

# Evaluation of the Effects of Added Nitrogen Interaction on Nitrogen Recovery Efficiency Calculations

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## Abstract

*Two studies were conducted in 1996 and 1997 at the University of Arizona Maricopa Agricultural Center (MAC) to evaluate the added nitrogen interaction (ANI) or 'priming effect' on the determination of nitrogen recovery efficiencies (NRE). The method employed was to compare NRE's as calculated by two different methods; the difference technique and the isotopic technique. The difference in NREs observed between the two methods indicates the extent of an ANI. Results demonstrated no statistical differences between NRE's calculated by the two methods. Therefore, no ANI was observed in the field. These results indicate that the less expensive method of calculating NREs (difference technique) is sufficient under irrigated cotton production systems in the desert Southwest.*

## Introduction

Nitrogen (N) is one of the most limiting factors in a cotton (*Gossypium* spp.) production system in the desert Southwest. A deficiency of N is most readily observed with the yellowing of older (lower) leaves first. Subsequent yellowing of young tissue will occur with increasing deficiency. Slow and stunted growth is also observed with deficient levels of N in the plant. Despite the large concentrations of N in the soil very little is found in the inorganic forms that are available for plant uptake and utilization. This being the case, supplemental fertilizer is nearly always added in the form of inorganic fertilizers in order to supply sufficient levels of N for crop needs. Due to the relatively inexpensive nature of N fertilizers in irrigated crop production systems, amounts are often applied in excess of crop demands to insure adequate levels. This practice often leads to very low fertilizer use efficiencies and unnecessary increases in production costs. Strategies have been developed in an effort to increase fertilizer use efficiencies to help producers trim production costs and to avoid potential environmental hazards commonly associated with excessive N fertilization.

The determination of the NRE is one method of assessing the effectiveness of applied fertilizer N. There are two methods commonly used to calculate NRE's; the difference method and the isotopic technique. There are however, potential errors associated with both techniques under different circumstances. The difference technique involves determining the amount of total N uptake in plots receiving 0 fertilizer N and comparing it to total N uptake in plots receiving fertilizer N. Equation 1 describes this calculation.

$$NRE = \frac{F - C}{N} * 100 \quad (\text{Eq. 1})$$

where:

F=total N uptake in fertilized plots (kg/ha)

C=total N uptake in unfertilized (check) plots (kg/ha)

N=total fertilizer N applied (lbs. N/acre OR kg N/ha)

Figure 1 also illustrates this concept. One of the assumptions associated with the difference technique is that the soil N transformations remain constant between the fertilized and the non-fertilized plots. It has been observed (Rao et. al., 1991) that the addition of fertilizer N stimulates soil N transformations and may result in an increase of available

inorganic N for uptake and utilization by the crop. This can lead to over-estimations in NRE values calculated using the difference method, which is referred to as an ANI (Jenkinson et. al., 1985).

The isotopic technique utilizes a naturally occurring, stable isotope of N ( $^{15}\text{N}$ ). Utilizing fertilizers enriched with  $^{15}\text{N}$  over and above natural abundance (0.3663 atom %  $^{15}\text{N}$ ) allows a researcher to explicitly track the movement, uptake, and utilization of fertilizer N. Using this technology one can determine a NRE by use of equation 2. The isotopic technique can also lead to an ANI (Jenkinson et. al., 1985). Pool substitution can lead to a decrease in plant-available  $^{15}\text{N}$  containing compounds ( $\text{NO}_3^- \text{-N}$  and  $\text{NH}_4^+ \text{-N}$ ). This occurs as  $^{15}\text{N}$  labeled fertilizer is immobilized as a result of soil N transformations. This renders this form of N unavailable for plant uptake, thus leading to a possible under-estimation of NRE using the isotopic technique. This is also referred to as ANI.

$$NRE = \frac{P(C - B)}{F(A - B)} * 100 \quad (\text{Eq. 2})$$

where:

- P=total N uptake (kg/ha)
- F=total applied fertilizer N (kg/ha)
- A=atom %  $^{15}\text{N}$  in fertilizer
- B=atom %  $^{15}\text{N}$  in plants grown with unlabeled fertilizer
- C= atom %  $^{15}\text{N}$  in plants grown with labeled fertilizer

A distinction can be made between the two types of ANI discussed above. The first is referred to as a ‘real’ ANI. A ‘real’ ANI is influenced by several factors including increased root growth, increased mineralization rates, and changes in a plants physiological processes induced by fertilizer N. These processes can all lead to an increase in the uptake of total soil-N, thus it is referred to as a ‘real’ ANI. The ANI associated with pool substitution is referred to as ‘apparent’ ANI. The effects due to pool substitution do not affect the plant directly and are referred to as ‘apparent’ because an increase in N uptake is not directly responsible for potential errors in NRE estimations. The most common type of ANI observed is a positive apparent ANI (Jenkinson et. al., 1985). The ANI phenomena is most commonly observed in pot experiments and has in only rare cases been observed in field studies (Rao et. al., 1991 and Hart et al., 1986). The objective of this study was to examine the NRE estimations using the two techniques, and then by comparing the techniques determine if any type of ANI could be observed in the field in an irrigated cotton production system.

## Materials and Methods

The studies were conducted on a Casa Grande sandy loam soil (fine-loamy, mixed, hyperthermic, Typic Natrigid (reclaimed) at the University of Arizona Maricopa Agricultural Center (MAC) located northwest of Casa Grande, AZ. Treatments consisted of a check, receiving 0 fertilizer N and a 1X and 2X fertilizer N treatments. The 1X treatment is the UA recommended N management regime based upon a feedback approach utilizing crop monitoring techniques (Silvertooth and Norton, 1998). The 2X rate is simply twice the 1X rate. Treatments and application dates are shown in Table 1 for 1996 and 1997. Each treatment was replicated 3 times in a randomized complete block design. Plots consisted of 8, 1m wide rows and extended the full length of the irrigation run (180 m). All fertilizer N was applied as ammonium sulfate  $(\text{NH}_4)_2\text{SO}_4$  with a side dress application rig. An open microplot technique (Silvertooth et al., 1998) was employed to determine NRE using the isotopic technique. Microplots consisted of 4, 1m wide rows extending 1m in length. Microplots were located within macroplots receiving 0 fertilizer N. Treatments managed in an identical manner except for the fertilizer N that was applied. In the  $^{15}\text{N}$  microplots, fertilizer N was applied as 5 atom % enriched ammonium sulfate  $(^{15}\text{NH}_4)_2\text{SO}_4$ . Applications were made in a simulated sidedress fashion by cutting a trench in the side of the bed to which a solution containing the fertilizer N was applied evenly and quickly covered with soil. The results obtained from the isotopic method in 1996 were compromised due to sampling error so results from only the difference technique will be presented for 1996.

Plots were managed optimally with respect to irrigation, pest management, etc. A set of basic plant measurements were taken during the course of the season which allowed for tracking thre crop progression toward maturity and also to asses the reproductive/vegetative balance of the crop. Basic plant measurements were collected on 14 day intervals and included: plant height, number of mainstem nodes, occurrence of first fruiting branch, number of aborted or

missing sites on first two positions of each fruiting branch, number of nodes above the top white bloom, number of blooms per unit area (15 m<sup>2</sup>), and percent canopy closure.

At the end of the season whole plant samples (above ground) were collected from each plot (both macro and micro). Plant samples were collected from a 1m<sup>2</sup> area in each microplot areas and from areas not receiving fertilizer N. Seedcotton was separated and ginned. The remaining plant dry matter (stover) was also collected and dried. Both the seed and stover portions were passed through a large hammer-mill followed by a Wylie mill. Sub-samples were further ground and to a very fine powder and subjected to total N and isotope ratio analysis by use of a Carlo-Erba N/A 1500 Elemental Analyzer and a VG Isomass mass spectrometer.. NRE estimates were then calculated using the two methods described above. Statistical analysis was then performed as outlined by Gomez and Gomez (1984) and the SAS Institute (1994) to detect differences between the NRE estimates as determined by the two methods.

## Results and Discussion

Total N uptake (Figure 2) in 1996 was lower than in 1997 for all three treatments. This can be explained by the lower overall yields observed in 1996 as compared to 1997 (Figure 3). Figure 3a shows the relationship between lint yield and total N uptake. In 1996 there appears to have been an inverse relationship, whereas in 1997 a positive relationship was observed. The fruit retention (FR) patterns and resultant source-sink relationships experienced in the 1996 crop can explain this inverse relationship. Plant measurement data collected in 1996 and 1997 illustrate that FR patterns were significantly different. In 1996 FR patterns tracked near or below the baseline long-term averages (Silvertooth and Norton, 1997; where treatments 3 and 4 correspond to treatments 1X and 2X in the present study). Results of FR patterns in 1997 (Silvertooth and Norton, 1998) illustrate above average FR patterns during the majority of the season. The higher FR patterns in 1997 resulted in a higher yields and a more balanced (vegetative/reproductive) crop. The high rates of N applied in 1996 led to excessive vegetative growth rates when the crop had a low level of FR, which in turn led to decreased yields. Increased N uptake resulted in increased vegetative growth rather than reproductive growth.

Figure 4 illustrates the NRE observed for the 1X and 2X rates using the difference technique. Decreasing NRE's were observed with increasing N rates. Using the difference technique we achieved NRE's of approximately 20 to 40%. The results obtained using the difference technique were very similar among the two years.

Estimates for NRE using the isotopic technique are presented in Figure 5. The Isotopic results are very similar to the difference method results observed for both treatments. Comparisons between the two methods, difference and isotopic, for both treatments are shown in Figure 6. The results show very little difference between the two methods for either treatment. Table 2 list analysis of variance results for the comparison between the two methods. Differences between the two methods were extremely small. No significant differences were declared (OSL=0.9976 and OSL=0.9389; 1X and 2X, respectively).

These results provide two important concluding points. First, it does not appear that we have an ANI affecting the estimates of NRE with either of the two methods. These results are consistent with Hart et. al. (1985) who also did not observe ANI under field conditions. Rao (1991) found that ANI was highly and positively correlated to several soil factors including; soil organic matter (SOM) level, soil microbial biomass, soil C:N ratios, and increasing fertilizer N rates. Results from this study are consistent with Rao's (1991) in that soils in the study area are very low in SOM (< 1.0%) The second conclusion is that the difference technique appears to be an adequate method for estimating NRE in irrigated cotton production systems in the desert Southwest and probably for other crops as well.

This study will be conducted again during the 1999 season.

## References

- Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research, Inc. Ed. John Wiley and Sons, Inc. p. 307.
- Hart, P.B.S., J.H. Rayner, and D.S. Jenkinson. 1986. Influence of pool substitution on the interpretation of fertilizer experiments with <sup>15</sup>N. *J. Soil Sci.* 37:389-403.
- Jenkinson, D.S., R.H. Fox, and J.H. Rayner. 1985. Interactions between fertilizer nitrogen and soil nitrogen – the so-called ‘priming’ effect. *J. Soil Sci.* 36:425-444.
- Rao, A.C.S., J.L. Smith, R.I. Papendick, and J.F. Farr. 1991. Influence of added nitrogen interactions in estimating recovery efficiency of labeled nitrogen. *Soil Sci. Soc. Am. J.* 55:1616-1621.
- Stout, W.L. 1995. Evaluating the ‘added nitrogen interaction’ effect in forage grasses. *Commun. Soil Sci. Plant Anal.* 26:2829-2841.
- SAS Institute. 1994. The SAS system for Windows. Release 6.10. SAS Inst., Cary, NC.
- Silvertooth, J.C., J.C. Navarro, E.R. Norton, and C.A. Sanchez. 1998. Evaluation of a Nitrogen-15 microplot design in a furrow irrigated row crop system. Cotton, A College of Agriculture Report. University of Arizona. Series P-112:.
- Silvertooth, J.C. and E.R. Norton. 1997. Nitrogen management experiments for Upland and Pima cotton, 1996. Cotton, A College of Agriculture Report. University of Arizona. Series P-108:389-401.
- Silvertooth, J.C. and E.R. Norton. 1998. Nitrogen management experiments for Upland and Pima cotton, 1997. Cotton, A College of Agriculture Report. University of Arizona. Series P-112:461-468.

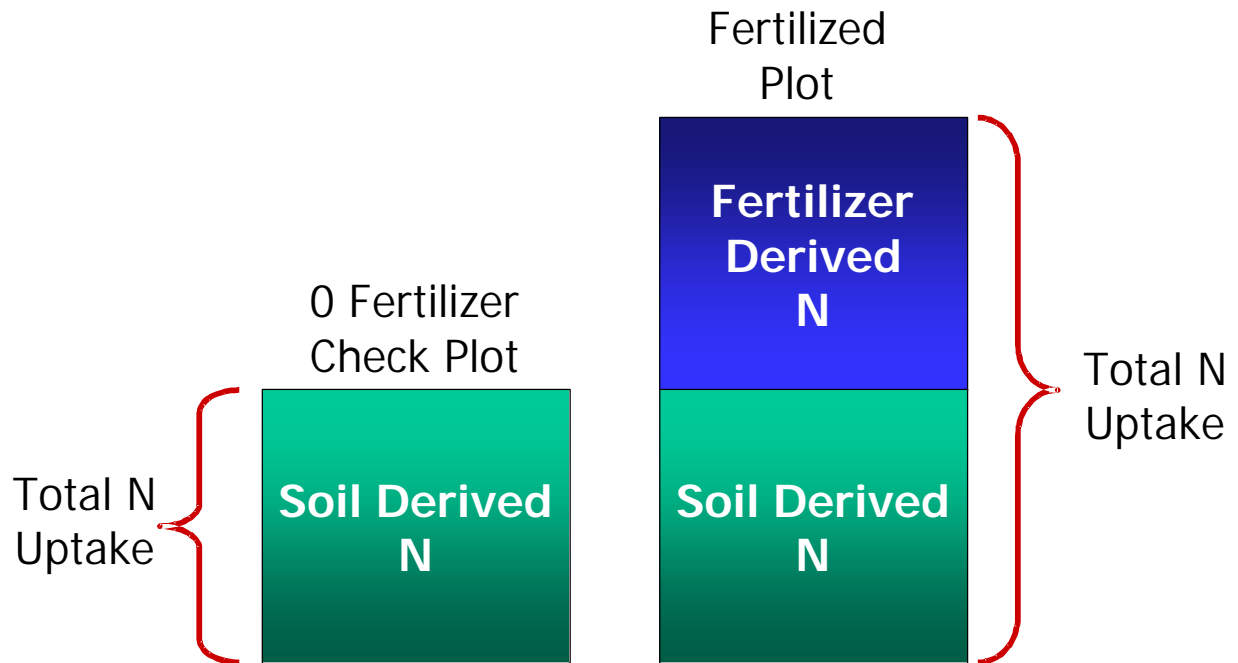


Figure 1. Schematic of NRE calculated using the difference technique

Table 1. Treatment outline and application dates for 1996 and 1997.

Date		Check	1X	2X
1996	1997			
17 May	14 May	0	56	112
6 June	9 June	0	56	112
19 June	20 June	0	56	112
Total		0	168	336

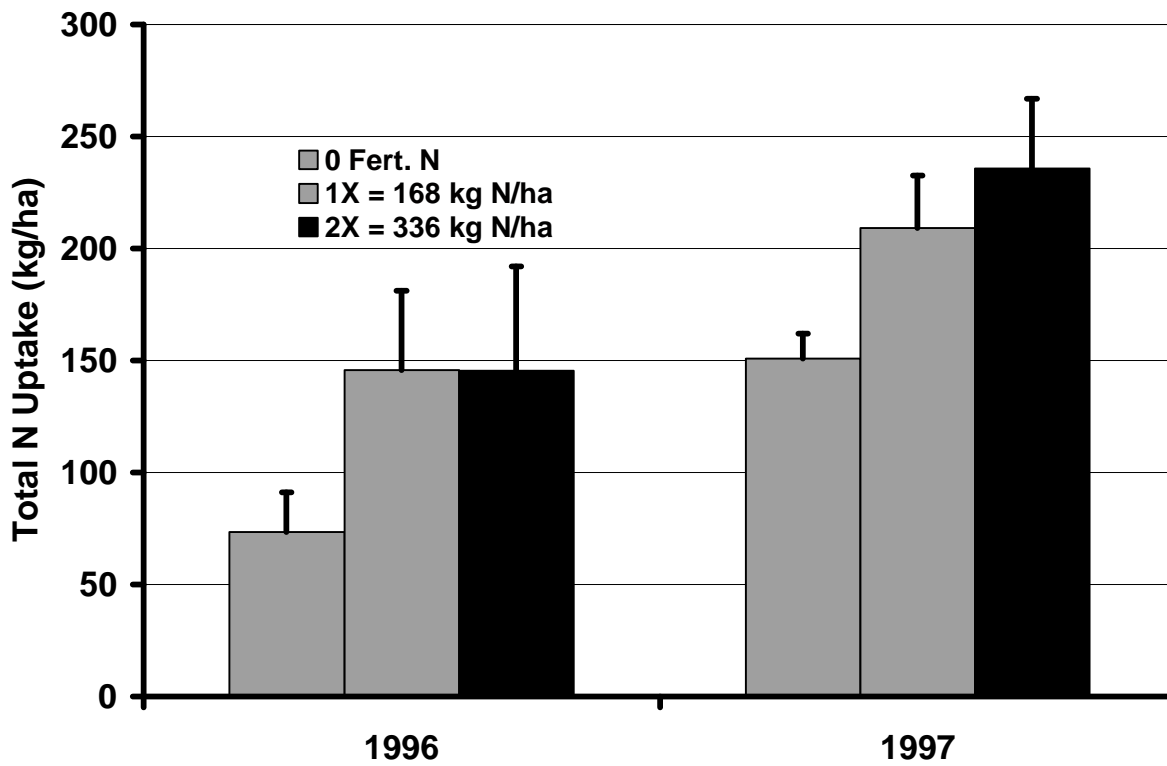


Figure 2. Total N uptake for both treatments in 1996 and 1997.

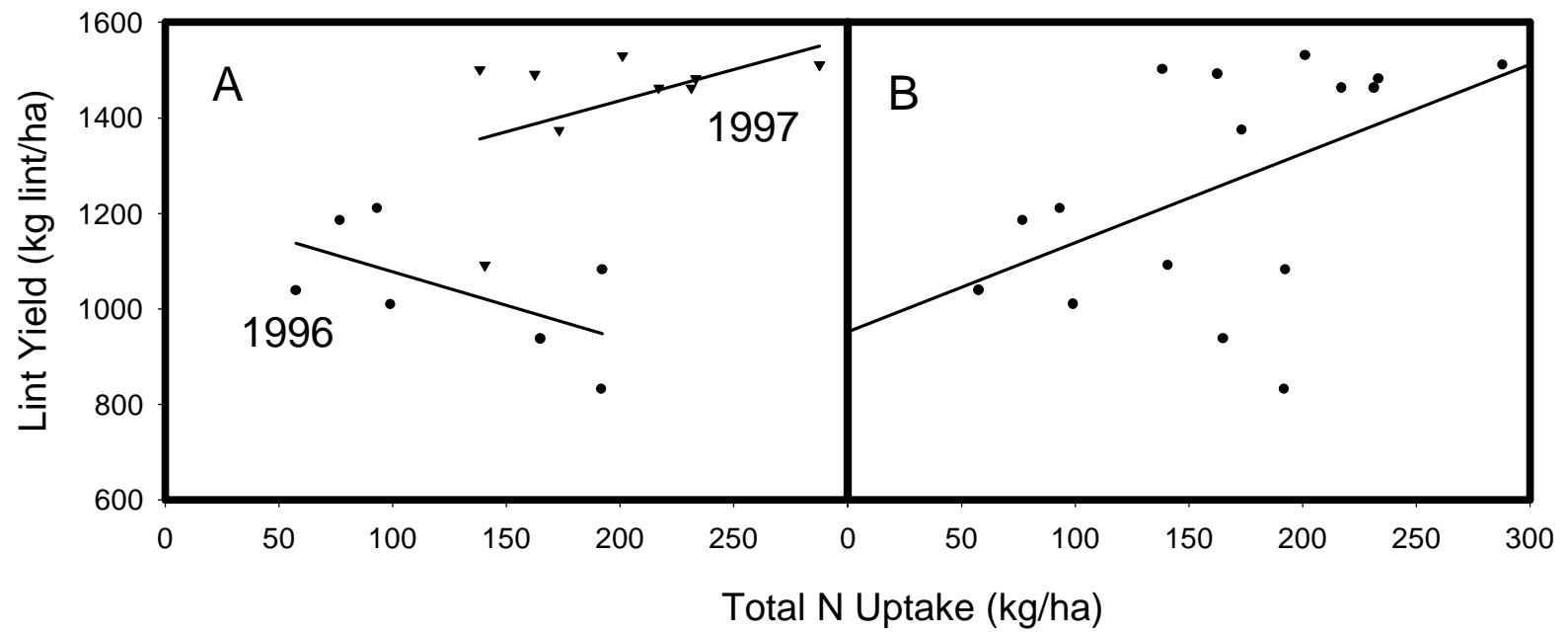


Figure 3. Total lint yield as a function of N uptake for 1996 and 1997 (A) and both years combined (B).

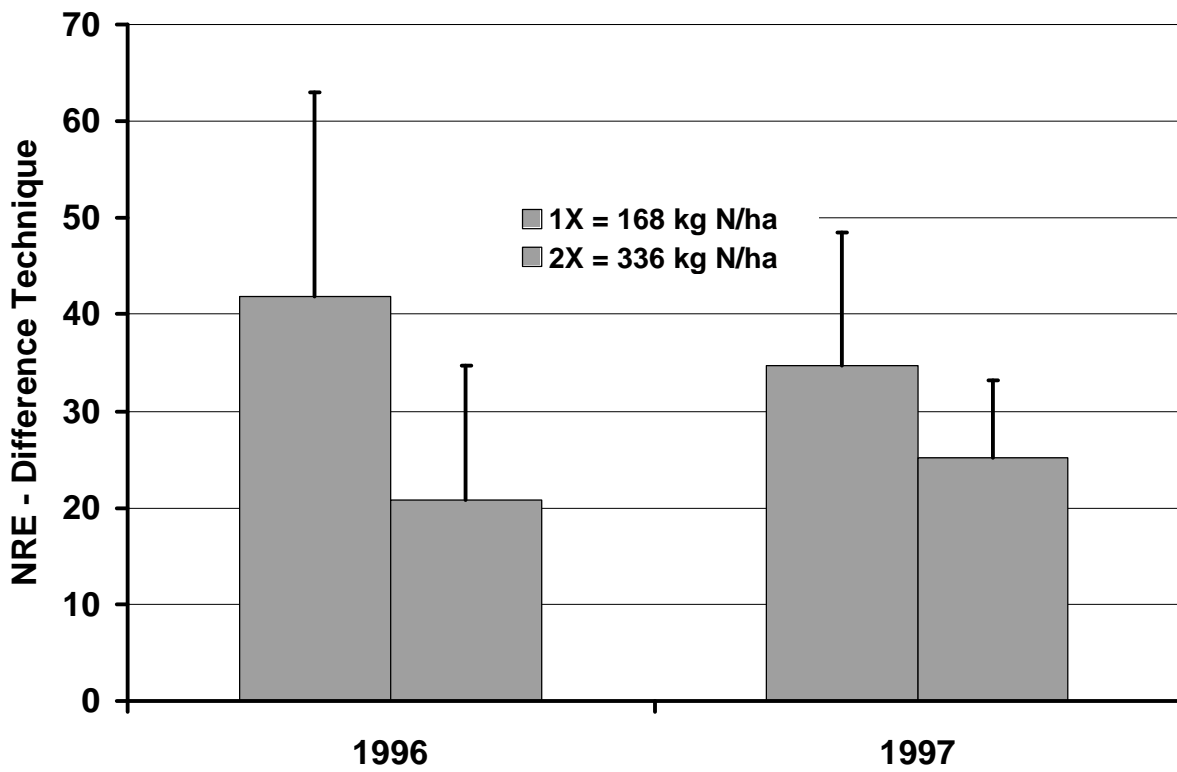


Figure 4. NRE estimates as determined using the difference technique for 1X and 2X treatments in both 1996 and 1997.

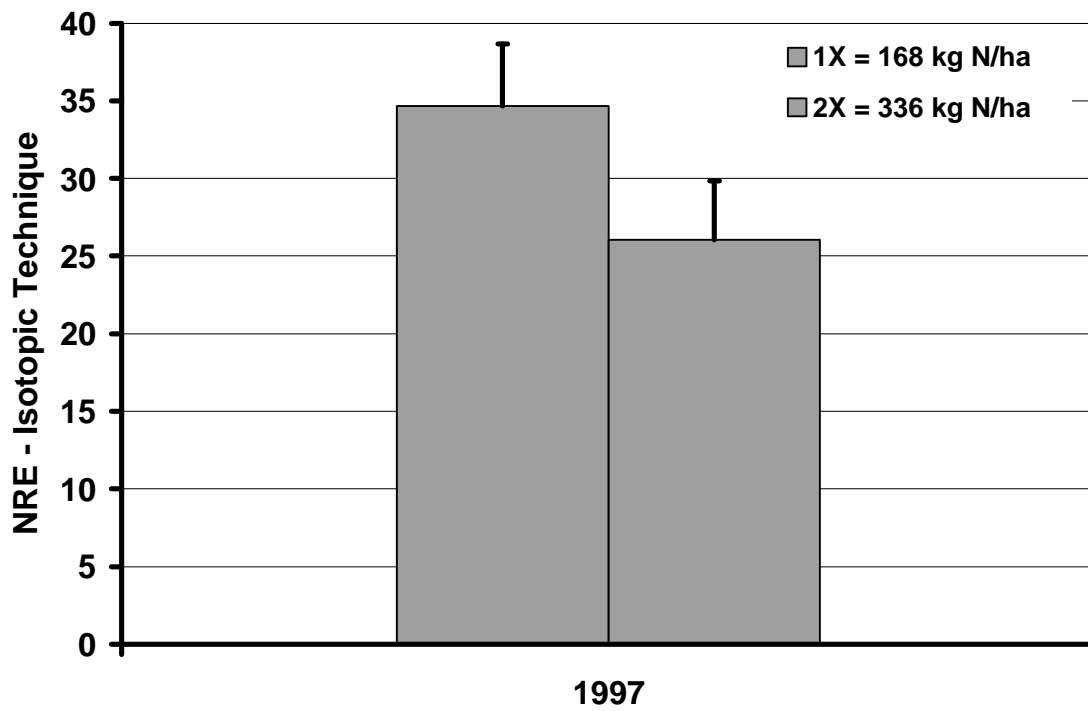


Figure 4. NRE estimates as determined using the isotope technique for 1X and 2X treatments in 1997.

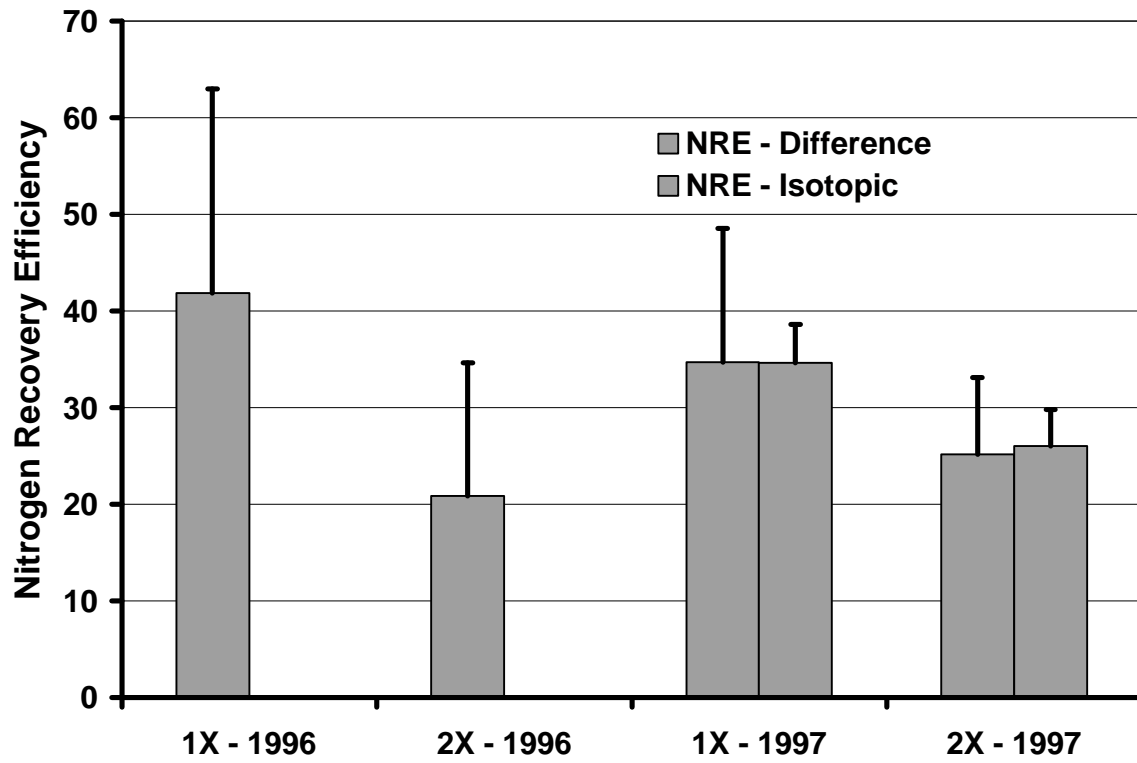


Figure 5. Comparison of isotope and difference techniques for 1X and 2X treatments in both 1996 and 1997.

Table 2. Statistical analysis of method comparisons for 1X and 2X rates, 1997.

<b>Treatment</b>	<b>Method</b>	<b>Mean</b>
1X	Difference	34.71a
	Isotopic	34.67a
<i>OSL</i>		0.9976
<i>LSD</i>		NS
<i>C.V. (%)</i>		45.06
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2X	Isotopic	26.04a
	Difference	25.17a
<i>OSL</i>		0.9389
<i>LSD</i>		NS
<i>C.V. (%)</i>		48.01