Enhanced Efficiency Liquid N Applications for Corn

FINAL REPORT

Investigators:
Kelly Nelson, Div. of Plant Sciences, Univ. of Missouri, Novelty, MO; Peter Motavalli, Dept. of Soil, Environ., and Atmos. Sci., Univ. of Missouri, Columbia, MO; and Bruce Burdick, Div. of Plant Sciences, Univ. of Missouri, Albany, MO.

Objectives and Relevance:

Corn production in Missouri covers an average area of approximately 2.9 million acres since 2004 and has a value of $1.2 billion in total production (NASS, 2009). High yield corn production systems have integrated fungicide applications (Nelson and Meinhardt, 2011) to maximize photosynthetic efficiency of the plant to meet the growing food, fuel, and fiber demands. Plant growth stimulation with the strobilurin fungicides has been related to a reduction in the incidence of disease as well as increased nitrate uptake and assimilation in small grains (Köhle et al., 2002). Research has shown that pyraclostrobin (Headline®) was important in stimulating nitric oxide, a key messenger in plants (Conrath et al., 2004). Increased nitrate uptake and assimilation following an application of a strobilurin fungicide would justify additional nitrogen fertilizer at the time of application to corn. Identifying fertilizer sources that synergistically increase yield with a fungicide treatment would provide opportunities to manage disease, reduce application costs, and provide additional fertilizer when crop demand is greatest.

Chlorophyll meters have been used to diagnose N deficiency and provide recommendations for N rates and yield responses (Scharf et al., 2006). Relative chlorophyll meter readings were the best predictor of yield response to N applications and required a high N reference, but absolute chlorophyll meter values were good predictors of grain yield from V10-R1. Farmers planning a fungicide application could utilize a chlorophyll meter as a decision aid to determine if an enhanced efficiency liquid N fertilizer should be combined with the fungicide.

In 2008, 2009, and 2010, N loss limited grain production in several production fields in upstate Missouri. Research in 2004 and 2005 evaluated rescue N applications for corn (Nelson et al., 2011). Late applications were beneficial for restoring yield; however, liquid N applications reduced yield when broadcast applied at 150 lbs N/acre from 2 to 4 ft tall corn. Over the past two years, commercially available liquid fertilizers were evaluated for corn grain yield response when applied at VT in the presence and absence of Headline (Nelson et al., 2009). Products were identified that consistently increased corn grain yield. Nitamin (30-0-0), slowly available N from triazone and methylene urea, at 1 gallon/acre increased yields 28 bu/acre at four of the six site years. When Nitamin was combined with pyraclostrobin at 6 oz/a, there were inconsistent yield responses. Other research evaluated rates of Nitamin up to 4 gallon/acre with and without Headline in 2008 and 2009 (Figure 1) (Nelson and Meinhardt, 2009). Combinations with Headline at 6 oz/acre were similar to this research; however, a reduced rate of Headline (3 oz/acre) with Nitamin at 1 gal/acre synergistically increased yield 26 bu/acre particularly when Headline was added to the spray mixture first followed by Nitamin. A rate response to Nitamin alone increased yield 2 bu/lb of applied N. Research is needed to confirm the effect of reduced rates of Nitamin and Headline as well as the efficiency of this N source for late applications in corn. If grain yield response and recommended rates could be related to SPAD leaf readings at the time of application, this would be a great tool to help farmers and custom applicators make informed decisions on what products to recommend at a VT application timing.

The objectives of this research were to:

1. Validate the effect of mixing order of an enhanced efficiency liquid N rates with a preventative fungicide, and
2. Provide foliar liquid fertilizer recommendations based on SPAD readings at VT.

Procedures:

Field research was established at the Greenley Research Center near Novelty and Hundley-Whaley Center near Albany in 2010 and 2011. Corn followed soybean and conventional tillage was used at both sites. Plots were 10 by 50 ft and arranged in a randomized complete block design with six replications at each site. This study was arranged as a three-factor factorial including soil applied ammonium nitrate at three rates (75, 150, and 300 lbs N/a), three enhanced efficiency liquid N rates (Nitamin at 0, 1, and 3 gal/acre), and four pyraclostrobin (Headline) treatments (non-treated control, Headline applied at 3 oz/acre plus nonionic surfactant added first or following the addition of Nitamin, and Headline at 6 oz/a added first followed by nonionic surfactant and Nitamin). Foliar treatments were applied on 12 July 2010 and 8 July 2011 at Novelty, and 13 July 2010 and 15 July 2011 at Albany when corn was at the VT stage of development (Ritchie et al., 1993). Foliar fertilizer and fungicide treatments were applied with a CO_2 propelled hand boom at 3 gal/acre. Field and management information is reported in Table 1. Supplemental irrigation was scheduled using the Woodruff chart.

Corn injury from 0 (no visual crop injury) to 100% (complete crop death) was evaluated 7 and 14 days after treatment (DAT) based on the combined visual effects of foliar treatments on necrosis, chlorosis, and stunting. The severity of common rust (*Puccinia sorghi*), northern corn leaf blight (*Exserohilum turcicum*), and grey leaf spot (*Cercospora zeae-maydis*) was rated on a scale of 0 (no disease) to 100% (complete infestation) 0, 28, and 42 DAT. A Minolta chlorophyll meter (SPAD-502, Konica Minolta, Hong Kong) was used determine absolute ear leaf greenness differences among treatments at the time of application and 28 DAT in order to help determine if an enhanced efficiency liquid N fertilizer would be beneficial in the presence or absence of a fungicide treatment, and determine if an enhanced efficiency fertilizer rate could be recommended based on leaf greenness. The center two rows were harvested for yield and converted to 15.5% moisture prior to analysis. All data were subjected to ANOVA and means separated using Fisher's protected LSD at $P = 0.05$ or 0.1. Data were combined over factors and locations when appropriate as indicated by the analysis of variance (data not presented).

Results:

Rainfall at both locations was extensive in 2010. Ammonium nitrate was soil-applied approximately 1 month after planting to increase efficiency of this factor (Table 1). However, conditions throughout the season were favorable for extensive N loss in 2010. Corn plant population at harvest was 26,000 to 28,000/acre at both locations (Table 2). The severity of disease was less than 1% at VT (Table 3). Chlorophyll meter readings indicated differences among soil applied N rates as expected at the time of the foliar VT applications (Table 3, Figure 1). The Albany site was greener than Novelty indicating less N loss at Albany in 2010 while both sites had higher chlorophyll meter readings in 2011 (Figure 1). We expected the 300 lb N/acre rate would be in the low response range to additional N (Scharf et al., 2006), and N would not have been limiting.

The different N rates provided different yielding environments that may respond to a slow-release liquid N application. Based upon previous research from V10 to R1 (Scharf et al., 2006), absolute chlorophyll meter readings at VT indicated that an addition of 130 to 180 lbs N/acre, 100 to 130 lbs N/acre, and 45 to 90 lbs N/acre was recommended for the soil applied rates of 75 lbs N/acre, 150 lbs N/acre, and 300 lbs N/acre, respectively, in 2010. In 2011, less than 25 lbs N/acre was needed based on absolute chlorophyll meter readings at the time of application. Since the Nitamin rates evaluated in this research were applied at 3.1 and 9.3 lbs N/acre for the 1 and 3 gal/acre rates, respectively.

Absolute chlorophyll meter readings at VT generally remain similar or decrease slightly over time in the absence of additional N (Scharf et al., 2006). Chlorophyll meter values 28 DAT indicated an increase in greenness with Nitamin at 3 gal/acre compared to the readings 0 DAT in some instances, while limited differences between the 0 and 28 DAT readings were observed when Nitamin was applied at 0 or 1 gal/acre (Figure 1). Based on the chlorophyll meter values, we expected yield differences for the 3 gal/acre rate of Nitamin; however, this was not the case (Table 2). Nitamin at 3 gal/acre injured corn 3 to 4% (Table 4) which probably negated any yield increase from this treatment. There was no interaction with pyraclostrobin on crop injury and pyraclostrobin had no effect on crop injury ($P = 0.57$).

Nitamin at 1 or 3 gallons/acre had no effect on corn yield in a low (soil applied N at 75 lbs/acre at Novelty and Albany in 2010 and 2011) or medium (soil applied N at 150 lbs/acre at Novelty and Albany in 2010 and 2011) yield environments (Table 2). This indicated that too much N was needed to overcome N deficiency with a Nitamin application. A rescue N application (Nelson et al., 2011) was necessary in this situation. However, rescue N applications of liquid UAN at high rates that were broadcast applied at 150 lbs N/acre caused extensive injury to corn reduced yield and should not be recommended (Nelson et al., 2011). Grain yields were reduced 7 to 10 bu/acre with Nitamin at 3 gal/acre at Novelty in a medium yield environment which was probably due to increased crop injury as a result of the Nitamin application. In a high yield environment (soil applied N at 300 lbs/acre at Novelty and Albany), Nitamin increased grain yields 6 bu/acre compared to the non-treated control. Similarly, Headline increased yield 6 to 9 bu/acre compared to the non-treated control in a high yield (>150 bu/acre) environment. This research indicated no significant effect of mixing order on corn response when Nitamin was applied at 1 gal/acre and Headline at 3 oz/acre.

Soil-applied N, foliar applied N, fungicide treatment, and site-year affected the severity of foliar disease in this research. The severity of grey leaf spot was less than 5% (Table 5). The severity of grey leaf spot increased slightly as preplant N rate increased and Nitamin rate increased from 1 to 3 gal/acre. Headline generally decreased the severity of grey leaf spot in a high yield environment (300 lbs N/acre), and with Nitamin at 1 gal/acre or in the absence of Nitamin. Northern corn leaf blight and common rust severity was affected by site-years and interactions among factors were observed (Tables 6 and 7). The severity of Northern corn leaf blight was <2% at Albany and Novelty in 2010 (Tables 6 and 7). The severity of Northern corn leaf blight increased slightly as the Nitamin rate increased at Novelty and Albany in 2011 (Table 6), and increased 3 to 6% at Novelty and 1 to 2% at Albany in 2011 (Table 7). Common rust was not present at Novelty or Albany in 2011 and was < 2% at Novelty in 2010 (Tables 6 and 7). As preplant N rates increased and Nitamin rates increased to 3 gal/acre, the severity of common rust generally increased (Table 7).

Headline had no effect on grain moisture ($P = 0.95$), but grain moisture was affected by preplant N rates (Table 8) and Nitamin rates (Table 9). At Novelty, grain disease (Diplodia) increased as the rate of preplant N increased 4% (Table 8) and slightly as the Nitamin rate increased (Table 9) in 2010, but no differences were observed at Novelty or Albany in 2011 or Albany in 2010. Headline did not affect grain disease (P = 0.27) similar to other research (Nelson and Meinhardt, 2011). There was an interaction between Nitamin rates and soil applied N rates on protein concentration with a 1.1 to 1.3% point increase as the soil applied N rate increased. Nitamin increased protein concentration 0.2% points as the rate increased from 0 to 3 gal/acre in a high yield environment (300 lbs N/acre), but there was no effect of Headline on protein concentrations (*P* = 0.36). There was a significant interaction between Headline and Nitamin rates (P = 0.04), but minimal differences in starch concentrations were observed (Table 9).

In summary, Nitamin at 1 gal/acre increased grain yields 11 bu/acre when chlorophyll meter readings at VT were greater than 45 in 2010, greater than 55 at Novelty in 2011, and greater than 63 at Albany in 2011. Nitamin at 1 or 3 gallons/acre had no effect on corn yield in a low (soil applied N at 75 lbs/acre at Novelty and Albany in 2010 and 2011) or medium (soil applied N at 150 lbs/acre at Novelty and Albany in 2010 and 2011) yield environments (Table 2). This indicated that too much N was needed to overcome N deficiency with a Nitamin application. Grain yields were reduced 7 to 10 bu/acre with Nitamin at 3 gal/acre at Novelty in a medium yield environment which was probably due to increased crop injury as a result of the Nitamin application. In a high yield environment (soil applied N at 300 lbs/acre at Novelty and Albany), Nitamin increased grain yields 6 bu/acre compared to the non-treated control. Similarly, Headline increased yield 6 to 9 bu/acre compared to the non-treated control in a high yield (>150 bu/acre) environment. This research indicated no significant effect of mixing order on corn response when Nitamin was applied at 1 gal/acre and Headline at 3 oz/acre. The severity of diseases in this research was <12% depending on the treatment and was affected by N fertility, Nitamin rate, and fungicide management in some instances depending on the location. Headline and Nitamin at 1 gal/acre shows promise in high yielding environments.

References:

Conrath, U., G. Amoroso, H. Köhle, and D.F. Sultemeyer. 2004. Non-invasive online detection of nitric oxide from plants and other organisms by mass spectroscopy. Plant J. 38:1015-1022.

Köhle, H., K. Grossmann, T. Jabs, M. Gerhard, W. Kaiser, J. Glaab, U. Conrath, K. Seehaus, and S. Herms. 2002. Physiological effects of the strobilurin fungicide F 500 on plants. *In* Modern Fungicides and Antifungal Compounds III. (Dehne, H.W., U. Gisi, K.H. Kuck, P.E. Russell, and H. Lyr, eds.). Bonn: Mann GmbH & Co. KG, pp. 61-74.

NASS. 2009. USDA National Agricultural Statistics Service. Online at http://www.nass.usda.gov/QuickStats/Create_Federal_Indv.jsp. Accessed Nov. 11, 2009.

Nelson, K.A., and C.G. Meinhardt. 2009. Effect of Nitamin and Headline on corn grain yield. Field Day Report. Greenley Memorial Research Center. pp. 67-71.

Nelson, K.A., and C.G. Meinhardt. 2011. Foliar boron and pyraclostrobin effects on corn yield. Agron. J. 103:1352-1358.

Nelson, K.A., P. Motavalli, W.G. Stevens, B. Burdick, and L. Sweets. 2009. Foliar Fertilizer and Fungicide Interactions on Corn. Missouri Soil Fertility and Fertilizers Research Update. Agron. Misc. Publ. #09-01.

Nelson, K.A., P.C. Scharf, W.G. Stevens, and B.A. Burdick. 2011. Rescue nitrogen applications for corn. Soil Sci. Soc. Am. J. 75:143-151.

Ritchie, S.W., J.J. Hanway, and G.O. Benson. 1993. How a corn plant develops. Iowa State Coop. Ext. Serv. Spec. Rep. 48. Ames, IA.

Scharf, P.C., S.M. Brouder, and R.G. Hoeft. 2006. Chlorophyll meter readings can predict nitrogen need and yield response of corn in the North-central USA. Agron. J. 98:655-665.

Table 1. Field and management information at Novelty and Albany in 2010 and 2011.

	Novelty		Albany	
Management information	2010	2011	2010	2011
Previous crop	Soybean	Soybean	Soybean	Soybean
Hybrid or cultivar	DK 63-42 VT3	DK 63-42 VT3	DK 63-42 VT3	Pioneer 33D49
Planting date	13 Apr.	1 Apr.	26 Apr.	3 May
Seeding rate (seeds/acre)	32,000	30,800	29,500	29,500
Harvest date	30 Sept.	12 Sept.	19 Oct.	26 Sept.
Maintenance fertilizer	13 Apr., MAP 32-160-300 (N-P-K)	NA	15 Apr., DAP 18-46-80 (N-P-K)	NA
Ammonium nitrate	7 May, Between-row at 75, 150, or 300 lbs N/acre	18 May, Between-row at 75, 150, or 300 lbs N/acre	26 May, Between-row at 75, 150, or 300 lbs N/acre	6 May, Between-row at 75, 150, or 300 lbs N/acre
Weed management				
Preemergence	15 Apr., Atrazine (2 qt/acre) + Outlook (21 oz/acre)	13 Apr., Lumax (2.5 qt/acre)	27 Apr., Lumax (3.2 qt/acre)	3 May, Lumax (3.2 qt/acre)
Postemergence	22 June, Roundup PowerMAX (30 oz/acre) + DAS (17 lbs/100 gal)	NA	NA	NA
Disease management	Pyraclostrobin +/- Nitamin	Pyraclostrobin +/- Nitamin	Pyraclostrobin +/- Nitamin	Pyraclostrobin +/- Nitamin
Date & Time	12 July, 1700 to 2100 h	8 July, 1000 to 1300	13 July, 1100 to 1600 h	15, July 800 to 1100 h
Air temperature (ºF)	72-83	79-84	84-89	83-87
Relative humidity (%)	63-83	62-70	61-77	66-83
Wind speed (MPH, direction)	1-3, E	0-1, W	3-4, S	2-5, S
Height (inches)	72-96	90-100	84-108	88-120
Leaf moisture	Dry	Dry	Dry	Dry

[†]Abbreviations: DAP, diammonium phosphate; DAS, diammonium sulfate; MAP, monoammonium phosphate; NA, None applied.

Table 2. Corn grain yield for the low (75 lbs N/acre), medium (150 lbs N/acre at Novelty and Albany), and high (300 lbs N/acre) yield environments, and severity of disease for preplant N rates at VT. Main effects were presented in the absence of interactions.

Treatment	Plant population	Low	Medium: Albany	Medium: Novelty	High
	No./acre	---------------- Bu/acre ----------------			
Non-treated	26,300	116	129	149	162
Nitamin (1 gal/acre)	26,000	113	126	152	168
Nitamin (3 gal/acre)	28,000	117	134	142	161
LSD (*P* = 0.1)†	NS	NS	NS	7	5
Non-treated	26,900	117	131	146	157
Headline (3 oz/acre) + Nitamin‡	26,200	113	131	147	163
Nitamin + Headline (3 oz/acre) ‡	27,600	117	128	151	166
Headline (6 oz/acre) + Nitamin‡	27,800	114	129	147	168
LSD (*P* = 0.1)§	NS	NS	NS	NS	6

†Data were averaged over Headline treatments, years (2010 and 2011) and locations (Albany and Novelty, except the medium yield environment).
‡Listed order is the mixing order.
§Data were averaged over Nitamin treatments, years (2010 and 2011) and locations (Albany and Novelty, except the medium yield environment).

Table 3. Chlorophyll meter readings at Novelty and Albany, and severity of disease for preplant N rates at VT. Data were combined over foliar fertilizer and fungicide treatments.

Preplant N rates	Chlorophyll meter: Novelty 2010	Albany 2010	Novelty 2011	Albany 2011	Average	Severity of disease†: Grey leaf spot	Common rust	Northern corn leaf blight
lbs N/acre	--------------------- SPAD units ---------------------					-------------------- % --------------------		
75	32.5	36.6	47.7	60.3	44.3	< 1	0	< 1
150	37.3	44.2	52.6	62.0	49.0	< 1	0	< 1
300	43.2	50.3	54.6	63.0	52.8	< 1	0	< 1
LSD (*P* = 0.01)	------------------- 1.0 -------------------				0.5	NS	NS	NS

†Common rust (*Puccinia sorghi*); grey leaf spot (*Cercospora zeae-maydis*); northern corn leaf blight (*Exserohilum turcicum*).

Table 4. Corn injury as affected by preplant N management and foliar Nitamin rate 14 d after treatment. Data were combined over four site-years and fungicide treatments.

Preplant N rates (lbs/acre)	Nitamin 0 gal/acre	Nitamin 1 gal/acre	Nitamin 3 gal/acre
	------------------------------------ % ------------------------------------		
75	0	1	4
150	0	1	4
300	0	1	3
LSD (*P* = 0.05)	------------------------------------ 1 ------------------------------------		

Table 5. Severity of grey leaf spot 42 d after treatment as affected by preplant N and Headline, and Nitamin rate and Headline. Data were combined over four-site years and main effects presented.

Fungicide treatment	Preplant N rate (lbs N/acre): 75	150	300	Nitamin rate (gal/acre): 0	1	3
	------- Severity of disease (%) -------					
Non-treated	3	4	5	4	4	4
Headline at 3 oz/acre + NIS fb Nitamin	3	3	4	3	3	4
Nitamin fb Headline at 3 oz/a + NIS	3	4	4	3	3	4
Headline at 6 oz/acre + NIS fb Nitamin	3	4	4	3	3	4
LSD (*P* = 0.1)	--------- 1 ---------			------ 1 ------		

Table 6. Severity of northern corn leaf blight severity as and common rust severity as affected by preplant N rate and location 42 d after treatment.

	Northern corn leaf blight				Common rust											
	Novelty	Novelty	Albany	Albany	Novelty 2010			Novelty 2011			Albany 2010			Albany 2011		
Preplant rate	2010	2011	2010	2011	0	1	3	0	1	3	0	1	3	0	1	3
(gal/acre)	Severity of disease (%)															
75	0	7	1	3	1	1	2	0	0	0	2	2	2	0	0	0
150	1	8	1	4	1	1	2	0	0	0	3	2	2	0	0	0
300	1	8	1	4	1	2	2	0	0	0	7	4	2	0	0	0
LSD (*P* = 0.1)	1				1											

Table 7. Effect of pyraclostrobin (Headline) treatment, location, and Nitamin rate on the severity of northern corn leaf blight and common rust 42 d after treatment.

	Northern corn leaf blight												Common rust											
	Novelty 2010			Novelty 2011			Albany 2010			Albany 2011			Novelty 2010			Novelty 2011			Albany 2010			Albany 2011		
Fungicide treatment†	0	1	3	0	1	3	0	1	3	0	1	3	0	1	3	0	1	3	0	1	3	0	1	3
	Severity of disease (%)																							
Non-treated	0	1	1	8	9	12	1	1	1	3	4	5	2	2	2	0	0	0	3	3	3	0	0	0
Headline at 3 oz/acre + NIS fb Nitamin‡	0	0	1	6	6	10	1	1	1	3	3	5	1	1	2	0	0	0	2	2	4	0	0	0
Nitamin fb Headline at 3 oz/a + NIS†	0	0	1	6	6	12	1	1	2	3	3	4	1	1	2	0	0	0	2	2	4	0	0	0
Headline at 6 oz/acre + NIS fb Nitamin†	0	1	1	5	5	11	1	1	1	3	3	4	1	1	2	0	0	0	2	2	5	0	0	0
LSD (*P* = 0.1)	1												1											

†Mixing order for fungicide treatments.

‡Abbreviations: fb, followed by; NIS, non-ionic surfactant.

Table 8. Effect of preplant N rate on grain moisture, disease (Diplodia) at each site-year, and protein concentration for Nitamin rates. Data were combined over site-year in the absence of inteactions.

	Grain	Grain disease (Diplodia)				Protein concentration		
Soil applied N	moisture	Novelty 2010	Novelty 2011	Albany 2010	Albany 2011	0	1	3
(lbs/acre)	%							
75	20.5	5	0	2	0	7.3	7.2	7.3
150	20.1	6	0	2	0	7.7	7.8	7.8
300	20.7	9	0	2	0	8.4	8.5	8.6
LSD (P = 0.05)	0.3	1				0.2		

Table 9. Effect of Nitamin rates on grain moisture, disease (Diplodia) at each site-year, and starch concentration for different Headline (pyraclostrobin) applications.

		Grain disease (Diplodia)				Starch concentration			
Nitamin rate	Grain moisture	Novelty 2010	Novelty 2011	Albany 2010	Albany 2011	Non-treated	Headline at 3 oz/acre + NIS fb Nitamin[†]	Nitamin fb Headline at 3 oz/a + NIS[†]	Headline at 6 oz/acre + NIS fb Nitamin[†]
(gal/acre)									
0	20.6	6	0	2	0	73.0	73.1	72.9	73.0
1	20.5	7	0	2	0	73.0	73.0	73.0	73.0
3	20.3	7	0	2	0	73.1	72.9	73.0	72.9
LSD (P = 0.05)	0.3	1				0.2			

[†]Mixing order for fungicide treatments.

[‡]Abbreviations: fb, followed by; NIS, non-ionic surfactant.

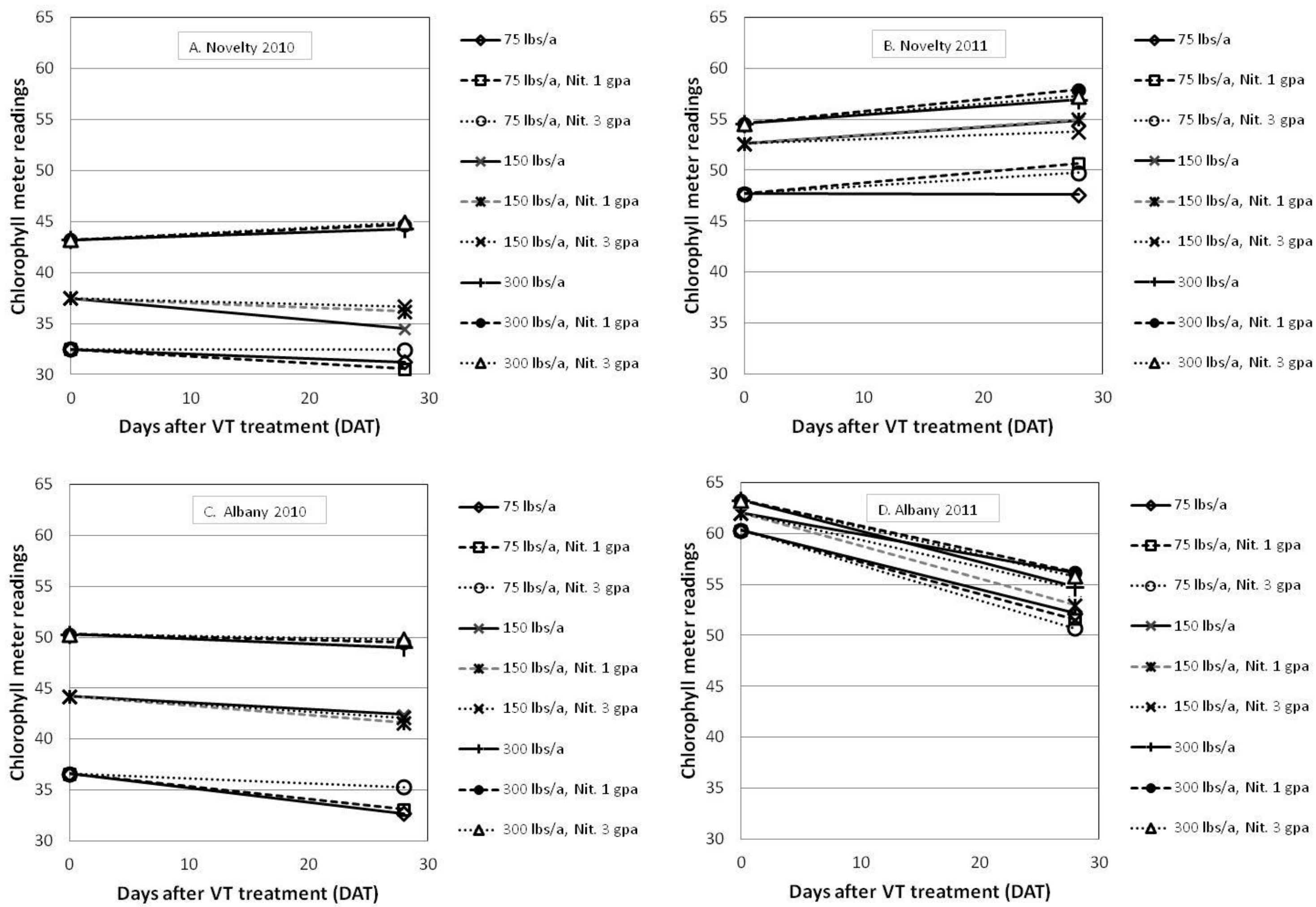

Figure 1. Chlorophyll meter readings at the time of application (VT) and 28 days after treatment (DAT) soil applied N treatments (75, 150, or 300 lbs N/acre) and Nitamin (Nit.) rates (0, 1 or 3 gallons per acre = gpa) at Novelty (2010 and 2011) and Albany (2010 and 2011). Data were combined over Headline treatments. LSD (*P*=0.1) is 1.