SITE-SPECIFIC NITROGEN AND IRRIGATION MANAGEMENT ACROSS NEBRASKA AGRO-ECOLOGICAL ZONES

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Abstract

Nitrogen leaching below furrow-irrigated ground has caused nitrate contamination in Nebraska's groundwater. Alternate row furrow irrigation and alternate row nitrogen fertilization is proposed as a method to decrease water use and decrease nitrogen leaching. Nitrogen (N) was applied at a uniform and variable rate based on spring grid sampling for nitrate. The experiment was conducted at three sites in Nebraska that represent a range of growing conditions. At these sites, the average growing degree-days range from 2550 to 3350 hu (base 50), mean annual precipitation (MAP) ranges from <13.8 to 30.5 in, and mean annual water balance ranges from -10.8 to 1.0 in. Irrigation method did not influence yields at the two sites with MAP greater than 19.7 in. Alternate row irrigation decreased yields at the lowest rainfall site. Both uniform and variable N rate application yielded the same. Over all the sites, the no nitrogen controls yielded 78% of the applied N treatments and there was no interaction between irrigation method and N response.

Problem and Previous Research

Increasing levels of nitrate in groundwater have been observed in some river valleys in Nebraska since the mid-1950's. In the most recent statewide evaluation of groundwater nitrate and pesticide levels, wells testing higher than 10 ppm NO_3-N were most often in irrigated river valleys. A significant number of wells exceed 10 ppm NO_3-N in irrigated corn producing areas with fine-textured soils with depths to ground water between 50 and 100 ft. Research has shown that nitrate has moved down at least 60 ft in 15 years under furrow-irrigated research plots on a silt loam soil.

The combination of alternate row irrigation and nitrogen application has not been thoroughly investigated in Nebraska. Its use may increase irrigation efficiency and decrease the nitrate leaching potential associated with furrow-irrigated fields. Previous research reports generally conclude that more N is conserved in the alternate furrow arrangement, but in some experiments water deficits occurred. When water deficits occur, N deficiencies may result. In Missouri, Hefner and Tracy (1995) conducted a three year study on a Tiptonville silt loam (fine-silty, mixed, thermic Typic Argiudoll) to determine whether an irrigation and fertilizer placement system that puts water and N fertilizer in adjacent furrows could improve corn grain yields. Corn grain yields were increased in each year of the study by placing irrigation water in every furrow. Placement of N in alternate furrows produced yields equal to every furrow placement in 1991 and 1992, and a 8.4 bu/acre increase in 1993.

In Nebraska, Martin et al. (1995) used a low energy precision application (LEPA) system on a lateral move irrigation system to apply water in alternate furrows and N in non-irrigated rows. Results indicate that the irrigated furrow was wetter than the non-irrigated furrow. The nitrate-N concentration beneath the fertilized furrows remained considerably higher than under the furrows that were irrigated but not fertilized even though the irrigation water contained about 30 ppm of nitrate-N. Using the SWMS_2D finite-element model Benjamin et al. (1994) predicted the greatest chemical leaching would be in the furrow in the every furrow irrigation (EFI) treatment. Soil water content after infiltration was more uniform for the EFI compared to the alternate furrow irrigation (AFI) in both the loamy sand and the clay loam. $CaCl_2$ moved least under the non-irrigated row in the AFI treatment. They cautioned that placing nitrogen in non-irrigated rows in AFI on loamy sands might reduce yields. Ridge placement of nitrogen would decrease leaching potential and maintain nitrogen availability. In a subsequent study, Benjamin et al., (1997) placed nitrogen-15-depleted $(NH_4)_2SO_4$ in furrows and the rows of AFI and EFI irrigation treatments. Average N uptake at the end of the season was 12% greater for the row-applied nitrogen than the furrow placement. Nitrogen placement in the furrow of the nonirrigated row of the AFI reduced nitrogen uptake compared to the EFI furrow nitrogen placement in a dry year (5 in seasonal rainfall), but not in a wet year (15.1 in seasonal rainfall). Nitrogen movement was calculated in the soil for nitrogen-15-depleted $(NH_4)_2SO_4$ by Benjamin et al. (1998). They found that in the drier year (5.6 in May – August rainfall), more N remained in the dry furrow of the AFI treatment compared to the EFI treatment. Plant biomass was not affected by irrigation method.

Research Objectives

1. Evaluate effects of alternate-furrow irrigation on corn grain yield and end-of-season soil residual nitrate-N, with and without variable rate N application, compared to the more common practice of every-furrow irrigation.

2. Evaluate the variables above across a range of precipitation regimes found in Nebraska at three locations, with a mean annual water balance ranging from 1 in to −10.8 in water (Figure 1 from Waltman et al. 1998).

Methods

This project was conducted across Nebraska at 2 locations in 1997 (Clay Center and North Platte) and 3 locations in 1998 and 1999 (Clay Center, North Platte, and Scottsbluff – Figure 1). Four management schemes were compared:

1. Every furrow application of anhydrous ammonia (fixed rate based on average soil nitrate, organic matter, and field average expected yield) and every furrow irrigation. **(EFI-uniform)**

2. Every furrow application of anhydrous ammonia (variable rate based on spatial soil nitrate, organic matter, and field average expected yield) and every furrow irrigation. **(EFI-variable)**

3. Every other furrow application of anhydrous ammonia (fixed rate based on average soil nitrate,

organic matter, and field average expected yield) and alternate row furrow irrigation in the non-N application furrows. **(AFI-uniform)**

4. Every other furrow application of anhydrous ammonia (variable rate based on spatial soil nitrate, organic matter, and field average expected yield) and alternate row furrow irrigation in the non-N application furrows. **(AFI-variable)**

Treatments within the four management schemes were either 6 or 8 rows for the length of the field; usually 1000-1250 ft. There was also a no nitrogen control for each irrigation treatment. Treatments were replicated 4 to 5 times in a randomized complete block split plot design. The main plots were irrigation treatments (AFI and EFI) and the subplots were nitrogen treatments (no nitrogen, uniform and variable). Anhydrous ammonia was applied sidedress (4 to 8 leaf growth stage) with a modified Blu-Jet tool bar with a Dickey John flow controller and heat expansion chamber (Figure 2). The software that controlled the variable rate applicator was Falcon v. 1.9, AgChem, Inc. The software that created the application maps was SGIS v 2.4, AgChem, Inc. The sites were grid sampled on staggered 100 ft intervals within each treatment strip for residual nitrate and soil organic matter during the fall or the spring before planting. Spatial data for organic matter and nitrate were used to develop spatial N rate recommendations using the University of Nebraska N recommendation algorithm (Hergert et al., 1995).

Surge irrigation was utilized at all locations for both irrigation treatments. Anticipating different advance rates for the hard (tire track) and soft (non tire-track) furrows, inflow rates were adjusted according to the furrow type. Soft furrows received greater flow rates and hard furrows reduced flow rates. Irrigation water was applied in sufficient quantity to maintain at least a 50% remaining available soil water balance. The EFI and AFI irrigation treatments were scheduled independently. Typically, four surge irrigation advance cycles were used. Advance-phase cycle times averaged 30, 50, 60 and 80 min for the 1st, 2nd, 3rd and 4th surges, respectively. Initial cutback cycle time averaged approximately 40 min.

Results

There was significant spatial variability in soil parameters (soil organic matter and residual nitrate-N) that influenced N dynamics at all three locations. Figure 3 illustrates these factors for the Clay Center site. At Clay Center, soil organic matter levels varied from about 1% in an area where topsoil had previously been removed to 3% in the better areas of the field.

At all locations and in most years, yields from treatments that received no N fertilizer (control plots) were significantly lower than those that received N (Figure 4). Grain yield was not significantly affected by N application method (variable versus uniform rate.) These results are consistent across locations and with previous studies in Nebraska (Ferguson et al., 1999) and show that variable rate N application provided no field-wide yield advantage compared to uniform N application. While rates varied within the variable rate application treatment, average treatment N rate was within 10 lbs/acre of the uniform rate at each site. The lack of yield difference between the variable and uniform N rates indicates that organic matter and residual nitrate-N were not so variable that the uniform application significantly under-applied nitrogen to a large area of the field. This is consistent with the hypothesis that the University of Nebraska recommendations are near the maximum of the response function and the N response function is either quadratic or linear plateau.

Corn grain yields for both AFI and EFI were the same at Clay Center and North Platte. The AFI had an average of 2.8 in less irrigation water applied per season at these locations. As was the case at Clay Center and North Platte, application of N fertilizer at the Scottsbluff location increased corn yield for both uniform and variable N applications. In contrast to the other two locations, grain yield at Scottsbluff was significantly lower for the AFI treatment compared to EFI in 1998 and 1999. Factors influencing the potential for AFI to reduce yield include soil water-holding capacity (which is lower at the Scottsbluff location due to coarser texture and lower soil organic matter relative to the North Platte and Clay Center locations), and mean annual water balance (Figure 1). With reduced precipitation the non-irrigated furrow may have insufficient moisture to allow either the N to move to the roots or the roots to adequately grow to the N.

End of season residual nitrate-N levels for each site are shown in Figure 5 (1998 values for Clay Center are missing due to laboratory error). In general, residual nitrate-N levels remaining after harvest are higher the farther west in the state, as mean annual precipitation decreases. At the Clay Center location, residual nitrate-N levels are generally unaffected by treatment other than the no-nitrogen checks. This is the case for the most part at North Platte as well, with the exception of 1998, when the variable N – alternate furrow irrigation treatment had a significantly lower residual nitrate-N level than the other fertilized treatments.

At the Scottsbluff location, the alternate furrow irrigation treatments tended to have significantly higher residual nitrate-N levels. This is consistent with the observed lower grain yield for these treatments and reduced nitrate uptake by the crop, as well as likely less nitrate-N leaching with the alternate furrow irrigation treatment. At the Scottsbluff site, for the alternate furrow treatments, the uniform application had greater residual nitrate-N than the variable application (Figure 5).

Summary

Theoretically, reduced leaching of fertilizer N with alternate-furrow N application should result in greater N use efficiency making it possible to produce similar grain yields using less fertilizer N than with the traditional every-furrow application method. Moreover, alternate-furrow application of irrigation water should result in more efficient use of irrigation water since less of the soil volume is wetted during irrigation and more precipitation can be captured and utilized by the crop as compared to every-furrow irrigation. At the Scottsbluff location with a greater mean annual water deficit, alternate furrow irrigation resulted in reduced yield potential and N use efficiency. Results of this study suggest that alternate-furrow application of N fertilizer and irrigation water is a viable management practice in central and west central Nebraska. Alternate-furrow application of N and irrigation water may not be as effective in dryer climates where insufficient moisture in the furrow where N fertilizer is applied may reduce availability of N to the plant.

Variable rate N application did not significantly influence grain yield, relative to uniform N application. Variability in soil residual nitrate-N was reduced with variable rate application, and variable rate application resulted in significantly less soil residual nitrate-N at the Scottsbluff location.

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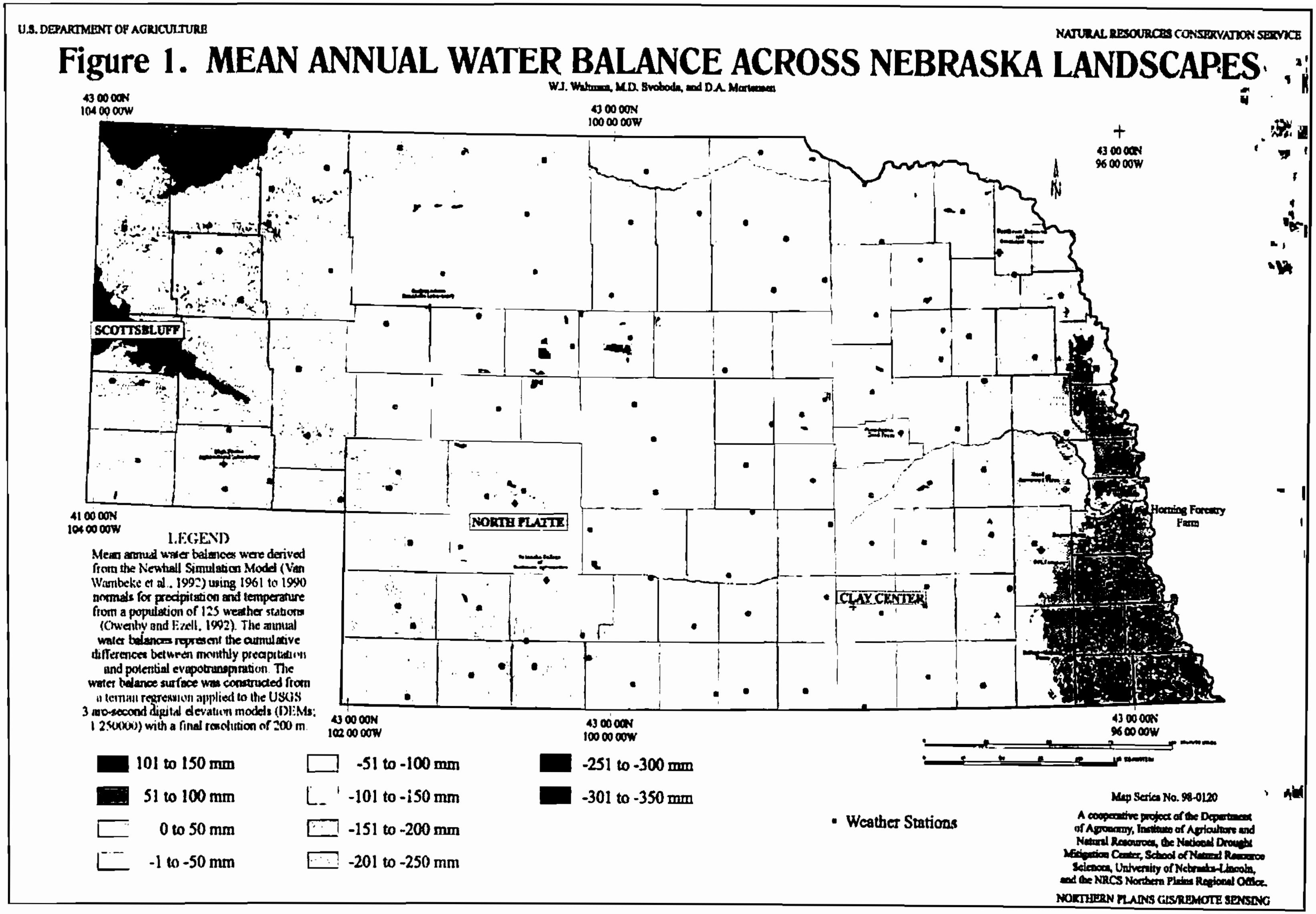

Mean annual water balances were derived from the Newhall Simulation Model (Van Wambeke et al., 1992) using 1961 to 1990 normals for precipitation and temperature from a population of 125 weather stations (Owenby and Ezell, 1992). The annual water balances represent the cumulative differences between monthly precipitation and potential evapotranspiration. The water balance surface was constructed from a terrain regression applied to the USGS 3 arc-second digital elevation models (DEMs; 1:250000) with a final resolution of 200 m.

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Figure 1. Mean annual water balance across Nebraska landscapes.

Figure 2. Variable rate anhydrous ammonia toolbar used to apply N treatments.

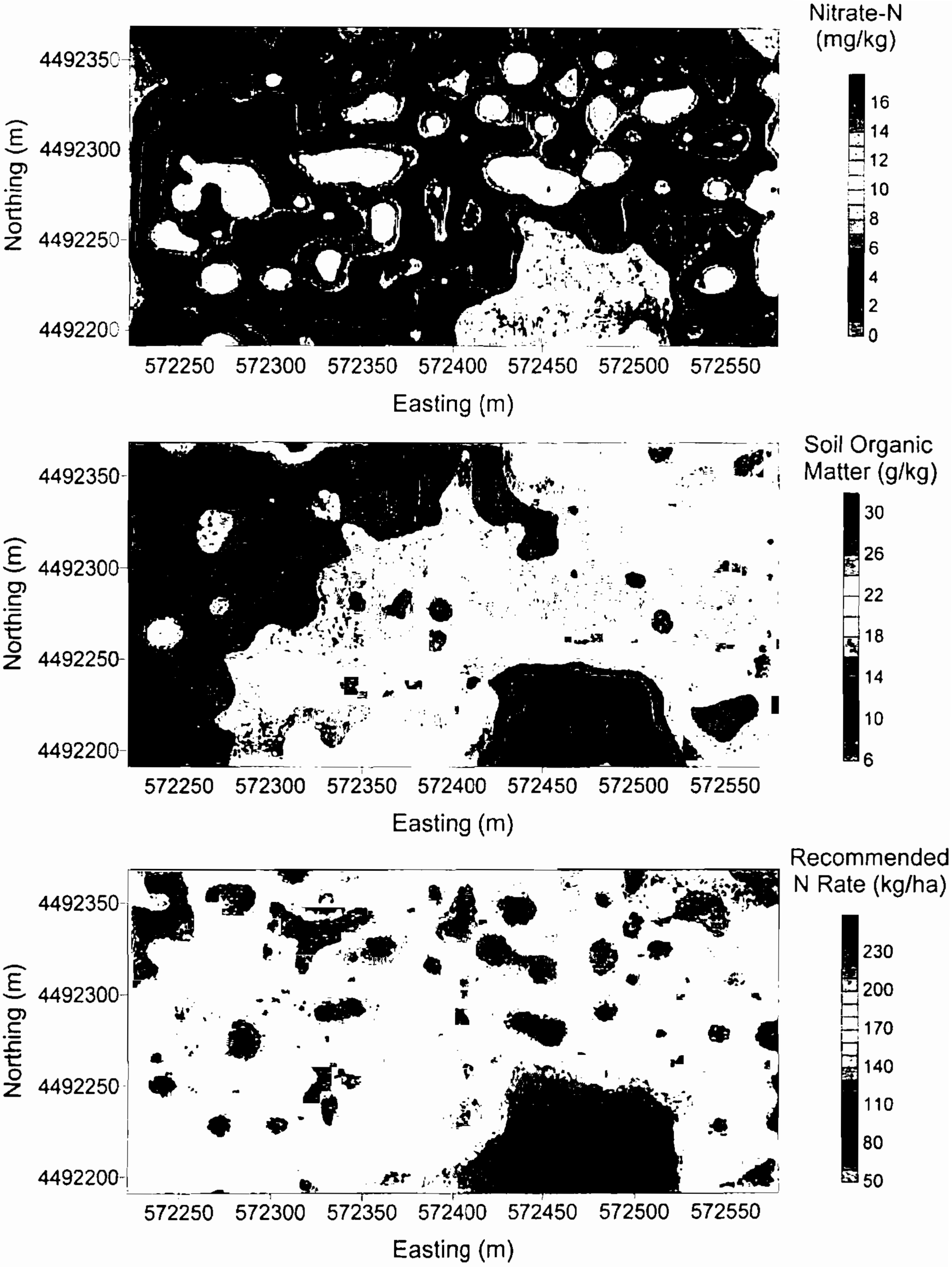

Figure 3. Soil residual nitrate-N, soil organic matter, and recommended N rate, Clay Center site, 1997.

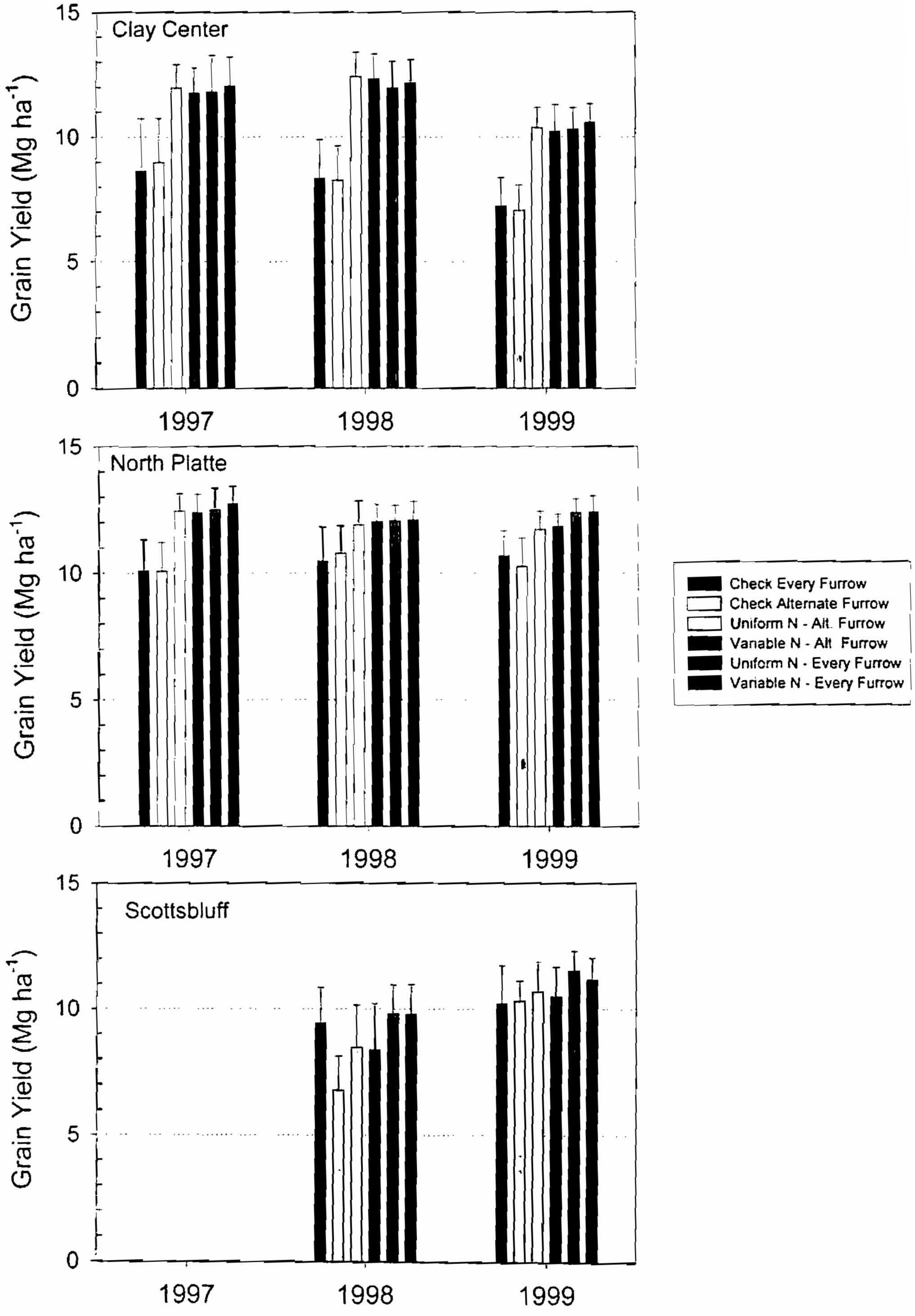

Figure 4. Grain yields for three sites, 1997 - 1999. Error bars are standard deviation.

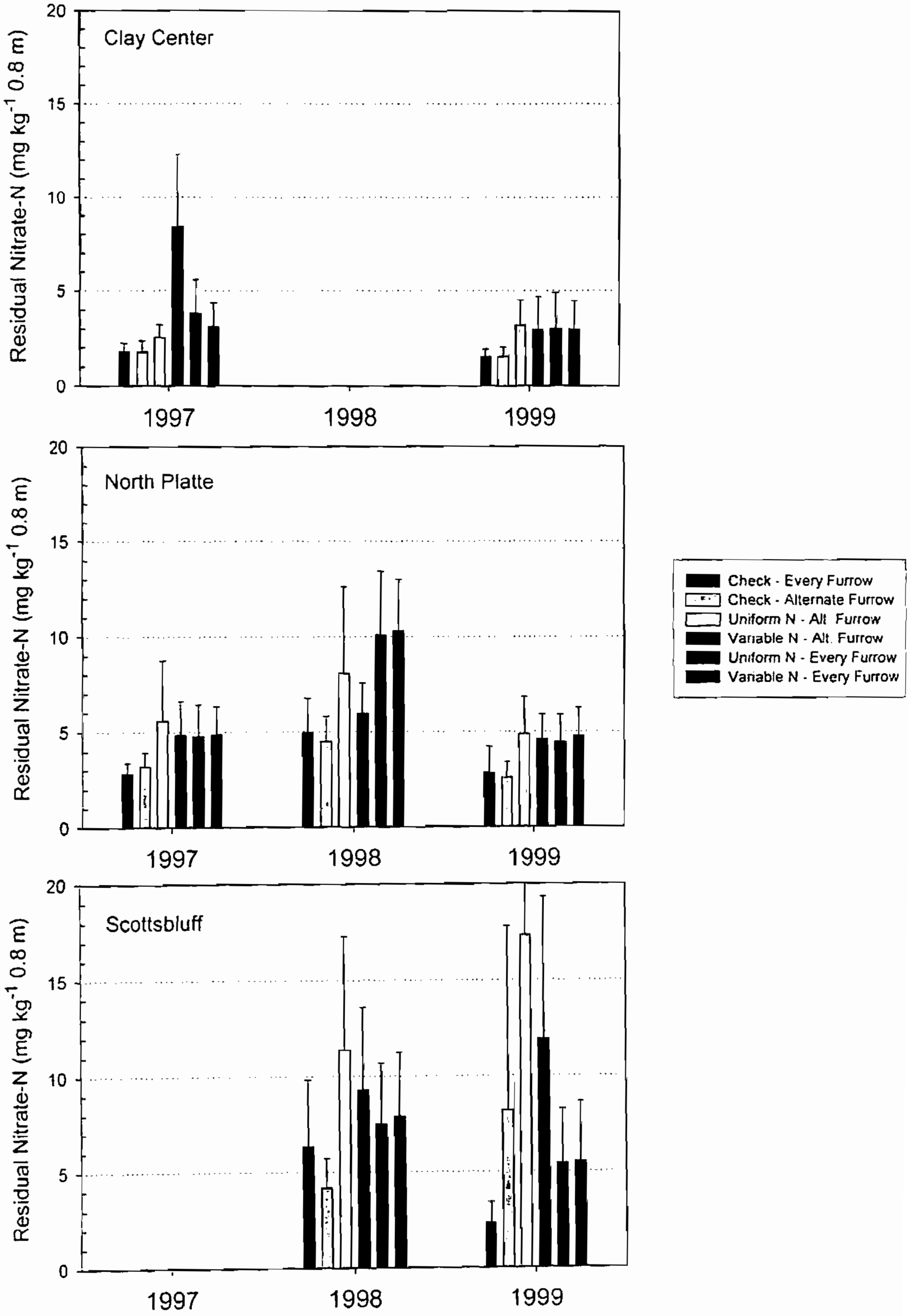

Figure 5. Average soil residual nitrate-N concentration to a depth of 0.8 m, 1997-1999. Error bars are standard deviation.

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