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Effect of Nitrogen Source and Weed Management Systems on No-Till Corn Yields

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Abstract

Field research was conducted at upstate Missouri to evaluate the impact of weed management systems and pre-plant nitrogen source selection [polymer-coated urea, (PCU); anhydrous ammonia (AA), urea, and ammonium nitrate (AN)] and side dressed urea ammonium nitrate (UAN) at 168 kg N ha^{-1} on no-till corn grain yield and weed growth. Small-seeded broadleaf weed heights responded differently to PCU and anhydrous ammonia in the two years of study. Corn heights were greater with AN and urea compared to PCU, AA, and side dressed UAN 7 to 9 weeks after planting. Nitrogen fertilizer source selection and weed management system affected total weed biomass (giant foxtail, common waterhemp, and common lambsquarters) at physiological maturity of corn. However, these factors showed no interactive effect on corn grain yields. An early postemergence application of atrazine + dimethenamid-*P* + glyphosate reduced total weed biomass 86% and 92% compared to atrazine + dimethenamid-*P* applied preemergence following AA and the non-fertilized control, respectively. A two-pass postemergence system (glyphosate followed by glyphosate) had 74 to 79% greater weed biomass compared to residual systems when following PCU. All weed management systems increased yield 1.5 to 5.09 Mg ha^{-1} compared to the non-treated control, and no yield difference was observed among weed management systems. PCU, AA, and side dressed UAN are preferred over broadcast urea for integrated weed management of no-till corn production in this region.

Keywords: ammonium nitrate, anhydrous ammonia, competition, polymer coated urea, urea, urea ammonium nitrate, weed removal

1. Introduction

Early in the growing season, weeds can accumulate N rapidly, which can contribute to early-season interference and subsequent yield loss in corn (*Zea mays* L.) (Teyker et al., 1991; Davis & Liebman, 2001; Evans et al., 2003a, 2013b; Cathcart & Swanton, 2004; Harbur & Owen, 2004; Lindquist et al., 2010), wheat (*Triticum aestivum* L.) (Blackshaw et al., 2002; Blackshaw et al., 2004), rice (*Oryza sativa* L.) (Ampong-Nyarko & De Datta, 1993a, 1993b), and canola (*Brassica napus* L.) (Blackshaw et al., 2011). Weeds can reduce soil NO_3-N up to 50% in corn (Lindquist et al., 2010). Several integrated weed management studies (Walker & Buchanan, 1982; Di Tomaso, 1995) have investigated nitrogen because direct uptake by weed species may affect control (Kim et al., 2006) and grain yields depending on fertilizer rate (Evans et al., 2003a, 2003b; Cathcart & Swanton, 2004; Lindquist et al., 2010), placement (Blackshaw et al., 2002; Blackshaw et al., 2004), timing (Blackshaw et al., 2004; Harbur & Owen, 2004), and source (Teyker et al., 1991; Davis & Liebman, 2001; Blackshaw et al., 2011). In corn, nitrogen fertilizer recommendations and the impact on weed interference may depend on the weed species (Harbur & Owen, 2004). Weed management has been more critical as rates of N were reduced (Evans et al., 2003b; Cathcart & Swanton, 2004). However, with the introduction of enhanced efficiency fertilizers such as polymer-coated urea (PCU), N source selection (Teyker et al., 1991) may be an important component of integrated weed management.

Best management practices are available to help farmers make informed decisions on increasing N use efficiency in corn (Scharf & Lory, 2006). A preplant surface broadcast application of urea in the absence of a urease or nitrification inhibitor typically is not recommended for no-till corn production due to risk of loss (Ferguson &

Kissel, 1986; Rochette et al., 2009) and yield loss (0.42 to 0.81 Mg ha^{-1}) compared to ammonium nitrate (AN) (Stecker et al., 1993). However, recent regulations have decreased the availability of AN to farmers, a situation that has prompted industry to develop technology that increases efficiency of urea fertilizers. Polymer-coated urea is a controlled-release urea fertilizer that allows farmers to broadcast apply preplant N and reduce gaseous fertilizer loss such as N_2O up to 49% in no-till compared to non-coated urea (Rochette et al., 2009; Halvorson et al., 2010). In canola, a preplant application of controlled-release N fertilizers and/or deep placement of N reduced overall weed growth and N uptake in the biomass of weeds, which could mitigate crop-weed competition for NO_3-N in soil (Blackshaw et al., 2011). However, minimizing weed growth by limiting soil N availability may reduce the effectiveness of herbicide applications (Evans et al., 2003b) due to reduced interception and retention of herbicides on weeds (Kim et al., 2006). Changes in N management might also affect the critical period for weed control (Evans et al., 2003a). Therefore, N management practices in no-till corn that promote controlled-release of available N early in a growing season may require more intensive weed management systems. Such systems could be similar to those used in research evaluating low N rates (Evans et al., 2003a, 2003b; Cathcart & Swanton, 2004; Lindquist et al., 2010) to obtain the potential yield benefits derived from reduced weed-crop competition and the subsequent increase in available soil N for crop uptake.

The Midwestern U.S. contains more than 4 million ha of claypan soils (Anderson et al., 1990). Low hydraulic conductivity in the claypan subsoil layer minimizes the potential for N loss through leaching, but it increases the potential for denitrification loss due to its high propensity for extended periods of soil saturation. Also, the potential can be large for volatilization loss from surface-applied urea-based fertilizers directly after application due to warm, moist soil conditions in the spring (Ferguson & Kissel, 1986). Maximizing no-till corn yields in a claypan soil requires N fertilizer with the lowest potential for denitrification and volatilization loss (Nash et al., 2012a). Injecting anhydrous ammonia (AA) at depth reduces the potential for volatilization loss and generally presents the lowest risk of yield-limiting denitrification loss compared to other conventional N fertilizers (Scharf & Lory, 2006; Nash et al., 2012a). Addition of a polymer coating around urea prills with PCU results in a slow release of available N over time. This reduces volatilization and denitrification loss compared to conventional urea fertilizers (Rochette et al., 2009; Halvorson et al., 2010), and increases grain yields in high-risk areas of fields compared to non-coated urea (Noellsch et al., 2009; Motavalli et al., 2012). Reduced gaseous N loss with AA and PCU might result in greater N availability throughout the growing season and increase overall weed growth by the time corn reaches physiological maturity.

Weed control in no-till corn with weed management systems is expected to vary, depending on the N source. This is due to aggressive weed growth that might result from readily available N sources such as non-coated urea or AN. The availability of N to the crop or weed in a no-till production system might depend on the N source selection because some sources are placed below the soil surface (AA) or are controlled-release (PCU) (Blackshaw et al., 2004; Blackshaw et al., 2011). Polymer-coated urea is a controlled-release N source that might limit early weed growth due to this technology's slow N release properties. Similarly, AA is banded 15 to 20 cm below the soil surface, and root growth is necessary to access this N source. In other research, AA and PCU yields were similar in high-risk N loss areas of a field (Noellsch et al., 2009; Motavalli et al., 2012). It may be imperative to have better early season weed control with an N source that is placed below the soil surface in a no-till production system.

Research conducted on how N sources and weed management systems affect crop production is very scanty. The handful of studies includes primarily an N source study on sweet corn (Davis & Liebman, 2001), greenhouse experiment with corn (Teyker et al., 1991), and no-till canola (Blackshaw et al., 2011). Most field corn research looks at conventional tillage systems (Davis & Liebman, 2001; Evans et al., 2003a, 2003b; Cathcart & Swanton, 2004; Lindquist et al., 2010). However, no research has evaluated how AA or new controlled-release PCU fertilizer affects no-till corn production with common weed management systems. We hypothesized that broadcast preemergence-applied PCU, deep placement of AA, and side dressed urea ammonium nitrate (UAN) would have shorter weeds than faster release N sources such as AN and non-coated urea. This would subsequently affect no-till corn grain yields, depending on which weed management systems were implemented. This research sought to determine how weed management systems and preplant N source selection affects no-till corn grain yield, weed heights, and weed control.

2. Materials and Methods

A field trial with three replications in 2006 and four replications in 2007 was conducted using 3.1 by 10.7 m plots at the University of Missouri Greenley Research Center near Novelty (40º01′ N, 92º11′ W). The study employed a split-plot design, with N source as the main plot and weed management system as the sub-plot. All N sources [AA, urea, PCU (ESN, Agrium, Inc.), AN] were applied preplant at 168 kg N ha^{-1}. Urea ammonium nitrate was applied in a dribble-band at 168 kg N ha^{-1} as a side dress best management practice control treatment (Scharf & Lory, 2006), and a non-fertilized control was included. The soil was a Putnam silt loam (fine, smectitic, mesic, Vertic Albaqualfs). No maintenance fertilizer was applied because soil test data showed that nutrient concentrations were high to very high (Table 1) (Buchholz, 2004).

Table 1. Soil test values and corn management practices

Management practice†	2006	2007
Soil test values		
Soil organic matter (g kg^{-1})	33‡	25
Cation exchange capacity (meq/100 g)	15.4	13.5
pH (0.01 *M* $CaCl_2$)	7.0	6.1
Bray I P (kg ha^{-1})	118	49
Exchangeable (1 *M* NH_4AOc)		
K (kg ha^{-1})	507	284
Ca (kg ha^{-1})	5990	4740
Mg (kg ha^{-1})	404	430
Planting date	28 Apr.	23 Apr.
Hybrid	DKC60-19	DKC60-19
Seeding rate (seeds ha^{-1})	74,100	76,100
Tillage	No-till	No-till
Fertilizer date		
Preplant N	28 Apr.	23 Apr.
Side dress UAN (30-cm tall corn)	5 June	29 May
Herbicide treatments (rate)‡		
§Atrazine (2.2 kg ai ha^{-1}) + glyphosate (0.84 kg ae ha^{-1})		
POST (10 cm tall weeds)	13 June	25 May
Atrazine + *S*-metolachlor + mesotrione premix (2.2 + 0.8 + 0.2 kg ai ha^{-1}) + NIS (0.25% v/v)		
POST (5 to 10 cm tall weeds)	9 June	17 May
Atrazine + dimethenamid-*P* premix (2.1 + 1.1 kg ai ha^{-1}) + NIS (0.25% v/v)		
POST (3 to 5 cm tall weeds)	2 June	10 May
Glyphosate (0.84 kg ae ha^{-1}) fb glyphosate (0.84 kg ae ha^{-1})		
POST (10 cm tall weeds) fb	13 June fb	25 May fb
POST (10 cm tall weeds)	1 July	24 June
Atrazine (2.2 kg ai ha^{-1}) fb glyphosate (0.84 kg ae ha^{-1})		
PRE fb POST (10 cm tall weeds)	3 May fb 13 June	24 Apr. fb 25 May
Atrazine + dimethenamid-*P* premix (2.1 + 1.1 kg ai ha^{-1}) + glyphosate (0.84 kg ae ha^{-1})		
POST (10 cm tall weeds)	13 June	25 May

†Abbreviations: fb, followed by; NIS, non-ionic surfactant (Activator-90, a mixture of alkylpolyoxyethylene ethers and free fatty acids, Loveland Industries Inc., Greeley, CO); POST, postemergence; PRE, preemergence; and UAN, urea ammonium nitrate.

‡All plots received a burndown application of glyphosate at 0.84 kg ae ha^{-1} on 20 Apr. 2006 and 23 Apr. 2007. Weed populations averaged 24 common waterhemp m^{-2}, 30 common lambsquarters m^{-2}, and 5 giant foxtail m^{-2} in the non-treated control.

§Herbicide chemical names: atrazine, 6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine; dimethenamid-*P*, 2-chloro-N-[(1-methyl-2-methoxy)ethyl]-N-(2,4-dimethyl-thien-3-yl)-acetamide); glyphosate, *N*-(phosphonomethyl)glycine formulated as Roundup WeatherMAX®; mesotrione, 2-[4-(methylsulfonyl)-2-nitrobenzoyl]-1,3-cyclohexanedione); and *S*-metolachlor, 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide.

Weed management systems included a non-treated weedy check, weed-free control, as well as standard preemergence only, early postemergence, and two-pass weed management systems. Herbicide application treatments, timings, and rates are reported in Table 1. All herbicide treatments were applied with a CO_2-propelled backpack sprayer calibrated to deliver 140 L ha^{-1}. The spray boom was equipped with 8002 flat-fan nozzles (Spray Systems Co., North Avenue, Wheaton, IL) spaced 38 cm apart and positioned 41 cm above the canopy. In the non-treated control, weed populations averaged over 2006 and 2007 were 24 common waterhemp [*Amaranthus tuberculatus* (Moq.) J.D.Sauer] m^{-2}, 30 common lambsquarters (*Chenopodium album* L.) m^{-2}, and 5 giant foxtail (*Setaria faberi* Herrm.) m^{-2}. In the non-treated control, three plants of each broadleaf weed species (common waterhemp and common lambsquarters) were marked with plastic stakes prior to spraying herbicides and heights were measured weekly starting 4 weeks after planting (WAP) in 2006 and 3 WAP in 2007 until 6 to 7 WAP. Corn heights in the weed-free control were measured 7 to 9 WAP to evaluate corn growth differences when plants were under high demand for N (Scharf & Lory, 2006). Season-long weed control was evaluated by harvesting two, 30- by 76-cm quadrants from each plot near physiological maturity in early September (Ritchie et al., 1993). Weeds were separated by species, dried, and weighed. The primary late-season weeds were giant foxtail, common waterhemp, and common lambsquarters.

A small-plot combine (Massey Ferguson 10, Kincaid Equipment Manufacturing, Haven, KS) harvested and weighed each plot's centermost two rows. Seed moisture was determined at harvest and adjusted to 150 g kg^{-1} before data analysis. All data were subjected to ANOVA using PROC GLM (SAS, 2013, vers. 9.3) and combined over site-years in the absence of interactions. Means were separated using Fisher's Protected LSD at P = 0.01. Standard errors of the means were presented for weed- and corn-height measurements.

3. Results and Discussion

3.1 Precipitation

Overall precipitation during the 2006 and 2007 growing seasons (550 mm) was similar (Figure 1). In 2006, drier spring conditions were favorable for optimal stand establishment. However, poorly drained claypan soils remained extremely wet during the spring of 2007. These conditions are conducive to gaseous nitrogen loss of urea in no-till corn on claypan soils (Nash et al., 2012a). The average temperature was 20.2ºC in 2006, and 21.2ºC in 2007 (Sandler et al., 2012). Throughout Sep. and Oct. 2006, temperatures were abnormally low, averaging 11.2ºC.

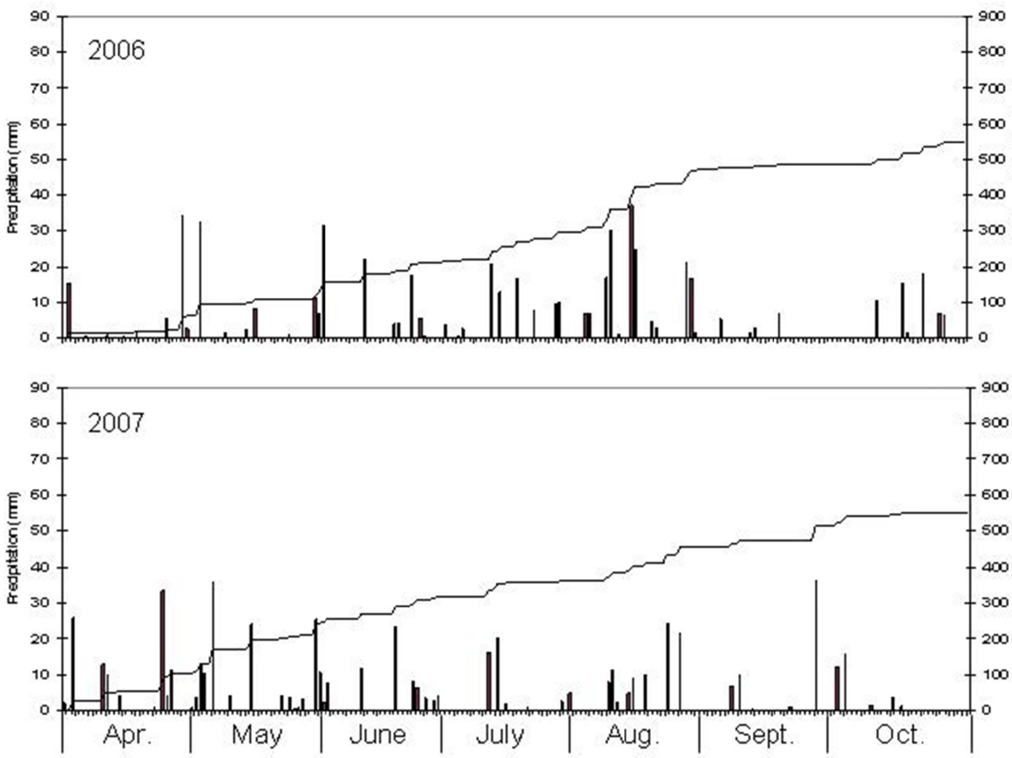

Figure 1. Daily (bars) and cumulative (line) precipitation during the growing season

3.2 Weed Heights

In 2006, common waterhemp heights with urea (Figure 2) and side dressed UAN (data not presented) were similar to the non-fertilized control. Plant heights were 3 to 8 cm greater 6 to 7 WAP when PCU, AA, or AN were applied, compared to the non-fertilized control (Figure 2A). Common waterhemp was tallest when PCU was applied compared to other N sources and the non-fertilized control 7 WAP. However, in 2007, soluble N sources such as AN and urea had the tallest common waterhemp plants 5 to 6 WAP followed by PCU (Figure 2B). Anhydrous ammonia and side dressed UAN (data not presented) were similar to the non-fertilized control. Common waterhemp height was affected by N source 3 to 7 WAP; however, in an Iowa study, common waterhemp height was not affected by AN application timings (Harbur & Owen, 2004).

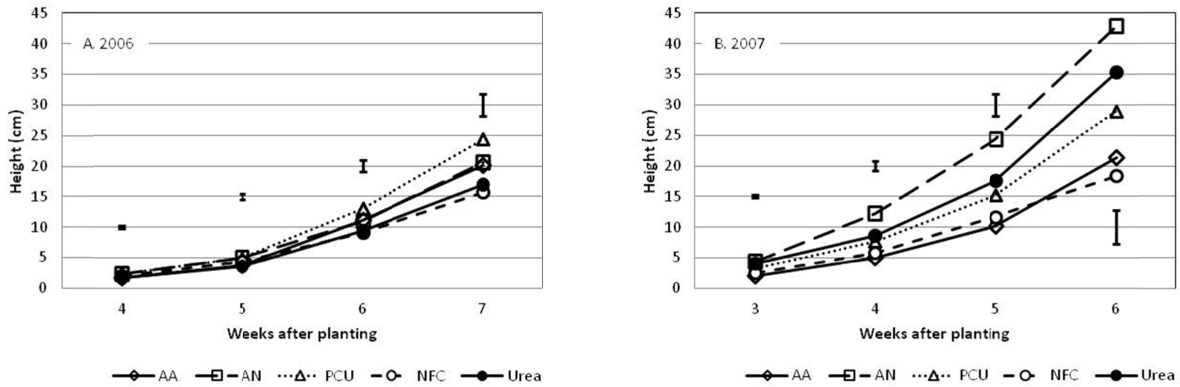

Figure 2. Common waterhemp height response to preplant nitrogen sources (AA, anhydrous ammonia; AN, ammonium nitrate; NFC, non-fertilized control; PCU, polymer-coated urea; and urea) at 168 kg N ha^{-1} in the non-treated weed management control 4 to 7 weeks after planting (WAP) in 2006 (A) and 3 to 6 WAP in 2007 (B). Vertical bars represent the standard error

Common lambsquarters heights with side dressed UAN (data not presented), preplant urea, and AA (Figure 3A) were similar to the non-fertilized control in 2006. Heights were similar among N sources 6 WAP, but were over 5 cm taller with PCU compared to other N sources and the non-fertilized control. In 2007, there was no difference in common lambsquarters heights between PCU, urea, and AN fertilizer sources. However, heights were similar to the non-fertilized control when AA was applied preplant (Figure 3B) or UAN was side dressed (data not presented).

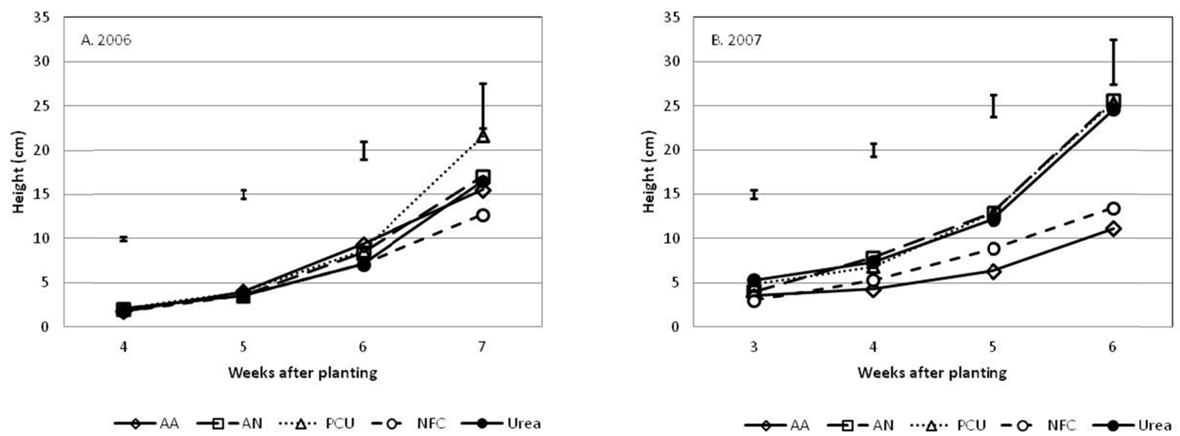

Figure 3. Common lambsquarters height response to preplant nitrogen sources (AA, anhydrous ammonia; AN, ammonium nitrate; NFC, non-fertilized control; PCU, polymer-coated urea; and urea) at 168 kg N ha^{-1} in the non-treated weed management control 4 to 7 weeks after planting (WAP) in 2006 (A) and 3 to 6 WAP in 2007 (B). Vertical bars represent the standard error

These data indicate that various N sources affected small-seeded broadleaf weed growth differently, depending on placement (AA injected below the soil surface or UAN dribble banded between the row) as well as PCU's slow-release properties. These results are similar to a four year, spring-wheat study in which subsurface banded or point-injected liquid N in the spring generally resulted in lower weed biomass compared to a surface broadcast application (Blackshaw et al., 2004). Herbicide label recommendations are based on weed heights, and N source selection might slightly affect the timing requirement for a postemergence herbicide based on the weed's growth. This has been shown in other research evaluating N rates (Evans et al., 2003a). In this experiment, herbicide treatments were applied at the same time (Table 1) to avoid confounding environmental conditions at the time of application.

3.3 Corn Heights

No significant differences occurred between N sources and year for corn heights 7 to 9 WAP for the weed-free control; therefore, data were pooled over years. Corn height in the weed-free control was similar for the non-fertilized control, AA (Figure 4), and side dressed UAN (data not presented). This was probably because the deep placement of AA and the between-row side dress application of UAN slowed overall corn growth slightly compared to the other N sources during a period of rapid N uptake (Scharf & Lory, 2006). This could affect canopy development and the crop's ability to interfere with weed growth and germination of late-emerging weeds. Higher N rates have helped corn plants compete with weeds more effectively (Evans et al., 2003b; Cathcart & Swanton, 2004). Corn was slightly taller (8 to 12 cm) with AN and urea compared to PCU 7 to 9 WAP. This was probably due to PCU's controlled-release of urea (Nash et al., 2012b). Weed and corn heights were shorter with AA and side dressed UAN which is likely due to the delayed availability of N. This effect was observed to a lesser extent with PCU on common waterhemp heights in 2007, but not in 2006.

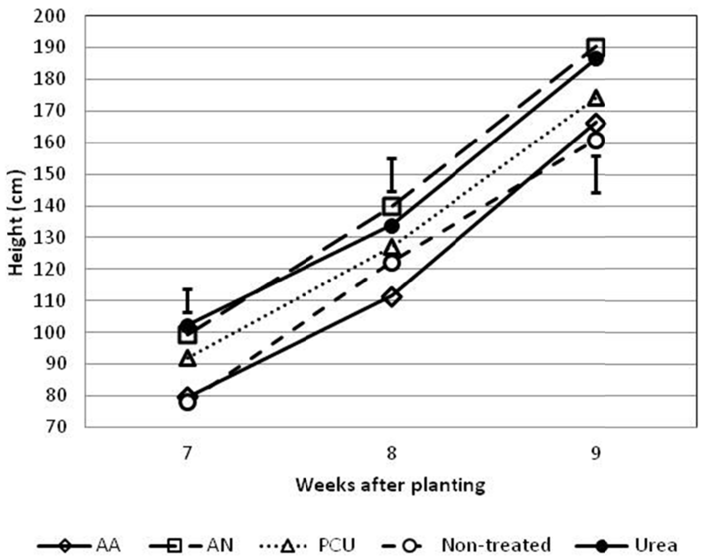

Figure 4. Corn height response to nitrogen fertilizer sources (preplant nitrogen sources (AA, anhydrous ammonia; AN, ammonium nitrate; NFC, non-fertilized control; PCU, polymer-coated urea; and urea) 7, 8, and 9 weeks after planting in the weed-free control. Data were combined over years (2006 and 2007). Vertical bars represent the standard error

3.4 Weed Control

At physiological maturity, an interaction between weed management systems and N source occurred for total weed dry weights, but no significant 3-way (year*N source*weed management system) interaction was detected (P = 0.83). Residual and sequential weed management programs helped reduce overall weed biomass, but it was the N source that affected total weed biomass (Table 2). All weed management systems showed greater than 90% weed control 28 days after treatment (visual observation), and total dry weights were less than the non-treated control. Total weed biomass was composed primarily of late-emerging common waterhemp and giant foxtail, and to a lesser extent of common lambsquarters.

Table 2. Total weed dry weight interaction between weed management system and nitrogen source at physiological maturity, and corn grain yield response to weed management systems

Weed management system[§]	Total weed dry weight[†]						Yield[‡]	
	NFC	Urea	AA	AN	PCU	UAN	2006	2007
	g m^{-2}						Mg ha^{-1}	
Non-treated	10.2	12.4	18.7	12.1	21.2	15.9	2.16	10.04
Glyphosate (POST) fb glyphosate (POST)	3.1	0.7	3.4	2.7	10.3	3.1	6.34	12.98
Atrazine (PRE) fb glyphosate (POST)	0.8	2.9	4.2	0.7	2.6	1.9	7.08	12.75
Atrazine + glyphosate (POST)	2.3	1.1	4.3	0.5	2.4	1.6	6.54	12.92
Atrazine + dimethenamid-*P* premix (PRE)	5.2	1.2	9.4	4.2	2.7	2.8	6.78	12.43
Atrazine + dimethenamid-*P* premix + glyphosate (POST)	0.4	0.1	1.3	0.7	2.2	1.5	6.51	12.65
Atrazine + *S*-metolachlor + mesotrione premix (POST)	4.4	3.7	1.5	3.6	2.6	3.5	7.25	11.98
Weed-free	0	0	0	0	0	0	7.24	13.53
LSD (P = 0.01)	--------------------- 4.0 ---------------------						-------1.63-------	

[†]Data were combined over years (2006 and 2007).

[‡]Data were combined over nitrogen sources.

[§]Abbreviations: AA, anhydrous ammonia; AN, ammonium nitrate; fb, followed by; NFC, non-fertilized control; PCU, polymer-coated urea; POST, postemergence; PRE, preemergence; and UAN, urea ammonium nitrate.

Differences in dry weights of individual weed species were due primarily to an interaction between year and weed management system (Table 3). Common waterhemp and giant foxtail dry weights were greater in 2007 than in 2006, probably because of more favorable overall growing conditions. However, common lambsquarters dry weights were greater in 2006 than in 2007 (data not presented). Individual weed control differences among management systems were due mainly to differences in application timing of the residual herbicide as a preemergence only (atrazine+dimethenamid-*P*) treatment compared to a sequential application of herbicides. Overall weed control differences were evident within a weed management system depending on the N source at physiological maturity (Table 2). The N source significantly affected common waterhemp dry weights (P = 0.0098) (Table 3). In a greenhouse experiment, redroot pigweed (*Amaranthus retroflexus* L.) was more competitive than corn under high NO_3-N levels (Teyker et al., 1991). Anhydrous ammonia, PCU, and side dressed UAN had common waterhemp dry weights that were 40 to 75% greater than the non-fertilized control or urea (data not presented). This indicated that PCU, deep placement of AA, and side dressed UAN also provided N to late germinating weeds such as common waterhemp. In other corn research, preplant and topdressed AN had similar common waterhemp seed production (Harbur & Owen, 2004).

Table 3. ANOVA table of giant foxtail, common lambsquarters, and common waterhemp dry weights when corn was at physiological maturity

		Giant foxtail		Common lambsquarters		Common waterhemp	
Source	df	F-value	Pr > F	F-value	Pr > F	F-value	Pr > F
Year	1	19.17	<0.0001	4.41	0.0459	67.68	<0.0001
Year*rep	5	3.06	0.0108	0.93	0.4611	1.73	0.1293
Nitrogen (N)	5	0.70	0.6262	1.19	0.3427	3.87	0.0098
Year*N	5	0.77	0.5787	0.64	0.6685	2.19	0.0878
Year*rep*N	25	2.19	0.0015	1.39	0.1100	1.16	0.2838
Weed management system (WMS)	7	11.03	<0.0001	2.37	0.0235	34.43	<0.0001
Year*WMS	7	7.02	<0.0001	2.11	0.0443	34.32	<0.0001
N*WMS	35	1.28	0.1495	1.35	0.1022	1.41	0.0763
Year*N*WMS	35	1.12	0.3070	1.45	0.0600	1.35	0.1010

3.5 Yield

Although an interaction between N source and weed management system was detected for final weed biomass, there was no such interaction for yield ($P = 0.62$); therefore, main effects are presented. Similarly, no interaction was observed between green foxtail [*Setaria viridis* (L.) Beauv.] density and N rates (Cathcart & Swanton, 2004), but in other research the critical period for weed control was affected by management of N rate (Evans et al., 2003a). A significant ($P < 0.0001$) two-way interaction (year* weed management system) for grain yield was observed. Grain yields averaged 6.14 Mg ha^{-1} greater in 2007 than in 2006 (Table 2), probably due to differences in precipitation distribution during the summer between years (Figure 1). Grain yields for all weed management treatments were similar to the weed-free control (Table 2). Weed management systems increased grain yield 1.65 to 5.09 Mg ha^{-1} in 2006 and 2007 compared to the non-treated control. Effective weed management systems that are based on recommended rates and timings (Table 1) provide no-till farmers with flexible management options regardless of the N fertilizer source.

All N sources increased yield compared to the non-fertilized control (Figure 5). Side dressed UAN had the highest overall yield (10.5 Mg ha^{-1}), which was similar to AA, AN, and PCU. A preemergence application of PCU and side dressed UAN increased yields 1.33 and 2.21 Mg ha^{-1} greater than urea, respectively. This was similar to other research evaluating anhydrous ammonia and PCU on claypan soils (Noellsch et al., 2009; Nash et al., 2013), but it differed from studies showing greater yield loss with a delayed application of AN compared to a preemergence application when weeds were allowed to compete with corn (Harbur & Owen, 2004). In Missouri, Stecker et al. (1993) reported greater N fertilizer use efficiency and yields (0.42 Mg ha^{-1}) with AN for no-till corn than with surface-applied urea. Since in both study years common waterhemp and lambsquarters heights were among the tallest with PCU 6 to 7 WAP, it may be assumed that greater corn yields with PCU than with urea did not stem from reduced weed growth and N uptake. This yield increase may have come from reduced environmental N loss and greater available N for corn uptake. This is counter to a four-year, no-till canola study on well drained soils in the semiarid Canadian prairies. The study found that PCU was generally effective in reducing weed biomass, but it only increased yields in 4 of 20 site-years compared to urea (Blackshaw et al., 2011). Contrasting responses among the studies presumably are due to differences in crops, soils, and climate.

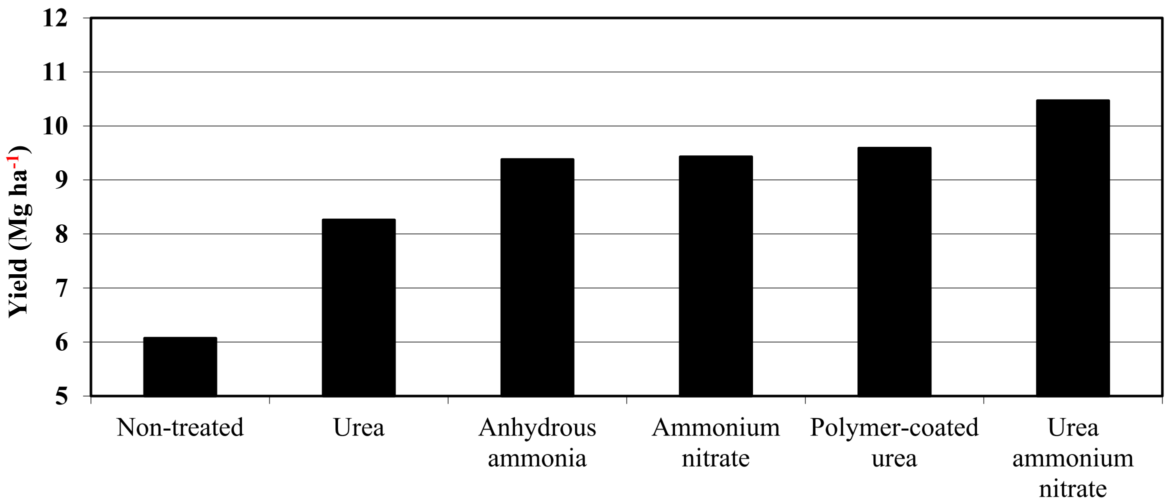

Figure 5. Corn grain yield response to nitrogen sources applied at 168 kg N ha^{-1}. Data were combined over years (2006 and 2007) and weed management systems. LSD ($P = 0.01$) is 1.30 Mg ha^{-1}

4. Conclusions

Small-seeded broadleaf weed heights responded differently to PCU and AA during the two years of this research. This indicated that N source might affect the critical period for weed control in a no-till production system. Corn heights were greater with AN and urea compared to PCU, AA, and side dressed UAN 7 to 9 WAP, indicating that N source could affect canopy development of no-till corn. The N fertilizer source and weed management system affected total weed biomass (giant foxtail, common waterhemp, and common lambsquarters) at physiological maturity of corn; however, these factors showed no interactive effect on corn grain yields. An early postemergence application of atrazine + dimethenamid-*P* + glyphosate reduced total weed biomass 86% and 92% compared to atrazine + dimethenamid-*P* applied preemergence following AA and the non-fertilized control, respectively. A two-pass postemergence system (glyphosate followed by glyphosate) had 74 to 79% greater weed biomass compared to residual systems when following a PCU application. All weed management systems increased yield 1.5 to 5.09 Mg ha^{-1} compared to the non-treated control, and no differences appeared among weed management systems. In this region, AA, broadcast PCU, and side dressed UAN are recommended over broadcast urea for no-till corn production. This study indicates that no-till corn farmers have several flexible options for N management and effective weed management systems that are based on label recommendations for weed heights and effective rates.

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