

Yield Responses to Variable Rate Fertilizer Applications Across a Hummocky Till Landscape in the Black Soil Zone.

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Introduction

Variable rate fertilizer (VRF) application is a management technique that has the potential to help producers increase the efficiency of their farm operations. In many prairie landscapes, pedological and hydrological conditions vary dramatically within a given field (Pennock et al. 1994). Producers, for some time now, have recognized this variability and have encouraged farm implement manufacturers to develop the technology that would allow farmers to vary fertilizer applications across a field. Farm implement manufacturers have responded to the interest in the farm community by developing equipment that will allow farm operators to make “on the go” adjustments to fertilizer rates. Unfortunately, research into the agronomic and economic implications of variable rate fertilizer applications has not kept pace with the technological advancements.

Researchers working on VRF studies are faced with three major challenges : (1) to correctly access the variability of factors controlling productivity, (2) to identify this variability and delineate areas with similar characteristics and, (3) to develop crop response models to determine appropriate variable input rates (Sawyer, 1994). Under dryland farming conditions, productivity is largely dictated by pedological and hydrological conditions that vary across a soil landscape (de Jong and Rennie, 1969). For example, in rolling terrain, the productivity is generally much lower on the knolls than the lower areas because of the relatively dry, infertile conditions. Soil organic carbon levels reflect the variation in long term moisture and fertility conditions within a soil landscapes (Verity and Anderson, 1990). Therefore, by delineating areas with similar organic carbon levels, zones or management units with similar productive potential can be established within soil landscapes. Through the application of different rates of fertilizer to each management unit, crop response models can be developed that reflect the variability in productive potential within soil landscapes.

The primary objective of this paper is to assess wheat and canola N yield responses within individual management units for a hummocky landscape in the Black Soil Zone. The paper will also examine the economic returns associated with the N responses.

Methods and Materials

Study Site Description

The study sites are located 40 km north of Saskatoon near the community of Hepburn (SE & NE 7-40-5-W3). The site is situated on a glacial till landscape that is part of the Oxbow soil association (Acton and Ellis, 1978). Soils at the site are dominantly Chemozemic with significant Gleysolic soils in the depressional areas. Slope gradients at the site range from 5 to 10%. Surface drainage at the site is local with the depressional areas separated by linear ridges. These ridges dissect the site at different angles resulting in a hummocky surface pattern. The glacial till parent material has a loam to clay loam texture.

The two research sites each cover an area that is 250 meters by 300 meters. The sites encompass several cycles within this knoll and depression landscape - one cycle extends from one knoll down into a depression and then to the top of the next knoll. A 9 by 11 point grid with a 25 meter sampling interval was used as a guide for the sample collection. At each grid point, soil cores were extracted and extruded using a truck mounted coring apparatus. Once extruded, the soil cores were described using the Canadian System of Soil Classification (Agriculture Canada, 1978). Samples were collected at 15 cm intervals to a depth of 60 cm.

Laboratory Methods

The soil samples collected in the field were subjected to a series of analytical procedures that provided information needed to characterize the soils. A number of chemical properties were examined: inorganic carbon, organic carbon, nitrate-nitrogen, pH, and electrical conductivity. Physical components include particle size distribution, moisture content, and moisture retention. Standard analytical techniques were used to gather all the information. The data generated from these procedures were used to facilitate the delineation of management units and establish their fertility status.

The grain samples collected during the harvest operation were dried and analyzed for protein, in the case of the wheat, and oil content for the canola. This information was factored into the economic assessment.

Experimental Design and Seeding

The management units at both sites were delineated using the image analysis of black and white photographs (McCann et al. 1996). The technique essentially stratifies the landscape into units with similar soil organic carbon levels. Four management units were delineated at each of the sites: (1) Knolls, (2) Mid-Slopes, (3) Lower-Slopes, and (4) Depressions. These units represent zones within the landscape with similar pedological and hydrological conditions, and hence, similar productive potential.

In order to assess the N response within each of the management units, a series of fertilizer trials were established. The fertilizer trials were seeded by the Saskatchewan Wheat Pool using their pared down Morris air seeder. The unit is 2.13 m wide with a 30 cm row spacing. The two outside rows were seeded to winter wheat which acted as a buffer between the strips. Figure 12 (Appendix A) illustrates the site design used for both sites. A number of N and P trials were seeded but in this paper, the only trials that will be covered represent applications of N from 0 to 2 times the recommended rate at 0.5 increments. These 5 trials were seeded in 15 randomized strips. The recommended rates were based on the fall soil analysis using the F.A.R. M. Phase II software (available from the Enviro-Test Laboratory in Saskatoon). Soils were sampled from the mid-slope unit according to recommended guidelines. The objective was to simulate a sampling program similar to that used by producers who utilize uniform fertilizer applications. The recommended rate of P was applied at a constant rate for each trial. Sulphur and micronutrient levels were sufficient at both sites.

Harvest Operations

A small plot harvester was used to collect grain yield samples. Ten meter long sections were harvested within each of the management units for each of the trials. Above ground biomass samples were taken adjacent to each of the harvest plots to assess the harvest index. Because each of the randomized trials intersect all of the management units several times, enough information was compiled to assess the N responses both within and between the management units.

Economic Assessment

The Canadian Wheat Board Initial payments for the 1996-97 crop year were used to evaluate the net economic returns from the wheat site. The calculations for net returns are based on the benefits from the fertilizer applications minus the cost of the fertilizer. Capital expenditures for equipment were not included in the assessment. Protein premiums were factored into the calculation at the wheat site. For the canola site, the figure of \$400 per tonne was used to assess the value of the grain. The cost of the nitrogen fertilizer was based on the spring of 1996 price of \$0.40 /lb of N.

Results and Discussion

Yield responses to the N treatments varied both within the management units and between them. At the canola site, there was a dramatic increase in yield from the knolls to the lower-slope units (Figure 1). Yield information for the depression unit could not be collected because the crop was flooded during a 65 mm rainfall event on July 4. The yield gradient across the management units is primarily a reflection of two main factors: (1) moisture, and (2) potential soil fertility. In a comparison between knoll and lower-slope management units, the lower-slope

management unit had better moisture conditions at the time of seeding (Figure 2). Moisture use during the growing season accentuated the moisture gradient resulting in the crop on the knolls undergoing drought stress by the early part of August (Figure 3). It is interesting to note that through the different water use and redistribution of moisture during the growing season, the lower-slope unit has similar available moisture levels in August as at the time of seeding, whereas the knoll unit's moisture levels are depleted. Spratt and McIver (1971), and de Jong and Rennie (1968) also attributed the higher absolute yields in the lower parts of the landscape to the better moisture conditions.

The increase in yield across the management units can also be attributed to a mineral N gradient (Figure 4). Spring soil mineral N values follow a topographic pattern with the knoll units having much lower values than the lower-slopes. In addition to this mineral N gradient, it is likely that more N became available during the growing season in the lower-slope unit as a consequence of the higher organic carbon levels.

Yield responses to the N treatments also occurred within the management units (Figure 1). For example, in the knoll unit a yield response occurs up to and beyond the recommended rate of 75 lbs/acre of N. A response is still evident at 1.5 times the recommended rate but at 2 times the recommended rate (150 lb N/acre), the response drops off. An examination of the harvest index data for the knoll unit suggests that the 150 lb. (N)/acre treatment produced a large amount of biomass relative to the seed yield (Figure 5). This lush growth of biomass underwent moisture stress late in the growing season probably resulting in a reduction in seed yield (Figure 3). On the mid-slope unit, the yield response to the nitrogen fertilizer leveled-off at the highest N rate. The leveling-off effect suggests that the crop underwent some moisture stress but not to the same extent as on the knolls. Finally, the yields on the lower management unit also increase with nitrogen application. Because of the favorable moisture conditions, a yield response is still evident at the highest rates of nitrogen.

A yield response to the nitrogen treatments was also evident at the wheat site (Figure 6). Like the canola site, different yield responses occurred both between the management units and between the treatments. The knoll management unit had the lowest yields. Within this unit, a response to the nitrogen treatments was evident up to the recommended rate of 55 lbs / acre. Beyond this point, yields declined likely as a result of moisture stress (Figure 7). The mid-slope unit also had a decline in yield at the higher nitrogen treatments.

Yield responses in the lower-slope management unit are much different from the other two management units. For example, there is no apparent response to any of the treatments. All four treatments have yields similar to the control or zero treatment (Figure 6). The lack of response can likely be attributed to the high nitrogen supplying power of these soils and the favourable moisture conditions. Initial mineral N levels were similar to all the other management units

(Figure 8). Therefore, it appears that nitrogen released from the soil over the growing season offset any seed yield response that may have occurred as a result of the nitrogen treatments. Though seed yields were unaffected, the N treatments did affect the harvest index (Figure 9). The higher N treatments produced large amounts of biomass which is reflected in the lower harvest grain to total biomass ratios. The excess N also delayed crop maturity and made the crop more susceptible to wind damage.

In an effort to assess the economic implications of VRF applications at these sites, the net returns for each of the treatments were examined. Figure 10 illustrates the net returns, on a per dollar basis, for the investment in fertilizer at the canola site. On both the knoll and mid-slope unit, the optimal returns are achieved at 112 lbs/acre treatment which is 1.5 times the recommended rate. The optimal rates are much different for the lower-slope unit. In this unit, the most favourable returns are achieved with no application of fertilizer. Positive returns do occur at the highest treatment but this treatment would not likely be recommended because of the additional risk incurred for minimal return.

Net returns at the wheat site were also assessed using the yield and protein data (Figure 11). Protein premiums were utilized in the calculation of the returns. Optimal returns on the knoll unit occurred at the 27.5 lbs / acre rate or 1/2 the recommended rate. The recommended rate on the mid-slope unit provided the best returns. In the lower-slope units, the net returns are similar to those found at the canola site: the optimum returns are achieved with no fertilizer application.

Summary

Based on the data from 1996, the highest absolute yields occurred in the lower parts of the landscape, whereas the highest response to the nitrogen treatments occurred in the mid- and knoll units. The low response on the lower-slope units indicates that appreciable savings may be realized in **this** part of the landscape through the reduction of fertilizer applications. What is not clear, however, is the long term effect of reduced applications. Over time, the capacity for the soil to release nitrogen may be depleted resulting in a need for fertilization in this part of the landscape.

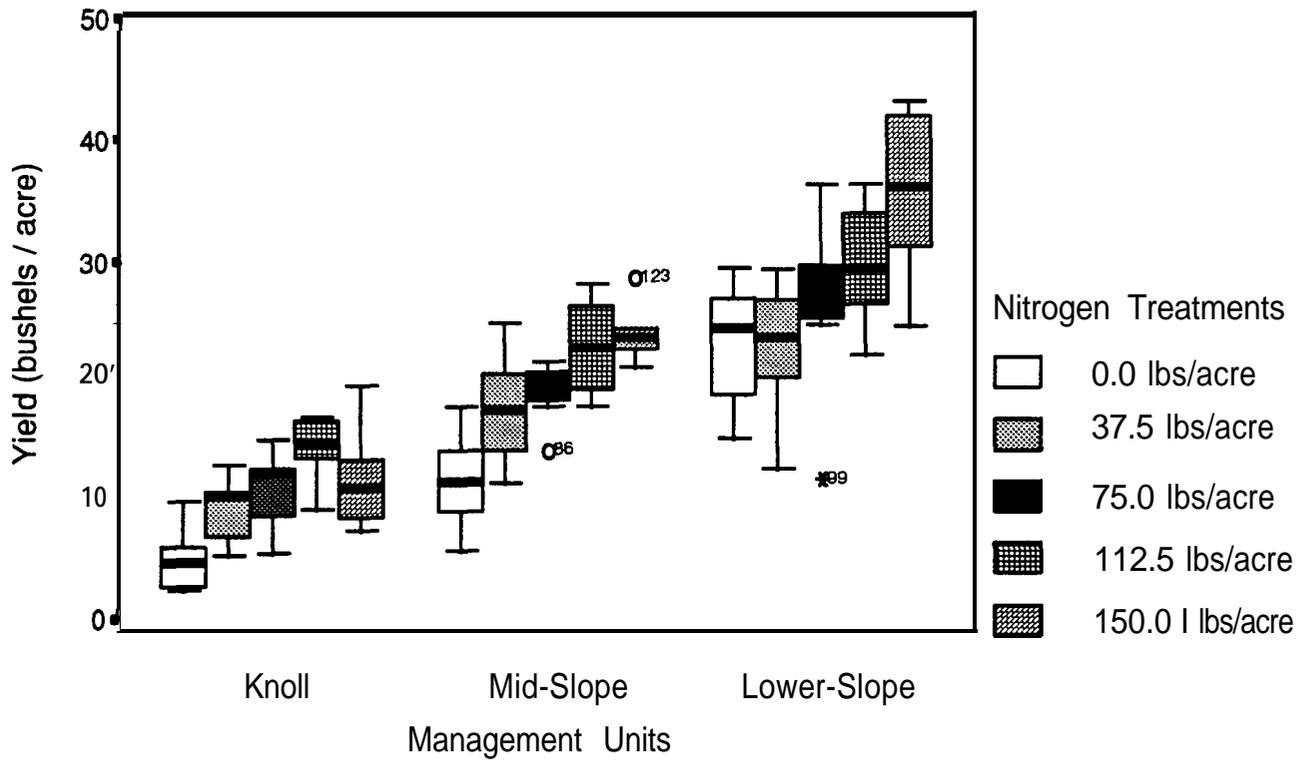
Acknowledgments

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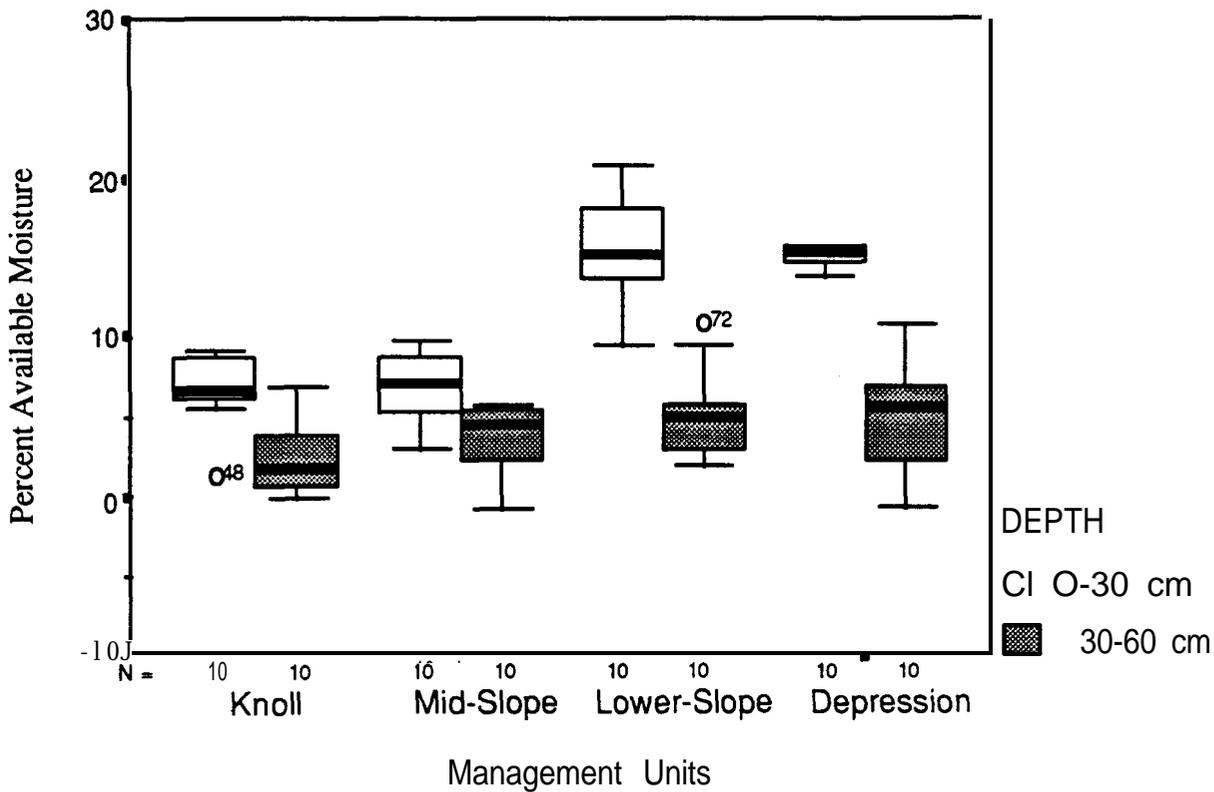
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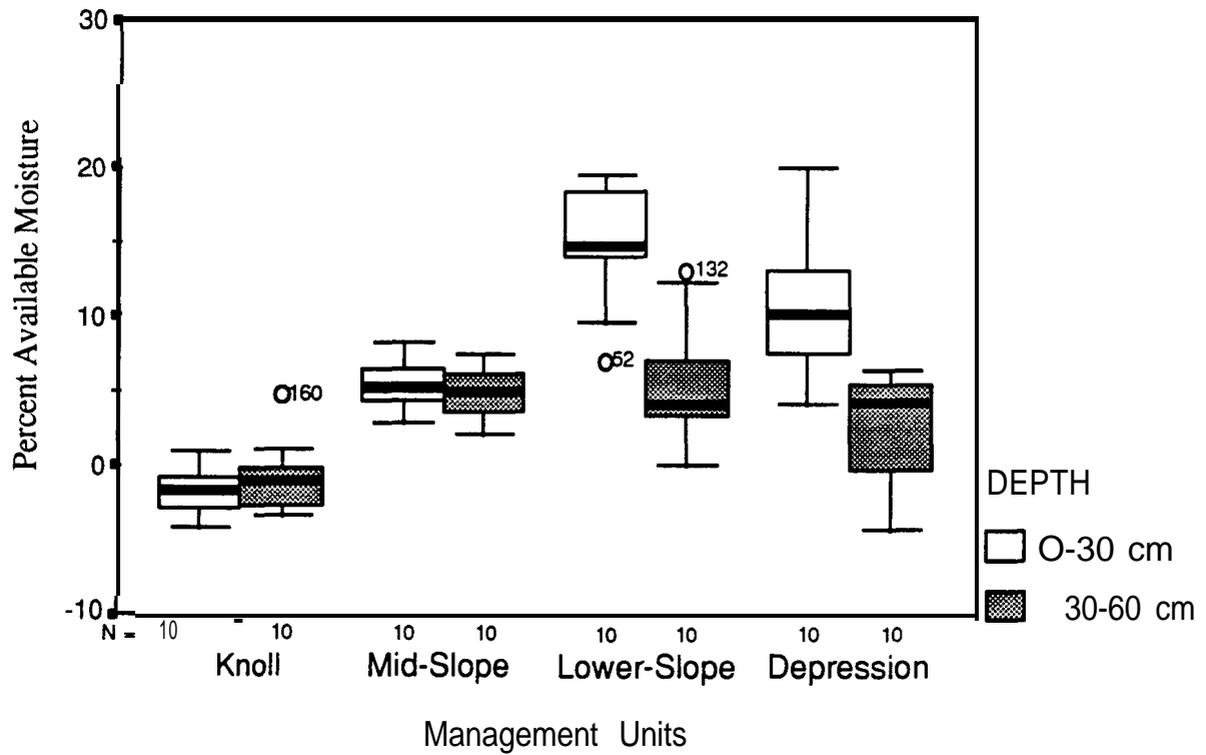
Appendix A



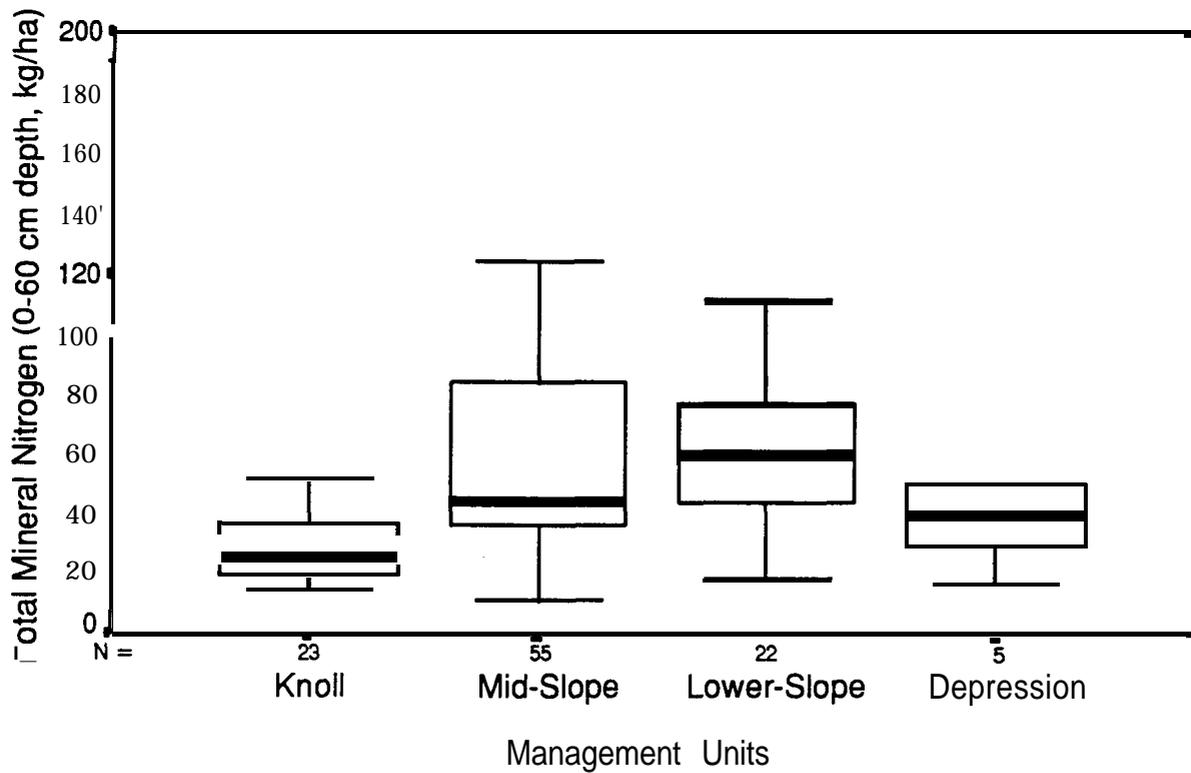
(Figure 1) Canola Site Yield Data for the Nitrogen Treatments.



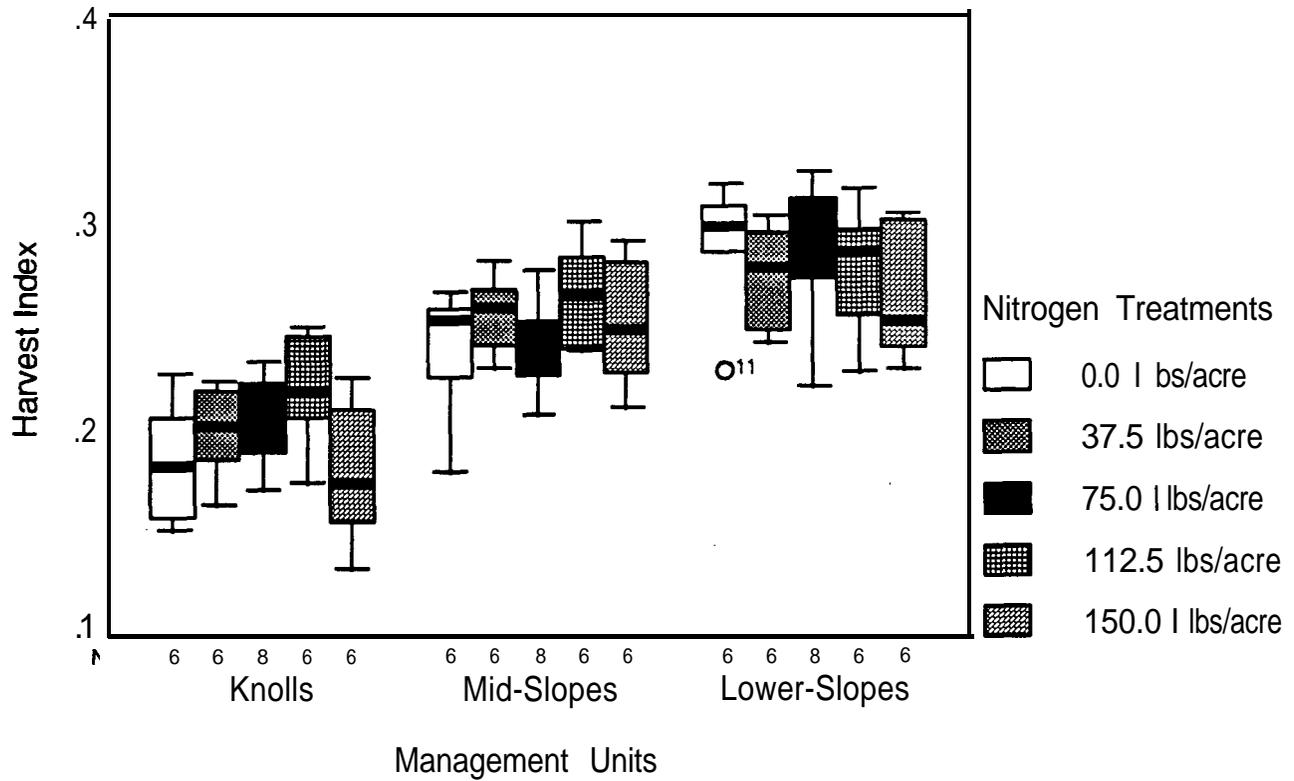
(Figure 2) Canola Site Available Moisture at the Time of Seeding.



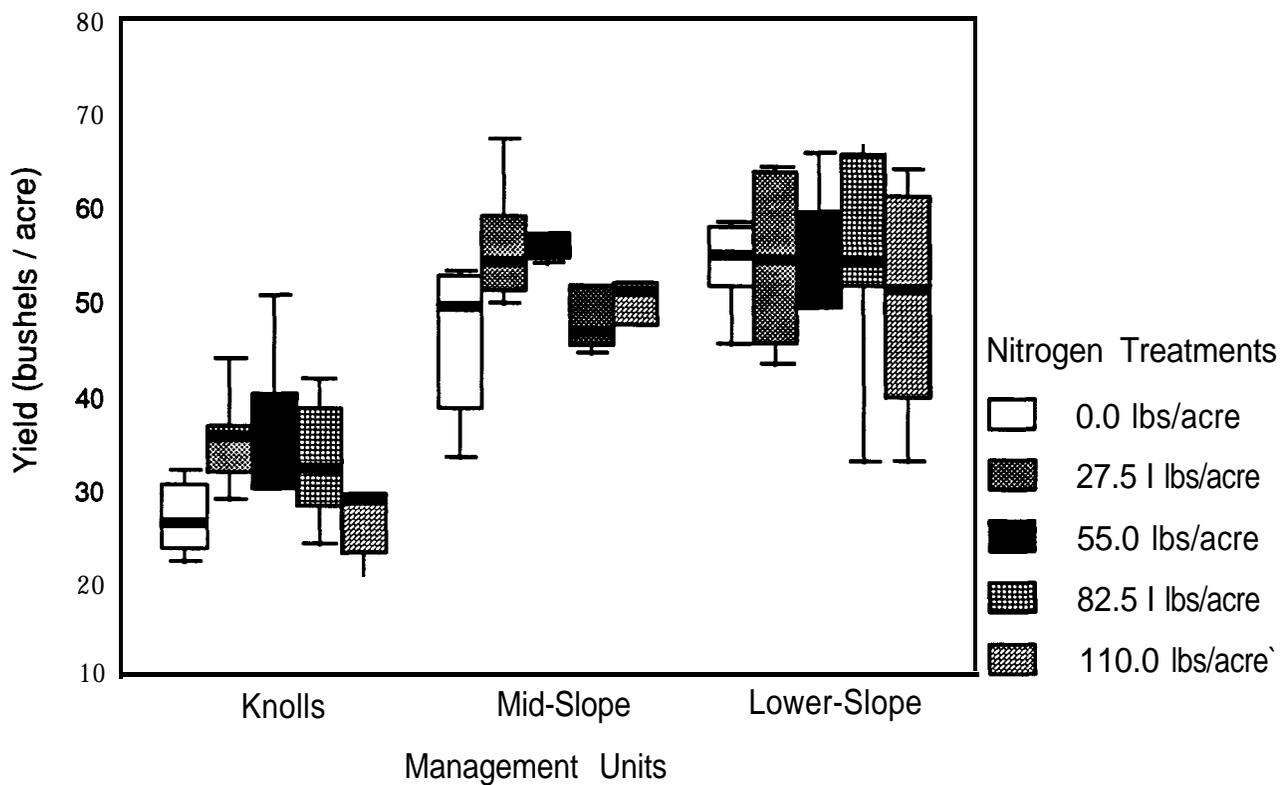
(Figure 3) Canola Site Available Moisture, August 2, 1996.



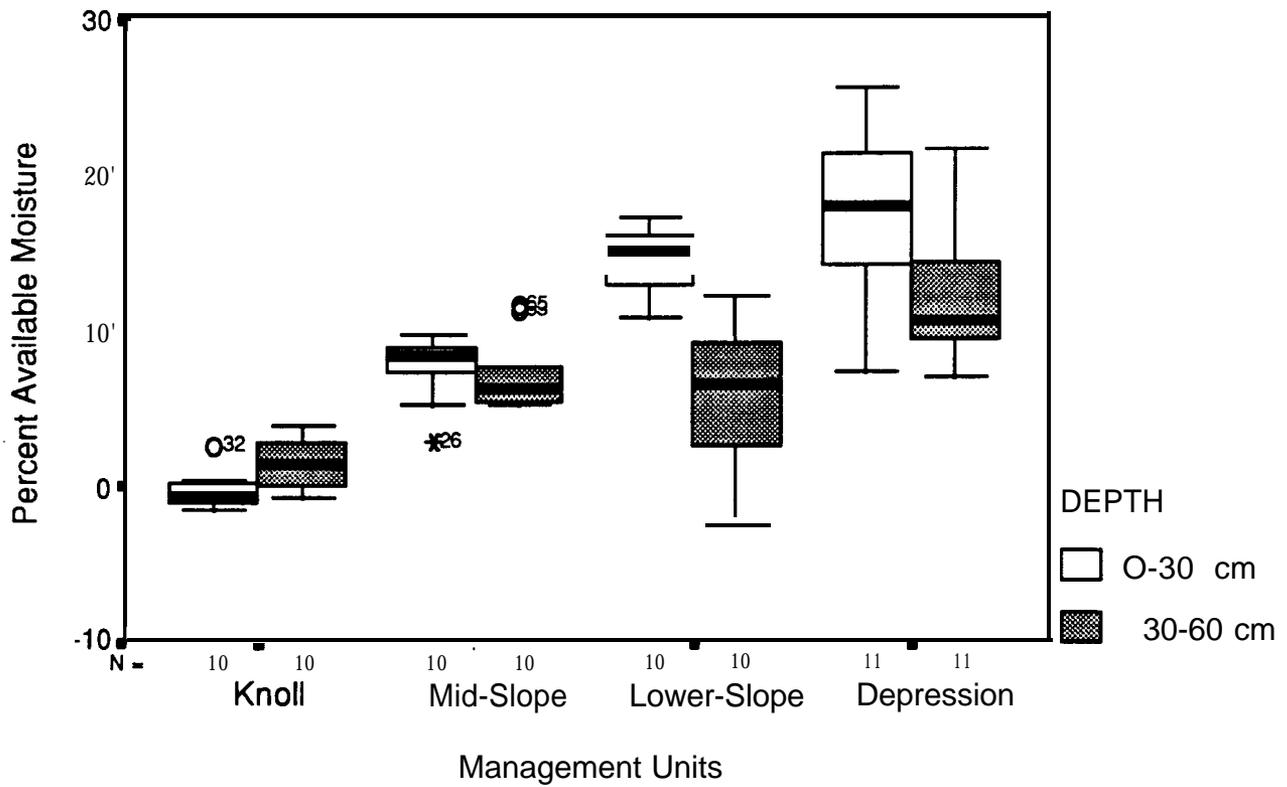
(Figure 4) Canola Site Total Mineral Nitrogen, May 1996.



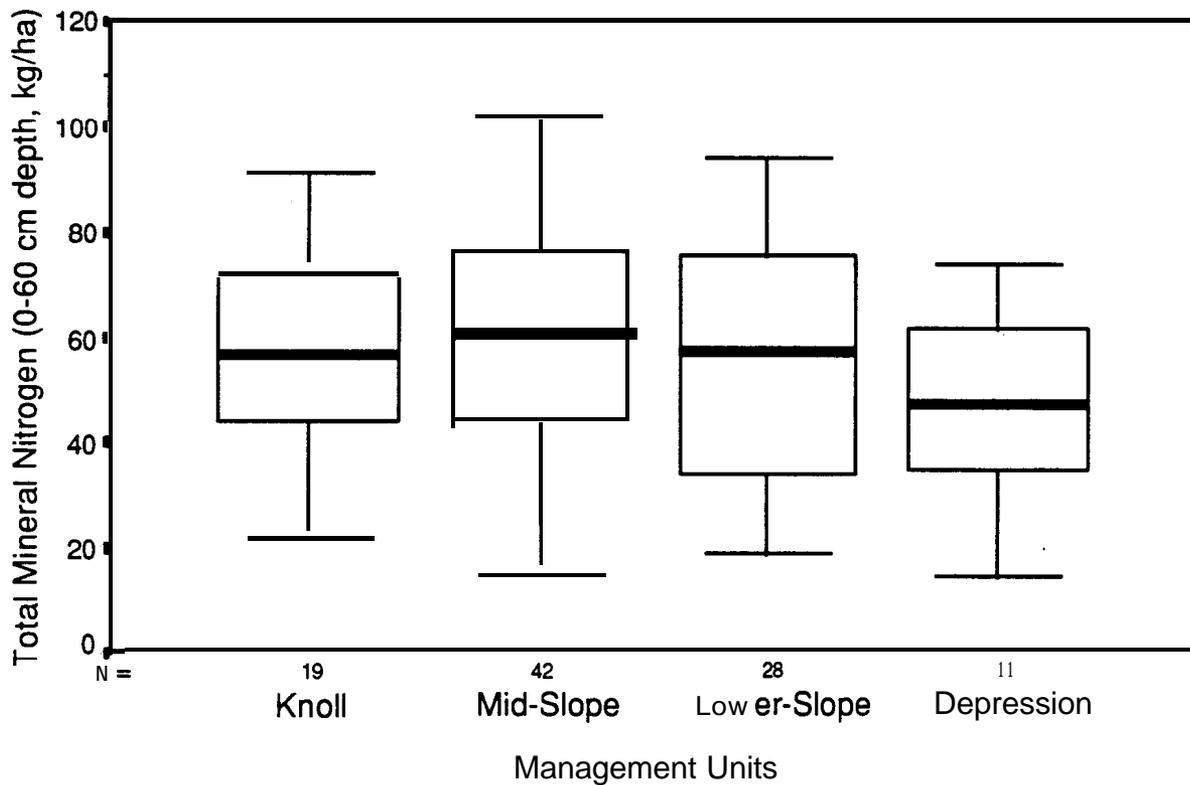
(Figure 5) Canola Site Harvest Index Data for the Nitrogen Treatments.



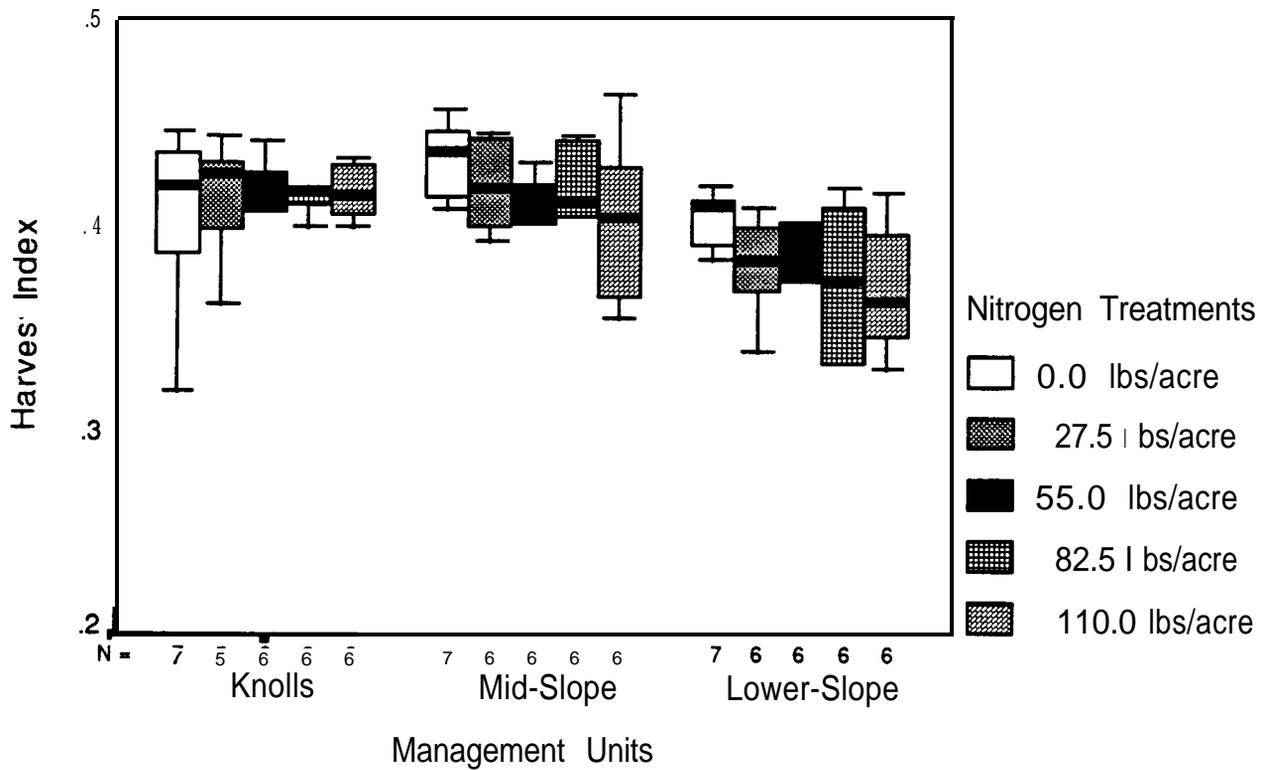
(Figure 6) Wheat Site Yield Data for the Nitrogen Treatments.



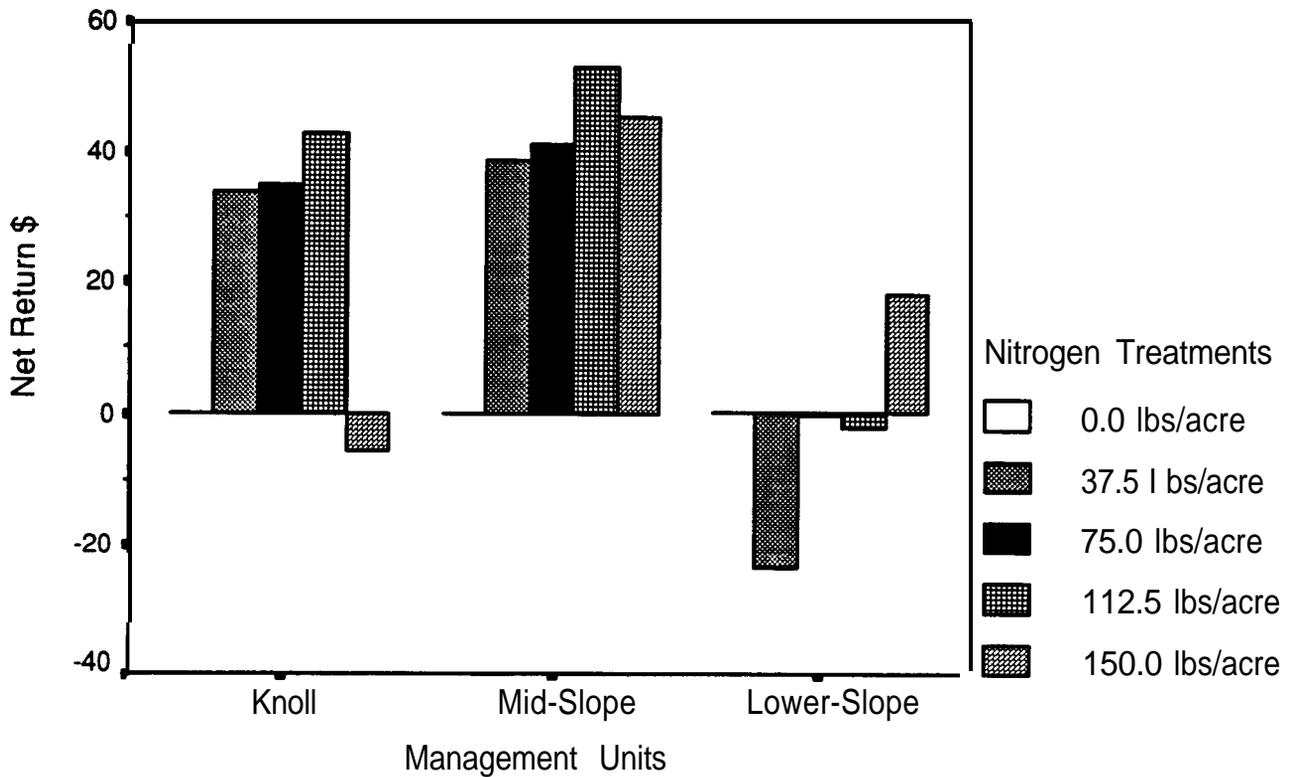
(Figure 7) Wheat Site Available Moisture, August 2, 1996.



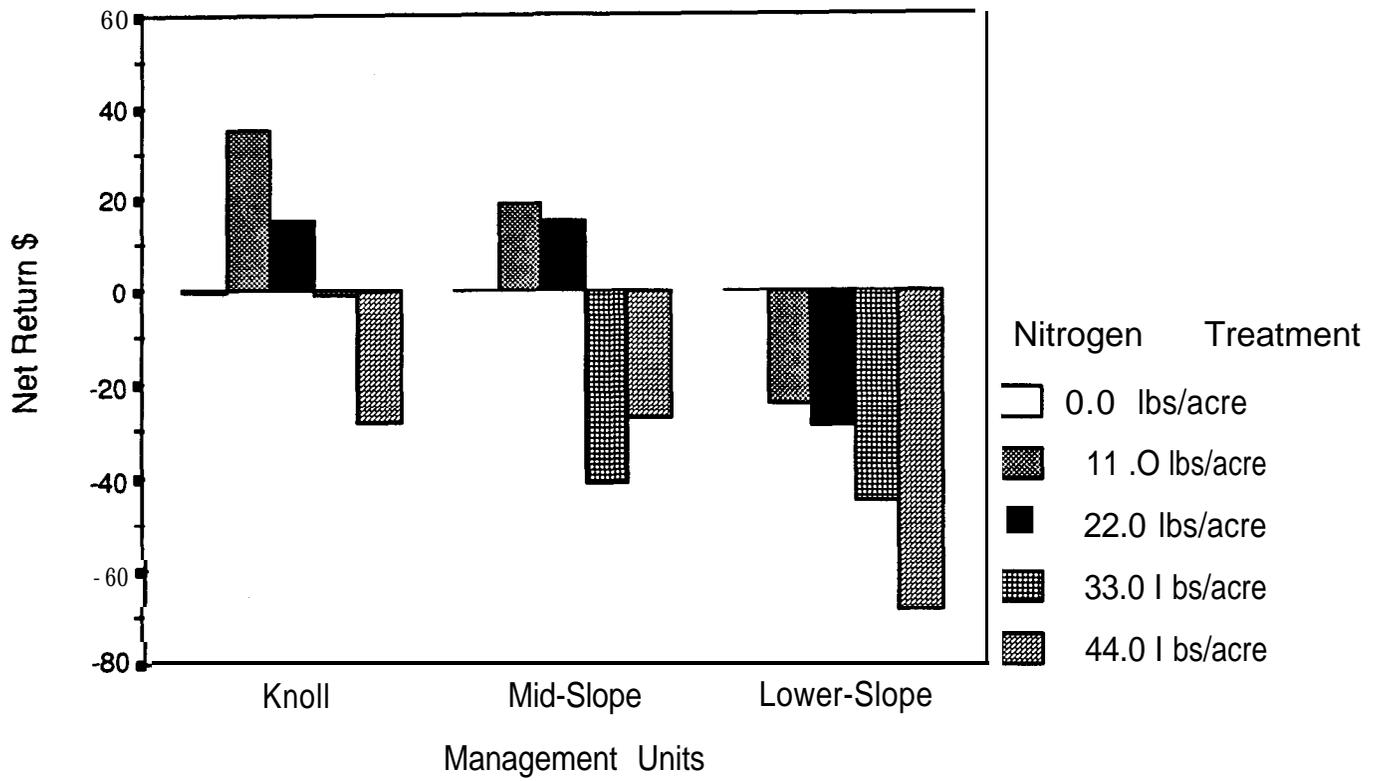
(Figure 8) Wheat Site Total Mineral Nitrogen, May 1996.



(Figure 9) Wheat Site Harvest Index Data for the Nitrogen Treatments.

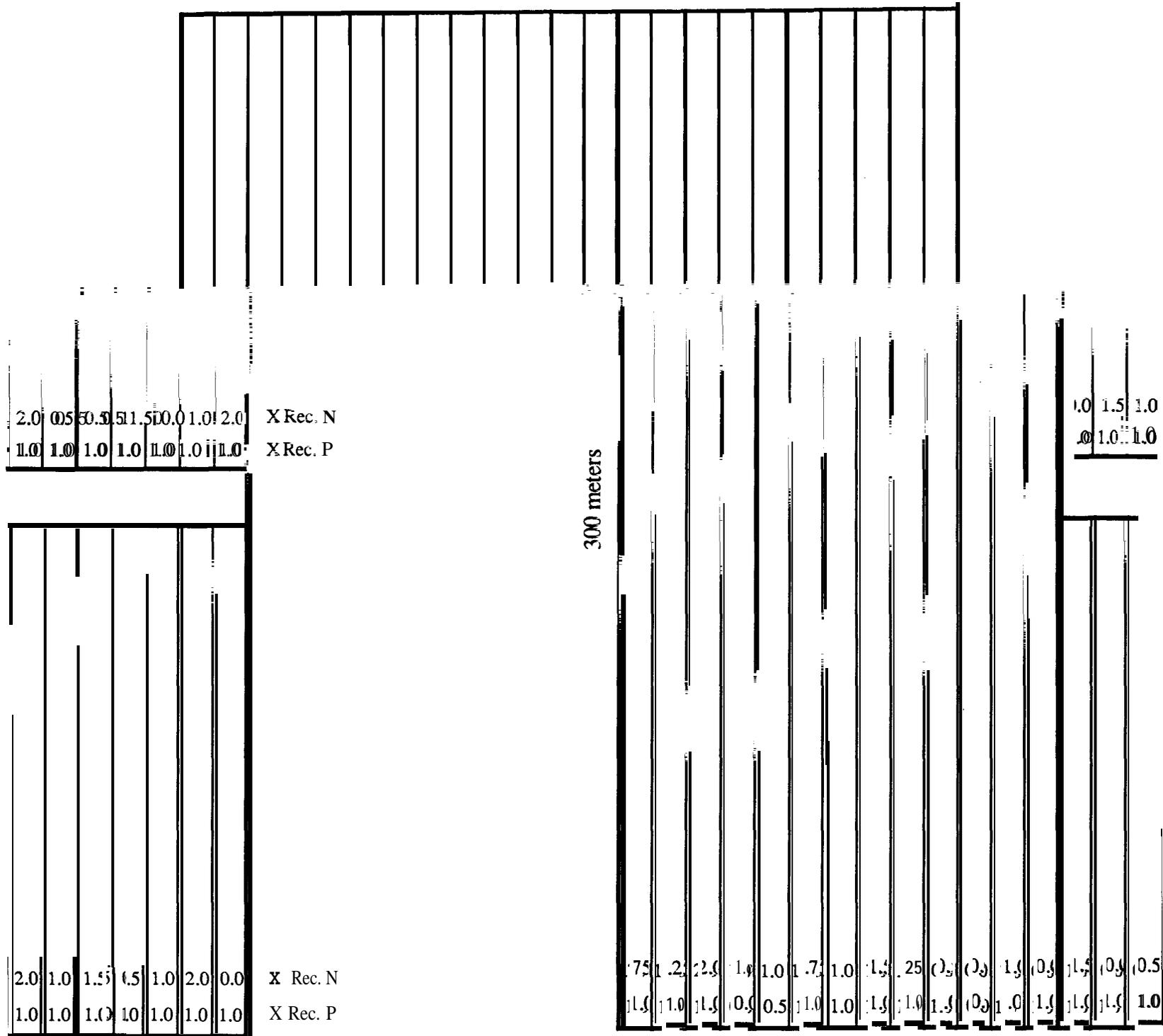


(Figure 10) Canola Site Net Returns for the Nitrogen Treatments.



(Figure 11) Wheat Site Net Returns for the Nitrogen Treatments.

50 meters



X Rec N = Multiple of the recommended nitrogen rate.
 X Rec P = Multiple of the recommended phosphorus rate.

(Figure 12) Site Design for VRF Study.