USING HISTORICAL YIELD PATTERNS IN FIELDS AS A MANAGEMENT TOOL TO VARIABLY APPLY NITROGEN

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ABSTRACT

In whole field studies in southern Illinois a uniform rate of N application was compared with variably applied rates of N based upon historical crop yields for each field. The fields used were partitioned in "low", "medium", and "high" zones of productivity depending upon the normalized yield of the preceding 5 to 10 years of crops grown. Two formulas were used to variably apply nitrogen. One formula (VRN-One) calculated a N rate that favored more fertilizer in "high" productivity regions and less N in the "low" productivity regions (example: 1.4 lb N/bu of expected yield in "high" and 1.0 lb N/bu in "low"). The second formula (VRN-Two) was the reversal of the previously described formula in which lower N rates (1.0 lb N/bu) were applied in the "high" productivity regions and higher N rates were applied (1.4 lb N/bu) in the "low" productivity regions. The outcome was that neither formula significantly increased corn yields compared to the uniform application rate based upon the whole field average yield. The average amount of N applied among the three formulas varied between 150 and 160 lb N/acre (168 and 179 kg N/hectare). Small plot data revealed that the less productive soils within a field (caused by poor drainage and excessive wetness) do indeed require more nitrogen to attain optimum yields under favorable seasonal conditions. It was concluded that a uniform rate of N applied to a field was in essence a variable rate of N application when within-field productivity variance was considered. Per unit of crop yield within a productivity region, more N needs to be applied in lower productivity soils and less N per unit of yield is required in highly productive soils. Residual soil nitrate levels were more a function of seasonal soil differences rather than employment of any specific formula for varying N rate.

INTRODUCTION

Increasing numbers of growers have accumulated several years of crop yield data, using yield monitors, in fields where historical patterns of above-average and below-average yields have been obtained. That is, high-yielding and low-yielding areas have been found to assume somewhat similar patterns year after year regardless of the growing season or crop species being grown. These areas in fields that vary in productivity should likely be fertilized differently (as crop removal of nutrients would vary) and would be a basis for variable-rate fertilizer application. However, most producers apply uniform rates of fertilizers to their soils even though known productivity differences occur.

Varying the rate of nitrogen (N) within a field to the soil's productivity potential should improve the overall crop N use efficiency. Conventional wisdom would suggest that soils with a potential for high yields should receive more N and lower productivity soils in fields should receive less N because of lower yields. A number of previous reports (Carr et al., 1991; Kitchen et al., 1995; Redulla et al., 1996; Sawyer, 1994) have suggested this or comparable approaches to whole-field variable rate fertilization.

With the advent of variable rate technology (VRT) and recent advances in fertilizer equipment, application rates can be tailored and varied as one traverses the field. It was the objective of this research to determine if agronomic, economic, and environmental benefits can be obtained by varying N application rates across the field as differing productivity areas are encountered. This would be compared with the standard practice of uniform N application based upon the average yield for the whole field.

The research contained in this report is described in three parts. First, a whole-field comparison of two variable N application formula methods will be made with a fixed (uniform) rate of N application. A second phase of this research will evaluate the response of corn to rates of N (with and without *nitrapyrin*) within selected historical low, medium, and high productivity regions of the field as a small plot study. The third aspect of this research will be to evaluate residual soil profile nitrate in the whole field and small plot studies following corn harvest to assess the efficacy of the treatments to reduce soil nitrates.

MATERIALS AND METHODS

A three-year study (2000-2002) was conducted in fields of a southern Illinois producer/cooperator, Mr. G. Kelly Robertson in Franklin County, Illinois. The same 27-acre field was used in the 2000 and 2002 studies and a 39-acre field was used in 2001. A corn-soybean rotation had been followed in these fields for the previous 10 years and yield monitor data and associated yield maps were available since 1994. The dominant soil type in the fields was Cisne silt loam (fine, smectitic, mesic Vertic Albaqualfs) with a slope of 0-2 percent. A smaller amount of Hoyleton silt loam (fine, smectitic, mesic Aquertic Hapludalfs) with a slope of 2-4 percent was also present. The major limiting factor and a contributor to low productivity areas within the fields was the occurrence of wet spots which restricted root development and plant growth. Tile drainage is not normally practiced because of a dense clay layer in the subsoil that restricts excess moisture drainage.

A normalized yield (NY) map of each field (given in Figures 1 and 2) shows the distribution of low, medium, and high productivity regions in each field. The 27-acre field (used for the 2000 and 2002 experiments) had about 7.9 acres with a NY of less than 90% (low), 12.5 acres with a NY of 90-110% (medium), and 6.8 acres with a NY greater than 110% (high). The 39-acre field used in 2001 had less within field historical yield variability. Low (<95% NY) productivity comprised 13.1 acres, medium (95-105% NY) made up 12.5 acres, and high productivity (>105% NY) areas occurred on 13.6 acres. The numerical points given in Figures 1 and 2 represent sampling point locations for post-harvest soil profile nitrates and sampling locations for ear-leaf N, stalk nitrates, and yield estimates. The average yield of the previous 5 corn-crop years for the 27-acre field was 160 bu/acre and was 165 bu/acre for the 39-acre field. Normalized yield is determined as the yield observed in each 60 foot by 60 foot grid divided by the field average yield.

Two computational methods of variable rate (VRN) application were used as a comparison with the uniform rate of N. The first method, referenced as VRN-One is based upon varying the applied N rate according to the normalized, historical yield zones as they are encountered when traversing the field. The formula for VRN-One is 1.2 times normalized (proven) yield within a cell less a soybean credit of 40 lb N/acre. This method essentially reduces N rates when proven, established yields are less than 100% and increases N rates when proven yields exceed 100%. The second variable N rate method, referred to as VRN-Two, essentially reverses the process of VRN-One. That is, it increases N rates in lower productivity areas (<90% NY) and decreases N rates when normalized yields exceed 110%. The formula for VRN-Two is 1.2 times normalized (proven) yield minus a 40 lb N/acre soybean credit for 90-110% yield levels; 1.0 times normalized yield minus a 40 lb N/acre soybean credit for yields greater than 110%; and 1.4 times normalized yield minus a 40 lb N/acre soybean credit for proven yields less than 90%. Uniform N application is based upon the field average yields of 160 and 165 bu/acre for the 27-acre and 39-acre fields, respectively. The uniform rate of N applied would be 152 and 158 lb N/acre for the two fields(example for 160 bu/acre average corn yield: (160 bu/acre x 1.2 lb N/bu)-40 lb N/acre soybean credit = 152 lb N/acre). Figure 3 shows graphically how N rates were applied in relation to normalized yield for the two computational methods in comparison to the uniform N application.

Variable application of N (as anhydrous ammonia) was accomplished with a controller on the applicator programmed in synchrony with a prescription map of the soil productivity indexes (normalized yield map) on a computer in the tractor. Both uniform and variable rate strips were 30 feet wide (12 rows) for the entire length of the field, excluding headlands. The toolbar was equipped with shanks spaced between each row, and the anhydrous ammonia was applied as a sidedressing to corn at the five-leaf stage of development.

The second phase of this research was a small plot evaluation of N rate and *nitrapyrin* use on corn grown in field areas identified as having low, medium, and high historical productivity. Low had normalized yields <90%, medium had normalized yields 90-110%, and high had normalized yields >110%. Nitrogen rate treatments selected were equivalent to 0.8, 1.0, 1.2, 1.4, 1.6, and 1.8 lb N/bu of expected yield, plus a zero-N check. *Nitrapyrin* as Stay-N 2000 was included with the N for the 0.8, 1.0, 1.2, 1.4, and 1.6 lb N/bu application treatments. A summary of the treatments is given in Table 1. All nitrogen treatments were replicated 3 times within a randomized, complete block arrangement in each of the productivity zones. Individual plot sizes were 15 feet (6 rows) wide by 35 feet long. The nitrogen source was 28% N UAN solution knifed in with an alternate row shank applicator. Application of N was at the five-leaf stage of development. Measurements taken included ear-leaf N at silking, grain moisture content, and grain yield.

The third phase of this research was soil profile nitrate concentrations found as residual N following harvest. Duplicate two-inch diameter soil cores were taken (with a tractor-mounted, hydraulic probe) to a 36-inch depth from each designated sampling point in the whole field studies (see Figures 1 and 2) and from the Check, 120, 150, and 180 lb N/acre treatments (with and without *nitrapyrin*) in the small plot studies. The duplicate cores taken were divided into 12-inch segments with depth and then composited as one-foot incremental samples. Soil nitrate concentration was then analyzed by a commercial laboratory (Brookside Laboratories, Inc., New Knoxville, Ohio).

RESULTS AND DISCUSSION

Whole Field Uniform N versus Variably-Applied N Results

Seasonal rainfall patterns and crop stress factors were different each year of the study. In 2000. rainfall was near ideal for corn production throughout the growing season and the whole-field averaged 214 bu/acre compared to a historical field average of 160 bu/acre. In 2001, the growing season rainfall was near normal and the whole-field average yield was 164 bu/acre which was nearly the same as the historical average of 165 bu/acre. In 2002, a severe dry period during the critical late July and early August period greatly reduced corn yields. The 2002 corn crop average was 126 bu/acre compared to a historical field average of 160 bu/acre.

The effect of the variable N application contrasted to uniform N application was different for each year of the study. In 2000, the VRN-One formula (which favored more N applied in high productivity zones and less N in low productivity zones) was the sole comparison with the uniform N application. Small hand-harvested areas in parcels of low, medium, and high productivity zones revealed the following yield results (bu/acre):

	Soil Productivity		
Application Formula	Low	Medium	High
VRN-One	191 a	210 b	239 a
Uniform N	202 a	233 a	236 a

Basically no differences were observed between the two formulas except yield in the medium productivity soils was increased using a uniform rate of N application. Data obtained from the combine yield monitor revealed a 3 bu/acre advantage for variable rate N application (using the VRN-One formula) compared to a uniform rate of N applied across productivity zones.

In 2001, the corn yields obtained generally paralleled the patterns of historical productivity in the field. Yield increased from an average of 127 bu/acre in the lowest historical yield zones (<70% NY) to an average of 184 bu/acre for the NY >110 percent. Strip yield comparison of the uniform N treatment with the two variable N formulas, as obtained from combine yield monitor data. were as follows:

Application Formula	Acres	N Applied (lb N/acre)	Yield (bu/acre)
VRN-One	11.2	153	168.3
VRN-Two	11.1	153	170.2
Uniform N	11.1	158	169.6

There was no significant difference among the yields obtained. and if any benefits did accrue, it was due to less N being applied and slightly more yield being obtained. Both, in all probability did not offset the cost of the increased technology required to make the variable rate applications.

In 2002. adverse summer growing conditions caused reduced corn yields. The yields obtained using the two formulas were both less than those obtained from uniform N application. The average amount of N applied per acre for VRN-One was about 7 lb N/acre more than uniform N, but the amount of N applied using VRN-Two was 6 lb N/acre less than uniform N. However, the VRN-Two formula resulted in 8 bu/acre less yield being obtained. The reduced yields with VRN-Two may have been the result of insufficient N being applied in the more productive regions of the field to fully match grain yield potential under the drought stress condition. Combine yield monitor data for the strips of variably-applied N compared to uniform N rate application were as follows:

Application Formula	Acres	N Applied (lb N/acre)	Yield (bu/acre)
VRN-One	9.1	159	127.6
VRN-Two	9.1	146	121.0
Uniform N	9.1	152	129.2

Intensive N Rate Studies on Small Plots in Soils of Varying Levels of Productivity

Small plot study results of varying N rates within plots constructed in low, medium, and high productivity soils are given in Figures 4, 5. and 6 for the 2000. 2001. and 2002 crop seasons. The data presented are yield averages for N rates both receiving and not receiving *nitrapyrin* addition. In 2000. a very favorable year for corn production, yields maximized at the highest rates of applied N. Yields of corn in low zones of soil productivity increased linearly with applied N reflecting the probability of high denitrification losses in these problematic soils. Curvilinear responses to increasing N were observed for the medium and high productivity soils suggesting that more efficient use of the applied N occurred on more productive soils.

In 2001(Figure 5), the corn yields obtained paralleled the historical soil productivity zones in which the small plots were established. Curvilinear responses to applied N were observed in plots of all three productivity zones. The "calculated" optimum amount of N needed for maximum yield increased from 59 lb N/acre in the low productivity soils to 117 lb N/acre in the high productivity soils. Greater amounts of N were required to meet the higher yields obtained in the more productive soils.

In 2002 (Figure 6), overall lower corn yields were observed due to the droughty conditions that prevailed during critical growing periods. The low productivity soils had lower overall yields across all N rates compared to the other two levels of productivity. However. yields in medium productivity soils exceeded those in soils of historically high productivity, likely because of the better drainage and the loss of subsoil moisture retention during the drought period. The "calculated" optimum amount of N which should be applied varied from 126 to 171 lb N/acre.

The effect on corn yield from *nitrapyrin* inclusion with the applied N across all three years and three levels of soil productivity is given in Figure 7. A significant increase in yield with *nitrapyrin* was observed only during the 2000 season, and then specifically in the low productivity soils. This was probably expected because of the high rainfall received and the persistence of wetness in these poorly-drained soils. Denitrification was the likely N loss pathway that was reduced by *nitrapyrin* and probably results in more of the applied N being used by the corn crop. Figure 8 shows the overall effect of *nitrapyrin* use in optimizing N utilization per bushel of corn produced. In 88 percent of the comparisons shown in Figure 8, a lower amount of N was calculated to be required to produce a bushel of corn when *nitrapyrin* was added compared to its non use.

Residual Soil Nitrate

Nitrates found in soils of the whole field variable N rate studies following corn harvest are shown in Figures 9 and 10. There was more variation in residual nitrates between seasons than there was between formulas used to vary N rates. Uniform N application did not result in any more residual nitrate being present in the soil than either of the variable rate N formulas used. Soil nitrates observed in 2002 were especially high in the 12-24 inch increment (Figure 10) compared to surface soil (Figure 9). Movement of nitrates into the subsurface must have occurred prior to the onset of the mid-season drought. Nitrate levels in the 2 to 3 foot increment depth (data not shown) decreased to around 5 ppm N and were not influenced by the formula used. Of particular note was the high nitrate levels observed in both the 0-12 inch and 12-24 inch increments in high productivity soils. These high levels were observed when using the VRN-One formula which favored higher N application in higher productivity soils.

Residual soil nitrates found in the small plot experiments from 2000 through 2002 are given in Figures 11, 12, and 13. Each figure shows nitrate present in one-foot increments to a depth of three feet. Note that Figures 12 and 13 do not contain soil nitrate data for the 2001 season as no incremental samples below the one foot depth increment were taken. Low amounts of residual nitrate were observed in 2000 regardless of the soil productivity level in which N rates were applied or the rate of N that was applied (120, 150, and 180 lb N/acre). Amounts present ranged from 3 to 7 ppm N in the topsoil to 1 to 3 ppm N in the lower subsoil. This was also the season when very high yields were obtained (Figure 4) and likely explains the lower levels of nitrates observed. In 2002, the year of unfavorable growing conditions due to drought, large amounts of residual nitrates were found especially in the plots located in medium and high productivity soils.

Nitrapyrin inclusion with the nitrogen applied in the small plot studies did not have any consistent influence on residual soil nitrate levels (Figure 14). In most all comparisons of 2000 and 2002 data, no differences in nitrates were observed from the employment of *nitrapyrin*. In 2001, at all soil productivity levels, greater amounts of nitrate were found when *nitrapyrin* was included with the fertilizer compared to its non addition. This may have been due to less N losses occurring as a result of using the inhibitor.

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Figure 1. Normalized crop yield map for uniform versus variable rate N application, with sample collection points, Franklin Co., IL, 2000 and 2002.

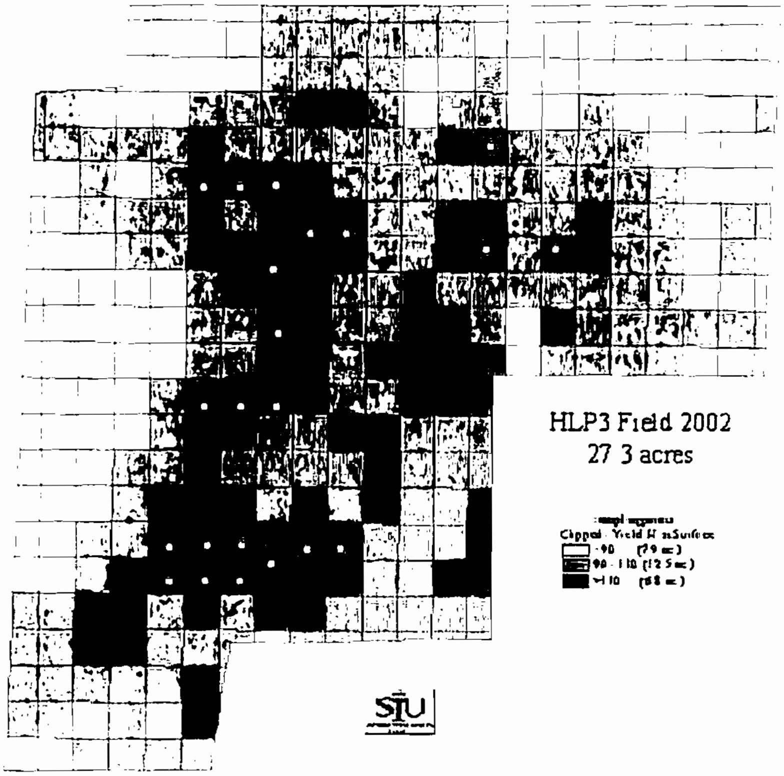


Figure 2. Normalized crop yield map for uniform versus variable rate N application, with sample collection points, Franklin Co., IL. 2001.

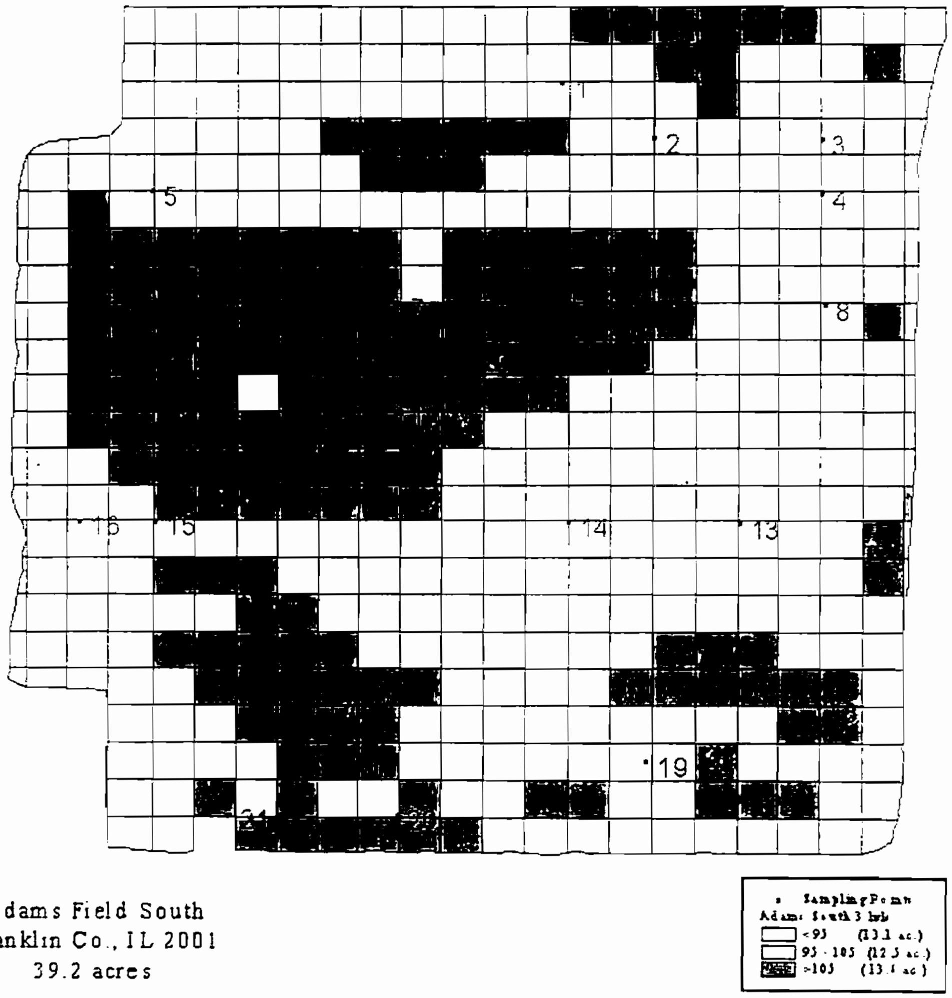


Figure 3. Predicted N to apply at Franklin Co., IL, 2000-2002.

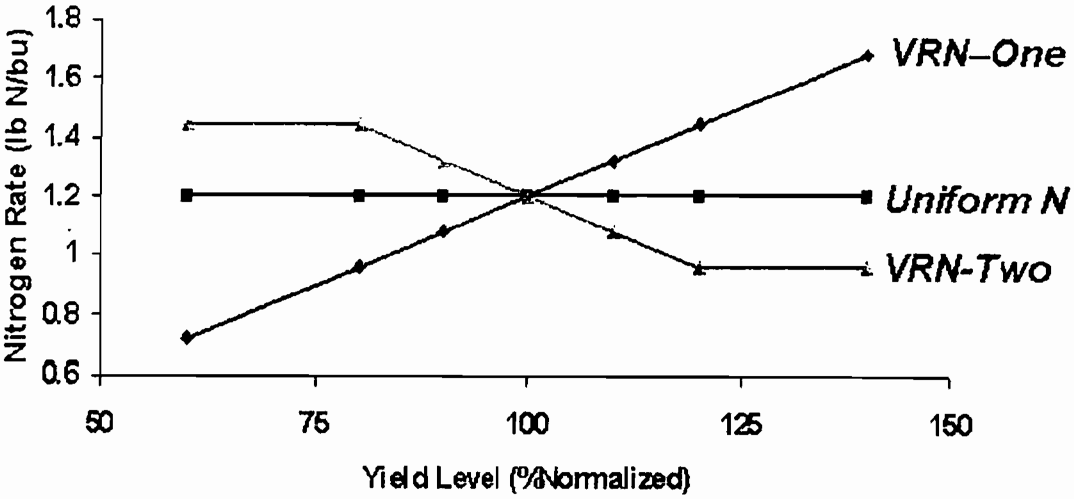
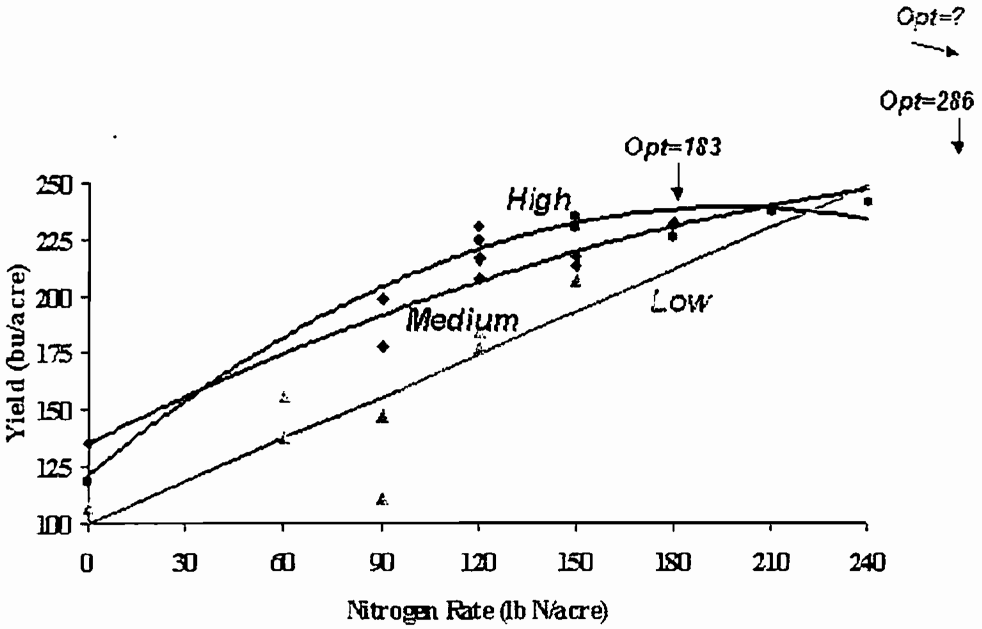


Figure 4. Effect of Nitrogen rate and soil productivity level on corn grain yield, Franklin Co., IL, 2000.



Small Plots

Figure 5. Effect of Nitrogen rate and soil productivity level on corn grain yield, Franklin Co., IL, 2001.

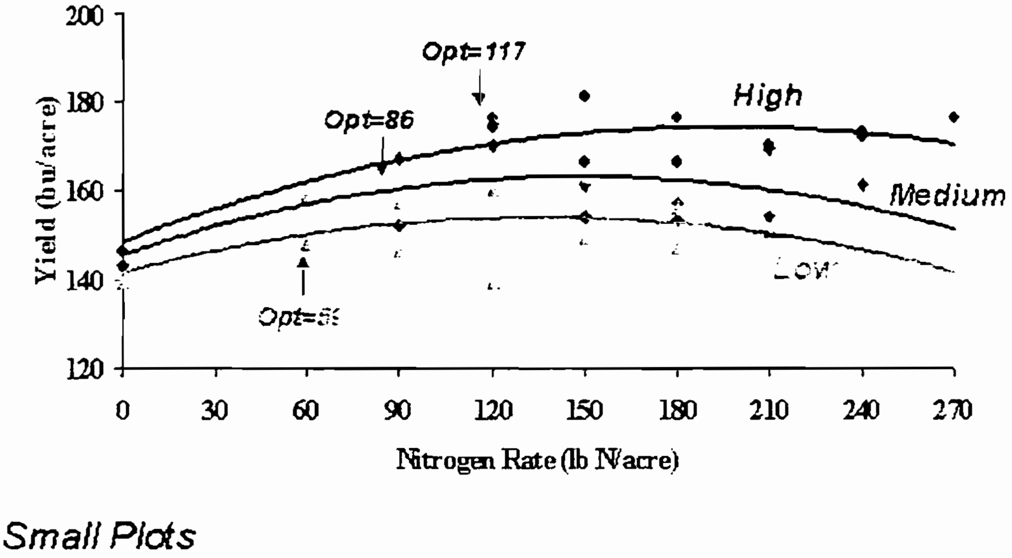


Figure 6. Effect of Nitrogen rate and soil productivity level on corn grain yield, Franklin Co., IL, 2002.

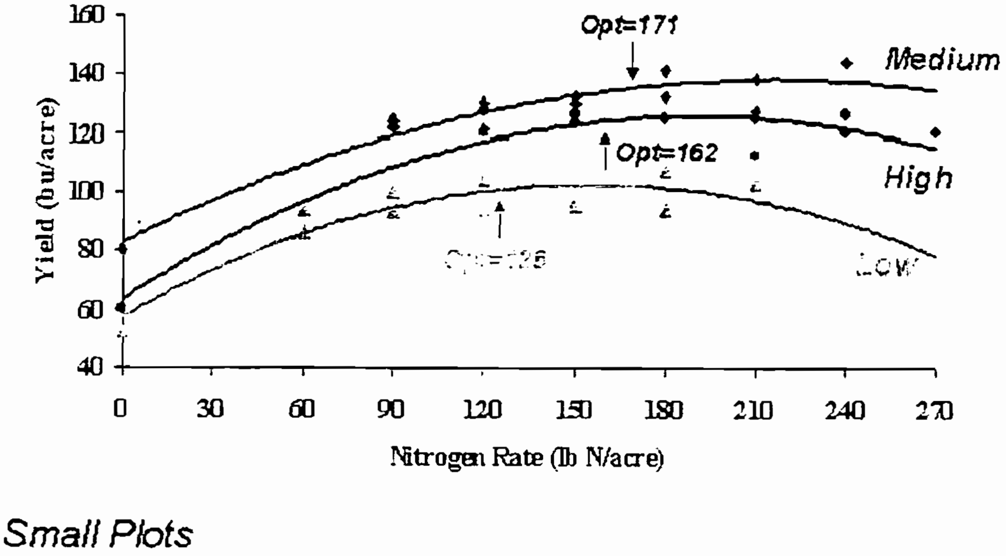


Figure 7. Corn yield as affected by Nitrapyrin on soils of Low. Medium, and High Productivity Potential, Franklin Co., IL, 2000-2002 (Small Plots).

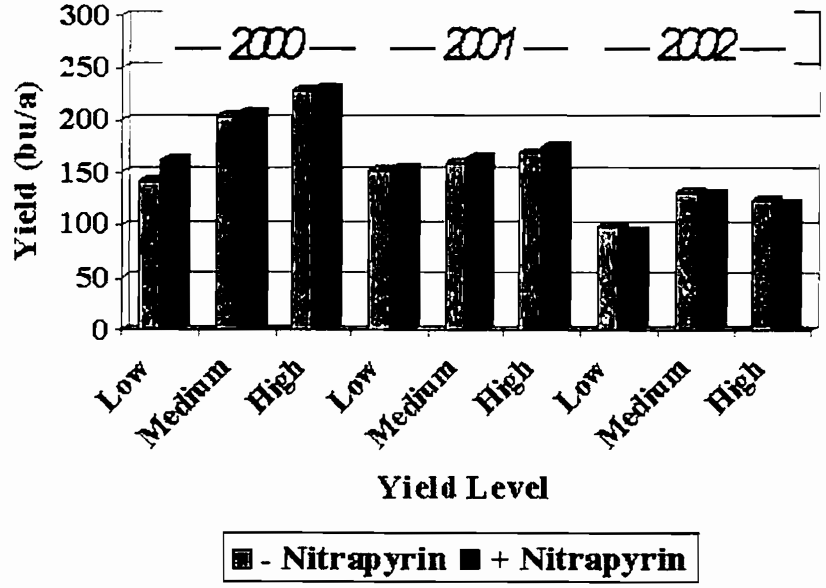


Figure 8. Nitrogen use efficiency as affected by Nitrapyrin of soils of Low, Medium, and High Productivity Potential, Franklin Co., IL, 2000-2002 (Small Plots).

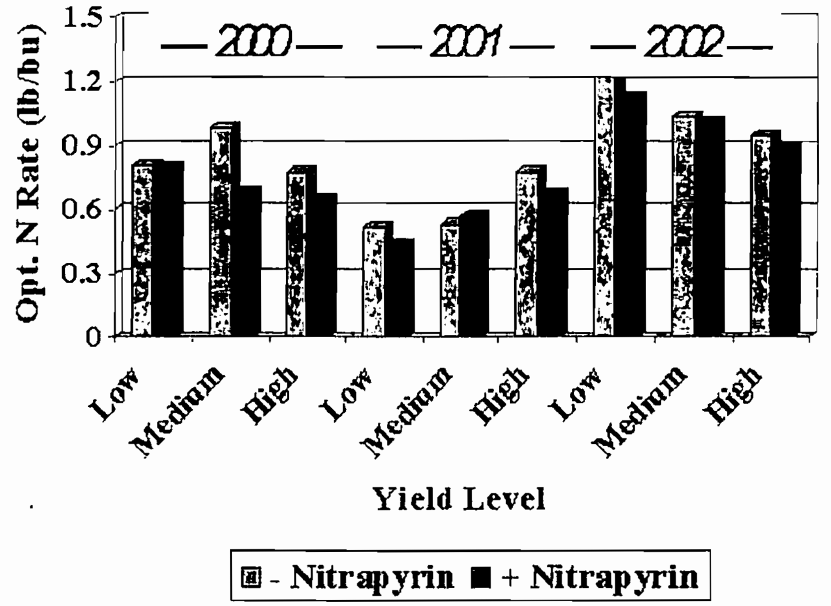


Figure 9. VRN Whole Field Study, 0-12 inch Soil Nitrate Levels, Franklin Co., IL, 2000-2002.

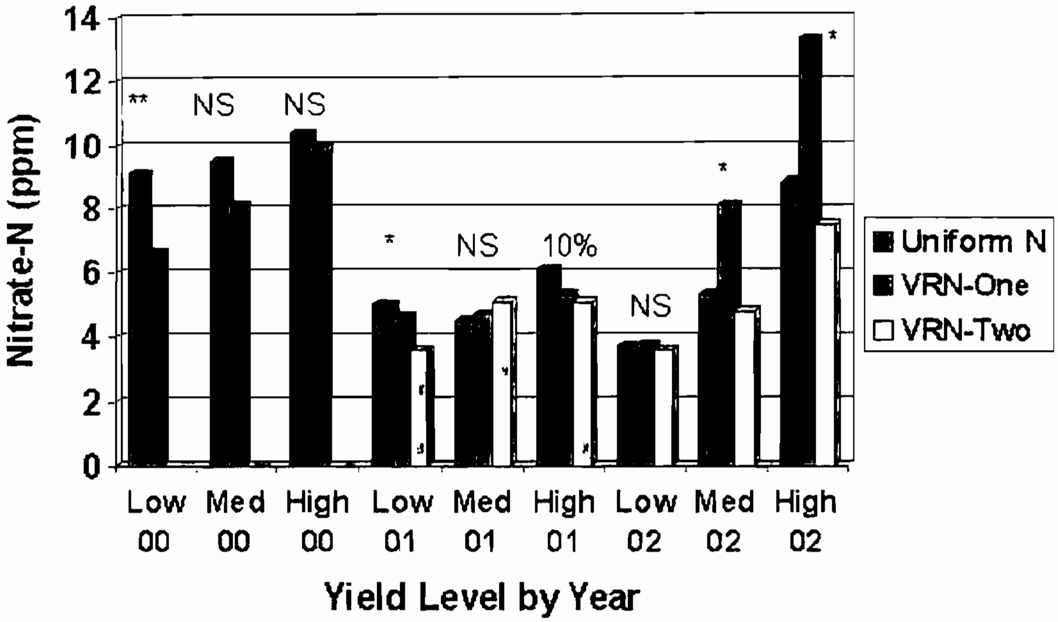


Figure 10. VRN Whole Field Study, 12-24 inch Soil Nitrate Levels, Franklin Co., IL, 2000-2002.

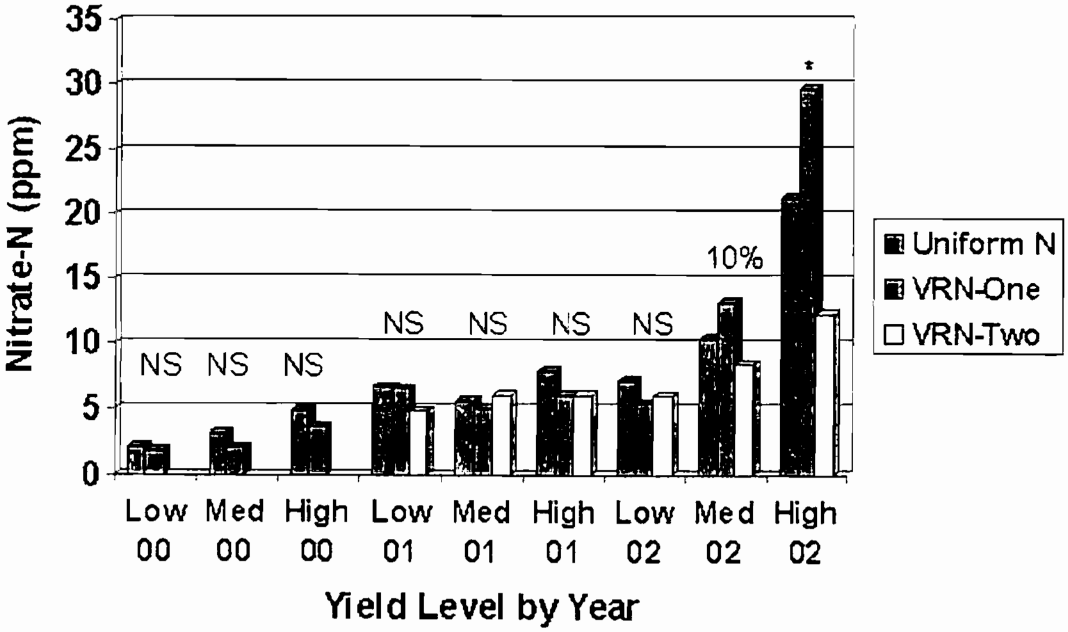


Figure 11. Small Plot Study, 0-12 inch Soil Nitrate-N Levels, Franklin Co., IL, 2000-2002.

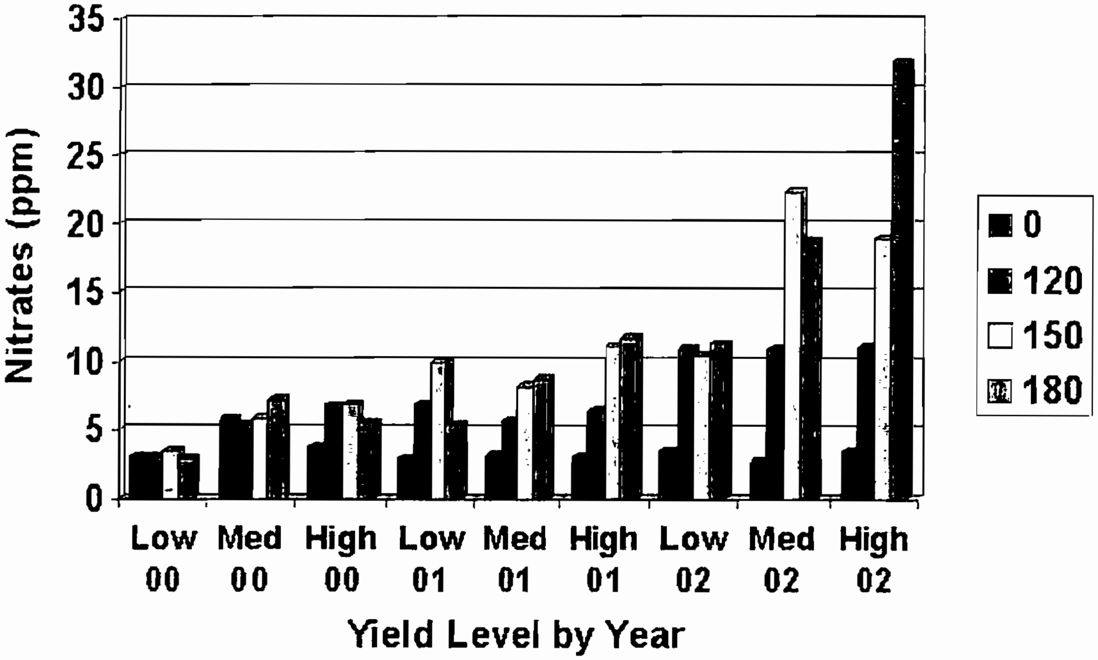


Figure 12. Small Plot Study, 12-24 inch Soil Nitrate-N Levels, Franklin Co., IL, 2000-2002.

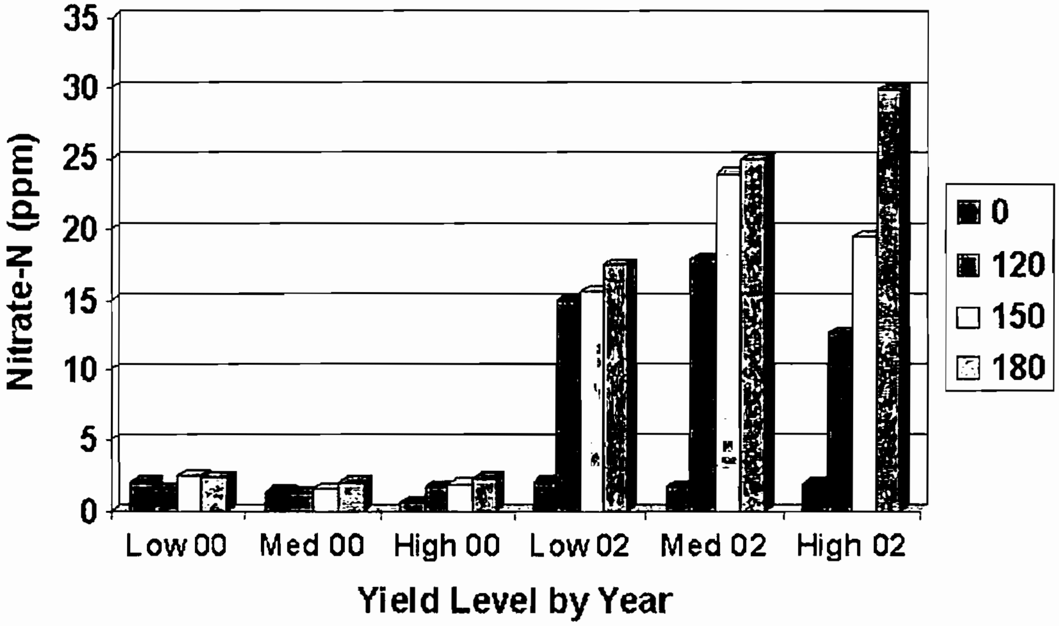


Figure 13. Small Plot Study, 24-36 inch Soil Nitrate-N Levels, Franklin Co., IL, 2000-2002.

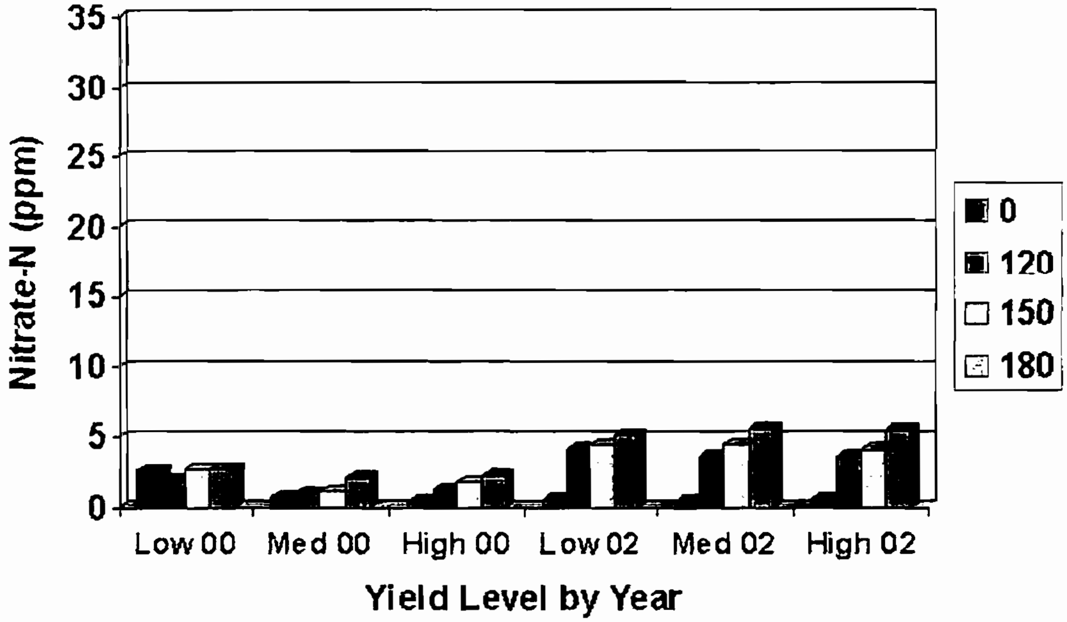
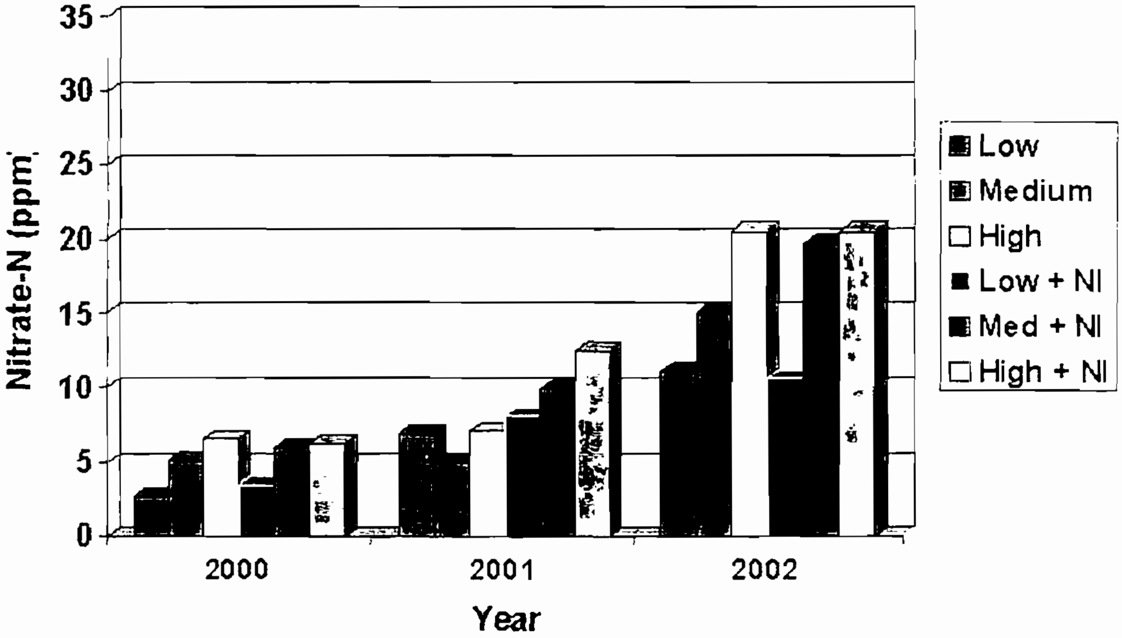


Figure 14. Small Plot Study, Nitrification Inhibitor Effects on Soil Nitrate-N Levels at the 0-12 inch depth (Ave. of 3 N Rates), Franklin Co., IL.



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