EVALUATION OF NITROGEN MANAGEMENT PRACTICES IN NO-TILL CORN PRODUCTION[1]

E.C. Varsa, S.A. Ebelhar, P.R. Eberle, Erik Gerhard, and Terry Wyciskalla[2]

Abstract

Experiments were conducted from 1995 to 1998 at the Dixon Springs Agricultural Center of the University of Illinois and the Belleville Research Center of Southern Illinois University to evaluate agronomically and economically several nitrogen (N) management options, including the use of the urease inhibitor AgrotaiN, in no-till corn production. Compared in these studies were N sources (urea, UAN, ammonium nitrate, and anhydrous ammonia), placement (dribble vs. broadcast for surface-applied N and injection of N) and timing (selected treatments with all N applied at planting compared to a split application) in both a corn-corn (CC) and corn-soybean (CS) rotation. The amount of N applied was fixed for all treatment comparisons but differed for each rotation – 180 lb N/acre for the CC rotation and 140 lb N/acre for the CS rotation.

The four highest yielding treatments at both locations were anhydrous ammonia, injected UAN at planting, injected UAN at sidedressing and ammonium nitrate. Treatments with the lowest yield were granular urea followed by broadcast UAN. The yield differential at Belleville comparing injected UAN and broadcast UAN, both at planting, was 44 bu/acre. At Dixon Springs that differential was 27 bu/acre. AgrotaiN gave the greatest benefit to yield when added to urea, some 25 bu/acre at Belleville and 13 bu/acre at Dixon Springs. The yield benefit that accrued from AgrotaiN addition to UAN was much less and it was not much different for the dribble or broadcast methods of N application. At both locations the CS rotation had the highest overall yields, despite 40 lb N/acre less N being applied. Ear leaf tissue N composition results followed the treatment trends observed with grain yield.

An economic assessment clearly showed that injected N sources gave the highest net economic returns in no-till corn. However, for those growers who prefer to use urea, AgrotaiN use was very cost effective.

[1]Presented at the 29th North Central Extension - Industry Soil Fertility Conference, November 17 - 18, 1999. St. Louis, MO.

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Introduction

Decisions concerning the management of nitrogen (N) in no-till corn production have a large impact on the agronomic performance of the crop. Surface application of urea-containing N fertilizers in the presence of previous crop residues can result in high volatilization losses of ammonia (Fenn and Hossner, 1985; Grant et al., 1996) and reduced crop N recovery and yield (Beyrouty et al., 1986; Mengel et al., 1982). Higher rates of N immobilization and denitrification losses of N are also known to occur in the presence of surface residues (Kitur et al., 1984; Rice and Smith, 1982; Rice and Smith, 1984).

Beyrouty et al. (1988) measured ammonia losses of up to 30 percent of the N applied as urea, and other researchers have indirectly estimated that losses can be as high as 50 percent when urea is surface applied. If a rainfall of 0.5 inch or more is received within a day or two following application, ammonia volatilization losses are greatly reduced. It is in situations where urea or other urea-containing N sources such as UAN are applied to a moist soil surface with residues and rapid drying conditions follow that high ammonia volatilization losses are likely to occur.

Urease inhibitor technology offers producers an additional option in N management for no-till corn production. AgrotaiN, a urease inhibitor commercially available since 1996 and marketed by IMC-Agrico, serves to reduce the rate of urea hydrolysis and increase the plant availability of the applied N. No-till corn yield increases have been reported by a number of researchers when using AgrotaiN with surface applied urea N sources. Fox and Piekielek (1993) reported that AgrotaiN-amended urea resulted in an average yield increase of 14 bu per acre in a 3-year study in Pennsylvania and Murphy and Ferguson (1997) reported a yield benefit up to 56 bu per acre in one of three years under ridge-till in Nebraska. In those studies the greatest response to AgrotaiN was associated with conditions where ammonia volatilization losses were high following N application.

This report contains the results of no-till corn studies in southern Illinois in which N fertilizers, placement, timing, and AgrotaiN are evaluated agronomically and economically in a corn-corn and corn-soybean rotation system.

Materials and Methods

Studies were initiated in 1995 and continued in 1996, 1997, and 1998 at the Dixon Springs Agricultural Center (DSAC) of the University of Illinois and the Belleville Research Center (BRC) of Southern Illinois University to evaluate N sources, placement, timing and AgrotaiN inclusion on no-till corn. Nitrogen sources that were surface-applied included: granular urea (without and with AgrotaiN at 0.14%) granular ammonium nitrate, and UAN solution (without and with AgrotaiN at 0.5 lb/acre) which was both broadcast sprayed and dribble placed. Injected N sources included UAN (knifed-in at DSAC and point injection-applied at BRC) and anhydrous ammonia. Split N treatments included a 40-lb N/acre application of UAN without AgrotaiN as a broadcast spray ("weed and feed") at corn planting followed by sidedressing of dribbled UAN (without and with AgrotaiN at 0.5lb/acre) and an injected UAN treatment. A total of 12 N fertilizer treatments were evaluated, along with a 0-N control, in both a corn following corn and a corn following soybean rotation at each of the two locations. A split-plot design was used with rotations being the main plots and N fertilizer treatments being subplots.

This experiment was replicated four times at the BRC and five times at the DSAC. For the corn following corn (CC) rotation the N rate was 180 lb N/acre and for the corn following soybean (CS) rotation the rate was 140 lb N/acre. The N rate was decreased by 40 lb N/acre for the CS rotation to reflect a N credit allowable for a previous crop of soybean. Reports of results for individual years (1995, 1996, 1997 and 1998) were presented in the Proceedings of the 1996, 1997, 1998 and 1999 Illinois Fertilizer Conferences.

Results and Discussion

Effect of N treatments and rotation on yield

Over the four years of study corn yield differences due to N treatments were not influenced differently by the two rotations at Dixon Springs but were affected by rotation at Belleville (Table 1). The significant interaction observed at Belleville was mainly a result of dribbled UAN not yielding appreciably better than broadcast UAN for the CS rotation compared to the CC rotation. Most previous research has shown that dribbling UAN to be a more affective method of N application than broadcasting regardless of the previous crop. In our studies, when yield was averaged over all N treatments, yield of corn was 4 and 8 bu/acre greater with CS than CC at the Dixon Springs and Carbondale locations, respectively.

The effects of N treatments averaged across rotations and four years of study at Belleville are presented in Figure 1. The four highest yielding treatments were injected UAN (174 bu/acre), injected UAN at sidedressing (170 bu/acre), anhydrous ammonia (163 bu/acre) and ammonium nitrate (153 bu/acre). These results show the great importance of subsurface N application in no-till corn production or the use of a non-volatile source of N fertilizer if applied to the surface. The two lowest yielding treatments were granular urea (114 bu/acre) and broadcast UAN (130 bu/acre). This shows the poor efficiency with which surface-applied urea and UAN are used by corn. AgrotaiN addition to urea resulted in a yield increase of 25 bu/acre, its addition to broadcast UAN increased yield 7 bu/acre, and its inclusion with dribbled UAN gave a yield increase of 10 bu/acre. AgrotaiN treatment of UAN that was dribbled at sidedressing resulted in an eight bu/acre increase. Over the 4 years, nitrogen applied to the CC rotation (180 lb N/acre) resulted in an average yield across N treatments of 139 bu/acre whereas 140 lb N/acre applied in N treatments to the CS rotation resulted in an overall yield of 147 bu/acre.

At Dixon Springs, yield responses to N sources, AgrotaiN, and placement were smaller (Table 2 and Figure 2). The smaller differences in yield responses to treatments were related to poor yields obtained in the 1996 (drought) and 1997 (excessive wetness) seasons. Despite the lower overall yields at Dixon Springs, the four highest yielding treatments were the same ones as occurred at Belleville, although the ranking was different. Clearly, the injected N sources were the ones that resulted in the highest yields. AgrotaiN addition to urea resulted in a 13 bu/acre increase while its inclusion with dribbled or broadcast UAN resulted in four to six bu/acre yield increases. The overall yield difference between the CC and CS rotations was four bu/acre, favoring the CS rotation.

Effect of N treatments and rotation on ear leaf N

The ear leaf N composition, averaged over the four years of study and across the two rotations, for Belleville and Dixon Springs is shown in Table 2 and in Figures 7 and 8. There was a clear parallel between those treatments that resulted in the highest grain yield and those that had the highest ear leaf N composition. The highest ear leaf N was observed with the following four N treatments, both at Belleville and Dixon Springs: anhydrous ammonia, injected UAN (at planting and as a sidedressing), and ammonium nitrate. Surface dribbled UAN with AgrotaiN gave nearly the same ear leaf N values as ammonium nitrate. For the most part, those treatments with high ear leaf N concentrations also resulted in the highest grain yields observed in the studies.

Economic evaluation of N management practices and AgrotaiN on no-till corn

General comments

The cost and net benefit of each of the 12 alternative N management practices was compared. Partial budget analysis compared added costs and added benefits for each N management practice relative to the check plot. Yield and net benefit comparisons (Table 6) between treatments with and without AgrotaiN were also made. All cost and net benefit comparisons were on a per acre basis. The economic evaluation was based on the corn-corn rotation because of few significant rotational differences and the common practice in southern Illinois of no-till corn following a previous corn crop. The only difference in net benefit/acre or cost/acre between the corn-corn and corn-soybean rotations was that the corn-soybean rotation costs less by the value of the 40 lb N/acre rate difference between the rotations.

Cost analysis

Costs for each N management treatment included the material costs (180 lb N and AgrotaiN) and application costs. The costs were calculated based upon typical application methods. A local fertilizer dealer was consulted. Prices were quoted in cost/ton, including any custom application charges and delivery charges (Twin County FS, Murphysboro, IL). Costs for labor and tractor services as reported by Lazarus (1997) were used for anhydrous ammonia and UAN (inj) applications because farmers typically provide these services.

Costs of materials per ton and per pound of N appear in Table 3. Anhydrous ammonia was the most cost effective treatment even though its cost per ton is the highest. This was due to the concentration of N in anhydrous ammonia, which is the highest at 82 percent, compared to the other treatments. Thus, the cost/lb of N at \$.198/1b N was less expensive for anhydrous ammonia than the other treatments. The next least expensive treatment was UAN (bc) at \$.258/lb N. The cost per acre of materials and application charges is presented in Table 4.

The costs of the alternative N management practices are summarized in Table 5. The N treatments are ranked from the least costly per acre to the most costly per acre. Anhydrous ammonia was the least cost N management practice. Anhydrous ammonia had a \$19.60 advantage over UAN broadcast which was the next least costly alternative. The UAN alternatives were then followed by urea. Ammonium nitrate was the most costly alternative other than the AgrotaiN treatments. Note that the broadcast UAN plus AgrotaiN treatment was $0.07 less expensive than the ammonium nitrate treatment.

Net Benefit Analysis

The net benefit of the alternative N management practices and the net benefit of the AgrotaiN treatments were calculated. The benefits were the value of the added yield per acre which resulted from the treatments. The increased yield was valued at $2.50 a bushel. The net benefit equaled benefit less material and application costs per acre. The results appear in Table 6. The UAN injected practice had the highest net benefit because of its 7.5 bushel yield advantage over the next best alternative which was anhydrous ammonia. The UAN injected practice had an $8 advantage over anhydrous ammonia and had a $33.00 advantage over ammonium nitrate. UAN injected, anhydrous ammonia and ammonium nitrate had the three highest net benefits. The sidedressed UAN dribbled plus AgrotaiN had the fourth highest net benefit of all treatments. The AgrotaiN treatment resulted in a $6.00 per acre increase over sidedressed UAN dribbled alone.

AgrotaiN had positive net economic benefits for three of the four practices that included AgrotaiN, although AgrotaiN treatments resulted in a positive yield effect for all treatments. The greatest benefit for using AgrotaiN was with urea. AgrotaiN had a $42 per acre advantage over urea. For UAN dribbled, AgrotaiN resulted in a net loss of $2.00 per acre.

Overall economic assessment

The UAN injected practice had the greatest net economic benefit of the N management practices evaluated due to its higher yield advantage. UAN was followed by anhydrous ammonia and ammonium nitrate in terms of net economic benefit. The AgrotaiN treatments were more costly per acre. The net benefits of AgrotaiN were $12 to $68 lower than the top three N management practices. Although for those farmers who prefer to use urea, AgrotaiN clearly had an advantage of $42 per acre. For UAN applications the results were mixed. AgrotaiN had an advantage for UAN broadcast and sidedressed dribble applications but not for dribble alone.

Interpretation of economic benefits is limited to the alternatives and application rates evaluated. In practice the actual net economic benefits could be greater or less than those observed. If we were to assume that the injected UAN practice at 180 lb of N reached the yield response plateau then its net benefit could possibly be greater with less N applied. Or, the net economic benefits of UAN broadcast, UAN dribbled or urea could be improved by increasing the rate of N application. This increase in N rate would imply greater cost but would narrow the differences in net economic benefits between the alternatives.

Summary

When grain yields were summarized over the four years of study (1995 - 1998) at the two locations (Belleville and Dixon Springs), several common observations were made. The four highest yielding treatments at both locations were anhydrous ammonia, injected UAN at planting, injected UAN at sidedressing, and ammonium nitrate. The treatments with the lowest yield were granular urea followed by broadcast UAN. AgrotaiN gave the greatest benefit to yield when added to urea. The yield benefit that accrued from AgrotaiN addition to UAN was much less and it was not clearly more beneficial for one placement method over the other. Ear leaf tissue N composition results followed the treatment trends observed with grain yield.

An economic assessment clearly showed that injected N sources gave the greatest net economic returns in no-till corn. However, for those growers who prefer to use urea, AgrotaiN use was very cost effective.

Acknowledgements

The authors gratefully acknowledge the financial support of the Illinois Fertilizer Research and Education Council (FREC) and the Illinois fertilizer checkoff program that made these studies possible.

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Table 1. No-Till Corn Yield As Affected by N Fertilizer Sources, AgrotaiN, Placement, and Timing Obtained From The Corn-Corn and Corn-Soybean Rotations Averaged Across Four Years of Study (1995-1998) at the Belleville and Dixon Springs Locations.[1]

Treatment	Belleville Corn-Corn Rotation[2]	Belleville Corn-Soybean Rotation[3]	Dixon Springs Corn-Corn Rotation[2]	Dixon Springs Corn-Soybean Rotation[3]
	bu/ac		bu/ac	
Dry N Sources(B'Cast):				
Urea	106	120	98	100
Urea + AgrotaiN	134 (+28)	143 (+23)	112 (+14)	112 (+12)
Ammonium Nitrate	151	156	118	119
Liquid N:				
UAN (B'Cast)	123	137	103	107
UAN + AgrotaiN (B'Cast)	128 (+5)	145 (+8)	107 (+4)	114 (+7)
UAN (Dribble)	139	137	108	112
UAN + AgrotaiN (Dribble)	143 (+4)	152 (+15)	110 (+2)	120 (+8)
Inject:				
UAN	172	176	123	121
Anhydrous Ammonia	158	166	122	130
Split (W&F + Sidedress):				
UAN (Dribble)	134	141	114	115
UAN + Agrotain (Dribble)	144 (+10)	145 (+4)	117 (+3)	118 (+3)
UAN (Inject)	170	170	124	124
Control (O-N)	34	53	62	73
Mean (Excluding Control)	139	147	112	116
Statistical Significance:				
Rotation	**		*	
Rotation X Treatment	**		NS	

[1] Values in parenthesis are the yield increases obtained with AgrotaiN addition to the N sources being compared.

[2] For the corn-corn rotation a total of 180 lb N/ac was applied as the various N sources. For the split (W & F + Sidedress) treatments 40lb N/ac was applied W & F as broadcast UAN and 140 lb N/ac was applied as sidedress UAN.

[3] For the corn-soybean rotation a total of 140 lb N/ac was applied as the various N sources. For the split (W & F + Sidedress) treatments 40 lb N/ac was applied W & F as broadcast UAN and 100 lb N/ac was applied as sidedress UAN.

Table 2. **No-Till Corn Ear Leaf N As Affected by N Fertilizer Sources, AgrotaiN, Placement, and Timing Obtained From The Corn-Corn and Corn-Soybean Rotations Averaged Across Four Years of Study (1995-1998) at the Belleville and Dixon Springs Locations.**

	Belleville		Dixon Springs	
Treatment	Corn-Corn Rotation[1]	Corn-Soybean Rotation[2]	Corn-Corn Rotation[1]	Corn-Soybean Rotation[2]
	%		%	
Dry N Sources(B'Cast):				
Urea	2.39	2.19	2.22	2.17
Urea + AgrotaiN	2.58	2.54	2.55	2.29
Ammonium Nitrate	2.74	2.66	2.52	2.47
Liquid N:				
UAN (B'Cast)	2.58	2.49	2.43	2.23
UAN + AgrotaiN (B'Cast)	2.57	2.54	2.38	2.31
UAN (Dribble)	2.75	2.45	2.50	2.27
UAN + AgrotaiN (Dribble)	2.72	2.63	2.48	2.47
Inject:				
UAN	2.98	2.86	2.79	2.47
Anhydrous Ammonia	2.92	2.77	2.85	2.61
Split (W&F + Sidedress):				
UAN (Dribble)	2.63	2.52	2.58	2.33
UAN + Agrotain (Dribble)	2.76	2.53	2.59	2.40
UAN (Inject)	2.91	2.75	2.76	2.51
Control (O-N)	1.71	1.68	2.06	1.87
Mean (Excluding Control)	2.71	2.58	2.55	2.38
Statistical Significance:				
Rotation	**		**	
Rotation X Treatment	*		NS	

[1]For the corn-corn rotation a total of 180 lb N/ac was applied as the various N sources. For the split (W & F + Sidedress) treatments 40lb N/ac was applied W & F as broadcast UAN and 140 lb N/ac was applied as sidedress UAN.

[2]For the corn-soybean rotation a total of 140 lb N/ac was applied as the various N sources. For the split (W & F + Sidedress) treatments 40 lb N/ac was applied W & F as broadcast UAN and 100 lb N/ac was applied as sidedress UAN.

Table 3. Cost of AgrotaiN per Gallon and N Materials per Ton and per Pound of N.

	Cost per gal	
AgrotaiN (2.21 lb ai/gal)	$43	
	Cost per ton	Cost per lb of N
Anhydrous ammonia	$325	$0.198
Ammonium nitrate (34-0 0)	$212	$0.312
UAN (32-0-0)	$165	$0.258
Urea (46-0-0)	$262	$0.285

Source: Twin County FS.

Table 4. Materials and Application Costs of N Management Practices Applying 180 lb N/acre with and without AgrotaiN.

Anhydrous Ammonia at $325/T	**Cost per acre**
Cost of anhydrous ammonia/lb of N = $0.198 x 180 lb N/ac	$ 35.64
Cost of toolbar at $18/ton 1640 lb N/180 lb N/ac=9.1 ac, $18/9.1 ac	1.98
Delivery cost: $30/load; 1 load = 2 T / 3280 lb of actual N x 180 lb/ac	1.64
Tractor cost	1.86
Labor cost	0.94
	$42.06
UAN (bc) at $165/T	
Cost of UAN/lb of N = $0.258 x 180 lb N/ac	46.44
Custom application charge	5.25
	$51.69
UAN (inj) at $165/T	
Cost of UAN/lb of N = $0.258 x 180 lb N/ac	46.44
Cost of toolbar (based on the same cost as for anhydrous ammonia)	1.98
Delivery cost at $30/load; 1 load = 1000 gal. at 3 lb N/gal	1.80
Tractor cost	1.86
Labor cost	0.94
	$53.02
UAN (dr) or Sidedress at $165/T	
Cost of UAN/lb of N = $0.258 x 180 lb N/ac	46.44
Custom application charge	7.00
	$53.44
Urea (bc) at $262/T	
Cost of Urea/lb of N = $0.285 x 180 lb of N/ac	51.30
Custom application charge	5.35
	$56.65
UAN + AgrotaiN (bc) at $165/T for UAN and $43/gal for AgrotaiN	
Cost of UAN/lb of N = $0.258 x 180 lb N/ac	46.44
Cost of AgrotaiN/ac	9.75
Custom application charge	5.25
	$61.44
Ammonium Nitrate (bc) at $212/T	
Cost of ammonium nitrate/lb of N = $0.312 x 180 lb of N/ac	56.16
Custom application charge	5.35
	$61.51
UAN + AgrotaiN (dr) at $165/T for UAN and $431gal for AgrotaiN	
Cost of UAN/lb of N = $0.258 x 180 lb N/ac	46.44
Cost of AgrotaiN/ac	9.75
Custom application charge	7.00
	$63.19
Urea + AgrotaiN (bc) at $262/T for urea and $43/gal for AgrotaiN	
Cost of Urea/lb of N = $0.285 x 180 lb of N/ac	51.30
Cost of AgrotaiN/ac	10.66
Custom application charge	5.35
	$67.31

Table 5. Cost of Applying 180 Pounds of N per Acre.

N Treatments	Cost/ac
Anhydrous Ammonia (inj)	$42.06
UAN (bc)	$51.69
UAN (inj) or Sidedress	$53.02
UAN (dr) or Sidedress	$53.44
Urea (bc)	$56.65
UAN + AgrotaiN (bc)	$61.44
Ammonium Nitrate (bc)	$61.51
UAN + AgrotaiN (dr)	$63.19
Urea + AgrotaiN (bc)	$67.31

bc broadcast
dr dribble
inj injected

Table 6. **Net Benefits of N Management Treatments and AgrotaiN Treatments for the Combined Years of 1995 through 1998 and Combined Sites of Belleville and Dixon Springs for the Corn-Corn Rotation.**

N Management Treatment	Treatment Yield Effect (bu/ac)	Net Benefit[1] of Treatment (per ac)	AgrotaiN Yield Effect (bu/ac)	Net Benefit of AgrotaiN (per ac)
UAN (inj)	99.5	$196		
Anhydrous Ammonia (inj)	92.0	$196		
Ammonium Nitrate (bc)	86.5	$155		
UAN + AgrotaiN (dr) Sidedress	82.5	$143	6.5	+$6
UAN (dr) Sidedress	76.5	$137		
UAN + AgrotaiN (d r)	78.5	$133	3.0	-$2
UAN (dr)	75.5	$135		
UAN + AgrotaiN (bc)	69.5	$112	4.5	+ $1
UAN (bc)	65.0	$111		
Urea + AgrotaiN (bc)	75.0	$120	21	+$42
Urea (bc)	54.0	$78		

[1]Net benefit of treatment over control = yield effect bu/ac - control yield x $2.50/bu - treatment materials and application cost/ac.

bc broadcast
dr dribble
inj injected

Figure 1. No-Till Corn Yield as Affected by N Fertilizers, AgrotaiN, and Rotation at the Belleville Research Center (Average 1995-1998).

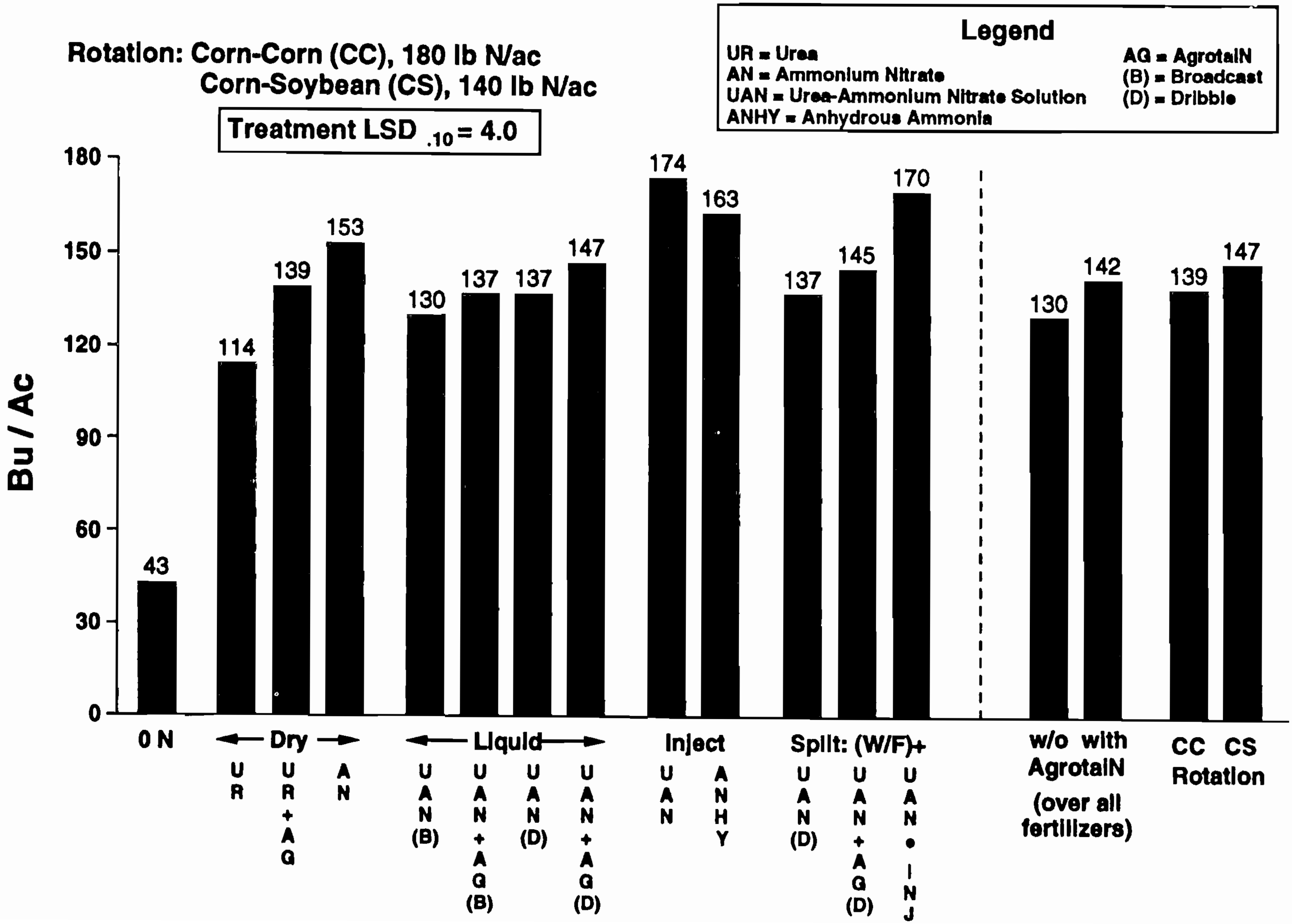


Figure 2. No-Till Corn Yield as Affected by N Fertilizers, AgrotaiN, and Rotation at the Dixon Springs Agricultural Center (Average 1995-1998).

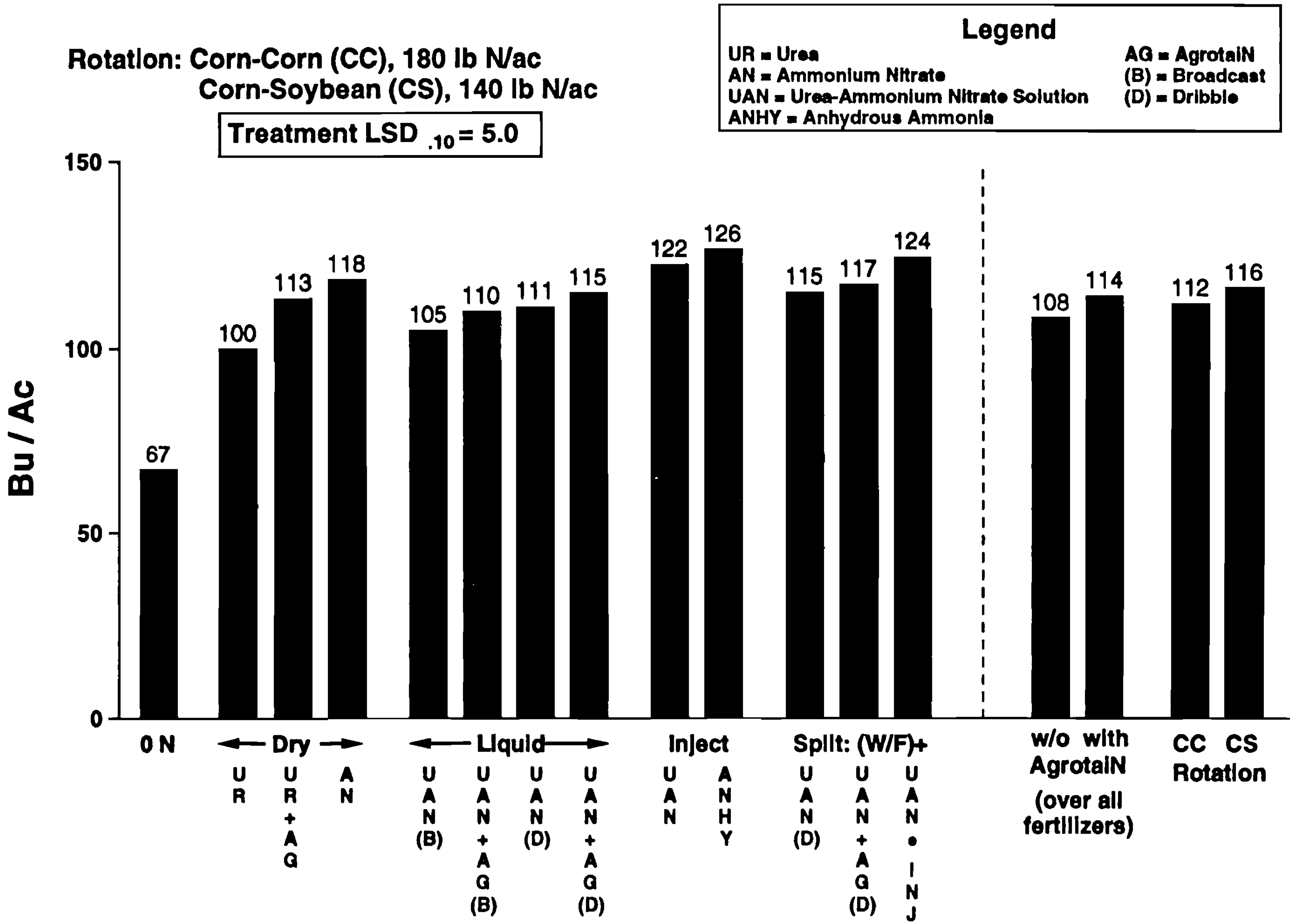
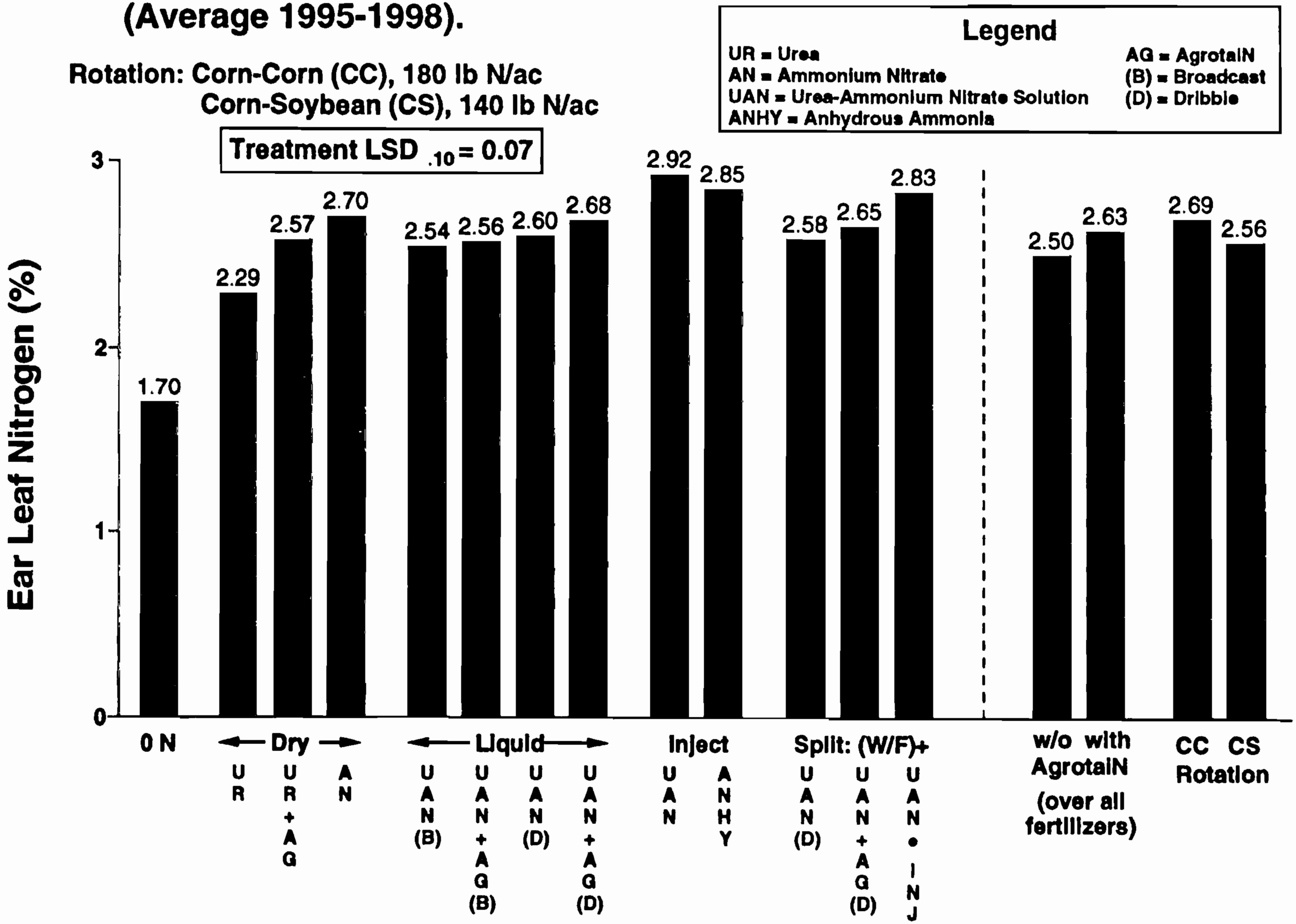


Figure 3. Nitrogen Composition of Corn Ear Leaf Tissue as Affected by N Fertilizers, AgrotaiN, and Rotation at the Belleville Research Center (Average 1995-1998).



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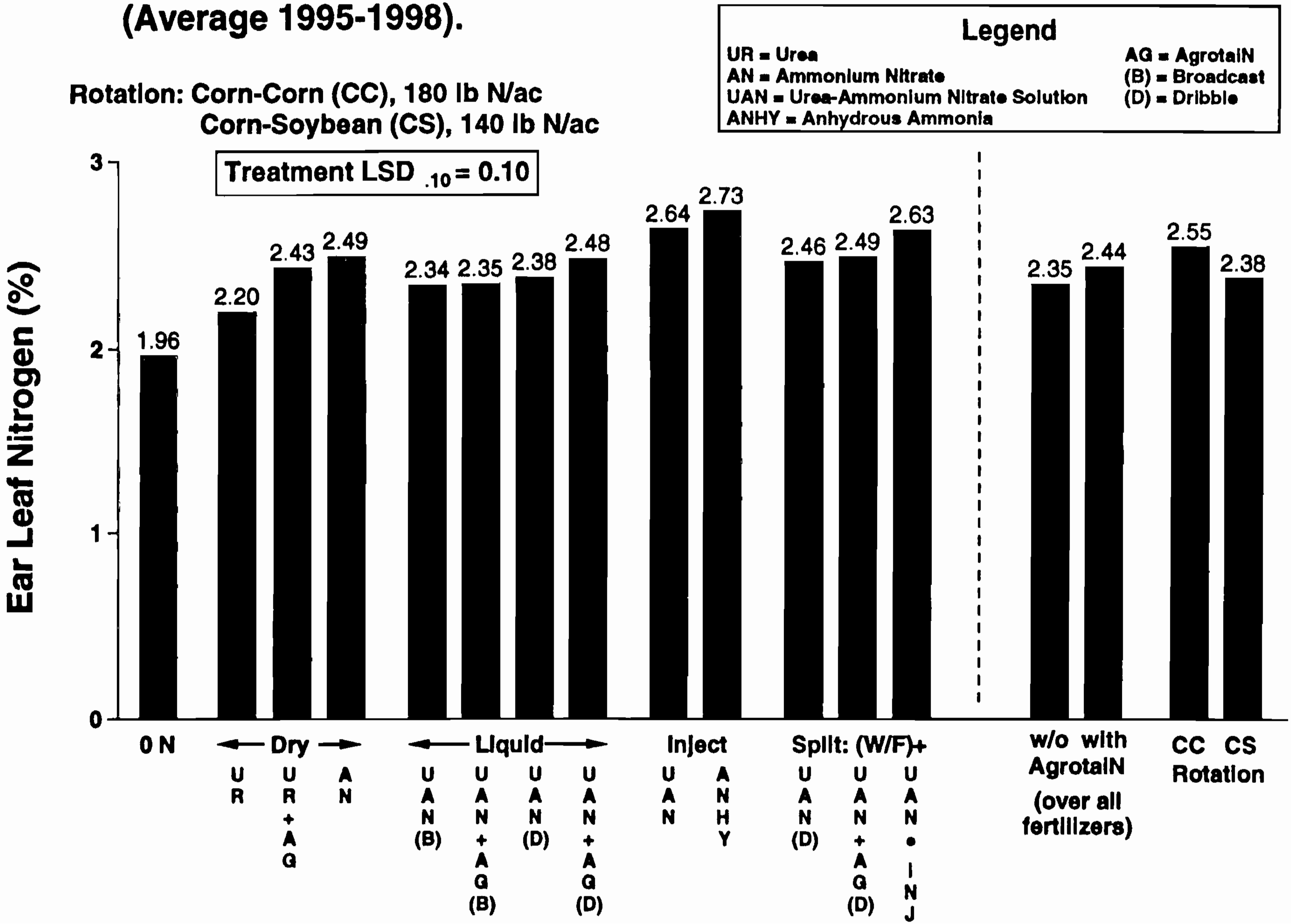

PROCEEDINGS OF THE

TWENTY-NINTH NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 15

November 17-18, 1999
St. Louis Westport Holiday Inn
St. Louis, Missouri

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Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
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