	0.384	0.385
Fall Banded Calcium Nitrate	1	0	0.365	0.385	0.375	0.378
		15	0.362	0.389	0.374	0.382
		30	0.371	0.382	0.370	0.382
		45	0.375	0.383	0.369	0.383
Spring Banded Conventional Urea	1	0	0.369	0.372	0.393	0.376
		15	0.410	0.389	0.407	0.376
		30	0.409	0.544	0.436	0.388
		45	0.409	0.557	0.444	0.380
Control	2	0	0.353	0.377	0.374	0.377
		15	0.374	0.369	0.377	0.380
		30	0.362	0.369	0.373	0.375
		45	0.375	0.377	0.368	0.373
Fall Banded NBPT-DCD Urea	2	0	0.376	0.376	0.368	0.376
		15	0.383	0.373	0.378	0.375
		30	0.371	0.375	0.368	0.376
		45	0.377	0.378	0.375	0.389
Fall Banded Conventional Urea	2	0	0.362	0.376	0.381	0.379
		15	0.384	0.386	0.381	0.389
		30	0.371	0.388	0.396	0.398
		45	0.384	0.406	0.387	0.410
Fall Banded Calcium Nitrate	2	0	0.371	0.372	0.372	0.380
		15	0.368	0.371	0.383	0.384
		30	0.362	0.373	0.380	0.378
		45	0.366	0.377	0.378	0.387
Spring Banded Conventional Urea	2	0	0.382	0.383	0.378	0.388
		15	0.399	0.396	0.386	0.411
		30	0.414	0.402	0.395	0.410
		45	0.424	0.396	0.378	0.436

Table B.10 (cont'd.). Concentrations of nitrous oxide emitted at Oak Bluff during spring 2007.

Site and treatment			Spring 2007			
Oak Bluff	Rep	Time	Date			
			May 30	June 2	June 8	June 11
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.362	0.368	0.370	0.380
		15	0.383	0.376	0.374	0.376
		30	0.378	0.386	0.369	0.388
		45	0.382	0.404	0.373	0.384
Fall Banded NBPT-DCD Urea	3	0	0.380	0.376	0.377	0.387
		15	0.373	0.369	0.371	0.391
		30	0.363	0.382	0.375	0.389
		45	0.361	0.452	0.381	0.377
Fall Banded Conventional Urea	3	0	0.366	0.378	0.382	0.387
		15	0.374	0.382	0.373	0.380
		30	0.385	0.387	0.371	0.386
		45	0.380	0.399	0.380	0.388
Fall Banded Calcium Nitrate	3	0	0.378	0.371	0.377	0.370
		15	0.382	0.373	0.373	0.382
		30	0.370	0.389	0.372	0.375
		45	0.377	0.395	0.374	0.378
Spring Banded Conventional Urea	3	0	0.370	0.366	0.369	0.380
		15	0.397	0.395	0.378	0.380
		30	0.403	0.424	0.375	0.386
		45	0.401	0.428	0.377	0.395
Control	4	0	0.378	0.356	0.379	0.381
		15	0.385	0.375	0.375	0.382
		30	0.395	0.382	0.372	0.385
		45	0.371	0.396	0.372	0.382
Fall Banded NBPT-DCD Urea	4	0	0.365	0.380	0.380	0.380
		15	0.383	0.388	0.370	0.380
		30	0.373	0.410	0.371	0.391
		45	0.384	0.437	0.377	0.388
Fall Banded Conventional Urea	4	0	0.374	0.367	0.376	0.381
		15	0.383	0.376	0.375	0.391
		30	0.372	0.388	0.369	0.394
		45	0.360	0.404	0.377	0.379
Fall Banded Calcium Nitrate	4	0	0.366	0.369	0.448	0.473
		15	0.374	0.373	0.371	0.379
		30	0.378	0.376	0.370	0.383
		45	0.368	0.382	0.372	0.375
Spring Banded Conventional Urea	4	0	0.385	0.383	0.373	0.371
		15	0.505	0.537	0.379	0.552
		30	0.564	0.678	0.412	0.610
		45	0.600	0.730	0.437	0.385

Table B.11. Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			April 10	April 13	April 17	April 20
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.361	0.367	0.353	0.352
		15	0.358	0.554	0.393	0.355
		30	0.377	0.662	0.391	0.357
		45	0.359	0.554	0.389	0.355
Fall Banded NBPT-DCD Urea	1	0	0.355	0.388	0.358	0.361
		15	0.391	1.113	0.389	0.372
		30	0.396	1.372	0.375	0.385
		45	0.388	0.747	0.367	0.402
Fall Banded Conventional Urea	1	0	0.345	0.360	0.342	0.348
		15	0.365	0.480	0.401	0.372
		30	0.368	0.533	0.402	0.362
		45	0.371	0.418	0.381	0.369
Fall Banded Calcium Nitrate	1	0	0.360	0.368	0.356	0.360
		15	0.375	0.387	0.432	0.358
		30	0.370	0.410	0.473	0.368
		45	0.371	0.432	0.458	0.352
Spring Banded Conventional Urea	1	0	0.356	0.368	0.343	0.353
		15	0.364	0.400	0.463	0.384
		30	0.363	0.428	0.539	0.384
		45	0.355	0.364	0.548	0.378
Control	2	0	0.353	0.370	0.338	0.358
		15	0.365	0.503	0.370	0.370
		30	0.360	0.514	0.358	0.360
		45	0.351	1.325	0.328	0.360
Fall Banded NBPT-DCD Urea	2	0	0.362	0.388	0.344	0.361
		15	0.397	1.220	0.379	0.378
		30	0.397	1.994	0.393	0.388
		45	0.379	0.496	0.368	0.381
Fall Banded Conventional Urea	2	0	0.362	0.428	0.353	0.359
		15	0.365	0.370	0.371	0.364
		30	0.362	0.532	0.347	0.377
		45	0.368	0.445	0.365	0.371
Fall Banded Calcium Nitrate	2	0	0.362	0.368	0.348	0.360
		15	0.437	2.536	0.368	0.392
		30	0.463	3.342	0.361	0.362
		45	0.483	0.485	0.353	0.373
Spring Banded Conventional Urea	2	0	0.362	0.363	0.344	0.349
		15	0.370	0.429	0.368	0.369
		30	0.377	0.468	0.367	0.360
		45	0.363	2.326	0.359	0.368

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			April 10	April 13	April 17	April 20
			μL N_2O L^{-1}			
Control	3	0	0.364	0.373	0.347	0.353
		15	0.480	0.501	0.486	0.396
		30	0.531	0.981	0.517	0.380
		45	0.563	1.313	0.529	0.366
Fall Banded NBPT-DCD Urea	3	0	0.364	0.358	0.349	0.343
		15	0.372	0.597	0.365	0.358
		30	0.359	0.417	0.378	0.352
		45	0.363	0.430	0.366	0.351
Fall Banded Conventional Urea	3	0	0.347	5.431	0.365	0.361
		15	0.367	0.356	0.389	0.355
		30	0.365	0.492	0.371	0.351
		45	0.369	0.427	0.360	0.356
Fall Banded Calcium Nitrate	3	0	0.362	0.378	0.356	0.353
		15	0.433	0.458	0.433	0.361
		30	0.444	0.747	0.401	0.361
		45	0.453	0.981	0.412	0.350
Spring Banded Conventional Urea	3	0	0.345	0.371	0.349	0.353
		15	0.379	0.523	0.393	0.360
		30	0.388	0.530	0.386	0.355
		45	0.390	0.526	0.376	0.355
Control	4	0	0.366	0.345	0.337	0.364
		15	0.393	0.406	0.469	0.395
		30	0.373	0.373	0.476	0.392
		45	0.389	0.386	0.466	0.408
Fall Banded NBPT-DCD Urea	4	0	0.351	0.358	0.352	0.353
		15	0.381	0.555	0.541	0.376
		30	0.383	0.382	0.622	0.374
		45	0.382	0.417	0.617	0.378
Fall Banded Conventional Urea	4	0	0.367	0.363	0.344	0.356
		15	0.449	0.369	0.552	0.409
		30	0.463	0.790	0.550	0.378
		45	0.477	0.792	0.539	0.381
Fall Banded Calcium Nitrate	4	0	0.356	0.364	0.363	0.358
		15	0.388	0.386	0.518	0.379
		30	0.398	0.699	0.481	0.369
		45	0.391	0.689	0.483	0.354
Spring Banded Conventional Urea	4	0	0.360	0.374	0.349	0.349
		15	0.404	0.812	0.433	0.368
		30	0.410	0.424	0.449	0.359
		45	0.413	0.527	0.428	0.354

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			April 25	April 27	May 1	May 4
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.350	0.361	0.361	0.368
		15	0.361	0.376	0.367	0.361
		30	0.362	0.382	0.362	0.370
		45	0.362	0.379	0.356	0.368
Fall Banded NBPT-DCD Urea	1	0	0.362	0.363	0.356	0.418
		15	0.368	0.367	0.365	0.369
		30	0.378	0.368	0.371	0.364
		45	0.359	0.371	0.355	0.360
Fall Banded Conventional Urea	1	0	0.358	0.365	0.363	0.370
		15	0.354	0.371	0.366	0.361
		30	0.367	0.380	0.366	0.366
		45	0.353	0.379	0.374	0.375
Fall Banded Calcium Nitrate	1	0	0.356	0.367	0.362	0.369
		15	0.355	0.364	0.358	0.361
		30	0.356	0.373	0.365	0.363
		45	0.360	0.381	0.359	0.363
Spring Banded Conventional Urea	1	0	0.354	0.362	0.362	0.360
		15	0.373	0.383	0.360	0.359
		30	0.368	0.374	0.364	0.368
		45	0.362	0.383	0.361	0.370
Control	2	0	0.357	0.358	0.365	0.408
		15	0.362	0.366	0.358	0.371
		30	0.366	0.357	0.369	0.356
		45	0.358	0.365	0.365	0.371
Fall Banded NBPT-DCD Urea	2	0	0.362	0.365	0.366	0.374
		15	0.384	0.380	0.362	0.367
		30	0.367	0.376	0.370	0.365
		45	0.368	0.381	0.361	0.361
Fall Banded Conventional Urea	2	0	0.353	0.364	0.370	0.362
		15	0.363	0.371	0.362	0.366
		30	0.360	0.370	0.365	0.361
		45	0.362	0.369	0.366	0.360
Fall Banded Calcium Nitrate	2	0	0.357	0.362	0.350	0.360
		15	0.389	0.406	0.369	0.370
		30	0.372	0.399	0.374	0.369
		45	0.367	0.396	0.370	0.366
Spring Banded Conventional Urea	2	0	0.361	0.360	0.363	0.379
		15	0.371	0.361	0.365	0.361
		30	0.373	0.365	0.363	0.368
		45	0.366	0.362	0.362	0.359

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			April 25	April 27	May 1	May 4
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.371	0.353	0.361	0.365
		15	0.403	0.391	0.382	0.360
		30	0.406	0.405	0.385	0.366
		45	0.385	0.403	0.384	0.366
Fall Banded NBPT-DCD Urea	3	0	0.349	0.358	0.364	0.359
		15	0.357	0.368	0.369	0.366
		30	0.361	0.369	0.368	0.369
		45	0.355	0.362	0.362	0.363
Fall Banded Conventional Urea	3	0	0.350	0.369	0.362	0.376
		15	0.366	0.404	0.381	0.397
		30	0.358	0.398	0.375	0.392
		45	0.355	0.391	0.378	0.395
Fall Banded Calcium Nitrate	3	0	0.355	0.357	0.365	0.371
		15	0.364	0.384	0.370	0.364
		30	0.361	0.386	0.377	0.357
		45	0.363	0.378	0.366	0.363
Spring Banded Conventional Urea	3	0	0.354	0.368	0.363	0.357
		15	0.367	0.391	0.375	0.364
		30	0.369	0.380	0.366	0.368
		45	0.354	0.393	0.373	0.365
Control	4	0	0.358	0.364	0.352	0.357
		15	0.380	0.381	0.351	0.361
		30	0.377	0.371	0.360	0.369
		45	0.369	0.378	0.369	0.366
Fall Banded NBPT-DCD Urea	4	0	0.353	0.362	0.352	0.366
		15	0.395	0.392	0.365	0.363
		30	0.383	0.408	0.368	0.372
		45	0.376	0.408	0.381	0.361
Fall Banded Conventional Urea	4	0	0.354	0.371	0.369	0.364
		15	0.365	0.421	0.385	0.373
		30	0.360	0.423	0.387	0.366
		45	0.349	0.428	0.390	0.364
Fall Banded Calcium Nitrate	4	0	0.363	0.370	0.360	0.363
		15	0.383	0.393	0.368	0.370
		30	0.379	0.395	0.364	0.367
		45	0.370	0.395	0.366	0.366
Spring Banded Conventional Urea	4	0	0.357	0.367	0.363	0.372
		15	0.356	0.373	0.375	0.364
		30	0.362	0.364	0.365	0.363
		45	0.353	0.362	0.363	0.356

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			May 8	May 11	June 5	June 8
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.350	0.362	0.393	0.372
		15	0.359	0.367	0.395	0.382
		30	0.359	0.368	0.379	0.385
		45	0.353	0.365	0.382	0.375
Fall Banded NBPT-DCD Urea	1	0	0.351	0.362	0.398	0.412
		15	0.364	0.360	0.386	0.386
		30	0.373	0.376	0.367	0.371
		45	0.357	0.368	0.377	0.373
Fall Banded Conventional Urea	1	0	0.349	0.361	0.397	0.377
		15	0.358	0.378	0.370	0.379
		30	0.356	0.367	0.364	0.380
		45	0.361	0.377	0.360	0.376
Fall Banded Calcium Nitrate	1	0	0.359	0.360	0.361	0.376
		15	0.355	0.482	0.371	0.381
		30	0.357	0.363	0.408	0.386
		45	0.359	0.366	0.368	0.379
Spring Banded Conventional Urea	1	0	0.355	0.361	0.358	0.365
		15	0.367	0.386	0.390	0.380
		30	0.368	0.369	0.374	0.375
		45	0.369	0.374	0.371	0.373
Control	2	0	0.360	0.361	0.384	0.383
		15	0.366	0.367	0.377	0.376
		30	0.369	0.369	0.380	0.377
		45	0.350	0.374	0.374	0.381
Fall Banded NBPT-DCD Urea	2	0	0.358	0.393	0.362	0.374
		15	0.368	0.366	0.372	0.377
		30	0.371	0.372	0.368	0.377
		45	0.375	0.379	0.361	0.375
Fall Banded Conventional Urea	2	0	0.355	0.361	0.386	0.378
		15	0.352	0.373	0.401	0.387
		30	0.350	0.373	0.372	0.376
		45	0.357	0.381	0.375	0.378
Fall Banded Calcium Nitrate	2	0	0.362	0.364	0.373	0.377
		15	0.402	0.368	0.365	0.381
		30	0.390	0.368	0.363	0.374
		45	0.385	0.365	0.377	0.376
Spring Banded Conventional Urea	2	0	0.346	0.357	0.383	0.393
		15	0.374	0.394	0.376	0.383
		30	0.370	0.391	0.353	0.379
		45	0.358	0.377	0.368	0.380

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			May 8	May 11	June 5	June 8
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.361	0.372	0.370	0.375
		15	0.376	0.382	0.383	0.377
		30	0.372	0.382	0.432	0.377
		45	0.364	0.391	0.378	0.376
Fall Banded NBPT-DCD Urea	3	0	0.351	0.370	0.388	0.379
		15	0.354	0.376	0.369	0.374
		30	0.353	0.372	0.367	0.381
		45	0.357	0.385	0.372	0.374
Fall Banded Conventional Urea	3	0	0.353	0.376	0.390	0.373
		15	0.362	0.367	0.364	0.374
		30	0.358	0.394	0.390	0.374
		45	0.356	0.422	0.351	0.386
Fall Banded Calcium Nitrate	3	0	0.349	0.372	0.378	0.378
		15	0.357	0.373	0.375	0.368
		30	0.349	0.383	0.395	0.377
		45	0.357	0.386	0.381	0.378
Spring Banded Conventional Urea	3	0	0.356	0.369	0.412	0.378
		15	0.362	0.378	0.399	0.372
		30	0.357	0.384	0.366	0.377
		45	0.366	0.394	0.382	0.379
Control	4	0	0.352	0.374	0.371	0.380
		15	0.360	0.404	0.367	0.382
		30	0.353	0.372	0.386	0.377
		45	0.361	0.378	0.373	0.380
Fall Banded NBPT-DCD Urea	4	0	0.366	0.376	0.410	0.381
		15	0.447	0.388	0.415	0.377
		30	0.493	0.385	0.374	0.376
		45	0.475	0.395	0.378	0.377
Fall Banded Conventional Urea	4	0	0.356	0.367	0.400	0.381
		15	0.370	0.389	0.411	0.382
		30	0.359	0.391	0.388	0.381
		45	0.359	0.386	0.408	0.387
Fall Banded Calcium Nitrate	4	0	0.352	0.363	0.385	0.373
		15	0.356	0.375	0.366	0.378
		30	0.355	0.387	0.368	0.374
		45	0.360	0.387	0.374	0.382
Spring Banded Conventional Urea	4	0	0.340	0.370	0.398	0.376
		15	0.355	0.369	0.365	0.377
		30	0.359	0.376	0.364	0.379
		45	0.360	0.384	0.397	0.379

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			June 11	June 14	June 16	June 19
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.366	0.369	0.378	0.387
		15	0.417	0.426	0.370	0.356
		30	0.419	0.444	0.385	0.322
		45	0.449	0.475	0.379	0.360
Fall Banded NBPT-DCD Urea	1	0	0.364	0.381	0.373	0.344
		15	0.380	0.381	0.377	0.379
		30	0.387	0.388	0.376	0.338
		45	0.401	0.412	0.394	0.369
Fall Banded Conventional Urea	1	0	0.362	0.370	0.379	0.350
		15	0.372	0.387	0.369	0.361
		30	0.371	0.336	0.390	0.357
		45	0.394	0.415	0.373	0.344
Fall Banded Calcium Nitrate	1	0	0.369	0.365	0.380	0.369
		15	0.449	0.375	0.382	0.335
		30	0.483	0.383	0.401	0.348
		45	0.487	0.390	0.421	0.356
Spring Banded Conventional Urea	1	0	0.373	0.362	0.373	0.364
		15	0.379	0.392	0.379	0.361
		30	0.381	0.405	0.394	0.352
		45	0.367	0.426	0.392	0.349
Control	2	0	0.368	0.366	0.370	0.348
		15	0.392	0.382	0.383	0.334
		30	0.381	0.397	0.395	0.355
		45	0.391	0.408	0.422	0.356
Fall Banded NBPT-DCD Urea	2	0	0.364	0.363	0.368	0.371
		15	0.374	0.375	0.382	0.336
		30	0.376	0.374	0.389	0.351
		45	0.382	0.376	0.385	0.352
Fall Banded Conventional Urea	2	0	0.359	0.365	0.365	0.376
		15	0.389	0.485	0.426	0.346
		30	0.387	0.518	0.467	0.333
		45	0.384	0.549	0.481	0.370
Fall Banded Calcium Nitrate	2	0	0.365	0.367	0.357	0.342
		15	0.366	0.380	0.374	0.356
		30	0.374	0.373	0.370	0.364
		45	0.362	0.371	0.368	0.351
Spring Banded Conventional Urea	2	0	0.375	0.377	0.376	0.355
		15	0.393	0.391	0.418	0.349
		30	0.385	0.400	0.405	0.356
		45	0.398	0.390	0.415	0.365

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007			
Brandon	Rep	Time	Date			
			June 11	June 14	June 16	June 19
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.377	0.411	0.378	0.357
		15	0.378	0.410	0.386	0.342
		30	0.374	0.394	0.393	0.382
		45	0.377	0.402	0.395	0.364
Fall Banded NBPT-DCD Urea	3	0	0.376	0.399	0.366	0.364
		15	0.378	0.408	0.384	0.361
		30	0.379	0.396	0.390	0.353
		45	0.382	0.482	0.390	0.358
Fall Banded Conventional Urea	3	0	0.379	0.400	0.365	0.357
		15	0.377	0.399	0.372	0.335
		30	0.381	0.391	0.366	0.359
		45	0.372	0.397	0.373	0.343
Fall Banded Calcium Nitrate	3	0	0.376	0.423	0.367	0.354
		15	0.371	0.402	0.398	0.347
		30	0.389	0.381	0.388	0.364
		45	0.378	0.401	0.392	0.349
Spring Banded Conventional Urea	3	0	0.381	0.398	0.375	0.378
		15	0.389	0.414	0.457	0.367
		30	0.376	0.398	0.477	0.358
		45	0.386	0.394	0.506	0.372
Control	4	0	0.375	0.402	0.371	0.346
		15	0.382	0.407	0.378	0.353
		30	0.389	0.423	0.388	0.358
		45	0.404	0.404	0.391	0.356
Fall Banded NBPT-DCD Urea	4	0	0.381	0.397	0.373	0.333
		15	0.377	0.400	0.381	0.364
		30	0.376	0.399	0.379	0.365
		45	0.378	0.402	0.361	0.372
Fall Banded Conventional Urea	4	0	0.378	0.403	0.367	0.373
		15	0.380	0.395	0.399	0.339
		30	0.377	0.429	0.420	0.358
		45	0.381	0.459	0.419	0.371
Fall Banded Calcium Nitrate	4	0	0.378	0.401	0.370	0.376
		15	0.367	0.401	0.381	0.322
		30	0.376	0.396	0.376	0.360
		45	0.387	0.411	0.363	0.366
Spring Banded Conventional Urea	4	0	0.366	0.400	0.368	0.359
		15	0.381	0.405	0.433	0.353
		30	0.393	0.444	0.413	0.355
		45	0.388	0.438	0.423	0.367

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007	
Brandon	Rep	Time	Date	
			June 29	July 3
			$\mu L\ N_2O\ L^{-1}$	
Control	1	0	0.399	0.399
		15	0.404	0.397
		30	0.407	0.390
		45	0.408	0.405
Fall Banded NBPT-DCD Urea	1	0	0.398	0.394
		15	0.404	0.389
		30	0.403	0.398
		45	0.401	0.403
Fall Banded Conventional Urea	1	0	0.398	0.395
		15	0.406	0.396
		30	0.404	0.396
		45	0.398	0.395
Fall Banded Calcium Nitrate	1	0	0.409	0.395
		15	0.408	0.400
		30	0.412	0.399
		45	0.400	0.401
Spring Banded Conventional Urea	1	0	0.405	0.398
		15	0.399	0.399
		30	0.400	0.394
		45	0.396	0.398
Control	2	0	0.405	0.398
		15	0.411	0.392
		30	0.412	0.398
		45	0.410	0.399
Fall Banded NBPT-DCD Urea	2	0	0.401	0.393
		15	0.402	0.387
		30	0.412	0.398
		45	0.406	0.398
Fall Banded Conventional Urea	2	0	0.402	0.396
		15	0.405	0.399
		30	0.409	0.396
		45	0.406	0.395
Fall Banded Calcium Nitrate	2	0	0.406	0.394
		15	0.407	0.392
		30	0.406	0.404
		45	0.397	0.394
Spring Banded Conventional Urea	2	0	0.403	0.401
		15	0.406	0.401
		30	0.407	0.401
		45	0.407	0.401

Table B.11 (cont'd.). Concentrations of nitrous oxide emitted at Brandon during spring 2007.

Site and treatment			Spring 2007	
Brandon	Rep	Time	Date	
			June 29	July 3
			$\mu L\ N_2O\ L^{-1}$	
Control	3	0	0.390	0.383
		15	0.392	0.393
		30	0.392	0.391
		45	0.389	0.394
Fall Banded NBPT-DCD Urea	3	0	0.397	0.392
		15	0.392	0.393
		30	0.389	0.397
		45	0.393	0.396
Fall Banded Conventional Urea	3	0	0.400	0.394
		15	0.396	0.391
		30	0.389	0.395
		45	0.393	0.389
Fall Banded Calcium Nitrate	3	0	0.394	0.388
		15	0.394	0.392
		30	0.391	0.391
		45	0.391	0.394
Spring Banded Conventional Urea	3	0	0.403	0.391
		15	0.394	0.390
		30	0.393	0.399
		45	0.399	0.390
Control	4	0	0.396	0.393
		15	0.390	0.391
		30	0.393	0.395
		45	0.397	0.389
Fall Banded NBPT-DCD Urea	4	0	0.392	0.388
		15	0.399	0.391
		30	0.391	0.392
		45	0.394	0.403
Fall Banded Conventional Urea	4	0	0.391	0.392
		15	0.388	0.397
		30	0.397	0.396
		45	0.393	0.399
Fall Banded Calcium Nitrate	4	0	0.392	0.392
		15	0.386	0.398
		30	0.398	0.393
		45	0.398	0.393
Spring Banded Conventional Urea	4	0	0.397	0.394
		15	0.401	0.391
		30	0.387	0.399
		45	0.401	0.392

Table B.12. Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007			
Indian Head	Rep	Time	Date			
			Mar.24	Mar. 26	Mar. 31	April 9
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.367	0.365	0.322	0.345
		15	1.165	0.439	0.353	0.346
		30	1.715	0.414	0.356	0.351
		45	1.775	0.477	0.343	0.358
Fall Banded NBPT-DCD Urea	1	0	0.358	0.361	0.323	0.349
		15	0.864	0.520	0.338	0.356
		30	1.251	0.545	0.338	0.360
		45	1.616	0.457	0.331	0.365
Fall Banded Conventional Urea	1	0	0.364	0.355	0.315	0.348
		15	1.317	0.454	0.347	0.353
		30	1.839	0.436	0.351	0.357
		45	2.142	0.441	0.378	0.359
Fall Banded Calcium Nitrate	1	0	0.359	0.357	0.315	0.346
		15	1.120	0.364	0.336	0.349
		30	1.291	0.369	0.325	0.350
		45	1.050	0.363	0.325	0.350
Spring Banded Conventional Urea	1	0	0.356	0.359	0.326	0.348
		15	1.156	0.444	0.364	0.351
		30	1.788	0.420	0.386	0.359
		45	1.999	0.425	0.379	0.360
Control	2	0	0.355	0.358	0.316	0.357
		15	0.916	0.420	0.326	0.345
		30	1.324	0.410	0.330	0.354
		45	1.351	0.426	0.333	0.351
Fall Banded NBPT-DCD Urea	2	0	0.372	0.363	0.321	0.344
		15	1.044	0.445	0.340	0.362
		30	1.700	0.433	0.347	0.359
		45	1.612	0.400	0.362	0.347
Fall Banded Conventional Urea	2	0	0.363	0.359	0.320	0.352
		15	0.786	0.625	0.366	0.359
		30	0.847	0.557	0.376	0.353
		45	0.834	0.566	0.381	0.352
Fall Banded Calcium Nitrate	2	0	0.363	0.360	0.324	0.352
		15	0.702	0.443	0.344	0.359
		30	0.876	0.426	0.341	0.353
		45	0.953	0.392	0.343	0.357
Spring Banded Conventional Urea	2	0	0.358	0.349	0.329	0.354
		15	0.499	0.364	0.331	0.355
		30	0.545	0.369	0.327	0.352
		45	0.567	0.367	0.331	0.356

Table B.12 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007			
Indian Head	Rep	Time	Date			
			Mar. 24	Mar. 26	Mar. 31	April 9
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.357	0.359	0.318	0.356
		15	0.371	0.361	0.324	0.359
		30	0.373	0.367	0.329	0.356
		45	0.378	0.378	0.322	0.365
Fall Banded NBPT-DCD Urea	3	0	0.355	0.367	0.319	0.361
		15	0.392	0.359	0.328	0.359
		30	0.398	0.365	0.316	0.362
		45	0.417	0.363	0.335	0.367
Fall Banded Conventional Urea	3	0	0.372	0.361	0.323	0.355
		15	0.588	0.368	0.321	0.362
		30	0.729	0.369	0.326	0.356
		45	0.879	0.366	0.333	0.366
Fall Banded Calcium Nitrate	3	0	0.359	0.364	0.314	0.355
		15	0.568	0.365	0.322	0.356
		30	0.650	0.368	0.321	0.354
		45	0.705	0.366	0.324	0.365
Spring Banded Conventional Urea	3	0	0.364	0.357	0.321	0.348
		15	0.377	0.367	0.317	0.360
		30	0.372	0.356	0.321	0.368
		45	0.375	0.364	0.325	0.357
Control	4	0	0.374	0.359	0.320	0.366
		15	1.961	0.450	0.374	0.359
		30	3.809	0.495	0.399	0.358
		45	4.043	0.555	0.406	0.368
Fall Banded NBPT-DCD Urea	4	0	0.363	0.363	0.321	0.359
		15	1.799	0.426	0.359	0.361
		30	2.061	0.442	0.382	0.368
		45	2.714	0.496	0.375	0.365
Fall Banded Conventional Urea	4	0	0.366	0.358	0.320	0.356
		15	1.604	0.385	0.349	0.362
		30	1.887	0.435	0.358	0.363
		45	2.281	0.449	0.363	0.366
Fall Banded Calcium Nitrate	4	0	0.365	0.361	0.333	0.355
		15	1.065	0.383	0.327	0.358
		30	1.623	0.399	0.327	0.362
		45	1.881	0.425	0.331	0.358
Spring Banded Conventional Urea	4	0	0.363	0.355	0.318	0.355
		15	1.068	0.406	0.353	0.372
		30	1.986	0.473	0.397	0.358
		45	2.037	0.560	0.425	0.368

Table B.12 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007			
Indian Head	Rep	Time	Date			
			April 14	April 18	April 27	April 29
			$\mu L\ N_2O\ L^{-1}$			
Control	1	0	0.361	0.432	0.359	0.365
		15	0.353	0.377	0.361	0.365
		30	0.354	0.452	0.365	0.361
		45	0.354	0.400	0.373	0.380
Fall Banded NBPT-DCD Urea	1	0	0.350	0.355	0.364	0.366
		15	0.346	0.376	0.361	0.376
		30	0.350	0.370	0.372	0.351
		45	0.345	0.421	0.371	0.403
Fall Banded Conventional Urea	1	0	0.349	0.367	0.363	0.372
		15	0.347	0.366	0.367	0.399
		30	0.357	0.374	0.405	0.362
		45	0.345	0.387	0.402	0.363
Fall Banded Calcium Nitrate	1	0	0.346	0.367	0.364	0.371
		15	0.348	0.424	0.367	0.375
		30	0.356	0.383	0.360	0.368
		45	0.359	0.369	0.361	0.416
Spring Banded Conventional Urea	1	0	0.347	0.375	0.354	0.368
		15	0.352	0.375	0.357	0.371
		30	0.357	0.364	0.376	0.368
		45	0.351	0.382	0.374	0.385
Control	2	0	0.351	0.364	0.366	0.359
		15	0.362	0.406	0.369	0.376
		30	0.351	0.521	0.365	0.372
		45	0.352	0.354	0.368	0.373
Fall Banded NBPT-DCD Urea	2	0	0.355	0.379	0.352	0.365
		15	0.353	0.499	0.361	0.377
		30	0.347	0.409	0.373	0.371
		45	0.355	0.456	0.360	0.391
Fall Banded Conventional Urea	2	0	0.347	0.369	0.360	0.366
		15	0.356	0.376	0.376	0.393
		30	0.355	0.388	0.383	0.368
		45	0.357	0.371	0.385	0.371
Fall Banded Calcium Nitrate	2	0	0.355	0.385	0.362	0.360
		15	0.359	0.373	0.367	0.375
		30	0.349	0.380	0.366	0.373
		45	0.364	0.392	0.371	0.385
Spring Banded Conventional Urea	2	0	0.358	0.379	0.361	0.363
		15	0.354	0.391	0.366	0.372
		30	0.351	0.370	0.359	0.370
		45	0.357	0.360	0.365	0.384

Table B.12 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007			
Indian Head	Rep	Time	Date			
			April 14	April 18	April 27	April 29
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.361	0.359	0.365	0.385
		15	0.360	0.360	0.378	0.382
		30	0.355	0.352	0.376	0.390
		45	0.370	0.350	0.372	0.395
Fall Banded NBPT-DCD Urea	3	0	0.356	0.355	0.371	0.374
		15	0.353	0.357	0.405	0.370
		30	0.363	0.350	0.412	0.421
		45	0.355	0.349	0.435	0.481
Fall Banded Conventional Urea	3	0	0.359	0.361	0.372	0.389
		15	0.358	0.360	0.398	0.389
		30	0.348	0.358	0.408	0.425
		45	0.352	0.360	0.411	0.435
Fall Banded Calcium Nitrate	3	0	0.353	0.361	0.373	0.371
		15	0.357	0.351	0.373	0.373
		30	0.354	0.360	0.368	0.375
		45	0.354	0.357	0.377	0.370
Spring Banded Conventional Urea	3	0	0.359	0.358	0.374	0.416
		15	0.353	0.361	0.367	0.442
		30	0.353	0.364	0.358	0.372
		45	0.357	0.355	0.368	0.381
Control	4	0	0.360	0.361	0.366	0.370
		15	0.356	0.361	0.370	0.375
		30	0.359	0.358	0.376	0.391
		45	0.354	0.360	0.383	0.729
Fall Banded NBPT-DCD Urea	4	0	0.360	0.355	0.363	0.380
		15	0.365	0.349	0.386	0.386
		30	0.369	0.358	0.379	0.395
		45	0.354	0.355	0.379	0.423
Fall Banded Conventional Urea	4	0	0.361	0.361	0.367	0.376
		15	0.352	0.359	0.383	0.384
		30	0.352	0.354	0.394	0.409
		45	0.357	0.351	0.396	0.440
Fall Banded Calcium Nitrate	4	0	0.372	0.366	0.374	0.397
		15	0.356	0.351	0.371	0.400
		30	0.367	0.360	0.375	0.383
		45	0.358	0.357	0.377	0.385
Spring Banded Conventional Urea	4	0	0.359	0.364	0.363	0.365
		15	0.351	0.356	0.376	0.375
		30	0.357	0.351	0.386	0.398
		45	0.368	0.353	0.378	0.749

Table B.12 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007			
Indian Head	Rep	Time	Date			
			May 5	May 16	May 18	May 25
			μL N_2O L^{-1}			
Control	1	0	0.374	0.355	0.369	0.364
		15	0.373	0.350	0.372	0.378
		30	0.369	0.369	0.368	0.384
		45	0.373	0.382	0.371	0.387
Fall Banded NBPT-DCD Urea	1	0	0.367	0.354	0.349	0.378
		15	0.373	0.378	0.375	0.372
		30	0.385	0.395	0.364	0.369
		45	0.375	0.391	0.384	0.409
Fall Banded Conventional Urea	1	0	0.372	0.349	0.361	0.372
		15	0.389	0.376	0.385	0.376
		30	0.390	0.399	0.391	0.389
		45	0.393	0.425	0.385	0.399
Fall Banded Calcium Nitrate	1	0	0.377	0.360	0.369	0.365
		15	0.376	0.353	0.365	0.370
		30	0.373	0.357	0.369	0.367
		45	0.369	0.353	0.362	0.379
Spring Banded Conventional Urea	1	0	0.371	0.355	0.348	0.364
		15	0.375	0.405	0.394	0.403
		30	0.365	0.424	0.392	0.422
		45		0.445	0.384	0.453
Control	2	0	0.373	0.352	0.355	0.370
		15	0.370	0.358	0.362	0.371
		30	0.366	0.364	0.364	0.373
		45	0.373	0.375	0.363	0.376
Fall Banded NBPT-DCD Urea	2	0	0.364	0.358	0.368	0.365
		15	0.380	0.362	0.372	0.366
		30	0.380	0.373	0.380	0.388
		45	0.381	0.382	0.362	0.387
Fall Banded Conventional Urea	2	0	0.367	0.361	0.360	0.371
		15	0.371	0.360	0.374	0.374
		30	0.380	0.368	0.386	0.386
		45	0.380	0.348	0.383	0.375
Fall Banded Calcium Nitrate	2	0	0.374	0.358	0.348	0.366
		15	0.374	0.362	0.364	0.378
		30	0.372	0.366	0.366	0.375
		45	0.379	0.379	0.363	0.419
Spring Banded Conventional Urea	2	0	0.363	0.356	0.368	0.372
		15	0.377	0.452	0.402	0.411
		30	0.366	0.521	0.414	0.448
		45		0.553	0.408	0.443

Table B.12 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007			
Indian Head	Rep	Time	Date			
			May 5	May 16	May 18	May 25
			$\mu L\ N_2O\ L^{-1}$			
Control	3	0	0.366	0.344	0.354	0.371
		15	0.368	0.408	0.360	0.368
		30	0.372	0.357	0.354	0.375
		45	0.371	0.386	0.358	0.381
Fall Banded NBPT-DCD Urea	3	0	0.364	0.356	0.365	0.370
		15	0.381	0.369	0.353	0.370
		30	0.381	0.372	0.369	0.385
		45	0.392	0.363	0.389	0.382
Fall Banded Conventional Urea	3	0	0.372	0.349	0.365	0.373
		15	0.373	0.386	0.363	0.370
		30	0.374	0.387	0.365	0.381
		45	0.373	0.377	0.362	0.380
Fall Banded Calcium Nitrate	3	0	0.371	0.357	0.352	0.370
		15	0.370	0.375	0.361	0.370
		30	0.377	0.365	0.365	0.381
		45	0.372	0.375	0.369	0.377
Spring Banded Conventional Urea	3	0	0.370	0.366	0.440	0.372
		15	0.367	0.370	0.353	0.528
		30	0.361	0.363	0.438	0.671
		45		0.374	0.452	0.758
Control	4	0	0.370	0.362	0.352	0.364
		15	0.368	0.379	0.348	0.370
		30	0.368	0.396	0.366	0.378
		45	0.383	0.341	0.348	0.386
Fall Banded NBPT-DCD Urea	4	0	0.377	0.489	0.352	0.356
		15	0.371	0.457	0.355	0.367
		30	0.376	0.360	0.358	0.428
		45	0.382	0.351	0.357	0.387
Fall Banded Conventional Urea	4	0	0.365	0.354	0.363	0.372
		15	0.385	0.396	0.357	0.372
		30	0.384	0.384	0.360	0.394
		45	0.393	0.369	0.368	0.415
Fall Banded Calcium Nitrate	4	0	0.364	0.354	0.367	0.363
		15	0.369	0.629	0.356	0.416
		30	0.373	0.564	0.370	0.377
		45	0.381	0.487	0.373	0.380
Spring Banded Conventional Urea	4	0	0.363	0.371	0.408	0.374
		15	0.372	0.384	0.348	0.456
		30	0.380	0.371	0.422	0.561
		45		0.369	0.420	0.564

Table B.12 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007		
Indian Head	Rep	Time	Date		
			May 28	May 30	June 2
			$\mu L\ N_2O\ L^{-1}$		
Control	1	0	0.386	0.355	0.378
		15	0.377	0.378	0.379
		30	0.387	0.394	0.380
		45	0.408	0.376	0.397
Fall Banded NBPT-DCD Urea	1	0	0.370	0.391	0.380
		15	0.384	0.373	0.402
		30	0.390	0.372	0.387
		45	0.401	0.391	0.395
Fall Banded Conventional Urea	1	0	0.371	0.365	0.374
		15	0.387	0.368	0.383
		30	0.396	0.370	0.383
		45	0.399	0.371	0.381
Fall Banded Calcium Nitrate	1	0	0.372	0.374	0.373
		15	0.368	0.366	0.367
		30	0.380	0.408	0.358
		45	0.386	0.409	0.373
Spring Banded Conventional Urea	1	0	0.371	0.380	0.389
		15	0.429	0.381	0.424
		30	0.490	0.407	0.463
		45	0.521	0.419	0.487
Control	2	0	0.341	0.374	0.358
		15	0.367	0.373	0.359
		30	0.383	0.410	0.377
		45	0.369	0.370	0.362
Fall Banded NBPT-DCD Urea	2	0	0.370	0.368	0.372
		15	0.386	0.373	0.385
		30	0.398	0.382	0.385
		45	0.436	0.401	0.380
Fall Banded Conventional Urea	2	0	0.372	0.355	0.382
		15	0.381	0.382	0.376
		30	0.378	0.363	0.374
		45	0.375	0.360	0.379
Fall Banded Calcium Nitrate	2	0	0.362	0.361	0.371
		15	0.375	0.380	0.383
		30	0.384	0.393	0.384
		45	0.382	0.385	0.399
Spring Banded Conventional Urea	2	0	0.376	0.373	0.368
		15	0.422	0.376	0.390
		30	0.453	0.398	0.393
		45	0.509	0.391	0.409

Table B.12 (cont'd.). Concentrations of nitrous oxide emitted at Indian Head during spring 2007.

Site and treatment			Spring 2007		
Indian Head	Rep	Time	Date		
			May 28	May 30	June 2
			$\mu L\ N_2O\ L^{-1}$		
Control	3	0	0.355	0.411	0.366
		15	0.365	0.370	0.381
		30	0.374	0.369	0.382
		45	0.384	0.368	0.392
Fall Banded NBPT-DCD Urea	3	0	0.364	0.370	0.361
		15	0.377	0.393	0.371
		30	0.438	0.373	0.391
		45	0.387	0.363	0.385
Fall Banded Conventional Urea	3	0	0.377	0.398	0.367
		15	0.384	0.364	0.377
		30	0.402	0.430	0.396
		45	0.385	0.384	0.393
Fall Banded Calcium Nitrate	3	0	0.412	0.378	0.361
		15	0.395	0.361	0.378
		30	0.369	0.377	0.395
		45	0.357	0.367	0.387
Spring Banded Conventional Urea	3	0	0.359	0.358	0.375
		15	0.556	0.425	0.496
		30	0.722	0.494	0.568
		45	0.753	0.418	0.626
Control	4	0	0.377	0.355	0.377
		15	0.370	0.363	0.371
		30	0.459	0.358	0.373
		45	0.398	0.357	0.379
Fall Banded NBPT-DCD Urea	4	0	0.361	0.369	0.378
		15	0.370	0.366	0.373
		30	0.390	0.367	0.386
		45	0.383	0.362	0.379
Fall Banded Conventional Urea	4	0	0.375	0.370	0.365
		15	0.373	0.374	0.377
		30	0.397	0.428	0.389
		45	0.427	0.436	0.386
Fall Banded Calcium Nitrate	4	0	0.367	0.380	0.366
		15	0.368	0.367	0.375
		30	0.421	0.363	0.367
		45	0.377	0.402	0.381
Spring Banded Conventional Urea	4	0	0.377	0.368	0.373
		15	0.524	0.434	0.589
		30	0.664	0.482	0.736
		45	0.720	0.480	0.845

APPENDIX C:

SUPPLEMENTARY TABLES FOR CHAPTER 4.0

Table C.1. Concentrations of nitrous oxide emitted in Experiment A.

Treatment	Rep	Dec. 1	Dec. 2	Dec. 4	Dec. 6	Dec. 7
		$\mu L\ N_2O\ L^{-1}$				
Control	1	10.572	5.335	0.745	0.942	0.879
Banded NBPT-DCD Urea		9.3473	3.941	0.783	0.461	0.793
Banded Conventional Urea		6.2997	5.763	1.164	1.627	3.609
Banded Calcium Nitrate		9.4407	6.599	5.789	6.799	6.926
Control	2	3.422	5.227	0.837	0.721	0.603
Banded NBPT-DCD Urea		3.9626	4.441	0.554	0.685	0.591
Banded Conventional Urea		4.2504	3.119	1.194	3.016	4.237
Banded Calcium Nitrate		3.994	7.731	8.418	8.165	8.376
Control	3	6.7256	6.503	0.456	0.395	0.323
Banded NBPT-DCD Urea		7.2604	5.892	0.684	0.632	0.562
Banded Conventional Urea		11.855	7.431	2.219	4.469	5.526
Banded Calcium Nitrate		7.9921	8.156	9.263	8.284	8.563
Control	4	7.6442	4.149	0.432	0.423	0.566
Banded NBPT-DCD Urea		5.7646	4.009	0.516	0.541	1.068
Banded Conventional Urea		6.9796	4.171	0.816	2.072	4.182
Banded Calcium Nitrate		6.6007	7.388	8.768	10.062	14.605

Treatment	Rep	Dec. 9	Dec. 13	Dec. 14	Dec. 16	Dec. 18
		$\mu L\ N_2O\ L^{-1}$				
Control	1	0.912	0.881	0.774	0.776	0.585
Banded NBPT-DCD Urea		0.869	1.252	1.370	1.678	3.973
Banded Conventional Urea		7.138	17.047	20.125	18.631	1.915
Banded Calcium Nitrate		6.471	5.084	4.914	4.413	14.857
Control	2	0.580	0.580	0.427	0.485	11.149
Banded NBPT-DCD Urea		0.814	1.319	1.639	2.476	0.430
Banded Conventional Urea		8.633	13.486	14.018	12.769	2.967
Banded Calcium Nitrate		7.302	5.206	5.120	4.421	3.512
Control	3	0.376	0.440	0.316	0.341	4.090
Banded NBPT-DCD Urea		0.600	0.933	1.155	2.259	3.718
Banded Conventional Urea		12.179	26.609	26.267	24.154	19.167
Banded Calcium Nitrate		7.681	5.264	5.204	4.697	0.282
Control	4	0.374	0.417	0.380	0.384	12.940
Banded NBPT-DCD Urea		1.207	2.240	2.708	3.501	0.285
Banded Conventional Urea		7.324	14.822	18.460	15.062	7.220
Banded Calcium Nitrate		13.868	11.125	10.955	9.032	4.424

Table C.1 (cont'd.). Concentrations of nitrous oxide emitted in Experiment A.

Treatment	Rep	Experiment A Date Dec. 24	Dec. 28	April 25	April 25	April 26
		$\mu L\ N_2O\ L^{-1}$				
Control	1	0.762	0.649	1.042	3.248	-3.763
Banded NBPT-DCD Urea		1.455	1.173	2.833	-4.972	-5.069
Banded Conventional Urea		7.316	4.484	0.750	-6.244	0.969
Banded Calcium Nitrate		2.587	2.028	1.539	-8.453	-2.196
Control	2	0.721	0.707	3.845	-7.908	-4.297
Banded NBPT-DCD Urea		1.750	1.121	0.642	-7.095	-3.972
Banded Conventional Urea		4.271	2.975	0.546	-6.652	-4.761
Banded Calcium Nitrate		1.349	0.975	0.425	-10.006	-5.362
Control	3	0.459	0.441	1.274	-3.489	-6.612
Banded NBPT-DCD Urea		3.598	2.231	1.852	-9.192	0.394
Banded Conventional Urea		7.847	5.671	1.998	-5.083	4.112
Banded Calcium Nitrate		1.854	0.025	0.982	-9.808	-4.716
Control	4	0.590	0.703	5.066	-4.958	-3.888
Banded NBPT-DCD Urea		3.841	3.361	8.196	-0.705	8.833
Banded Conventional Urea		5.248	6.136	4.703	-8.688	-0.427
Banded Calcium Nitrate		3.883	3.583	3.692	-4.191	1.486
Treatment		**Date April 26**	**April 26**	**April 30**	**May 1**	**May 4**
		$\mu L\ N_2O\ L^{-1}$				
Control	1	7.042	31.475	0.787	0.110	0.438
Banded NBPT-DCD Urea		4.772	52.030	1.216	1.119	0.574
Banded Conventional Urea		21.752	25.331	12.741	15.889	9.104
Banded Calcium Nitrate		11.907	12.671	3.594	4.295	1.254
Control	2	5.134	25.417	0.720	0.038	0.322
Banded NBPT-DCD Urea		8.034	19.478	2.455	3.109	1.846
Banded Conventional Urea		8.526	7.448	4.232	6.149	2.760
Banded Calcium Nitrate		4.571	13.143	1.250	1.424	0.695
Control	3	1.945	24.366	0.739	-0.031	0.460
Banded NBPT-DCD Urea		13.870	47.963	3.913	3.565	2.757
Banded Conventional Urea		24.696	4.605	9.565	8.389	6.988
Banded Calcium Nitrate		6.241	34.021	1.686	1.563	0.629
Control	4	5.141	21.903	0.715	-0.049	0.357
Banded NBPT-DCD Urea		10.465	10.465	2.407	3.084	2.019
Banded Conventional Urea		12.441	5.629	4.745	2.891	2.811
Banded Calcium Nitrate		12.322	15.388	2.506	2.087	1.062

Table C.1 (cont'd.). Concentrations of nitrous oxide emitted in Experiment A.

Treatment	Rep	Experiment A				
		Date				
		May 7	May 9	May 11	May 14	May22
		$\mu L\ N_2O\ L^{-1}$				
Control	1	0.790	0.493	0.465	0.329	0.325
Banded NBPT-DCD Urea		1.093	0.516	0.477	0.761	0.985
Banded Conventional Urea		12.471	6.073	7.293	6.949	2.898
Banded Calcium Nitrate		1.217	0.854	0.682	0.540	0.722
Control	2	-0.013	0.260	0.194	0.092	0.173
Banded NBPT-DCD Urea		2.349	1.636	1.444	1.574	1.723
Banded Conventional Urea		3.451	1.425	0.845	0.390	0.160
Banded Calcium Nitrate		0.420	0.432	0.296	0.394	0.719
Control	3	0.150	0.310	0.193	0.175	0.226
Banded NBPT-DCD Urea		3.151	2.606	2.352	2.627	2.507
Banded Conventional Urea		6.994	4.561	4.163	3.739	2.085
Banded Calcium Nitrate		0.409	0.434	0.404	0.656	0.330
Control	4	0.197	0.164	0.319	0.267	0.462
Banded NBPT-DCD Urea		2.065	1.519	1.504	1.661	1.981
Banded Conventional Urea		3.316	2.190	1.567	2.182	1.333
Banded Calcium Nitrate		0.920	0.623	0.673	0.403	0.577
Treatment		Date				
		May 23				
		$\mu L\ N_2O\ L^{-1}$				
Control	1	0.274				
Banded NBPT-DCD Urea		1.227				
Banded Conventional Urea		3.656				
Banded Calcium Nitrate		1.074				
Control	2	0.218				
Banded NBPT-DCD Urea		2.261				
Banded Conventional Urea		0.440				
Banded Calcium Nitrate		0.710				
Control	3	0.248				
Banded NBPT-DCD Urea		3.388				
Banded Conventional Urea		2.176				
Banded Calcium Nitrate		0.428				
Control	4	0.458				
Banded NBPT-DCD Urea		2.613				
Banded Conventional Urea		1.627				
Banded Calcium Nitrate		0.770				

Table C.2. Concentrations of ammonium and nitrate in soil at thaw and 4 weeks after thaw in Experiment A.

At Thaw			
Treatment	Rep	NH_4	NO_3
		mg kg^{-1}	
Control	1	1.95	19.05
Banded NBPT-DCD Urea		83.00	62.85
Banded Conventional Urea		37.55	130.35
Banded Calcium Nitrate		2.25	62.90
Control	2	420.00	19.00
Banded NBPT-DCD Urea		58.60	68.10
Banded Conventional Urea		5.00	128.75
Banded Calcium Nitrate		2.85	156.90
Control	3	2.00	20.80
Banded NBPT-DCD Urea		26.65	79.40
Banded Conventional Urea		8.05	108.15
Banded Calcium Nitrate		2.90	144.35
Control	4	2.20	23.35
Banded NBPT-DCD Urea		33.05	79.00
Banded Conventional Urea		8.50	110.35
Banded Calcium Nitrate		2.90	143.50
4 Weeks after Thaw			
Control	1	0.80	25.55
Banded NBPT-DCD Urea		7.95	111.35
Banded Conventional Urea		1.00	145.90
Banded Calcium Nitrate		0.95	138.40
Control	2	0.75	27.00
Banded NBPT-DCD Urea		12.35	124.70
Banded Conventional Urea		0.75	145.05
Banded Calcium Nitrate		0.80	144.85
Control	3	0.80	24.85
Banded NBPT-DCD Urea		45.65	118.60
Banded Conventional Urea		1.05	153.85
Banded Calcium Nitrate		1.35	145.05
Control	4	0.55	27.95
Banded NBPT-DCD Urea		1.35	109.55
Banded Conventional Urea		1.05	186.35
Banded Calcium Nitrate		0.70	143.65

Table C.3. Concentrations of nitrous oxide emitted in Experiment B.

Treatment	Rep	Moisture	Nov.21	Nov.22	Nov.23	Nov25
		% WFPS		Date ($\mu L\ N_2O\ L^{-1}$)		
Control	1	50	0.033	0.032	0.039	0.028
Banded NBPT Urea			0.117	0.213	0.308	0.755
Banded NBPT-DCD Urea			0.108	0.184	0.191	0.200
Banded Conventional Urea			0.091	0.311	0.692	1.235
Banded Calcium Nitrate			0.103	0.179	0.164	0.134
Control	1	50	0.017	0.032	0.032	0.036
Banded NBPT Urea			0.107	0.204	0.280	0.648
Banded NBPT-DCD Urea			0.095	0.237	0.302	0.383
Banded Conventional Urea			0.156	0.383	0.763	1.478
Banded Calcium Nitrate			0.247	0.508	0.459	0.409
Control	2	50	0.023	0.027	0.025	0.023
Banded NBPT Urea			0.100	0.264	0.338	0.733
Banded NBPT-DCD Urea			0.100	0.144	0.159	0.206
Banded Conventional Urea			0.110	0.324	0.641	1.265
Banded Calcium Nitrate			0.076	0.214	0.219	0.207
Control	2	50	0.061	0.045	0.031	0.022
Banded NBPT Urea			0.097	0.195	0.272	0.753
Banded NBPT-DCD Urea			0.086	0.141	0.189	0.216
Banded Conventional Urea			0.115	0.284	0.489	0.957
Banded Calcium Nitrate			0.153	0.197	0.199	0.149

Table C.3 (cont'd.). Concentrations of nitrous oxide emitted in Experiment B.

Treatment	Experiment B					
	Rep	Moisture	Date			
		% WFPS	Nov.28	Nov.29	Nov.30	Dec.2
			$\mu L\ N_2O\ L^{-1}$			
Control	3	50	0.109	0.061	-0.015	0.021
Banded NBPT Urea			0.651	0.476	0.764	4.602
Banded NBPT-DCD Urea			0.132	0.107	0.124	0.202
Banded Conventional Urea			0.245	0.420	0.786	2.096
Banded Calcium Nitrate			0.346	0.386	0.402	0.393
Control	3	50	0.480	0.099	0.061	0.015
Banded NBPT Urea			0.192	0.186	0.349	2.231
Banded NBPT-DCD Urea			0.187	0.083	0.149	0.189
Banded Conventional Urea			0.284	0.415	0.916	2.907
Banded Calcium Nitrate			0.191	0.142	0.168	0.105
Control	4	50	-0.004	0.058	0.088	0.088
Banded NBPT Urea			0.209	0.231	0.368	2.527
Banded NBPT-DCD Urea			0.116	0.114	0.147	0.327
Banded Conventional Urea			0.400	0.589	1.324	3.441
Banded Calcium Nitrate			0.072	1.255	1.089	0.663
Control	4	50	2.778	0.040	0.046	0.003
Banded NBPT Urea			0.211	0.220	0.414	2.647
Banded NBPT-DCD Urea			0.745	0.325	0.427	1.210
Banded Conventional Urea			0.805	0.752	1.367	4.155
Banded Calcium Nitrate			0.260	0.198	0.303	0.371

Table C.3 (cont'd.). Concentrations of nitrous oxide emitted in Experiment B.

Treatment	Experiment B						
	Rep	Moisture	Date				
		% WFPS	Dec.3a	Dec.3b	Dec.4a	Dec.4b	Dec.4c
			$\mu L\ N_2O\ L^{-1}$				
Control	1	50	0.055	-0.003	0.092	-0.139	1.147
Banded NBPT Urea			0.070	0.476	0.587	1.569	2.333
Banded NBPT-DCD Urea			0.056	0.236	0.119	0.091	0.162
Banded Conventional Urea			0.121	0.339	0.578	1.034	1.622
Banded Calcium Nitrate			0.034	-0.004	0.110	0.711	0.882
Control	1	70	0.025	-0.009	0.088	4.678	10.408
Banded NBPT Urea			0.040	0.792	1.578	12.052	21.874
Banded NBPT-DCD Urea			0.044	0.317	0.648	11.082	20.421
Banded Conventional Urea			0.076	1.325	1.859	13.619	24.074
Banded Calcium Nitrate			0.014	0.061	0.196	5.526	11.888
Control	2	50	0.035	0.038	0.077	-0.101	-0.032
Banded NBPT Urea			0.066	0.042	0.313	0.677	1.013
Banded NBPT-DCD Urea			0.056	0.014	0.126	0.086	0.828
Banded Conventional Urea			0.110	0.338	0.799	1.628	4.226
Banded Calcium Nitrate			0.052	0.041	0.174	0.118	0.294
Control	2	70	0.007	-0.009	0.057	4.246	11.179
Banded NBPT Urea			0.055	0.577	1.161	9.886	20.546
Banded NBPT-DCD Urea			0.022	0.053	0.167	6.769	15.276
Banded Conventional Urea			0.056	0.834	0.896	7.154	12.648
Banded Calcium Nitrate			0.023	-0.001	0.131	0.599	1.054

Table C.3 (cont'd.). Concentrations of nitrous oxide emitted in Experiment B.

Treatment	Experiment B						
	Rep	Moisture	Date				
		% WFPS	Dec.4d	Dec.5	Dec.6	Dec.8	Dec.13
			$\mu L\ N_2O\ L^{-1}$				
Control	1	50	0.055	0.244	0.336	0.149	0.144
Banded NBPT Urea			2.384	2.206	2.802	4.154	2.654
Banded NBPT-DCD Urea			0.397	0.583	1.480	1.324	0.740
Banded Conventional Urea			1.412	1.397	2.033	2.941	1.557
Banded Calcium Nitrate			1.101	0.752	0.531	0.204	0.130
Control	1	70	11.765	22.099	21.623	7.788	2.655
Banded NBPT Urea			22.655	39.233	55.900	38.532	14.467
Banded NBPT-DCD Urea			19.628	34.132	23.586	11.870	7.651
Banded Conventional Urea			23.255	39.201	36.643	15.247	6.430
Banded Calcium Nitrate			12.166	24.410	22.259	10.590	4.627
Control	2	50	0.110	0.207	0.263	0.319	0.096
Banded NBPT Urea			1.166	1.517	2.450	2.641	1.420
Banded NBPT-DCD Urea			0.440	0.615	0.960	1.491	0.839
Banded Conventional Urea			2.716	2.472	2.045	2.736	1.552
Banded Calcium Nitrate			0.381	0.517	0.622	11.463	0.137
Control	2	70	11.468	36.324	59.796	44.737	14.809
Banded NBPT Urea			20.179	44.345	54.838	41.688	16.683
Banded NBPT-DCD Urea			15.801	39.573	51.246	33.814	12.401
Banded Conventional Urea			12.457	14.339	11.991	9.433	3.654
Banded Calcium Nitrate			1.241	0.923	0.443	0.242	0.143

Table C.3 (cont'd.). Concentrations of nitrous oxide emitted in Experiment B.

Treatment	Experiment B		
	Rep	Moisture	Date
		% WFPS	Dec.14
			$\mu L\ N_2O\ L^{-1}$
Control	1	50	4.660
Banded NBPT Urea			2.798
Banded NBPT-DCD Urea			0.650
Banded Conventional Urea			1.552
Banded Calcium Nitrate			0.008
Control	1	70	2.982
Banded NBPT Urea			21.981
Banded NBPT-DCD Urea			8.497
Banded Conventional Urea			7.324
Banded Calcium Nitrate			4.984
Control	2	50	-0.026
Banded NBPT Urea			1.449
Banded NBPT-DCD Urea			0.808
Banded Conventional Urea			1.288
Banded Calcium Nitrate			-0.113
Control	2	70	20.869
Banded NBPT Urea			22.872
Banded NBPT-DCD Urea			16.754
Banded Conventional Urea			4.865
Banded Calcium Nitrate			-0.148

Table C.3 (cont'd.). Concentrations of nitrous oxide emitted in Experiment B.

Treatment		Experiment B					
	Rep	Moisture			Date		
		%WFPS	Dec.8a	Dec.8b	Dec.9a	Dec.9b	Dec.9c
					μL N_2O L^{-1}		
Control	3	50	0.807	0.103	0.055	0.059	-1.465
Banded NBPT Urea			0.184	0.879	1.115	1.589	-4.655
Banded NBPT-DCD Urea			0.122	0.124	0.112	0.131	-4.380
Banded Conventional Urea			0.506	1.305	1.092	1.200	14.626
Banded Calcium Nitrate			0.114	0.743	0.862	1.022	31.652
Control	3	70	0.211	0.108	0.251	4.457	-2.470
Banded NBPT Urea			0.227	2.845	6.075	20.901	-0.197
Banded NBPT-DCD Urea			0.121	0.220	0.499	3.551	-4.927
Banded Conventional Urea			0.339	1.574	2.097	3.464	-3.692
Banded Calcium Nitrate			0.139	0.174	0.201	0.886	27.685
Control	4	50	0.047	0.334	0.690	0.741	-4.673
Banded NBPT Urea			0.171	0.789	0.865	0.938	-1.341
Banded NBPT-DCD Urea			0.089	0.168	0.149	0.218	-3.009
Banded Conventional Urea			0.267	2.424	2.534	2.484	1.809
Banded Calcium Nitrate			0.134	1.595	2.382	3.412	-4.793
Control	4	70	0.053	0.261	1.796	12.990	-3.562
Banded NBPT Urea			0.126	1.699	3.003	17.533	22.822
Banded NBPT-DCD Urea			0.165	3.587	7.187	25.067	-3.796
Banded Conventional Urea			0.248	3.602	7.103	27.959	-3.710
Banded Calcium Nitrate			0.065	0.352	0.551	3.312	24.153

Table C.3 (cont'd.). Concentrations of nitrous oxide emitted in Experiment B.

Treatment	Experiment B						
	Rep	Moisture	Date				
		% WFPS	Dec.9d	Dec.10	Dec.12	Dec.13	Dec.14
			$\mu L\ N_2O\ L^{-1}$				
Control	3	50	-0.377	-0.122	0.078	0.082	0.078
Banded NBPT Urea			1.851	3.058	1.405	3.050	2.588
Banded NBPT-DCD Urea			-0.284	0.324	0.381	0.779	0.658
Banded Conventional Urea			0.849	3.117	0.789	1.487	1.117
Banded Calcium Nitrate			0.737	1.505	0.836	1.915	1.607
Control	3	70	6.872	5.289	0.880	1.408	0.659
Banded NBPT Urea			31.463	32.022	7.724	11.596	7.900
Banded NBPT-DCD Urea			4.457	4.740	1.668	2.932	1.966
Banded Conventional Urea			2.955	3.142	1.492	2.838	1.911
Banded Calcium Nitrate			1.063	0.548	0.213	0.282	0.180
Control	4	50	0.474	0.269	0.057	0.060	0.048
Banded NBPT Urea			0.848	2.021	0.999	2.111	1.772
Banded NBPT-DCD Urea			-0.147	0.824	0.468	0.956	0.749
Banded Conventional Urea			2.254	3.253	1.514	2.815	1.881
Banded Calcium Nitrate			6.931	1.425	0.420	0.698	0.405
Control	4	70	22.375	20.266	3.839	5.975	3.252
Banded NBPT Urea			32.908	42.716	9.822	14.415	9.049
Banded NBPT-DCD Urea			38.516	52.435	22.104	36.752	20.790
Banded Conventional Urea			43.469	54.846	17.022	30.733	14.240
Banded Calcium Nitrate			4.854	3.723	0.614	0.838	0.420

Table C.3 (cont'd.). Concentrations of nitrous oxide emitted in Experiment B.

Treatment	Experiment B				
	Rep	Moisture	Date		
		%WFPS	Dec.18	Dec.20	Dec.21
			$\mu L\ N_2O\ L^{-1}$		
Control	3	50	0.028	0.047	-0.060
Banded NBPT Urea			1.769	1.387	0.513
Banded NBPT-DCD Urea			0.311	0.217	-0.023
Banded Conventional Urea			0.685	0.602	0.206
Banded Calcium Nitrate			1.425	1.444	0.701
Control	3	70	0.298	0.309	0.090
Banded NBPT Urea			3.869	2.753	1.480
Banded NBPT-DCD Urea			0.900	0.890	0.181
Banded Conventional Urea			1.150	1.196	0.485
Banded Calcium Nitrate			0.056	0.081	-0.026
Control	4	50	0.025	0.046	0.016
Banded NBPT Urea			0.840	0.424	0.140
Banded NBPT-DCD Urea			0.289	0.215	0.076
Banded Conventional Urea			1.146	1.193	0.708
Banded Calcium Nitrate			0.607	0.916	0.540
Control	4	70	1.342	1.202	0.708
Banded NBPT Urea			4.855	3.357	1.407
Banded NBPT-DCD Urea			8.027	7.556	4.522
Banded Conventional Urea			10.686	9.652	1.738
Banded Calcium Nitrate			0.125	0.172	0.015

Table C.4. Concentrations of ammonium and nitrate in soil in Experiment B.

At Freeze					
Treatment	Rep	Moisture	NH_4	NO_2	NO_3
		% WFPS		mg kg^{-1}	
Control	1	50	0.59	0.66	97.98
Banded NBPT Urea			70.99	3.87	75.37
Banded NBPT-DCD Urea			94.68	0.65	111.93
Banded Conventional Urea			70.96	2.98	100.05
Banded Calcium Nitrate			1.45	0.66	228.84
Control	1	50	0.65	0.65	89.20
Banded NBPT Urea			140.89	5.84	125.31
Banded NBPT-DCD Urea			159.53	0.65	109.82
Banded Conventional Urea			109.01	5.33	147.25
Banded Calcium Nitrate			3.03	0.00	176.02
Control	2	50	0.59	0.66	87.12
Banded NBPT Urea			104.09	5.87	108.27
Banded NBPT-DCD Urea			98.67	1.27	101.72
Banded Conventional Urea			139.57	6.52	129.19
Banded Calcium Nitrate			4.59	0.66	245.45
Control	2	50	1.04	0.65	83.15
Banded NBPT Urea			162.12	7.74	119.35
Banded NBPT-DCD Urea			59.21	0.65	99.45
Banded Conventional Urea			102.78	3.77	108.69
Banded Calcium Nitrate			3.26	0.65	235.23
Control	3	50	0.41	82.96	0.35
Banded NBPT Urea			101.64	143.47	12.58
Banded NBPT-DCD Urea			75.74	106.77	1.30
Banded Conventional Urea			0.77	173.15	0.51
Banded Calcium Nitrate			0.93	101.21	0.62
Control	3	50	46.54	129.83	2.12
Banded NBPT Urea			93.03	127.25	0.92
Banded NBPT-DCD Urea			2.54	123.51	4.48
Banded Conventional Urea			14.40	342.77	0.94
Banded Calcium Nitrate			0.27	81.59	0.38
Control	4	50	153.02	143.52	15.21
Banded NBPT Urea			59.21	111.77	0.75
Banded NBPT-DCD Urea			73.75	111.41	7.93
Banded Conventional Urea			1.01	178.82	0.48
Banded Calcium Nitrate			0.76	87.96	0.35
Control	4	50	58.27	143.88	3.61
Banded NBPT Urea			88.44	118.32	1.21
Banded NBPT-DCD Urea			32.32	129.90	1.32
Banded Conventional Urea			1.30	191.45	0.50
Banded Calcium Nitrate			3.26	0.65	235.23

Table C.4 (cont'd.). Concentrations of ammonium and nitrate in soil in Experiment B.

At Thaw					
Treatment	Rep	Moisture	NH_4	NO_2	NO_3
		% WFPS		mg kg^{-1}	
Control	1	50	1.68	0.32	84.57
Banded NBPT Urea			201.68	3.00	224.76
Banded NBPT-DCD Urea			95.96	0.55	112.49
Banded Conventional Urea			100.54	1.64	130.83
Banded Calcium Nitrate			0.49	0.61	234.24
Control	1	70	0.86	0.30	81.05
Banded NBPT Urea			94.33	0.99	128.65
Banded NBPT-DCD Urea			135.42	0.57	115.47
Banded Conventional Urea			87.51	1.46	108.21
Banded Calcium Nitrate			0.97	0.25	221.96
Control	2	50	0.93	0.49	85.80
Banded NBPT Urea			65.50	0.92	143.57
Banded NBPT-DCD Urea			115.50	0.81	107.36
Banded Conventional Urea			115.01	1.26	129.20
Banded Calcium Nitrate			1.42	0.34	213.64
Control	2	70	0.51	0.42	85.41
Banded NBPT Urea			133.25	1.63	119.24
Banded NBPT-DCD Urea			166.08	0.64	117.28
Banded Conventional Urea			75.50	0.95	116.30
Banded Calcium Nitrate			1.42	0.28	212.38
Control	3	50	25.41	0.50	81.52
Banded NBPT Urea			54.53	1.06	99.73
Banded NBPT-DCD Urea			95.86	0.62	99.16
Banded Conventional Urea			79.47	1.05	102.15
Banded Calcium Nitrate			20.86	0.43	196.18
Control	3	70	2.87	0.50	77.55
Banded NBPT Urea			58.84	0.69	98.00
Banded NBPT-DCD Urea			94.00	0.62	95.08
Banded Conventional Urea			223.66	3.63	113.23
Banded Calcium Nitrate			2.90	0.36	213.55
Control	4	50	1.51	0.43	81.69
Banded NBPT Urea			171.16	1.82	175.58
Banded NBPT-DCD Urea			108.86	0.37	96.55
Banded Conventional Urea			85.30	1.76	77.43
Banded Calcium Nitrate			2.97	0.40	211.74
Control	4	70	1.07	0.40	82.39
Banded NBPT Urea			158.45	1.49	100.97
Banded NBPT-DCD Urea			157.01	0.36	107.13
Banded Conventional Urea			105.40	1.51	109.66
Banded Calcium Nitrate			2.32	0.44	132.70

Table C.4 (cont'd.). Concentrations of ammonium and nitrate in soil in Experiment B.

At End of Sampling					
Treatment	Rep	Moisture	NH_4	NO_2	NO_3
		% WFPS		mg kg^{-1}	
Control	1	50	5.32	2.13	438.64
Banded NBPT Urea			1.16	0.42	222.83
Banded NBPT-DCD Urea			31.16	0.37	184.76
Banded Conventional Urea			1.32	0.43	210.54
Banded Calcium Nitrate			0.71	0.37	236.28
Control	1	70	0.80	0.23	82.41
Banded NBPT Urea			5.01	0.49	229.26
Banded NBPT-DCD Urea			30.10	0.28	275.99
Banded Conventional Urea			0.97	0.35	254.41
Banded Calcium Nitrate			0.89	0.26	229.78
Control	2	50	1.40	0.33	117.90
Banded NBPT Urea			1.05	0.33	212.02
Banded NBPT-DCD Urea			28.54	0.31	180.75
Banded Conventional Urea			1.19	0.36	215.75
Banded Calcium Nitrate			1.94	0.33	254.19
Control	2	70	3.03	0.24	86.01
Banded NBPT Urea			4.45	0.24	218.25
Banded NBPT-DCD Urea			15.64	0.23	232.56
Banded Conventional Urea			0.90	0.26	228.49
Banded Calcium Nitrate			0.78	0.26	215.98
Control	3	50	2.15	0.60	87.72
Banded NBPT Urea			1.25	0.33	212.35
Banded NBPT-DCD Urea			42.21	0.52	198.36
Banded Conventional Urea			1.41	0.00	229.25
Banded Calcium Nitrate			1.56	0.41	244.41
Control	3	70	1.85	0.56	96.65
Banded NBPT Urea			1.10	0.29	236.85
Banded NBPT-DCD Urea			46.10	0.42	219.78
Banded Conventional Urea			1.33	0.34	230.58
Banded Calcium Nitrate			1.15	0.33	221.56
Control	4	50	1.89	0.46	94.72
Banded NBPT Urea			1.64	0.46	244.26
Banded NBPT-DCD Urea			18.27	0.30	203.10
Banded Conventional Urea			1.47	0.39	223.49
Banded Calcium Nitrate			1.65	0.55	225.79
Control	4	70	1.76	0.48	96.07
Banded NBPT Urea			1.75	0.45	249.78
Banded NBPT-DCD Urea			1.98	0.32	206.46
Banded Conventional Urea			1.34	0.36	270.22
Banded Calcium Nitrate			1.40	0.40	220.02