

THE UNIVERSITY OF MANITOBA

**EFFECTS OF NITROGEN SUPPLY, WATER SUPPLY AND
TEMPERATURE ON THE YIELD AND QUALITY OF CEREALS AND
OILSEEDS GROWN IN SOUTHERN MANITOBA**

by

© DALE MITCHELL MARANTZ

A THESIS

**SUBMITTED TO THE FACULTY OF GRADUATE STUDIES IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE**

DEPARTMENT OF SOIL SCIENCE

WINNIPEG, MANITOBA

SPRING, 1989

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ISBN 0-315-51677-1

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DALE MITCHELL MARANTZ

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

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ABSTRACT

In southern Manitoba moisture and nitrogen are frequently limiting factors in the production of cereal and oilseed crops. Variations in the severity of limitations among years result in large year to year variations in yield and quality of crops grown. Fertilizer trials were established in 1972 to determine the severity of the variations. A total of 58 field experiments, 29 on fallow and 29 on stubble were conducted over six years to determine the effect of selected soil and climatic parameters on the response of wheat (Triticum Aestivum cv. Neepawa, Glenlea), barley (Hordeum Vulgare cv. Conquest, Fergus), canola (Brassica Napus cv. Tower), and flax (Linum Usitatissimum cv. Dufferin) to applied fertilizer nitrogen.

Regression analysis was used to quantify the importance of soil $\text{NO}_3\text{-N}$, fertilizer N, nitrogen supply (Ns), water supply (Ws), and growing degree days (Gdd) on yield and grain protein percentage of the cereal and oilseed crops. A technique using normalized standard partial regression coefficients was used to assess the relative contribution of soil and fertilizer N in the determination of yield and grain protein percentage. Stepwise regression analysis was used to select significant independent variables for entry into yield and protein prediction equations

Grain yield of cereal crops was increased when N fertilizer was applied to nonfallow sites. A small increase in yield was also obtained on fallow sites when N fertilizer was applied. Both varieties of wheat and barley indicated significant positive responses to fertilizer N and soil $\text{NO}_3\text{-N}$. Soil $\text{NO}_3\text{-N}$ was almost two times more important than fertilizer N in the determination of final grain yield of cereals. Seed yield of oilseed crops was increased when N fertilizer was applied to nonfallow sites. A small increase in seed yield was also obtained on fallow sites when N fertilizer was applied. Soil $\text{NO}_3\text{-N}$ and fertilizer N were less significant in explaining the variation in grain yields of

flax and canola than for the cereal crops. Fertilizer N was three times more important than soil NO₃-N in the determination of seed yields of canola and flax.

Grain protein percentage of both the cereals and oilseeds increased with increases in soil NO₃-N and fertilizer N on both fallow and nonfallow sites. A significant positive response to applied fertilizer N and soil NO₃-N on grain protein percentage of both cereals and oilseeds was evident from the regression analysis. Grain protein percentage of cereal grains remained relatively constant or decreased slightly when 34 kg N ha⁻¹ were added to soils low in soil NO₃-N; grain protein percentage increased greatly with application of N fertilizer in excess of 67 kg ha⁻¹. The decrease in grain protein percentage which was evident for cereal crops was less evident for both flax and canola. Fertilizer N was about one and a half times more important in the determination of grain protein percentage of cereal crops than soil NO₃-N and about two times more important in the determination of grain protein percentage of the oilseeds.

Regression analysis revealed a significant relationship between grain yields of cereal crops and calculated values for Ws. The variation in grain yields explained by the calculated values for Ws averaged about 30% for the two varieties of wheat and 26% for the two varieties of barley. A poor relationship existed between yields of canola and the calculated values for Ws. Grain yield data for flax showed a better correlation with Ws than canola. The relationship between Ws and grain protein percentage of both cereals and oilseeds was not well defined.

The stepwise regression resulted in both Ws and Ns being included in the cereal grain yield prediction equations; Ws was included only as an interaction term with Ns. Variables chosen for the model accounted for 72 and 66 percent of the reduction in total variance in yields for the two varieties of wheat, Neepawa and Glenlea and 80 and 84 percent for the two varieties of barley, Conquest and Fergus. The cereal grain yield equation worked well within a range of Ws and Ns values which were similar to the highest proportion of observed values. However, outside the range of observed values,

estimates for yields did not perform as expected. Predicted yields did not reach values similar to the highest actual yields. For canola, 69 percent of the total variation was accounted for by a relationship to soil and climatic variables. Gdd was selected in addition to Ns and Ws by the stepwise technique as a variable which accounted for a significant portion of the total variance. For flax, the variables chosen for the model accounted for 78 percent of the total variance.

The protein prediction equation selected by the stepwise technique resulted in a significant portion of the variation in protein percentage of cereal grains being explained by the selected variables. The variables chosen for the model accounted for 53 and 71 percent of the reduction in total variance in grain protein percentages for the two varieties of wheat, Neepawa and Glenlea and 58 and 73 percent for the two varieties of barley, Conquest and Fergus. Estimates of grain protein percentage for the cereals appeared to fall within the expected range when calculated coefficients and selected values for Ws and Ns were substituted into the prediction equation. However, at the highest values for Ns, the model generated predicted values which were slightly higher than those actually recorded. For canola, the equation resulted in 66 percent of the variation in grain protein percentages being explained by the selected variables. However, for flax, only 53 percent of the variation in grain protein percentages was explained by the model. Estimates of the grain protein percentage of canola were similar to actual observations from the field experiments. Estimates of grain protein percentage of flax were similar to actual values at low Ns, but were 20% higher at the highest values of Ns used to test the sensitivity of the model.

Regression analysis used here may be effective in describing the relationship and importance of independent variables and dependent variables, but it does not describe accurately the ability of developed equations to predict or estimate dependent variables. Further development of these equations is recommended, particularly in the case of flax and canola, where small data bases limit the usefulness of the equations. Furthermore,

testing of these equations both on data sets within the same range of data employed to create them as well as data sets from outside this range is the only reasonable method to evaluate their effectiveness and reliability.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to:

Manitoba Department of Agriculture for the financial assistance provided during completion of this work.

Dr. G. J. Racz, Professor and Department Head, Department of Soil Science, University of Manitoba, under whose supervision this study was completed.

Dr. C. F. Shaykewich, Dr. P. McVetty and K. S. McGill for serving on the examining committee.

Academic Staff and graduate students of the Department of Soil Science for their assistance and cooperation during the course of this research.

My wife, Alison, for her encouragement, patience and understanding.

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CHAPTER I

INTRODUCTION

In western Canada, the response of crops to fertilizer nitrogen is affected by several soil and environmental related factors. Soil factors such as nitrate-nitrogen content and stored soil water and climatic factors such as growing season precipitation and growing degree days significantly affect crop response to the addition of fertilizer nitrogen. Soil testing laboratories in the prairie provinces could provide more precise nitrogen fertilizer recommendations if models were available which relate crop response to fertilizer nitrogen as a function of both factors. In this way, nitrogen fertilizer recommendations made by soil testing laboratories would be more specific since the recommendations could be altered depending upon soil and environmental conditions.

Yield and grain protein percentage of cereal and oilseed crops have been shown to vary with nitrogen supply, water supply, and temperature. At present, the amounts of nitrogen fertilizer recommended by the Manitoba Provincial Soil Testing Laboratory for a particular yield ("target yield") is based mainly on nitrogen supply as the relationship between yield and nitrogen supply and water supply have not been investigated in Manitoba.

The grading of wheat on a protein basis has made it more important that producers grow wheat of a particular grain protein percentage. Also, barley produced in Manitoba is used both in the brewing and feed industries. Barley of a low grain protein percentage is desirable for the brewing industry. In contrast, increases in grain protein percentage of feed barley and other feed grains would be of considerable value to the feed industry, provided grain protein percentages could be increased at little cost to the producer. It was shown in previous studies that the amounts of available nitrogen in the soil and the amounts of fertilizer nitrogen applied at seeding greatly influence the protein percentages of grains. It was also found that the amount of nitrogen fertilizer required to produce grain of a

particular protein percentage can be predicted provided that the available soil nitrogen is known. Since water supply and temperature also influence grain protein percentage, a study was initiated to provide information for predicting nitrogen fertilizer requirements for a particular grain protein percentage in the various climatic areas of Manitoba.

Data for this study was obtained from field experiments conducted in southern Manitoba during the period from 1972-1977. A total of ten experimental sites (58 site years) were selected based on location, cropping history and initial levels of $\text{NO}_3\text{-N}$ in the soil profile. The experimental design of the field experiments was a randomized complete block with six replicates. Treatments (fertilizer rates applied annually at time of seeding) remained the same throughout the term of the experiment. The field experiments had the following specific objectives:

- (a) to quantify the influence of soil nitrate nitrogen and fertilizer nitrogen and water supply on the yield and grain protein percentage of cereal and oilseed crops in southern Manitoba.
- (b) to derive statistical models relating yields and grain protein percentage to a number of independent variables including soil nitrogen, fertilizer nitrogen and water supply.

This presentation is the first formal summary of the data collected during the field experiment phase of the project. This report summarizes the effects of soil nitrogen and fertilizer nitrogen on yield and grain protein percentage of the crops used in the study and presents equations which relate variations in yield and protein to soil $\text{NO}_3\text{-N}$, rate of N fertilization and weather. The equations will be presented to the Manitoba Provincial Soil Testing Laboratory for use in predicting nitrogen fertilizer requirements for a particular yield and grain protein percentage in the various climatic areas of Manitoba.

CHAPTER II

LITERATURE REVIEW

A. EFFECT OF NITROGEN ON YIELD

1. Nitrate-nitrogen and Grain Yield

In Manitoba, the N fertilizer requirements of crops are determined on the basis of the nitrate nitrogen ($\text{NO}_3\text{-N}$) soil test. Yield responses to fertilizer N are common when soils contain low amounts of $\text{NO}_3\text{-N}$ whereas yield increases are not normally obtained when soils contain high amounts of $\text{NO}_3\text{-N}$. Nyborg et al.(1976) reviewed the rationale of the available nitrogen ($\text{NO}_3\text{-N}$) soil test in western Canada. The authors concluded that the fall $\text{NO}_3\text{-N}$ soil test was suitable to the annual cropping practised in western Canada because mineralization occurred at reasonable rates during the prolonged cold period during which no crop is grown. However, several factors were outlined which affected the usefulness of the $\text{NO}_3\text{-N}$ soil test as a predictor of fertilizer N requirements. Included among these factors are time of sampling, depth of sampling and crop rotation.

Several investigators have shown that the $\text{NO}_3\text{-N}$ content of the soil profile at time of seeding influences yields and response to N fertilizers (Soper and Huang 1963; Peterson and Altoc 1965; Young et al. 1967; Herron et al. 1968). Cook et al. (1956) showed that accumulation of $\text{NO}_3\text{-N}$ during incubation in pots, originally leached of all available $\text{NO}_3\text{-N}$, gave close relationships ($r = 0.83^{**}$ on stubble and 0.85^{**} on fallow) to yield response of wheat.

In Manitoba, Soper and Huang (1963) found that the $\text{NO}_3\text{-N}$ content of the soil to a depth 122 cm gave the best correlation with yield response to N fertilizer. A later study (Soper et al. 1971) showed that uptake of N by barley was significantly correlated with the amount of $\text{NO}_3\text{-N}$ in the surface 60 cm of soil and that yields were related to N uptake. Also in Manitoba, Soper (1971) reported that for dryland conditions, canola responded to

fertilizer N when soil N was less than 100 kg ha⁻¹ and large increases in canola yield were possible when soil N was less than 60 kg ha⁻¹.

In Alberta, Nyborg et al.(1974) conducted 96 field experiments and found that the amount of NO₃-N, determined to depths of 15 or 60 cm, was closely correlated with the yield of cereal crops ($r^2 = 0.64^{**}$ to 0.66^{**}). Similarly, data from north-eastern Saskatchewan showed that barley yield in experiments conducted on eighteen stubble fields were significantly related to levels of NO₃-N in the surface 60 cm of soil (Nuttall 1971).

2. Fertilizer Nitrogen and Grain Yield

The importance of N fertilizer in crop production in western Canada has been documented by numerous research studies. Warder et al. (1962), Racz et al (1965), Nuttall (1971), and Dubetz (1976) have reported responses in both yield and grain protein percentage of cereals and oilseeds to increasing rates of N fertilizer and increasing levels of soil NO₃-N. Holmes and Ainsley (1977) reported that fertilizer N resulted in an increased canola yield in 23 out of 26 field experiments in the United Kingdom and that canola required 187 kg ha⁻¹ of N for optimal yield increases. In Manitoba, Alkier (1972) demonstrated that yields of Neepawa wheat were greater on fallow than on nonfallow sites when no N fertilizer was added. Furthermore, that yields of wheat on nonfallow sites increased from 986 kg ha⁻¹ to 2336 kg ha⁻¹ when 101 kg N ha⁻¹ were added. Responses to N fertilizer were limited by initially high levels of NO₃-N on fallow sites.

Several authors have indicated the importance of N fertilizer to the yield of canola grown on soils low in available N (nonfallow soils) (Henry and MacDonald, 1978; Soper 1971). Studies from northern Alberta have demonstrated that, for canola grown on fallow sites, phosphorus is the primary fertilizer requirement and that response to N fertilizer is not apparent on these soils. However, while canola did not respond to N fertilizer alone there appeared to be an additional benefit from the addition of 11 kg ha⁻¹ with phosphorus applications (Anderson and Kusch 1967). Data from the United Kingdom suggested that

response to fertilizer N on fallow soils would occur with application of N fertilizer in excess of 150 kg ha^{-1} (Holmes and Ainsley 1977,1978).

Dybing (1965) demonstrated that, under controlled environmental conditions, the application of fertilizer N (67 kg ha^{-1}) increased vegetative growth and boll production of flax. Furthermore, boll production increased directly with the level of N and was markedly limited with the reduction of N availability at flowering.

Results have shown that when initial soil $\text{NO}_3\text{-N}$ levels are low, small additions of N fertilizer result in large increases in yield (Partridge, 1971) and that an optimum level of N fertilizer exists beyond which no significant yield increases occur. Henry et al. (1986) reviewed the effects of applied N and water on yield of wheat in western Canada. The authors reported that under irrigated conditions in Saskatchewan the first increment of fertilizer N (10 kg ha^{-1}) provided $25.6 \text{ kg grain ha}^{-1}$ for hard red spring wheat and from 27.6 to 28.0 kg ha^{-1} of grain for soft wheat and utility wheats. A similar study from southern Alberta (Dubetz 1976) showed that under fully irrigated conditions the initial applications of N fertilizer produced from 9 to 40 kg ha^{-1} wheat grain under varied soil $\text{NO}_3\text{-N}$ conditions.

B. EFFECT OF NITROGEN ON GRAIN PROTEIN PERCENTAGE

In Canada, wheat is graded to some degree on the basis of grain protein percentage. High grain protein percentage wheat is desirable for high quality milling and baking products. High protein barley grain is a valuable feed and low protein barley grain is desirable for the brewing industry.

1. Nitrate-nitrogen and Grain Protein Percentage

The effects of soil $\text{NO}_3\text{-N}$ on the grain protein percentage of wheat has been generally recognized by researchers. Burke (1925) reported seven year average grain protein percentages for wheat to be 15.9% on fallow fields and 11.6% on stubble fields.

This was despite the fact that yield of fallow seeded wheat was 60% higher than continuously cropped wheat; the average $\text{NO}_3\text{-N}$ on fallow fields was 5.6 ug g^{-1} and 2.5 ug g^{-1} on stubble fields to 0.9 m. From this the author showed that soil $\text{NO}_3\text{-N}$ to a depth of 0.9 m was closely related ($r^2 = 0.37^*$) to the total N percentage of spring wheat grain. In Manitoba, Racz et al. (1965) reported that canola and flax grown on fallow fields had a higher percent N in the tissue than canola and flax grown on nonfallow fields.

It has been shown that N in excess of that which is required to increase grain yield results in increases protein percentage of the grain (Eck, 1957). Nuttall et al. (1979) found that soils high in nitrate nitrogen in northeastern Saskatchewan produced the highest percent N in spring wheat grain. Smika and Greb (1973) showed that $\text{NO}_3\text{-N}$ at seeding could be used to predict percent grain protein of winter wheat in the Great Plains of the United States with considerable accuracy.

Working in Alberta, Walker (1975) reported that soil $\text{NO}_3\text{-N}$ and fertilizer N accounted for more than half of the variance in percent grain N of Galt barley. The relationship between grain protein percentage of canola and soil $\text{NO}_3\text{-N}$ was demonstrated by Henry and MacDonald (1978) in Saskatchewan. The authors reported that the protein percentage of canola was highly correlated with soil $\text{NO}_3\text{-N}$ and fertilizer N ($r = 0.74^{**}$, irrigated and $r = 0.44^{**}$, dryland). Work in Manitoba has shown the $\text{NO}_3\text{-N}$ test to be a reliable predictor of the protein percentage of cereal grains as well as grain yields. The grain protein percentage of Neepawa wheat not fertilized with N in ten field experiments was closely correlated ($r = 0.74^{**}$) to amount of $\text{NO}_3\text{-N}$ in the soil to 122 cm. The correlation with grain protein percentage was even closer for wheat fertilized with N (Alkier 1972).

2. Fertilizer Nitrogen and Grain Protein Percentage

In Manitoba, Partridge (1971) demonstrated that protein percentages of wheat grain were significantly lower when $80 - 100 \text{ kg N ha}^{-1}$ were applied than when no N was added

for wheat grown in pots in a growth chamber. However, N additions in excess of 80-100 kg N ha⁻¹ resulted in significant increases in grain protein. Walker (1975) found that below a soil NO₃-N content of 20 kg N ha⁻¹, percent N in the grain remained constant or declined with additions of 34 or 67 kg N ha⁻¹ and increased when greater amounts of fertilizer N were added. Similarly, Dubetz (1976) reported the possibility of increasing grain protein 51-76 percent with applications of N fertilizer above the 100 kg N ha⁻¹ required for optimum yield increase addition.

The addition of fertilizer N also increases the amount of grain protein in the mature seed of canola (Finlayson et al. 1970). Bhatti (1964) reported that N fertilization (85 kg ha⁻¹) increased the yield and grain protein percentage of two varieties of canola, Golden and Arlo. In these experiments, the mean grain protein percentage of the two varieties was between 33 and 40% depending on the location.

Where N is deficient, and factors other than N are in good supply, initial increments of N fertilizer result in large increases in yield and consequent decreases in tissue percent N. Terman et al. (1969) working with winter wheat in Nebraska reported that grain yield was negatively correlated with grain protein percentage regardless of N fertilizer additions. In a later study Terman (1979) showed that at each rate of applied N fertilizer, grain protein concentrations were inversely related to grain and straw yields of winter wheat in North Carolina.

It appears that as increments of N gradually become less effective in increasing yield the result is an increase in N content of the plant tissue. At some critical point, no increase in yield results from further additions of N and any additional N continues to increase N content and hence grain protein. In addition, N available late in the growing season can contribute to an increase in grain protein percentage, including available soil NO₃-N (McNeal and Davis 1954). Grain protein can also be increased by late sprayings of N fertilizers after yield potentials have been determined (Finney et al. 1957).

N (soil and fertilizer) contributes to the yield and the grain protein percentage of cereals and oilseeds. The degree of the contribution is related to the availability of the N and the time at which its availability is greatest. At an N application rate most effective in increasing yield, an inverse relationship exists between yield and grain protein percentage and has been referred to as the inverse yield - nitrogen law (Wilcox 1949). However, when N is added in excess of that needed to just attain near maximum yields, grain protein is increased as well. Therefore, it is possible to obtain both high yields and high grain protein if N supply is maintained at a high level.

C. EFFECT OF MOISTURE ON YIELD AND GRAIN PROTEIN PERCENTAGE

1. Moisture and yield

Spring soil moisture reserves and growing season precipitation are important factors affecting crop production in western Canada. Hopkins (1935) found a significant correlation between yield of wheat in western Canada and the amount and distribution of growing season precipitation. Lehane and Staple (1962) used multiple regression analysis to determine that June and July precipitation and stored soil moisture below 30 cm were important factors influencing yields in southwestern Saskatchewan. An earlier study (Staple and Lehane, 1954) showed that at least 150 mm of water use was required to produce any grain and that beyond 150 mm each additional mm of water produced an additional 12 kg ha⁻¹ of grain. de Jong and Rennie (1967) suggested a threshold limit of 12.5 cm to produce a 600 kg ha⁻¹ wheat crop and that a curvilinear relationship exists between yield and moisture use.

Canola grown in the greenhouse under conditions of low soil moisture tension will normally yield higher than canola grown under high soil moisture tension (Nuttall, 1973). Krogman and Hobbs (1975) expanded the work of Nuttall to field conditions and showed that irrigation treatments more than doubled yields by promoting greater plant growth, more

Pods, more seeds per pod and larger seeds than where irrigation was not applied. A maximum yield of 3000 kg ha⁻¹ was obtained where irrigation maintained soil moisture in the upper half of the available range until pod ripening.

2. Moisture and Grain Protein Percentage

Various authors have reported a decrease in yield and an increase in grain protein percentage with increasing soil moisture stress (Dubetz 1961; Lehane and Staple 1962; Terman et al. 1969) and others have shown the importance of considering the phenological stage at which stress is applied (Robins and Domingo 1962). The effects of moisture stress on the grain protein percentage of wheat was shown to be greatest when the stress occurred late in the growing season at a time when grain filling was occurring (Campbell et al. 1981; Smika and Greb 1973).

In Manitoba, Partridge and Shaykewich (1972) reported that grain yields and grain protein percentages of Neepawa wheat were not significantly influenced by low to moderate soil moisture stress but that stress in excess of that used in their experiments would, in most cases, result in increased percent grain protein and decreased yields. Nuttall (1973) reported that the grain protein percentage of canola, grown in the greenhouse, was increased with moisture stress and that protein percentages up to 41% could be obtained under high soil moisture tension.

D. EFFECT OF MOISTURE AND NITROGEN ON YIELD AND GRAIN PROTEIN PERCENTAGE

1. Moisture x Nitrogen and Yield

Because of the mobility of N in the soil and its dependence on moisture to facilitate its movement, a great deal of research has been done examining the interaction between N fertility and moisture. Fertilizer N has been reported to increase yields and water use efficiency of dryland crops (Viets 1962; Ramig and Rhoades 1963; Singh et al. 1975) and

has been shown to increase depth of extraction of moisture from the soil profile (Kmoch et al. 1957).

In Saskatchewan, Read and Warder (1974) reported that rainfall during the growing season had a greater influence on yield of wheat than stored soil water when no fertilizer was added. However, the opposite was true when plots were fertilized.

The effect of N and moisture on the yield of canola was examined by Henry and MacDonald (1978). The authors reported that canola yields in Saskatchewan were increased nearly fourfold by the combination of irrigation and high rates of fertilizer N (224 kg ha^{-1}). In addition, the increase due to irrigation and fertilizer N together was more than double the sum of the increase due to the two factors applied separately. Bauer et al. (1965) reported that wheat grain yields on N check plots increased with increases in precipitation and stored soil water. However, N fertilizer treatments demonstrated that the rate of N required for maximum wheat production increased as moisture became less limiting.

2. Moisture x Nitrogen and Grain Protein Percentage

Fernandez and Laird (1959) demonstrated the interaction between N and moisture on the grain protein percentage of spring wheat in Central Mexico. Results showed that yields on the lowest moisture stress treatments, increased 26 kg ha^{-1} per kg of N applied. Grain protein decreased by one percentage point for a 50 kg N ha^{-1} treatment and the 100 kg N ha^{-1} treatment returned protein to the original level. Rates beyond the 100 kg N ha^{-1} level also increased grain protein. When moisture stress increased, the yield increase from fertilizer N decreased to 12 kg ha^{-1} per kg of fertilizer N applied with high rates of N resulting in the highest grain protein percentage.

Sosulski et al. (1966) suggested that moisture is the most important factor controlling grain yields and N the most important factor controlling grain protein. Because of the significant interaction demonstrated between N and moisture on grain yield, it

follows that a similar interaction should occur for grain protein. The effect of N fertilizer on percent grain protein at constant and variable moisture was demonstrated by Hutcheon and Paul (1966). It was shown that, with increasing soil moisture stress, the percent grain protein of Thatcher wheat increased, but total dry matter yield, water use and grain yield decreased. In addition, grain protein increased with successive increments of N fertilizer when moisture was held constant. Henry and MacDonald (1978) reported that the grain protein percentage of canola in Saskatchewan was higher under dryland than under irrigated conditions when fertilizer N was applied.

Regression models developed by Bole and Pittman (1980b) further demonstrated the interaction between moisture and N fertility. With their models, percent protein in barley grain could be described with some degree of accuracy ($R^2 = 0.49^{**}$) using fertilizer N, soil moisture, and growing season precipitation. Grain protein levels of up to 19% were reported when nitrogen supply (soil and fertilizer) was between 100 - 180 kg N ha⁻¹ and available soil moisture maintained at less than 100 mm. Dubetz (1976) reported a maximum grain protein level of 21% for Neepawa wheat with relatively high rates of N fertilizer when moisture stress occurred at flowering.

E. OTHER FACTORS AFFECTING YIELD AND GRAIN PROTEIN PERCENTAGE

Variation in yields and grain protein percentages among locations and years highlights the importance of quantifying as many independent variables as possible. Significant relationships between variability in fertility and moisture have been previously covered in this review, yet these factors alone cannot fully account for all variations in yield and grain protein. Other factors which may lead to yield and grain protein variability are discussed below.

1. Temperature

Temperature affects growth mainly through its influence on respiration rate and morphology (Friend 1966). The net effect of an increase in temperature is dependent upon the extent of dry matter loss through increased respiration rate, and dry matter increase through increases in leaf area ratio. Various studies have shown temperature to be a major factor influencing rate of development and in turn yield and grain protein percentage (Sosulski et al. 1966; Fulton and Findlay 1965; Partridge 1971). Friend et al. (1962) used growth chamber experiments to determine critical parameters of temperature for Marquis wheat. Temperatures of -2°C and 33.5°C were found to be critical temperature limits and maximum vegetative growth occurred at approximately 18° to 25°C .

The effects of temperature on yield and grain protein percentage of cereals under field conditions are confounded by interactions between N and temperature and N, temperature and moisture. As a result, several investigations have used all three variables to assess the effect of temperature (Hutcheon and Paul 1966; Sosulski et al. 1966). Mack (1965) used field experiments under three soil temperature conditions (9° , 18° and 27°C), three moisture regimes (low, seasonal and high), and two fertility levels (high and low) to examine their influence on yield and nutrient content of barley. Results demonstrated that yields of barley were significantly lower regardless of moisture when soil temperature was near 27°C than when it was near 9° or 18°C . Highest yields were obtained at 18°C . Lower yields at the higher soil temperatures were the result of a hastening in maturity. Experimental results of Kolderud (1975) supported the previous work and also showed that a decrease in yield with an increase in temperature was the result of a combined effect of higher maturation rate and lower net assimilation rate.

Fulton and Findlay (1965) used controlled environmental conditions to examine the effects of temperature and moisture on yield and nutrient percentage of oat tissue. Ambient air temperatures were maintained at 13° , 18.5° and 24°C and combined with variable

moisture levels. Grain yield increased as supply of soil moisture increased at each of the 13° and 18.5° C treatments. The 24° C treatment required additional moisture to attain maximum yield. Nutrient percentages were shown to increase with increasing temperature due either to an increase in nutrient availability or a decrease in yield. Sosulski et al. (1966) examined the combined influence of N, temperature and moisture on yield of Thatcher wheat. Lower temperatures and N fertilization favoured development at medium and high soil moisture. Temperature was reported to be the only environmental factor to have a consistent influence on kernel weight, with lower temperatures giving higher kernel weights. Furthermore, the authors reported that grain protein percentage decreased as grain yield increased, suggesting an increase in temperature resulted in increased grain protein.

Several authors have reported increases in grain protein with increasing temperature (Kolderup 1975; Campbell and Davidson 1979b; Campbell et al. 1981). The latter grew Manitou spring wheat at three combinations of day/night temperatures (27/12°C, 22/12°C, 17/12°C) in controlled environment chambers. Temperature treatments were combined with three levels of N fertilizer (58, 116, 174 kg N ha⁻¹) and three levels of moisture stress (-0.3, -15 and -40 bars). Temperature was the most important factor affecting yield and grain protein percentage and moisture the least important. Yields were equal at 17° and 22°C but were greater than those at 27°C. The effect of temperature on grain protein percentage was independent of N and moisture.

Increasing temperature affects grain protein mainly through its influence on yields. In Manitoba, Partridge and Shaykewich (1972) found that 85 percent of the effect of temperature was indirect through its influence on yield, and 15 percent could be directly related to what was probably increased protein synthesis at higher temperatures. Experimental results of Campbell and Davidson (1979b) are consistent with earlier work. However, the authors concluded that 51 percent of the effect of temperature was due to its independent action and the rest due to its effect on yield.

Kolderup (1975) conducted experiments in which the effect of temperature on different growth phases were considered. Growth was divided into three periods which included a vegetative phase, a seed development phase and a ripening phase. Results supported earlier work which demonstrated that grain protein was higher at higher temperatures. N uptake was shown to be greater at lower temperatures. Hence, higher grain protein at higher temperatures was attributed to the concentration of N due to lower yields. Results suggest that N was taken up by the plant during early stages of development. Rate of uptake and translocation were independent of temperature. Thus, the effect of temperature was to shorten the maturation period which decreased the total amount of starch produced for the grain, and increase the concentration of N (protein) within the grain.

2. Light

In field conditions, the effects of light intensity are confounded with those of temperature and photoperiod. However, by using controlled environment chambers it has been possible to study the effects of light intensity alone.

Friend et. al. (1962) reported that net assimilation rate increased with increases in light intensity up to full daylight. It appears that an increase in light intensity up to a certain limit usually increases the rate of leaf expansion. Friend (1966) reported the light saturation point of wheat was twice that of normal summer intensities and that high light intensities under field conditions are unlikely to limit yields.

Increases in grain yield may result from an increase in the number of heads, number of fertile florets or an increase in kernel weight. Partridge (1971) reported that increased light intensity resulted in a doubling of tiller numbers (increase in number of heads) and a subsequent yield increase. Decreasing light intensity resulted in a marked decrease in grain yield irrespective of N and moisture treatments and increasing light intensity significantly decreased percent grain protein at all levels of added N and under high and low moisture

regimes. Campbell and Read (1968) varied light intensities in the growth chamber and found an increase in grain protein of spring wheat of approximately seven percent. However, under higher temperatures and moisture stress the effect of light intensity was almost negligible.

3. Photoperiod

Acceleration in development of spring wheat by increased photoperiod was reported by Riddell et. al. (1958). Increasing daylength from 8 to 16 hours accelerated development of floral primordia. Rate of development under greenhouse conditions may be increased by interrupting dark periods with periods of brief illumination.

N content of the grain was found by Kolderup (1975) to increase with increased photoperiod. Long days (10 hour daylight and 14 hour low light) resulted in higher grain protein percentage (22 percent higher in some cases) than those kept in 10 hour daylight and 14 hour darkness.

4. Plant Variety

Yield and grain protein percentage varies with varieties grown. Racz (1974) reported yields of Glenlea wheat exceed those of Neepawa wheat with differences remaining relatively constant regardless of the amount of fertilizer N added. However, grain protein percentage of Neepawa wheat was greater than that of Glenlea wheat when 9 kg N ha⁻¹ was added. When higher rates of N fertilizer were added, differences in grain protein became less.

F. SOIL TEST CALIBRATION

The proper calibration of soil tests in terms of fertilizer requirements provides the working basis for soil testing laboratories. Calibration refers to the assessment of the the

relationship between yield, fertilizer application rate and the soil test and in most cases requires the use of a mathematical model.

The characteristics of yield response curves and surfaces have been the subject of many investigations. Liebig (1855) is considered a pioneer in the study of responses of plants to nutrients. Liebig suggested that crop yield was directly proportional to quantities of limiting nutrients in the soil. Mitscherlich (1909) was among the first to describe the functional relationship between crop response and fertilizer applied. He suggested that plant growth follows a curvilinear pattern and that the law of diminishing returns was applicable to plant response, thereby implying that succeeding increments of fertilizer result in smaller increases in yield than the previous increments. Reviews of the original ideas on response curves and models used to describe them are available in Heady and Dillon (1961) and Boyd et al. (1976).

Complex mathematical models for soil test calibration have been developed over time. Cate and Nelson (1971) first described a simple procedure for partitioning soil test correlation data into two groups based on the probability of obtaining a response to fertilizer (high and low). The use of more elaborate models has developed as a result of the need to quantify an increasingly large number of on-site variables and their contribution to yield response to fertilizer. Colwell (1978) described a procedure by which some researchers have assigned physical and biological parameters to theoretical models. However, the author reported that no fundamental theoretical model had yet been found which could accurately describe the relationship between nutrient application and crop yield and therefore, the models most often chosen were empirical based on actual observations.

In most cases, response functions of a single nutrient application are categorized as being either linear, exponential or quadratic (polynomial). Quadratic or polynomial models have become most popular because of their ability to reach a maximum and then decrease, thereby describing a yield depressing effect (Melsted and Peck 1977). Johnson (1953) compared polynomial and exponential functions used for fitting response curves

and concluded that polynomial models gave a better fit and were most suited for purposes of interpolation. Heady et al. (1963) reported that the second degree polynomial has been most often employed as the basic equation for calibration of soil tests because of its simplicity of application and expandability to results of other equations and experiments. Anderson and Nelson (1975) however, reported that use of second degree polynomial models may result in biases in the estimation of fertilizer rates due to a ceiling placed on crop yield imposed by environmental, varietal and management factors.

Regression methodology and multiple regression techniques were described by Draper and Smith (1967). This type of analysis attempts to account for variation in a dependent variable by using a linear or other combination of independent variables combined in a model. Using this methodology, the limitations described by Anderson and Nelson could be accounted for in regression models. Agronomic experiments using multiple regression techniques deal primarily with the yields of crops as influenced by soil fertility, chemistry and the interacting effects of climate. Leonard et al. (1962) reported that experiments of this type normally need be repeated for a number of years because of the variation that occurs due to location and years. Laird and Cady (1969) described a procedure for selecting regressor variables for yield predictions using data collected at a number of experiments over time, thereby including the variation that may occur. The procedure described used the residual sum of squares as the criterion for variable selection. A regressor variable remained in the model based on a statistical test used to evaluate the reduction in residual sum of squares. The authors concluded that a general yield equation with regression coefficients that are meaningful in an agronomic sense is preferred.

In western Canada, several research studies have used soil and climatic factors for the development of statistical models which predict yield and subsequently fertilizer requirements (Soper et al. 1971; Read and Warder 1974; Walker 1975). Read et al. (1982) reported that responses of wheat in southwestern Saskatchewan were related to soil measurements of available water, $\text{NO}_3\text{-N}$ and NaHCO_3 -extractable phosphorus.

However, the soil and climatic variables used accounted for only 20-40 percent of the yield variability which occurred on fallow and nonfallow sites, respectively.

In central Alberta, Heapy et al. (1976a) used a multi-equation system described by Dillon (1961) to develop a barley yield equation based on the effects of soil and fertilizer N and P. The combined model accounted for only 36-38 percent of the variance in yield for pooled data for 17 site years. As part of the equation, a moisture stress term was included but calculated from a second equation derived from data collected outside the study (Heapy et al. 1976b). Variation explained by the model was increased to 57 percent with incorporation of the water stress variable.

Bole and Pittman (1980a b) used soil and climatic factors to describe yield and grain protein percentage of barley using statistical procedures. The authors found that the model could successfully describe yields and grain protein percentage of barley in the Brown Soil Zone of southern Alberta, but could not be depended upon for extrapolation outside this area.¹

Thus, the calibration of soil tests is best accomplished with the use of a statistical model to describe the relationship between yield of crop, fertilizer application rate, and soil tests (Colwell 1978). Regression surfaces have proved most valuable in developing a statistical model and can be used for the direct calculation of fertilizer requirements, expected profits, and the expected economic value of soil testing.

¹ Personal communication with Dr. J. Bole, June 1985

CHAPTER III

METHODS AND MATERIALS

This project consisted of field experiments conducted during the period from 1972 to 1977. The purpose of these experiments was twofold. The first objective was to examine the effects of N fertilizer, soil $\text{NO}_3\text{-N}$ and climate on yield and yield components of various cereal and oilseed crops grown in southern Manitoba. The second objective was to derive crop yield and plant protein prediction equations which could be used by the Manitoba Provincial Soil Testing Laboratory to estimate nitrogen fertilizer requirements needed for optimal crop production in Manitoba.

A. DESCRIPTION OF EXPERIMENTAL SITES

The climate in the experimental area of southern Manitoba is broadly classified as continental, with predominantly warm summers and cold winters. Precipitation is often limiting and is therefore climatically classified as semi-arid. Agriculture in the area is dominated by cereal grain farming in combination with mixed farming. The cereal crops of major importance are barley and wheat. Flax and canola are the other major crops grown in the area.

A total of 58 field experiments, 29 on fallow and 29 on stubble were conducted over six years. Table 1 lists the experimental sites selected, their legal description and the crops seeded. Locations were selected to include the major crop production areas, major soil types, and climatic areas of southern Manitoba. In addition, sites were chosen based on cropping history (fallow or stubble) and soil $\text{NO}_3\text{-N}$ content.

Tables 2-7 list some characteristics of experimental sites. Soils selected varied in texture, ranging from clay at Dufrost to very fine sandy loam at Glenboro. Soils were

sampled at time of seeding to a depth of 120 cm to determine NO₃-N content and soil moisture content. Six cores were taken per experimental site. Bulk density for each field location was also measured and used to calculate NO₃-N in terms of kg N ha⁻¹ and to convert percent H₂O to millimeters of water (Appendix A). Soil sampling depths on experimental sites were: 0-15, 15-30, 30-60, 60-90, 90-120 centimeters.

Table 1. Site Location, Legal Description and Dates of Fertilizer Trials for Field Experiments Conducted from 1972-1977 in Southern Manitoba

Site and Year	Legal Location	Crop Seeded
Birtle - 1972-1974	NE 4-17-25	Wheat, Barley
Boissevain - 1976-1977	SW 9-3-19	Canola, Flax
Brandon - 1975	NE 15-11-19	Canola, Flax
Carman - 1976-1977	NE 15-2-24	Canola, Flax
Dufrost - 1972	NE 1-5-3E	Wheat, Barley
Glenboro - 1972	SE 3-7-14	Wheat, Barley
- 1973	NE 34-6-14	Wheat, Barley
- 1974	NW 34-6-14	Wheat, Barley
Goodlands - 1972-1975	NE 15-2-24	Wheat, Barley, Canola, Flax
Hamiota - 1975	SE 14-14-24	Canola, Flax
- 1976-1977	NE 36-13-24	Canola, Flax
Morris - 1973	RL 334	Wheat, Barley
Pilot Mound - 1972, 1973, 1977	NE 17-3-11	Wheat, Barley, Canola, Flax
- 1974, 1975-1976	SW 3-3-11	Wheat, Barley, Canola, Flax
Portage - 1972-1977	WL 299	Wheat, Barley
Roland - 1975	NE 25-5-5	Canola, Flax

Table 2. Some Characteristics of Soils on the Experimental Sites (1972)

Location	Soil Name	Texture	pH	Organic Matter %	Carbonate Content (% CaCO ₃)	NaHCO ₃ Ext. P ug gm ⁻¹	Exch K ug gm ⁻¹	Nitrate - Nitrogen Content (kg ha ⁻¹)		Conductivity mS/cm
								0-61 cm	0-122 cm	
<u>Goodlands</u>										
Nonfallow	Waskada	CL	7.9	2.7	1.07	3.5	327	21	41	0.4
Fallow	Waskada	CL	7.7	4.3	0.84	8.0	442	83	130	0.5
<u>Glenboro</u>										
Nonfallow	Glenboro	FSL	7.8	6.0	0.14	5.0	361	21	27	0.3
Fallow	Glenboro	FSL	7.7	6.1	0.82	7.7	376	75	106	0.4
<u>Portage</u>										
Nonfallow	Riverdale	SiCL	8.1	4.5	6.95	7.8	423	11	14	0.5
Fallow	Riverdale	SiCL	7.8	4.7	11.69	6.7	343	126	146	0.9
<u>Pilot Mound</u>										
Nonfallow	Carroll	CL	7.8	6.5	0.68	9.6	497	19	29	0.2
Fallow	Carroll	CL	7.3	6.4	0.18	9.9	558	60	74	0.5
<u>Birtle</u>										
Nonfallow	Newdale	CL	7.8	5.8	3.00	4.4	300	12	34	1.5
Fallow	Newdale	CL	7.9	5.9	1.32	9.5	377	78	99	1.6
<u>Dufrost</u>										
Nonfallow	Red River	C	8.0	6.7	0.00	22.0	768	57	73	0.3
Fallow	Red River	C	7.7	6.8	0.45	24.0	770	71	73	0.4

Table 3. Some Characteristics of Soils on the Experimental Sites (1973)

Location	Soil Name	Texture	pH	Organic Matter %	Carbonate Content (% CaCO ₃)	NaHCO ₃ Ext. P ug gm ⁻¹	Exch K ug gm ⁻¹	Nitrate - Nitrogen Content (kg ha ⁻¹)		Conductivity mS/cm
								0-61 cm	0-122 cm	
Goodlands										
Nonfallow	Waskada	CL	7.5	2.4	2.21	4	362	12.5	21.2	0.6
Fallow	Waskada	CL	7.6	2.5	4.17	4	364	49.1	58.1	0.6
Glenboro										
Nonfallow	Glenboro	VFSL	6.7	8.0	0.64	6	319	23.7	41.0	0.2
Fallow	Glenboro	VFSL	6.3	7.5	0.32	12	398	70.2	90.0	0.6
Portage										
Nonfallow	Riverdale	SiCL	7.7	2.9	10.89	4	290	35.3	47.6	0.4
Fallow	Riverdale	SiCL	7.6	2.9	10.98	7	280	67.1	92.2	0.5
Pilot Mound										
Nonfallow	Snowflake	CL	6.3	4.2	0.82	24	1077	57.7	85.7	1.1
Fallow	Snowflake	CL	6.4	5.0	1.08	30	662	124.3	164.3	1.2
Birtle										
Nonfallow	Newdale	CL	7.8	6.6	3.68	7	356	28.8	42.6	0.4
Fallow	Newdale	CL	7.1	6.5	0.36	8	416	62.7	84.7	1.0
Morris										
Nonfallow	Red River	C	6.8	5.6	1.57	25	654	27.8	38.6	0.6
Fallow	Red River	C	6.7	6.4	0.64	42	732	50.8	62.5	0.3

Table 4. Some Characteristics of Soils on the Experimental Sites (1974)

Location	Soil Name	Texture	pH	Organic Matter %	Carbonate Content (% CaCO ₃)	NaHCO ₃ Ext. P ug gm ⁻¹	Exch K ug gm ⁻¹	Nitrate - Nitrogen Content (kg ha ⁻¹)		Conductivity mS/cm
								0-61 cm	0-122 cm	
<u>Glenboro</u>										
Nonfallow	Glenboro	VFSL	6.5	4.5	0.43	6	419	12	21	0.4
Fallow	Glenboro	VFSL	6.3	4.8	0.57	7	329	30	73	0.2
<u>Pilot Mound</u>										
Nonfallow	Snowflake	CL	6.7	5.4	0.15	14	249	22	41	0.2
Fallow	Snowflake	CL	7.2	5.8	0.43	11	259	59	118	0.2
<u>Birtle</u>										
Nonfallow	Newdale	CL	7.6	5.2	2.08	6	395	28	72	0.4
Fallow	Newdale	CL	7.0	5.2	2.00	11	259	59	108	0.5

Table 5. Some Characteristics of Soils on the Experimental Sites (1975)

Location	Soil Name	Texture	pH	Organic Matter %	Carbonate Content (% CaCO ₃)	NaHCO ₃ Ext. P ug gm ⁻¹	Exch K ug gm ⁻¹	Nitrate - Nitrogen Content (kg ha ⁻¹)		Conductivity mS/cm
								0-61 cm	0-122 cm	
<u>Roland</u>										
Nonfallow	Myrtle	C	7.1	5.2	1.18	18	463	57	107	0.2
Fallow	Myrtle	C	7.2	6.6	1.16	22	526	126	166	0.4
<u>Pilot Mound</u>										
Nonfallow	Snowflake	CL	6.8	5.6	0.55	13	428	26	40	0.2
Fallow	Snowflake	CL	6.8	6.3	0.18	11	307	33	49	0.3
<u>Goodlands</u>										
Nonfallow	Waskada	CL	7.3	4.0	2.18	3	364	14	24	0.2
Fallow	Waskada	CL	7.3	4.6	12.38	4	300	48	65	0.3
<u>Hamiota</u>										
Nonfallow	Newdale	CL	7.8	5.1	1.79	2	286	12	18	0.2
Fallow	Newdale	CL	4.7	2.1	1.45	12	280	60	85	0.3
<u>Brandon</u>										
Nonfallow	Beresford	CL	7.6	5.6	1.80	9	513	30	48	0.3
Fallow	Beresford	CL	7.1	6.5	3.84	11	597	56	67	0.5

Table 6. Some Characteristics of Soils on the Experimental Sites (1976)

Location	Soil Name	Texture	pH	Organic Matter %	Carbonate Content (% CaCO ₃)	NaHCO ₃ Ext. P ug gm ⁻¹	Exch K ug gm ⁻¹	Nitrate - Nitrogen Content (kg ha ⁻¹)		Conductivity mS/cm
								0-61 cm	0-122 cm	
<u>Pilot Mound</u>										
Nonfallow	Snowflake	CL	6.0	4.7	0.16	8	450	13	29	0.3
Fallow	Snowflake	CL	5.9	4.9	0.56	13	460	49	63	0.4
<u>Roland</u>										
Nonfallow (1)	Altona	FSL	6.0	7.0	0.91	22	850	31	60	0.4
Nonfallow (2)	Altona	FSL	6.7	6.2	0.36	27	1000	61	181	0.6
<u>Boissevain</u>										
Nonfallow	Waskada	L	7.1	3.6	0.54	6	280	7	11	0.3
Fallow	Waskada	L	6.9	5.1	0.32	7	280	44	67	0.6
<u>Hamiota</u>										
Nonfallow	Newdale	CL	7.6	2.8	0.32	3	350	21	32	0.5
Fallow	Newdale	CL	7.5	5.0	4.02	5	360	30	54	0.5
<u>Portage La Prairie</u>										
Nonfallow	Riverdale	SiCL	7.6	2.7	11.55	4	360	29	54	0.5
Fallow	Riverdale	SiCL	7.6	2.0	9.82	14	350	70	95	0.8

Table 7. Some Characteristics of Soils on the Experimental Sites (1977)

Location	Soil Name	Texture	pH	Organic Matter %	Carbonate Content (% CaCO ₃)	NaHCO ₃ Ext. P ug gm ⁻¹	Exch K ug gm ⁻¹	Nitrate - Nitrogen Content (kg ha ⁻¹)		Conductivity mS/cm
								0-61 cm	0-122 cm	
<u>Roland</u>										
West Fallow	Altona	FSL	6.7	4.0	0.20	5	114	24	45	0.4
East Fallow	Altona	FSL	7.7	5.9	0.62	10	394	33	44	0.5
<u>Boissevain</u>										
Nonfallow	Waskada	L	7.2	5.7	0.38	14	190	14	22	0.2
Fallow	Waskada	L	7.5	4.8	1.62	12	200	81	99	0.7
<u>Pilot Mound</u>										
North Nonfallow	Snowflake	CL	6.3	5.8	0.42	23	300	9	14	0.4
South Nonfallow	Snowflake	CL	6.4	6.1	0.32	21	386	14	21	0.6
<u>Hamiota</u>										
North Fallow	Newdale	L	7.7	6.7	2.28	19	223	67	78	0.6
South Fallow	Newdale	L	7.2	5.9	0.82	13	278	75	109	0.7
South Nonfallow	Newdale	L	7.2	5.4	0.74	9	270	15	25	0.2
<u>Portage La Prairie</u>										
Nonfallow	Riverdale	SiCL	7.75	4.6	11.4	4.4	281	25	25	0.6

B. DESCRIPTION OF FIELD EXPERIMENTS

In instances in which both fallow and nonfallow sites were selected, the sites were placed on the same soil type approximately 30 m apart. The experiments were factorial and designed as a Randomized Complete Block (Cochrane and Cox 1958) with six replicates. Treatments remained the same throughout the term of the experiment. Types of crops grown, corresponding growing season and location were reported in Table 1. Crops consisted of: Spring Wheat (Triticum Aestivum cv. Neepawa, Glenlea), Barley (Hordeum Vulgare cv. Conquest, Fergus), Canola (Brassica Napus cv. Tower), and Flax (Linum Usitatissimum cv. Dufferin). Rate of seeding was 110 kg ha⁻¹ for the cereals, 45 kg ha⁻¹ for flax and 9 kg ha⁻¹ for canola. Seeding and harvest dates for each crop are reported in Appendix A. P as 11-55-0 was applied with the seed at rates of 46 and 20 kg P₂O₅ ha⁻¹ for cereals and canola crops, respectively. No P fertilizer was placed with the seed of flax.

Experimental plots were six meters long and consisted of six rows at 18 cm spacings. Six rates of nitrogen were applied as ammonium nitrate (34-0-0), broadcast on the soil surface at time of seeding. Cereal crops were treated with rates of 34, 67, 101, 134, 202, 267 kg N ha⁻¹. Canola and flax received 29, 63, 96, 130, 197, 264 kg N ha⁻¹ and 25, 58, 92, 125, 193, 260 kg N ha⁻¹, respectively. A small amount of nitrogen was received on the check treatments for the cereals (9 kg ha⁻¹) and canola (4 kg ha⁻¹) with the application of phosphate fertilizer at the recommended rate. All sites were treated with appropriate herbicides following recommended rates and good weed control was obtained.

At maturity the total above ground portion of the crops was harvested from each treatment. The center two rows of each treatment were sampled for a three meter length. Samples were placed in cotton bags and dried at 27° C until suitable for threshing. Yields of grain and straw were determined for each sample. Samples of grain and straw from the replicates for each treatment were composited prior to analysis. Bushel weight and percent

plump kernels (barley only) were determined, and total nitrogen determined on straw and grain.

Soil samples were taken at time of harvest to determine available moisture and residual nitrogen. Sampling depths at harvest were the same as those used at time of seeding.

C. ANALYTICAL PROCEDURES

1. Soil Analysis

Soil moisture content was determined gravimetrically. Bulk density was determined as described by Black (1965) in which the bulk density is determined by weight and volume measurements on samples obtained using a core sampler. The two measurements were used to calculate millimeters of water in the soil by the following method:

$$\text{Percent soil moisture} \times \text{bulk density (g/cm}^3\text{)} \times \text{depth (mm)} = \text{mm of soil water}$$

The $\text{NO}_3\text{-N}$ content of the soil samples was determined as described by Bremner (1965). Five grams of soil and 25 ml of extracting solution (0.01 M CaSO_4) were shaken in a flask for 10 minutes. Calcium hydroxide (0.2 g) was added and shaking was continued for another 10 minutes. Magnesium carbonate (0.5 g) was then added and shaking continued for 2 more minutes. The solution was then filtered and a 10 ml aliquot was taken to dryness over low heat. The residue was dissolved in 2 ml of phenoldisulfonic acid and allowed to stand for 10 minutes before dilution with water and 20 ml of 7.5 M ammonium hydroxide solution to a volume of 50 ml. The color intensity was determined on a spectrophotometer at a wavelength of 415 u.

Soil pH was determined on a 1:1 soil-water suspension using a universal pH meter.

Conductivity was measured using a 1:1 soil-water suspension and a conductivity cell. Organic matter was determined by chromic acid digestion using the Wakley and Black procedure (Black 1965). Carbonate content was determined by the measurement of CO₂ liberated with the addition of hydrochloric acid (Black 1965). Available phosphorus was determined using 0.5 M NaHCO₃ as the extractant (Olsen et al. 1965) and determined colorimetrically. Exchangeable potassium was determined by atomic absorption spectrophotometry after extraction of the sample using 1 M ammonium acetate at pH 7.0.

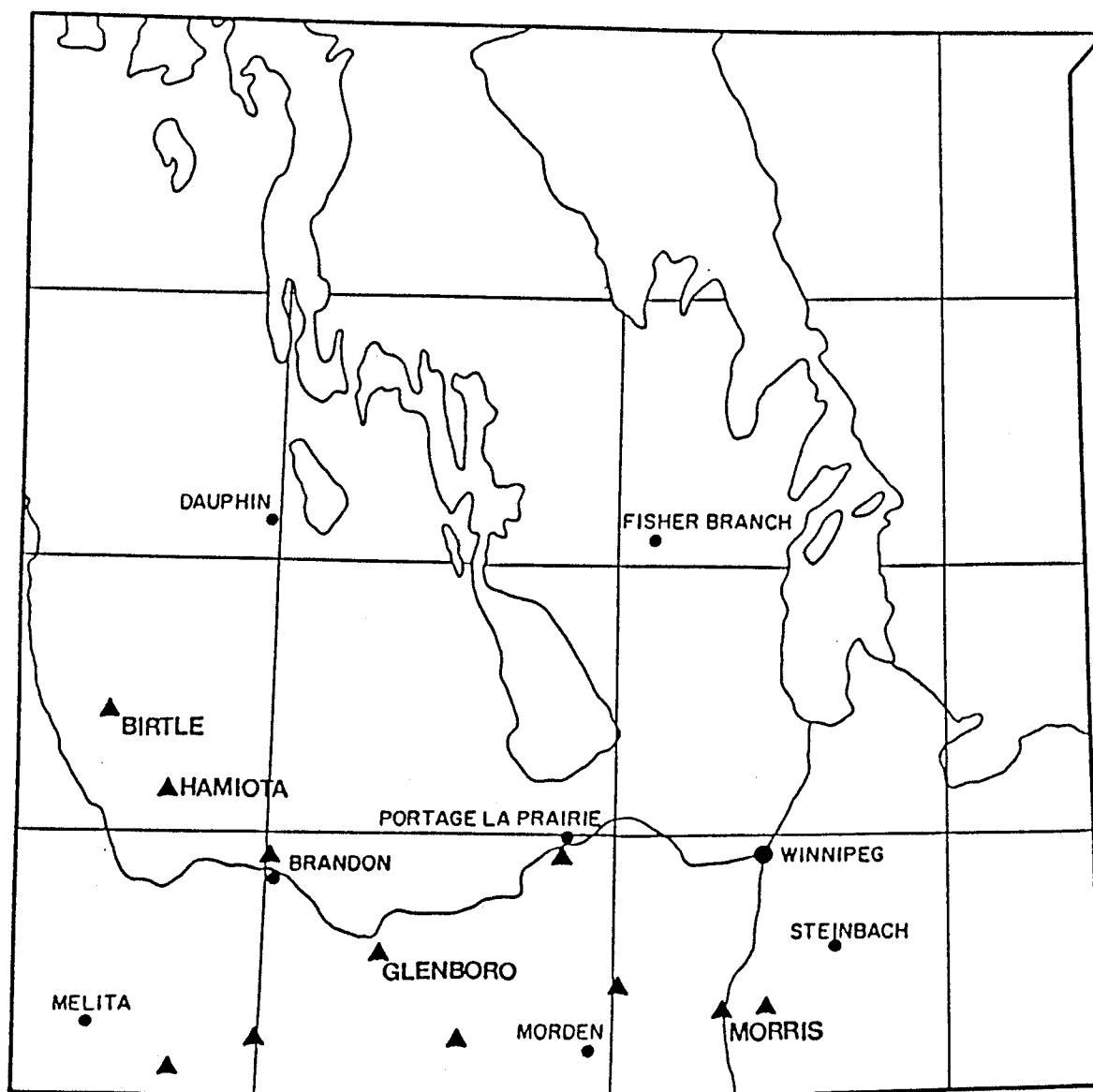
2. Plant Analysis

Grain protein percentage was determined by the method described by Jackson (1958). The grain was finely ground and dried at 45°C for 12 hours. Total nitrogen was determined on a one gram sample by the Kjeldahl method. The factor used in converting percent nitrogen to percent protein was 5.7 for cereals and 6.25 for oilseeds at 13.5 percent moisture.

D. DEVELOPMENT OF CLIMATIC DATABASE

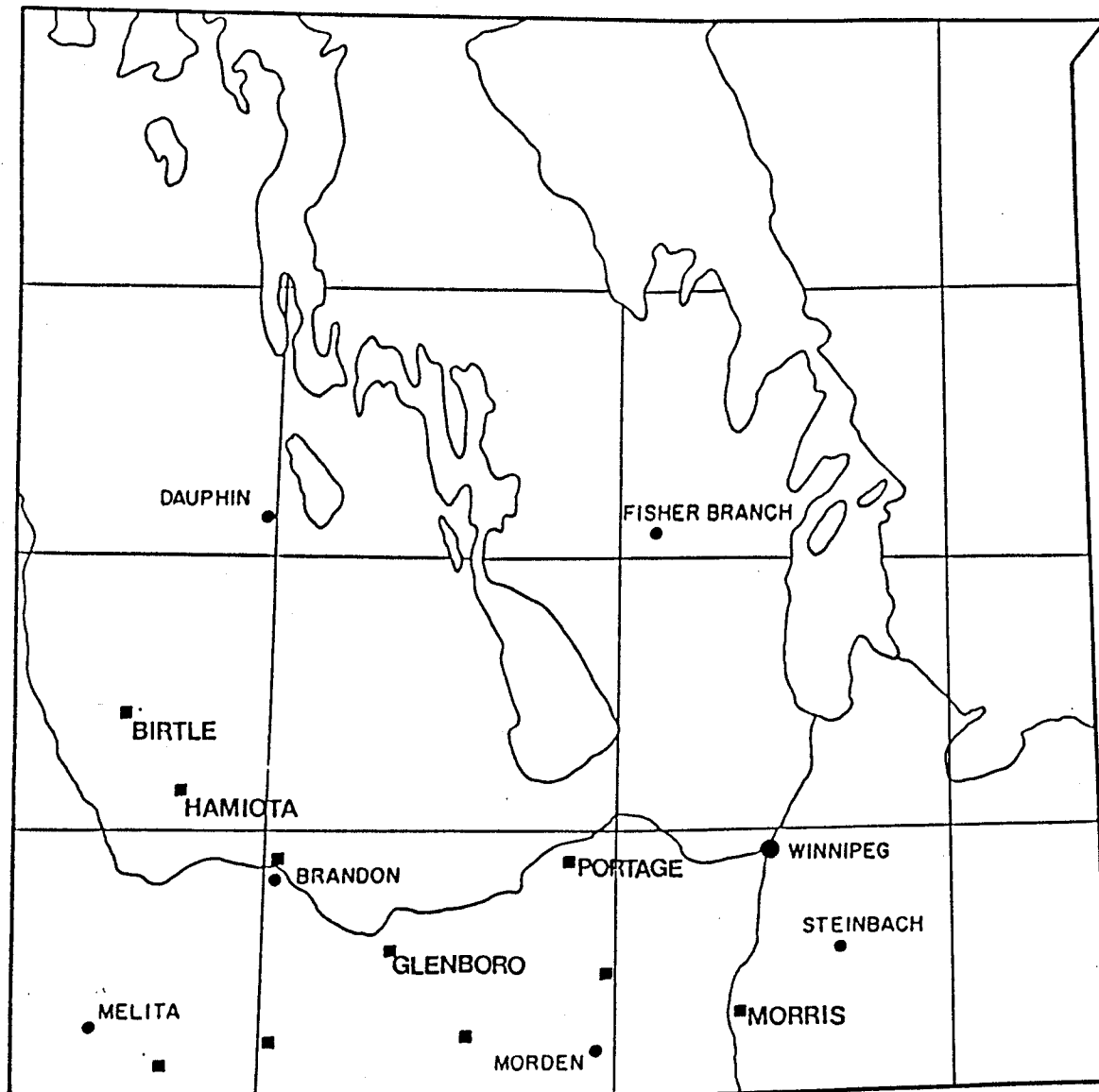
Experimental sites were selected to include the major crop production areas of southern Manitoba and located in close proximity to Atmosphere Environment Service (A.E.S.) climatological recording stations. Figure 1 shows the the location of A.E.S. recording stations and Figure 2 the location of the experimental sites used in this study. Table 8 gives the station numbers and latitudes as they are indexed in the A.E.S. climatological station data catalogue. The A.E.S. catalogue contains the station name and number, latitude, longitude, and elevation of each of recording stations.

Climatic data used in this study consisted of daily recordings of minimum and maximum temperatures and precipitation recorded at the aforementioned A.E.S. climatological recording stations. Daily maximum and minimum temperatures and



▲ AES RECORDING STATIONS

Figure 1. Location of Atmospheric Environment recording stations used to collect environmental data for experimental sites (1972-1977)



■ SITE LOCATIONS

Figure 2. Locations of experimental sites used for fertilizer trials in in Southern Manitoba (1972-1977)

precipitation were obtained from the magnetic tapes on which the data were stored by A.E.S.. Fortran programs were designed to access and retrieve these data in a manner which could later be used to create environmental variables for entry into the statistical models.

TABLE 8. Climatological Station Numbers Corresponding to Experimental Locations in Southern Manitoba as Indexed by Atmosphere Environment Service (A.E.S.)

Location	Station Number	Latitude
Birtle	5011240	50.42
Boissevain	5020320	49.23
Brandon	5010480	49.41
Carman	5022480	49.42
Dufrost	5021920	49.35
Glenboro	5011051	49.57
Goodlands	5011080	49.13
Hamiota	5011240	50.18
Pilot Mound	5022125	49.20
Portage	5012322	49.98

E. DERIVATION OF CLIMATIC VARIABLES

1. Solar Energy at the Top of the Atmosphere (Q₀) and Daylength

Values for daylength and solar energy were calculated for each location according to the method of Robertson and Rusello (1968). Equations are used to calculate daylength and solar energy from latitude of the experimental sites. Fortran programs were used to

calculate these values which were utilized in the models to be discussed later.

2. Temperature

As stated previously, temperature is an important consideration in relating climatic parameters to development of crops. Accumulated values which represent temperature may be used as parameters to estimate development of crops. Growing degree days, corn heat units, and biometeorological time scales may be used as accumulated values. The corn heat unit equation relates specifically to corn development and will not be discussed here.

2.1. Growing degree days

Growing degree days were calculated for the period from date of seeding to date of maturity (harvest). The formula used for calculation of degree days is as follows:

$$\text{GDD} = \sum_{S}^M [\{\text{maxt}(x) + \text{mint}(x)\}/2 - \text{bo}] \quad (1)$$

Where:

S = date of seeding

M = date of maturity

maxt, mint = maximum and minimum temperatures.

x = all days between seeding and maturity

bo = base temperature

The degree day equation is based on the concept that plants require a specific amount of heat in order to reach full development and that a base temperature (bo) existed below which phenological development is arrested and above which growth response to

temperature is linear. The base temperature used in this study was 5° C.

2.2. Biometeorological Time Scale

A biometeorological time scale (Robertson, 1968) was used to estimate rate of crop development based on daily minimum and maximum temperatures and photoperiod. The Biometeorological model used daily minimum and maximum temperatures and photoperiod to assess each days contribution to one of five phenological growth stages. The mathematical expression used is as follows:

$$S_2 = \sum \left[\{a_1(L-a_0) + a_2(L-a_0)^2\} \{b_1(T_1-b_0) + b_2(T_1-b_0)^2 + d_1(T_2-b_0) + d_2(T_2-b_0)^2\} \right] S_1$$

Where:

L = daily photoperiod

T₁ = daily maximum temperatures

T₂ = daily minimum temperatures

a₀, a₁, a₂, b₀, b₁, b₂, d₁, d₂ = coefficients based on crop response

S₂, S₁ = phenological stages

Table 9 gives the phenological stages used in this study and corresponding coefficients established for each stage of development are shown in Tables 10 (wheat) and 11 (barley).

TABLE 9. Biometeorological and Phenological Times as Determined by the Biometeorological Time Scale used in the Calculation of Crop Development (Robertson 1968).

Phenological Stage	Biometeorological Time
Seeding	0
Emergence	1
Jointing	2
Heading	3
Soft Dough	4
Ripe	5

TABLE 10. Biometeorological Time Scale Coefficients for Wheat (Robertson 1968)

	Planting Dough to Emergence Ripening	Emergence to Jointing	Jointing to Heading	Heading to Soft Dough	Soft to
a ₀	0.0E0	8.413E0	10.93E01	0.94E0	24.38E0
a ₁	0.0E0	1.005E0	9.256E ⁻¹	1.389E0	1.140E0
a ₂	0.0E0	0.0E0	-6.025E ⁻¹	-8.191E0	-20.0E0
b ₀	44.37	23.64E0	42.65E0	42.18E0	37.67E0
b ₁	1.086E0	-3.512E ⁻³	2.958E ⁻⁴	2.458E ⁻⁴	6.733E ⁻⁵
b ₂	-2.230E ⁻⁴	5.026E ⁻⁵	0.0E0	0.0E0	0.0E0
d ₁	9.732E ⁻³	3.666E ⁻⁴	3.943E ⁻⁴	3.109E ⁻⁵	3.442E ⁻⁴
d ₂	-2.267E ⁻⁴	-4.282E ⁻⁶	0.0E0	0.0E0	0.0E0

TABLE 11. Biometerological Time Scale Coefficients for Barley (Williams 1974)

	Planting to Emergence	Emergence to Jointing	Jointing to Heading	Heading to Soft Dough	Soft Dough to Ripening
a ₀	0.100E20	6.1361	1.00	2.061	-0.6970
a ₀	-0.989E-19	1.297	0.1841	0.3229	0.08793
a ₂	0.0E0	0.0E0	-0.01334	0.0E0	0
b ₀	4.34	10.09	-1.361	15.91	4.144
b ₁	0.01664	0.001128	-0.004423	0.002927	0
b ₂	-0.0005417	-0.00005725	-0.00008797	-0.0001638	0
d ₁	0.01416	0.0007619	0.002052	0.02282	0
d ₂	4.805E-4	1.854E-5	9.511E-6	4.666E-3	7.821E-4

3. Water Supply

Water supply was calculated for the period from seeding to harvest based on measurements of soil moisture, precipitation, and calculated values of potential evapotranspiration (P.E.). Water supply was calculated using two methods:

a)

$$\frac{(\% \text{ soil water in spring} - \% \text{ soil water in fall})}{100} \times \frac{\text{bulk density}}{\text{density}} \times \sum \text{depths} = \text{change in water content}$$

Rainfall was summed from seeding to maturity and added to the change in water content to equal the total water used by the crop. Measurements included water which may have been lost by runoff or deep percolation. Values for water supply were then calculated by subtracting potential

evapotranspiration which was calculated by the method of Baier and Robertson (1965) as:

$$P.E. = 0.086 \times (0.928 \times T_{\max} + 0.933 \times (T_{\max} - T_{\min}) + (0.0486 \times Q_0) - 87.03)$$

where:

P.E. = Daily Potential Evapotranspiration (mm)

$T_{\max}$ = Maximum Temperature (C)

$T_{\min}$ = Minimum Temperature (C)

Q_0 = Solar Energy ($\text{cal cm}^{-2} \text{d}^{-1}$)

Thus, values for water supply were defined as less than zero when potential evapotranspiration exceeded water use and as greater than zero when potential evapotranspiration was less than water use.

b)

A soil moisture budgeting technique was used to modify potential evapotranspiration in terms of crop type and phenological stage of development. In this method water supply was calculated as follows:

$$\text{Water supply} = (\text{change in soil water} + \text{precip}) - P.E. \times CU$$

where:

P.E. = potential evapotranspiration (mm)

CU = Consumptive use factor

$P.E. \times CU$ = actual evapotranspiration (mm)

precip = precipitation (mm)

change in soil water = from seeding to harvest (mm)

Actual evapotranspiration was calculated by multiplying potential evapotranspiration by a consumptive use coefficient (CU). These coefficients are characteristic for each stage in phenological development of the crop and reflect changes in leaf area index. Coefficients were calculated as the ratio of actual to potential evapotranspiration, as determined by plant type, stage of development and ground cover (Hobbs and Krugman 1968). Multiplying potential evapotranspiration by the consumptive use coefficients modified P.E. to actual evapotranspiration in terms of location. Table 12 gives consumptive use coefficients for each phenological stage of development as determined by the biometeorological time scale.

TABLE 12. Consumptive Use Factors Used to Calculate Actual Evapotranspiration Based on Stage of Development (Hobbs and Krogman 1968)

Stage	Consumptive Use Factor
0<BMTS>1	CU = .3
1<BMTS>2	CU = .3 + .5 x (BMTS - 1)
2<BMTS>3	CU = .8 + .2 x (BMTS - 2)
3<BMTS>4	CU = 1.0 + {(-.2) x (BMTS - 3)}
4<BMTS>5	CU = .8 + {(-.3) X (BMTS - 4)}
BMTS=5	CU = .5
BMTS >5	CU = .3

F. STATISTICAL MODELLING PROCEDURES

All models were developed using the General Linear Model of Statistical Analysis System (SAS, 1982). A stepwise multiple regression technique was used to determine the

importance of each of the independent variables in the reduction in variation associated with the dependent variables. The stepwise technique using the backward elimination procedure selected variables by calculating statistics for the model including all independent variables. The variables were then deleted from the model sequentially until all variables which remained in the model produced the desired F statistic significant at 0.10 level of probability. The procedure continued until all independent variables with no significant contribution to the model had been removed.

Multiple regression and least squares analyses was employed such that a linear combination of independent variables accounted for possible variation in a dependent variable. Equations of this type are expressed as:

$$Y = b_0 + b_1(X_1) + b_2(X_2) + \dots b_K(X_K)$$

where:

Y = dependent variable

b_0 = intercept on dependent scale

b_K = regression coefficients

X_K = independent variables

Least squares estimates were used such that the sum of squares of the deviations of the observed points from the predicted line would be at a minimum (Steel and Torrie, 1980). The proportion of variation in dependent variables that is accounted for by the independent variable(s) was evaluated as R^2 or the coefficient of determination. The coefficients of determination reported were in all cases adjusted for the inclusion of any extra independent variables in the regression. The adjusted R^2 value reduces the coefficient to a level expected when using the model in a new sample from the same population.

Multiple regression equations were applied to complete sets of data for each crop

and all years for both yield and protein content. Data obtained in the field experiment portion of this study was determined as being not linear since most relationships in agricultural research are not linear (Gomez and Gomez, 1976). Thus, data was treated in a nonlinear manner using quadratic functions and/or transformations to linear forms. After regression coefficients and equations were determined, specified values for independent variables were substituted back into the equations to determine the sensitivity of the equations within the original framework.

CHAPTER IV

RESULTS AND DISCUSSION

A. NITRATE NITROGEN CONTENT OF SOILS

Soil nitrate-nitrogen ($\text{NO}_3\text{-N}$ to 60 cm) contents varied with location, year and field cropping history (tables 2-7, pp. 20-25). Fallow sites generally contained higher levels of $\text{NO}_3\text{-N}$ than nonfallow sites. The highest $\text{NO}_3\text{-N}$ level to 60 cm on a fallow site was 127 kg ha^{-1} at Roland in 1975, the lowest was at Glenboro in 1974 (30 kg ha^{-1}). The values for $\text{NO}_3\text{-N}$ on nonfallow sites to 60 cm ranged from 85 kg ha^{-1} at Pilot Mound in 1973 to only 7 kg ha^{-1} at Boissevain in 1976.

Variation in soil $\text{NO}_3\text{-N}$ is often a reflection of climatic conditions, fertilizer practices, and cropping practices prior to soil sampling. Typically, low soil $\text{NO}_3\text{-N}$ is expected on nonfallow fields following a cropping season while higher soil $\text{NO}_3\text{-N}$ is expected on fallowed fields. High $\text{NO}_3\text{-N}$ values on nonfallow sites may result from periods of drought during which crop removal of nutrients is low or residual nitrogen from high fertilizer N applications. Low $\text{NO}_3\text{-N}$ values on fallow sites may result from poor weed control during the fallow period or leaching of nitrates from the rooting zone during periods of high rainfall.

Although $\text{NO}_3\text{-N}$ was present in the soils below depths of 60 cm and can be utilized by crops, most calibrations between $\text{NO}_3\text{-N}$ content of soils and crop yield or response to N fertilizer have been conducted using soil $\text{NO}_3\text{-N}$ to a depth of only 60 cm (Heapy, 1971; Soper et. al., 1971). In Manitoba, $\text{NO}_3\text{-N}$ to 60 cm has been shown to predict nitrogen uptake and hence response to N fertilizer equally as well as soil $\text{NO}_3\text{-N}$ to 120 cm (Soper et. al., 1971). At this time, all provincial and most state soil testing facilities recommend soil sampling to 60 cm for the determination of available $\text{NO}_3\text{-N}$. Consequently, the remaining references to soil available N will refer to accumulated $\text{NO}_3\text{-N}$ to 60 cm.

B. WATER CONTENT OF SOILS

Values for soil moisture at seeding also varied with location, year and field history. Tables 13 to 18 list volumetric water contents (millimeters of available water) for experimental sites. Soil moisture was favorable at most sites at time of seeding. The highest spring soil moisture to 120 cm was at Morris in 1973; the lowest was at Glenboro in 1973. The water content of nonfallow sites was usually less than fallow sites at time of seeding. The largest differences were apparent at soil depths below 30 cm. i.e. the differences among fallow and nonfallow sites increased as the depth of the soil profile increased. After cropping, the water content of fallow and nonfallow sites were similar.

Soil moisture at time of harvest was measured on treatments with a moderate level of applied N. However, N fertilization increases leaf area and leaf area duration of most crops and results in a greater potential for increased water use through transpiration (Campbell et al. 1977). In addition, N fertilization results in changes in plant rooting pattern and a consequent alteration in the pattern of soil water extraction (Knoch et al. 1957; Warder et al. 1963; Hoyt and Rice 1977; Campbell et al. 1977). In the drier regions of the prairies growing season water use under varied N fertility may appear to be the same because all available soil water is depleted (Anderson and Read 1966). This may not however, apply to regions outside the Brown and possibly the Dark Brown Soil Zones because of the greater amounts of available moisture during the growing season. Hence, measurement of harvest soil moisture taken as an average of moderate N fertilizer treatments may have resulted in a slight overestimation of soil moisture remaining in the heavily N fertilized treatments and a slight underestimation of moisture remaining in the treatments with low rates of applied N fertilizer.

C. YIELD OF GRAIN

1. Effect of Soil and Fertilizer Nitrogen

1.1. Cereal Crops

A complete listing of all grain yields as affected by N fertilizer for each location and

Table 13 Water Content of Soils (mm) (1972)

Depth (cm)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost
<u>Spring Sampling - Nonfallow</u>						
0-15	43.18	38.51	47.71	56.29	61.43	57.84
15-30	45.29	43.68	54.45	63.12	60.59	71.72
30-60	92.62	85.13	80.09	126.20	100.78	125.39
60-90	93.48	102.92	66.26	57.37	106.26	132.19
90-120	82.01	102.00	85.68	147.63	103.80	119.06
<u>Spring Sampling - Fallow</u>						
0-15	48.15	37.58	43.95	69.18	63.36	56.03
15-30	50.09	44.09	56.09	72.99	65.36	75.48
30-60	99.98	97.19	105.00	134.32	116.51	156.70
60-90	109.80	112.5	94.65	139.83	122.94	154.04
90-120	109.80	112.5	87.67	169.40	114.43	142.08
<u>Fall Sampling - Nonfallow</u>						
0-15	35.01	34.23	33.41	51.93	52.74	28.82
15-30	36.96	32.67	27.65	46.29	42.97	44.06
30-60	63.54	86.35	51.17	81.93	69.59	97.38
60-90	73.85	84.78	53.58	96.74	86.82	107.50
90-120	80.99	91.35	79.83	115.47	91.68	119.06
<u>Fall Sampling - Fallow</u>						
0-15	41.92	25.89	37.74	46.56	50.84	30.29
15-30	29.92	29.35	33.21	39.22	36.91	46.20
30-60	44.04	69.80	69.08	78.76	59.17	100.39
60-90	72.62	81.45	73.13	95.79	71.04	106.93
90-120	81.60	88.65	84.44	118.05	86.17	121.30

Table 14 Water Content of Soils (mm) (1973)

Depth (cm)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris
<u>Spring Sampling - Nonfallow</u>						
0-15	42.23	40.18	46.34	56.04	50.49	72.61
15-30	39.98	46.44	65.18	52.35	48.49	88.94
30-60	81.79	96.15	146.41	85.46	95.77	129.91
60-90	88.97	89.09	122.00	93.63	95.50	139.21
90-120	97.17	39.25	114.68	107.07	98.75	146.70
<u>Spring sampling - Fallow</u>						
0-15	48.60	43.65	52.09	54.59	53.67	70.15
15-30	40.29	48.86	47.69	61.28	48.02	86.96
30-60	84.86	99.65	91.28	113.04	107.97	170.40
60-90	96.27	96.62	117.11	139.95	110.11	167.59
90-120	84.12	64.34	107.36	130.13	104.30	153.02
<u>Fall Sampling - Nonfallow</u>						
0-15	31.74	39.65	47.08	31.44	30.34	49.72
15-30	28.49	43.03	48.25	26.95	27.01	52.46
30-60	64.45	99.05	96.30	60.74	61.18	102.92
60-90	80.35	66.72	78.99	68.88	62.56	108.20
90-120	83.17	38.36	91.92	94.65	68.55	123.67
<u>Fall Sampling - Fallow</u>						
0-15	35.57	42.08	52.73	34.87	25.27	47.14
15-30	26.91	48.12	49.51	33.08	23.06	51.91
30-60	51.62	101.04	54.96	63.59	51.73	105.74
60-90	61.75	76.20	76.28	64.53	63.14	111.27
90-120	75.59	58.26	93.97	79.44	70.37	123.97

Table 15 Water Content of Soils (mm) (1974)

Depth (cm)	Glenboro	Pilot Mound	Birtle
<u>Spring Sampling - Nonfallow</u>			
0-15	54.31	52.57	49.68
15-30	60.17	53.62	47.49
30-60	127.36	123.77	98.43
60-90	87.32	115.66	97.72
90-120	87.23	104.93	93.37
<u>Spring Sampling - Fallow</u>			
0-15	54.34	60.38	54.68
15-30	61.22	56.62	47.40
30-60	121.74	116.86	102.25
60-90	94.77	132.47	112.69
90-120	87.54	117.38	103.59
<u>Fall Sampling - Nonfallow</u>			
0-15	48.52	53.78	39.75
15-30	37.50	44.63	27.63
30-60	87.42	57.49	56.17
60-90	67.03	76.04	70.15
90-120	66.28	78.91	76.81
<u>Fall Sampling - Fallow</u>			
0-15	51.97	51.68	42.49
15-30	36.78	38.38	28.51
30-60	89.51	56.28	56.92
60-90	69.97	43.57	67.93
90-120	66.59	59.59	78.81

Table 16. Water Content of Soils (mm) (1975)

Depth (cm)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon					
<u>Spring Sampling - Nonfallow</u>										
0-15	49.14	50.96	50.27	46.61	56.70					
15-30	47.47	49.31	47.52	43.94	56.51					
30-60	79.90	92.17	87.89	87.76	104.58					
60-90	67.73	113.00	92.32	95.26	120.98					
90-120	70.72	115.43	85.25	94.67	104.68					
<u>Spring Sampling - Fallow</u>										
0-15	56.16	55.77	48.88	49.73	58.14					
15-30	63.91	53.25	47.30	46.17	63.09					
30-60	122.54	100.55	96.72	97.90	135.66					
60-90	119.71	101.25	89.02	100.99	110.68					
90-120	119.28	121.91	87.61	105.98	114.97					
<u>Fall Sampling - Fallow</u>										
	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>				
0-15	30.96	--	--	--	35.91	--	40.37	33.15	43.92	42.84
15-30	27.95	--	--	--	35.04	--	39.08	33.41	48.70	47.68
30-60	59.20	--	--	--	68.82	--	77.62	56.01	86.94	96.60
60-90	68.59	--	--	--	68.30	--	65.71	54.68	91.81	89.66
90-120	67.73	--	--	--	72.53	--	71.59	75.36	89.66	84.94
<u>Fall Sampling - Nonfallow</u>										
0-15	27.90	--	18.81	--	35.11	27.53	39.59	35.69	--	42.48
15-30	30.00	--	22.88	--	38.54	27.81	38.88	35.24	--	45.62
30-60	62.10	--	42.29	--	75.80	42.32	79.82	73.65	--	82.32
60-90	66.03	--	44.96	--	67.82	51.34	74.53	69.68	--	84.94
90-120	69.44	--	45.77	--	62.64	65.47	71.59	65.94	--	69.93

Table 17 Water Content of Soils (mm) (1976)

Depth (cm)	Carman		Pilot Mound		Hamiota		Boissevain		Portage La Prairie	
<u>Spring Sampling - Nonfallow</u>										
0-15	49.86	53.28	62.10		44.07		50.49		37.09	
15-30	60.65	57.34	60.77		44.96		50.19		38.37	
30-60	100.80	109.20	131.27		91.29		90.45		64.77	
60-90	98.41	106.93	124.74		88.92		90.74		90.87	
90-120	79.66	104.80	103.68		130.87		82.54		104.13	
<u>Spring Sampling - Fallow</u>										
0-15	--	--	62.17		39.98		48.71		33.64	
15-30	--	--	61.72		39.49		47.25		43.09	
30-60	--	--	138.45		87.76		90.00		110.11	
60-90	--	--	129.60		87.76		86.18		108.42	
90-120	--	--	120.69		90.74		74.78		95.55	
<u>Fall Sampling - Nonfallow</u>										
	<u>Flax</u>	<u>Flax</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>
0-15	30.96	30.24	31.40	34.50	43.10	25.94	19.40	33.07	21.05	16.56
15-30	33.12	32.29	32.19	35.05	22.68	30.78	21.00	25.62	17.77	16.82
30-60	73.50	59.22	100.95	71.42	46.75	53.36	43.20	43.20	24.77	32.77
60-90	77.96	74.98	78.17	68.85	60.65	72.96	57.00	46.97	45.24	46.41
90-120	78.38	80.09	89.51	78.17	78.89	65.66	71.14	64.30	76.05	62.40
<u>Fall Sampling - Fallow</u>										
0-15	--	--	--	28.98	40.37	26.91	21.78	23.56	21.91	18.29
15-30	--	--	--	31.81	25.52	23.29	21.21	21.00	15.88	22.49
30-60	--	--	--	70.62	48.95	48.95	36.00	35.55	44.96	51.05
60-90	--	--	--	75.74	62.93	61.10	36.02	39.67	58.89	67.86
90-120	--	--	--	79.38	77.06	76.15	45.14	57.91	69.03	62.79

Table 18. Water Content of Soils (mm) (1977)

Depth (cm)	Carman		Pilot Mound		Hamiota		Boissevain		Portage La Prairie			
<u>Spring Sampling - Nonfallow</u>												
0-15	--	--	64.71		45.87		56.69		37.81			
15-30	--	--	59.77		45.66		55.19		37.68			
30-60	--	--	128.73		91.78		95.54		65.14			
60-90	--	--	125.46		89.92		96.74		92.87			
90-120	--	--	102.76		105.87		88.54		101.15			
<u>Spring Sampling - Fallow</u>												
0-15	48.98	50.15	--		41.20	38.96	48.71		--			
15-30	52.57	51.38	--		39.98	36.79	47.25		--			
30-60	98.74	101.52	--		91.49	92.75	90.00		--			
60-90	99.96	99.80	--		89.70	85.76	86.18		--			
90-120	96.79	97.65	--		90.19	90.68	74.78		--			
<u>Fall Sampling - Nonfallow</u>												
	<u>Flax</u>	<u>Flax</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>	<u>Flax</u>	<u>Canola</u>
0-15	--	--	35.15	37.42	31.62	33.56	34.50	26.84	20.40	33.67	23.47	18.57
15-30	--	--	36.25	35.05	32.97	35.85	22.68	31.08	22.09	27.82	19.32	16.22
30-60	--	--	69.18	67.76	99.95	92.27	46.75	52.63	41.40	43.20	25.79	34.12
60-90	--	--	70.15	69.00	78.17	67.85	60.65	71.32	56.09	46.97	44.94	46.92
90-120	--	--	75.19	78.17	88.61	79.17	76.43	65.78	73.74	65.90	76.05	64.54
<u>Fall Sampling - Fallow</u>												
0-15	30.96	30.20	--	--	--	--	39.57	29.61	22.58	24.57	--	--
15-30	34.25	34.18	--	--	--	--	30.52	28.97	23.21	21.58	--	--
30-60	73.50	60.57	--	--	--	--	47.56	50.95	38.56	35.87	--	--
60-90	77.96	75.19	--	--	--	--	61.73	66.89	34.02	39.76	--	--
90-120	78.38	80.99	--	--	--	--	78.56	75.16	44.98	55.43	--	--

year is available in appendix A. Grain yields of the various cereal crops decreased in order:

Conquest barley, Fergus barley, Glenlea wheat and Neepawa wheat. In general, yields of all crops were higher on fallow than on nonfallow sites; a reflection of the higher initial $\text{NO}_3\text{-N}$ levels and stored soil water. The yields of Glenlea wheat on fallow sites were approximately 15% higher than yields of Neepawa wheat on fallow. However, Glenlea yielded only slightly better than Neepawa on nonfallow sites. Yields of Conquest and Fergus barley were similar on both fallow and nonfallow sites.

Yields of all cereal crops were increased when N fertilizer was applied to nonfallow sites. In most cases, yields increased with increases in applied N when less than 101 kg ha^{-1} were added. Yields remained relatively constant when more than 101 kg ha^{-1} were added to the nonfallow sites. Small increases in yield were also obtained on fallow sites when N fertilizer was applied. Increases in yield on the fallow sites were normally obtained with the lower rates of applied fertilizer N (34 or 67 kg ha^{-1}).

Grain yield data from all site years was combined for regression analysis to quantify the effect of applied fertilizer N and soil $\text{NO}_3\text{-N}$ on grain yield of wheat and barley over a wide range of environmental conditions. Both varieties of wheat and barley showed a significant positive response to applied fertilizer N and a significant positive effect of soil $\text{NO}_3\text{-N}$ content (table 19). Since many relationships between fertilizers and yield response are nonlinear, quadratic terms were included in the equation to improve the regression fit. Low standard errors for regression coefficients combined with significant coefficients of determination (R^2) for the equations indicate fertilizer N and soil test N contributed significantly towards explaining the variation in grain yields. A large portion of the remaining variation is likely due to environmental variables and their interrelationship with mineral nutrition.

Most workers in the past have determined the relative importance of the independent variables by comparing regression coefficients directly (Staple and Lehane 1954; de Jong and Rennie 1969; Bauer 1972). However, Steele and Torie (1960) suggest that

Table 19. Regression Coefficients, Standard Errors for Regression Coefficients and Coefficients of Determination for Yield of Wheat and Barley as a Function of Soil Nitrogen (NO₃-N 60 cm) and Fertilizer Nitrogen.

Variable	<u>Regression Coefficients</u>											
	<u>Wheat</u>			<u>Glenlea</u>			<u>Conquest</u>			<u>Barley</u>		
	Neepawa											Fergus
	bi	Sb	Std Coef	bi	Sb	Std Coef	bi	Sb	Std Coef	bi	Sb	Std Coef
Intercept	1394	126.3	0.000	1281	156.1	0.000	1398	158.0	0.000	1630	154.4	0.000
Soil Nitrogen	21.5	3.7	2.398	37.4	4.6	1.233	38.8	4.7	1.281	39.8	4.6	1.406
Fertilizer Nitrogen	7.1	1.5	0.827	7.1	1.8	0.669	10.5	1.9	0.975	9.9	1.8	0.994
Soil Nitrogen ²	-0.06	0.03	-2.066	-0.14	0.04	-0.578	-0.19	0.04	-0.838	-0.19	0.04	-0.875
Fertilizer Nitrogen ²	-0.02	0.005	-0.589	-0.017	0.007	-0.456	-0.03	0.007	-0.700	-0.03	0.006	-0.741
R ²		0.41**			0.56**			0.42**			0.51**	
S.E.E		569.5			614.9			712.7			608.0	

** = Significant at the 1% Level of Probability

comparison of standard partial regression coefficients is a more precise approach. Standard partial regression coefficients were calculated and are reported (table 19). When the above regression is analysed in this manner, yield was on average, almost two times more sensitive to soil $\text{NO}_3\text{-N}$ than to fertilizer N. However, this effect did vary among the cereal crops. Data for Neepawa wheat indicated that soil $\text{NO}_3\text{-N}$ was almost three times as important in the determination of final grain yields whereas for Conquest barley soil $\text{NO}_3\text{-N}$ was only 1.5 times as important as fertilizer N. The importance of the soil test for $\text{NO}_3\text{-N}$ to estimate the effect on grain yields is reflected in the values of the standard partial regression coefficients.

Comparing the regression coefficients for wheat with their counterparts for barley indicated that only small differences were present; this suggests that a similar response surface exists for each variety of wheat and barley used in these experiments. The exception was Neepawa wheat which displayed a regression coefficient for soil $\text{NO}_3\text{-N}$ that was less than the other cereal crops.

Nitrogen supply (soil nitrogen + fertilizer nitrogen) was not included in the above regressions because of its weighted relationship to the other variables which were included. However, the combination of soil and fertilizer N has been used in the past as an indicator of the total N supply to the plant (Bole and Pittman 1980). Previous studies, including those of Bole and Pittman have assumed the effect of soil and fertilizer N to be additive (Heapy et al. 1976a; Zentner and Read 1977). However, N utilization was calculated for the data from these experiments to estimate an average efficiency of fertilizer N over the range of rates used in the experiments (appendix B).

Utilization of N fertilizer was greater on nonfallow than on fallow sites, suggesting that utilization decreased with increases in available N. Mean percent utilization on nonfallow sites varied from about 40 to 50 percent and remained relatively constant at applied rates of less than 100 kg ha^{-1} ; utilization decreased at rates beyond the 100 kg ha^{-1} level. On fallow sites, utilization of added N usually decreased with the amount of fertilizer

N applied. Because utilization of added N averaged about 50 percent, the nitrogen supply term to be used in these regressions was modified to reflect the efficiency of fertilizer N added.

Experimental grain yields increased with successive increases in nitrogen supply (soil nitrogen +0.5 fertilizer nitrogen or N_s) up to about 250 kg ha⁻¹ for each of the cereal crops used in these experiments (Figures 3 and 4). The pattern of response was one of diminishing returns with the largest yield increases occurring at lower levels of N_s and smaller yield increases occurring at higher levels. Regression analysis was significant ($p = 0.01$) and positive for an equation with the form:

$$Y = \partial + \beta_1 N_s + \beta_2 N_s^2 \quad (4)$$

Combining soil NO₃-N and fertilizer N terms into one variable (N_s) for entry into a regression analysis resulted in a slight reduction of the ability of the independent term(s) to explain variability of the dependent term. However, a sizeable measure of convenience was added by making the equation a single variable, second order polynomial. The N_s term is used primarily to add convenience to regressions that require interaction terms.

The variations in experimental grain yields explained by the regression and described by the squared correlation coefficient (R^2) were 37 and 33% for Neepawa and Glenlea wheat, respectively, and 36 and 44% for Conquest and Fergus barley, respectively, when the N_s term was used (table 20). Standard errors for the regression equations were slightly higher when N_s was used as an independent variable rather than soil and fertilizer N.

1.2. Oilseed crops

A complete summary of oilseed grain yields as affected by N fertilizer for each location and year is presented in appendix A. In general, yields of canola exceeded those

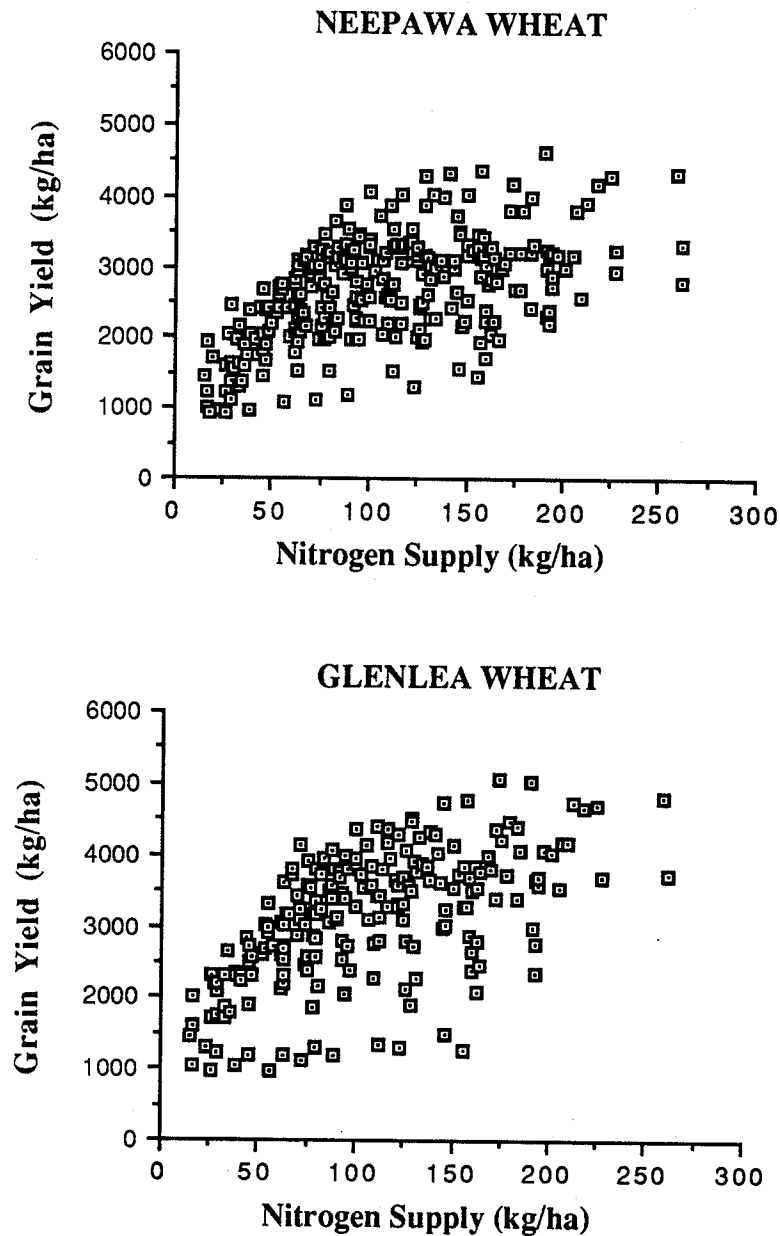


Figure 3. Effect of Nitrogen Supply (soil N + 0.5 Fertilizer N) on Yield of Wheat (1972 - 1975)

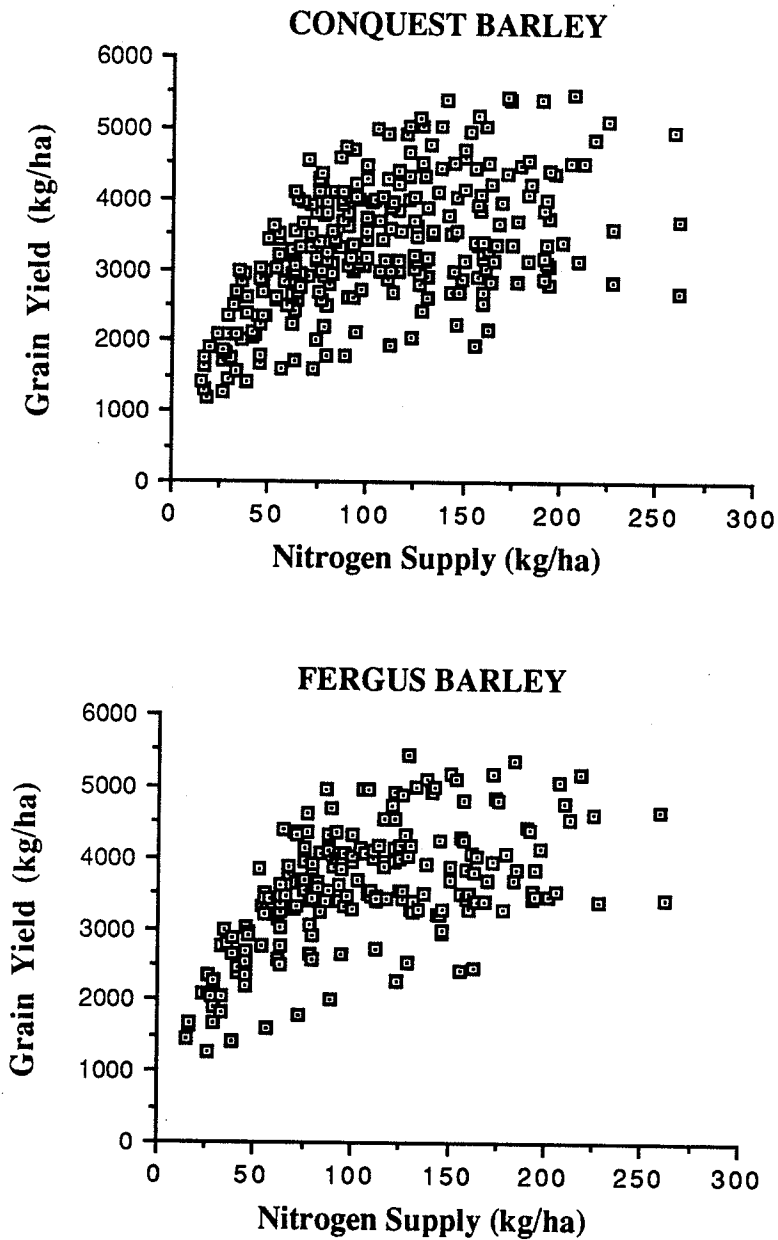


Figure 4. Effect of Nitrogen Supply (soil N + 0.5 fertilizer N) on Yield of Barley (1972 - 1975)

Table 20. Regression Equations and Coefficients of Determination for the Effect of Nitrogen Supply (soil nitrogen + 0.5 fertilizer nitrogen) on Yield of Wheat and Barley

Variable	<u>Regression Coefficients</u>			
	Neepawa	<u>Wheat</u> Glenlea	Conquest	<u>Barley</u> Fergus
	<u>bi</u>	<u>bi</u>	<u>bi</u>	<u>bi</u>
Intercept	1437	1314	1405	1569
Ns	23.050	19.560	29.009	30.570
Ns ²	-0.0507	-0.0510	-0.0836	-0.0908
R ²	0.37**	0.33**	0.36**	0.44**
S.E.E	602.8	731.4	742.1	653.6

** = Significant at the 1% Level of Probability

of flax by a considerable amount. As expected, yields of canola and flax were higher on fallow than on nonfallow sites.

In most cases, seed yields of oilseed crops were increased when N fertilizer was applied to nonfallow sites. Where responses to N fertilizer occurred, yields increased with increases in applied N when less than 96 kg ha^{-1} were added. However, yield increases were smaller than those obtained for the cereal crops. Yields remained relatively constant when more than 130 kg ha^{-1} were added to the nonfallow sites. Small increases in yield were also obtained on fallow sites when N fertilizer was applied. Increases in yield on the fallow sites were normally obtained with the lower rates of applied fertilizer N (9 or 25 kg ha^{-1}).

Grain yield data from all site years was once again combined for regression analysis to quantify the effects of soil and fertilizer N (table 21). In general, available soil N and fertilizer N were considerably less significant in explaining the variation in yields than was the case for the cereal crops. For canola, only 12% of the variation in grain yields was explained by variations in soil and fertilizer N, the remaining variation is attributed to experimental error and/or other factors. For flax, less than 5% of the variation was explained by the variation in soil and fertilizer N.

Standard Partial Regression Coefficients were once again calculated and are also reported in table 21. A comparison of the standard partial regression coefficients indicated that fertilizer N was significantly more important (3 times) in explaining the variation in seed yields of canola and flax than soil $\text{NO}_3\text{-N}$ (table 21). This was opposite to what had occurred for the cereal crops.

Poor correlation between soil N, fertilizer N and grain yields for these experimental sites is likely the result of factors not accounted for in the model. For the cereal crops, soil and fertilizer N accounted for a significant portion of the yield variability (table 19). The smaller data base (less site years) for the oilseed crops compared to the cereal crops may have allowed greater variation in climatic, environmental or random factors, and probably

Table 21. Regression Coefficients, Standard Errors for Regression Coefficients and Coefficients of Determination for Yield of Flax and Canola as a Function of Soil Test Nitrogen (NO₃-N, 60 cm) and Applied Nitrogen

Variable	<u>Regression Coefficients</u>					
	Dufferin Flax			Tower Canola		
	bi	Sb	Std Coef	bi	Sb	Std Coef
Intercept	1305	212	0.000	1113	270	0.000
Soil Nitrogen	-3.1	11.4	-0.116	-11.1	15.2	-0.281
Fertilizer Nitrogen	2.3	2.0	0.413	7.4	2.6	0.904
Soil Nitrogen ²	0.09	0.15	0.283	-0.15	0.20	0.289
Fertilizer Nitrogen ²	-0.007	0.008	0.328	-0.019	0.009	-0.628
R ²	0.05 NS			0.12*		
S.E.E	475.1			677.0		

NS = Not Significant at Either 1% or 5% Levels of Probability

* = Significant at the 5% Level of Probability

account for the lower coefficients of determination with the oilseeds than the cereals.

Experimental grain yields appeared to increase with increases in N_s although a considerable variation in the data was apparent (figure 5). When N_s was used as a single parameter to account for available N, little improvement over the previous regression model was apparent. The amount of variation in grain yields explained by using equation 4 was again 12% for canola and less than 5% for flax .

It is apparent that less than half of the variation in grain yields of the cereal and oilseed crops can be explained by fertilizer treatments, soil N or a combination of the two. The above regressions make no attempt to consider other variables which may influence the yields such as environmental or climatological parameters. The variation due to environmental factors is part of the error or residual variation in the regression analysis. The need then arises for some measure of climatic or environmental conditions to explain residual variation. For this purpose, a water supply term was calculated.

2. Effect of Water Supply

2.1. Cereal Crops

The calculation of the water supply (W_s) term was described earlier in the text. Aspects of the methodology used in the calculation of water supply and the analysis of the relationship between W_s and experimental grain yields are described briefly:

- (a) Total water use during the growing season was determined on samples collected from all experimental sites. Total water use = (spring soil moisture-fall soil moisture) + growing season precipitation.
- (b) A biometeorological timescale described by Robertson (1968) was used to estimate cereal crop development and divide the growing season into five growth intervals: (1) Planting to emergence (2) emergence to jointing (3) jointing to heading (4) heading to soft dough (5) soft dough to ripening.
- (c) A daily soil moisture budget was computed using potential evapotranspiration

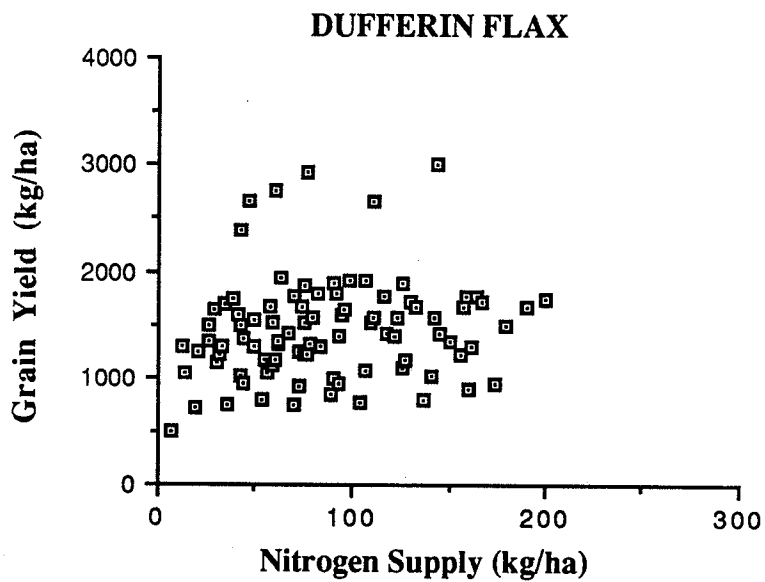
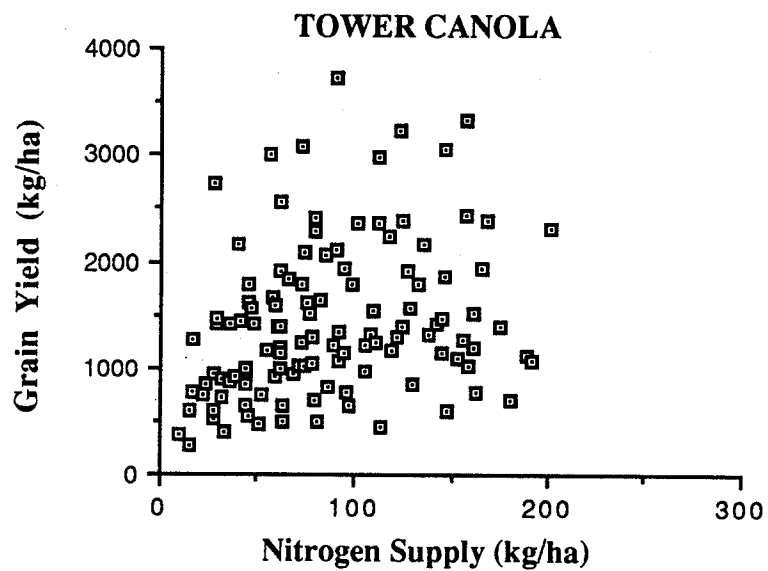


Figure 5. Effect of Nitrogen Supply (soil N + 0.5 fertilizer N) on yield of Flax and Canola (1975 - 1977)

and adjusted to actual evapotranspiration using coefficients (consumptive use factors) to estimate changes in water use for the five growth intervals.

(d) Water Supply was computed for each site year as the difference between total water use and actual evapotranspiration.

(e) The effect of Water Supply on yield and grain protein percentage was studied by regression analysis.

A term representing water supply or deficit was calculated in previous work (Racz, 1974). However, earlier methods used potential evapotranspiration not actual evapotranspiration to estimate water evaporated or transpired during the growing season. The method used in this study considered physiological changes in a crop by using a biometeorological time scale to modify potential evapotranspiration rates based on crop development and the portion of the soil surface covered by the crop during the growing season. This calculated value should be a better estimate of crop water stress because of the consideration given to changes in ground cover as the crop develops. Also, the use of the biometeorological time scale allowed for a more accurate approximation of the changes in moisture availability during the growing season.

Computed values for soil water supply varied with location year and field cropping history (table 22). The lower water contents in the nonfallow sites at the time of seeding are reflected in the calculated values for soil water supply on these sites. The calculated values for water supply using the biometeorological time scale indicated values for wheat were generally lower than those for barley. For wheat, water supply values calculated in this manner varied from -131 mm at Roland in 1977 to 191 mm at Pilot Mound in 1975. For barley, water supply values ranged from -73 mm at Glenboro in 1977 to 199 mm at Dufrost in 1973.

A negative water supply value suggests a moisture deficit occurred during the growth of the crop. Moisture deficits have been shown to significantly reduce yields of cereal crops (Racz 1974; Entz 1985). Positive water supply values suggest more water

Table 22. Calculated Values for Water Supply (mm)

Location	Year	History*	P.E.†	<u>Water Supply</u>		Location	Year	History	P.E.†	<u>Water Supply</u>	
				Wheat	Barley					Wheat	Barley
Birle	1972	NF	-130.9	-41.9	18.5	Hamiota	1975	NF	-41.0	32.3	-
		F	-42.0	46.9	107.4			F	-13.5	58.9	-
	1973	NF	-117.6	1.4	52.5		1976	NF	-102.3	13.9	-
		F	-67.3	51.8	102.8			F	-113.2	2.9	-
	1974	NF	-142.8	-34.4	8.6		1977	NF	-119.7	-8.6	-
		F	-113.1	-4.6	38.4			F	-82.7	28.4	-
Boissevain	1976	NF	-111.5	-11.7	-	Pilot Mound	1972	NF	-34.6	68.1	115.3
		F	-131.4	-31.6	-			F	14.9	117.7	164.9
	1977	NF	-81.6	24.1	-		1973	NF	-65.8	31.0	74.8
		F	-55.8	49.9	-			F	40.7	143.4	186.7
Brandon	1975	NF	-3.3	118.7	-		1974	NF	-177.5	-83.1	-31.9
		F	31.8	150.1	-			F	-51.8	51.5	102.7
Dufrost	1972	NF	-151.9	-21.1	11.6		1975	NF	91.4	181.1	-
		F	-81.1	41.8	82.5			F	101.5	191.3	-
	1973	NF	-44.1	87.5	120.6		1976	NF	-146.1	-52.8	-
		F	34.5	166.1	199.1			F	-109.7	-16.3	-
Glenboro	1972	NF	-158.6	-31.2	8.8	Portage	1972	NF	-127.0	-58.5	-25.7
		F	-113.3	28.1	73.3			F	-125.4	-56.8	-24.1
	1973	NF	-50.1	47.7	80.7		1973	NF	12.7	133.4	175.3
		F	-71.5	58.4	91.3			F	-13.6	107.1	148.9
	1974	NF	-211.1	-84.8	-68.8		1976	NF	-133.9	-33.4	-
		F	-215.6	-89.3	-73.4			NF	-105.2	-3.2	-
Goodlands	1972	NF	-93.4	28.1	71.4	Roland	1975	NF	-88.9	10.9	-
		F	-15.5	106.1	149.3			F	44.5	145.3	-
	1973	NF	-80.9	12.6	73.1		1976	NF	-232.1	-131.1	-
		F	-35.9	57.5	118.0			F	-144.6	-43.6	-
	1975	NF	-14.3	71.7	121.7		1977	NF	-153.3	-38.7	-
		F	46.5	137.4	187.4			F	-118.3	-3.6	-

† Calculation for water supply without correction for crop development, using potential rather than actual evapotranspiration.

* F= fallow, NF= nonfallow

was available during the growing season than was required and excess moisture remained at maturity. However, in many cases during these experiments, plots were not harvested at maturity. In instances harvests were taken a few days after maturity and a period of time was allowed to pass during which temperature and rainfall measurements were added to the estimate. Also, soil moisture in the fall was taken at harvest time and not at physiological maturity. Since the estimates continued until the crop was harvested (beyond maturity) additional precipitation records included in the calculation of water supply may account for higher than normal values.

Regression analysis revealed a significant relationship ($P = 0.01$) between grain yields of cereal crops and calculated values for W_s (figures 6 and 7). The significant relationship indicates grain yields increased as W_s increased up to a point beyond which some other factor became limiting. In general, the variation in grain yields explained by the calculated values for W_s and indicated by the squared multiple correlation coefficients, averaged about 30% for the two varieties of wheat and 26% for the two varieties of barley. The remaining variation was likely due to the effects of the N sources (soil and fertilizer) and random error.

Similar regression coefficients (water supply (W_s)), among the cereal crops indicate that a similar response surface existed and that each variety of wheat and barley responded to additional moisture in much the same way. Although the variation in yields explained by W_s were significant, a more accurate assessment of moisture effects would be possible if the efficiency of precipitation was taken into account. The timing and distribution of precipitation during the growing season and moisture availability has a pronounced influence on the grain yields of cereal crops grown in western Canada (Campbell and Zentner 1986). Precipitation received during grain development is generally reported to be most important with respect to final grain yields (Brown 1971; Bauer 1972). It is possible that variation in experimental grain yields explained by moisture supply alone would be higher if this efficiency were taken into account. Also, if moisture measurements had been

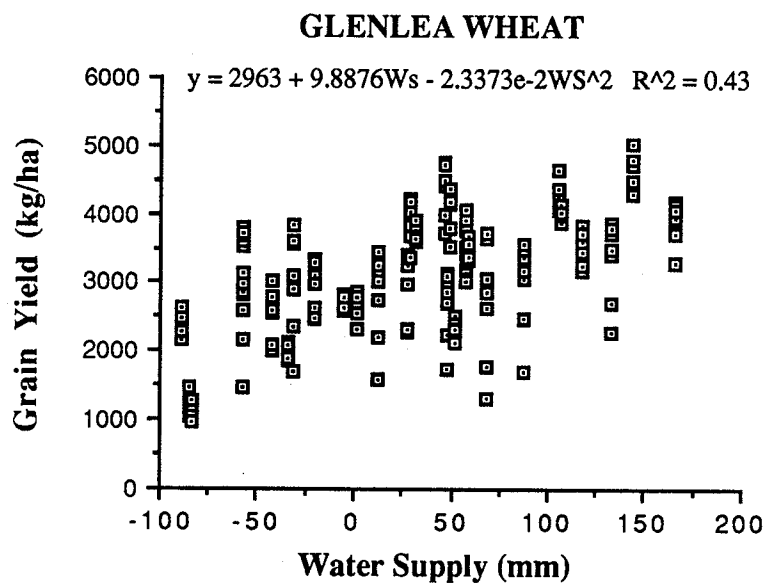
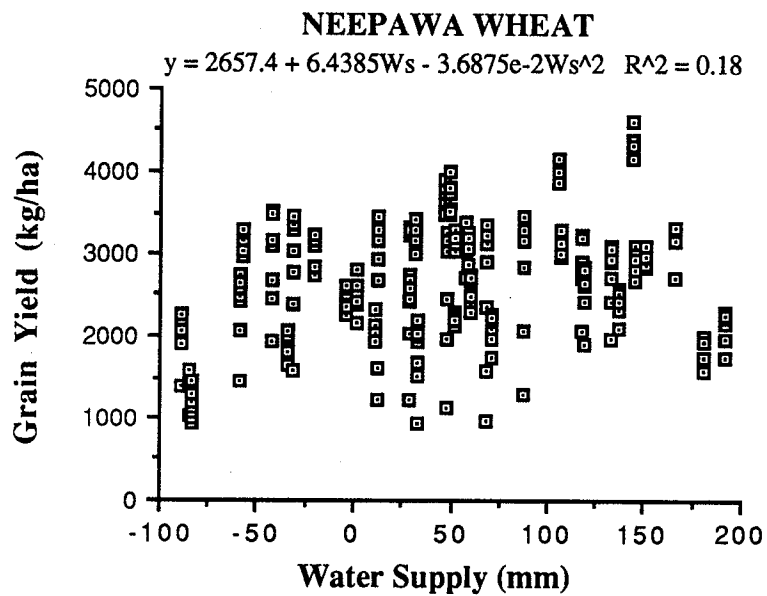


Figure 6. Effect of Water Supply on Yield of Wheat (1972 - 1975)

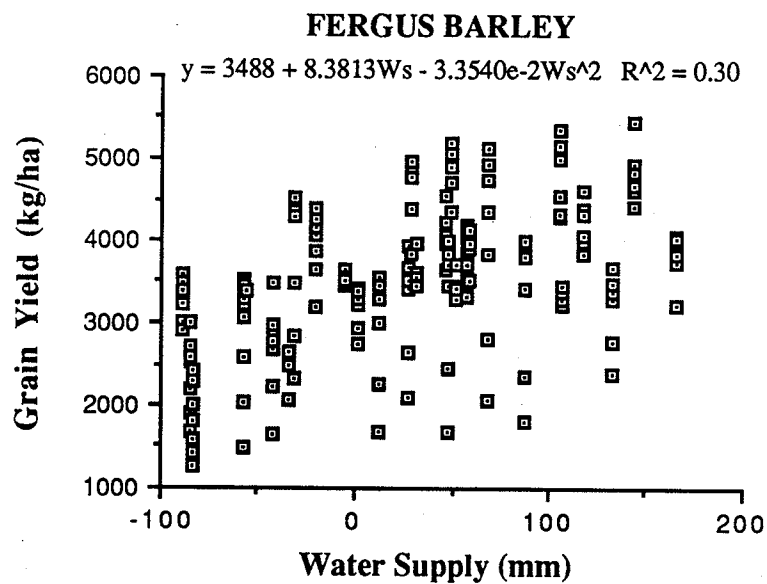
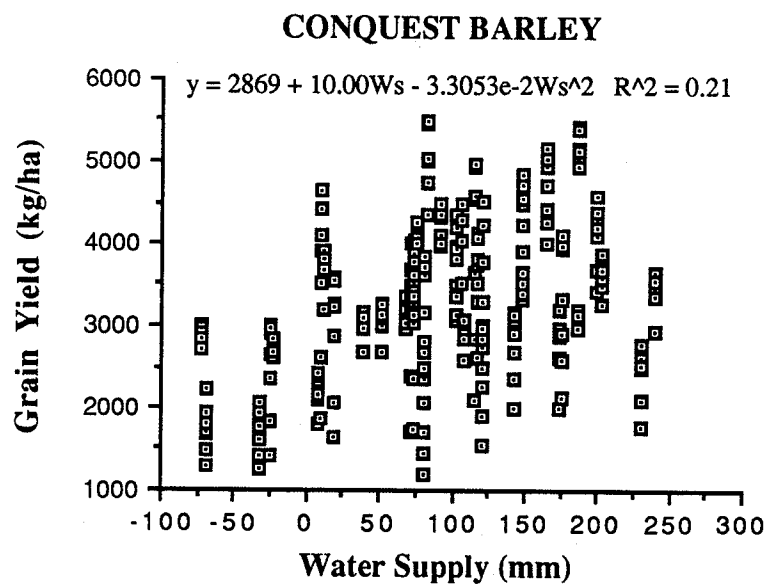


Figure 7. Effect of Water Supply on Yield of Barley (1972 - 1975)

made at maturity and not harvest a more accurate estimate of the effects may have been possible.

2.2 Oilseed Crops

The method, described above, used to calculate W_s was not used for canola and flax in these experiments. The biometeorological time scale developed by Robertson (1968) originated from experiments with wheat and coefficients for barley were later developed by Williams (1974). A biometeorological time scale for flax or canola was not available for estimating stage of phenological development. Coefficients used in the biometeorological times scale are used to calculate the intervals among growth stages and since growth stages of oilseeds differ considerably from cereal crops this method of estimating growth stages was not effective for oilseed crops.

Water supply (Racz, 1974) was used to describe the relationship between yields of canola and flax and available moisture. Aspects of the methodology used to calculate water supply were as follows:

(a) Total water use during the growing season was determined on samples collected from all experimental sites. Total water use = (spring soil moisture - fall soil moisture) + growing season precipitation.

(b) Potential evapotranspiration was estimated by the following equation:

$$P.E. = 0.086 \times (0.928 \times T_{\max} + 0.933 \times (T_{\max} - T_{\min}) + (0.0486 \times Q_0) - 87.03)$$

where:

P.E. = Potential Evapotranspiration (mm)

$T_{\max}$ = maximum temperature (C)

$T_{\min}$ = minimum temperature (C)

Q_0 = Solar Radiation at the top of the atmosphere at a specified time and day ($\text{cal cm}^{-2} \text{d}^{-1}$)

(c) Values for water supply (Ws) were defined as less than zero when potential evapotranspiration exceeded water use and as greater than zero when potential evapotranspiration was less than water use.

Calculated values for water supply at experimental sites where canola and flax were seeded were shown previously (table 22). A poor relationship existed between yields of canola and the calculated values for water supply (figure 8). In most cases, calculated values appeared to separate moisture deficient from moisture sufficient sites. However, results obtained for several sites did not conform to the general observation of increased yield with increased water supply. Despite being among the driest sites, yields at Roland and Pilot Mound in 1977 were higher than most other sites used to construct the data base. Its again possible that time of precipitation during the growing season was responsible for the higher grain yields even though total moisture received was somewhat less than at other sites. For example, if moisture was received in early June and late July the total rainfall could be high but the crop may suffer moisture stress in between these dates at a time when the moisture contribution is of more importance. Similarly, if moisture were received in late June or early July (heading or pod formation) the total amount may be less important than the timing of the precipitation.

Grain yield data for flax showed a better correlation with water supply than canola (figure 9). Regression analysis used on the complete data set indicated that 25% of the variation in grain yields could be explained by the calculated water supply term when a linear relationship was employed. Unlike the data for wheat and barley the relationship did not appear to conform to the nonlinear pattern; in fact the amount of variation explained by the regression decreased and no reduction in the error sum of squares was evident when a second order polynomial was used instead of the linear function. The nonlinear term used earlier to describe the relationship between yield and Ws has the advantage of describing a maximum yield beyond which further increases result in minimal or no further increases in yields; a situation which is more realistic than that described by the latter linear function.

TOWER CANOLA

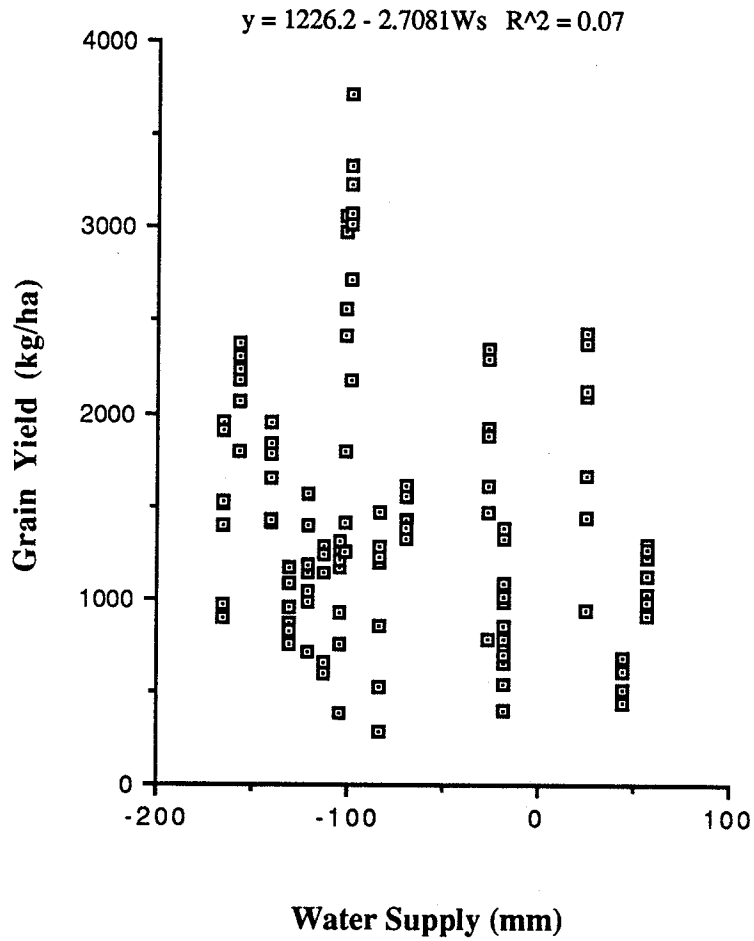


Figure 8. Effect of Water Supply on Yield of Tower Canola (1975 - 1977)

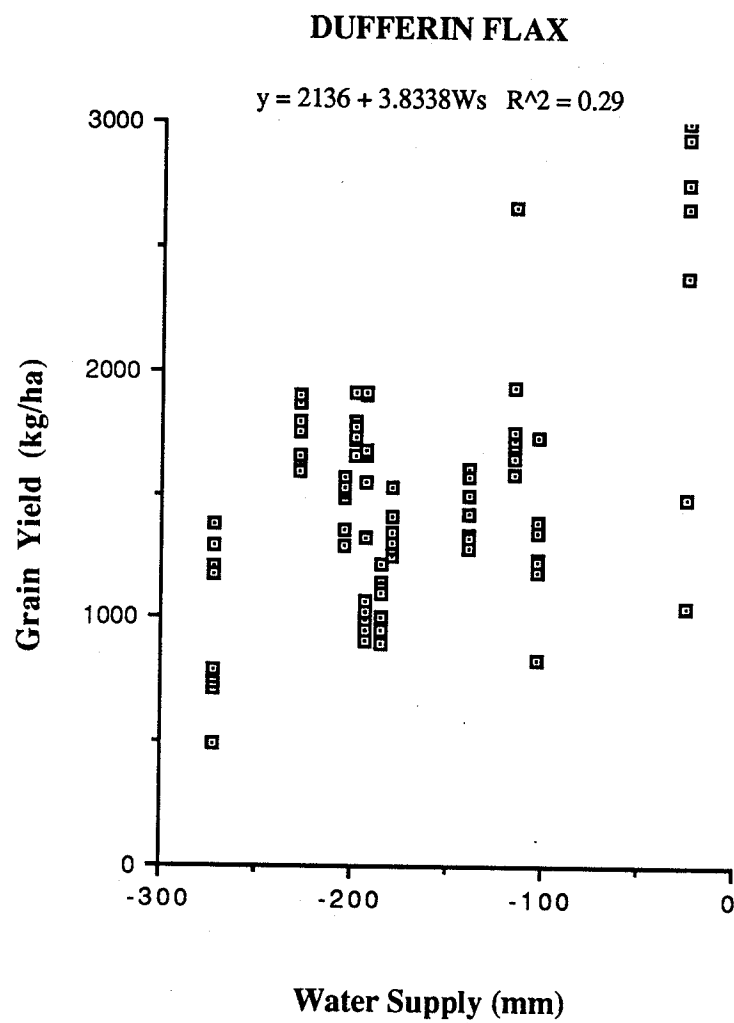


Figure 9. Effect of Water Supply on Yield of Dufferin Flax (1975 - 1977)

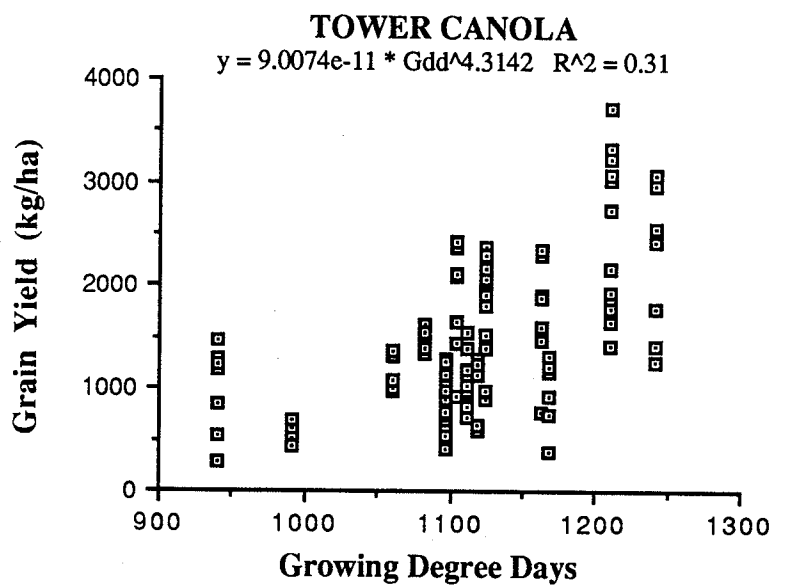
With the possible exception of canola, the calculated terms used to describe the availability or deficiency of moisture were effective in describing variation in grain yields. However, it is apparent that W_s alone was not the most important factor affecting yields. Prior knowledge suggests that a combination of N and moisture or the interaction between the two variables may account for a larger portion of the variation than either of these variables alone.

3. Effect of Temperature (Growing Degree Days)

The derivation of Growing Degree Days (Gdd) was described earlier in the text. Accumulated Gdd above a base temperature of 5° C were estimated for each experimental site from the time of seeding to the time of harvest. The calculated values varied with site location and year. Values ranged from 917 at Glenboro in 1972 to 1146 at Dufrost in 1973 for sites seeded to cereal crops. For sites seeded to oilseeds values ranged from 941 at Hamiota in 1975 to 1242 at Pilot Mound in 1977.

A poor relationship was obtained when calculated values for Gdd were related to grain yields for each of the cereal crops (r^2 - Conquest, 0.05; Fergus, 0.10; Neepawa, 0.05; Glenlea, 0.11). It is possible that the dominant effect of temperature in this case was indirect, ie. having a greater influence on available moisture and reflected in the water supply term(s) previously shown.

For canola, a somewhat better relationship was apparent when Gdd were used in regression with experimental grain yields (figure 10). Grain yields of canola were significantly related to degree days ($P = 0.01$) when a logarithmic relationship was used for the regression model ($r^2 = 0.31$). The logarithmic relationship suggests that percentage increases in yield resulted directly from increases in temperature (Gdd). Data for flax, however, showed a poor relationship that was not significant at either the 1 or the 5% level of significance.



4. Effects of Water Supply and Temperature on Yield Response to Nitrogen Supply

In the previous sections evidence was presented to show the individual effects of nitrogen supply, water supply and temperature on grain yields of cereal and oilseed crops. Earlier regression analysis indicated that little more than 50 percent of the variation in yields was explained by any one of the independent variables chosen from pooled data for all site years.

With the objective of obtaining yield equations of some value in predicting N fertilizer requirements, interrelationships between the independent variables were examined to quantify their effect on a selected dependent variable; this requires a statistical model to describe the relationship and interrelationships (Colwell, 1966). Although other models have been employed to describe the relationship between yield and applied fertilizer, regression models such as those described earlier have proven most effective and can be used for the direct calculation of fertilizer requirements, expected profits, and the expected economic value of soil testing.

A stepwise multiple regression technique was used to determine the importance of each of the selected independent variables in the reduction in variation associated with the dependent variable(s). The stepwise technique used the backward elimination procedure to select significant variables by calculating statistics for the model including all independent variables. Nonsignificant variables were then deleted from the model sequentially until only those variables which remained in the model produced the desired F statistic which was significant at less than $P = 0.10$ level.

4.1. Grain Yield of Cereals

Multiple regression analysis was used to describe the yield of cereal crops (yield, kg ha^{-1}) in terms of water supply (Ws, mm), nitrogen supply (Ns, kg ha^{-1}) and Growing Degree Days (Gdd) in the form:

$$Y = N_s / (\partial + \beta_1 N_s + \beta_2 N_s^2 + \beta_3 W_s + \beta_4 W_s^2 + \beta_5 N_s * W_s + \beta_6 N_s * W_s^2 + \beta_7 N_s^2 * W_s + \beta_8 N_s^2 * W_s^2 + \beta_9 G_{dd} + \beta_{10} G_{dd}^2 + \beta_{11} G_{dd} * W_s + \beta_{12} G_{dd} * N_s + \beta_{13} G_{dd} * W_s^2 + \beta_{14} G_{dd} * N_s^2) \quad (5)$$

Where ∂ is a constant and β_1 -14 are regression coefficients. A linearized form of the equation was used because of the difficulty in fitting nonlinear equations by regression techniques (MacDonald, 1978).

The stepwise regression technique used for cereal crops resulted in the following variables for entry into the model at the 0.10 level of significance:

$$Y = N_s / (\partial + \beta_1 N_s + \beta_5 N_s * W_s + \beta_6 N_s * W_s^2) \quad (6)$$

The above equation, chosen by the stepwise technique, resulted in a significant portion of the variation in yields being explained by the selected variables (table 23). The variables chosen for the model accounted for 72 and 66% of the reduction in total variance in yields for the two varieties of wheat, Neepawa and Glenlea and 80 and 84% for the two varieties of barley, Conquest and Fergus.

The backwards stepwise technique indicated that Gdd values calculated for the sites contributed little to a reduction in the total variance. Although Gdd may have agronomic significance it was excluded from the model because of its inability to reduce the total variance in yields. Similarly, the W_s term alone did not meet the requirements for entry into the model despite its obvious agronomic significance. This likely resulted because W_s had little or no effect at low levels of N_s . However, the W_s term appeared in two interaction terms, $N_s * W_s$ and $N_s * W_s^2$. Hence, much of the effect of the water supply was accounted for in the $N_s * W_s$ and the $N_s * W_s^2$ terms. The regression coefficients for all terms in the model were highly significant ($P=0.10$). The equations in table 23 can then be used to predict fertilizer requirements for the various climatic (moisture) areas of Manitoba if the available soil NO_3-N is known.

Table 23. Regression Equations and Coefficients of Determination for Yield of Wheat and Barley as a Function of Nitrogen Supply and Water Supply

Crop	Variety	Intercept	Ns	Ns x Ws	<u>Regression Coefficients</u>		
					Ns x Ws x Ws	S.E.E	R ²
Wheat	Neepawa	0.00922	0.000288	-9.430E-07	5.970E-09	569.1	0.72**
	Glenlea	0.00932	0.000251	-1.260E-06	5.540E-09	477.1	0.66**
Barley	Conquest	0.00641	0.000289	-1.160E-06	4.239E-09	505.8	0.80**
	Fergus	0.00542	0.000255	-6.046-07	1.69E-09	539.4	0.84**

Ns = Nitrogen Supply (soil nitrogen + 0.5 fertilizer nitrogen)
 Ws = Water Supply
 ** = Significant at 1% level of probability

The equations calculated by the model were only slightly better than those calculated in the earlier work (Racz 1972). This is not surprising since the moisture deficits calculated previously were also highly significant in describing the variation in grain yields. The above equations do however combine a total of five years of data as opposed to the two years work used to build the earlier models. Also in table 23, the W_s term considered actual rather than potential evapotranspiration which is considered to be more sound agronomically. The larger data base used to develop these equations would also be more effective in predicting yields from an independent data set in which climatic conditions may vary. Unfortunately, no independent data set, within the same climatic influence, was available for testing the models developed.

4.1.1. Sensitivity of the Model for Cereal Crops

Selected values for N_s and W_s were entered into equation 6, using coefficients developed for the cereal crops, to evaluate the sensitivity of the model. The W_s values chosen were considered to encompass the majority of observations for each crop. The range of N_s values was selected to represent the majority of observations from the field experiments. W_s values of between -75.0 mm and 75.0 mm were chosen for wheat (table 24).

For Neepawa wheat, predicted yields in the driest situation ($W_s = -75$) ranged from 1314 kg ha⁻¹ to 2281 kg ha⁻¹ for N_s values of between 25 and 200 kg ha⁻¹. At the higher selected value for moisture supply ($W_s = 75$), estimated values for yield were between 1614 kg ha⁻¹ and 3367 kg ha⁻¹ for nitrogen supplies between 25 and 200.

The model appeared to work acceptably well within the range of W_s and N_s values chosen. However, for W_s values greater than 75 mm, yields of Neepawa wheat showed little increase and actually decreased when W_s values greater than 100 mm were substituted into equation 6. This is not unexpected because actual yields of Neepawa wheat were lower than anticipated at the highest calculated values for W_s . W_s values for Neepawa wheat

Table 24. Predicted Yield of Wheat for Selected Nitrogen Supply Values and Water Supply Values for Southern Manitoba

Variety	Nitrogen Supply * (kg ha ⁻¹)	<u>Water Supply (mm)</u>			
		-75.0	-25.0	25.0	75.0
-----kg ha ⁻¹ -----					
Neepawa	25	1314	1462	1570	1614
	50	1734	2001	2210	2297
	75	1941	2282	2557	2675
	100	2064	2454	2775	2915
	125	2164	2570	2925	3081
	150	2204	2654	3034	3202
	175	2247	2717	3117	3294
	200	2281	2767	3182	3367
Glenlea	25	1334	1518	1679	1784
	50	1776	2117	2443	2673
	75	1996	2438	2880	3206
	100	2128	2637	3163	3560
	125	2216	2774	3361	3814
	150	2279	2873	3508	4003
	175	2326	2948	3620	4151
	200	2363	3007	3710	4269

* Nitrogen Supply = soil N + 0.5 fertilizer N

ranged from -89.4 to 191.3 mm. However, 68% of the observations occurred at W_s values of less than 75.0 mm. The average actual yield for W_s values in excess of 75 mm was less than 3000 kg ha⁻¹ for all N_s ; these yields would be considered somewhat low for wheat under sufficient moisture conditions and result in the lower yield estimates at the higher W_s values.

Predicted yields of Glenlea wheat for N_s values from 25 to 200 kg ha⁻¹ ranged from 1334 to 2363 kg ha⁻¹ at W_s equal to -25.0 mm and from 1784 to 4269 kg ha⁻¹ at W_s equal to 75.0 mm. Predicted grain yields for Glenlea wheat were higher than those for Neepawa wheat at the highest W_s value substituted into equation 6 (75.0 mm); this was also the case for the actual experimental yields. For Glenlea wheat, W_s values ranged from -89.4 to 166.1 mm. However, 80% of the observations were made at W_s values of less than 75.0 mm. The average yield for the observations greater than 75.0 mm was 3815 kg ha⁻¹ which is considerably higher than the average yields for Neepawa wheat within the same range.

Estimated yields of barley using coefficients developed from equation 6 are tabulated (table 25). Yields of Conquest barley ranged from 1524 to 2316 kg ha⁻¹ at the lowest value for W_s substituted into the equation (-75.0 mm). At the highest value used in the equation ($W_s = 75.0$ mm) predicted yields of Conquest barley ranged from 2074 to 3878 kg ha⁻¹ for N_s values from 25 to 200 kg ha⁻¹. Predicted yields of Conquest barley increased with increases in water supply up to 150.0 mm. However, at W_s values beyond the 150.0 mm increases in estimated yields declined and predicted yields actually decreased at higher W_s levels. W_s values for Conquest barley ranged from -73.4 to over 200.0 mm. However, less than 50% of the observations occurred at W_s values of less than 75.0 mm. The average for actual yields for W_s values in excess of 75 mm was less than 3500 kg ha⁻¹; which is somewhat lower than expected for conditions where moisture is not a limiting factor.

Table 25. Predicted Yield of Barley for Selected Nitrogen Supply Values and Water Supply Values for Southern Manitoba

Variety	Nitrogen Supply * (kg ha ⁻¹)	<u>Water Supply (mm)</u>			
		-75	-25	25	75
-----kg ha ⁻¹ -----					
Conquest	25	1524	1733	1927	2074
	50	1894	2228	2559	2825
	75	2061	2762	2873	3213
	100	2156	2599	3061	3450
	125	2217	2689	3185	3609
	150	2260	2752	3275	3724
	175	2291	2799	3341	3811
	200	2316	2835	3393	3878
Fergus	25	1899	2049	2185	2294
	50	2391	2635	2863	3053
	75	2617	2912	3193	3431
	100	2747	3073	3388	3658
	125	2831	3179	3517	3809
	150	2890	3254	3609	3917
	175	2934	3310	3678	3998
	200	2968	3353	3731	4061

* Nitrogen Supply: soil N = 0.56 g m⁻² N

* Nitrogen Supply = soil N + 0.5 fertilizer N

Predicted yields were higher for Fergus barley than for Conquest barley for the ranges of W_s and N_s substituted into equation 6. For the lowest W_s value substituted into the model (-75.0 mm), predicted yields of Fergus barley ranged from 1899 to 2968 kg ha⁻¹. At the highest W_s value, estimated yields ranged from 2294 to 4061 kg ha⁻¹ for N_s values from 25 to 200 kg ha⁻¹. For Fergus barley, W_s values ranged from -89.4 to 166.1 mm. However, greater than 75% of the observations fell below the selected value of 75.0 mm and actual yields beyond the highest range averaged over 3900 kg ha⁻¹.

Yield estimates for the cereals appeared to fall within the expected range when calculated coefficients and selected values for W_s and N_s were substituted into equation 6. However, at W_s values higher than those selected for data shown in tables 24 and 25 predicted yields did not increase as expected, and in some cases estimates were lower than for W_s values which were equal to or less than the highest value chosen for estimated yields shown in tables 24 and 25.

The model appeared to work well within a range of W_s and N_s values which were similar to the highest proportion of observed values. However outside the range of experimental or observed values, estimates for yields did not perform as expected as evidenced by the decrease in yields at higher W_s values (more favorable moisture conditions). As a result, predicted yields using equation 6 may not reach values similar to the highest actual yields obtained in the field experiments. Other studies have shown that testing regression models outside the range of data used to create the model may result in errors in estimation (Bole and Pittman, 1980). In this case there appears a need for more studies at high moisture supply ranges.

4.2 Grain Yield of Oilseeds

Multiple regression analysis was used to describe the relationship between grain yield of oilseeds, W_s , N_s and Gdd. The Backward Stepwise Technique, described earlier, was applied to oilseed crops using the initial model described earlier as equation 5. Once

again, a linearized form of the equation was used because of the difficulty in fitting nonlinear equations by regression analysis.

The stepwise regression technique used for oilseed crops chose the following variables for entry into the model at the 0.10 level of significance:

$$Y = N_s / (\alpha + \beta_1 N_s + \beta_2 N_s * W_s + \beta_3 G_{dd} * N_s) \quad (7)$$

The above equation, chosen by the stepwise technique, resulted in a significant portion of the variation in yields being explained by the selected variables. Regression coefficients and coefficient of determination for grain yield of canola are tabulated (table 26).

Table 26. Regression Coefficients and Coefficient of Determination Between Yields of Canola, Nitrogen supply, Water supply and Temperature

Variety	Regression Equation	Coefficient of Determination (R^2)
Tower	$Y = N_s / (0.0177 + 0.00398 * N_s + 1.450E-06 * N_s * W_s - 2.940E-06 N_s * G_{dd})$	0.69**

Y = yield of canola (kg ha⁻¹)

Ns = nitrogen supply (kg ha⁻¹)

Ws = water supply (mm)

Gdd = degree days

** = significant at 1% level of probability (p=0.10)

For canola, 69% of the total variation was accounted for by a relationship to soil and climatic variables. Gdd was selected by the stepwise technique as a variable which resulted in a significant reduction in the total variance; this was not the case for the cereal crops which did not benefit from the addition of Gdd to the equation.

The addition of Gdd was only significant at the chosen level (p=0.10) when combined in the term with Ns. The agronomic significance of this term is not easily

explained since few authors have reported a significant interaction between nitrogen supply and temperature. It is possible that the Gdd term is more important to final grain yields when N is in good supply; i.e. N deficiency restricts yields at low levels of Ns more than Gdd. Some researchers have indicated the significant negative effect of increasing temperature on grain yield (Partridge and Shaykewich, 1972). It is possible that a temperature x moisture x nitrogen term may have resulted in significance in the model although none was attempted.

Regression coefficients and coefficient of determination for grain yield of flax are tabulated (table 27).

Table 27. Regression Coefficients and Coefficient of Determination Between Yield of Flax, Nitrogen Supply, Water Supply and Temperature

Variety	Regression Equation	Coefficient of Determination (R^2)
Dufferin	$Y = Ns / (0.0045 + 0.00168 * Ns - 1.828E-06 * Ns * Ws - 1.054E-06 * Ns * Gdd)$	0.78**

Y = yield of flax (kg ha^{-1})

Ns = nitrogen supply (kg ha^{-1})

Ws = water supply (mm)

Gdd = degree days

** = significant at 1% level of probability ($p=0.01$)

The model selected by the stepwise technique for flax was the same as the model selected for canola (equation 7). The variables chosen for the model resulted in a 78% reduction in the total variance. Ws was selected for entry into the model at the $p = 0.10$ level of significance despite the fact that alone it accounted for only 5% of the variation in yields (figure 8). The Ns x Ws term was once again significant in accounting for a large

proportion of the effect of N and moisture. The Gdd variable was selected for entry into the model in combination with Ns.

4.2.1 Sensitivity of the Model for Oilseed Crops

An independent data set for flax and canola was not available for testing the model. Therefore, selected values for Ns and Ws were entered into equation 7 using coefficients developed for flax and canola to evaluate the sensitivity of the model. The Ns and Ws values chosen were considered to be representative of the majority of actual observations from the original data.

Estimated grain yields from equation 7 showed yields of both flax and canola increased with increases in Ns and Ws (table 28). Predicted grain yields also increased with increases in Gdd. For canola, estimated yields ranged from 500 kg ha⁻¹ at 1000 Gdd and Ns equal to 25 kg ha⁻¹ to 1734 kg ha⁻¹ at 1200 Gdd and Ns equal to 200 kg ha⁻¹.

Estimates of canola yield were somewhat lower than actual yields obtained from the field experiments (table 29). In some cases, actual yields of canola exceeded 2000 kg ha⁻¹; estimates using the selected parameters did not exceed 1800 kg ha⁻¹. However, estimated yields of canola did not decline when higher values for Ws (more favorable moisture) were entered into equation 7. Therefore, under less moisture deficient conditions and higher Gdd predicted yields may exceed 2000 kg ha⁻¹.

Estimates of flax yield were higher than the estimates made for canola yields using the selected parameters; this was not the case for the actual field results. Predicted yields of flax ranged from 888 kg ha⁻¹ at 1000 Gdd and Ns equal to 25 kg ha⁻¹ to 2069 kg ha⁻¹ at 1200 Gdd and 200 kg ha⁻¹ Ns. Predicted yields increased with increases in Ns, Ws and Gdd. Yield estimates were close to actual yields obtained in field experiments (table 30).

The Statistical models developed are useful in describing the factors that effect crop yield. However, the conclusions derived from the models should be carefully examined. The General Linear Model (SAS, 82) procedures used here determines the correlations

Table 28. Predicted Yield of Flax and Canola for Selected Nitrogen Supply and Moisture Deficit Values for Southern Manitoba.

		<u>Water Supply (mm)</u>							
Crop	Nitrogen Supply* (kg ha ⁻¹)	-175.0	-125.0	-75.0	-25.0				
-----kg ha ⁻¹ -----									
		<u>Growing Degree Days</u>							
		<u>1000</u>	<u>1200</u>	<u>1000</u>	<u>1200</u>	<u>1000</u>	<u>1200</u>	<u>1000</u>	<u>1200</u>
Canola	25	500	707	518	746	539	788	560	836
	50	607	944	634	1013	665	1093	699	1187
	75	654	1062	686	1150	722	1255	762	1381
	100	680	1133	715	1234	754	1355	797	1503
	125	697	1180	733	1291	775	1424	821	1588
	150	708	1214	746	1331	789	1473	837	1649
	175	716	1239	756	1362	800	1511	849	1697
	200	724	1259	764	1386	808	1540	859	1734
Flax	25	888	1093	967	1214	1060	1366	1174	1560
	50	965	1212	1059	1363	1172	1557	1313	1815
	75	994	1258	1093	1421	1215	1633	1367	1920
	100	1009	1282	1112	1452	1237	1674	1395	1977
	125	1018	1297	1123	1471	1251	1700	1413	2012
	150	1025	1307	1131	1484	1261	1717	1425	2037
	175	1029	1314	1136	1494	1268	1730	1434	2055
	200	1033	1320	1140	1501	1273	1740	1441	2069

*Nitrogen Supply = Soil N + 0.5 Fertilizer N

Table 29. Effect of Nitrogen Fertilizer and Water Supply on Yield of Tower Canola (kg ha⁻¹)

N-Added (kg ha ⁻¹)	<u>Water Supply (mm)</u>					
	-25.0 to -75.0		-75.1 to -125.0		-125.1 to -175.0	
	NonFallow	Fallow	NonFallow	Fallow	NonFallow	Fallow
4	858	729	1534	1577	934	1255
29	1451	753	1216	1588	966	1529
63	1636	784	1645	1615	1157	1876
96	2003	985	2002	1330	1306	1638
130	2203	909	2166	1546	1462	1655
197	2366	809	2158	1419	1524	1967
264	2153	883	2294	1383	1422	1748
Mean Soil Available N (kg ha ⁻¹)	23	54	15	44	24	50

Yields represent means of all sites 1975-1977

Table 30. Effect of Nitrogen Fertilizer and Water Supply on Yield of Dufferin Flax (kg ha⁻¹)

N-Added (kg ha ⁻¹)	Water Supply (mm)							
	-25.0 to -75.0		-75.1 to -125.0		-125.1 to -175.0		-175.1 to -225.0	
	NonFallow	Fallow*	NonFallow	Fallow*	NonFallow	Fallow±	NonFallow	Fallow
0	1042	--	1519	--	1245	1285	1153	1285
25	1484	--	2197	--	1280	1339	1257	1280
58	2385	--	1555	--	1529	1319	1266	1314
92	2752	--	1409	--	1413	1600	1343	1325
125	2941	--	1239	--	1299	1565	1360	1225
193	2655	--	1553	--	1405	1425	1345	1281
260	2997	--	1490	--	1346	1499	1352	1189
Mean Soil Available N (kg ha ⁻¹)	14	--	30	--	21	49	20	48

Yields represent means of all nonfallow sites 1976-1977

* No sites met criteria

+ One site only

between factors and not necessarily a cause and effect relationships (Porter et al., 1982). As a result, the models for each crop are limited by the range of data used to create the model and may be invalid for data outside the range. Therefore as predictive models the equations may be limited in their usefulness. The ultimate test of a model would be to verify the model on an independent data set (Sakamoto and LeDuc 1977).

The results of the statistical analyses do however indicate that N_s , the combination of soil and fertilizer N, is the most important factor in determining grain yields for this particular set of data. However, a significant $N_s \times W_s$ term was evident in each equation indicating that moisture determined the effectiveness of N_s in determining yields. The importance of water in maximizing the effect of nitrogen on yield has been reported (Viets, 1962; Ramig and Rhoades, 1963; Singh et. al., 1975, Bole and Pittman, 1980). Under more limited moisture conditions moisture alone may be the most important factor influencing yields (Sosulski et. al., 1966).

D. GRAIN PROTEIN

1. Effect of Soil and Fertilizer Nitrogen

1.1 Cereal Crops

Grain protein percentages for each experimental site are documented in appendix A. The grain protein percentage of barley was less than that of wheat. In general, the grain protein percentage of Conquest barley was slightly greater than Fergus barley. Also, the grain protein percentage of Neepawa wheat was, in most cases, slightly greater than grain protein percentages of Glenlea wheat.

The protein percentage of cereal grains grown without fertilizer N increased with increases in the amount of soil NO_3-N available at seeding. Protein percentage of the grain from fallow sites was generally greater than that of grain from nonfallow sites, when no fertilizer N was applied. Grain protein percentages were increased by the application of N fertilizer on both fallow and nonfallow sites. Grain protein percentages remained relatively

constant or increased only slightly when 34 kg ha⁻¹ were added to soils very low in available NO₃-N (nonfallow sites); yields were usually increased with application of N at this rate. Protein percentages of cereal grains grown on nonfallow sites were increased significantly with application of N fertilizer in excess of 67 kg ha⁻¹. Although yields were increased when more than 67 kg N ha⁻¹ were applied, the rate of yield increase with applied N above 67 kg ha⁻¹ was not as great as for lower amounts.

Protein percentages of grains grown on fallow sites were increased considerably even when 34 kg N ha⁻¹ were applied; yields increased only slightly when this rate of fertilizer N was applied. Protein percentages of cereal grains grown on fallow sites increased with increases in the amount of fertilizer N applied. Increases in grain protein percentages were usually relatively small when more than 101 kg N ha⁻¹ were applied.

Data from all site years was combined for regression analysis to quantify the effect of applied fertilizer N and soil NO₃-N on grain protein percentages of wheat and barley over a wide range of environmental conditions. A significant positive response to applied fertilizer N and a significant effect of soil NO₃-N on the grain protein percentage of both varieties of wheat and barley was evident from the regression analysis (table 31). Quadratic terms were included in the regressions to improve the fit. However, coefficients for quadratic terms were small and not significant for either variety of wheat or barley.

Low standard errors for regression coefficients in addition to significant coefficients of determination (R²) for the regressions indicated fertilizer N and soil NO₃-N contributed significantly towards explaining the variation in grain protein percentages. For Neepawa and Glenlea wheats, soil and fertilizer N accounted for a 46 and 67% reduction in the variation of grain protein. For Conquest and Fergus barley, a reduction of 52 and 66% in the variation of grain protein was obtained through regression with soil and fertilizer N. These variables have been shown to significantly affect grain protein percentages although soil NO₃-N at depths below about 30 cm may play a larger role than soil N in the top 30 cm

Table 31. Regression Coefficients, Standard Errors for Regression Coefficients, Standard Partial Regression Coefficients and Coefficients of Determination for Grain Protein Percentage of Wheat and Barley as a Function of Soil Nitrogen (NO₃-N 60 cm) and Fertilizer Nitrogen.

Variable	<u>Regression Coefficients</u>											
	<u>Wheat</u>			<u>Barley</u>								
	Neepawa			Glenlea			Conquest			Fergus		
	bi	Sb	Std Coef	bi	Sb	Std Coef	bi	Sb	Std Coef	bi	Sb	Std Coef
Intercept	11.16	0.283	0.000	9.577	0.244	0.000	8.311	0.235	0.000	7.078	0.255	0.000
Soil Nitrogen	0.043	0.003	0.498	0.050	0.007	0.910	0.047	0.007	0.953	0.043	0.008	0.763
Fertilizer Nitrogen	0.020	0.008	1.189	0.025	0.003	1.281	0.019	0.003	1.069	0.025	0.003	1.251
Soil Nitrogen ²	ns	--	--	ns	--	--	ns	--	--	ns	--	--
Fertilizer Nitrogen ²	ns	--	--	ns	--	--	ns	--	--	ns	--	--
R ²	0.46**			0.67**			0.52**			0.66**		
S.E.E	1.28			0.96			1.06			1.00		

** = Significant at the 1% Level of Probability

(Porter et al. 1982). No attempt was made here to distinguish between the effects of soil $\text{NO}_3\text{-N}$ at varying depths.

A comparison of the Standard Partial Regression Coefficients indicated that Fertilizer N was on average about 1.5 times more important in the determination of grain protein percentage than soil $\text{NO}_3\text{-N}$; this was opposite to what was reported for the determination of grain yields. Once again, there were differences among the various crops. Data for Neepawa wheat indicated that fertilizer N was closer to 2.5 times more important in the determination of grain protein than soil $\text{NO}_3\text{-N}$. For Conquest barley, the ratio was almost 1:1 for soil $\text{NO}_3\text{-N}$ and fertilizer N.

For Glenlea wheat and Fergus barley, the amount of variation explained by soil and fertilizer N was greater for grain protein percentages than for grain yields. However, similar to the regressions performed for yields, a significant portion of variation in grain protein of all the cereal crops could not be explained by soil and fertilizer N alone. Again it was assumed that remaining variation was due to environmental factors and their interrelationship with mineral nutrition.

Comparing regression coefficients for soil and fertilizer N for wheat with those for barley indicated that only small differences were present; this suggested that similar response surfaces existed for each variety of wheat and barley used in these experiments or that response to soil and fertilizer N occurs in much the same manner.

Nitrogen supply (N_s) was again used as a single independent variable combination of soil and fertilizer N to explain variation in grain protein percentages. Grain protein increased with successive increases in N_s up to about 200 kg ha^{-1} for each of the cereal crops used in these experiments (figures 11 and 12). For the combined data, the pattern of response appeared again to be one of diminishing returns with the largest increases in grain protein percentage occurring at lower levels of N_s and smaller increases occurring at higher levels. However, in many cases, data for individual sites showed that grain protein percentages remained constant or decreased at low levels of N_s (See appendix A for grain

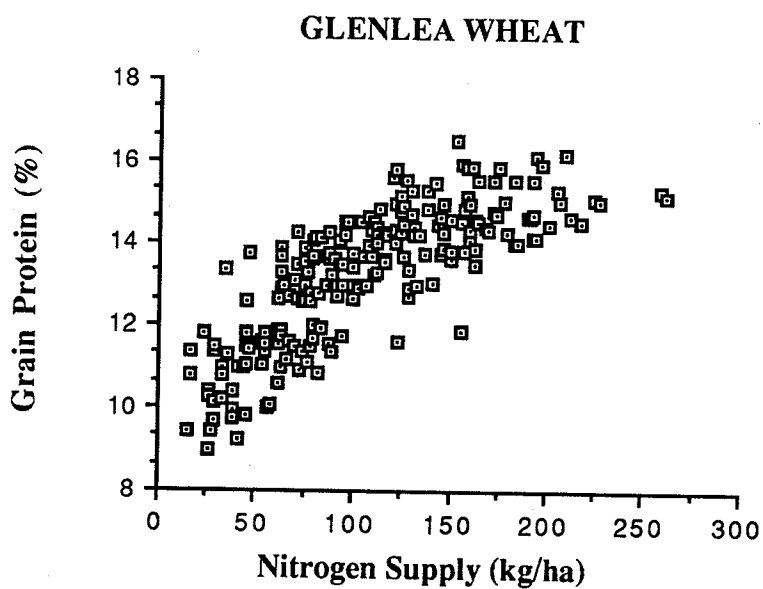
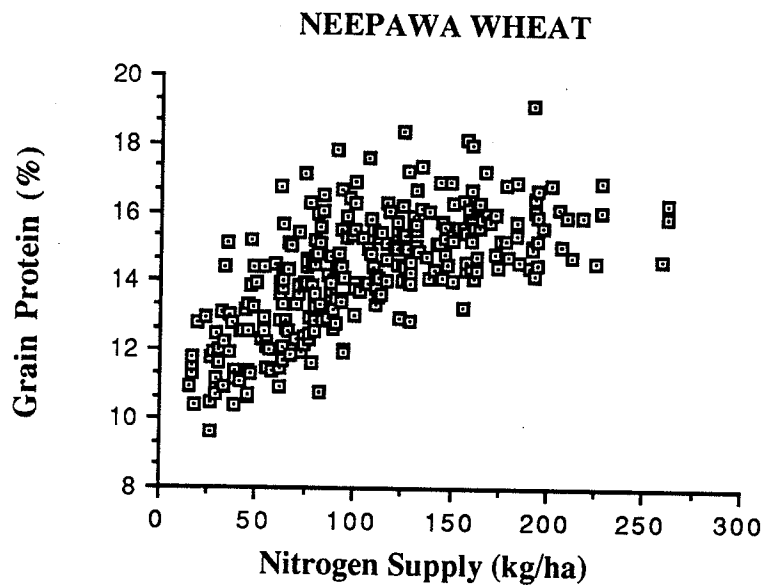


Figure 11. Effect of Nitrogen Supply (soil N + 0.5 fertilizer N) on Grain Protein Percentage of Wheat (1972 - 1975)

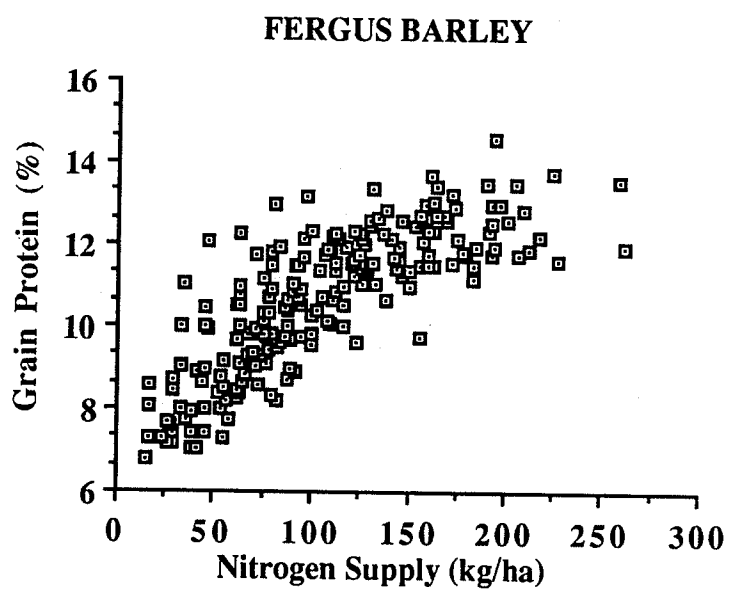
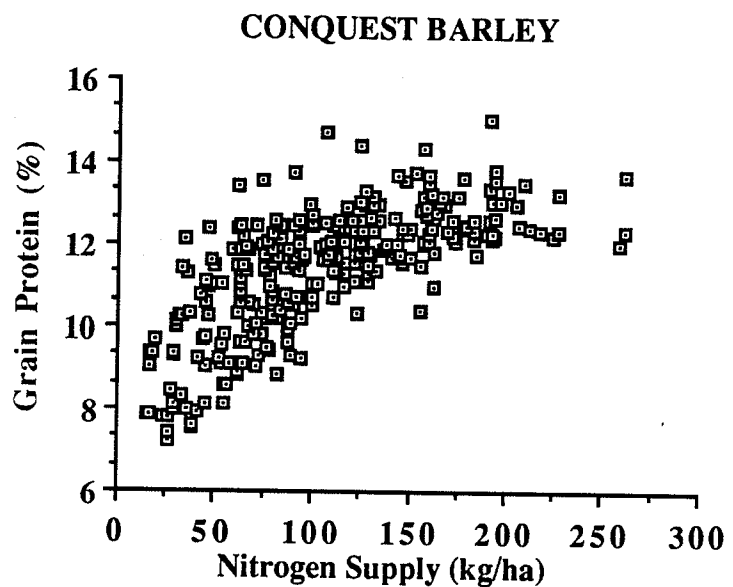


Figure 12. Effect of Nitrogen Supply (soil N + 0.5 fertilizer N) on Grain Protein Percentage of Barley (1972 - 1975)

protein percentages). This depression in grain protein and the reason for the depression is well documented in the literature (Terman 1979). However, the decline in grain protein percentage for individual sites is not apparent when data from all site years is combined.

Regression analysis showed the relationship between N_s and grain protein percentage for each variety of wheat and barley was significant ($P = 0.01$) and positive. The amount of variation in grain protein explained by N_s was 50 and 69% for Neepawa and Glenlea wheat, respectively, and 55 and 69% for Conquest and Fergus barley, respectively (table 32). The amount of variation explained by the N_s term was considerably higher for grain protein than for grain yields, suggesting that N_s may play a greater role in the determination of grain protein than it does in determination of grain yields.

1.2 Oilseed Crops

A complete listing of grain protein percentages for flax and canola is available in Appendix A. The grain protein percentages of both flax and canola were higher on fallow sites than on nonfallow sites when no N fertilizer was applied; this was likely the result of the higher available soil NO_3-N on fallow sites. Grain protein percentages of both flax and canola increased when N fertilizer was applied to both nonfallow and fallow sites. In most cases, grain protein increased up to the 100 kg ha^{-1} rate when fertilizer N was applied to nonfallow sites. Increases in grain protein were apparent on fallow sites when fertilizer N was applied. However, increases were smaller and were less evident with applications of N fertilizer above 60 kg ha^{-1} . Despite a relatively large increase in yield which occurred at the low rates of applied fertilizer N (30 kg ha^{-1}) the decrease in grain protein which was evident for cereal crops was less evident for both flax and canola.

Data from all site years was combined for regression analysis to quantify the effect of applied fertilizer N and soil NO_3-N on grain protein percentage of flax and canola over a wide range of environmental conditions. A significant positive response to applied

Table 32. Regression Coefficients and Coefficients of Determination for Grain Protein Percentage of Wheat and Barley as a Function of Nitrogen Supply (soil nitrogen + 0.5 fertilizer nitrogen)

Variable	<u>Regression Coefficients</u>				
	Neepawa	<u>Wheat</u>	Glenlea	Conquest	<u>Barley</u>
	<u>bi</u>		<u>bi</u>	<u>bi</u>	<u>bi</u>
Intercept	10.465		9.084	7.876	6.514
Ns	0.0549		0.0573	0.0559	0.0559
Ns ²	0.00014		0.00014	0.00013	0.00012
R ²	0.50**		0.69**	0.55**	0.69**
S.E.E	1.22		0.92	1.02	1.96

** = Significant at the 1% Level of Probability

fertilizer N and a significant effect of soil $\text{NO}_3\text{-N}$ on grain protein of both flax and canola was evident from the regression analysis (table 33). Quadratic terms were included in the equation to improve the regression fit. Regression coefficients for the quadratic terms were again small and were not significant for the quadratic fertilizer N term.

Low standard errors for regression coefficients in addition to significant squared correlation coefficients for the equations indicated fertilizer N and soil test N contributed significantly towards explaining the variation in grain protein. Tower canola showed a better relationship to soil and fertilizer N ($R^2 = 0.46$) than did Dufferin flax ($R^2 = 0.28$). The significant relationship between grain protein percentage of canola and available soil and fertilizer N was reported previously by Nuttall (1972).

A comparison of the partial standard regression coefficients indicated that fertilizer N was two times more important in the determination of grain protein percentage of canola but was eight times more important for the flax sites (table 33). The importance of fertilizer N in the determination of grain protein percentage is evident for both the cereal and the oilseed crops.

The relationship between soil and fertilizer N and grain protein percentage was again better than the relationship between yield and soil and fertilizer N. Data from the oilseed crops support the earlier conclusion that soil and fertilizer N may play a larger role in the determination of grain protein than they do for yields. Despite the better relationship between grain protein and soil and fertilizer N, a significant portion of the variation in grain protein remains which is likely due to the effects of environmental factors.

For the oilseed crops, grain protein percentages increased with successive increases in N_s up to about 100 kg ha^{-1} (figure 13). Once again, the response appeared to have the largest increases in grain protein percentage at lower levels of N_s and smaller increases at higher levels. The relationship between grain protein percentages of flax and canola show that a significant portion of the variation can be accounted for by the N_s term. However,

Table 33. Regression Coefficients, Standard Errors for Regression Coefficients, Standard Partial Regression Coefficients and Coefficients of Determination for Grain Protein Percentage of Flax and Canola as a Function of Soil Nitrogen (NO₃-N, 60 cm) and Fertilizer Nitrogen

Variable	<u>Regression Coefficients</u>					
	Dufferin Flax			Tower Canola		
	bi	Sb	Std Coef	bi	Sb	Std Coef
Intercept	22.476	0.843	0.000	15.227	1.013	0.000
Soil Nitrogen	-0.012	0.045	-0.104	0.256	0.057	0.673
Fertilizer Nitrogen	0.022	0.008	0.882	0.026	0.010	1.356
Soil Nitrogen ²	0.001	0.001	0.513	-0.002	0.001	-0.835
Fertilizer Nitrogen ²	ns	--	--	ns	--	--
R ²		0.28**			0.46**	
S.E.E		1.88			2.54	

** = Significant at the 1% Level of Probability

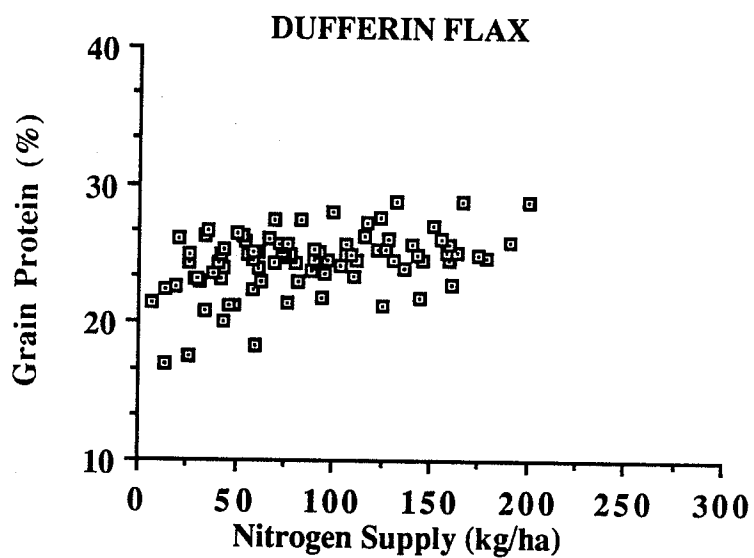
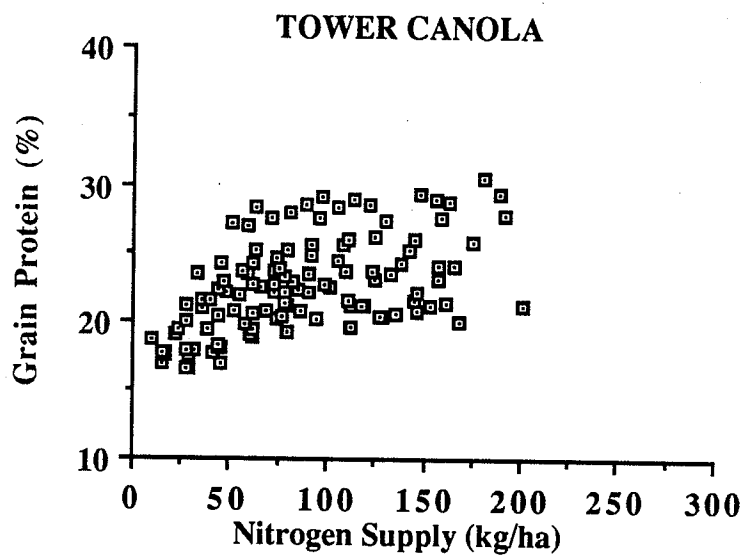


Figure 13. Effect of Nitrogen Supply (soil N + 0.5 fertilizer N) on Grain Protein Percentage of Flax and Canola (1975 - 1977)

the amount of the variation accounted for by Ns was less than when soil and fertilizer N were used as independent terms (table 34).

2. Effect of Water Supply

2.1. Cereal Crops

Regression analysis was used to determine the effects of Ws on the grain protein percentage of both varieties of wheat and barley used in these experiments. Earlier reports have shown that high water stress is an important factor in the determination of grain protein in cereals (Sosulski et al. 1966, Terman 1969). However, in addition to reports of the strong interaction between high moisture stress and grain protein, others have suggested that soil moisture stress at moderate levels has a smaller impact on grain protein and that N has a greater effect in the determination of protein levels (Partridge and Shaykewich 1972).

Results of the regression analysis for these experiments indicated that Ws had little effect in explaining the variation in grain protein percentages of the cereal crops (figures 14 and 15). The amount of variation explained by the regression of Ws as an independent variable was less than 5% for both varieties of wheat and barley. However, it is possible that the moisture stress at these sites was not high enough to significantly affect the grain protein of the cereals and that moisture stress at levels greater than those experienced here may have had a greater influence.

Results of these experiments would suggest that the possibility exists for producing high protein cereals at Ws values as low as -100 mm and as high as 200 mm provided that N from soil and fertilizer is in adequate supply. However, because of the significant positive relationship which existed between water supply and yields, it would only be possible to produce high yielding, high protein cereals under the most favorable of moisture conditions. Similarly, if grain protein percentages are independent of moisture, within the range of Ws used in these experiments, low protein cereals such as barley could

Table 34. Regression Coefficients and Coefficients of Determination for Grain Protein Percentage of Flax and Canola as a Function of Nitrogen Supply (soil nitrogen + 0.5 fertilizer nitrogen)

Variable	<u>Regression Coefficients</u>	
	Dufferin Flax	Tower Canola
	<u>bi</u>	<u>bi</u>
Intercept	21.916	10.465
Ns	0.04297	0.10251
Ns ²	-0.0003269	-0.0001239
R ²	0.19**	0.33**
S.E.E	1.99	2.80

** = Significant at the 1% Level of Probability

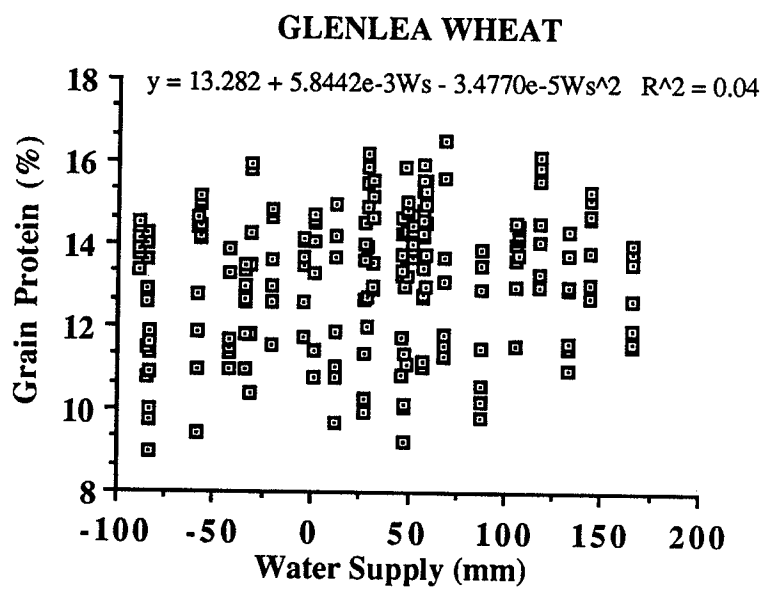
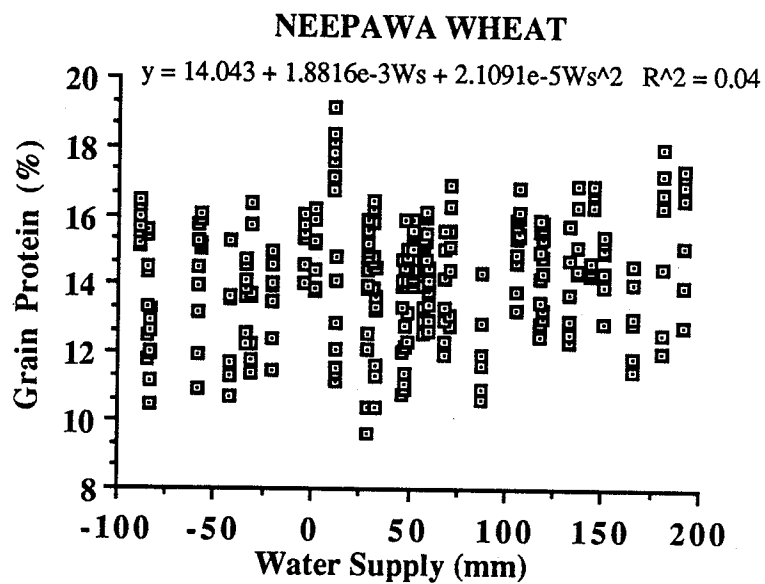


Figure 14. Effect of Water Supply on Grain Protein Percentage of Wheat (1972 - 1975)

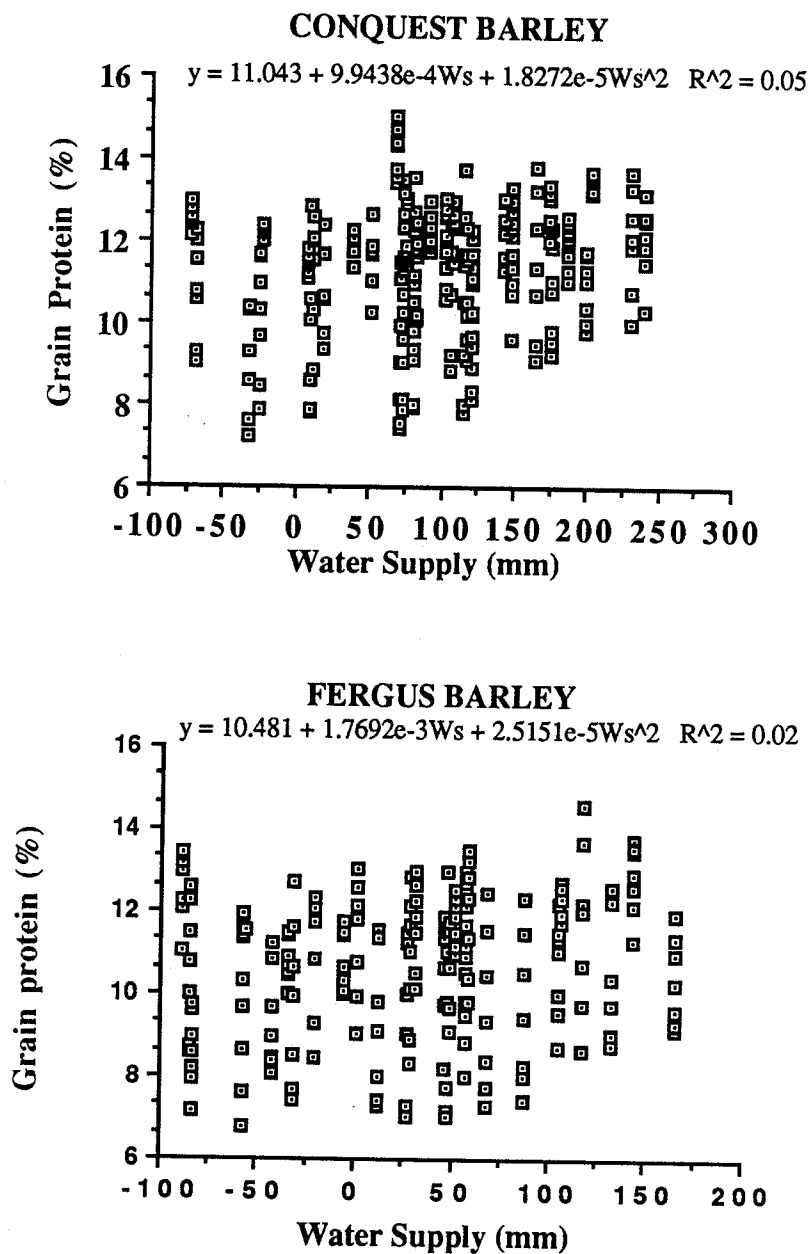


Figure 15. Effect of Water Supply on Grain Protein Percentage of Barley (1972 - 1975)

be obtained at moisture levels suitable for high yields depending on the amounts and availability of soil and fertilizer N.

2.2. Oilseed Crops

Data was once again combined for oilseed crops to determine, through regression analysis, the effect of Ws on the grain protein percentages of both canola and flax. The amount of variation explained by the regression of Ws to grain protein percentage was better for canola and flax than it was for the cereal crops (figure 16). The amount of variation in grain protein percentages accounted for by the use of Ws as an independent variable was 40% for flax and 36% for canola. However, the relationship between grain protein percentage and Ws for flax differed from the relationship between grain protein percentage and Ws for canola.

For flax, grain protein decreased with successive increases in Ws (more favorable moisture). The highest grain protein percentage for flax occurred at Ws values of about -200 mm; the lowest occurred at Ws values of between 0 and -25 mm. As a result, the coefficients for Ws in the regression equation were negative for both the linear and quadratic terms. Grain protein percentage of canola on the other hand, responded to increases in Ws in a positive manner. The highest grain protein percentages occurred at the most favorable moisture conditions and the lowest grain protein percentages occurred where moisture appeared to be the most limiting; the opposite to what occurred for flax. As a result, the coefficient for Ws for the linear term was positive, indicating the increases in grain protein with increases in Ws.

The apparent contradiction in results for canola and flax may have resulted from the calculated values for Ws being more favorable for canola than for flax. Calculated values for Ws for flax ranged from about -25 mm to -300 mm; for canola the Ws values ranged from about 50 mm to -150 mm. This suggested that the more severe water stress occurred on the experimental sites seeded to flax. In most cases, flax and canola were not seeded at

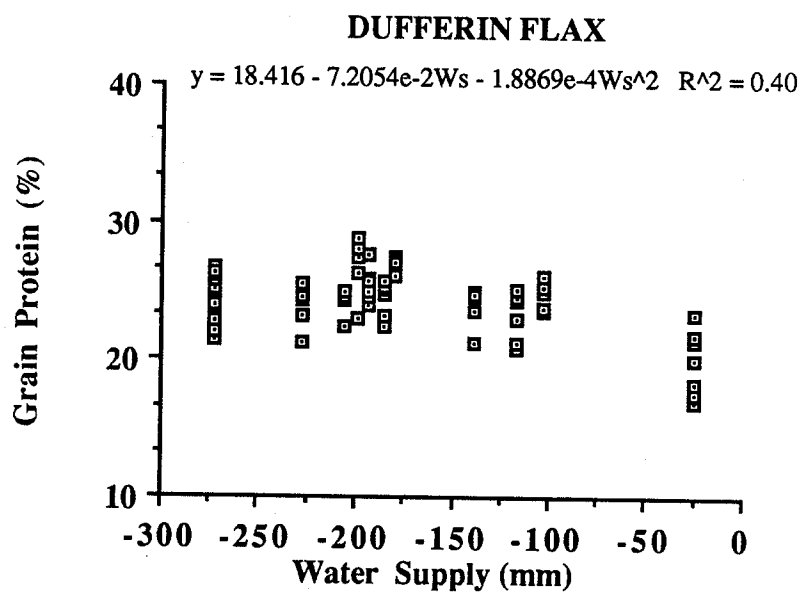
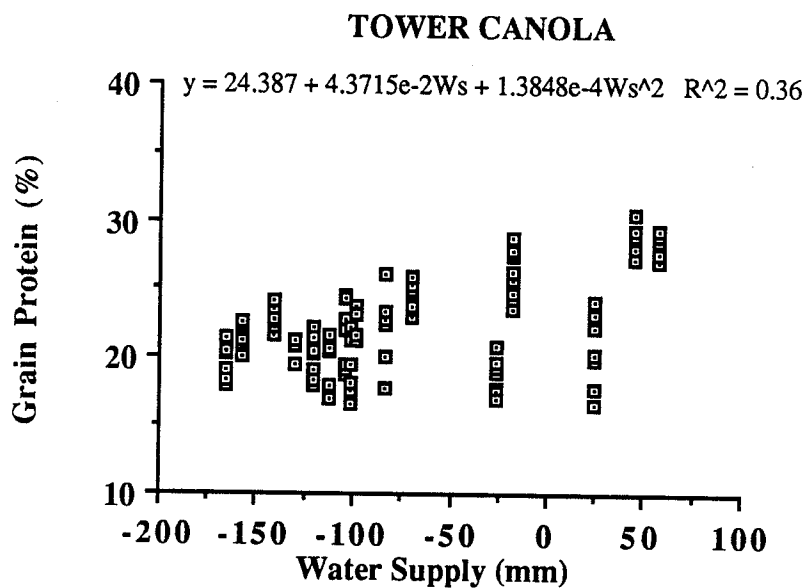


Figure 16. Effect of Water Supply on Grain Protein Percentage of Canola and Flax (1975 - 1977)

the same sites in the same years. As a result moisture conditions for flax and canola were different. As reported earlier, water stress at higher levels would tend to have a greater effect on grain protein. Most of the effect on grain protein would occur through the influence on yield. Presumably, the higher yields at the more favorable moisture situations for flax resulted in lower grain protein percentages and the lower yields at the higher water stress resulted in higher grain protein percentages. However, this did not appear to be the case for canola.

Data from the oilseed crops in these experiments would suggest flax is unlikely to reach its highest yield and grain protein percentage under the most favorable moisture conditions, estimated for this set of data, regardless of the available levels of Ns. However, high yielding, high protein canola would appear possible if Ws and Ns are both favorable.

3. Effect of Temperature (Growing Degree Days)

3.1 Cereal Crops

Temperature has been shown to significantly affect grain protein percentage of cereal crops, mostly through its influence on yields. In most cases, temperatures high enough to cause plant stress are high enough to reduce yields and consequently increase protein percentage of the cereal grains (Campbell et al. 1981). Gdd was were used as an independent variable representing temperature to determine the effect on grain protein percentage of each variety of cereal crop used in these experiments.

Gdd gave a poor relationship when used as an independent variable in regression with grain protein percentage of the cereal crops. The amount of variation explained by Gdd was less than 1% for each of the varieties of wheat and barley (data not shown). The poor results of the regression analysis are not surprising because of the poor relationship exhibited earlier between Gdd and yields. If the effect of temperature on grain protein is

secondary through its effect on yield, it is likely that some relationship between Gdd and yields would have been apparent.

Most past studies in which temperature was used to study the effect on grain protein were carried out in growth chamber conditions (Campbell and Davidson 1979b, Partridge and Shaykewich 1972). Under these circumstances, temperatures could be varied at different growth stages and the effects of high temperatures at critical times could be recorded. However, under the conditions of these experiments temperature peaks during critical growth stages were not recorded and as a result the Gdd term may have tended to mask any temperature extremes during the growing season. Also, it is likely that high temperature conditions required to reduce yields and thereby increase grain protein were not realized during the course of these experiments.

3.2 Oilseed Crops

The effects of Gdd on the grain protein percentage of canola and flax were once again determined through regression. The amount of variation explained by the regression was 18% for canola and 5% for flax (figure 17). Results of this regression suggested that the Gdd term plays a more significant role in the determination of grain protein percentage of canola and flax than it does for cereals. This was also apparent in previous regressions using Gdd and seed yields of flax and canola.

Despite the somewhat greater amount of variation explained by the regression for oilseeds compared to cereals, a considerable amount of the variation was left unaccounted for with the use of Gdd as an independent variable. Again it is possible that the temperature conditions required to cause a significant reduction in yields were not apparent during the course of these experiments.

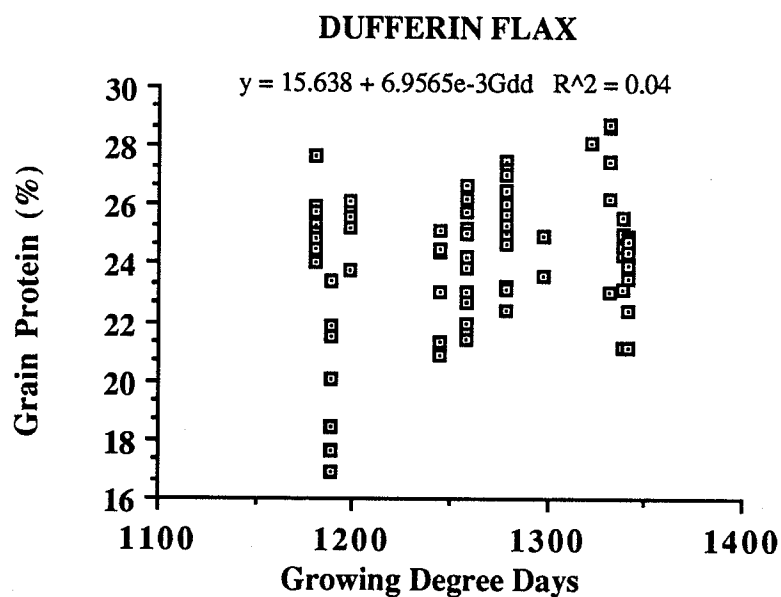
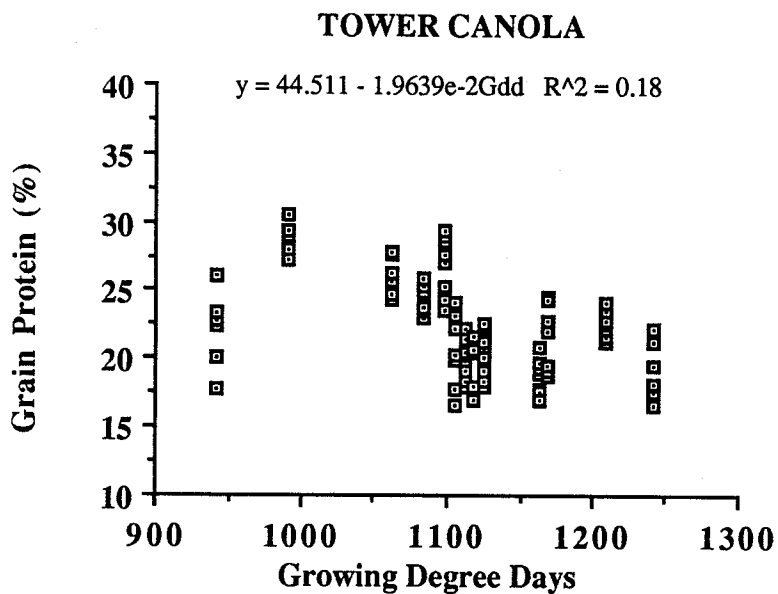


Figure 17. Effect of Growing Degree Days on Grain Protein Percentage of Flax and Canola (1975 - 1977)

4. Effect of Moisture Supply and Temperature on Grain Protein Response to Nitrogen Supply

In the previous sections evidence was presented to show the individual effects of nitrogen supply, water supply and temperature on grain protein percentage of cereal and oilseed crops. Earlier regression analysis indicated that little more than 50 percent of the variation in yields was explained by any one of the independent variables chosen from pooled data for all site years. For grain protein percentages the majority of the effects were related to the soil and fertilizer nitrogen supply.

A stepwise multiple regression technique was used to determine the importance of each of the selected independent variables in the reduction in variation associated with the dependent variable, in this case grain protein percentage. The stepwise technique used the backward elimination procedure to select variables by calculating statistics for the model including all independent variables. The variables were then deleted from the model sequentially until only those variables which remained in the model produced the desired F statistic which was significant at less than 0.10 level.

4.1 Grain Protein Percentage of Cereals

Multiple regression analysis was used to describe the grain protein percentage of cereal crops in terms of water supply (W_s , mm), nitrogen supply (N_s , kg ha⁻¹) and growing degree days (Gdd) in the form:

$$\begin{aligned} \text{Grain Protein (\%)} = & \text{constant} + \beta_1 N_s + \beta_2 N_s^2 + \beta_3 W_s + \beta_4 W_s^2 + \\ & \beta_5 N_s * W_s + \beta_6 N_s * W_s^2 + \beta_7 N_s^2 * W_s + \beta_8 N_s^2 * W_s^2 + \beta_9 G_{dd} + \\ & \beta_{10} G_{dd}^2 + \beta_{11} G_{dd} * W_s + \beta_{12} G_{dd} * N_s + \beta_{13} G_{dd} * W_s^2 + \\ & \beta_{14} G_{dd} * N_s^2 \end{aligned} \quad (7)$$

Where ∂ is a constant and β_1 -14 are regression coefficients.

The stepwise regression technique used for cereal crops resulted in the following variables entry into the model at the 0.10 level of significance:

$$\text{Grain Protein (\%)} = \text{Constant} + \beta_1 N_s + \beta_2 N_s^2 + \beta_3 W_s + \beta_4 W_s^2 + \beta_5 N_s * W_s \quad (8)$$

Equation 8, chosen by the stepwise technique, resulted in the removal of Gdd from the initial equation. This was not unexpected because earlier regression analysis had shown very little effect of Gdd on protein percentage of cereal grain. Although variables selected by the stepwise technique were significant and therefore included in the final equation, many of the coefficients were small and were unlikely to have a significant effect on the ability of the equation to predict grain protein percentage (table 35). This was true particularly for terms which included W_s . Data presented earlier showed that W_s had only a minimal effect on the protein percentage of the cereal grains used in these experiments.

The use of equation 8 resulted in a significant portion of the variation in grain protein percentage being explained by the selected variables. The variables chosen for the model accounted for 53 and 71% of the reduction in total variance in grain protein for the two varieties of wheat, Neepawa and Glenlea and 58 and 73% for the two varieties of barley, Conquest and Fergus. Despite its agronomic importance in the determination of grain protein percentages, temperature in the form of Gdd was not chosen for entry into the model at the $P=0.10$ level of significance. Again, it is most likely that the temperature conditions needed to influence grain protein were not realized during the course of these experiments or not reflected in the Gdd term.

4.1.1. Sensitivity of the Model for Cereal Crops

The best method to evaluate the performance of the chosen model is to test on an independent data set. However, no other data was available to test the accuracy of the model. Therefore, to evaluate the sensitivity of the model, selected values for N_s and W_s

Table 35. Regression Equations and Coefficients of Determination for Grain Protein Percentage of Wheat and Barley as a Function of Nitrogen Supply and Water Supply

Crop	Variety	Intercept	Ns	Ns ²	Ws	Ws ²	<u>Regression Coefficients</u>		
							Ns x Ws	S.E.E	R ²
Wheat	Neepawa	10.21	0.056	-0.0003	-0.003	0.0004	0.0002	1.201	0.53**
	Glenlea	9.189	0.058	-0.0003	-0.002	0.0005	0.0003	0.912	0.71**
Barley	Conquest	7.724	0.051	-0.0001	-0.003	0.0003	0.0001	1.000	0.58**
	Fergus	6.226	0.062	-0.0004	-0.002	0.0008	0.0003	0.911	0.73**

Ns = Nitrogen Supply (soil nitrogen + 0.5 fertilizer nitrogen)

Ws = Water Supply

** = Significant at 1% level of probability

were entered into equation 8, using the coefficients developed for the cereal crops. The range of N_s and W_s values selected for entry into the model were the same as those used for the yield model. These values were selected to represent the majority of observations from the field experiments.

Values for grain protein percentage of Neepawa wheat were slightly higher than the predicted values of Glenlea wheat; this was also the case for the actual data. Predicted grain protein percentages for both Neepawa and Glenlea wheat increased with increases in N_s at approximately the same rate. Values for Conquest barley were slightly higher than for Fergus barley at low levels of N_s . However, varietal differences in predicted protein values of barley grain were less at higher rates of N_s .

W_s values of between -25.0 mm and 75.0 mm were chosen for wheat (table 36). For Neepawa wheat, predicted grain protein in the driest situation ($W_s = -75$) ranged from 11.9 to 20.5% for N_s values of between 25 and 200 kg ha⁻¹. At the higher selected value for moisture ($W_s = 75$), estimated values for grain protein ranged between 11.4 and 20.0% for nitrogen supplies of between 25 and 200 kg ha⁻¹. Grain protein percentages of both varieties of wheat showed very little change with increases in W_s from -75.0 to 75.0. This was not unexpected because of the small coefficients which were generated for W_s and the poor relationship between grain protein percentage of cereals and W_s (shown earlier).

Estimated protein percentage of barley grain using coefficients developed from equation 8 are tabulated (table 37). Predicted grain protein of Conquest barley ranged from 9.3 to 17.8% at the lowest value for W_s substituted into the equation (-75.0 mm). At the highest value used in the equation ($W_s = 75.0$ mm) predicted grain protein of Conquest barley ranged from 9.0 to 17.5% for N_s values from 25 to 200 kg ha⁻¹. Predicted grain protein percentage of Conquest barley decreased with increases in water supply (more favorable moisture). However, decreases in grain protein with increases in moisture were once again small.

Table 36 . Predicted Grain Protein Percentage of Wheat Grain for Selected Nitrogen Supply Values and Water Supply Values for Southern Manitoba

Variety	Nitrogen Supply * (kg ha ⁻¹)	<u>Water Supply (mm)</u>			
		-75.0	-25.0	25.0	75.0
-----% Protein-----					
Neepawa	25	11.9	11.7	11.5	11.4
	50	13.2	13.0	12.9	12.8
	75	14.5	14.3	14.2	14.0
	100	15.8	15.6	15.4	15.3
	125	17.0	16.8	16.7	16.6
	150	18.2	18.0	17.8	17.8
	175	19.4	19.2	19.0	18.9
	200	20.5	20.3	20.1	20.0
Glenlea	25	10.8	10.7	10.6	10.5
	50	12.2	12.1	11.9	11.9
	75	13.6	13.4	13.3	13.3
	100	14.9	14.8	14.7	14.6
	125	16.2	16.0	15.9	15.9
	150	17.4	17.3	17.2	17.1
	175	18.6	18.5	18.4	18.3
	200	19.8	19.7	19.6	19.5

*Nitrogen supply = soil N + 0.5 fertilizer N

Table 37. Predicted Grain Protein Percentage of Barley Grain for Selected Nitrogen Supply Values and Water Supply Values for Southern Manitoba

Variety	Nitrogen Supply * (kg ha ⁻¹)	<u>Water Supply (mm)</u>			
		-75	-25	25	75
-----% Protein-----					
Conquest	25	9.3	9.2	9.0	9.0
	50	10.5	10.4	10.3	10.3
	75	11.8	11.7	11.5	11.5
	100	13.0	12.9	12.8	12.7
	125	14.2	14.1	14.0	13.9
	150	15.4	15.3	15.2	15.1
	175	16.6	16.6	16.4	16.4
	200	17.8	17.7	17.6	17.5
Fergus	25	8.6	8.0	7.5	6.9
	50	10.1	9.5	8.9	8.5
	75	11.6	11.0	10.4	9.9
	100	13.0	12.4	11.9	11.4
	125	14.4	13.8	13.2	12.7
	150	15.7	15.1	14.6	14.1
	175	17.0	16.4	15.9	15.4
	200	18.3	17.7	17.2	16.7

*Nitrogen supply = soil N + 0.5 fertilizer N

For the lowest W_s value substituted into the model (-75.0 mm), predicted grain protein of Fergus barley ranged from 8.6 to 18.3%. At the highest W_s value (75.0 mm), estimated grain protein ranged from 6.9 to 16.7% for N_s values from 25 to 200 kg ha⁻¹. Once again small decreases in grain protein percentages were apparent when a value for W_s indicating more favorable moisture was substituted into the equation.

Estimates of grain protein percentages for the cereals appeared to fall within the expected range when calculated coefficients and selected values for W_s and N_s were substituted into equation 8. However, at the highest values for N_s , the model generated predicted values which were slightly higher than those actually recorded. For example, the highest predicted value for Conquest barley was over 17% whereas the highest actual value was about 15%. Similarly, the highest predicted value for Neepawa wheat was about 20% whereas the highest actual value was slightly less than 19%.

4.2 Grain Protein Percentage of Oilseeds

Multiple regression analysis was also used to describe the relationship between grain protein percentage of oilseeds, W_s , N_s and Gdd. The Backward Stepwise Technique, described earlier, was applied to oilseed crops using the initial model described earlier as equation 7.

The stepwise regression technique chose the following variables for entry into the model at the $P = 0.10$ level of significance:

$$\text{Grain Protein (\%)} = \text{Constant} + \beta_1 N_s + \beta_2 W_s + \beta_3 W_s * W_s + \beta_4 N_s * W_s \quad (9)$$

The above equation, chosen by the stepwise technique, resulted in a significant portion of the variation in grain protein percentages of both Dufferin flax and Tower canola being explained. However, the variation in grain protein percentages for Dufferin flax was slightly less well represented by the model than for Tower canola (table 38). For canola, the equation resulted in 66% of the variation in grain protein being explained by the selected

Table 38. Regression Equations and Coefficients of Determination Between Grain Protein Percentage of Flax and Canola, Nitrogen Supply and Water Supply

Variety	Regression Equation	R ²	S.E.E
Dufferin	% GP = 15.998+0.038Ns+0.072Ws-0.0001Ws ² -0.0006Ns*Ws	0.53**	1.52
Tower	% GP= 20.218+0.046Ns+0.017Ws-0.0001Ws ² -0.0004Ns*Ws	0.66**	2.22

% GP = percent grain protein

Ns = nitrogen supply

Ws = water supply

** = significant at 1% level of probability

variables. However, for flax, only 53% of the variation in grain protein was explained by the model.

In both cases, Gdd was not included as a variable in the model at the level of significance required for entry ($P=0.10$). Although Gdd term was included in the model for yields, it was not included in the model for grain protein percentages. The poor relationship between Gdd and grain protein percentages of the oilseed crops was shown previously (figure 17).

4.2.1 Sensitivity of the Model for Oilseeds

An independent data set for flax and canola was not available for testing the model for grain protein. Therefore, selected values for N_s and W_s were entered into equation 9 using coefficients developed for flax and canola to evaluate the performance of the model. N_s and W_s values chosen were considered to be representative of the majority of actual observations from the original data.

Estimated grain protein percentages from equation 9 showed grain protein of both flax and canola increased with increases in N_s (table 39). Also, predicted grain protein decreased with increases in available moisture. For canola, estimated grain protein ranged from 20% at N_s equal to 25 kg ha⁻¹ to 29% at N_s equal to 200 kg ha⁻¹. The decreases in grain protein with increases in W_s were small for canola and differences became less at higher values of N_s . Because N_s played a greater role in the determination of grain protein percentages for canola it is likely that as N_s became less limiting the effects of W_s were less obvious.

Estimates of the grain protein percentage of canola were similar to actual observations from the field experiments. However, in some cases, actual grain protein percentages of canola were less than 20%; estimates using the selected parameters did not go below the 20% level. Low grain protein percentages in the actual observations occurred mostly on treatments that had N_s values of less than 25 kg ha⁻¹. Grain protein of Tower

Table 39. Predicted Grain Protein Percentage of Flax and Canola for Selected Nitrogen Supply and Moisture Deficit Values for Southern Manitoba.

		<u>Water Supply (mm)</u>			
Crop	N-Supply * (kg ha ⁻¹)	-175.0	-125.0	-75.0	-25.0
-----% Protein-----					
Canola	25	21.28	20.68	20.58	20.98
	50	22.26	21.71	21.66	22.11
	75	23.23	22.73	22.73	23.23
	100	24.21	23.76	23.81	24.36
	125	25.18	24.78	24.88	25.48
	150	26.16	25.81	25.96	26.61
	175	27.13	26.83	27.03	27.73
	200	28.11	27.86	28.11	28.86
Flax	25	26.53	24.42	21.80	18.69
	50	27.52	25.40	22.70	19.65
	75	28.52	26.38	23.74	20.60
	100	29.51	27.36	24.71	21.56
	125	30.50	28.34	25.68	22.52
	150	31.50	29.32	26.65	23.47
	175	32.49	30.30	27.62	24.43
	200	33.49	31.29	28.59	25.39

*Nitrogen Supply = soil N + 0.5 fertilizer N

canola did not exceed the 30% level in either the actual or predicted observations. The grain protein percentages appeared to be somewhat lower in comparison to what other researchers have reported (Nuttall 1972).

Estimates of flax grain protein were higher than the estimates made for canola using the selected parameters; this was also the case for the actual field results. Predicted grain protein of flax ranged from about 18% at N_s equal to 25 kg ha^{-1} to over 33% at 200 kg ha^{-1} N_s . Predicted yields increased with increases in N_s and decreased with increases in W_s (more favorable moisture). Estimates of grain protein percentages of flax were similar to actual values at low N_s , but were 20% higher at the highest values of N_s used to test the sensitivity of the model.

Chapter V

Summary and Conclusions

Response of crops to fertilizer nitrogen is affected by several soil and environmental related factors. Soil factors such as $\text{NO}_3\text{-N}$ content and stored soil water and climatic factors such as growing season precipitation and temperature significantly affect crop response to the addition of fertilizer N. The Manitoba Provincial Soil Testing Laboratory could provide more accurate N fertilizer recommendations if simple models were available which relate crop response to fertilizer N as a function of both soil and climatic factors. In this way, N fertilizer recommendations made by the Laboratory would be increased in value since the recommendations could be altered depending upon soil and environmental conditions.

This project was undertaken to study the response pattern of cereal and oilseed crops to applied N fertilizer, available soil N and certain environmental factors. During 1972 to 1977, a total of 58 field experiments, 29 on fallow and 29 on stubble were conducted over six years to determine the effect of soil and selected climatic parameters on the response of wheat, barley, canola, and flax to applied fertilizer nitrogen. The field experiments had the following specific objectives:

- (a) to quantify the influence of soil $\text{NO}_3\text{-N}$ and fertilizer N, a calculated value for water supply, and a calculated value for temperature on the yield and grain protein percentage of cereal and oilseed crops in southern Manitoba.
- (b) to derive simple statistical models relating yields and grain protein percentage to a number of independent variables including soil N, fertilizer N, water supply, and growing degree days and to use these models to predict yield, grain protein percentage and N fertilizer requirements.

The effect of soil and fertilizer N on yield and grain protein percentage of crops grown in western Canada has been recognized for some time now. The relationship

between yield, grain protein percentage and nutrients from soil and fertilizer has been quantified with regression techniques by many researchers in the past. In addition, many of these researchers have recognized the importance of moisture availability to crop response to soil and applied nutrients and some have constructed terms to represent available moisture or moisture stress to include these effects in regression analysis. However, in many cases, the effect of moisture stress on yield and grain protein percentage was determined on experiments conducted in the growth chamber; few have determined the effects of moisture deficits from data collected under field conditions. This study attempted to define a "water supply" term which could represent moisture availability over the growing season and use that term in conjunction with soil and fertilizer to describe the yields and grain protein percentages of wheat, barley, canola and flax.

Results presented here showed clearly that soil and fertilizer N or a combination of these soil factors represents the largest influence on the determination of yield and grain protein percentage of the cereal and oilseed crops used in these experiments. Approximately 50% of the variation in yields and grain protein percentages were explained with the use of these soil factors alone. The term calculated to represent moisture availability (Ws) accounted for a smaller portion of the variation in cereal yields but was still significant. Ws had little effect in explaining the variation in yields of oilseeds, in particular Canola ($r^2 = 0.07$); flax was somewhat more affected by Ws ($r^2 = 0.29^*$). In most cases, the level of water stress did not appear to be significant enough to affect the yields of the oilseed crops. In addition, the smaller database for the oilseed crops likely allowed more room for random error to affect the relationships.

Ws had only a small effect on the grain grain protein percentage of either oilseed or cereal crops. In the case of the cereals, less than 5% of the variation in grain protein percentage could be explained by the regression analysis with Ws as an independent variable. It was most likely that the degree of moisture stress required to significantly influence grain protein percentage was either not realized during the course of these

experiments or not reflected in the W_s term. For the oilseeds, a somewhat better relationship was found between grain protein percentage and W_s . Regression analysis showed that about 40% of the variation in grain protein percentage of both flax and canola could be explained by the W_s term. The term used to select temperature effects (growing degree days) did not appear to have a significant effect on the determination of grain yield or grain protein percentage of the cereal crops. However, Gdd was shown to significantly affect the yield of both canola and flax.

Models were developed using the stepwise technique for selection of significant variables for entry into a regression model. The following model was chosen as the best for describing the grain yield of cereals:

$$Y = N_s / (\partial + \beta_1 N_s + \beta_5 N_s * W_s + \beta_6 N_s * W_s^2)$$

The above model accounted for 72 and 66% of the reduction in total variance in yields for the two varieties of wheat, Neepawa and Glenlea, respectively and 80 and 84% for the two varieties of barley, Conquest and Fergus, respectively.

A similar model was developed for the oilseed crops. However, the importance of Gdd in the determination of grain yields was selected by the entry of this variable into the model at the $P=0.10$ level of significance:

$$Y = N_s / (\partial + \beta_1 N_s + \beta_2 N_s * W_s + \beta_3 Gdd * N_s)$$

For Canola, 69% of the total variation in grain yields was accounted for by the above relationship to soil and climatic variables.

The stepwise technique was also used to select variables for entry into a regression model to describe the effect of the selected independent variables on the grain protein percentage of both cereal and oilseed crops. For cereals, the following model was selected by the stepwise procedure:

$$\% \text{ Protein} = \text{Constant} + \beta_1 N_s + \beta_2 N_s^2 + \beta_3 W_s + \beta_4 W_s^2 + \beta_5 N_s * W_s$$

The variables chosen for the above model accounted for 53 and 71% of the reduction in total variance in grain protein percentages for the two varieties of wheat, Neepawa and

Glenlea, respectively and 58 and 73% for the two varieties of barley, Conquest and Fergus, respectively.

The stepwise regression technique used for oilseed crops chose the following variables for entry into the model at the 0.10 level of significance:

$$\% \text{ Protein} = \text{Constant} + \beta_1 N_s + \beta_2 W_s + \beta_3 W_s * W_s + \beta_4 N_s * W_s$$

The above equation resulted in a significant portion of the variation in grain protein percentages of both Dufferin Flax and Tower Canola being explained. However, the variation in grain protein percentages for Dufferin flax was slightly less well represented by the model than for Tower Canola. The equation resulted in 66% of the variation in grain protein percentages of Canola being explained by the selected variables. However, for flax, only 53% of the variation in grain protein percentages was explained by the model.

The above models appeared to work well within the range of data used to create the coefficients. However, no independent data set was available for testing the models. Therefore, it is difficult to judge the reliability of the estimates under a wide range of environmental and soil conditions.

The following conclusions can be drawn from the evidence presented:

- a) Soil N (0-60 cm) and fertilizer N or a combination of the two (nitrogen supply) account for the greatest portion of variation for grain yields and grain protein percentage. Nitrogen supply appears to play a larger role in the determination of grain protein percentage than it does in the determination of yields.
- b) The calculated value for water supply used in this study can be effective in describing the variation in yields. However, the usefulness of this value would likely have been increased had it taken into account the timing of the precipitation and the variation in soil water extraction between treatments that are heavily fertilized with N and those that are not.

- c) Growing Degree Days do little to explain the variation in yields or grain protein percentages. It is most likely that the temperature conditions required to affect grain yields and grain protein percentage were either not realized during the course of these experiments or not reflected in the Gdd term
- d) The simple regression models developed appear to work well within the range of data used to create them. However, an independent data set is essential for the testing of the model; no such data set was available for this purpose.

Further development of these equations is recommended, particularly in the case of flax and canola, where small data bases limit the usefulness of the equations.

Furthermore, testing of these equations both on data sets within the same range of data employed to create them as well as data sets from outside this range is the only reasonable method to evaluate their effectiveness and reliability. Regression analysis used here may be effective in describing the relationship between independent variables and dependent variables, but it does not describe accurately the ability of developed equations to predict or estimate dependent variables.

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Appendix A.

Table A1 Bulk Densities for Experimental Sites (Kg/m³) - 1972 (Values are mean of Fallow and Nonfallow)

Depth	Experimental Site					
	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost
0-15	1,370	1,110	1,150	1,110	1,380	930
15-30	1,470	1,390	1,260	1,310	1,470	1,240
30-61	1,480	1,400	1,270	1,320	1,460	1,300
61-91	1,700	1,500	1,300	1,320	1,670	1,380
91-122	1,700	1,500	1,300	1,320	1,670	1,380

* Samples were taken to a depth of 91 cm. Value listed for the 91 to 122 cm - depth is same as for the 61-91 cm.

Table A2 Date of Seeding - 1972

Location	Fallow	Non Fallow
Goodlands	May 3	May 3
Glenboro	May 5	May 4
Portage	May 9	May 12
Pilot Mound	May 12	May 12
Birtle	May 16	May 16
Dufrost	May 19	May 19

Note: Soil samples obtained in Spring for soil moisture and nitrate-nitrogen determination were taken immediately prior to seeding.

Table A3 Bulk Densities for Experimental Sites (Kg/m³) - 1973 (values are mean of fallow and nonfallow).

Depth (cm)	Experimental Site					
	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris
0-15	1,330	1,230	1,370	1,080	1,220	1,200
15-30	1,460	1,370	1,440	1,190	1,220	1,370
30-61	1,550	1,550	1,320	1,340	1,480	1,380
61-91	1,570	1,470	1,310	1,370	1,480	1,420
91-122*	1,570	1,470	1,310	1,370	1,480	1,420

* Samples were taken to a depth of 91 cm. Value listed for the 91-122 cm depth is same as for the 61-91 cm depth.

Table A4 Date of Seeding - 1973

Location	Fallow	Non Fallow
Goodlands	May 1	May 1
Glenboro	May 2	May 2
Portage	May 9	May 9
Pilot Mound	May 3	May 4
Birtle	May 15	May 15
Morris	May 14	May 14

Note: Soil samples obtained in Spring for soil moisture and nitrate-nitrogen determination were taken immediately prior to seeding.

Table A5 Bulk Densities for Experimental Sites (Kg/m³)
(Values are mean of Fallow and Nonfallow)

Depth (cm)	Experimental Site		
	Glenboro	Pilot Mound	Birtle
0-15	1,230	1,080	1,220
15-30	1,370	1,190	1,220
30-61	1,550	1,340	1,480
61-91	1,470	1,370	1,480
91-122*	1,470	1,370	1,480

* Samples were taken to a depth of 91 cm. Value listed for the 91 to 122 cm - depth is same as for the 61-91 cm depth.

Table A6 Date of Seeding - 1974

Location	Fallow	Non Fallow
Glenboro	May 29	May 29
Pilot Mound	May 31	May 31
Birtle	June 3	June 3

Note: Soil samples obtained in Spring for soil moisture and nitrate-nitrogen determination were taken immediately prior to seeding.

Table A7 Bulk Densities for Experimental Sites (Kg/m³) - 1975 (Values are mean of Fallow and Nonfallow)

Depth	Experimental Site				
	Goodlands	Roland	Brandon	Hamiota	Pilot Mound
0-15	1,330	1,200	1,200	1,300	1,100
15-30	1,460	1,370	1,370	1,350	1,250
30-61	1,550	1,380	1,400	1,470	1,330
61-91	1,570	1,420	1,430	1,470	1,350
91-122	1,570	1,420	1,430	1,570	1,350

* Samples were taken to a depth of 91 cm. Value listed for the 91 to 122 cm - depth is same as for the 61-91 cm.

Table A8 Date of Seeding - 1975

Location	Fallow	Non Fallow
Roland	May 9	May 9
Pilot Mound	May 16	May 16
Goodlands	May 22	May 22
Hamiota	May 27	May 27
Brandon	May 28	May 28

Note: Soil samples obtained in Spring for soil moisture and nitrate-nitrogen determination were taken immediately prior to seeding.

Table A9 Bulk Densities for Experimental Sites (Kg/m³) - 1976 (Mean of Fallow and Nonfallow)

Depth	Experimental Site				
	Pilot Mound	Carman	Boissevain	Hamiota	Portage La Prairie
0-15	1,150	1,200	1,320	1,300	1,150
15-30	1,270	1,380	1,400	1,350	1,260
30-61	1,330	1,400	1,500	1,470	1,270
61-91	1,350	1,420	1,520	1,520	1,300
91-122	1,350	1,420	1,520	1,520	1,300

* Samples were taken to a depth of 91 cm. Value listed for the 91 to 122 cm - depth is same as for the 61-91 cm.

Table A10 Date of Seeding - 1976

Location	Fallow	Non Fallow
Carman	---	May 7 (site 1 and 2)
Pilot Mound	May 8	May 8
Portage	May 11	May 11
Boissevain	May 19	May 19
Hamiota	May 20	May 20

Note: Soil samples obtained in Spring for soil moisture and nitrate-nitrogen determination were taken immediately prior to seeding.

Table A11 Bulk Densities for Experimental Sites (Kg/m³) - 1977 (Mean of Fallow and Nonfallow)

Depth	Experimental Site				
	Carman	Boissevain	Pilot Mound	Hamiota	Portage
0-15	1,200	1,320	1,150	1,300	1,150
15-30	1,380	1,400	1,270	1,350	1,260
30-61	1,400	1,500	1,330	1,470	1,270
61-91	1,420	1,520	1,350	1,520	1,300
91-122	1,420	1,520	1,340	1,520	1,300

* Samples were taken to a depth of 91 cm. Value listed for the 91 to 122 cm - depth is same as for the 61-91 cm.

Table A12 Date of Seeding - 1977

Location	Fallow and Nonfallow
Carman	May 9
Portage	May 10
Pilot Mound	May 12
Boissevain	May 13
Hamiota	May 17

Note: Soil samples obtained in Spring for soil moisture and nitrate-nitrogen determination were taken immediately prior to seeding.

Table A13 Yield of Grain* - Conquest Barley (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	1718	1856	1430	2093	1637	3190	1988
34	2373	2612	1830	2829	2070	3791	2585
67	3214	3509	2344	3633	2863	3787	3226
101	3488	3902	2638	4562	3259	3679	3588
134	3683	4108	2912	4566	3236	3681	3698
202	3988	4659	2997	4936	3580	3899	4011
269	3773	4417	2966	4956	3540	3820	3912
<u>Fallow Sites</u>							
9	3918	3246	2617	3993	3528	4366	3612
34	4468	3165	2677	4255	4028	4741	3890
67	4218	3425	2682	4699	4277	5006	4052
101	4758	3618	2840	4935	4486	5031	4278
134	4708	3759	2803	5152	4495	5036	4327
202	4539	3342	2831	5042	4470	5438	4278
269	4853	3136	2682	4412	4500	5470	4176

* Air-dry basis (approximately 6.5 to 7.5% moisture)

Table A14 Yield* of Grain - Conquest Barley (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	1757	1450	2127	4090	2691	1548	2277
34	2363	2055	2573	4272	2684	2249	2699
67	3027	2821	2900	4020	2990	3295	3175
101	3528	3152	3312	4031	3115	3774	3485
134	3938	3600	3932	4026	3083	4220	3801
202	3883	3700	4098	4061	3120	4505	3895
269	4031	3824	3958	4001	3273	4510	3933
<u>Fallow Sites</u>							
9	2614	4097	3322	5034	3947	3423	3741
34	3302	3976	3405	5404	3795	3669	3926
67	3524	3995	3555	5162	3970	4082	4049
101	3735	4311	3549	5464	3949	4303	4209
134	3820	4442	3517	5393	4331	4389	4316
202	4124	4355	3634	5113	4203	4586	4337
269	4050	4491	3385	4939	4356	4194	4237

* Air-dry basis (approximately 6.5 to 7.5% moisture)

Table A15 Yield* of Grain-Conquest Barley (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1297	1253	1096	1549
34	1472	1428	1799	1566
67	1689	1618	2252	1854
101	1696	1609	2190	1831
134	1791	1786	2136	1904
202	1920	2061	2435	2138
269	2218	1935	2165	2106
<u>Fallow Sites</u>				
9	2985	3061	3048	3031
34	2817	3397	2678	2960
67	2968	3363	2997	3109
101	2796	3135	2978	2969
134	2717	3475	3121	3105
202	2916	3400	3157	3158
269	2840	3347	3095	2093

*Air-Dry Basis (approximately 6.5 to 7.5% moisture)

Table A16 Yield of Grain*-Conquest Barley (1975) (kg /ha)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	2956	1763	1912	1185	1997	1963
34	3126	2083	2488	1703	2352	2350
67	3072	2488	2993	2355	2671	2716
101	2983	2567	2757	2436	2903	2729
134	3022	2624	2943	2491	3051	2826
202	3340	2788	2969	2685	3177	2992
269	3183	2518	2851	2677	3131	2872
<u>Fallow Sites</u>						
9	3862	2940	3025	2578	2600	3001
34	3492	3432	2960	3000	2000	2977
67	3258	3641	3083	3013	2605	3120
101	3687	3421	3185	2853	2981	3225
134	3720	3446	3195	2953	3205	3304
202	3581	3543	3142	3128	2895	3238
269	3689	3369	3117	3057	2880	3222

*Air-Dry basis (approximately 6.5 to 7.5% moisture)

Table A17 Yield of Grain* - Fergus Barley (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	2089	2337	1469	2078	1635	3209	2137
34	2660	2853	2041	2802	2232	3646	2706
67	3413	3491	2595	3840	2667	3868	3313
101	3666	4333	3123	4360	2762	4080	3722
134	3546	4340	3065	4940	2909	4173	3829
202	3445	4529	3389	4731	3484	4252	4053
269	3520	4280	3219	5114	2958	4385	3913
<u>Fallow Sites</u>							
9	4304	3838	3381	4396	3661	4367	3992
34	4330	4375	3211	4617	3983	4694	4202
67	4554	4967	3511	4071	4092	4946	4358
101	4985	4885	3285	4006	4094	4916	4362
134	5170	4978	3468	4338	4235	5088	4547
202	5349	4823	3389	4063	4066	5179	4479
269	5167	4767	3443	3833	4548	5076	4473

* Air-dry basis (approximately 6.5 to 7.5% moisture)

Table A18 Yield of Grain* - Fergus Barley (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	1690	1692	2383	3611	2754	1809	2323
34	2264	2467	2773	3959	2939	2344	2791
67	3007	3441	3298	3980	3233	3418	3397
101	3003	3708	3390	3498	3413	3406	3404
134	3547	3870	3677	3554	3313	3826	3632
202	3446	4005	3492	3445	3297	4014	3608
269	3276	3842	3683	3445	3396	3816	3577
<u>Fallow Sites</u>							
9	3331	4144	3329	5441	3868	3214	3889
34	3475	4114	3231	4935	3919	3746	3904
67	3566	4119	3277	4798	4056	4075	3980
101	3951	4144	3412	4850	4181	4036	4096
134	3946	3899	3293	4422	4192	3868	3938
202	3688	3952	3381	4626	4025	3862	3923
269	3707	3528	3451	4677	4153	3824	3926

* Air-dry basis (approximately 6.5 to 7.5% moisture)

Table A19 Yield of Grain*--Fergus Barley (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1674	1269	2056	1733
34	1895	1415	2521	1943
67	2186	1584	2554	2108
101	2514	1792	2634	2314
134	2567	2015	2651	2411
202	2722	2281	2529	2511
269	2999	2415	2471	2619
<u>Fallow Sites</u>				
9	2997	3368	3462	3276
34	2911	3708	3524	3381
67	3354	3401	3632	3463
101	3566	3454	3546	3522
134	3475	3420	3538	3478
202	3226	3296	3497	3340
269	3394	3433	3529	3452

*Air-Dry Basis (approximately 6.5 to 7.5% moisture)

Table A20 Yield of Grain* - Neepawa Wheat (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	1236	1589	1464	963	1930	2742	1654
34	2048	2377	2057	1589	2454	2824	2223
67	2753	2769	2429	2359	2680	3229	2704
101	3296	3028	2473	2908	3093	3099	2984
134	3313	3278	2567	3138	3167	3190	3106
202	3219	3360	2750	3369	3526	3148	3229
269	3294	3457	2651	3230	3487	3238	3227
<u>Fallow Sites</u>							
9	3885	2435	2981	2078	3655	3480	3087
34	4069	2458	2968	2759	3481	3547	3214
67	4039	2556	3024	2783	3871	3732	3334
101	4013	2418	3208	2722	3879	3524	3294
134	4011	2437	3171	2892	3741	3988	3373
202	3991	2672	3254	3332	3799	3816	3461
269	4163	2566	3303	3194	3899	3795	3488

* Air-dry basis (approximately 6.5 to 7.5% moisture).

Table A21 Yield of Grain* - Neepawa Wheat (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	1214	1114	1978	3006	2160	1303	1795
34	1623	1961	2426	3152	2372	2050	2264
67	2684	2439	2710	3251	2556	2835	2746
101	2949	3023	2908	3202	2425	3167	2946
134	3149	3041	2929	3287	2544	3440	3065
202	3293	3250	3109	3422	2619	3156	3142
269	3466	3176	3049	3156	2816	3279	3157
<u>Fallow Sites</u>							
9	2723	3244	2988	4280	3123	2696	3175
31	3077	3081	3128	4339	3198	3153	3568
67	3035	3090	3269	4377	3046	3282	3350
101	3400	3077	3300	4172	3302	3334	3432
134	3061	2867	2983	4616	3138	3296	3328
202	3172	3190	2981	4282	3123	3306	3342
269	3205	3181	2995	4316	3186	3310	3367

* Air-dry basis (approximately 6.5% to 7.5% moisture)

Table A22 Yield of Grain*-Neepawa Wheat (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1019	925	1648	1197
34	1382	986	1838	1392
67	1472	1075	1795	1447
101	1521	1133	1995	1550
134	1510	1185	1982	1559
202	1534	1290	1989	1605
269	1580	1452	2062	1698
<u>Fallow Sites</u>				
9	1287	2281	2323	1997
34	1897	2164	2425	2162
67	2062	2252	2268	2194
101	2185	2206	2604	2332
134	2247	2130	2451	2276
202	2265	2218	2381	2288
269	2248	2181	2568	2332

*Air-Dry Basis (approximately 6.5 to 7.5% moisture)

Table A23 Yield of Grain*--Neepawa Wheat (1975) (kg /ha)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	2115	1571	1726	938	1889	1648
34	1981	1739	1969	1522	2418	1926
67	1963	2013	2084	1688	2618	2073
101	2046	1969	2213	1944	2656	2166
134	2027	1984	2244	2010	2762	2205
202	1941	1940	2200	2029	2823	2187
269	2324	1728	2235	2180	2803	2254
<u>Fallow Sites</u>						
9	3025	1758	2596	2376	2840	2519
34	3091	2206	2335	2291	2975	2580
67	3005	2146	2083	2563	2966	2553
101	2688	2290	2564	2524	2843	2582
134	2885	2227	2487	2485	3095	2636
202	2948	2255	2524	2740	2880	2669
269	2808	1974	2406	2707	2963	2572

*Air-Dry basis (approximately 6.5 to 7.5% moisture)

Table A24 Yield of Grain* - Glenlea Wheat (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	2296	1717	1469	1316	2008	2641	1908
34	2314	2342	2184	1783	2083	2475	2197
67	2995	2914	2836	2621	2733	3086	2865
101	3250	3087	2601	2882	2541	3107	2912
134	3409	3566	2868	3065	2578	3326	3136
202	3285	3591	3139	3655	2790	3294	3293
269	3261	3821	2983	3718	3009	2979	3296
<u>Fallow Sites</u>							
9	4048	3370	3772	3165	3720	3534	3603
34	4343	3683	3608	3236	3994	3783	3775
67	4366	3839	3506	3459	4414	4153	3957
101	4264	4051	3724	3442	4505	4280	4045
134	4122	4033	3595	3596	4748	4311	4068
202	4380	4221	3690	3824	4478	4367	4161
269	4649	4174	3732	3707	4724	4175	4194

* Air-dry basis (approximately 6.5 to 7.5% moisture)

Table A25 Yield of Grain* - Glenlea Wheat (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	1593	1742	2298	3632	2327	1711	2217
34	2214	2247	2696	3924	2569	2492	2690
67	2732	2728	3418	3767	2732	3069	3186
101	3022	3002	3500	3592	2849	3177	3191
129	3176	3123	3725	3690	2714	3387	3304
202	3441	3091	3856	3684	2723	3489	3381
269	3239	2877	3787	3641	2794	3546	3315
<u>Fallow Sites</u>							
9	3003	3583	4155	4482	3799	3306	3722
34	2868	3575	3960	4301	3790	3735	3705
67	3232	3547	3868	4753	3816	3899	3853
101	3285	3311	3937	5050	3799	4181	3928
134	3273	3665	3870	5036	3903	3935	3947
202	3526	3387	3980	4706	3758	4131	3916
269	3392	3545	4039	4791	4056	4071	3983

* Air-dry basis (approximately 6.5 to 7.5% moisture)

Table A26 Yield of Grain* - Dufferin Flax (1976) (kg /ha)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
	1208	1325	1288	490	1245	1628	1197
25	1377	1654	1351	710	1280	1593	1327
58	1171	1897	1489	735	1529	1654	1412
92	1207	1907	1506	792	1413	1868	1449
125	1380	1553	1516	755	1299	1789	1382
193	1178	1663	1522	782	1405	1898	1408
260	1294	1671	1568	795	1346	1752	1404
<u>Fallow Sites</u>							
0	-		1285	938	1145	1772	1285
25	-		1339	1034	1008	1798	1295
58	-		1319	911	1125	1906	1315
92	-		1600	988	1213	1774	1394
125	-		1565	1071	951	1654	1310
193	-		1425	1028	1099	1718	1318
260	-		1499	945	896	1728	1267

*Air-Dry basis

Table A27 Yield of Grain* Dufferin Flax (1977) (Kg/ha)

Treatment (kg N/ha)	Carman East	Pilot Mound South	Portage	Mean
<u>Nonfallow Sites</u>				
0	16.94	10.42	13.45	13.60
25	26.62	14.84	17.33	19.60
58	19.30	23.85	11.80	18.32
92	15.77	27.52	12.42	18.57
125	16.45	29.41	8.33	18.06
193	17.18	26.55	13.88	19.20
260	17.55	29.97	12.26	19.93

* Air Dry Basis

Table A2 Yield of Grain*-Tower Rape (1975) (kg /ha)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	278	402	340
29	-	532	541	537
63	-	855	655	755
96	-	1193	700	947
130	-	1288	761	1025
197	-	1231	851	1041
264	-	1469	782	1126
<u>Fallow Sites</u>				
4	472	985	911	789
29	496	1010	1021	842
63	507	1061	1220	929
96	644	1325	978	982
130	438	1380	1299	1039
197	607	1010	1270	938
264	687	1079	1128	

*Air-Dry basis

Table A29 Yield of Grain* - Tower Rape (1976) (kg /ha)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	599	381	835	896	678
29	601	752	868	970	798
63	649	925	751	1394	930
96	1144	1174	948	1511	1194
130	1288	1248	828	1947	1328
197	1234	1205	1173	1904	1379
264	1140	1316	1081	1523	1265
<u>Fallow Sites</u>					
4	-	1577	713	1797	1362
29	-	1588	988	2070	1549
63	-	1615	1402	2349	1789
96	-	1330	1034	2232	1532
130	-	1546	1136	2173	1618
197	-	1419	1559	2375	1784
264	-	1383	1187	2309	1626

*Air-Dry basis

Table A30 Yield of Grain* - Tower Rape (1977) (kg /ha)

Treatment (kg N/ha)	Carman		Pilot Mound	Boissevain	Portage	Mean
<u>Nonfallow Sites</u>						
	<u>East</u>	<u>West</u>				
4	21.25	14.08	12.56	7.82	9.35	14.21
29	21.72	14.26	14.10	14.66	14.35	15.82
63	30.14	18.34	17.89	16.09	16.63	19.82
96	30.79	16.52	25.63	19.20	20.87	22.60
130	37.16	17.83	24.13	22.90	21.17	24.64
197	32.25	17.86	29.73	23.53	23.79	25.43
264	33.32	19.44	30.61	18.75	24.32	25.29

* Air Dry Basis

Table A21 Protein Content* of Conquest Barley Grain (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	7.44	7.79	7.84	7.79	9.33	8.85	8.19
34	7.53	7.84	8.48	8.00	9.33	10.34	8.60
67	8.13	8.59	9.70	9.22	9.75	11.55	9.51
101	9.01	10.07	10.34	10.49	10.59	12.03	10.44
134	9.91	10.60	10.97	11.45	10.63	12.08	10.96
202	11.07	11.55	11.61	12.56	11.70	12.08	11.79
269	11.47	12.83	11.66	13.17	12.41	12.61	12.38
<u>Fallow Sites</u>							
9	9.64	10.23	12.30	9.12	8.81	10.18	10.07
34	10.68	10.71	12.01	9.49	9.20	10.07	10.38
67	10.95	11.61	12.23	10.71	10.74	11.59	11.33
101	11.36	12.35	12.40	11.35	11.48	11.71	11.80
134	11.68	12.67	12.20	12.30	11.74	11.93	12.11
202	12.12	13.14	12.30	13.23	12.43	12.21	12.60
269	12.31	13.46	12.30	13.78	12.38	12.45	12.81

* % Protein = % N x 5.7 (expressed on a 13.5% moisture basis).

Table A32 Protein Content* of Conquest Barley Grain (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	7.84	7.98	9.22	11.90	10.27	8.03	9.21
34	8.13	7.93	9.57	11.41	10.27	8.13	9.24
67	9.03	9.12	9.82	11.65	11.06	8.88	9.93
101	9.62	9.82	10.76	11.75	11.85	9.42	10.54
134	10.27	10.51	11.06	12.55	11.70	10.22	11.05
202	11.31	11.80	11.85	12.89	11.75	11.11	11.79
269	11.55	12.74	12.35	13.04	12.65	10.96	12.22
<u>Fallow Sites</u>							
9	9.12	11.75	12.45	11.31	10.56	9.82	10.83
34	9.62	11.85	12.45	11.70	10.81	9.97	11.07
67	10.17	11.95	12.70	12.00	11.75	10.41	11.50
101	10.51	12.30	12.89	12.05	12.60	11.01	11.89
134	11.55	12.01	12.94	12.25	12.64	11.26	12.11
202	11.65	12.55	12.94	12.20	12.79	11.65	12.30
269	12.30	12.99	13.29	12.00	13.04	11.75	12.56

* Protein Content = % N x 5.7 (expressed on a 13.5% moisture basis).

Table A33 Protein Content* of Conquest Barley Grain (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	9.01	7.24	11.45	9.23
34	9.29	7.64	11.12	9.35
67	10.60	8.61	11.51	10.24
101	10.77	9.29	11.22	10.42
134	11.57	9.29	11.62	10.82
202	11.97	10.32	11.80	11.36
269	12.26	10.37	11.80	11.47
<u>Fallow Sites</u>				
9	12.14	10.83	11.34	11.43
34	12.37	11.34	11.74	11.81
67	12.48	11.34	12.02	11.94
101	12.60	11.74	12.08	12.14
134	12.54	12.02	12.26	12.27
202	12.94	12.08	12.26	12.42
269	12.77	12.14	12.26	12.39

*% Protein = %N x 5.7 (expressed on a 13.5% moisture basis)

Table A34 Protein Content* of Conquest Barley Grain (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	13.40	9.98	9.69	9.35	11.29	10.74
34	13.57	10.77	10.26	10.15	11.63	11.28
67	13.74	11.86	11.06	10.94	12.20	11.96
101	14.71	12.08	11.34	11.17	12.54	12.37
134	14.36	12.60	11.69	12.26	12.94	12.77
202	14.31	13.28	12.08	12.37	12.94	13.00
269	15.05	13.68	12.26	13.54	13.05	13.32
<u>Fallow Sites</u>						
9	13.17	10.32	11.06	11.51	12.37	11.69
34	13.68	11.46	11.91	11.69	12.03	12.15
67	13.51	11.86	12.43	12.31	12.48	12.52
101	13.64	12.14	12.48	12.48	12.54	12.66
134	13.57	12.54	12.37	12.94	13.05	12.89
202	13.22	12.60	12.71	12.37	13.17	12.81
269	13.68	13.17	12.60	12.65	13.34	12.09

*Protein Content = % N x 5.7 (expressed on a 13.5% moisture basis)

Table A35 Protein Content* of Fergus Barley Grain (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	7.17	7.67	6.76	7.30	8.06	8.42	7.56
34	7.01	7.41	7.64	7.72	8.44	9.28	7.92
67	7.27	8.53	8.65	8.36	8.97	10.81	8.77
101	9.06	9.91	9.70	9.36	8.39	11.71	9.69
134	10.01	10.65	10.34	10.42	9.68	11.71	10.47
202	11.23	11.59	11.34	11.53	10.85	12.08	11.44
269	11.49	12.71	11.93	12.43	11.23	12.35	12.03
<u>Fallow Sites</u>							
9	8.70	8.31	11.55	8.67	8.22	9.11	9.10
34	9.54	8.92	11.45	9.75	9.72	9.65	9.84
67	10.02	10.11	11.77	10.70	10.62	10.71	10.66
101	11.02	11.00	11.82	12.17	11.36	11.53	11.49
134	11.34	11.70	11.93	12.02	11.63	10.63	11.54
202	11.50	12.15	11.61	13.65	11.74	11.53	12.03
269	12.19	12.85	11.93	14.55	11.89	11.74	12.53

% Protein = % N x 5.7 (expressed on a 13.5% moisture basis)

Table A36 Protein Content* of Fergus Barley Grain (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	7.29	7.14	8.93	10.51	9.03	8.03	8.49
34	7.44	7.04	8.78	10.12	9.92	7.44	8.46
67	7.98	7.74	9.03	11.50	10.76	8.28	9.22
101	9.12	9.82	9.72	11.90	11.80	9.42	10.30
134	9.82	11.06	10.41	12.25	12.15	10.51	11.03
202	11.55	11.55	12.25	12.65	12.60	11.46	12.01
269	11.36	12.94	12.55	12.99	13.04	12.30	12.53
<u>Fallow Sites</u>							
9	8.03	9.82	11.75	11.31	9.82	9.17	9.98
34	8.83	10.41	11.95	12.10	10.91	9.27	10.58
67	9.47	11.36	12.30	12.60	11.70	9.62	11.18
101	9.82	12.35	11.95	12.89	12.10	10.27	11.56
134	10.51	12.84	12.65	13.49	12.45	10.96	12.15
202	10.96	13.24	12.70	13.73	12.74	11.36	12.46
269	11.16	13.49	12.60	13.54	12.99	11.95	12.62

* % Protein = % N x 5.7 (expressed on a 13.5% moisture basis).

Table A37 Protein Content* of Fergus Barley Grain (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	8.55	7.18	9.98	8.57
34	8.72	7.92	10.43	9.02
67	10.03	8.21	10.49	9.57
101	10.77	8.61	10.72	10.03
134	11.46	8.95	10.89	10.43
202	12.26	9.63	11.40	11.09
269	12.60	9.75	11.46	11.27
<u>Fallow Sites</u>				
9	11.00	10.94	10.03	10.65
34	12.08	11.17	10.32	11.19
67	12.26	11.51	10.66	11.47
101	12.94	11.86	10.08	11.62
134	13.17	12.14	11.40	12.23
202	13.34	12.31	11.51	12.38
269	13.40	12.54	11.74	12.56

*%Protein = %N x 5.7 (expressed on a 13.5% moisture basis)

Table A38 Protein Content* of Neepawa Wheat Grain (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	9.66	11.82	10.94	12.98	11.36	11.45	11.37
34	10.41	11.40	11.58	11.96	10.69	12.40	11.41
67	12.11	12.22	13.22	12.31	11.68	13.52	12.51
101	13.86	13.65	13.97	13.38	11.74	13.99	13.43
134	13.94	13.73	14.50	14.20	13.64	14.07	14.02
202	14.95	15.74	15.24	15.03	13.54	14.55	14.84
269	15.62	16.38	15.76	15.61	15.27	14.97	15.60
<u>Fallow Sites</u>							
9	13.27	12.53	15.05	12.87	10.79	12.37	12.82
34	13.83	14.39	15.16	12.50	12.02	13.22	13.52
67	14.66	14.79	15.21	13.46	13.38	13.94	14.24
101	14.92	14.97	15.21	14.18	13.94	14.47	14.62
134	15.32	15.11	15.21	14.97	14.15	14.15	14.82
202	15.75	15.21	16.06	15.61	14.74	14.84	15.37
269	15.86	15.86	15.90	15.88	14.71	15.05	15.51

* % Protein = % N x 5.7 (expressed on a 13.5% moisture basis).

Table A39

Protein Content* of Neepawa Wheat Grain (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	11.58	10.98	12.55	13.89	14.43	10.98	12.40
34	11.18	11.11	12.25	14.63	13.88	10.65	12.28
67	11.44	11.38	12.35	14.78	13.83	10.95	12.46
101	12.07	12.17	12.94	15.82	15.22	11.64	13.31
134	12.89	12.83	13.74	16.22	15.27	11.95	13.82
202	14.08	14.53	14.73	16.12	15.92	12.87	14.71
269	14.84	15.90	15.72	16.41	16.22	14.38	15.58
<u>Fallow Sites</u>							
9	12.94	14.43	15.47	14.29	15.08	11.51	13.95
34	12.55	14.74	16.07	14.31	14.73	11.90	14.05
67	13.34	15.30	15.52	14.33	15.87	12.89	14.54
101	13.93	15.53	16.02	14.46	15.47	13.03	14.74
134	15.12	16.06	16.12	14.46	15.52	14.03	15.22
202	15.17	15.94	15.97	14.55	15.57	14.06	15.21
269	15.32	16.13	16.76	14.66	15.62	14.56	15.51

* % Protein = %N x 5.7 (expressed on a 13.5% moisture basis)

Table A40 Protein Content* of Neepawa Wheat Grain (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	11.80	10.49	12.26	11.51
34	12.48	11.17	12.54	12.06
67	13.34	12.03	13.68	13.01
101	14.31	11.97	13.91	13.39
134	14.48	12.65	14.08	13.73
202	15.45	12.94	14.59	14.32
269	15.56	13.28	14.71	14.51
<u>Fallow Sites</u>				
9	15.16	14.14	14.02	14.44
34	15.22	13.97	14.59	14.59
67	15.68	14.42	15.50	15.20
101	15.96	14.42	15.50	15.29
134	16.47	14.42	15.33	15.40
202	16.53	14.31	15.73	15.52
269	16.25	14.19	16.07	15.50

%Protein = %N x 5.7 (expressed on a 13.5% moisture basis)

Table A.4/ Protein Content* of Neepawa Wheat Grain (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	16.76	12.03	12.83	10.43	13.05	13.02
34	17.10	12.60	13.11	11.63	13.28	13.54
67	17.84	14.48	14.42	11.34	14.36	14.49
101	17.61	16.25	15.16	13.34	14.82	15.44
134	18.41	16.70	15.56	13.28	15.33	15.86
202	18.13	17.21	16.25	13.68	15.68	16.19
269	19.15	18.01	16.87	14.31	15.85	16.84
<u>Fallow Sites</u>						
9	16.64	12.83	14.42	12.65	12.88	13.88
34	16.93	13.97	14.36	12.94	13.97	14.43
67	16.64	15.11	15.16	13.45	14.31	14.93
101	16.82	16.50	16.25	13.79	14.99	15.67
134	16.64	16.93	16.25	14.02	15.28	15.82
202	16.87	17.33	16.30	14.08	15.45	16.00
269	16.25	17.21	16.87	14.54	15.05	15.98

*Protein Content = % N x 5.7% (expressed on a 13.5% moisture basis)

Table A42 Protein Content* of Glenlea Wheat Grain (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	10.23	10.40	9.40	11.82	11.36	11.08	10.74
34	9.91	10.38	9.45	11.32	11.36	13.20	10.96
67	11.34	11.80	10.94	11.55	11.47	13.67	11.82
101	12.67	13.47	11.87	13.09	10.95	14.31	12.75
134	13.62	14.25	12.77	13.67	11.68	14.84	13.50
202	14.02	15.79	14.39	15.64	13.26	14.79	14.68
269	14.54	15.91	14.63	16.54	13.86	15.05	15.12
<u>Fallow Sites</u>							
9	11.55	12.02	14.20	12.99	10.87	11.93	12.28
34	12.94	12.69	14.47	13.30	11.71	12.83	13.02
67	13.62	13.91	14.95	14.04	13.20	13.51	13.90
101	12.94	14.92	15.05	14.52	13.38	14.15	14.19
134	14.80	15.47	14.10	15.55	13.75	14.31	14.69
202	14.85	15.90	15.05	15.86	14.23	14.42	15.08
269	14.64	16.20	15.16	16.15	14.65	14.68	15.28

* % Protein = % N x 5.7 (expressed on a 13.5% moisture basis).

Table A42

Protein Content* of Glenlea Wheat Grain (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	10.75	10.12	10.96	12.89	10.78	10.17	10.95
34	9.66	9.23	11.61	13.55	11.44	9.82	10.89
67	11.01	10.06	11.48	12.99	13.29	10.56	11.57
101	11.84	11.38	12.99	14.64	14.05	11.46	12.73
134	13.69	12.96	12.93	15.17	14.54	13.49	13.80
202	14.18	14.25	13.75	15.17	14.71	12.89	14.16
269	14.94	15.90	14.35	15.57	14.58	13.89	14.87
<u>Fallow Sites</u>							
9	11.01	12.96	14.28	12.70	12.70	11.55	12.53
34	11.18	13.71	14.11	13.04	13.69	11.60	12.89
67	12.80	14.51	13.72	13.79	14.21	11.95	13.50
101	13.39	14.94	14.18	14.73	14.84	12.65	14.12
134	14.25	15.30	14.21	14.63	15.27	13.54	14.53
202	14.61	15.53	14.38	15.08	15.53	13.79	14.83
269	15.53	15.27	14.44	15.27	15.93	13.98	15.07

*% Protein = % N x 5.7 (expressed on a 13.5% moisture basis)

Table A44 Protein Content* of Glenlea Wheat Grain (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	10.77	8.95	11.00	10.31
34	11.51	9.75	11.80	11.02
67	12.60	10.03	12.65	11.76
101	12.88	10.89	12.60	12.12
134	13.62	11.34	12.94	12.63
202	13.97	11.63	13.34	12.98
269	14.25	11.86	13.57	13.22
<u>Fallow Sites</u>				
9	13.34	13.68	11.74	12.92
34	13.74	13.85	12.60	13.39
67	13.85	13.97	13.51	13.77
101	14.14	14.31	13.68	14.04
134	14.54	14.42	13.68	14.21
202	14.36	14.31	14.08	14.25
269	14.54	14.71	14.14	14.46

*% Protein = %N x 5.7 (expressed on a 13.5% moisture basis)

Table A45 Protein Content* of Dufferin Flax Grain (%) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
0	23.06	25.00	22.38	21.44	26.13	23.19	23.53
25	25.25	25.19	24.31	22.50	26.31	24.38	24.66
58	25.06	25.31	24.81	26.63	26.50	25.06	25.56
92	25.75	25.63	24.56	26.19	26.00	25.56	25.62
125	21.81	27.63	24.94	24.25	27.44	24.31	25.06
193	26.12	25.00	24.94	24.19	27.19	21.13	24.76
260	22.69	25.94	24.94	23.87	27.06	24.56	24.84
<u>Fallow Sites</u>							
0	-		21.13	24.00	23.25	27.44	23.96
25	-		23.94	24.81	23.13	23.06	23.99
58	-		24.88	25.06	22.38	28.06	25.10
92	-		23.50	24.50	24.63	26.19	24.71
125	-		24.50	24.88	25.06	28.75	25.80
193	-		24.44	25.75	25.31	28.69	26.05
260	-		24.75	24.88	25.63	28.75	26.00

*% Protein = % N x 6.25 (expressed on an oven-dry basis)

Table A46 Protein Content* of Dufferin Flax Grain (%) (1977)

Treatment (kg N/ha)	Carman East	Pilot Mound South	Portage	Mean
		<u>Nonfallow Sites</u>		
0	20.9	16.9	24.4	20.7
25	21.3	17.6	23.6	20.8
58	23.0	20.1	25.9	23.0
92	24.4	18.4	25.6	22.8
125	24.5	21.5	23.8	23.3
193	24.5	23.4	25.2	24.4
260	25.1	21.9	26.1	24.4

% Protein: % N x 6.25 (Expressed on Oven Dry Basis)

Table A47 Protein Content* of Tower Rape Grain (%) (1975)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	17.77	23.50	20.64
29	-	19.98	24.28	22.13
63	-	22.31	25.29	23.80
96	-	22.73	25.29	24.01
130	-	23.44	27.62	25.53
197	-	26.07	27.38	26.73
264	-	26.13	28.81	27.47
<u>Fallow Sites</u>				
4	27.32	24.28	26.96	26.19
29	28.45	24.75	27.68	26.96
63	27.91	25.65	28.57	27.38
96	29.17	25.71	28.39	27.76
130	28.99	26.24	28.51	27.91
197	29.35	27.62	28.93	28.63
264	30.42	27.74	29.29	29.15

*Protein Content = %N x 6.25 (expressed on a 8.5% moisture basis)

Table A48 Protein Content* - Tower Rape Grain (%) (1976)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	16.98	18.70	19.39	17.96	18.26
29	17.96	19.16	21.10	18.30	19.13
63	20.36	19.50	20.87	19.10	19.96
96	20.59	21.96	20.87	20.47	20.97
130	21.33	22.70	20.87	20.24	21.29
197	21.67	24.48	21.16	20.47	21.95
264	22.70	24.30	21.16	21.45	22.40
<u>Fallow Sites</u>					
4	-	22.88	17.96	22.25	21.03
29	-	23.56	18.30	22.42	21.43
63	-	23.96	19.10	22.59	21.88
96	-	24.82	22.19	21.27	22.76
130	-	23.79	20.24	20.59	21.54
197	-	25.33	20.47	20.13	21.98
264	-	25.79	21.45	21.22	22.82

*% Protein = % N x 6.25 (expressed on a 8.5% moisture basis)

Table A49 Protein Content^a Tower Rape Grain (%) (1977)

Treatment (kg N/ha)	Carman		Pilot Mound	Boissevain	Portage	Mean
<u>Nonfallow Sites</u>						
	<u>East</u>	<u>West</u>				
4	21.2	21.6	17.6	17.7	16.6	18.9
29	21.7	22.2	16.6	17.6	17.8	19.2
63	23.7	22.5	18.1	16.9	19.8	20.2
96	23.7	23.0	19.5	19.0	20.3	21.1
130	23.6	22.8	21.2	19.2	22.1	21.8
197	23.8	23.6	21.2	19.7	23.2	22.3
264	23.2	24.1	22.2	20.9	24.2	22.9

* (8.5% Basis)

Appendix B.

Table B1 Yield of Straw - Conquest Barley (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	1546	1448	1105	2200	1763	2579	1774
34	2196	1596	1562	2073	2159	2856	2074
67	2869	2771	2081	3363	3234	2911	2873
101	3168	3345	2278	4101	3886	2914	3283
134	3446	3919	2368	4517	3985	3161	3566
202	3608	3621	2942	4421	4571	3138	3717
269	3834	3908	3276	4766	4816	3293	3983
<u>Fallow Sites</u>							
9	4213	3034	2710	4313	3779	3528	3597
34	4408	3272	2554	4603	3877	3821	3756
67	4413	3642	2796	5199	4800	4696	4258
101	4925	3681	3070	5581	4691	4420	4395
134	4964	3863	3107	6270	4949	4730	4648
202	5170	3463	3168	6102	5492	4442	4640
269	5114	3400	2940	6576	5162	4409	4601

Table B2 Yield of Straw - Conquest Barley (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
9	1444	1353	2125	3735	2454	1709	2137
34	1959	1864	2437	3724	2557	2592	2522
67	2285	2558	2785	4188	2857	3328	2999
101	3492	2975	3369	4400	2961	3367	3427
134	2996	3894	3675	4000	3365	3545	3541
202	3778	3856	3758	4235	3360	4284	3879
269	3899	4372	3627	4424	3270	3248	3807
<u>Fallow Sites</u>							
9	2952	3659	3269	5252	3989	3278	3733
34	3335	3560	3698	5475	3840	3572	3913
67	3412	3728	3932	5924	3939	3910	4189
101	4007	4024	3874	5466	3989	3974	4222
134	3630	3991	3881	5346	3469	4084	4118
202	4943	4478	3956	5711	4324	4421	4636
269	3391	4557	3618	5712	4580	4283	4404

Table B3 Yield of Straw -Conquest Barley (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1357	1284	2018	1553
34	1681	1387	1942	1670
67	1782	1538	2044	1788
101	1963	1597	2033	1865
134	2107	1755	1999	1953
202	2349	1907	2202	2153
269	2634	1922	1961	2173
<u>Fallow Sites</u>				
9	3012	2894	2972	2959
34	3266	3147	2863	3092
67	3459	3093	3030	3194
101	3192	3032	3005	3077
134	3218	3342	3175	3245
202	3605	3140	3221	3322
269	3264	3164	3155	3194

Table B4 Yield of Straw -Conquest Barley (1975) (kg /ha)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	3277	1737	1459	875	1550	1780
34	3670	2067	2143	1426	2041	2269
67	3823	2605	2522	2035	2290	2655
101	3924	2722	2347	2244	2583	2764
134	3886	2764	2799	2256	2642	2869
202	4456	2913	2670	2375	2823	3047
269	4330	2859	2740	2496	2803	3046
<u>Fallow Sites</u>						
9	4932	2976	2647	2467	3141	3253
34	5009	3558	2926	2338	3126	3391
67	4737	3786	2957	2465	3300	3449
101	5123	3630	2974	2367	3534	3526
134	5157	3663	2928	2467	3660	3575
202	5214	3869	3604	2551	3550	3758
269	5283	3549	3491	2564	3494	3676

Table *B5* Yield of Straw - Fergus Barley (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle Dufrost	Mean	
<u>Nonfallow Sites</u>							
9	1636	2107	1288	2173	1522	2855	1931
34	2475	2228	1763	2730	2129	2956	2380
67	3452	3566	2675	3985	2821	3208	3285
101	3936	4708	2880	4390	2670	2891	3580
134	4100	5014	3176	5366	3204	3536	4067
202	4533	4733	3615	5611	3756	3362	4269
269	4674	4560	3893	5379	3416	3541	4263
<u>Fallow Sites</u>							
9	4778	4030	3650	5114	4318	4160	4342
34	5793	4760	3602	6066	4134	4404	4792
67	5553	5107	3694	6475	5198	4305	5057
101	5677	5153	3494	6269	4747	4519	4977
134	5085	5274	3886	6640	5265	4831	5164
202	5336	5575	3977	6542	6021	4553	5334
269	5583	5522	4088	7274	5880	4414	5461

Table B6 Yield of Straw - Fergus Barley (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	1383	1612	2485	4094	2624	1613	2284
34	2258	2206	2817	3660	3083	2326	2725
67	3166	3307	3469	4701	3497	3388	3588
101	3765	3675	3742	4561	3625	3703	3845
134	3922	4296	4107	4609	3812	3614	4077
202	3536	4140	4446	5115	3832	3717	4131
269	3737	3902	4598	4602	3821	3653	4052
<u>Fallow Sites</u>							
9	3359	4208	3508	5583	4504	3808	4162
34	3646	4668	3759	5505	4786	4001	4394
67	3951	4610	3744	5498	4652	4047	4417
101	4471	4852	3379	5510	4863	4493	4595
134	4586	4786	3740	5788	4715	4170	4631
202	4576	4677	3683	6027	4870	4411	4707
269	4612	5368	4193	6002	4841	4131	4857

Table 67 Yield of Straw - Fergus Barley (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1521	1389	2141	1812
34	2244	1487	2472	2068
67	2645	1696	2456	2266
101	3055	1895	2523	2491
134	3240	2178	2608	2676
202	3603	2412	2439	2818
269	3637	2491	2536	2887
<u>Fallow Sites</u>				
9	3401	3707	3396	3501
34	3647	3773	3497	3639
67	3910	3726	3256	3631
101	4915	3874	3335	4041
134	4217	3721	3511	3816
202	4085	3919	3465	3823
269	4316	3914	3483	3904

Table 68 Yield of Straw - Neepawa Wheat (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	1449	2209	1468	1539	2384	2584	1940
34	2327	2988	1989	2434	3534	2680	2659
67	3140	3637	2358	3819	3752	2983	3282
101	3675	3735	2405	4673	4300	2853	3608
134	3450	4364	2326	5141	5268	2782	3890
202	3424	3637	2744	4896	5366	2903	3829
269	3678	4626	2932	5019	4713	2955	3988
<u>Fallow Sites</u>							
9	5048	3166	3397	3720	5480	3916	4122
34	5130	3372	4692	4927	5104	3896	4521
67	4873	3490	4032	4674	5954	4155	4530
101	5064	3433	3992	5145	5619	3796	4509
134	5267	3471	3947	5146	5440	4517	4632
202	4925	3412	4019	5764	5498	4174	4632
269	5641	4000	3951	5652	5267	4470	4832

Table 69 Yield of Straw - Neepawa Wheat (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	2053	1659	3694	3958	3966	1257	2764
34	2600	1903	4590	4054	3650	2740	3256
67	3949	3558	5221	4756	3621	3787	4105
101	3720	4385	5396	5018	3575	3342	4239
134	4271	4433	5439	5055	4044	4199	4573
202	4054	4688	5472	4604	3652	3964	4405
269	4696	4691	5560	4395	3613	4273	4534
<u>Fallow Sites</u>							
9	4007	5178	5795	6316	5180	3716	4987
34	4459	5593	5797	6306	5289	4620	5344
67	4948	5535	6028	6065	5458	4618	5442
101	5303	5209	5923	6232	5478	4521	5444
134	4247	5790	5879	6626	4700	4649	5314
202	4831	5738	6217	6119	5206	4888	5499
269	5123	5699	5590	5822	5380	4997	5435

Table 8.10 Yield of Straw - Neepawa Wheat (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1387	1149	1966	1501
34	1897	1259	2125	1761
67	2062	1393	2239	1898
101	2145	1530	2371	2015
134	2247	1522	2293	2020
202	2265	1658	2378	2100
269	2248	1888	2370	2168
<u>Fallow Sites</u>				
9	3956	3425	2871	3417
34	3881	3228	3046	3385
67	4015	3446	2873	3445
101	4277	3282	3193	3584
134	4313	3254	3056	3541
202	4140	3356	3351	3503
269	4404	3504	3200	3703

Table 811 Yield of Straw -Neepawa Wheat (1975) (kg /ha)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	3938	2516	2000	1039	2332	2365
34	4028	2816	2416	1729	2946	2787
67	4497	3677	2688	1944	3206	3202
101	4499	3735	2951	2215	3189	3318
134	4633	4022	2920	2295	3394	3453
202	4284	4065	3142	2315	3598	3481
269	3306	3859	3221	2572	3321	3256
<u>Fallow Sites</u>						
9	5286	3059	3395	2690	4177	3721
34	5167	4110	3321	2699	4293	3918
67	5733	4456	3079	3215	4278	4152
101	5593	5146	3750	2993	3937	4284
134	5370	5024	3733	2865	4558	4310
202	5353	4634	3789	3186	4521	4297
269	5253	4583	3891	2984	4456	4233

Table B12 Yield of Straw - Glenlea Wheat (1972) (Kg/ha)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	2042	1717	1393	1799	2855	2775	2098
34	2248	2391	1989	2473	2574	3240	2486
67	2814	3042	2697	3735	2748	3249	3049
101	2998	3174	2495	4070	3000	3180	3154
134	3280	3876	2708	4378	3063	3322	3438
202	2981	3818	3007	5219	3529	3325	3648
269	3035	3986	2859	5363	3800	3014	3677
<u>Fallow Sites</u>							
9	3905	3950	3763	5389	4772	3806	4265
34	4352	4123	3388	5366	5168	3867	4378
67	4269	4637	3398	5583	5568	4097	4593
101	4291	4652	3633	6299	5598	4264	4790
134	4184	4838	3492	6366	5884	4199	4828
202	4570	4700	3662	6825	5608	4393	4960
269	4724	5012	3595	6185	6047	4346	4986

Table B13 Yield of Straw - Glenlea Wheat (1973) (kg/ha)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	1855	1531	3525	3520	3492	1598	2587
34	1886	2216	4309	4058	3854	2626	3158
67	2262	2834	4151	4012	3015	3455	3288
101	2733	3288	4714	3955	3241	3329	3544
134	2463	3571	4491	4476	2883	3713	3600
202	3373	3686	4916	4627	4085	3674	4060
269	2630	3571	5064	3136	4560	3608	3761
<u>Fallow Sites</u>							
9	4283	4222	5270	6047	4617	3814	4708
34	4060	4229	5097	5713	4570	4189	4644
67	4441	4375	5229	6608	4922	4502	4902
101	4892	4275	5232	6181	4885	4529	5000
134	4441	4454	5124	5830	5437	4666	4931
202	4125	4342	4719	5663	4907	4557	4719
269	4043	4331	5061	5854	5274	4592	4860

Table 14 Yield of Straw -Glenlea Wheat (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1387	1212	2084	1561
34	1700	1270	2167	1712
67	1864	1193	2377	1811
101	1817	1372	2061	1749
134	2057	1667	2231	1985
202	2056	1667	1696	1950
269	2331	1639	2315	2094
<u>Fallow Sites</u>				
9	3623	3305	3384	3437
34	3631	3409	3370	3470
67	3681	3376	3727	3595
101	3807	3294	3653	3585
134	4072	3429	3580	3694
202	3750	3549	3649	3649
269	4075	3592	3641	3769

Table 615 Yield of Straw - Dufferin Flax (1976) (kg/ha)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
9	3151	3086	2233	1752	2913	3295	2755
25	3194	3318	2295	2744	3180	3295	3004
58	3670	2366	2728	2728	3562	3400	3125
92	3015	3632	2114	2845	3561	3769	3156
125	3420	2655	2205	3049	3149	3935	3069
193	2835	3225	2447	3137	3397	3953	3166
260	3240	3218	2270	2866	3144	3854	3099
<u>Fallow Sites</u>							
9	—		2232	3009	3208	5220	3417
25	—		2241	3097	3151	5427	3479
58	—		2350	3064	3351	5370	3534
92	—		2564	3162	3441	5310	3619
125	—		2662	3240	3180	5093	3544
193	—		2271	3128	3471	5486	3589
260	—		3850	2865	3486	5073	3819

Table B6 Yield of Straw - Dufferin Flax (1977) (kg /ha)

Treatment	Carman East	Pilot Mound South	Portage	Mean
0	57.00	28.28	37/75	41.01
25	87.93	37.43	48.59	57.98
58	70.56	57.75	42.50	56.94
92	63.76	74.77	38.17	59.90
125	60.00	77.12	27.29	54.80
193	60.05	64.63	52.55	59.08
260	60.67	69.61	38.86	56.38

Table B17 Yield of Straw - Tower Rape (1975) (kg /ha)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	881	1407	1144
29	-	1671	1692	1682
63	-	2498	2136	2317
96	-	2353	2338	2346
130	-	2847	2421	2634
197	-	3171	2728	2950
264	-	3031	2531	2781
<u>Fallow Sites</u>				
4	2013	2073	2862	2316
29	1912	2305	3129	2459
63	1933	2465	3226	2541
96	2193	2886	2705	2595
130	1191	2830	3415	2479
197	2355	2499	3217	2690
264	1940	2313	3043	2432

Table 8 Yield of Straw - Tower Rape (1976) (kg/ha)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	3634	3208	4133	2362	3334
29	3767	4113	3726	4177	3946
63	4340	4957	4163	5155	4654
96	4890	4946	4202	5224	4816
130	5055	4885	3912	5761	4903
197	5555	5166	4588	5647	5239
264	5325	5353	4571	5148	5099
<u>Fallow Sites</u>					
4	-	5662	4135	4440	4746
29	-	5625	4693	4661	4993
63	-	5901	5404	5236	5514
96	-	5413	4521	5141	5025
130	-	5383	5124	5074	5194
197	-	5439	5487	5308	5411
264	-	3743	4936	5322	4667

Table 19 Yield of Straw - Tower Rape (1977) (kg /ha)

Treatment (kg N/ha)	Carman		Pilot Mound	Boissevain	Portage	Mean
	<u>Nonfallow Sites</u>					
	<u>East</u>	<u>West</u>				
4	51.98	36.49	33.76	20.32	35.53	35.62
29	45.49	42.07	40.88	37.93	42.98	41.87
63	58.87	50.38	43.30	42.50	45.73	48.16
96	61.25	47.35	60.55	50.63	50.19	53.99
130	67.24	50.17	55.84	56.93	45.17	55.09
197	61.13	50.35	57.44	59.53	51.30	55.95
264	59.04	57.31	63.96	63.26	48.81	58.48

Table 20 Utilization of Added Nitrogen by Conquest Barley (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	----	----	----	----	----	----	----
34	48.3	46.6	44.6	45.3	33.3	81.9	50.1
67	51.1	58.1	51.3	60.3	48.9	62.1	55.4
101	49.4	60.4	45.3	73.5	51.4	45.0	54.3
134	47.7	57.6	42.5	66.1	39.5	37.1	48.5
202	44.2	50.8	35.4	56.4	37.0	28.2	42.1
269	35.7	46.5	29.6	49.5	32.3	23.1	36.2
<u>Fallow Sites</u>							
9	----	----	----	----	----	----	----
34	81.3	32.3	14.0	37.3	54.3	41.3	43.5
67	41.8	40.9	15.4	56.4	65.6	69.1	48.3
101	56.8	44.7	17.2	55.1	57.7	50.6	47.1
134	46.1	42.3	14.2	60.4	50.2	44.5	43.0
202	37.4	29.6	12.1	49.4	44.0	35.6	34.8
269	34.7	24.4	8.4	40.7	35.3	29.9	29.0

Table B21

Utilization of added Nitrogen - Conquest Barley (%) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	45.90	44.40	40.97	21.10	23.47	55.57	38.57
67	48.18	53.35	36.08	14.38	27.48	62.52	40.33
101	52.21	47.76	40.33	16.53	32.81	56.16	40.97
134	47.48	49.18	44.57	16.33	22.86	55.92	39.39
202	41.75	42.88	38.34	17.84	21.39	57.08	36.55
269	34.64	40.60	30.52	16.85	20.09	36.28	29.83
<u>Fallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	63.27	13.60	37.33	59.67	18.23	33.83	37.66
67	44.92	12.77	29.75	54.42	27.80	36.25	34.32
101	46.17	29.37	23.54	37.41	34.83	42.56	35.65
134	40.50	27.30	18.81	30.43	33.89	24.97	29.32
202	37.13	24.61	16.87	24.24	25.21	35.22	27.21
269	29.10	24.76	9.70	16.88	24.43	25.58	21.74

Table 822 Utilization of Added Nitrogen-Conquest Barley (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	-	-	-	-
34	23.73	17.05	0	13.56
67	30.02	19.87	8.75	19.55
101	26.11	16.57	3.85	15.51
134	25.96	15.18	7.77	16.30
202	22.39	15.34	16.25	17.99
269	21.99	11.29	4.84	12.71
<u>Fallow Sites</u>				
9	-	-	-	-
34	18.50	50.23	54.41	41.03
67	25.63	20.46	20.04	22.04
101	11.32	3.68	17.56	10.85
134	8.69	19.41	18.98	15.69
202	12.92	12.17	14.09	13.06
269	7.73	9.38	12.11	9.74

Table 23 Utilization of Added Nitrogen - Conquest Barley (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	-	-	-	-	-	-
34	35.38	45.44	59.97	56.62	49.71	49.42
67	29.30	53.63	56.96	57.31	48.52	49.14
101	36.29	40.07	36.03	43.16	43.00	39.71
134	29.97	35.19	35.67	40.26	37.37	35.49
202	30.15	32.50	28.80	32.23	20.04	30.54
269	25.26	23.13	22.41	25.69	23.02	23.90
<u>Fallow Sites</u>						
9	-	-	-	-	-	-
34	11.18	96.74	42.91	48.23	-	49.77
67	1.51	58.31	37.01	37.84	9.80	28.89
101	31.62	44.67	31.19	22.62	20.80	30.18
134	17.57	39.12	24.40	23.00	26.84	26.19
202	13.35	30.89	23.44	15.63	17.93	20.25
269	13.77	25.33	18.30	13.39	14.62	17.08

Table B24 Utilization of Added Nitrogen by Fergus Barley (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	----	----	----	----	----	----	----
34	44.6	32.3	49.6	55.3	49.3	51.6	47.1
67	45.9	50.4	53.1	66.8	46.1	56.8	53.2
101	54.5	67.0	56.3	65.4	28.5	49.1	53.5
134	49.6	62.1	45.2	71.1	33.2	42.7	50.6
202	46.3	47.6	41.1	56.9	34.8	31.2	43.0
269	35.4	42.5	33.5	52.1	22.9	26.3	35.5
<u>Fallow Sites</u>							
9	----	----	----	----	----	----	----
34	59.9	71.3	1.3	80.3	67.6	53.3	55.6
67	45.6	78.2	17.4	44.6	68.1	56.6	51.8
101	60.8	65.0	5.9	49.5	47.5	49.6	46.4
134	48.1	63.1	11.7	43.2	47.9	35.8	41.6
202	41.6	47.9	7.3	39.2	35.9	32.6	34.1
269	36.1	41.2	7.7	37.6	33.2	24.4	30.0

Table B25

Utilization of added Nitrogen - Fergus Barley (%) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	44.40	50.20	27.43	13.47	43.63	36.47	35.93
67	49.55	56.22	37.15	38.47	44.20	56.12	46.95
101	43.43	61.23	32.27	16.98	46.00	50.64	41.76
134	45.45	59.04	34.12	23.53	37.38	50.26	41.63
202	38.85	43.68	31.09	17.18	27.33	41.74	33.31
269	27.93	36.07	26.54	12.93	25.35	34.90	27.29
<u>Fallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	42.33	49.10	20.33	11.53	46.57	50.73	36.77
67	36.70	44.62	20.28	12.68	46.42	41.10	33.63
101	39.70	40.71	10.96	18.36	29.43	36.91	29.35
134	38.71	35.35	15.03	12.88	37.81	32.58	28.73
202	29.35	28.61	11.31	20.38	25.27	28.77	23.95
269	23.99	25.12	11.03	16.06	22.87	23.70	20.46

Table 26 Utilization of Added Nitrogen-Fergus Barley (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	-	-	-	-
34	27.73	18.27	44.55	30.18
67	41.12	17.13	22.69	26.98
101	41.16	16.78	20.91	26.28
134	37.89	18.90	17.71	24.83
202	34.23	16.75	11.55	20.84
269	30.09	15.06	9.55	18.23
<u>Fallow Sites</u>				
9	-	-	-	-
34	48.68	53.18	36.18	46.01
67	47.63	19.40	23.83	30.29
101	62.51	19.63	18.76	33.63
134	39.62	14.06	20.82	24.83
202	25.70	9.47	14.65	16.61
269	23.51	10.27	12.42	15.40

Table ~~627~~ Utilization of Added Nitrogen by Neepawa Wheat (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	70.6	66.3	61.6	53.3	44.3	37.3	55.6
67	75.2	72.5	58.5	59.7	36.7	45.8	58.1
101	76.6	51.4	44.1	59.7	37.1	31.4	50.1
134	58.5	48.7	37.3	55.9	40.1	25.5	44.3
202	41.1	39.2	30.8	44.2	32.0	16.8	34.0
269	33.5	35.2	23.7	35.6	29.9	15.5	28.9
<u>Fallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	56.3	50.6	41.6	67.6	32.0	34.6	46.7
67	38.4	30.0	19.0	39.7	55.9	35.7	36.5
101	30.0	17.5	17.6	32.4	37.4	22.1	26.2
134	28.7	15.6	12.6	32.8	30.1	27.3	24.5
202	20.3	13.5	14.0	34.9	22.0	18.1	20.5
269	18.4	12.9	10.2	27.8	18.6	14.6	17.1

Table B28

Utilization of Added Nitrogen - Neepawa Wheat (%) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	39.80	65.47	48.50	41.13	17.67	65.13	46.28
67	58.57	55.27	37.92	31.36	15.88	65.73	44.12
101	49.29	57.60	36.63	32.40	15.74	54.80	41.08
134	45.73	49.68	34.50	28.90	14.53	49.40	37.12
202	37.91	41.44	30.07	20.33	11.78	35.38	29.49
269	33.50	37.02	26.05	12.60	12.87	32.50	25.76
<u>Fallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	40.07	22.60	42.70	22.10	17.83	57.70	33.83
67	30.50	15.22	28.23	16.03	15.88	49.00	25.81
101	34.37	15.17	22.68	6.76	16.27	35.61	21.81
134	24.89	18.46	12.09	19.35	6.94	34.90	15.33
202	21.09	15.98	10.81	6.35	7.56	25.54	14.56
269	17.84	13.46	8.79	3.79	7.23	20.95	12.01

Table 629 Utilization of Added Nitrogen-Neepawa Wheat (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	-	-	-	-
34	49.86	13.23	33.73	32.27
67	32.92	12.75	38.75	28.14
101	26.88	9.70	22.28	19.62
134	21.53	9.60	32.76	21.30
202	17.19	14.47	13.29	14.98
269	13.12	8.38	10.50	10.67
<u>Fallow Sites</u>				
9	-	-	-	-
34	69.41	0	29.59	49.50
67	48.75	2.29	13.33	21.46
101	39.66	.72	22.70	21.03
134	31.28	0	14.17	22.73
202	21.73	3.02	8.18	10.98
269	17.10	2.00	9.08	9.39

Table 830 Utilization of Added Nitrogen - Neepawa Wheat (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	-	-	-	-	-	-
34	16.18	32.47	41.18	64.53	59.74	43.82
67	22.58	44.04	38.03	38.55	53.63	39.37
101	17.40	38.31	31.68	41.20	41.10	33.94
134	21.84	35.28	28.46	31.73	36.41	30.74
202	11.95	26.92	21.00	22.48	26.41	21.95
269	13.39	18.78	18.81	20.00	20.19	18.23
<u>Fallow Sites</u>						
9	-	-	-	-	-	-
34	28.12	74.35	-	10.59	52.91	41.49
67	15.58	50.78	-	25.30	30.31	30.49
101	1.59	51.17	18.51	17.09	21.78	22.03
134	7.54	39.42	11.84	12.35	26.67	19.56
202	5.70	20.06	11.63	12.96	18.79	15.63
269	1.75	19.49	7.82	10.37	12.39	10.36

Table 631 Utilization of Added Nitrogen by Glenlea Wheat (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	----	----	----	----	----	----	----
34	12.0	56.9	55.6	42.6	16.0	42.3	37.6
67	42.1	62.5	62.8	55.6	30.9	49.6	50.7
101	43.6	57.5	42.5	52.3	16.3	37.7	41.7
134	41.2	60.0	40.7	49.1	16.1	36.7	40.7
202	27.6	47.4	37.0	50.0	19.7	24.6	34.5
269	21.9	38.1	26.5	43.6	18.6	15.1	27.4
<u>Fallow Sites</u>							
9	----	----	----	----	----	----	----
34	76.6	51.6	0.0	24.0	56.9	55.3	44.2
67	51.6	53.4	1.8	28.7	68.5	50.6	42.5
101	27.2	51.3	11.1	28.4	51.8	43.3	35.6
134	30.7	42.0	0.0	34.8	45.1	34.8	31.3
202	26.6	35.0	5.6	30.2	32.2	25.3	25.9
269	22.1	27.9	5.3	24.0	28.3	18.1	21.0

Table B32

Utilization of Added Nitrogen - Glenlea Wheat (%) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	38.40	38.60	58.83	60.43	43.47	62.53	50.38
67	46.62	40.67	53.28	22.32	37.85	58.13	43.15
101	43.76	42.19	48.78	24.51	31.81	47.73	39.80
134	45.53	42.18	43.15	26.61	23.73	50.62	38.64
202	37.40	33.11	34.37	19.20	21.30	34.64	30.00
269	26.59	27.41	29.75	11.74	17.38	29.09	23.66
<u>Fallow Sites</u>							
9	-----	-----	-----	-----	-----	-----	-----
34	7.06	35.30	*	13.07	31.60	45.77	26.56
67	35.06	33.93	*	41.45	25.07	36.92	34.49
101	30.84	22.13	3.98	48.33	23.94	39.97	28.20
134	28.48	27.68	1.31	37.55	26.12	31.73	25.65
202	24.58	17.64	1.92	21.71	16.53	25.85	18.04
269	29.53	13.29	3.95	19.51	18.31	19.77	15.73

* N uptake greater with 9 kg N/ha added than with 34 or 67 kg N/ha.

Table 33 Utilization of Added Nitrogen-Glenlea Wheat (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	-	-	-	-
34	31.14	11.41	20.77	21.11
67	22.31	3.12	26.71	17.38
101	14.83	8.18	8.77	10.59
134	17.77	9.13	12.17	13.02
202	12.58	7.52	6.88	8.99
269	12.40	5.78	7.55	8.58
<u>Fallow Sites</u>				
9	-	-	-	-
34	0	21.77	65.50	43.64
67	1.08	16.10	48.65	21.94
101	2.59	3.21	34.11	13.30
134	10.90	1.36	25.35	12.54
202	5.23	4.42	16.89	8.85
269	7.72	3.59	14.06	8.46

Table 634 Utilization of Added Nitrogen - Dufferin Flax (%) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
0	-		-	-	-	-	-
25	48.52	4.84	30.80	93.24	20.48	71.68	44.93
58	6.91	25.22	25.71	55.16	30.72	39.03	30.46
92	8.96	16.40	6.59	40.93	20.91	37.97	21.96
125	6.90	3.41	4.10	29.10	15.82	18.46	12.97
193	6.36	2.04	9.69	21.95	11.32	15.93	11.22
260	3.40	2.96	2.41	16.54	6.13	12.33	7.30
<u>Fallow Sites</u>							
0	-		-	-	-	-	-
25	-		10.20	30.52	0.0	0.0	10.18
58	-		20.47	10.86	0.0	34.07	16.35
92	-		18.33	9.62	8.45	0.0	9.10
125	-		16.75	13.46	0.0	4.28	8.62
193	-		8.01	7.80	3.87	7.44	6.78
260	-		11.66	3.75	0.44	7.42	5.82

Table 335 Utilization of Added Nitrogen Dufferin Flax (%) (1977)

Treatment (kg N/ha)	Carman East	Pilot Mound South	Portage	Mean
0	-	-	-	-
25	166.1	57.3	69.1	97.5
58	49.9	91.6	21.6	54.4
92	25.2	74.7	8.4	36.1
125	23.3	80.3	00.0	34.5
193	17.8	52.3	14.8	28.3
260	15.4	40.5	7.6	21.2

Table 636 Utilization of Added Nitrogen - Tower Rape (%) (1975)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	-	-	-
29	-	52.17	33.83	43.00
63	-	56.90	32.13	44.52
96	-	49.01	25.78	37.40
130	-	41.75	27.89	34.82
197	-	34.82	20.49	27.66
264	-	28.75	15.30	22.03
<u>Fallow Sites</u>				
4	-	-	-	-
29	24.28	20.48	36.55	30.10
63	18.00	24.78	42.38	28.39
96	21.58	29.36	11.72	20.89
130	2.10	27.01	25.22	18.11
197	12.53	11.17	16.90	13.53
264	3.91	8.70	10.16	7.59

Table 837 Utilization of Added Nitrogen Tower Rape (%) (1976)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	-	-	-	-	-
29	24.24	58.34	23.14	47.14	38.22
63	36.29	39.43	21.84	24.24	30.45
96	45.70	47.15	22.19	42.15	39.30
130	40.68	40.64	10.15	47.88	34.84
197	34.77	32.36	19.33	34.04	30.13
264	26.77	28.14	14.29	20.39	22.40
<u>Fallow Sites</u>					
4	-	-	-	-	-
29	-	33.72	62.07	67.90	54.56
63	-	26.44	64.86	47.92	46.41
96	-	14.34	35.98	29.78	26.70
130	-	16.29	39.06	19.07	24.81
197	-	15.23	39.55	15.73	23.50
264	-	5.00	19.56	13.97	12.84

Table 38 Utilization of Added Nitrogen Tower Rape (%) (1977)

Treatment kg N/ha)	Carman		Pilot Mound	Boissevain	Portage	Mean
<u>Nonfallow Sites</u>						
	<u>East</u>	<u>West</u>				
4	-	-	-	-	-	-
29	44.1	30.9	25.0	92.6	77.9	54.1
63	94.6	76.7	38.0	51.4	63.3	64.8
96	75.7	24.3	68.8	57.9	63.8	58.1
130	81.0	20.4	55.1	55.1	54.4	53.2
197	42.3	18.8	46.3	43.8	48.3	40.1
264	33.1	20.9	45.7	30.9	38.3	33.8

Table B39 Nitrogen Content of Conquest Barley Straw (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	0.30	0.37	0.43	0.34	0.55	0.48	0.41
34	0.32	0.33	0.46	0.32	0.41	0.52	0.39
67	0.34	0.37	0.62	0.33	0.43	0.70	0.47
101	0.46	0.45	0.69	0.43	0.53	0.79	0.56
134	0.56	0.60	0.77	0.53	0.55	0.86	0.65
202	0.82	0.80	0.92	0.69	0.64	0.93	0.80
269	0.99	1.18	1.09	0.92	0.78	0.98	0.99
<u>Fallow Sites</u>							
9	0.37	0.47	1.07	0.33	0.32	0.41	0.50
34	0.44	0.59	1.13	0.32	0.36	0.46	0.55
67	0.53	0.68	1.19	0.41	0.48	0.64	0.66
101	0.74	0.90	1.18	0.50	0.57	0.76	0.78
134	0.81	1.02	1.27	0.64	0.68	0.85	0.88
202	1.04	1.42	1.39	0.85	0.90	0.91	1.09
269	1.22	1.71	1.55	1.11	1.06	1.03	1.28

Table B40 Nitrogen Content of Conquest Barley Straw (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	0.31	0.39	0.37	0.61	0.48	0.40	0.43
34	0.27	0.37	0.32	0.64	0.60	0.39	0.43
67	0.31	0.40	0.40	0.75	0.55	0.39	0.47
101	0.43	0.43	0.42	0.85	0.78	0.47	0.56
134	0.47	0.46	0.51	0.92	0.71	0.57	0.61
202	0.74	0.71	0.71	1.12	1.00	0.67	0.83
269	0.82	0.93	0.85	1.29	1.09	0.95	0.99
<u>Fallow Sites</u>							
9	0.35	0.53	0.74	0.74	0.39	0.46	0.54
34	0.37	0.60	0.82	0.78	0.48	0.46	0.59
67	0.37	0.65	0.83	1.04	0.52	0.47	0.65
101	0.59	0.88	0.91	1.04	0.78	0.70	0.90
134	0.57	1.05	0.96	1.09	0.93	0.77	0.90
202	0.72	1.17	1.09	1.28	0.91	1.01	1.03
269	0.97	1.37	1.11	1.32	1.06	1.17	1.17

Table 34/Nitrogen Content of Conquest Barley Straw (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	0.56	0.38	0.97	0.64
34	0.58	0.41	0.97	0.65
67	0.76	0.49	1.04	0.76
101	0.97	0.58	1.09	0.88
134	1.10	0.57	1.23	0.97
202	1.26	0.62	1.30	1.06
269	1.35	0.72	1.33	1.13
<u>Fallow Sites</u>				
9	0.95	0.73	0.68	0.79
34	1.09	0.74	0.83	0.89
67	1.21	0.75	0.96	0.77
101	1.27	0.82	1.12	1.07
134	1.35	0.88	1.17	1.13
202	1.39	0.94	1.27	1.20
269	1.48	0.99	1.44	1.30

Table 842 Nitrogen Content of Conquest Barley Straw (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	0.83	0.37	0.39	0.45	0.55	0.52
34	0.82	0.38	0.39	0.48	0.62	0.54
67	0.98	0.57	0.46	0.50	0.77	0.66
101	1.32	0.60	0.57	0.64	0.81	0.79
34	1.40	0.70	0.67	0.74	0.84	0.87
202	1.53	1.03	0.98	0.95	0.97	1.09
269	1.74	1.09	1.10	1.04	1.10	1.21
<u>Fallow Sites</u>						
9	1.32	0.34	0.52	0.57	0.69	0.69
34	1.40	0.61	0.70	0.67	0.62	0.80
67	1.57	0.55	0.85	0.85	0.70	0.90
101	1.69	0.80	0.99	0.90	0.81	1.04
134	1.65	0.92	1.06	1.02	1.12	1.15
202	1.80	1.06	1.25	1.04	—	1.29
269	1.86	1.33	1.37	1.11	1.28	1.39

Table 643 Nitrogen Content of Fergus Barley Straw (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	0.33	0.32	0.40	0.35	0.48	0.42	0.38
34	0.36	0.32	0.39	0.35	0.41	0.43	0.38
67	0.38	0.39	0.48	0.40	0.48	0.57	0.45
101	0.54	0.50	0.66	0.47	0.48	0.64	0.55
134	0.70	0.65	0.64	0.56	0.60	0.69	0.64
202	0.85	0.71	0.82	0.77	0.71	0.75	0.77
269	1.02	1.05	0.95	0.94	0.78	0.83	0.93
<u>Fallow Sites</u>							
9	0.42	0.35	0.76	0.33	0.43	0.38	0.45
34	0.49	0.43	0.78	0.43	0.50	0.43	0.51
67	0.57	0.54	0.83	0.48	0.66	0.57	0.61
101	0.78	0.67	0.85	0.67	0.65	0.65	0.70
134	0.80	0.85	0.89	0.66	0.80	0.67	0.78
202	1.02	1.02	0.94	0.89	0.88	0.86	0.94
269	1.16	1.18	0.98	1.10	0.98	0.89	1.05

Table B44 Nitrogen Content of Fergus Barley Straw (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	0.36	0.36	0.47	0.65	0.41	0.36	0.44
34	0.31	0.36	0.38	0.62	0.42	0.35	0.41
67	0.38	0.35	0.47	0.71	0.50	0.37	0.46
101	0.43	0.47	0.48	0.71	0.66	0.53	0.55
134	0.50	0.54	0.52	0.94	0.73	0.58	0.64
202	0.78	0.61	0.67	0.93	0.79	0.72	0.75
269	0.81	0.71	0.72	0.96	1.00	0.95	0.86
<u>Fallow Sites</u>							
9	0.33	0.53	0.71	0.63	0.47	0.40	0.51
34	0.37	0.65	0.75	0.69	0.49	0.45	0.57
67	0.46	0.79	0.85	0.75	0.65	0.50	0.67
101	0.54	0.81	0.84	0.86	0.47	0.57	0.68
134	0.68	1.00	0.96	0.89	0.87	0.73	0.86
202	0.88	1.15	0.98	1.13	0.88	0.95	1.00
269	0.95	1.35	1.00	1.19	1.00	1.07	1.09

Table 64/ Nitrogen Content of Fergus Barley Straw (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	0.48	0.37	0.74	0.53
34	0.52	0.39	0.79	0.57
67	0.70	0.46	0.85	0.67
101	0.74	0.47	0.97	0.73
134	0.87	0.55	1.00	0.81
202	1.08	0.55	1.08	0.90
269	1.18	0.64	1.18	1.00
<u>Fallow Sites</u>				
9	0.72	0.64	0.63	0.66
34	0.89	0.74	0.68	0.77
67	0.94	0.83	0.85	0.87
101	1.15	0.88	0.94	0.99
134	1.21	0.88	1.06	1.05
202	1.34	0.89	1.14	1.12
269	1.43	0.99	1.18	1.20

Table 846 Nitrogen Content of Neepawa Wheat Straw (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	0.27	0.27	0.26	0.29	0.22	0.35	0.28
34	0.24	0.27	0.27	0.22	0.22	0.38	0.27
67	0.31	0.29	0.35	0.24	0.21	0.41	0.30
101	0.36	0.29	0.37	0.23	0.26	0.48	0.33
134	0.39	0.40	0.41	0.29	0.27	0.48	0.37
202	0.41	0.44	0.45	0.36	0.31	0.38	0.39
269	0.43	0.53	0.48	0.48	0.48	0.45	0.48
<u>Fallow Sites</u>							
9	0.31	0.44	0.39	0.27	0.17	0.32	0.32
34	0.34	0.49	0.48	0.28	0.21	0.32	0.35
67	0.39	0.44	0.48	0.26	0.32	0.36	0.38
101	0.43	0.47	0.48	0.31	0.27	0.40	0.39
134	0.52	0.53	0.49	0.36	0.36	0.43	0.45
202	0.55	0.50	0.57	0.54	0.32	0.45	0.49
269	0.55	0.60	0.55	0.62	0.39	0.49	0.53

Table B47 Nitrogen Content of Neepawa Wheat Straw (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	0.28	0.27	0.25	0.43	0.46	0.32	0.34
34	0.27	0.22	0.26	0.45	0.45	0.27	0.32
67	0.26	0.23	0.27	0.46	0.46	0.33	0.34
101	0.29	0.28	0.33	0.57	0.53	0.38	0.40
134	0.31	0.38	0.37	0.59	0.47	0.38	0.42
202	0.43	0.39	0.48	0.62	0.49	0.55	0.50
269	0.46	0.60	0.57	0.63	0.59	0.60	0.58
<u>Fallow Sites</u>							
9	0.31	0.43	0.54	0.59	0.40	0.26	0.42
34	0.32	0.50	0.58	0.61	0.42	0.27	0.45
67	0.36	0.49	0.62	0.67	0.45	0.37	0.49
101	0.36	0.60	0.63	0.66	0.46	0.39	0.52
134	0.47	0.76	0.67	0.73	0.48	0.51	0.60
202	0.53	0.74	0.74	0.71	0.55	0.57	0.64
269	0.57	0.80	0.77	0.67	0.57	0.59	0.66

Table 848 Nitrogen Content of Neepawa Wheat Straw (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	0.34	0.27	0.34	0.32
34	0.38	0.30	0.48	0.39
67	0.46	0.31	0.55	0.44
101	0.52	0.30	0.52	0.45
134	0.58	0.33	0.55	0.49
202	0.70	0.34	0.64	0.56
269	0.66	0.35	0.61	0.54
<u>Fallow Sites</u>				
9	0.43	0.34	0.39	0.39
34	0.49	0.36	0.43	0.43
67	0.60	0.38	0.49	0.49
101	0.64	0.41	0.54	0.53
134	0.62	0.42	0.58	0.54
202	0.68	0.44	0.59	0.57
269	0.73	0.44	0.57	0.58

Table 349 Nitrogen Content of Neepawa Wheat Straw (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	0.49	0.27	0.29	0.27	0.36	0.34
34	0.58	0.27	0.34	0.30	0.35	0.37
67	0.69	0.34	0.44	0.33	0.48	0.46
101	0.70	0.46	0.39	0.42	0.55	0.50
134	0.88	0.56	0.52	0.39	0.57	0.58
202	0.92	0.77	0.57	0.43	0.56	0.65
269	1.02	0.77	0.70	0.46	0.62	0.71
<u>Fallow Sites</u>						
9	0.70	0.27	0.45	0.43	0.43	0.46
34	0.75	0.33	0.49	0.42	0.51	0.50
67	0.76	0.43	0.55	0.48	0.53	0.55
101	0.78	0.52	0.57	0.50	0.61	0.59
134	0.87	0.55	0.56	0.49	0.63	0.62
202	0.84	0.67	0.71	0.52	0.81	0.71
269	0.87	0.75	0.66	0.57	0.71	0.71

Table B50 Nitrogen Content of Glenlea Wheat Straw (%) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	0.29	0.31	0.29	0.34	0.29	0.36	0.31
34	0.29	0.31	0.27	0.29	0.29	0.41	0.31
67	0.35	0.36	0.34	0.30	0.30	0.44	0.35
101	0.40	0.42	0.41	0.31	0.35	0.47	0.39
134	0.41	0.45	0.41	0.41	0.37	0.51	0.43
202	0.48	0.60	0.48	0.46	0.46	0.55	0.51
269	0.48	0.57	0.49	0.60	0.46	0.55	0.53
<u>Fallow Sites</u>							
9	0.31	0.33	0.54	0.33	0.29	0.34	0.36
34	0.35	0.34	0.55	0.33	0.32	0.39	0.38
67	0.40	0.43	0.57	0.33	0.39	0.39	0.42
101	0.42	0.48	0.62	0.40	0.41	0.41	0.46
134	0.49	0.51	0.62	0.50	0.39	0.44	0.49
202	0.55	0.60	0.67	0.64	0.53	0.46	0.58
269	0.53	0.64	0.68	0.67	0.50	0.48	0.58

Table B51 Nitrogen Content of Glenlea Wheat Straw (%) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	0.27	0.26	0.22	0.36	0.37	0.30	0.30
34	0.29	0.30	0.27	0.41	0.39	0.31	0.33
67	0.34	0.30	0.31	0.48	0.43	0.33	0.37
101	0.36	0.34	0.31	0.56	0.39	0.39	0.39
134	0.51	0.38	0.41	0.60	0.47	0.42	0.47
202	0.50	0.46	0.42	0.65	0.57	0.51	0.52
269	0.52	0.58	0.57	0.68	0.57	0.53	0.58
<u>Fallow Sites</u>							
9	0.30	0.41	0.51	0.41	0.40	0.35	0.40
34	0.31	0.47	0.52	0.46	0.39	0.35	0.42
67	0.37	0.60	0.55	0.54	0.40	0.40	0.48
101	0.39	0.69	0.63	0.59	0.47	0.48	0.54
134	0.48	0.72	0.63	0.64	0.55	0.53	0.60
202	0.57	0.85	0.64	0.65	0.58	0.57	0.64
269	0.60	0.79	0.69	0.75	0.62	0.59	0.67

Table 65² Nitrogen Content of Glenlea Wheat Straw (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	0.37	0.28	0.40	0.35
34	0.46	0.28	0.43	0.39
67	0.61	0.31	0.49	0.47
101	0.60	0.34	0.51	0.48
134	0.73	0.35	0.52	0.53
202	0.74	0.37	0.55	0.55
269	0.89	0.40	0.56	0.59
<u>Fallow Sites</u>				
9	0.57	0.38	0.45	0.47
34	0.67	0.44	0.60	0.57
67	0.77	0.44	0.64	0.62
101	0.82	0.44	0.71	0.66
134	0.87	0.46	0.71	0.68
202	0.94	0.47	0.79	0.73
269	0.96	0.47	0.79	0.74

Table 6.3 Nitrogen Content of Dufferin Flax Straw (%) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
0	0.35	0.49	0.54	0.46	0.39	0.44	0.45
25	0.39	0.40	0.58	0.46	0.46	0.50	0.47
58	0.43	0.45	0.59	0.57	0.46	0.50	0.50
92	0.48	0.43	0.61	0.68	0.67	0.51	0.56
125	0.48	0.54	0.67	0.72	0.83	0.36	0.60
193	0.67	0.50	0.66	0.86	0.71	0.69	0.68
260	0.55	0.53	0.61	0.96	0.67	0.62	0.66
<u>Fallow Sites</u>							
0	-		0.58	0.50	0.51	0.46	0.51
25	-		0.61	0.57	0.47	0.63	0.57
58	-		0.67	0.68	0.55	0.67	0.64
92	-		0.51	0.67	0.55	0.50	0.56
125	-		0.60	0.78	0.61	0.61	0.65
193	-		0.71	0.76	0.66	0.68	0.70
260	-		0.71	0.81	0.67	0.82	0.75

Table B54 Nitrogen Content of Dufferin Flax Straw (%) (1977)

Treatment	Carman East	Pilot Mound South	Portage	Mean
0	0.32	0.35	0.51	0.39
25	0.40	0.31	0.53	0.41
58	0.47	0.32	0.77	0.52
92	0.54	0.37	0.70	0.54
125	0.63	0.53	0.81	0.65
193	0.64	0.59	0.79	0.67
260	0.69	0.54	0.94	0.72

Table 355 Nitrogen Content of Tower Rape Straw (%) (1975)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	0.52	0.63	0.58
29	-	0.49	0.62	0.56
63	-	0.59	0.71	0.65
96	-	0.53	0.76	0.65
130	-	0.51	0.98	0.75
197	-	0.81	0.88	0.85
264	-	0.74	1.00	0.87
<u>Fallow Sites</u>				
4	0.64	0.48	0.98	0.70
29	0.83	0.64	0.97	0.81
63	1.04	0.74	1.10	0.96
96	0.99	0.67	1.18	0.95
130	1.17	0.80	1.11	1.03
197	1.16	0.94	1.21	1.10
264	1.19	0.91	1.27	1.12

Table 36 Nitrogen Content of Tower Rape Straw (%) (1976)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	0.42	0.47	0.58	0.61	0.52
29	0.51	0.42	0.67	0.57	0.54
63	0.71	0.38	0.88	0.71	0.67
96	0.69	0.52	0.88	0.61	0.68
130	0.71	0.59	0.85	0.59	0.69
197	0.95	0.73	0.98	0.69	0.84
264	1.06	0.82	1.05	0.79	0.93
<u>Fallow Sites</u>					
4	-	0.51	0.54	0.60	0.55
29	-	0.61	0.62	0.71	0.65
63	-	0.66	0.68	0.61	0.65
96	-	0.85	0.89	0.78	0.84
130	-	0.87	1.04	0.81	0.91
197	-	1.05	0.92	0.79	0.92
264	-	1.09	1.01	0.86	0.99

Table 857 Nitrogen Content of Tower Rape Straw (%) (1977)

Treatment (kg N/ha)	Carman		Pilot Mound	Boissevain	Portage	Mean
	<u>Nonfallow Sites</u>					
	<u>East</u>	<u>West</u>				
4	0.63	0.63	0.45	0.44	0.45	0.52
29	0.57	0.63	0.41	0.39	0.47	0.49
63	0.77	0.57	0.42	0.37	0.51	0.53
96	0.90	0.63	0.53	0.45	0.56	0.61
130	0.93	0.56	0.62	0.45	0.67	0.65
197	0.93	0.70	0.60	0.59	0.74	0.71
264	1.02	0.81	0.84	0.70	0.80	0.83

*(oven dry Basis)

Nb/ No Hamiota

Table 858 Nitrogen Uptake by Conquest Barley (Kg N/ha) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	29	32	26	38	39	66	38
34	40	44	37	49	46	88	51
67	58	67	56	74	67	103	71
101	74	90	67	108	86	106	89
134	88	105	78	123	87	111	99
202	113	131	93	148	109	119	119
269	120	153	101	167	121	123	131
<u>Fallow Sites</u>							
9	87	77	90	83	71	99	84
34	110	83	90	91	84	108	95
67	111	100	95	116	110	140	112
101	140	118	103	134	124	144	127
134	144	129	104	160	133	153	138
202	158	132	110	178	155	166	150
269	176	138	108	188	160	174	158

Table 859 Nitrogen Uptake - Conquest Barley - (kg N/ha) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	30	27	40	113	64	30	51
34	41	37	54	116	67	44	60
67	58	58	64	119	77	67	74
101	78	71	81	125	92	82	88
134	90	88	100	131	90	101	100
202	110	109	118	146	102	141	97
269	119	131	122	155	113	123	127
<u>Fallow Sites</u>							
9	55	110	101	146	93	77	88
34	72	110	110	160	95	85	105
67	81	113	116	177	108	97	115
101	96	134	121	178	124	116	128
134	105	141	122	181	134	123	135
202	125	155	131	189	140	144	147
269	129	171	123	186	155	142	151

Table 860 Nitrogen Uptake Conquest Barley - (kg N/Ha) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	29	22	65	39
34	36	26	57	40
67	47	34	71	50
101	54	37	68	53
134	63	41	75	59
202	73	52	87	70
269	86	52	77	72
<u>Fallow Sites</u>				
9	96	83	85	88
34	101	95	99	98
67	112	95	96	101
101	108	86	100	98
134	108	108	109	108
202	122	106	112	114
269	116	108	116	114

Table 66 Nitrogen Uptake-Conquest Barley - (kg N/ha) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	102	39	40	24	51	51
34	109	50	56	39	63	63
67	117	70	74	58	79	80
101	134	75	72	63	90	87
134	136	82	83	74	96	94
202	158	100	94	85	105	108
269	165	97	96	89	108	111
<u>Fallow Sites</u>						
9	161	67	77	70	82	91
34	160	95	87	81	65	98
67	157	102	97	90	84	106
101	188	108	104	88	99	117
134	180	115	105	96	114	122
202	183	125	120	97	114	128
269	193	131	122	101	117	133

Table 362 Nitrogen Uptake by Fergus Barley (Kg N/ha) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	34	40	24	36	32	64	38
34	45	47	36	50	45	76	50
67	60	69	55	76	58	97	70
101	84	104	76	97	56	109	88
134	96	120	81	128	73	116	102
202	122	132	102	147	97	122	121
269	124	150	110	171	90	131	129
<u>Fallow Sites</u>							
9	91	74	102	90	75	91	87
34	106	94	97	112	93	104	101
67	118	122	109	114	116	124	117
101	148	135	103	134	119	137	129
134	151	155	113	142	134	134	138
202	170	166	112	164	143	152	151
269	184	180	118	186	160	152	163

Table 6.3 Nitrogen Uptake - Fergus Barley - (kg N/ha) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	28	28	52	97	57	32	49
34	38	40	56	97	67	40	57
67	57	62	72	119	83	66	76
101	67	85	80	110	99	80	87
134	85	103	93	124	103	96	101
202	102	112	110	128	108	113	112
269	99	121	119	128	121	122	118
<u>Fallow Sites</u>							
9	60	99	97	150	92	71	95
34	71	110	100	149	103	83	103
67	81	123	108	153	119	93	113
101	96	134	104	164	118	103	120
134	109	142	116	162	139	110	129
202	115	151	116	187	139	123	139
269	121	161	123	188	149	130	145

Table 64/Nitrogen Uptake Fergus Barley (kg N/ha) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	36	22	58	39
34	43	27	69	46
67	60	32	72	55
101	74	38	77	63
134	84	46	81	70
202	102	55	81	79
269	114	62	83	86
<u>Fallow Sites</u>				
9	87	93	87	89
34	99	106	96	101
67	114	104	101	107
101	144	112	104	120
134	137	111	113	120
202	137	112	115	121
269	148	120	120	129

Table 865 Nitrogen Uptake by Neepawa Wheat (Kg N/ha) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	27	41	34	28	47	68	41
34	46	59	50	41	57	76	55
67	73	85	68	64	67	94	75
101	100	88	74	84	80	95	87
134	101	102	79	99	96	99	96
202	105	115	92	113	106	97	105
269	112	131	93	119	122	105	114
<u>Fallow Sites</u>							
9	109	72	97	60	83	94	86
34	123	84	108	78	90	101	97
67	130	86	106	83	116	113	106
101	134	84	111	88	116	112	108
134	143	87	111	100	119	125	114
202	146	94	122	127	123	125	123
269	153	101	121	131	129	129	127

Table B66 Nitrogen Uptake - Neepawa Wheat - (kg N/ha) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	32	27	56	95	76	30	53
34	40	45	67	104	78	48	64
67	67	60	76	112	83	71	78
101	77	81	88	123	87	82	90
134	88	90	97	129	92	93	98
202	104	106	112	181	95	97	108
269	118	122	121	124	106	113	118
<u>Fallow Sites</u>							
9	77	110	118	151	109	67	105
34	86	113	128	155	110	83	112
67	93	115	132	158	114	96	118
101	108	120	136	153	121	99	123
134	106	130	129	172	113	110	109
202	115	138	134	160	120	114	130
269	121	141	137	157	123	120	133

Table 3.7 Nitrogen Uptake Neepawa Wheat (kg N/ha) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	28	21	45	31
34	40	25	54	39
67	47	29	59	45
101	53	30	65	49
134	55	34	66	51
202	60	37	71	56
269	62	44	72	59
<u>Fallow Sites</u>				
9	57	73	73	68
34	74	69	81	78
67	85	74	81	80
101	93	74	94	87
134	96	73	91	87
202	99	78	88	89
269	102	78	96	92

Table 868 Nitrogen Uptake - Neepawa Wheat - (kg N/ha) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	86	42	47	21	55	50
34	87	48	57	38	71	60
67	97	67	68	42	86	72
101	99	76	75	58	92	80
134	111	85	81	59	99	87
202	106	94	85	62	104	90
269	118	88	93	70	105	95
<u>Fallow Sites</u>						
9	131	50	85	68	87	84
34	137	71	79	67	101	91
67	137	80	76	81	103	95
101	129	97	100	81	105	102
134	137	99	97	80	118	106
202	139	105	104	90	121	112
269	132	98	102	91	116	108

Table 869 Nitrogen Uptake by Glenlea Wheat (Kg N/ha) (1972)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	50	39	30	36	52	65	45
34	49	54	45	46	53	75	54
67	74	76	67	68	68	94	75
101	90	93	68	84	64	99	83
134	101	115	81	97	68	110	96
202	102	130	100	132	87	110	110
269	104	137	96	148	97	101	114
<u>Fallow Sites</u>							
9	101	88	122	95	91	93	98
34	122	102	118	99	105	106	109
67	131	120	119	110	132	122	122
101	123	137	129	120	137	132	130
134	137	141	116	138	147	134	136
202	150	155	129	151	150	139	146
269	156	159	131	156	161	137	150

Table 370 Nitrogen Uptake - Glenlea Wheat - (kg N/ha) 1973

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	37	37	55	100	59	37	54
34	46	45	71	115	69	54	67
67	64	59	86	111	81	72	79
101	76	75	97	120	87	81	90
134	94	90	109	137	87	101	102
202	108	99	120	134	99	103	110
269	104	106	130	127	102	111	113
<u>Fallow Sites</u>							
9	75	104	138	131	109	85	107
34	73	111	137	131	114	95	109
67	94	122	128	155	121	105	121
101	101	122	137	175	128	120	131
134	109	137	134	177	139	124	137
202	120	136	137	170	138	132	139
269	122	136	143	179	153	133	144

Table 67 Nitrogen Uptake Glenlea Wheat (kg N/ha) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	27	20	47	32
34	35	24	53	36
67	39	22	63	41
101	40	28	55	41
134	49	31	63	48
202	50	35	60	49
269	59	35	67	54
<u>Fallow Sites</u>				
9	87	73	67	76
34	85	78	84	82
67	88	82	95	88
101	90	75	99	88
134	101	74	100	91
202	97	81	104	93
269	108	82	104	98

Table 872 Nitrogen Uptake - Dufferin Flax (1976) (kg N/ha)

Treatment (kg N/ha)	Carmen	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
0	55 78	58	14	63	60	55
25	68 79	65	38	68	78	66
58	59 93	73	46	81	83	72
92	64 93	64	52	82	95	75
125	64 82	63	51	83	83	71
193	68 82	76	57	85	91	76
260	64 86	64	57	79	92	74
<u>Fallow Sites</u>						
0	-	56	51	58	101	67
25	-	58	58	53	100	67
58	-	68	57	58	121	76
92	-	73	59	66	100	75
125	-	77	67	57	107	77
193	-	71	66	66	116	80
260	-	86	60	60	121	82

Table 872 Nitrogen Uptake - Dufferin Flax (1977) (kg N/ha)

Treatment (kg N/ha)	Carman East	Pilot Mound South	Portage	Mean
<u>Nonfallow Sites</u>				
0	75	38	72	62
25	127	53	91	90
58	104	95	82	94
92	96	109	76	94
125	102	142	54	99
193	106	138	97	114
260	112	143	88	114

Table 874 Nitrogen Uptake Tower Rape (kg N/ha) (1975)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	12	24	18
29	-	26	32	29
63	-	46	42	44
96	-	57	47	52
130	-	65	58	62
197	-	79	63	71
264	-	86	63	74
<u>Fallow Sites</u>				
4	34	50	69	51
29	39	56	77	58
63	43	63	93	67
96	53	76	78	69
130	35	83	100	72
197	57	70	100	75
264	42	71	94	69

Table B7/ Nitrogen Uptake Tower Rape (Kg N/ha) (1976)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	33	27	52	50	40
29	38	42	56	61	49
63	53	50	64	63	57
96	74	70	71	88	76
130	83	78	63	110	84
197	99	89	88	115	98
264	101	99	88	101	97
<u>Fallow Sites</u>					
4	-	91	44	96	77
29	-	99	60	114	91
63	-	106	83	124	104
96	-	103	77	123	101
130	-	111	93	119	107
197	-	119	120	125	122
264	-	103	94	131	109

Table 576 Nitrogen Uptake Tower Rape (kg N/ha) (1977)

Treatment (kg N/ha)	Carman		Pilot Mound	Boissevain	Portage	Mean
	<u>Nonfallow Sites</u>					
	<u>East</u>	<u>West</u>				
4	111	76	54	33	43	63
29	108	82	58	60	65	75
63	170	123	75	63	81	102
96	183	96	119	87	103	118
130	216	99	124	103	112	131
197	191	109	144	116	135	139
264	96	128	173	112	142	130

Table 677 Bulk Density -- Conquest Barley (1972) (Kg/m³)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	621	599	621	611	621	653	621
34	626	599	620	617	642	668	628
67	635	602	620	641	633	651	631
101	635	618	623	647	640	657	637
134	645	609	633	647	636	658	638
202	631	617	626	650	633	658	636
269	627	615	617	656	630	658	633
<u>Fallow Sites</u>							
9	648	626	626	648	612	648	635
34	648	612	621	648	636	661	638
67	646	621	620	645	640	665	640
101	648	633	621	631	648	661	641
134	636	626	625	638	640	661	637
202	636	627	626	614	636	661	633
269	645	628	625	606	640	662	632

Table 878 Bulk Density - Conquest Barley (kg/m³)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	596	611	596	635	630	594	610
34	600	614	596	628	621	612	612
67	597	615	599	627	632	617	615
101	586	612	604	626	622	619	611
134	594	606	607	624	606	631	611
202	576	601	605	624	614	633	609
269	581	613	601	616	625	637	612
<u>Fallow Sites</u>							
9	595	615	602	627	648	605	615
34	592	617	596	626	642	600	612
67	596	615	597	617	645	614	614
101	591	611	604	620	633	605	611
134	594	615	596	615	633	606	610
202	582	612	594	612	630	596	604
269	572	601	584	610	626	594	598

Table 879 Bulk Density - Conquest Barley (kg /m³) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	581	601	619	600
34	587	605	614	602
67	586	616	620	607
101	581	622	619	607
134	586	611	619	605
202	590	620	628	613
269	585	610	619	605
<u>Fallow Sites</u>				
9	605	600	636	614
34	614	621	640	625
67	595	611	632	613
101	611	612	636	620
134	614	610	636	620
202	607	611	601	606
269	612	606	633	617

Table 880 Bulk Density - Conquest Barley (kg /m³) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	571	595	620	614	613	603
34	551	597	614	616	602	596
67	550	584	618	601	608	592
101	541	591	613	600	605	590
134	543	590	604	601	611	590
202	546	576	600	601	612	589
269	546	563	595	605	604	583
<u>Fallow Sites</u>						
9	619	618	602	626	605	614
34	593	602	597	625	601	604
67	596	602	592	612	602	601
101	595	594	601	611	597	599
134	601	584	589	615	602	598
202	589	579	575	618	613	595
269	587	582	577	612	593	590

Table 38/ Bulk Density - Fergus Barley (1972) (Kg/m³)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	701	696	668	667	690	721	691
34	688	693	665	675	692	717	688
67	696	701	667	696	692	710	693
101	670	698	675	707	692	707	697
202	700	686	671	713	688	705	693
269	696	692	667	717	682	701	692
<u>Fallow Sites</u>							
9	720	698	685	702	707	715	705
34	720	698	686	688	711	713	703
67	722	698	687	681	711	715	702
101	710	698	681	662	710	712	696
134	712	696	681	672	713	705	697
202	707	677	683	658	708	705	690
269	705	670	683	657	714	702	688

Table 682 Bulk Density - Fergus Barley (kg/m²) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	695	681	670	695	697	678	686
34	686	675	672	697	668	685	680
67	673	668	680	691	697	683	682
101	678	658	680	692	693	686	681
134	685	653	680	693	686	691	681
202	668	656	675	686	692	701	680
269	667	642	703	686	693	698	681
<u>Fallow Sites</u>							
9	682	671	671	698	711	666	683
34	683	667	675	700	707	672	684
67	685	663	668	692	706	672	681
101	686	667	676	692	708	665	682
134	681	662	666	678	703	665	676
202	670	667	665	673	700	655	672
269	671	660	662	685	703	653	672

Table 883 Bulk Density - Fergus Barley (kg /m³) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	668	682	666	672
34	673	681	667	674
67	667	682	671	673
101	668	681	668	672
134	665	680	668	671
202	657	678	667	667
269	652	612	663	642
<u>Fallow Sites</u>				
9	668	653	663	661
34	672	657	666	665
67	677	651	661	663
101	673	656	662	664
134	675	656	662	664
202	666	645	662	658
269	671	645	660	659

Table 884 Bulk Density -- Neepawa Wheat (1972) (Kg/m³)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	757	751	803	757	811	789	778
34	767	751	801	782	812	792	784
67	778	761	809	789	811	791	791
101	782	773	807	789	811	792	792
134	786	776	808	789	814	791	794
202	783	778	803	787	811	789	792
269	784	782	804	787	809	791	793
<u>Fallow Sites</u>							
9	789	767	808	787	812	796	793
34	789	769	807	791	811	798	794
67	791	762	806	787	811	799	793
101	794	764	801	786	811	798	792
134	794	766	801	786	808	798	792
202	792	766	797	786	809	794	791
269	792	767	806	783	807	796	792

Table 88 Bulk Density - Neepawa Wheat (kg/m³) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	796	751	749	809	787	756	775
34	802	748	754	808	778	771	777
67	803	748	763	811	773	782	780
101	806	752	768	809	777	786	783
134	806	754	764	806	783	792	784
202	803	751	773	804	776	786	782
269	804	748	769	803	779	792	782
<u>Fallow Sites</u>							
9	803	768	764	786	781	786	781
34	811	766	762	781	786	788	782
67	808	768	772	776	786	788	783
101	808	767	764	783	786	793	784
134	799	771	769	786	783	794	784
202	803	767	773	782	786	793	784
269	801	768	761	777	783	798	781

Table 886 Bulk Density - Neepawa Wheat (kg /m³) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	753	758	743	751
34	754	762	748	755
67	752	766	744	754
101	749	766	749	755
134	756	764	753	758
202	748	764	744	752
269	748	766	747	754
<u>Fallow Sites</u>				
9	757	754	752	754
34	756	756	749	754
67	752	753	743	749
101	751	756	746	751
134	756	751	742	750
202	756	751	746	751
269	754	754	746	751

Table 87 Bulk Density - Neepawa Wheat (kg /m³) - (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	724	743	773	748	717	741
34	710	744	772	742	713	736
67	708	728	762	767	717	732
101	718	721	761	754	721	734
134	714	718	757	751	715	730
202	710	724	748	754	730	733
269	703	720	743	752	720	728
<u>Fallow Sites</u>						
9	745	761	757	737	751	750
34	743	748	753	746	758	750
67	744	742	748	748	759	748
101	741	736	751	744	759	746
134	736	728	748	737	762	742
202	743	732	743	743	769	746
269	737	728	733	735	762	739

Table 388 Bulk Density - Glenlea Wheat (1972) (Kg/m³)

Treatment (Kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Dufrost	Mean
<u>Nonfallow Sites</u>							
9	811	771	809	789	804	811	799
34	791	776	812	797	811	811	799
67	799	784	806	798	804	808	801
101	804	791	807	796	804	809	802
134	804	791	806	794	806	808	802
202	803	789	808	793	798	806	799
269	803	788	803	789	801	809	799
<u>Fallow Sites</u>							
9	816	798	809	794	819	816	809
34	814	799	809	799	821	814	809
67	811	799	809	792	822	816	808
101	811	804	809	806	823	811	810
134	803	801	808	793	819	812	807
202	808	796	806	792	821	811	806
269	811	797	806	796	819	812	807

Table 889 Bulk Density - Glenlea Wheat (kg /m³) (1973)

Treatment (kg N/ha)	Goodlands	Glenboro	Portage	Pilot Mound	Birtle	Morris	Mean
<u>Nonfallow Sites</u>							
9	794	728	757	801	777	774	772
34	786	726	758	798	783	776	771
67	784	723	764	793	789	783	773
101	781	726	762	789	777	781	769
134	781	736	781	784	781	792	776
202	686	739	767	779	788	792	758
269	774	725	767	771	791	791	770
<u>Fallow Sites</u>							
9	797	773	761	802	794	778	784
34	798	773	767	801	797	782	786
67	803	776	759	799	786	791	786
101	804	772	749	797	792	789	784
134	798	782	757	796	793	796	787
202	798	773	752	792	788	796	783
269	784	768	753	784	791	791	778

Table 8 Bulk Density -Glenlea Wheat (kg /m³) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	747	751	752	750
34	747	759	756	754
67	742	759	754	752
101	748	762	751	754
134	742	759	758	753
202	745	757	753	752
269	738	756	754	749
<u>Fallow Sites</u>				
9	751	737	744	744
34	756	736	742	745
67	758	739	737	745
101	752	736	736	741
134	751	732	737	740
202	741	734	732	736
269	751	731	736	739

Table 39/ Bulk Density - Dufferin Flax (kg /m³) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
0	629	643	613	600	601	643	621
25	621	634	602	610	608	607	614
58	608	640	602	603	614	613	613
92	614	636	602	597	600	626	613
125	615	646	601	586	606	616	612
193	611	644	607	591	603	625	614
260	629	642	619	599	605	617	618
<u>Fallow Sites</u>							
0	-	-	608	597	616	610	608
25	-	-	617	589	610	609	606
58	-	-	600	590	607	619	614
92	-	-	611	590	598	617	604
125	-	-	606	586	607	613	603
193	-	-	612	598	608	609	607
260	-	-	613	590	605	624	608

Table B92 Weight = Kilogram Per Hectolitre Dufferin Flax (1977)

Treatment (kg N/ha)	Carman East	Pilot Mound South	Portage	Mean
<u>Nonfallow Sites</u>				
0	58.4	58.2	59.1	58.57
25	58.7	59.0	58.2	58.63
58	58.8	57.5	62.7	59.67
92	58.7	57.8	58.3	58.27
125	59.7	58.6	59.4	59.23
193	60.0	59.6	59.1	59.57
260	59.6	60.9	62.8	61.10

Table 893 Bulk Density - Tower Rape (1975) (kg /m³)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	678	664	671
29	-	675	673	674
63	-	657	647	652
96	-	636	648	642
130	-	635	644	639
197	-	643	641	642
264	-	646	646	646
<u>Fallow Sites</u>				
4	710	638	653	667
29	725	637	651	671
63	706	638	652	665
96	694	637	655	662
130	721	640	658	673
197	694	637	655	662
264	729	641	651	674

Table 894 Bulk Density - Tower Rape (kg/m³) (1976)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	655	680	669	666	668
29	653	666	672	667	665
63	641	667	701	663	668
96	661	669	673	668	668
130	669	671	673	668	670
197	671	670	675	669	671
264	671	674	675	672	673
<u>Fallow Sites</u>					
4	-	682	653	677	671
29	-	687	667	678	677
63	-	686	672	678	678
96	-	680	673	682	678
130	-	681	679	684	681
197	-	675	676	683	678
164	-	679	678	684	680

Table 895 Weight = Kilogram Per Hectolitre Tower Rape (1977)

Treatment (kg N/ha)	Carman		Pilot Mound	Boissevain	Portage	Mean
<u>Nonfallow Sites</u>						
	<u>East</u>	<u>West</u>				
4	66.0	67.1	66.0	65.2	65.9	66.0
29	66.8	67.1	65.8	66.0	66.9	66.5
63	66.8	67.5	66.0	65.7	67.5	66.7
96	66.4	67.6	66.2	66.2	67.1	66.7
130	66.4	67.1	66.4	66.9	67.2	66.8
197	65.9	67.5	66.0	67.2	66.9	66.7
264	66.2	67.2	66.9	67.1	67.1	66.9

Table 8% Oil Content* - Dufferin Flax (%) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
0	40.5	40.2	40.1	39.4	39.7	43.2	40.5
25	40.9	40.8	40.7	40.8	39.3	41.4	40.7
58	40.0	41.1	41.0	39.8	39.1	41.2	40.4
92	40.3	40.6	40.8	38.5	39.6	41.9	40.3
125	39.2	39.9	40.5	37.4	39.4	41.6	39.7
193	40.1	39.8	40.8	37.3	38.8	41.5	39.7
260	39.5	39.4	40.6	37.8	38.2	40.4	39.3
<u>Fallow Sites</u>							
0	-	-	42.4	38.9	40.7	40.2	40.6
25	-	-	41.8	39.3	39.9	40.8	40.5
58	-	-	40.7	38.5	39.5	40.5	39.8
92	-	-	42.0	38.8	38.8	40.5	40.0
125	-	-	40.2	38.6	39.7	30.5	39.5
193	-	-	40.5	38.8	39.2	39.4	39.5
260	-	-	40.6	37.8	38.9	39.1	39.1

*Oven-Dry basis

Table 897 Oil Content Dufferin Flax (%) (1977)

Treatment	Carman	Pilot Mound	Portage	Mean
		<u>Nonfallow Sites</u>		
0	42.8	41.6	41.4	41.9
25	44.1	44.3	41.9	43.4
58	43.2	43.3	39.6	42.0
92	42.8	42.6	40.4	41.9
125	42.9	42.6	39.7	41.7
193	41.9	42.9	40.5	41.8
260	41.3	42.7	39.3	41.1

* Oven Dry Basis

Table 898 Oil Content - Tower Rape (%) (1975)

Treatment (kg N/ha)	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>				
4	-	46.1	41.7	43.9
29	-	45.8	42.1	43.9
63	-	44.6	40.7	42.6
96	-	43.9	40.3	42.1
130	-	43.9	39.7	41.8
197	-	41.7	39.7	40.7
264	-	42.0	39.6	40.8
<u>Fallow Sites</u>				
4	35.3	43.7	40.4	39.8
29	36.8	43.1	40.7	40.2
63	37.3	42.6	40.2	40.0
96	36.4	42.8	39.8	39.7
130	36.3	42.2	40.4	39.6
197	35.6	41.3	39.9	38.9
264	34.8	41.3	39.8	38.6

* 8.5% Moisture Basis

Table 899 Oil Content* Tower Rape - (%) (1976)

Treatment (kg N/ha)	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>					
4	44.4	45.0	43.8	43.2	44.1
29	43.1	44.5	43.2	42.8	43.4
63	40.2	43.2	42.7	43.8	42.5
96	41.7	43.5	41.5	43.5	42.6
130	41.4	42.3	41.4	43.4	42.1
197	40.0	41.4	41.0	42.2	41.2
264	39.6	41.2	40.9	41.6	40.8
<u>Fallow Sites</u>					
4	-	42.6	43.3	40.0	42.0
29	-	42.1	42.7	41.2	42.0
63	-	41.3	42.1	42.5	42.0
96	-	40.4	40.6	42.5	41.2
130	-	40.7	39.2	41.3	40.4
197	-	40.2	41.2	41.9	41.1
264	-	39.7	40.5	41.2	40.5

* 8.5% moisture basis

Table B100 Oil Content - Tower Rape (%) (1977)

Treatment	Carman		Pilot Mound	Boissevain	Portage	Mean
	<u>Nonfallow Sites</u>					
	<u>West</u>	<u>East</u>				
4	45.0	44.0	47.7	48.2	47.0	46.4
29	44.9	43.1	48.5	47.5	46.8	46.2
63	44.9	41.9	47.8	47.9	45.3	45.6
96	44.8	41.4	46.6	46.2	45.4	44.9
130	44.5	41.6	45.5	56.1	44.8	44.5
197	44.1	41.1	46.8	44.2	44.5	44.1
264	43.8	40.7	44.6	43.2	43.9	43.2

* 8.5% moisture basis

Table C1 Yield of Grain* - Random Oats (1977) (kg /ha)

Treatment (kg N/ha)	Carman	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
	East	North				
9	28.74	14.08	14.29	21.63	22.91	21.94
34	34.52	20.43	23.75	29.82	25.88	28.45
67	37.98	26.33	32.15	37.76	23.01	32.96
101	39.45	26.25	34.71	41.27	24.45	35.29
134	38.55	28.56	36.37	42.45	26.16	36.30
202	38.44	27.60	36.18	43.42	25.48	35.74
269	38.86	23.64	32.01	41.15	25.28	32.47
<u>Nonfallow Sites</u> <u>Fallow Sites</u>						
	West	South		South	North	
9	28.80	23.12	34.14	45.50	43.42	40.99
34	31.81	32.93	34.01	49.68	43.30	42.33
67	34.12	39.35	34.32	51.91	43.34	43.19
101	35.32	45.60	34.84	51.47	42.51	42.94
134	34.06	47.93	34.32	50.15	44.57	43.01
202	33.18	45.88	33.94	50.46	42.05	42.15
269	25.68	40.68	31.60	51.26	41.55	41.47

Air Dry Basis (Approximately 6.5 to 7.5% Moisture)

Table C2 Yield of Grain* - Random Oats (1976) (kg /ha)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
9	3349	3203	2711	1397	4551	-	3042
34	4078	3503	2997	2089	4344	-	3402
67	3919	3386	3338	2515	4643	-	3560
101	3839	3544	3484	2534	4719	-	3624
134	3829	3252	3285	2833	4550	-	3550
202	3793	3119	3598	2401	4178	-	3418
269	3704	3328	3429	2733	4477	-	3534
<u>Fallow Sites</u>							
9	-		2771	2770	3624	4245	3378
34	-		2542	2639	3160	4013	3089
67	-		2554	2593	3457	4047	3163
101	-		2702	2538	3598	4050	3222
134	-		2553	2848	3692	3718	3203
202	-		2495	2527	3258	4259	3135
269	-		2496	2488	3246	4281	3129

*Air-Dry basis (approximately 6.5 to 7.5% moisture)

Table C3 Yield of Grain*-Random Oats (1975) (kg /ha)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	2440	1725	1889	1482	2093	1926
34	2488	1881	2033	2229	2535	2233
67	2704	2206	2249	2405	2731	2459
101	2671	1806	2167	2853	2987	2497
134	2427	2007	2293	2542	2946	2443
202	2502	1997	2253	2711	2831	2459
269	3148	1602	2087	2552	2931	2464
<u>Fallow Sites</u>						
9	3203	2153	2284	2609	2867	2623
34	3128	2552	1955	2545	2775	2591
67	2694	2470	1920	2524	2935	2509
101	2656	2449	1987	2318	2628	2408
134	2823	2591	1912	2381	2526	2447
202	2833	2585	2179	2689	2337	2525
269	2505	*2409	2229	2318	2505	2393

*Air-Dry basis (approximately 6.5 to 7.5% moisture)

Table C4/Yield of Grain*--Random Oats (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1241	1327	2351	1640
34	1700	1324	2384	1803
67	1788	1494	1542	1941
101	1792	1597	2392	1928
134	1792	1609	2613	2005
202	1772	1771	2653	2065
269	2012	2784	2501	2099
<u>Fallow Sites</u>				
9	3642	2948	2928	3173
34	3435	2966	3124	3175
67	3545	2682	2908	2045
101	3638	3230	2978	3282
134	3392	2986	3267	3216
202	3637	3180	3109	3308
269	3500	3101	3371	3324

*Air-Dry Basis (approximately 6.5 to 7.5 moisture)

Table 25. Protein Content* of Random Oats (%) (1977)

Treatment (kg N/ha)	Carman	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
	East	North				
9	8.78	7.35	7.64	8.87	11.19	8.65
34	9.66	8.53	7.54	9.22	11.83	9.23
67	10.30	10.21	8.78	9.86	12.52	10.12
101	10.75	10.65	9.37	10.74	12.57	10.54
134	11.49	11.00	10.06	11.00	13.41	11.18
202	11.59	11.98	10.40	11.14	12.57	11.30
269	11.73	12.72	11.19	11.64	13.31	11.81
<u>Nonfallow Sites</u> <u>Fallow Sites</u>						
	West	South		South	North	
9	9.86	6.85	10.30	9.27	10.01	-
34	10.01	7.79	10.70	9.47	10.55	-
67	10.16	9.02	11.14	9.47	11.04	-
101	10.06	9.71	10.65	9.66	10.90	-
134	11.44	9.86	10.90	9.81	10.90	-
202	11.34	10.05	11.39	9.71	11.39	-
269	11.59	10.55	11.59	10.06	10.65	-

*% Protein: % N x 5.7 (Expressed on a 13.5% Moisture Basis)

Table C6 Protein Content* of Random Oats Grain (%) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
9	9.91	11.44	12.82	7.35	9.07	-	10.12
34	10.45	12.57	8.48	8.58	10.11	-	10.04
67	11.09	12.52	9.27	9.66	10.90	-	10.69
101	11.83	12.38	11.34	10.90	11.04	-	11.50
134	11.93	12.87	11.44	11.64	11.44	-	11.86
202	12.72	12.33	11.09	11.19	12.52	-	11.97
269	11.98	12.62	11.88	12.77	12.28	-	12.31
<u>Fallow Sites</u>							
9	-		10.05	11.19	8.43	11.20	10.24
34	-		10.90	11.64	9.91	11.09	10.89
67	-		11.48	12.28	10.90	11.98	11.66
101	-		12.18	11.88	11.04	11.59	11.67
134	-		12.23	12.57	9.66	11.73	11.55
202	-		12.23	12.82	11.44	11.59	12.02
269	-		12.08	12.92	11.39	11.83	12.06

*% Protein = %N x 5.7 (Expressed on a 13.5% moisture basis)

Table 67 Protein Content* of Random Oats Grain (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	13.28	10.06	9.92	8.89	10.83	10.60
34	13.05	10.43	11.40	9.01	11.40	11.06
67	13.11	12.14	11.74	10.60	11.63	12.04
101	14.31	13.17	12.14	11.34	12.08	12.61
134	14.42	13.34	13.11	11.46	12.26	12.94
202	14.76	13.57	13.11	11.74	12.26	13.09
269	14.94	14.19	13.11	12.26	12.43	13.38
<u>Fallow Sites</u>						
9	12.83	10.77	12.48	11.51	11.06	11.73
34	12.54	11.63	13.00	12.20	11.63	12.20
67	12.54	12.03	13.51	12.08	11.91	12.41
101	12.94	12.37	13.34	12.54	11.86	12.61
134	12.83	12.43	13.51	12.60	11.91	12.66
202	12.77	12.31	13.28	12.32	12.48	12.63
269	15.22	13.45	13.40	12.88	12.26	13.44

*Protein Content = %N x 5.7 (expressed on a 13.5% moisture basis)

Table 68 Protein Content* of Random Oat Grain (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	11.23	8.49	9.41	9.71
34	12.08	9.29	10.94	10.77
67	12.60	10.77	10.94	11.43
101	13.11	10.77	11.29	11.72
134	13.11	11.06	11.23	11.80
202	13.97	11.74	11.86	12.52
269	13.91	12.08	12.20	12.73
<u>Fallow Sites</u>				
9	12.71	12.03	10.37	11.70
34	13.11	12.03	11.00	12.04
67	13.22	12.88	10.60	12.23
101	13.62	14.25	10.94	12.93
134	13.51	13.45	11.12	12.69
202	14.08	13.45	11.06	12.86
269	13.79	12.88	11.63	12.76

*% Protein = %N x 5.7 (expressed on a 13.5% moisture basis)

Table C9 Yield of Straw Random Oats (1977) (Kg/ha)

Treatment (kg N/ha)	Carman	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
	East	North				
9	32.34	17.66	19.26	26.85	26.28	26.93
34	38.19	25.78	33.61	36.07	30.16	35.24
67	41.88	32.43	44.85	45.83	24.91	39.56
101	43.86	34.20	48.82	51.38	27.87	44.55
134	42.36	36.53	50.78	54.58	29.88	46.15
202	44.59	35.09	53.38	56.28	31.37	47.29
269	45.40	32.02	51.58	54.90	29.74	45.38
<u>Nonfallow Sites</u> <u>Fallow Sites</u>						
	West	South		South	North	
9	35.83	30.31	48.31	61.00	51.24	55.52
34	38.81	44.05	50.37	63.95	60.87	58.40
67	35.50	51.54	50.69	68.70	61.05	60.15
101	45.56	60.19	52.63	72.33	60.65	61.87
134	45.65	63.25	53.24	68.09	62.59	61.31
202	45.74	64.56	52.09	70.90	61.62	61.54
269	35.49	68.50	49.43	73.31	60.79	61.18

Table 6 Yield of Straw Random Oats (1976) (kg/ha)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
9	3109	3958	1786	3189	4322		3273
34	3933	4071	2950	4477	4391		3964
67	3748	3803	3752	5242	4939		4297
101	3960	4310	4222	4951	5130		4515
134	3962	4038	4066	5522	4511		4420
202	3582	4066	4225	5418	4548		4368
269	3869	4123	4540	6061	4662		4657
<u>Fallow Sites</u>							
9	-		4245	4156	4756	4766	4481
34	-		4949	4167	4892	4965	4743
67	-		4582	4502	5439	5070	4898
101	-		4748	5657	5569	5035	5252
134	-		4451	4508	5864	5157	4995
202	-		5049	4357	5357	5493	5064
269	-		4734	4484	5361	5245	4956

Table 64/ Yield of Straw -Random Oats (1975) (kg /ha)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	4462	2123	1580	1239	2246	2330
34	4885	2376	1869	1811	2170	2622
67	4277	2753	2256	1993	2622	2780
101	4121	2659	2252	2447	2878	2871
134	4785	2910	2339	2407	2962	3081
202	4674	2974	2490	1429	2877	2889
269	3706	2478	2272	2336	3006	2760
<u>Fallow Sites</u>						
9	4480	2607	2919	2381	3150	3107
34	4234	3245	2694	2211	2972	3071
67	4050	3770	2941	2207	3209	3235
101	4227	3780	2879	2095	3067	3210
134	4276	3922	2838	2110	2806	3190
202	4218	3937	3432	2347	2632	3313
269	5034	3709	3340	2292	3126	3500

Table 2 Yield of Straw -Random Oats (1974) (kg /ha)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	1532	1352	1839	1575
34	2066	1466	1823	1785
67	2379	1603	2028	2004
101	2475	1732	1924	2044
134	2561	1770	1982	2104
202	2548	1911	2065	2175
269	2686	1928	1920	2177
<u>Fallow Sites</u>				
9	3814	3282	3073	3389
34	3922	3217	3146	3428
67	3966	2959	2940	3288
101	4196	3272	2871	3446
134	4197	3068	3201	3489
202	4246	3475	3070	3597
269	4136	3245	3317	3566

Table 43 Nitrogen Content of Random Oat Straw (%) (1977)

Treatment (kg N/ha)	Carman	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
	East	North				
9	0.38	0.28	0.35	0.25	0.55	0.37
34	0.40	0.27	0.35	0.33	0.64	0.41
67	0.54	0.42	0.39	0.35	0.91	0.64
101	0.67	0.54	0.59	0.46	0.91	0.64
134	1.07	0.65	0.54	0.59	1.02	0.77
202	0.85	0.92	0.82	0.79	1.11	0.92
269	1.30	1.10	1.02	0.88	1.08	1.13
<u>Nonfallow Sites</u> <u>Fallow Sites</u>						
	West	South		South	North	
9	0.49	0.32	0.49	0.36	0.35	0.40
34	0.48	0.40	0.62	0.47	0.61	0.57
67	0.59	0.47	0.71	0.66	0.70	0.69
101	0.74	0.56	0.93	0.78	0.69	0.80
134	0.83	0.67	0.94	0.81	0.73	0.83
202	1.04	0.93	1.19	0.94	0.84	0.99
269	1.17	1.34	1.21	0.99	0.90	1.03

Table C14 Nitrogen Content of Random Oat Straw (%) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
9	0.44	1.01	0.29	0.36	0.23	—	0.47
34	0.58	1.19	0.28	0.39	0.31	—	0.55
67	0.69	1.22	0.46	0.45	0.37	—	0.64
101	0.89	1.31	0.68	0.51	0.53	—	0.78
134	0.86	1.05	0.77	0.67	0.58	—	0.79
202	1.26	1.49	0.96	0.86	0.81	—	1.08
269	1.39	1.55	1.10	0.93	0.80	—	1.15
<u>Fallow Sites</u>							
9	—		0.55	0.64	0.27	0.57	0.51
34	—		0.73	0.70	0.29	0.57	0.57
67	—		0.79	0.93	0.45	0.83	0.75
101	—		1.07	1.02	0.49	0.98	0.89
134	—		1.10	1.13	0.54	1.04	0.95
202	—		1.15	1.21	0.68	1.14	1.05
269	—		1.37	0.90	0.74	1.20	1.05

Table 6. Nitrogen Content of Random Oat Straw (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	0.84	0.57	0.41	0.41	0.57	0.56
34	0.93	0.70	0.43	0.36	0.53	0.59
67	1.06	0.80	0.55	0.44	0.71	0.71
101	1.11	1.02	0.70	0.57	0.78	0.84
134	1.29	0.97	0.79	0.67	0.83	0.91
202	1.41	1.19	1.30	0.78	0.96	1.13
269	1.34	1.32	0.94	0.85	1.04	0.90
<u>Fallow Sites</u>						
9	1.27	0.41	1.69	0.64	0.70	0.74
34	1.28	0.43	1.74	0.67	0.99	0.82
67	1.48	0.57	0.81	0.70	1.14	0.94
101	1.39	0.86	0.83	0.76	1.15	1.00
134	1.53	0.93	0.87	0.74	1.14	1.04
202	1.40	0.93	0.92	0.87	1.19	1.06
269	1.41	1.28	0.99	0.90	1.11	1.14

Table C16 Nitrogen Content of Random Oat Straw (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	0.39	0.25	0.40	0.35
34	0.50	0.29	0.48	0.42
67	0.67	0.40	0.61	0.56
101	0.81	0.43	0.68	0.64
134	0.91	0.49	0.67	0.69
202	1.08	0.55	0.71	0.78
269	1.16	0.57	0.69	0.81
<u>Fallow Sites</u>				
9	0.74	0.67	0.70	0.70
34	0.85	0.69	0.81	0.78
67	0.97	0.74	0.96	0.89
101	1.07	0.70	1.05	0.94
134	1.12	0.70	1.01	0.94
202	1.18	0.79	1.15	1.04
269	1.30	0.82	1.18	1.10

Table C17 Utilization of Added Nitrogen Random Oats (%) (1977)

Treatment (kg N/ha)	Carman	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
	<u>East</u>	<u>North</u>				
9	-	-	-	-	-	-
34	72.0	60.3	69.1	77.9	57.3	69.9
67	64.8	69.3	75.2	75.3	24.6	62.7
101	55.9	53.0	68.8	71.8	26.2	57.8
134	56.6	58.8	57.4	63.3	30.0	54.4
202	34.8	38.8	47.8	50.8	19.3	40.1
269	34.6	27.6	37.2	38.3	14.2	31.3
<u>Nonfallow Sites</u> <u>Fallow Sites</u>						
	<u>West</u>	<u>South</u>		<u>South</u>	<u>North</u>	
9	-	-	-	-	-	-
34	39.7	113.2	42.6	66.2	77.9	62.2
67	30.6	99.1	35.0	63.4	54.4	50.9
101	35.1	93.6	33.2	54.0	32.2	39.8
134	34.4	80.3	26.3	38.9	30.0	31.7
202	26.8	62.5	26.3	31.8	21.8	26.6
269	11.7	55.3	16.1	26.8	15.0	19.3

Table 68 Utilization of Added Nitrogen - Random Oats (%) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound		Boissevain		Hamiota		Portage		Mean
<u>Nonfallow Sites</u>											
9	-	-	-	-	-	-	-	-	-	-	-
34	96.41	82.29	0.0	-	76.50	-	39.53	-	-	-	58.95
67	108.27	33.75	13.18	-	67.28	-	46.31	-	-	-	53.96
101	96.69	35.27	37.30	-	52.92	-	43.29	-	-	-	53.09
134	37.50	13.05	27.13	-	56.76	-	31.75	-	-	-	33.24
202	31.04	14.24	24.93	-	37.28	-	26.62	-	-	-	26.62
269	25.01	14.61	22.83	-	36.93	-	22.16	-	-	-	24.31
<u>Fallow Sites</u>											
9	-	-	-	-	-	-	-	-	-	-	-
34	-	-	49.79	-	19.03	-	16.74	-	0.0	-	21.39
67	-	-	30.34	-	32.03	-	43.07	-	30.66	-	34.03
101	-	-	41.74	-	33.55	-	35.51	-	24.40	-	33.80
134	-	-	27.53	-	28.79	-	23.89	-	16.60	-	24.20
202	-	-	22.06	-	16.55	-	19.80	-	21.20	-	19.90
269	-	-	18.82	-	7.65	-	15.85	-	17.08	-	14.85

Table C19 Utilization of Added Nitrogen - Random Oats (%) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	-	-	-	-	-	-
34	8.32	39.24	42.62	57.85	18.68	33.34
67	13.33	48.15	36.52	48.06	28.45	35.10
101	14.24	31.42	26.89	50.00	30.04	30.72
134	16.85	28.87	28.48	36.61	24.64	26.49
202	15.67	22.97	25.16	23.20	16.67	20.75
269	8.38	13.16	13.33	20.34	15.06	14.05
<u>Fallow Sites</u>						
9	-	-	-	-	-	-
34	-	59.47	8.71	18.29	39.06	31.38
67	-	41.34	5.70	8.37	37.97	23.35
101	-	40.28	4.97	3.36	16.76	16.34
134	2.79	35.84	3.34	3.60	8.85	10.88
202	-	23.65	8.50	8.59	4.69	11.36
269	4.86	22.13	7.65	3.61	5.70	8.79

Table 2. Utilization of Nitrogen-Random Oats (%) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	-	-	-	-
34	11.41	2.55	47.23	20.41
67	18.98	0	12.83	15.91
101	35.11	16.87	26.31	26.10
134	28.30	14.16	16.01	19.49
202	21.92	13.33	13.10	16.12
269	20.04	10.69	8.41	13.05
<u>Fallow Sites</u>				
9	-	-	-	-
34	11.41	2.55	47.23	20.40
67	18.98	0	12.83	15.91
101	24.76	13.05	14.71	17.51
134	13.90	6.48	17.95	12.78
202	15.81	10.09	11.14	12.35
269	11.19	5.06	13.31	9.85

Table 21 Nitrogen - Uptake - Random Oats (Kg N/ha) (1977)

Treatment (kg N/ha)	Carman	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
	East	North				
9	63	26	29	46	66	48
34	83	42	48	68	81	68
67	102	68	75	92	78	86
101	115	75	94	114	88	102
134	135	101	102	127	102	117
202	128	99	120	143	100	124
269	152	96	125	145	100	128
<u>Fallow Sites</u>						
	<u>Nonfallow Sites</u>		<u>Fallow Sites</u>			
	West	South		South	North	
9	75	34	95	107	108	103
34	84	68	105	125	130	120
67	91	96	114	145	140	133
101	106	124	124	157	136	139
134	117	138	126	155	144	142
202	124	154	143	166	147	152
269	102	179	134	175	144	151

Table C11 Nitrogen Uptake - Random Oats (Kg N/ha) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
9	80	114	75	32	93	-	79
34	109	137	60	53	102	-	92
67	149	132	80	72	120	-	111
101	174	145	108	81	132	-	128
134	126	127	107	103	131	-	119
202	139	138	121	101	142	-	128
269	143	149	132	127	148	-	140
<u>Fallow Sites</u>							
9	-		79	89	76	124	92
34	-		92	91	77	118	95
67	-		95	106	100	140	110
101	-		117	118	107	144	122
134	-		112	123	104	142	120
202	-		119	118	112	162	128
269	-		126	105	114	165	128

Table C23 Nitrogen Uptake - Random Oats - (kg N/ha) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	109	45	42	30	64	58
34	107	54	52	45	66	65
67	113	72	63	57	78	77
101	118	72	66	76	90	84
134	128	79	76	72	92	89
202	136	87	88	72	93	95
269	127	76	73	80	100	91
<u>Fallow Sites</u>						
9	135	54	74	72	81	83
34	128	70	72	74	90	87
67	124	77	73	74	102	90
101	124	90	74	71	94	91
134	134	98	74	72	89	93
202	127	97	86	85	86	96
269	143	109	90	78	92	102

Table 24 Nitrogen Uptake Random Oats (kg N/ha) (1974)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	32	25	50	36
34	49	28	59	46
67	60	37	66	54
101	65	40	65	57
134	68	43	69	60
202	75	50	75	67
269	85	53	72	70
<u>Fallow Sites</u>				
9	118	91	80	96
34	120	91	92	101
67	128	88	87	101
101	140	102	94	112
134	134	99	103	112
202	148	110	102	120
269	146	103	114	121

Table 2 Bulk Density - Random Oats (kg /m³) (1976)

Treatment (kg N/ha)	Carmen		Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>							
9	438	392	485	408	477	-	441
34	427	410	456	432	453	-	436
67	423	428	459	397	436	-	429
101	432	432	434	405	441	-	429
134	428	422	438	399	426	-	423
202	429	430	430	404	421	-	423
269	431	406	422	406	434	-	420
<u>Fallow Sites</u>							
9	-		452	426	457	471	452
34	-		404	423	437	479	436
67	-		429	412	429	477	437
101	-		427	408	441	481	439
134	-		416	419	418	466	430
202	-		411	404	411	477	426
269	-		394	403	412	464	418

Table C16 Bulk Density - Random Oats (kg /m³) (1975)

Treatment (kg N/ha)	Roland	Pilot Mound	Goodlands	Hamiota	Brandon	Mean
<u>Nonfallow Sites</u>						
9	395	428	440	490	527	456
34	376	424	453	493	531	455
67	382	423	442	506	526	456
101	382	413	449	517	522	457
134	383	426	445	512	521	457
202	384	404	430	511	540	454
269	464	402	431	496	530	464
<u>Fallow Sites</u>						
9	468	404	444	492	498	461
34	469	411	429	510	483	460
67	464	414	416	507	483	457
101	464	401	434	495	484	455
134	496	393	428	495	484	459
202	480	411	412	496	477	455
269	395	416	434	482	479	441

Table C27 Bulk Density -Random Oats (1974) (kg /m³)

Treatment (kg N/ha)	Glenboro	Pilot Mound	Birtle	Mean
<u>Nonfallow Sites</u>				
9	435	390	463	429
34	461	415	453	443
67	435	413	441	430
101	436	419	443	433
134	439	430	446	438
202	441	403	448	431
269	466	408	449	441
<u>Fallow Sites</u>				
9	510	421	468	466
34	508	439	460	469
67	509	418	473	467
101	513	439	464	472
134	493	444	476	471
202	491	434	460	462
269	495	413	483	464

Table 28 Weight = Kilogram Per Hectolitre - Random Oats (1977)

Treatment (kg N/ha)	Carman	Pilot Mound	Boissevain	Hamiota	Portage	Mean
<u>Nonfallow Sites</u>						
	<u>East</u>	<u>North</u>				
9	49.9	51.7	50.9	56.2	51.2	51.6
34	50.6	51.8	50.2	53.2	50.6	51.1
67	51.3	50.6	53.2	55.9	51.4	51.7
101	51.9	52.1	51.9	55.9	51.3	51.9
134	50.6	51.9	54.0	54.6	51.3	51.8
202	50.4	51.4	53.4	56.1	50.2	51.7
269	51.6	49.7	52.5	55.4	51.8	50.7
<u>Fallow Sites</u>						
	<u>West</u>	<u>South</u>		<u>South</u>	<u>North</u>	
9	51.4	50.2	52.3	53.3	57.0	54.2
34	50.4	5.3	53.3	53.2	55.0	53.8
67	51.4	50.7	52.2	54.3	56.7	54.4
101	50.3	49.7	56.4	54.6	57.0	54.0
134	49.5	50.8	51.7	54.2	53.9	53.3
202	50.6	50.0	51.4	51.8	55.9	53.0
269	47.6	46.1	51.1	53.7	55.0	53.3