SK-17

1996

Project Name: Agronomic and Economic Assessment of Variable Rate Fertilization.

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Interim Progress Report: January 1, 1997.

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 most Saskatchewan soil landscapes, the fertility and moisture conditions vary dramatically across a farm field. 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. This project will narrow the gap between these bodies of knowledge. The objectives of the project are three fold: (1) examine the agronomic implications of VRF, (2) assess the economic component of VRF, and (3) develop the mapping tools to delineate management units on the farm scale.

Executive Summary

Work on the project "Agronomic and Economic Assessment of Variable Rate Fertilization" is progressing according to schedule. The Saskatchewan Wheat Pool, Flexi-Coil, Westco, and the Potash and Phosphate Institute have supported the project at the levels indicated in the proposal. The continued support from these agencies is important if the objectives of this project are to be achieved. Much of the summer was spent monitoring the sites for various soil and climatic properties. In addition to this work, considerable time was spent establishing and collecting data from the calibration sites.

Climatic Conditions

The 1996 growing season was comprised of climate events that presented a number of challenges for agronomic research. In other words, it was a typical Saskatchewan summer. Because of the cool wet spring, we were forced on two occasions to postpone the seeding of the trials. During the first five weeks of growing season, warm weather, combined with adequate precipitation enabled the crop to developed rapidly making up, in part, for the late seeding date (Appendix A, Figure 1). Please note that all figures are presented in Appendix A. Growing season precipitation was 37 mm above the 30 year average for the climate station at Rosthern: 288.9 mm vs. 251.9 mm. On July 4th, a destructive storm dropped 65mm of rain on the site creating extensive flooding in the depressions and wind related damage in the crop (Figure 2). Crop development was delayed as a result of the storm but the warm weather in August combined with the late frost provided the crop with adequate time for maturation.

Spring Sampling Program

An intensive spring sampling program was conducted at both sites to establish the background mineral nitrogen (N) levels. At each site, a 110 point sampling grid was set up over the area designated for the fertilizer trials. Samples were taken to a depth of 60 cm and KCL extractions were done in the field to ensure that the measured NH_4 was representative of the available NH_4 levels in the field. Results from the analyses are illustrated in figures 13 & 14. At both sites, the mineral N values are in the 60 kg/ha range. Information collected by Enviro-Test Laboratories in the fall of 1995 indicates that other fields in this township had nitrate N values as high as 50 kg/ha with a mean of 30 kg/ha. Soil nitrate values in this study were close to 50 kg/ha. Why the above average values? Discussion with the cooperators revealed that both had used recommended rates of fertilizer in the spring of 1995: 65 and 80 kg/ha of N for the wheat and canola crops respectively. Both sites had produced above average crops that should have depleted the nitrogen applied in the spring: 35 bushels of canola, and 40 bushels of wheat. In view of these circumstances, the only plausible explanation for the high values is mineralization.

Climatic conditions in the fall of 1995 were ideal for the mineralization of N. The fall was warm with above average precipitation which provided a perfect environment for the microbes to mineralize N. In contrast, the climatic conditions during the fall of 1996 were cool and with normal precipitation levels. A mineral N sampling program conducted on the area designated for next years trials revealed much lower values (Figures 15 & 16). These lower values are likely a result of the fact that the conditions were too cool and dry for the mineralization of large amounts of N. Information collected by Enviro-Test Laboratories in the fall of 1996 for this township also showed a dramatic decrease from the 1995 values: maximum values of 27 kg/ha in 1996 vs. 50 kg/ha in 1995. It will be interesting to assess the impact that these lower background levels of N have on yield responses.

Seeding Operations

The final seeding operations were concluded on June 3. On two separate occasions, the cool wet conditions forced us to postpone the seeding of the trials. The experimental designs for the seeding trials are illustrated in figures 18 & 19. For more information on the seeding operations refer to the June 1, 1996 interim report. Because of the weather related seeding delays, we were forced to seed into soils that had higher than optimal moisture levels. These wet conditions, combined with the 10 days of warm dry weather immediately after seeding, produced crusting problems that hampered seedling emergence. Despite the emergence problems, adequate plant densities were established at both sites.

Image Analysis Calibration Sites

In order to further develop the image analysis mapping technique, 8 calibration sites were established in a ten mile radius of the research sites (for more information on the mapping procedure refer to the June 1, 1996 interim report). The sites are primarily situated on glacial till landscapes with two sites on sandy parent material. The slope gradients at all the sites are generally less than ten percent. A 30 point sampling grid was laid out at each site with soil samples and profile descriptions made at each grid point. The soil samples are currently being analyzed for organic carbon. Topographic data was also collected at each site and will be used to develop terrain models. In order to establish ground control points for the image rectification operation, a GPS survey was done at each of the sites. The results from this survey will be used in conjunction with the soil organic carbon data to refine the image analysis technique.

Soil Moisture Monitoring Program

Over the course of the growing season, a program was set up to monitor the soil moisture conditions in each fertilizer trial. Gravimetric soil moisture measurements were taken on a biweekly basis. A preliminary examination of the data suggests that soil moisture varied between the management units but not between the treatments (Figures 3a-b & 4a-b). As one might expect, the lowest moisture levels occurred in the knoll units and progressively increased in a downslope direction. It is also interesting to note that the soil moisture distribution that existed at the time of seeding (early June) is very similar to that which existed near the end of the growing season (early August). Over the growing season moisture levels fluctuated with the different precipitation events but the water use appears to be more or less uniform across the landscape. During the winter months, the moisture data will be used to calculate available moisture which, in turn, will be used to estimate the moisture use efficiency for each of the management units.

Pest Control

Potential pest problems were closely monitored over the growing season. Weed control was effected with "in crop" applications of herbicides in the early part of July. During the third week in July, a wheat midge infestation was detected and controlled with an application of the insecticide "Lorsban". At the canola site, populations of diamond back moths and bertha army worms were well below the control threshold. The Sask. Wheat Pool provided the control for both the weeds and the wheat midge.

Harvest Operations

Harvest operations were conducted at the sites in late September and early October. The Sask. Wheat Pool provided the equipment and most of the labor for the sample collection and processing. Yield and harvest index data were collected for each of the treatments within each of the management units (Figures 5 - 8). At the canola site, there was a dramatic increase in yield from the knolls to the lower-slope units. The yield gradient across the management units was probably a reflection of two factors: (1) the moisture conditions, and (2) the nitrogen supplying power of the soils. In a comparison between knoll and lower-slope management units, the lower-slope management unit has better moisture conditions (Figure 4) and because of its relatively high organic carbon levels, a greater capacity for supplying N (Figure 13).

Differences in yield also occur between treatments within the management units. For example, the yields on knoll unit at the canola site increased with the increase in nitrogen fertilizer and then dramatically dropped off at the highest treatment (Figure 5). Why the reduction in yield at the high rates of nitrogen? The explanation can likely be attributed to moisture stress. 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 (Figure 6). This lush growth of biomass likely underwent moisture stress late in the growing season resulting in a reduction in seed yield. On the mid-slope unit, the yield response to the nitrogen fertilizer leveled off at the highest rate. The leveling off effect suggests that the crop may have undergone 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. No yield data was collected for the depressional unit because these areas were flooded out during the July 4th storm.

A yield response to the nitrogen treatments was also evident at the wheat site (Figure 7). The samples are currently being analyzed for protein. Like the canola site, different yield responses occurred both between management units and between treatments. Despite the fact that spring soil mineral N values for the management units were similar (Figure 14), differences in yield between the units did occur. For example, the knoll unit had the lowest yields whereas the mid-slope and lower-slope units had similar values. The higher yields in these units is partly a reflection of the better moisture conditions but perhaps more importantly, is an indication of the higher N supplying power of these soils.

Yield differences also occurred in response to the fertilizer treatments (Figure 7). For example, in the knoll unit, a response to the nitrogen treatments was evident up to the recommended rate of 55 lbs./ acre. Beyond this point, yields probably declined as a result of moisture stress. A similar scenario occurs in the mid-slope unit with the yields declining at the higher nitrogen treatments. Again, the reduction in yield is likely due to moisture stress late in the season. Yield responses in the lower-slope management unit are much different from the other two management units: there is no apparent response to any of the treatments. All four treatments have similar yields as the control or zero treatment. The lack of response can most likely be attributed to the high nitrogen supplying power of these soils and the favourable moisture conditions. Nitrogen released from the soil over the growing season appears to have offset any response that may have occurred as a result of the nitrogen treatments.

In an effort to access the economic implications of VRF applications at these sites, the net returns for each of the treatments were examined. Figure 9 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 be recommended because the returns fall short of the recommendation criteria where the last dollar spent on fertilizer should produce a return of $1.50.

Net returns at the wheat site were also assessed (Figure 10). 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 which suggests that the Farm Phase II recommendations were appropriate for the mid-slope unit which is often assumed to be the average conditions in the field. 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. This low return 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. Further research is required to properly address this question.

Fertilizer trials were also set up to determine the response to phosphorus fertilizer (Figures 11 & 12). At the canola site, there was little or no response to the phosphorus treatments. The only management unit with a slight response was the knoll unit (Figure 11). Responses at the wheat site were quite different (Figure 12). In general, there was a appreciable yield response to the phosphorus treatments in all the management units. At the wheat site there appeared to be a dramatic "pop up" effect from the phosphorus treatments. These results are in keeping with other studies where a "pop up" effect was found in the cereal crop but not in the canola.

Yield information was also collected from the area where the automated fertilizer applications were made last spring (for details on the automated application, refer to the June 1996 interim report). In order to make a comparison between the automated VRF application and the uniform application, several square meter samples were taken for yield measurements (Figure 17). Differences between the two applications do exist but the problem arises in accessing the factors contributing to the differences. For example, the automated application for the knoll unit produced a higher yield than the uniform despite the fact that less product was applied: 40 lbs./acre vs. 55 lbs./acre. The yield data from the nitrogen trials -situated adjacent to the automated site- indicate that the highest yields were obtained with the recommended rate of fertilizer: 55 lbs/acre (Figure 7). Why the higher yields with the 45 lbs/acre treatment? It is difficult to determine if the automated system was actually applying the prescribed fertilizer. Lag time problems were occurring during the operation and perhaps more fertilizer was applied to the knolls than was prescribed.

The automated system also produced higher yields on the mid-slope unit: approximately ten bushels/acre. Once again, it is difficult to attribute the higher yields directly to the higher fertilizer rates because we are not certain if the prescribed amount was actually applied. If the correct amounts were applied, the difference in yield is far greater than could be attributed to the 10 lb./acre difference in fertilizer. These examples underline the problem associated with using VRF applications to assess yield responses. For scientific research, variable rate fertilizer applications may introduce a degree of uncertainty that could otherwise be avoided by applying uniform rates to different treatments.

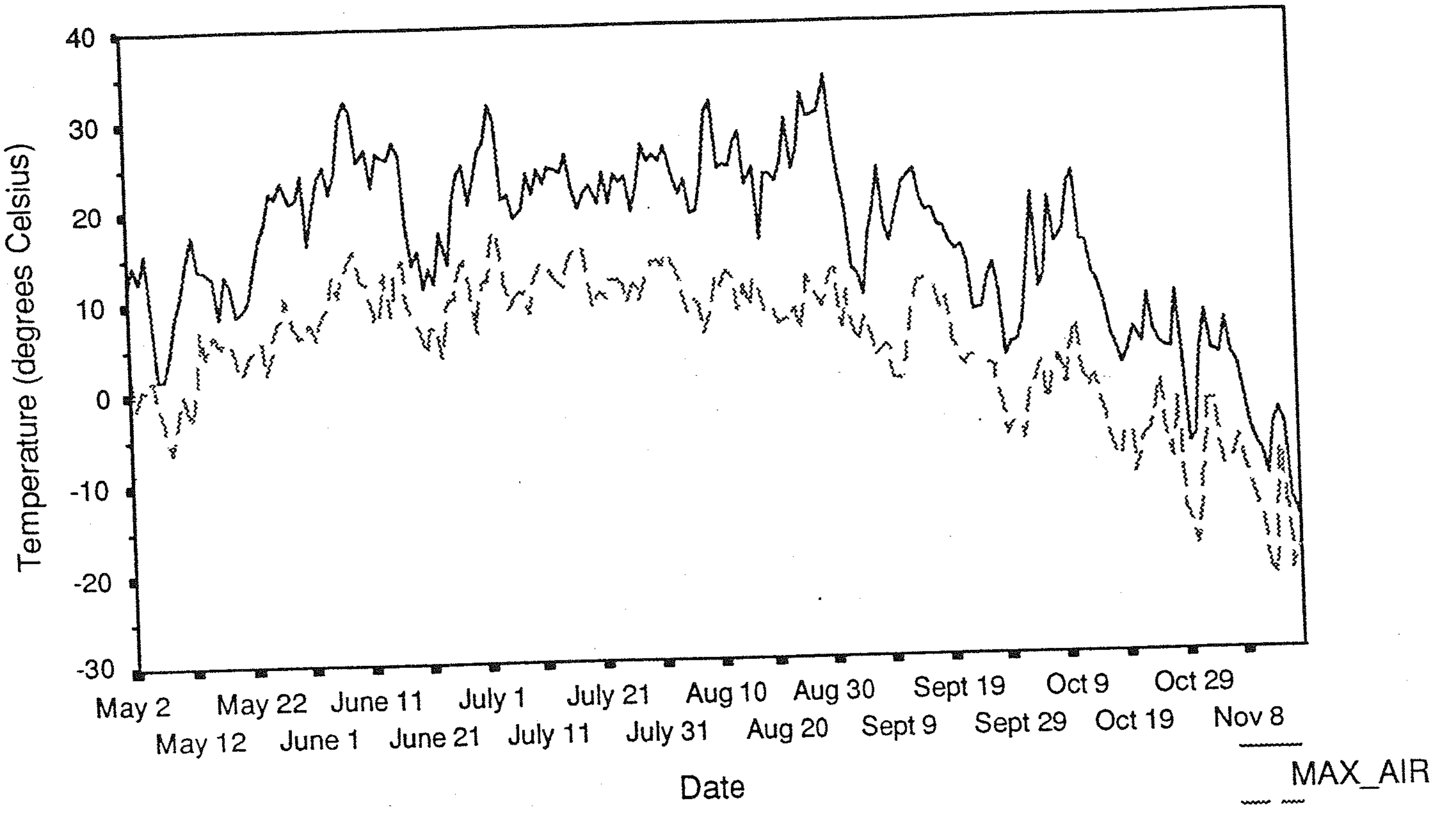
Indications for Further Development

Having completed the initial year of the study, we are very encouraged by the information obtained from the fertilizer trials. Moreover, due to the uncertainty regarding the positional accuracy of the VRF units, we believe that the best results will be obtained during the 1997 and 1998 seasons by using a similar approach to that used during the 1996 season. With this approach, a series of trials will be set up using rates of N ranging from 0 to 2 times the recommended rate with a 0.5 increment. Trials for the P treatments will have rates of 0, 0.5, and 1.0 times the recommended rate. This approach is also similar to the design that will be used at the 4 proposed sites under the AFIF agreement. Researchers in Montana and Minnesota have also concluded that the best approach for variable rate fertilizer research is to vary fertilizer rates between treatments, not within them.

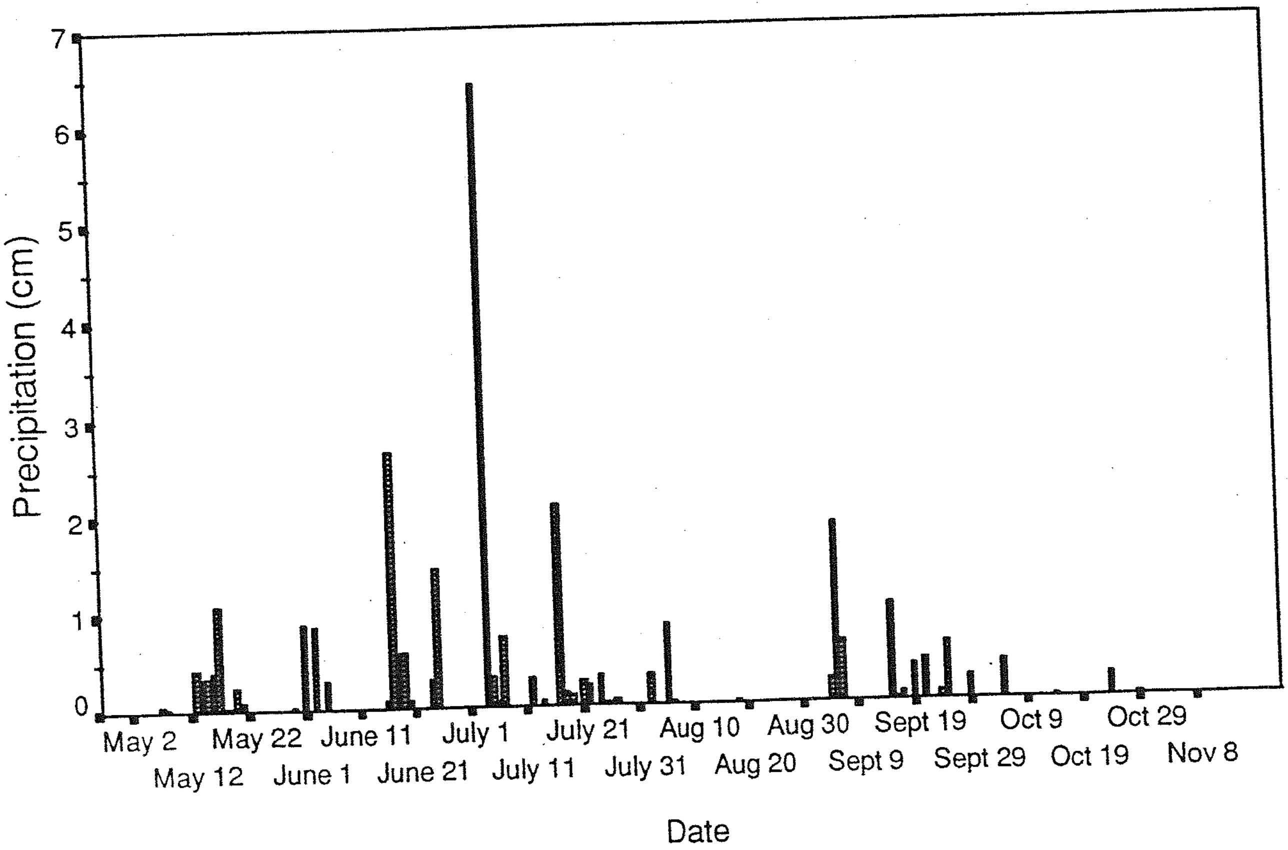
Work in Progress

Work over the winter months will primarily focus of data analysis. The moisture data will be examined to assess the moisture use within each of the management units. Yield response curves will be created for each management unit and these curves will form the basis for the economic analysis. The protein data will be also be factored into the economic evaluation. Finally, the information from the image analysis calibration sites will be used to further develop this mapping technique.

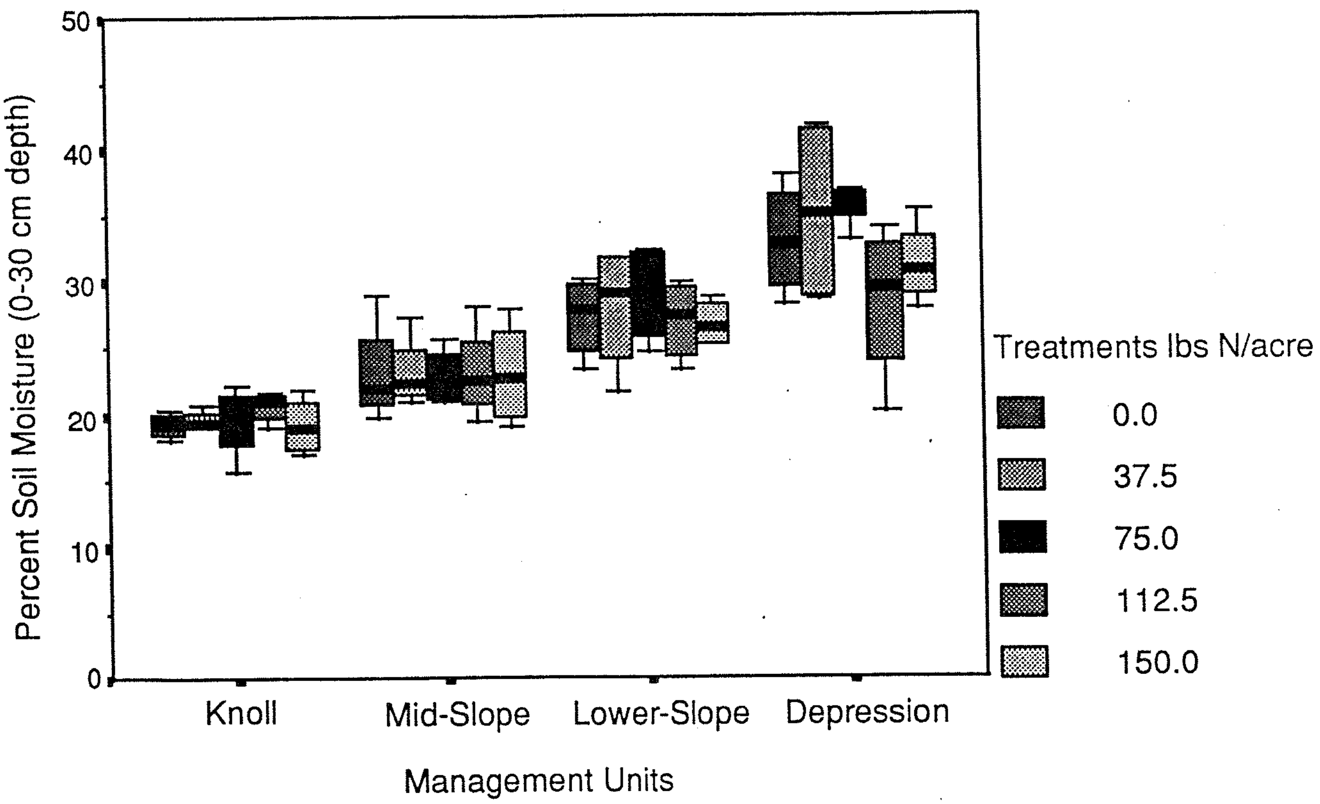
Appendix A



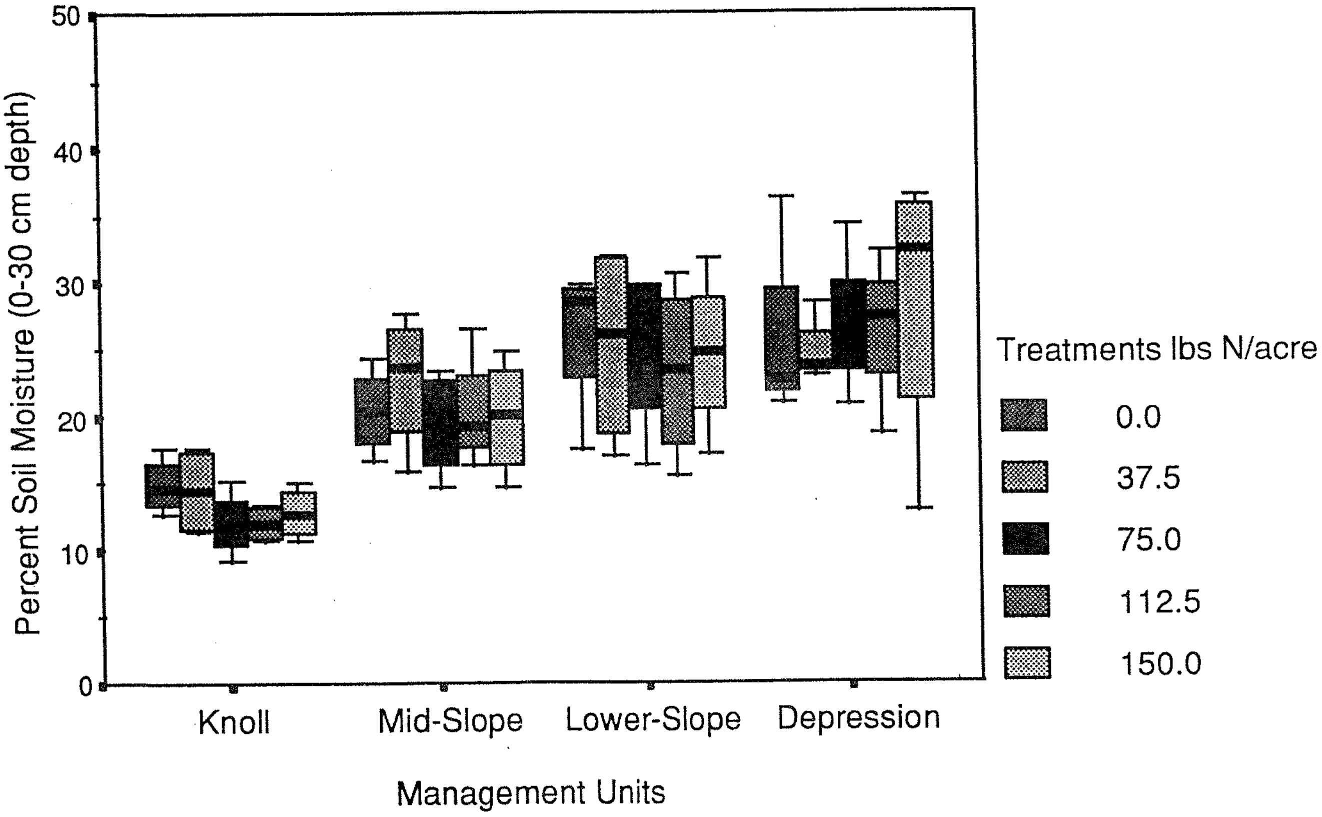
(Figure 1) Maximum and Minimum Air Temperatures for May - October 1996.



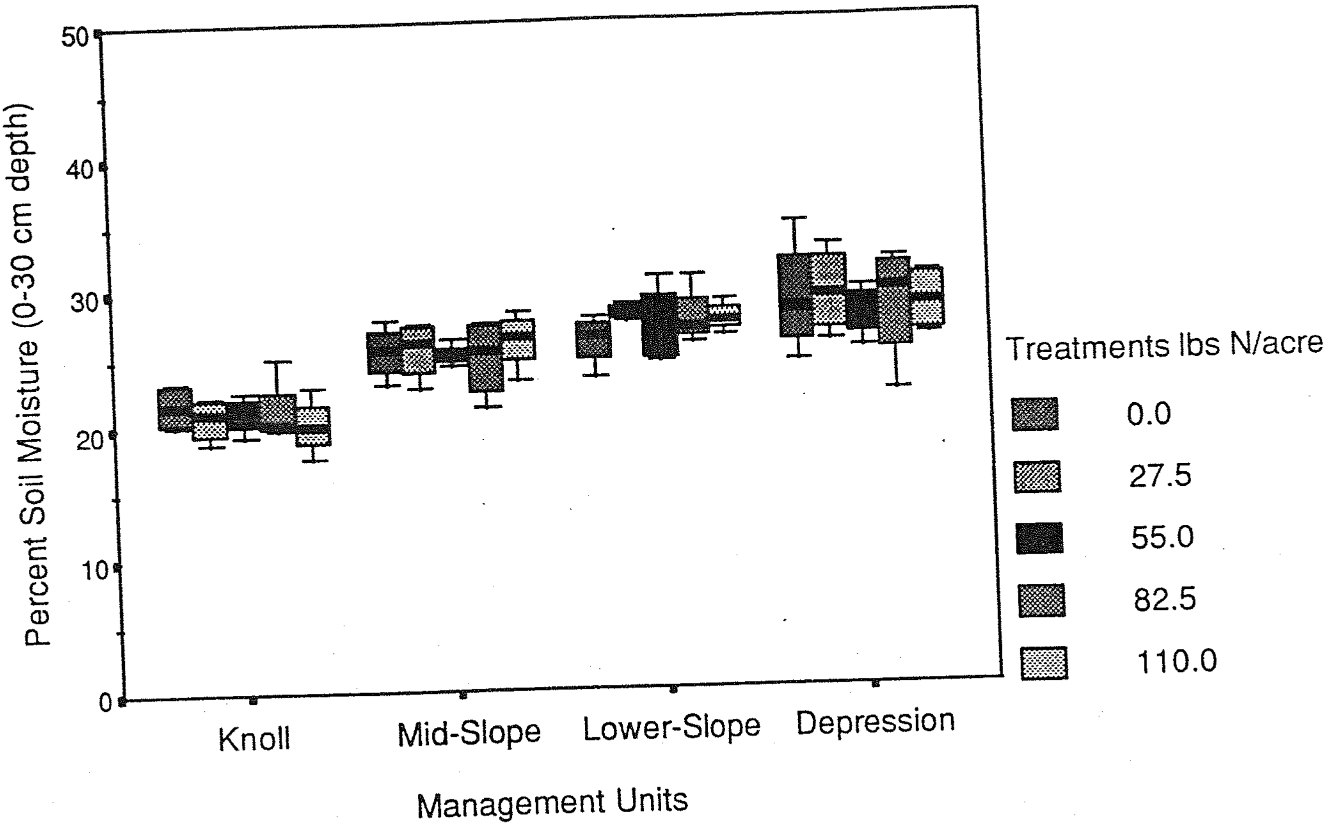
(Figure 2) Precipitation for the May - October Period 1996.



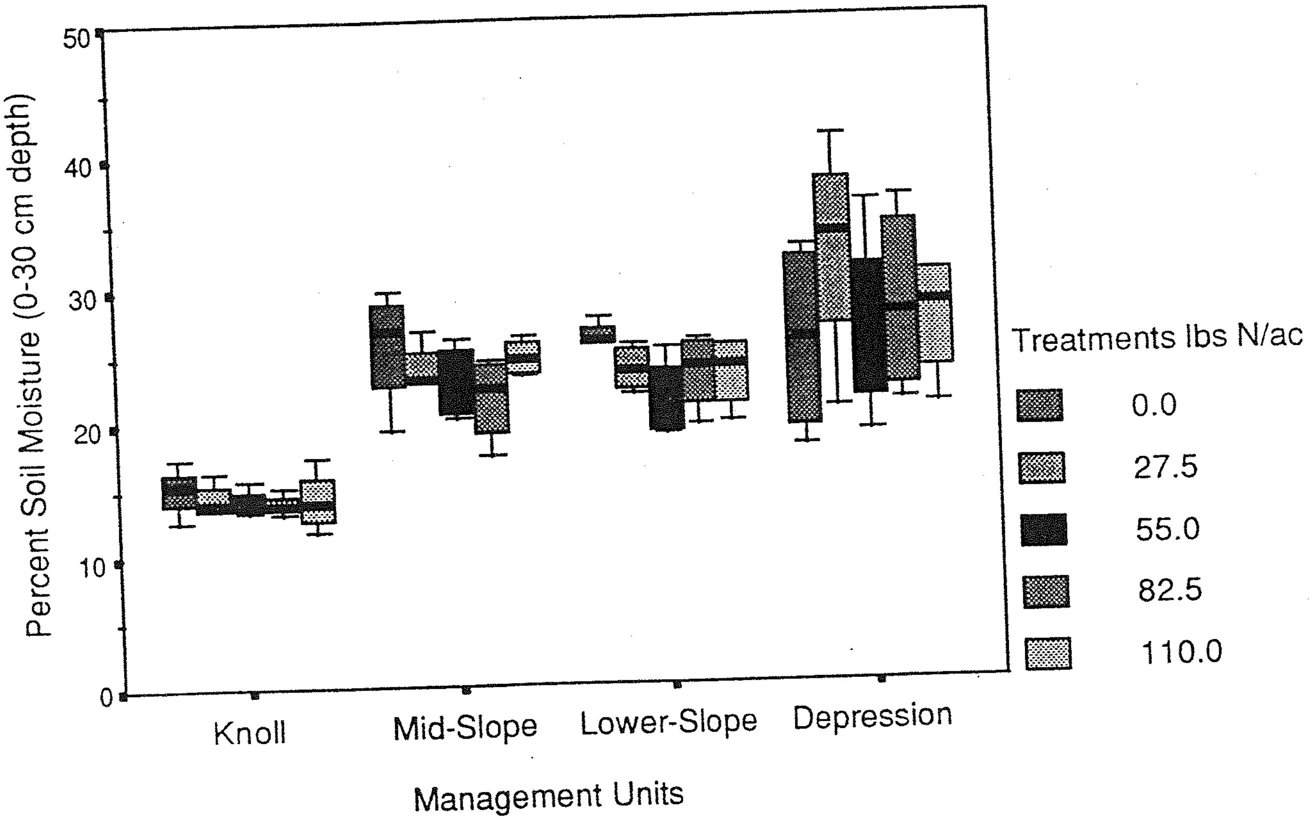
(Figure 3a) Canola Site Soil Moisture Levels for June 4, 1996.



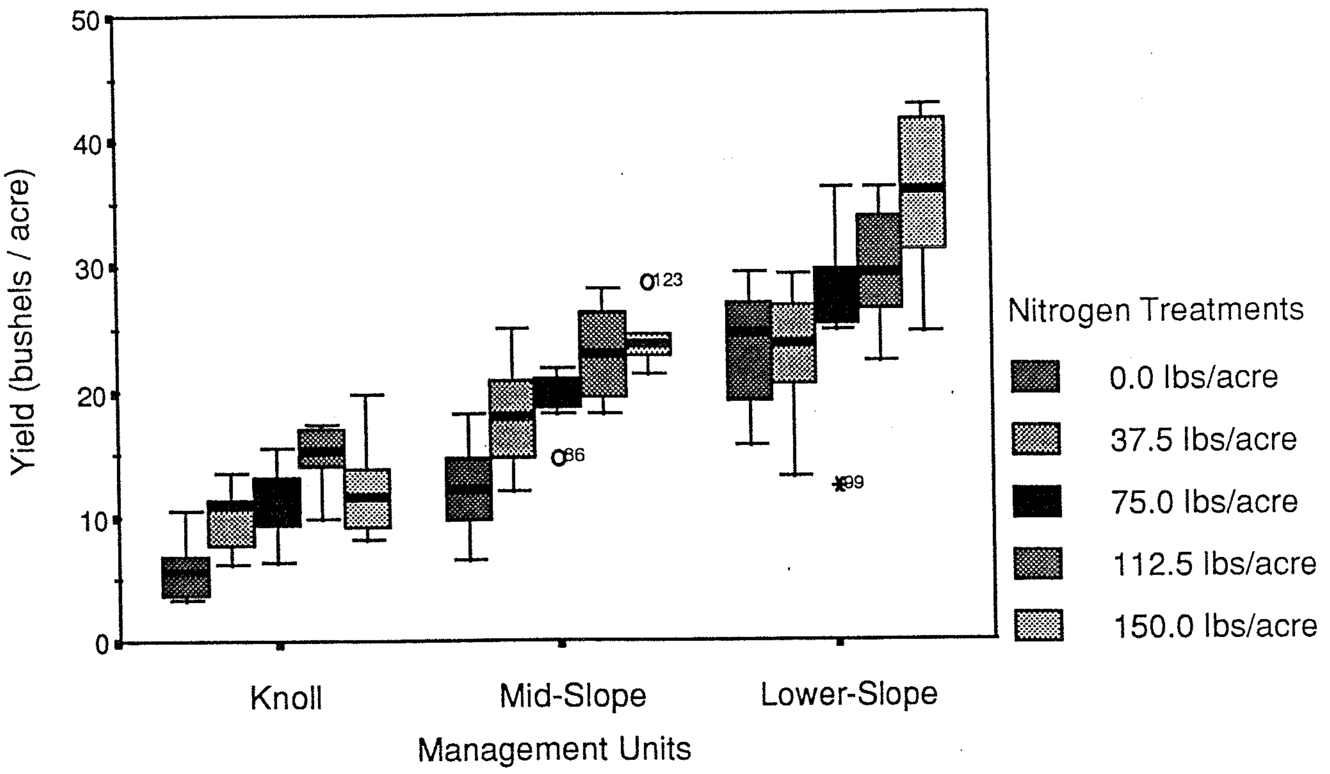
(Figure 3b) Canola Site Soil Moisture Levels for August 2, 1996.



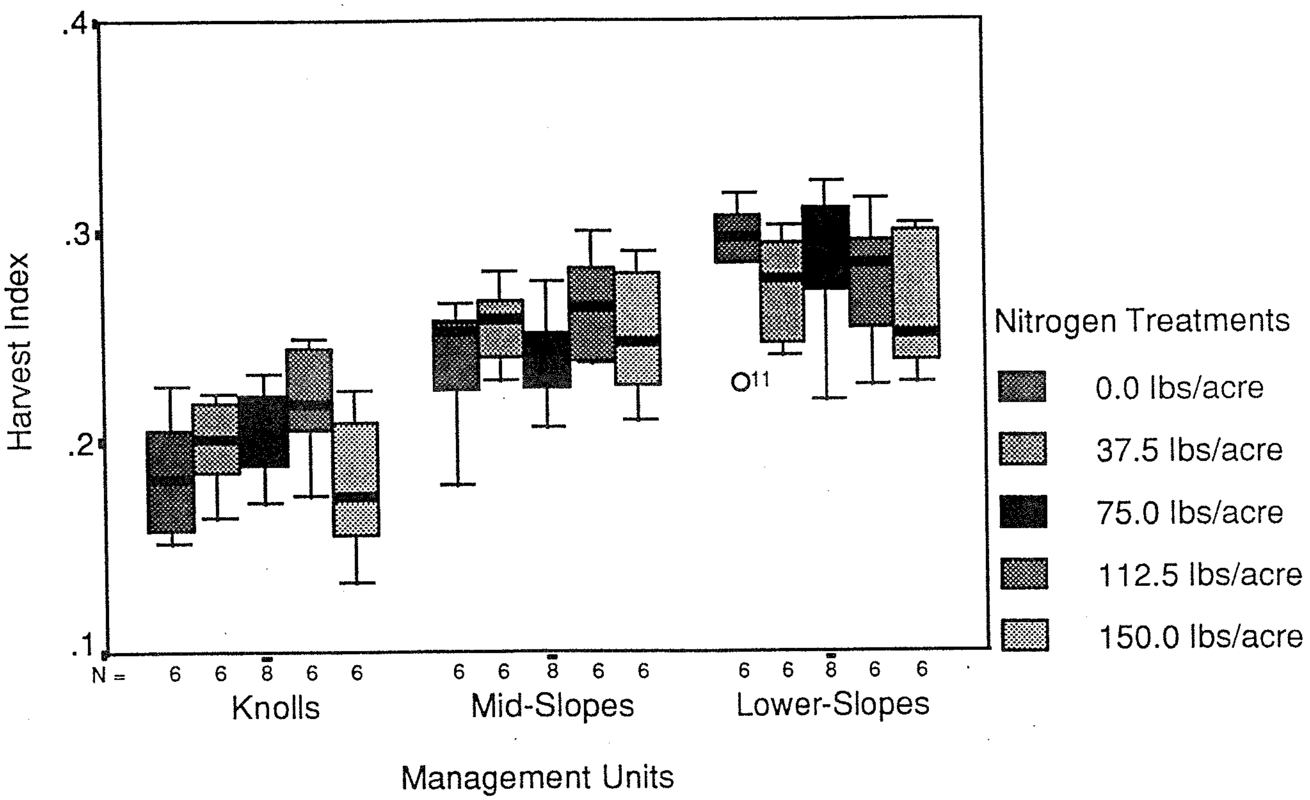
(Figure 4a) Wheat Site Soil Moisture Levels for June 6, 1996.



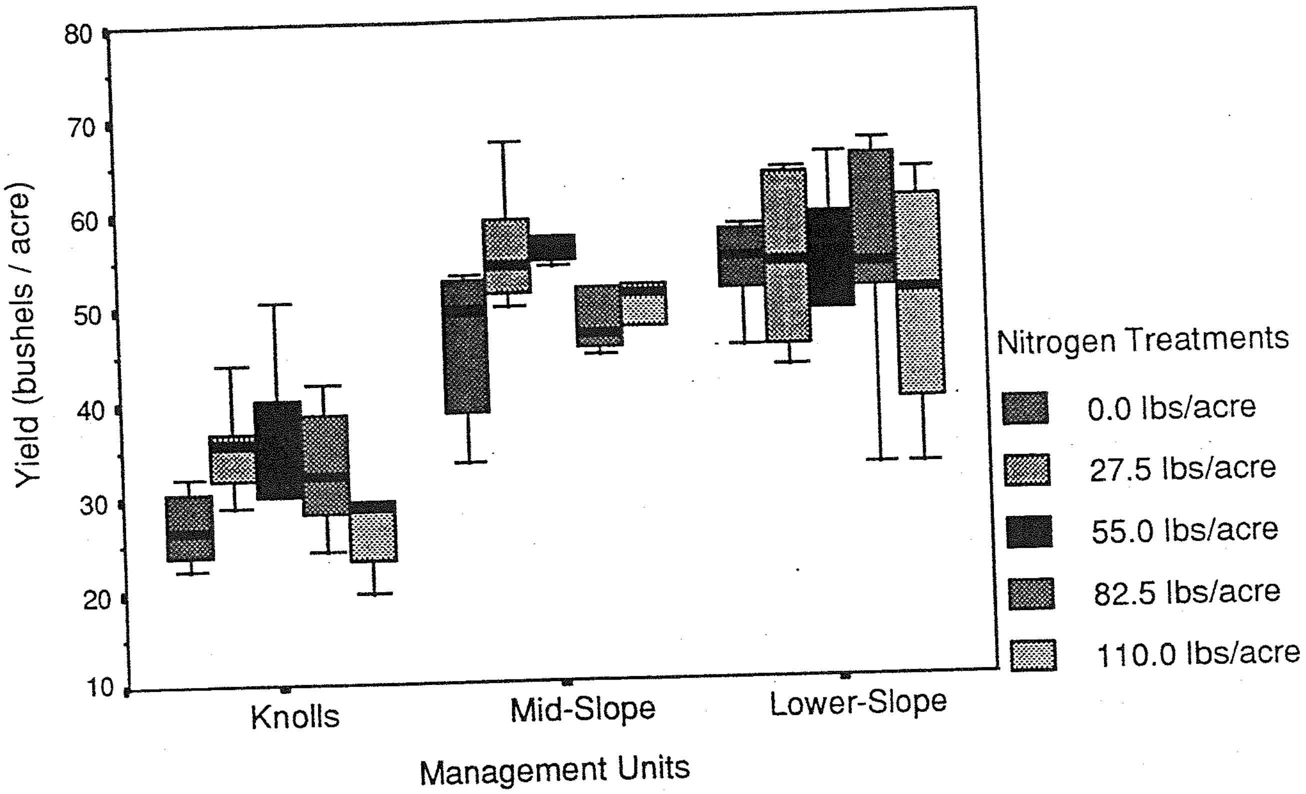
(Figure 4b) Soil Moisture Levels for August 2, 1996.



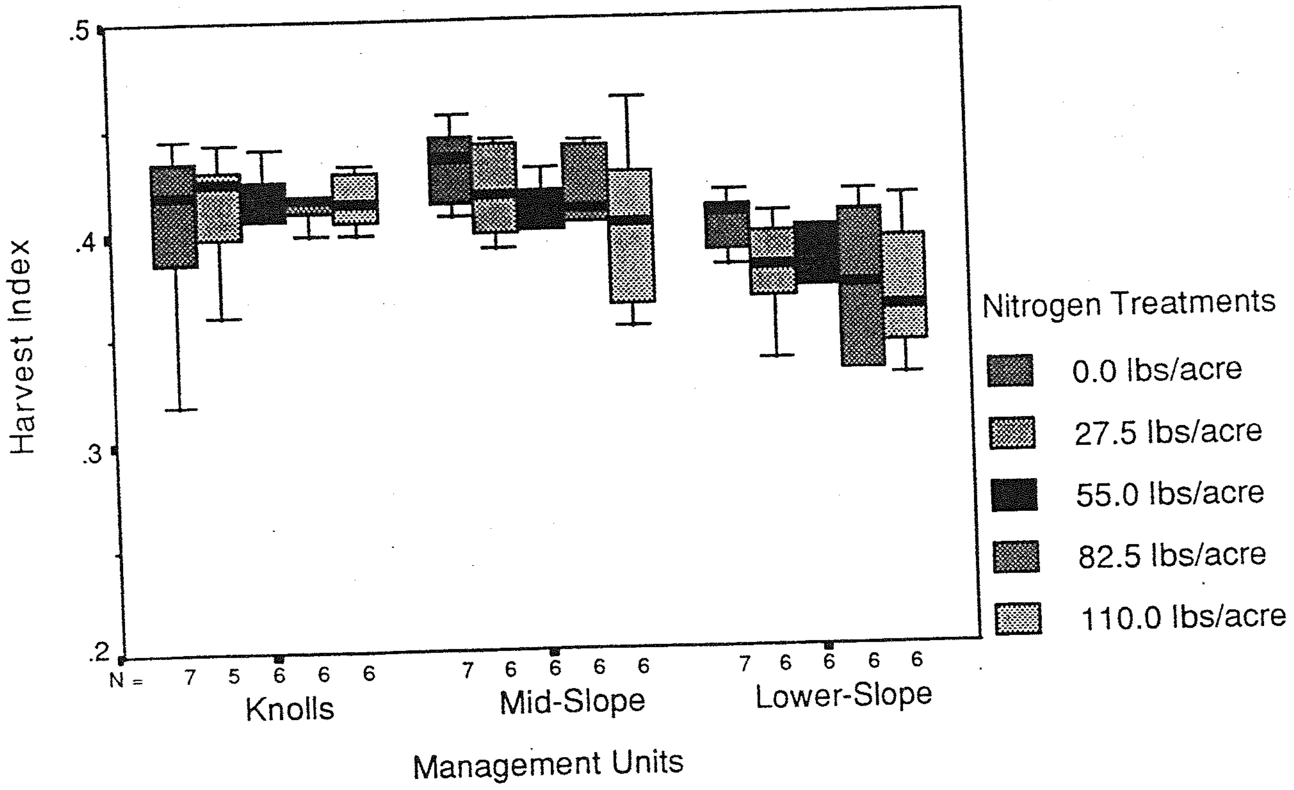
(Figure 5) Canola Site Yield Data.



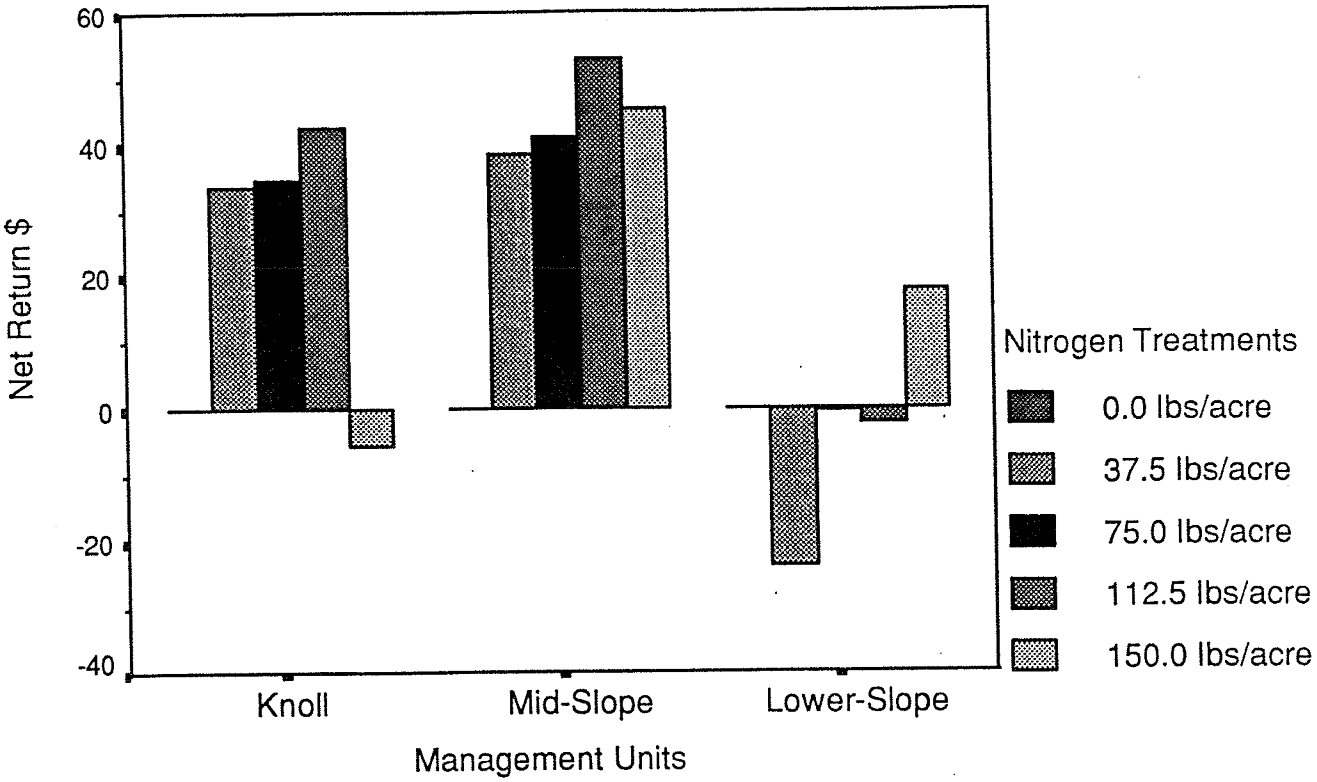
(Figure 6) Canola Site Harvest Index Data.



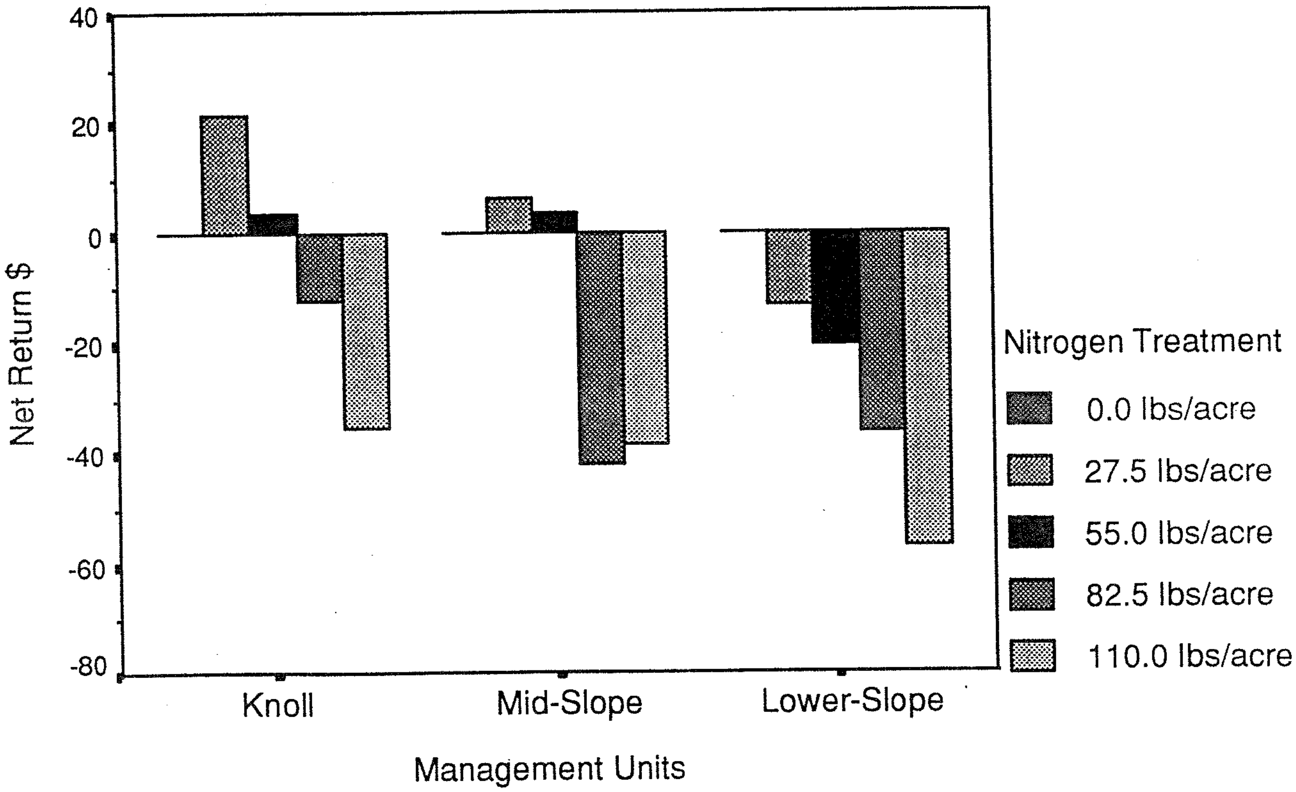
(Figure 7) Wheat Site Yield Data.



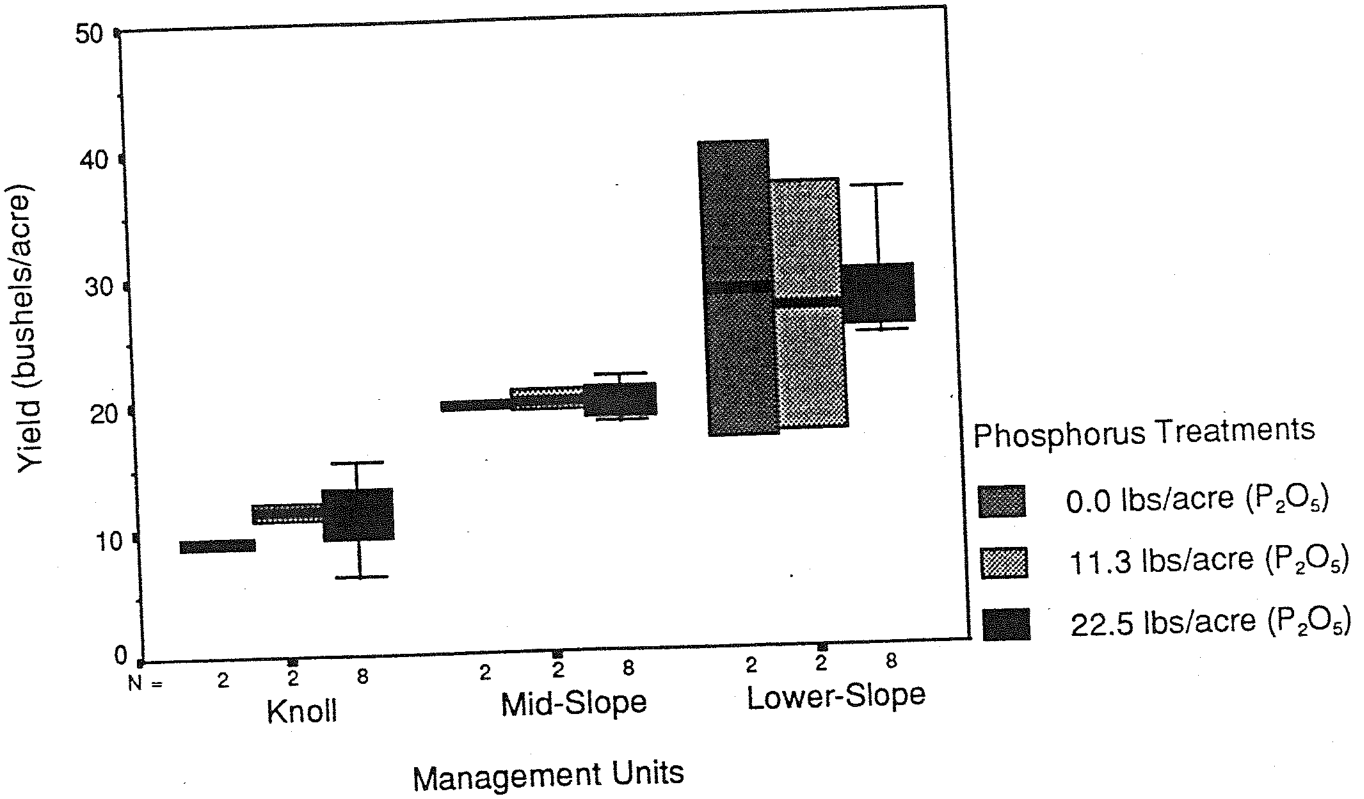
(Figure 8) Wheat Site Harvest Index Data.



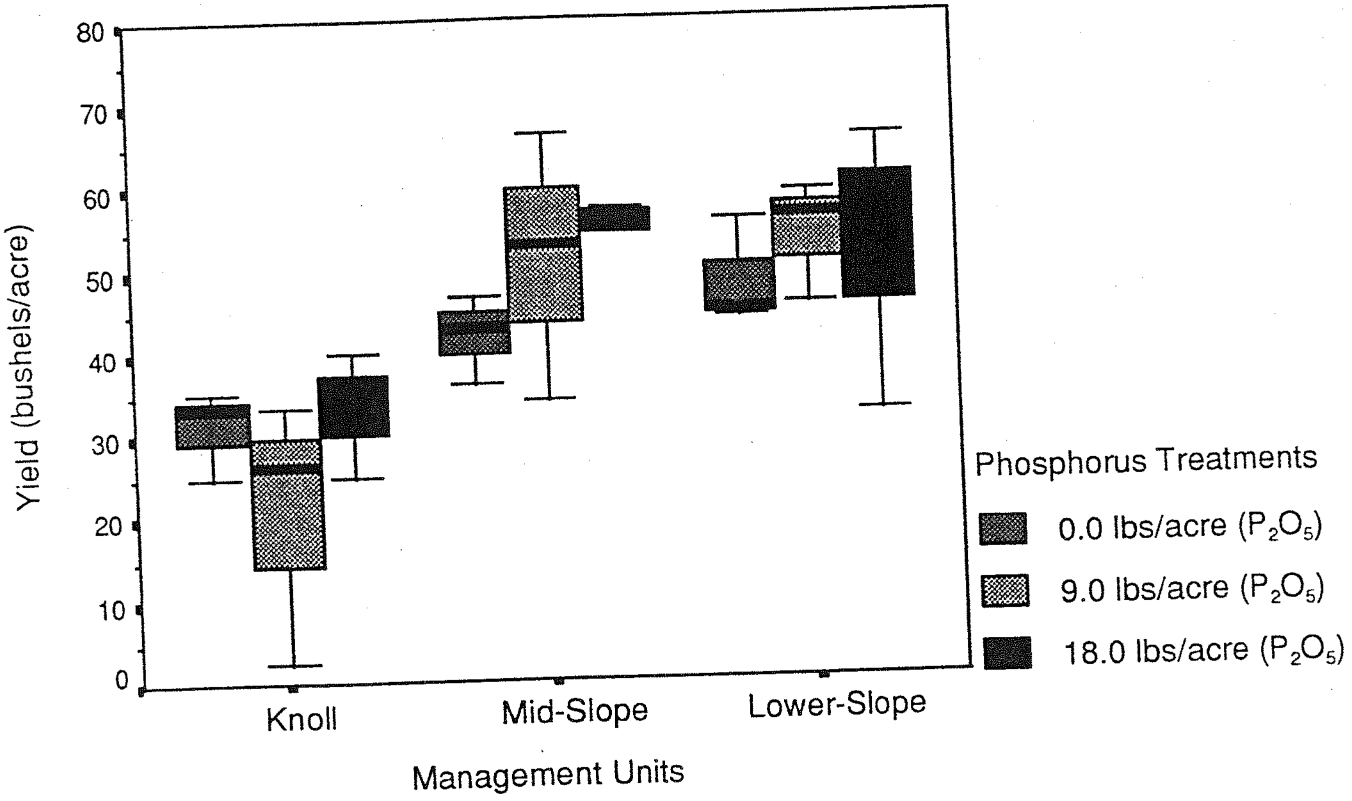
(Figure 9) Canola Site Net Returns.



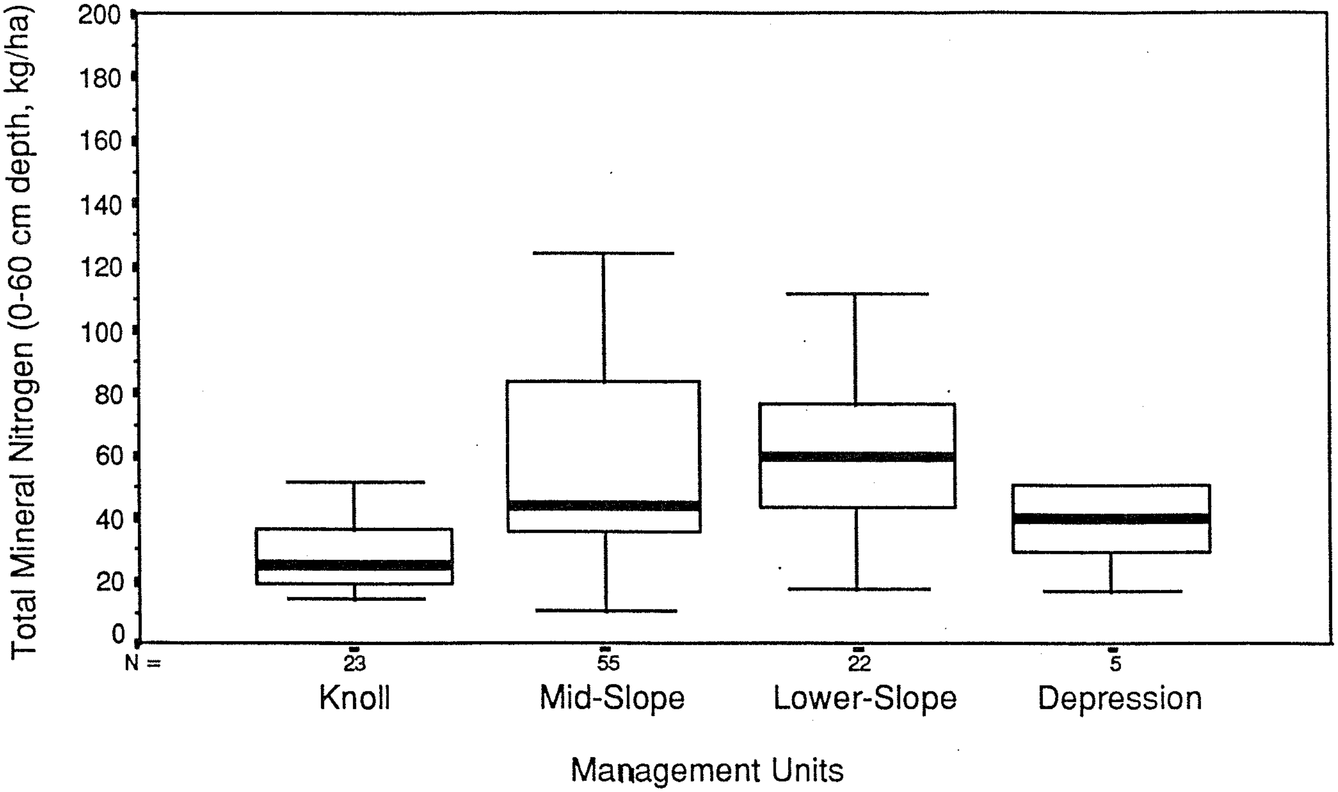
(Figure 10) Wheat Site Net Returns.



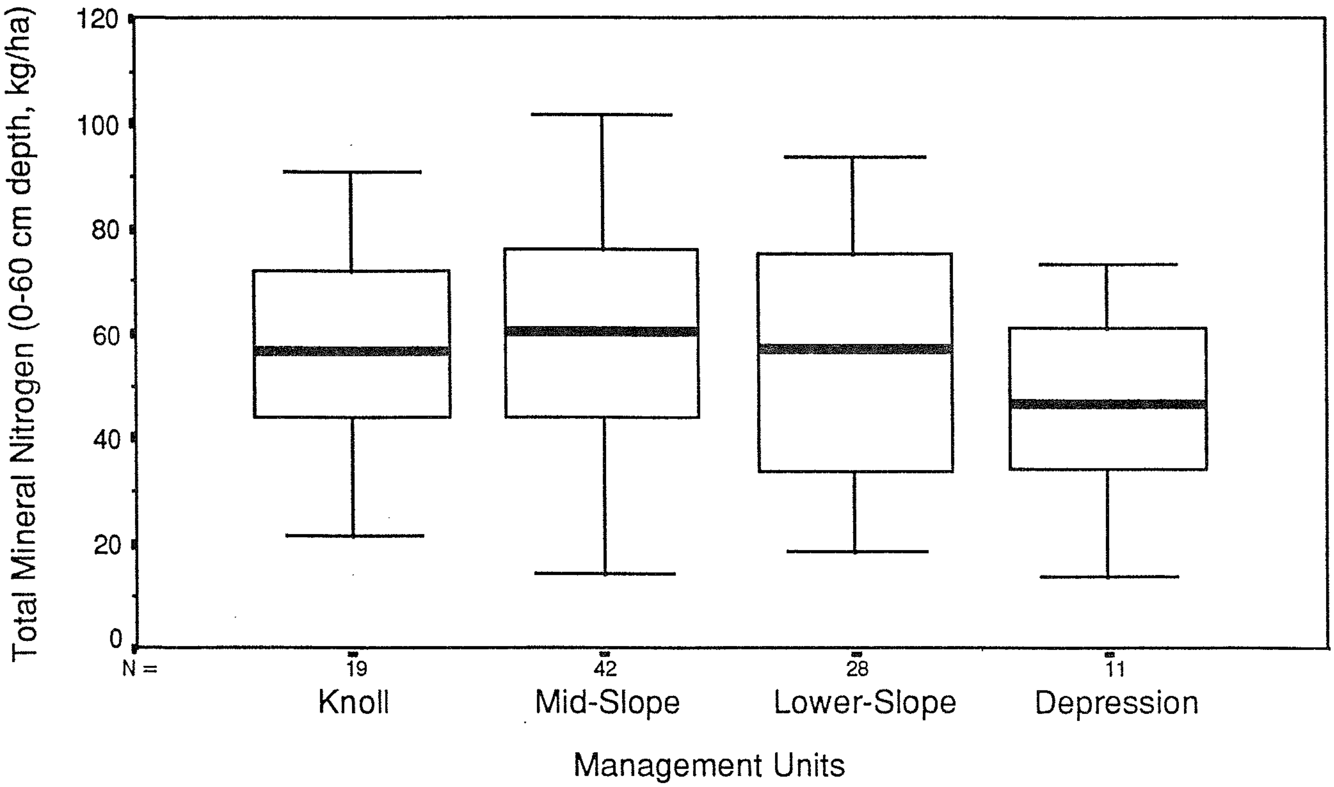
(Figure 11) Canola Site Yield Responses to Phosphorus Treatments.



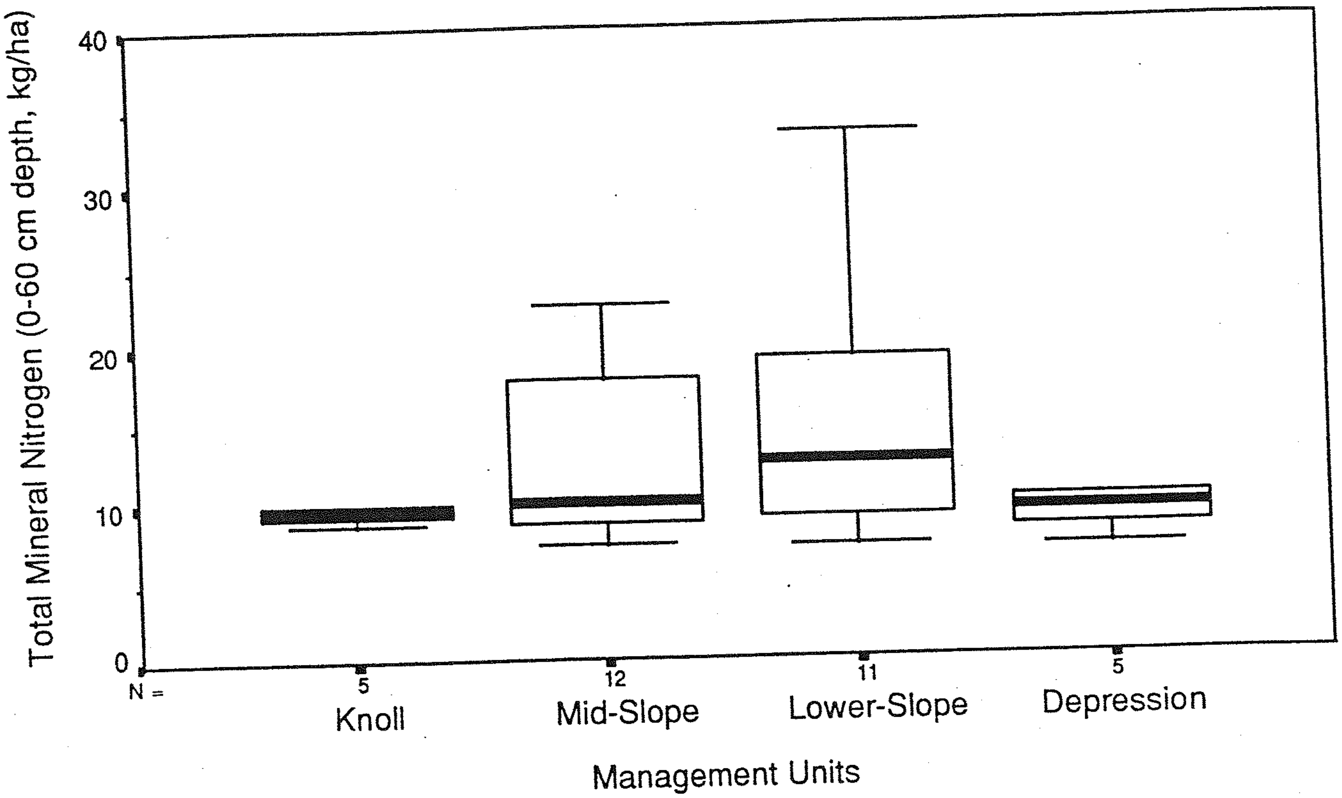
(Figure 12) Wheat Site Yield Responses to Phosphorus Treatments.



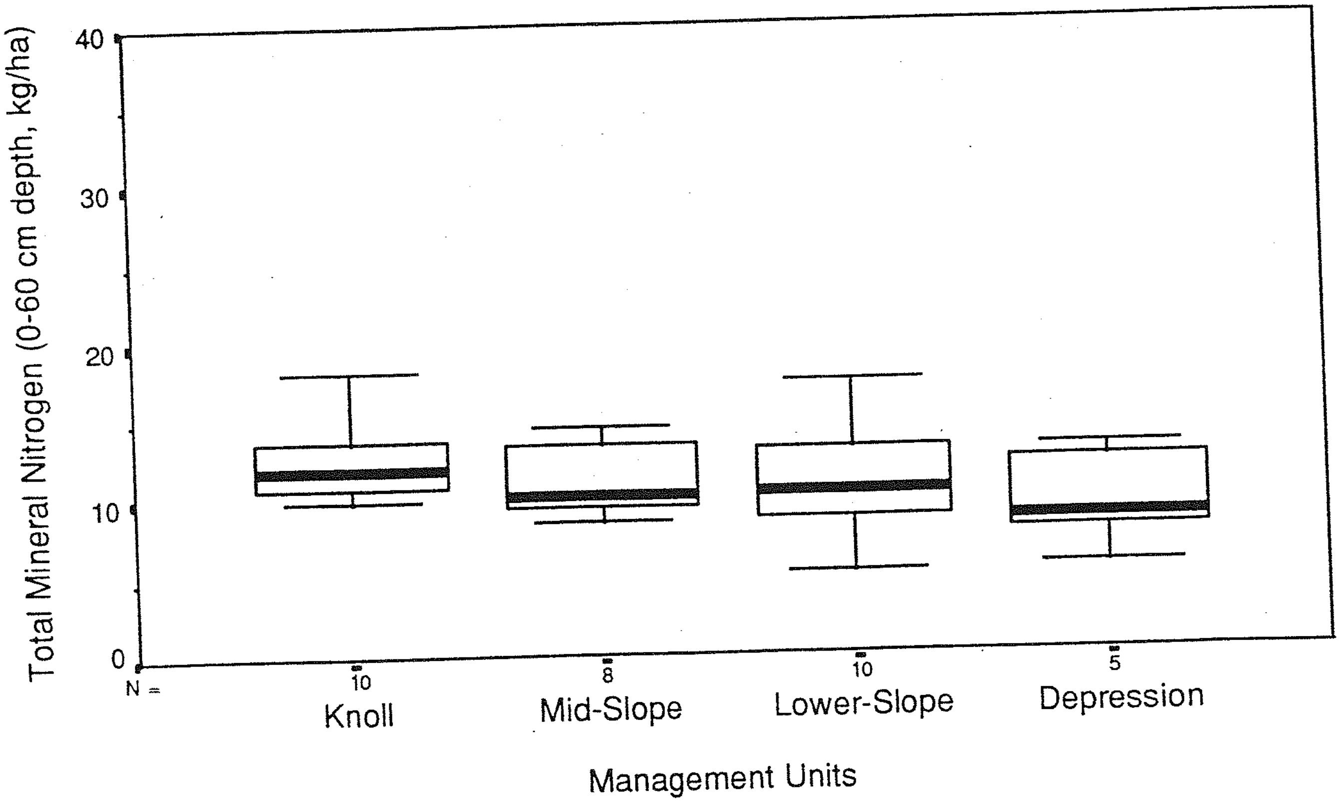
(Figure 13) Canola Site Total Mineral Nitrogen, May 1996.



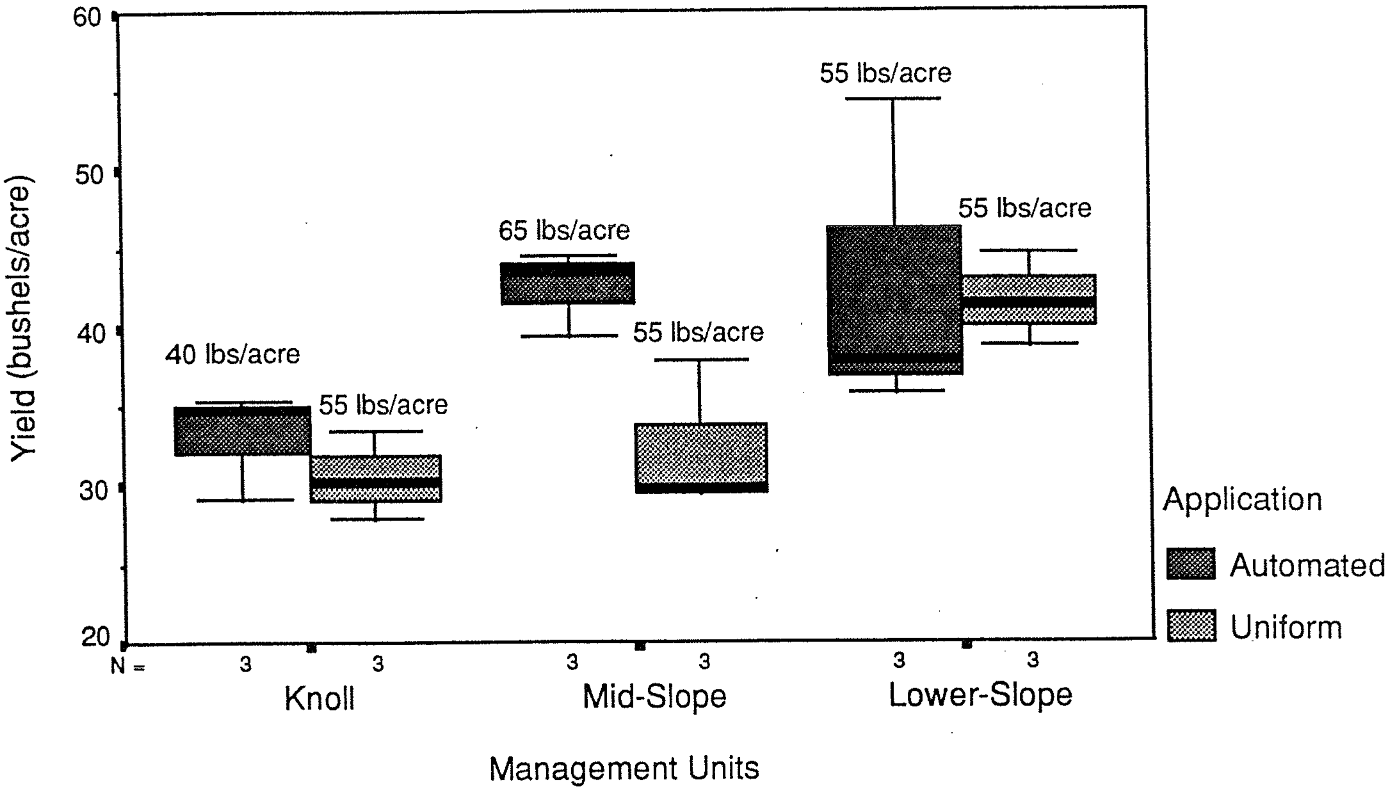
(Figure 14) Wheat Site Total Mineral Nitrogen, May 1996.



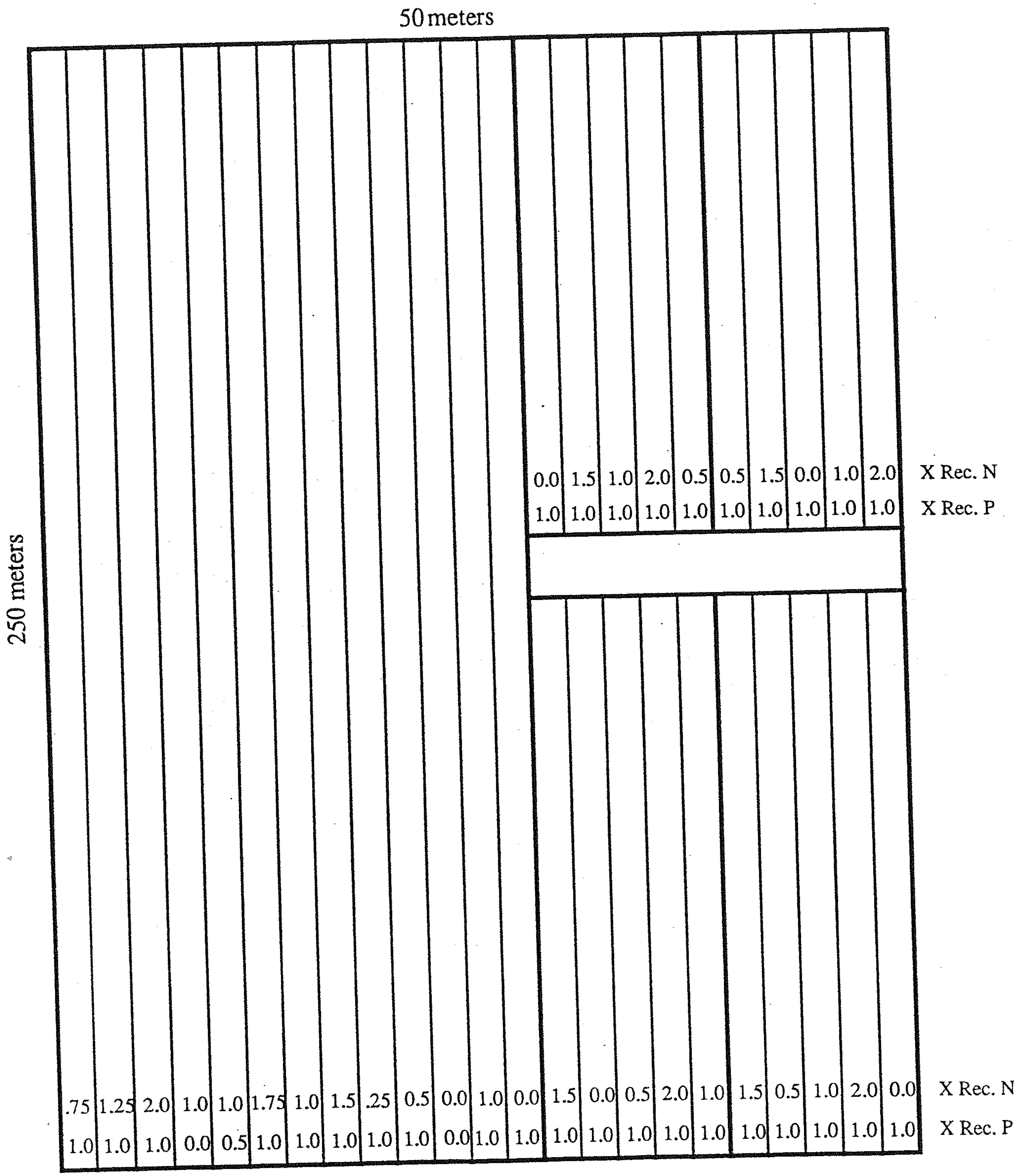
(Figure 15) Canola Site Total Mineral Nitrogen, October 1996.



(Figure 16) Wheat Site Total Mineral Nitrogen, October 1996.

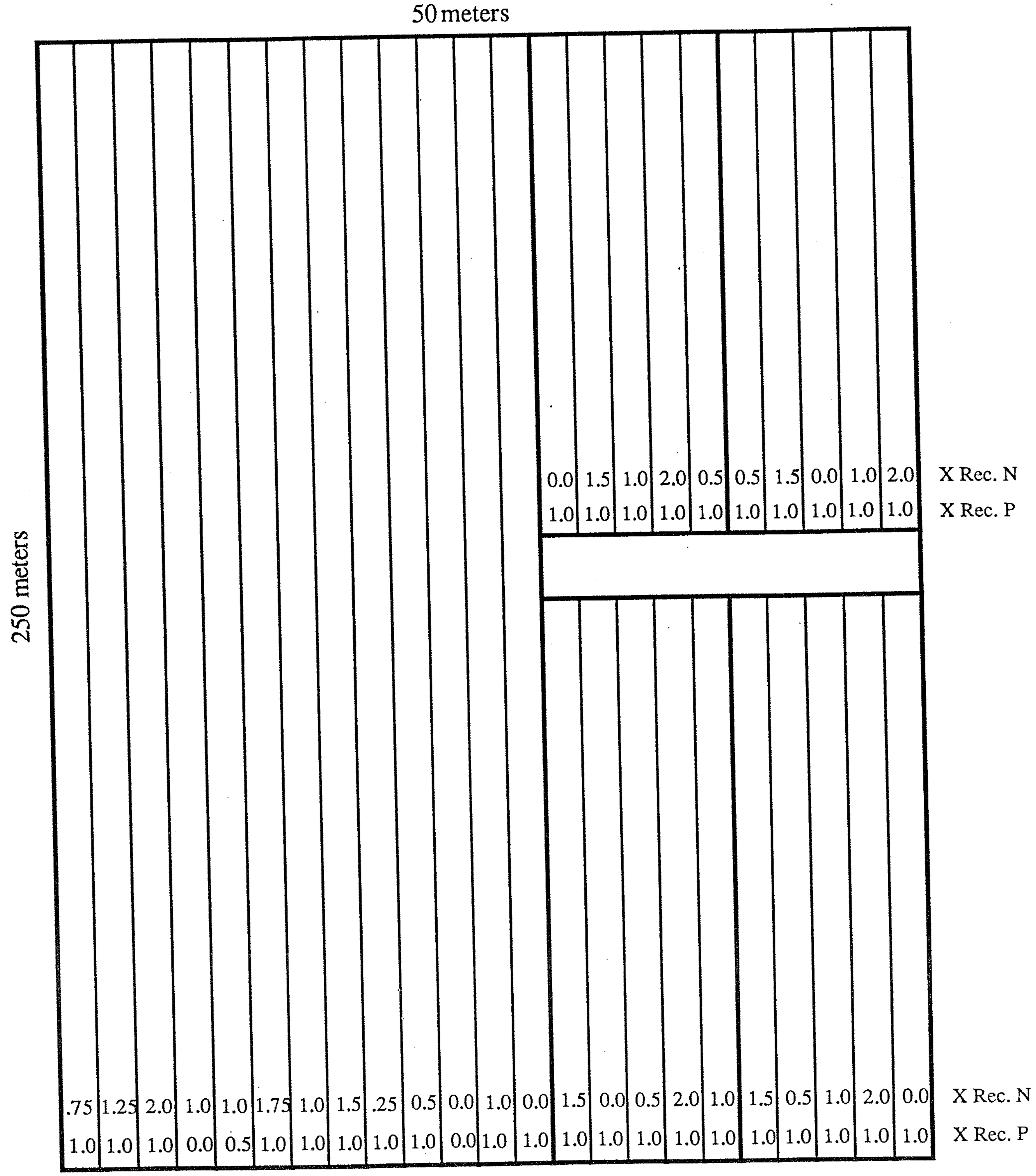


(Figure 17) Yield Responses to Automated vs. Uniform Nitrogen Applications.



Recommended Nitrogen Rate = 75 lbs/acre (N)
Recommended Phosphate Rate = 22 lbs/acre (P_2O_5)

(Figure 18) Experimental Design for the Canola Site.



Recommended Nitrogen Rate = 55 lbs/acre (N)
Recommended Phosphate Rate = 18 lbs/acre (P_2O_5)

(Figure 19) Experimental Design for the Wheat Site.