WINTER ANNUAL WEEDS AFFECT NITROGEN AVAILABILITY FOR NO-TILL CORN

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Abstract

Winter annual weeds effects on nitrogen availability have not been adequately studied. The objective of this study was to determine winter annual weeds effects on nitrogen availability for rainfed no-till corn (*Zea mays* L.) following soybeans (*Glycine max* L. Merr.). Field research was conducted in 2010-2011 at 14 sites with heavy winter annual weed pressure in eastern Kansas. A two-factor factorial arrangement in a randomized complete block design with three replications included three herbicide application dates (November-March, April, and May) and five N rates (0, 15, 30, 60, and 120 lb N ac^{-1}). Soil nitrate-N, early corn N uptake, N status at corn silking, and grain yield were assessed. Across site-years, winter annual weed above-ground biomass contained 16 lbs N ac^{-1} in May. Soil nitrate-N from a 0- to 24-in depth in June was reduced by 11 lbs ac^{-1} from the earliest to the latest herbicide application dates. Early N uptake by corn at the V5-V8 growth stage was the higher with the earliest herbicide application date. The N status of corn at silking was reduced as herbicide application was delayed. Herbicide application for weed control prior to April increased corn yields in 2010. Delaying control of winter annual weeds after March decreased the nitrogen available for no-till corn in eastern Kansas.

Introduction

A no-till corn-soybean rotation on well-drained soils in the U.S. Corn Belt is a very profitable cropping system (Stanger et al., 2008). Reduced tillage, lack of winter crops in the rotation, change in herbicide programs, and late spring weed control are some factors contributing to the increasing prevalence of winter annual weeds (WAWs) in no-till corn-soybean rotations. Winter annuals weeds include both obligate (fall germination) and facultative (fall or early spring) species. No-till practices in a corn-soybean rotation helps create a niche that favors winter annual broadleaf species such as henbit (*Lamium amplexicaule* L.) and shepherd's-purse (*Capsella bursa-pastoris* L.) (Derksen et al., 2002). Producers and industry professionals perceive WAWs as an agronomic concern.

Addressing the management of WAWs prior to no-till corn is particularly important. Studies suggest that dense stands of WAWs slow the warming of soil at planting time (Monnig et al., 2007), cause allelopathic effects (Vaughn et al., 2006), increase damages from lepidopteron in corn (Monning et al., 2007), and reduce corn yield (Mannam et al., 2008). However, the use of N by WAWs is an additional factor that may negatively impact no-till corn yields. Very little attention is given to WAWs inorganic N uptake, immobilization, and the corresponding N mineralization in a no-till corn-soybean rotation. No-till research in Georgia found that henbit and cut-leaf evening primrose (*Oenolthea laciniate* Hill.) dominated stands can uptake 15 to 32 lbs N ac^{-1} (Sainju and Singh, 2001). The carbon to nitrogen (C:N) ratio in the above-ground biomass of henbit/cut-leaf evening primrose dominated stands is 20 to 24 in Georgia (Sainju et al., 2007). In North Carolina, the C:N ratio of henbit and chickweed (*Stellaria media* L.) is 15, 22, and 24-37 during December, March, and April, respectively (Ranells and Wagger, 1997). When C:N ratios are below 25, the release of N occurs early in the decomposition process (Ranells and Wagger, 1997; Sainju and Singh, 2001).

Studies that have assessed the N use by WAWs and its ensuing effects on nitrogen availability for no-till corn in a corn-soybean rotation could not be found in the current body of literature. Therefore, the objective of the study is to determine WAWs effects on nitrogen availability for corn in a rainfed no-till corn-soybean rotation with different herbicide application dates and fertilizer N rates.

Materials and Methods

Field research was conducted in cooperation with producers and Kansas State University staff at 14 sites in eastern Kansas from 2010 to 2011 (Table 1). All sites were rainfed no-till corn following soybeans. Experimental design was a two-factor factorial arrangement in a randomized complete block design with three replications. There were three different herbicide application dates per site (Table 2): fall to early pre-plant (Nov. to Mar.), preplant (Apr.), and late spring (May). The corn planting dates ranged from 12 Apr. to 1 June (Table 2). After the collection of WAW biomass in May, five N rates of 0, 15, 30, 60, and 120 lbs N ac^{-1} were applied via broadcast urea. Plot size was 15 ft by 50 ft, except 10 ft by 50 ft at Site 8.

Soil samples from each block were taken to a 0- to 6-in depth pre-plant and analyzed for P, K, pH, and organic matter (OM). This information was utilized in concert with Kansas State University recommendations for applying sufficiency rates of P and K. In early June when corn was assessed for above-ground biomass, composite soil samples for nitrate-N (KCL extraction) from each plot were collected at a 0- to 24-in depth with a 0.75 inch inner diameter push probe.

Two 10.75 ft^2 polyvinyl chloride square frames were divided into nine small 1.2 ft^2 grids and two grids in each frame was utilized to determine above-ground weed biomass and N uptake from two fixed locations in the front and back of each plot (outside the grain yield harvest area) prior to last herbicide application treatment. Weed biomass samples were oven-dried at 140 degrees F for 3 days, weighed, and ground to pass a 0.08 inch screen. Tissue analysis included total carbon and nitrogen by dry combustion. Winter annual weed control was performed with a backpack CO^2 sprayer with 30 inch nozzle spacing (three 110 degree nozzles, boom width of 7.5 ft). Burndown treatments consisted of glyphosate (0.77 lbs a.i. ac^{-1}) with or without 2,4-D (0.475 lbs a.i. ac^{-1}), acetochlor (0.94 lbs a.i. ac^{-1}), flumetsulam (0.03 lbs a.i. ac^{-1}), and clopyralid (0.10 lbs a.i. ac^{-1}) depending on planting and emergence timing of corn in accordance with the labels.

A composite sample whole corn plants from each plot was assessed for above-ground N uptake at the V5-V8 growth stage. Whole plant corn samples were oven-dried at 140 degrees F for 3 days, weighed, and ground to pass a 0.08 inch screen. Tissue analysis for nitrogen was done by either by H_2SO_4-H_2O_2 method or dry combustion. Chlorophyll meter (CM) readings to determine N status were assessed at R1-R2 corn growth stage from the ear leaf of twenty corn plants in the middle two rows using a Minolta SPAD 502 Chlorophyll Meter. Final corn yield was determined by harvesting 25 ft from each of the middle two rows for each plot. Grain yields were adjusted to 15.5 % moisture.

Data was analyzed using the MIXED procedure in SAS using blocks as a random factor (SAS Institute, 2010). For analysis across site-years, block and site were considered as random in the model. Mean separation was performed by a BONFERRONI adjustment for the small number of planned comparisons to control the family-wise error rate. Statistical significance was evaluated at $P \leq 0.10$. Site 13 CM readings and grain yield data was not obtained due to crop death from extreme drought. Sites 8, 10, and 11 grain yield has yet to be collected.

Results and Discussion

Winter Annual Weed N Uptake and C:N ratio

The most common WAWs were henbit (*Lamium amplexicaule* L.) and field pennycress (*Thlaspi arvense* L.) across site-years. Winter annual weed control was excellent at all sites. The above-ground N uptake from WAWs near weed maturity in May ranged from 6.2 to 28.5 lbs N ac^{-1} across site-years (Table 3) with a mean of 15.8 lbs N ac^{-1}. The C:N ratio ranged from 16 to 32 across site-years (Table 3) with a mean of 24. These findings on N uptake and C:N ratios for WAWs are similar to previous studies done in the southeastern United States (Ranells and Wagger, 1997; Sainju and Singh, 2001). More recent research at Nebraska found that WAW N uptake by mid-April was 4 to 13 lbs N ac^{-1} and by mid-May was 21 to 33 lbs N ac^{-1} (Bernards and Sandell, 2011). The accumulation of N in WAW biomass by mid-May was very similar to those found in Nebraska.

Soil Nitrate-N and Early Corn N Uptake

The soil-nitrate-N and early corn N uptake differences from herbicide application dates and N rates were evaluated by site and across site-years, with significant differences indicated by analysis of variance (Table 4). There was no significant date by N rate interaction when analyzed across site-years. Soil nitrate-N (Table 2) was significantly affected at all sites by the addition of nitrogen fertilizer (Table 4). Five of the 14 sites showed a significant change in soil nitrate-nitrogen due to different herbicide application dates (Table 4). An additional two sites showed a significant interaction between date and N rate. At the seven unresponsive sites (Sites 4, 6, 8, 7, 9, 10, 13) to herbicide application dates, it is possible that soil nitrate-nitrogen was affected by the treatments, but could not be statistically confirmed. Results from the mean separation test for each site found no significant change in soil nitrate-nitrogen to fertilizer N rates up to 30 lbs ac^{-1} at these sites. The small changes in soil nitrate-N expected from low rates of N fertilizer and WAW N uptake could not be confirmed at these sites. Across site-years, soil nitrate-N was affected by the different weed control dates (Table 4). Soil nitrate-N to a 24-inch depth was reduced by delaying weed control from the November-March dates until May (Table 5) and increased by higher N fertilizer rates (Table 6).

Early uptake of N by corn at the V5-V8 growth stage was affected at all sites by the different rates of nitrogen fertilizer (Table 4) except Site 1. Site 13 was the farthest south location and was under drought conditions even at the start of the study. At Site 13, early growth was likely not limited by nitrogen. It was observed that early growth differences at Site 13 for weed control dates were mostly due to a difference in time of emergence. Soil moisture was only sufficient enough with the fall herbicide application to germinate the corn in April; the latter two control dates emerged several weeks later in May once a significant rainfall event occurred. Site 13 soil moisture conditions were not representative of the other sites in this study. Across site-years, N fertilizer rates of 60 and 120 lb ac^{-1} were not significantly different (Table 6). These results suggest that applying 60 lbs N ac^{-1} was sufficient to maximize early N uptake. Early uptake of N was affected at nine of the 14 sites by the date of herbicide application with an additional two sites affected at certain N fertilizer rates. Of the three unresponsive sites, Site 3 and 4 were where the lowest WAW N uptake occurred (Table 3). Site 1 had to be replanted twice from excessively wet soil conditions causing significant stand loss that were not due to the treatments effects. The final planting on 1 June achieved an adequate stand (Table 2). The saturated soil conditions and late planting at Site 1 may explain the deviation in response. Across site-years, the November-March WAW control dates maximized early corn N uptake (Table 5).

Chlorophyll Meter Readings and Grain Yield

The CM readings from herbicide application dates and N rates were evaluated by site and across site-years, with significant differences indicated by analysis of variance (Table 7). There was no significant date by N rate interaction when analyzed across site-years. The CM reading at all sites, except Site 1, were responsive to N fertilizer rates (Table 7). The extended period of saturated soil conditions at Site 1 led to visible symptoms of nitrogen deficiency across N rates prior to the R1 growth stage. Across site-years, there was a significant increase in CM readings with each additional rate increase in N fertilizer (Table 6). The CM readings were significantly affected by date of weed control at nine of the 14 sites (Table 7). Similar to early N uptake results, Sites 1, 3, and 4 not significantly affected by the date of weed control. Across site-years, significantly lower CM readings were recorded with each subsequent delay in weed control (Table 5). This suggests that the N accumulated into above-ground WAW biomass in April and May or N immobilized during the decomposition process was not available for uptake by the early reproductive stages of corn growth in July. To achieve comparable N status at silking for the November through March control dates at the zero N rate, equivalent to 15 and 30 lbs N ac^{-1} for April and May control dates were needed (Figure 1). The best management practice is to control WAWs early to minimize the need to increase N fertilizer inputs.

In 2010, corn gain yield response to N fertilizer rates was significant at five of the seven sites (Table 7). The lack of response at Site 1 was due excessive N losses. Three of the seven sites were responsive to the date of weed control. Across sites in 2010, there was a significant difference between herbicide application dates ($p = 0.046$). The grain yield for the Nov. - Mar., Apr., and May weed control dates were 80.1, 74.4, and 74.4 bu ac^{-1}, correspondingly. Our results found significantly higher corn yields with earlier control of WAWs contrary to other studies. In Missouri, Nelson et al. (2006) found no difference in grain yield between herbicide application dates in the fall, spring, and late spring. In Illinois, Krausz et al. (2003) found no yield differences between November and May dates of WAW control. In Indiana, Creech et al. (2008) found no yield differences between fall and spring WAW control. A recent study in Nebraska did find delaying WAW removal until mid-May did reduce corn yield (Mannam et al., 2008). The objectives and methods of these cited studies were not designed to assess nitrogen availability and its effect on grain yield. The yield data for 2011 is currently being collected.

Summary and Conclusions

The results of this study were based on sites with heavy pressure of WAWs. The WAW N uptake and the corresponding C:N ratio by May was great enough at most sites to affect soil nitrate-nitrogen, early corn N uptake, N status at silking, and grain yield across N fertilizer rates. Across site-years, there was no significant interaction between herbicide application date and N rate for the soil nitrate-nitrogen, early corn N uptake, and CM readings. The determination of 120 lbs N ac^{-1} as the maximum N rate was based on realistic N rates used by producers in the area. A higher rate than 120 lbs N ac^{-1} would have removed doubt of a short supply of nitrogen. The data from this study suggest that producers can increase nitrogen availability and grain yield for rain-fed no-till corn following soybeans in eastern Kansas by controlling WAWs prior to April even at a 120 lbs N ac^{-1} fertilizer rate. Soil moisture and risk of soil compaction is generally higher in early spring than is in the fall months following harvest. Starting WAW control in the fall would increase the window of application. We recommended that parts or all of a no-till field with heavy WAW pressure receive fall herbicide applications to decrease the probability of having an inadequate supply of nitrogen available for corn in eastern Kansas.

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Tables and Figures

Table 1. Site information, dominant soil, and organic matter (OM).

		Dominant soil		
Site	County	Series	Subgroup	OM
				%
		2010		
1	Franklin	Woodsen	Abruptic Argiaquolls	2.9
2	Jackson	Wymore	Aquertic Argiudolls	3.2
3	Jefferson	Grundy	Aquertic Argiudolls	4.0
4	Marshall	Wymore	Aquertic Argiudolls	2.8
5	Osage	Woodsen	Abruptic Argiaquolls	3.5
6	Reno	Ost	Udic Argiustolls	2.3
7	Riley	Belvue	Typic Udifluvents	1.4
		2011		
8	Atchison	Grundy	Aquertic Argiudolls	3.0
9	Franklin	Woodsen	Abruptic Argiaquolls	2.9
10	Jefferson	Grundy	Aquertic Argiudolls	3.5
11	Jefferson	Grundy	Aquertic Argiudolls	3.5
12	Osage	Woodsen	Abruptic Argiaquolls	3.3
13	Reno	Ost	Udic Argiustolls	2.2
14	Riley	Smolan	Pachic Argiustolls	2.7

Table 2. Planting, herbicide application, N application, soil nitrate-nitrogen sampling, early corn nitrogen uptake sampling, and chlorophyll meter (CM) reading dates.

		Time of Herbicide Application					
Site	Planting date	Nov. – Mar.	Apr.	May	N application	Soil and plant sampling	CM
				2010			
1	1 June	29 Mar.	12 Apr.	18 May	18 May	28 Jun.	3 Aug.
2	12 Apr.	19 Nov.	1 Apr.	11 May	11 May	1 Jun.	8 Jul.
3	14 Apr.	29 Mar.	13 Apr.	17 May	17 May	7 Jun.	12 Jul.
4	20 Apr.	7 Nov.	1 Apr.	8 May	8 May	4 Jun.	8 Jul.
5	20 Apr.	26 Mar.	12 Apr.	14 May	14 May	10 Jun.	7 Jul.
6	14 Apr.	16 Mar.	8 Apr.	3 May	3 May	3 Jun.	14 Jul.
7	25 May	16 Mar.	8 Apr.	21 May	21 May	24 Jun.	27 Jul.
				2011			
8	6 May	10 Dec.	12 Apr.	26 May	26 May	13 Jun.	21 Jul.
9	20 Apr.	15 Nov.	8 Apr.	16 May	14 May	7 Jun.	14 Jul.
10	1 May	10 Dec.	12 Apr.	17 May	17 May	13 Jun.	21 Jul.
11	4 May	10 Dec.	12 Apr.	17 May	17 May	13 Jun.	21 Jul.
12	19 Apr.	11 Nov.	9 Apr.	17 May	12 May	7 Jun.	14 Jul.
13	14 Apr.	16 Nov.	6 Apr.	15 May	15 May	2 Jun.	na†
14	29 Apr.	10 Nov.	6 Apr.	16 May	15 May	6 Jun.	12 Jul.

† na, data not available due to crop death from extreme drought

Table 3. Mean N uptake and carbon to nitrogen (C:N) ratio of above-ground winter annual weed biomass.

Site	N uptake	C:N ratio
	lbs ac^{-1}	
	2010	
1	13.1	28
2	10.3	21
3	7.9	20
4	6.2	26
5	15.4	19
6	19.5	16
7	24.6	24
	2011	
8	28.5	32
9	16.4	19
10	22.2	29
11	15.5	25
12	16.0	29
13	11.8	29
14	12.8	24

Table 4. Analysis of variance for soil nitrate-N and early corn N uptake response to treatments.

	Fixed effects					
	Soil nitrate-nitrogen			Early corn N uptake		
Site	Date (D)	N rate (N)	D x N	Date (D)	N rate (N)	D x N
	- $p > F$ -					
			2010			
1	0.034	0.004	0.823	0.862	0.002	0.476
2	0.050	<0.001	0.253	0.004	<0.001	0.944
3	0.260	0.001	0.087	0.724	<0.001	0.981
4	0.472	<0.001	0.490	0.925	<0.001	0.295
5	0.040	0.002	0.206	0.218	<0.001	0.020
6	0.686	0.004	0.924	<0.001	<0.001	0.185
7	0.162	0.035	0.348	<0.001	0.017	0.661
			2011			
8	0.158	<0.001	0.869	<0.001	<0.001	0.906
9	0.261	<0.001	0.320	<0.001	0.061	0.710
10	0.844	<0.001	0.143	<0.001	<0.001	0.776
11	0.004	<0.001	<0.001	<0.001	<0.001	0.012
12	0.010	<0.001	0.748	<0.001	<0.001	0.145
13	0.150	0.003	0.540	<0.001	0.471	0.830
14	<0.001	<0.001	0.138	<0.001	<0.001	0.129
			Across Sites and Years			
	0.027	<0.001	0.449	<0.001	<0.001	0.355

Table 5. Effects of herbicide application date of winter annual weeds on soil nitrate-nitrogen, early corn N uptake, and chlorophyll meter (CM) readings across sites and years.

Herbicide application date	Soil nitrate-N	Early corn N uptake	CM reading
	-------- lbs ac^{-1} -------		
Nov. - Mar.	72.0a†	11.5a	43.8a
Apr.	65.4ab	8.6b	42.3b
May	60.7b	8.4b	40.9c

† Means within a column followed by the same letter are not significantly different at the 0.10 probability level.

Table 6. Effects of nitrogen fertilizer rate on soil nitrate-N, early corn N uptake, and chlorophyll meter (CM) readings sites and years.

N rate	Soil nitrate-N	Early corn N uptake	CM reading
	---------------- lbs ac^{-1} --------------- ---		
0	35.8d†	6.5c	36.7e
15	43.0cd	8.2b	38.4d
30	51.2c	9.1b	40.5c
60	78.4b	11.4a	45.7b
120	122.0a	12.3a	50.1a

† Means within a column followed by the same letter are not significantly different at the 0.10 probability level.

Table 7. Analysis of variance for chlorophyll meter readings and grain yield response to treatments.

	Fixed effects					
	Chlorophyll meter reading			Grain yield		
Site†	Date (D)	N rate (N)	D x N	Date (D)	N rate (N)	D x N
	- *p* > *F* -					
			2010			
1	0.104	0.577	0.283	0.938	0.166	0.353
2	0.009	<0.001	0.203	0.038	<0.001	0.508
3	0.627	0.003	0.213	0.750	0.043	0.498
4	0.393	<0.001	0.144	0.235	<0.001	<0.001
5	0.001	<0.001	0.089	0.001	<0.001	0.115
6	0.776	<0.001	0.540	0.271	<0.001	0.771
7	0.181	0.008	0.239	0.010	0.123	0.469
			2011			
8	<0.001	<0.001	0.682	-‡	-	-
9	0.062	<0.001	0.088	0.152	<0.001	0.118
10	0.002	<0.001	0.211	-	-	-
11	<0.001	<0.001	0.180	-	-	-
12	<0.001	<0.001	0.267	0.001	<0.001	0.041
14	<0.001	<0.001	0.061	0.013	0.005	0.019
			Across Sites and Years			
	<0.001	<0.001	0.554	-	-	-

† Site 13 data not available due to crop death from extreme drought

‡ Grain yield has not been quantified, data will be incorporated later

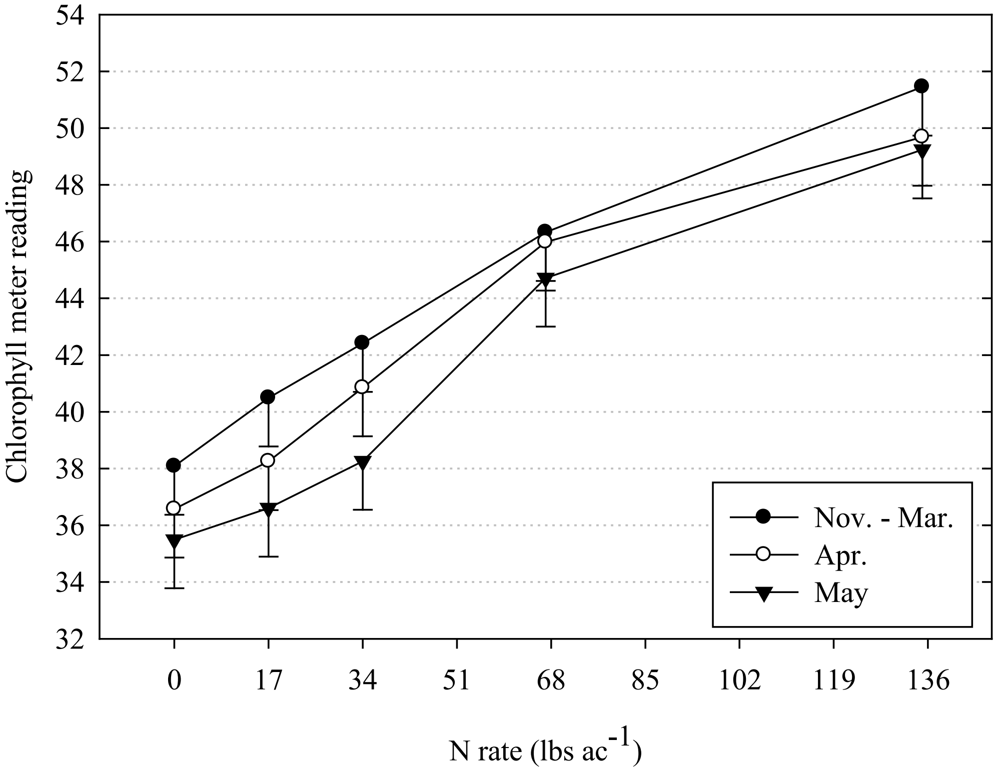

Figure 1. Chlorophyll meter reading response to N rate by herbicide application dates.

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