EFFECT OF FOLIAR NITROGEN ON WHEAT QUALITY AND CHEAT REDUCTION

By

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ABSTRACT

Cheat (*Bromus secalinus* L.) has long been a problem weed associated with wheat (*Triticum aestivum* L.) production in Oklahoma. The presence of cheat in wheat causes decreased yields through competition for nutrients and water and can cause dockage at market of up to 40%. Herbicidal control of cheat is now available and appears to be economically advantageous to the producer. Two field experiments were established in the fall of 1998 and 1999 at the Perkins Research Station and Efaw Research Station near Stillwater, to determine the effect of foliar nitrogen (N) on cheat reduction, wheat yield, and wheat grain protein. This study was designed to evaluate the effect of foliar N applied prior to cheat flowering on cheat seed reduction when cheat was grown with wheat and as a monoculture. Foliar N was applied as urea-ammonium nitrate (UAN) prior to cheat flowering, but two weeks after wheat flowering was complete. Foliar N was applied at rates of 11, 22, and 34 kg N ha^{-1} with an offset boom sprayer to simulate aerial applications. Presence of cheat decreased wheat yields by an average of 19%. Foliar N application resulted in a trend of increasing wheat yields of the wheat-only plots at low N rates. Conversely,

wheat yield of wheat/cheat plots showed no response to applied foliar N. This suggests that if cheat is present, there is a decreased likelihood of achieving a wheat yield increase due to foliar N applied. Total N concentration of wheat grain was increased by foliar N at each site in both years of the trial. Cheat seed reduction (%) due to applied N was only observed at Stillwater in 2000. Cheat reduction was not affected by foliar N applications in 1999 apparently because it was applied past the point of expected efficacy.

INTRODUCTION

Cheat infestations in wheat pose serious problems to farmers in the Great Plains. According to Ratliff and Peeper (1987) approximately 1.4 million hectares of winter wheat in Oklahoma are infested with cheat. Losses in grain and forage yield, delayed harvesting, seed cleaning expense, and dockage at market are all associated with cheat presence in wheat (Ratliff and Peeper, 1987). Recently foliar N applications were investigated as a method of reducing cheat seed production when applied after wheat flowering (Phillips et al., 1999). The use of foliar UAN may not only reduce cheat seed, but also provide a useful way to increase wheat yields and grain protein.

The effect of preplant fertilizers on weeds has been extensively researched. Banks et al. (1976) reported that the presence of weeds increased as more N, P, and K were made available. Sexsmith and Pittman (1963) reported that early spring applications of N fertilizers increased germination of wild oat (*Avena fatua* L.) seed. Similarly Sexsmith and Pittman (1963) reported that preplant N fertilizer applications increased wild oat infestation. They suggested the use of N fertilizers in fallow years to induce seed germination followed by a tillage event in order to reduce the amount of seed available to infest the ensuing crop. Fawcett and Slife (1978) showed no significant affect on common lambsquarters (*Chenopodium album* L.) population due to ammonium nitrate fertilization applied in late winter.

The use of foliar N treatments, based on previous research, may be a viable weed control method. Work conducted by Donnelly et al. (1977) showed decreases in grain sorghum (*Sorghum bicolor* L.) yields associated with foliar N applications before maturity due to accelerated grain drying. They also reported decreases in grain moisture levels associated with foliar N treatments. Cheat generally flowers one to two weeks after wheat, and it is within this time period that applied foliar N may desiccate cheat heads without adversely affecting the wheat (Phillips et al., 1999). Chen et al. (1997) reported significant decreases in cheat seed yield with increased foliar N applications, noting over 50% reduction associated with rates of 13 and 21 kg N ha^{-1} foliarly applied. Ensuing work by Phillips et al. (1999) showed cheat seed reduction as high as 70% at N rates of 22 kg N ha^{-1}.

Losses of N by volatilization from plant tissue can be significant in corn (*Zea mays* L.) and wheat (Kanampiu et al., 1997; Francis et al., 1993; Daigger et al., 1976). Late-season replenishment of this N by fertilizer applications may become more important to increasing nitrogen use efficiency (NUE). A split application of fertilizer N, as opposed to a single application in the fall, has been shown to increase NUE and protein contents of wheat grain, which is a highly desirable trait for bread production. Mahler et al. (1994) showed increases in winter wheat NUE associated with a split application of N. This increased NUE has important economical and environmental implications. Higher NUE values result in less loss of N by leaching, immobilization, and denitrification which can lead to environmental degradation (Mahler et al., 1994). Wuest and Cassman (1991) reported that N fertilization at anthesis resulted in larger increases in grain N than N applied as preplant only. Hence, late-season applications of N resulted in higher efficiency with respect to N uptake.

Effects of post flowering foliar N applications on wheat grain yield has shown mixed results. Gooding and Davies (1992) report that on average, yield response decreases as N application is delayed beyond flag leaf emergence. It has been noted, however, that if preplant N is limiting, foliar N applied during and after anthesis may increase grain yield (Sylvester-Bradley et al., 1984; Below et al., 1984). Finney et al. (1957) reported increases in wheat yield due to application of an additional 56 kg N ha^{-1} of foliar urea up to 11 days after flowering. Furthermore, foliar N applied after flowering may result in yield increases by reducing the potential for lodging which is associated with high preplant N applications (Gooding et al., 1991).

Hunter and Stanford (1973) reported higher protein content associated with spring application of fertilizer N compared to fall application. They showed average protein contents were increased from 10.9% to 14.3%. Strong (1986) also reported higher protein values associated with a split application of N as opposed to a single preplant fertilizer event. Other work conducted by Wuest and Cassman (1992) report similar increases in grain protein due to split applications of N.

Despite extensive research conducted to determine the effects of split applications of N on wheat NUE and grain protein, the use of foliar N as a late-spring N application method is not common. Research conducted by Finney et al. (1957) and Strong (1986) showed increases in wheat grain protein content when urea solutions were foliarly applied during the fruiting period. Similar work conducted by Pushman and Bingham (1976) on irrigated wheat showed that foliar N applications of urea at anthesis resulted in significantly higher protein values. Gooding and Davies (1992) report that yield increases are less likely to occur following anthesis, and therefore dilution of extra grain N by increased amount of carbohydrate is unlikely. Thus, application of foliar N after anthesis may not positively effect grain yield, but may improve grain quality by increasing total grain N.

The premise that pre-flowering foliar N application may desiccate cheat heads and post-anthesis application of foliar N may increase wheat grain protein and improve NUE are the basis for this research. The objectives of this study were to evaluate a range of post wheat flowering N rates on cheat seed reduction and wheat grain protein content.

MATERIALS AND METHODS

Experimental sites were established in the fall of 1998 and 1999 at the Perkins Research Station in Perkins, Oklahoma (Teller sandy loam, fine-mixed, thermic, Udic Argiustoll) and at the Efaw Research Station in Stillwater, Oklahoma (Kirkland silt loam, fine-mixed, thermic, Udertic Paleustoll). A randomized complete block experimental design with 12 treatments, replicated four times was used at each site. Main plot sizes were 6.1 by 7.6 m, and included cheat-only plots, wheat-only plots, and wheat-cheat plots. Winter wheat 'Jagger' and cheat were sown in all plots at rates of 90 kg ha^{-1} and 50 kg ha^{-1}, respectively. A 67 kg N ha^{-1} blanket treatment of ammonium nitrate was broadcast applied and incorporated prior to planting.

Foliar applications at rates of 0, 11, 22, and 34 kg N ha^{-1} were made using an offset boom sprayer, passed across the plot, to simulate aerial application. For the 11, 22, and 34 kg N ha^{-1} rates, 1.0 mL of the surfactant Surf-King Plus (Estes Inc., 1994) was added per L of UAN (28-0-0). If cheat flowering was delayed in the cheat only plot (compared to the wheat-cheat plot), foliar N was also delayed to maintain physiological stage consistency with regard to timing of foliar N application. Wheat and cheat were harvested using a Massey Ferguson 8XP self-propelled combine which harvested an area of 2 X 6.1 m from the center of each plot. The combine was set to collect all cheat and wheat in the bin. The sample was then processed in a seed cleaner to separate the wheat, cheat, and other materials. Wheat and cheat yields were determined after cleaning. A subsample of cheat from each treatment was tested for percent germination as per the work of Copeland (1978). One hundred seeds were placed on wet germination paper, refrigerated at 4°C for five days, placed in a germination chamber at 25°C for seven days, and then germination counts were made. The remaining cheat was evenly redistributed on the specific plot from which it was removed, and immediately after redistribution was incorporated via one 5-6" disking to simulate true harvesting conditions and determine the effect of multiple years of foliar N application on long-term cheat yield. A subsample of wheat grain from each treatment was taken for total N analysis using a Carlo-Erba NA 1500 dry combustion analyzer (Schepers et al., 1989). Cheat seed reduction was determined using the following equation: Reduction (%) = 1 - (CG * CY/B) * 100 where CG is cheat germination, CY is the cheat yield, B is the product of highest percentage cheat germination and the yield of cheat where no foliar N was applied (Chen, 1997). Analysis of variance was performed by location and year (SAS, 1999). Over year and location analysis was not used due to heterogeneity of error. Single degree of freedom, non-orthogonal contrasts were used to partition differences due to treatments.

RESULTS AND DISCUSSION

Cheat reduction due to foliar N was only observed once out of the four site-years. Wheat grain total N concentration of the check plots was typically decreased because of cheat presence due to competition for available N, and total grain N generally increased when foliar N was applied. Wheat grain yield response to applied N was sporadic but did occur.

Wheat Yield

Cheat presence decreased wheat yield three out of four site-years (excluding Perkins in 1999) by an average of 19% (comparison of wheat yield from wheat-only plots with wheat/cheat plots not receiving foliar N). Application of foliar N at lower rates ($\leq$ 22 kg N ha^{-1}) resulted in higher average yields compared to that of the check in all four site-years. Foliar N applied at 11 kg N ha^{-1} to wheat-only plots at Perkins in 1999 resulted in the highest yield (Table 3). In 1999 at Stillwater, application of foliar N to wheat-only plots at a rate of 22 kg N ha^{-1} resulted in the highest yields (Table 4).

Foliar N applications higher than 22 kg N ha^{-1} generally decreased yield, possibly due to burn injury, which was visible in some years. Application of foliar N at Perkins in 2000 resulted in a negative linear response in wheat yield, independent of cheat presence (Table 5). At Stillwater in 2000, a negative quadratic response in wheat yield was observed as the foliar N rate increased (Table 6). A trend for increased wheat yields in the wheat-only plots was seen in all four site-years, especially at the low N rate (11 kg N ha^{-1}). In the wheat/cheat plots wheat yields did not increase in any year as a result of applying foliar N. To some extent these results suggest that if cheat is present, there is a decreased likelihood of achieving a wheat yield increase due to foliar applied N.

Grain N

Increases in total wheat grain N due to foliar N application were observed in all four site-years. At Perkins in 1999, foliar N applied at a rate of 34 kg N ha^{-1} increased grain N of wheat-only and wheat/cheat plots by 11 and 14%, respectively (Table 3). A linear increase in total grain N of wheat/cheat plots was observed at Stillwater in 1999 (Table 4). A linear response of grain N to foliar N in wheat/cheat plots, and in wheat-only plots was observed at Perkins in 2000 (Table 5). At Stillwater in 2000, a linear response of grain N to applied foliar N was observed independent of cheat presence (Table 6).

With few exceptions grain N levels were maximized at the highest foliar N rate (34 kg N ha^{-1}). However, due to the decreases in grain yield associated with the higher N rates, N uptake was not increased with increasing foliar N applied.

It is interesting to note that total grain N of wheat in wheat/cheat plots was more responsive to higher foliar N rates than wheat-only plots, with the exception of Perkins in 1999. This could possibly be due to competition for soil N in wheat/cheat plots resulting in N deficient wheat or possibly N dilution of grain N in the wheat-only plots.

Cheat Yield

No reductions in cheat yield were observed as a result of foliar N application at either location in 1999. This is possibly due to late application of foliar N. In order to effectively desiccate cheat heads, foliar N should be applied just prior to cheat flowering. In 1999 wet conditions through early May delayed N applications approximately two weeks later than optimum. Cheat anthers were found in early May, a sign of anthesis, and foliar N was not applied until May 20th, thus reduction of cheat due to foliar N was not expected.

At Perkins in 2000, increases in cheat yield were found with increasing foliar N applied at flowering. A linear response to applied foliar N was noted for wheat/cheat plots and a quadratic trend was found for cheat only plots (Table 5). Presence of ryegrass at this location may account for the increase in cheat yield, because separation of the similarly sized and shaped cheat and ryegrass seed by a mechanical seed cleaner is nearly impossible. At Stillwater in 2000, cheat yield of the cheat only plots showed a negative linear response to applied N (Table 6). This was the only site-year where cheat yield was effectively decreased with application of foliar N. Reduction of cheat yield in wheat/cheat plots was not observed.

Cheat Reduction

Significant differences in cheat reduction due to foliar N were not observed in 1999. However, it should be noted that at Stillwater in 1999, application of foliar N at 22 kg N ha^{-1} tended to increase cheat production above that of the check (Table 4). As mentioned in the previous section, delayed foliar N application may have enhanced cheat seed production since N was not applied prior to cheat flowering when foliar N fertilizer was expected to desiccate cheat heads and reduce both cheat yields and cheat seed germination percentage.

A negative linear trend for cheat reduction of wheat/cheat plots due to foliar N was observed at Perkins in 2000 (Table 5). Application of foliar N actually increased cheat yield above that of the check, again possibly due to the presence of ryegrass (*Lolium multiflorum* L.) within the experiment. Increased cheat reduction with increasing N applied was observed at Stillwater in 2000 in both the cheat only and wheat/cheat treatments (Table 6).

CONCLUSIONS

Despite the observation that applied foliar N effectively resulted in cheat reduction in only one of the four site-years, it may still prove to be a viable method of reducing cheat infestation in agricultural fields. As noted earlier, application of foliar N in 1999 was delayed nearly two weeks past the point of optimum timing. Unfortunately, if a producer implemented this management practice, similar environmental problems (wind, moisture, etc.) would be encountered.

Grain yield of wheat-only plots tended to respond to applied foliar N at low application rates, while grain yield of wheat/cheat plots did not. This may suggest a decreased likelihood of increasing wheat grain yield when cheat is present.

Application of post flowering foliar N resulted in increased total grain N above the check (no foliar N applied) at each location in both years. This is economically important if producers are able to receive premium payments for protein content of the grain. Equally important is the environmental aspect of post flowering N applications which should be expected to decrease loss of N from the soil/plant system by volatilization from the plant tissue during anthesis. Management of preplant and topdress N applications which allow for post flowering adjustments of grain N could potentially reduce environmental impacts of N fertilizers by reducing the early season rates. It should be pointed out, however, that application of high foliar N rates (> 22 kg N ha^{-1}) may result in decreased wheat yields as demonstrated at Perkins in 1999 and 2000 and Stillwater in 2000. If the practice of applying post flowering N could be further researched and fine-tuned it could be a viable method for increasing grain N.

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TABLE 1. Fertilization, planting, foliar N application, and harvest dates for Stillwater and Perkins in 1998 and 1999.

Location	Fertilization	Planting	Foliar N application	Harvest
Efaw	05/10/98	15/11/98	20/05/99	17/06/99
	04/10/99	18/10/99	05/05/00	05/07/00
Perkins	16/09/98	12/10/98	20/05/99	14/06/99
	07/10/99	18/10/99	04/05/00	31/05/00

TABLE 2. Initial soil test values for Perkins and Stillwater in September of 1998.

Location	NH_4-N	NO_3-N	P	K	pH
	----------------------------mg kg^{-1}	----------------------			
Perkins	26.0	5.6	24.3	159	5.78
Classification: Teller sandy loam, fine-mixed, thermic, Udic Argiustoll					
Stillwater	29.2	9.5	29.0	205	5.90
Classification: Kirkland silt loam, fine-mixed, thermic, Udertic Paleustoll					

NH_4-N and NO_3-N – 2 *M* KCl; P and K – Mehlich III; pH – 1:1 soil:water.

TABLE 3. Treatment means and single degree of freedom contrasts for grain yield, total grain N, cheat yield, and cheat reduction, Perkins, OK, 1999.

Treatment	N rate (kg ha^{-1})	Wheat yield kg ha^{-1}	Total grain N g kg^{-1}	Cheat yield kg ha^{-1}	Cheat Reduction, %
Cheat only	0	-------	-------	1176	0.0
Cheat only	11	-------	-------	1369	(11.9)
Cheat only	22	-------	-------	1145	2.4
Cheat only	34	-------	-------	1199	(2.1)
Wheat/cheat	0	1691	21.9	356	0.0
Wheat/cheat	11	1884	23.4	290	15.6
Wheat/cheat	22	1484	21.8	458	(10.8)
Wheat/cheat	34	1604	24.2	387	(13.4)
Wheat only	0	1939	23.0	-------	-------
Wheat only	11	2282	24.6	-------	-------
Wheat only	22	1512	23.2	-------	-------
Wheat only	34	1749	26.2	-------	-------
SED		330	1.9	146	11.7
CV, %		26	11.1	26	104.4
RI		1.18			
Contrast					
N rate linear (wheat only)		NS	NS	-------	-------
N rate quadratic (wheat only)		NS	NS	-------	-------
N rate linear (wheat/cheat)		NS	NS	NS	NS
N rate quadratic (wheat/cheat)		NS	NS	NS	NS
N rate linear (cheat only)		-------	-------	NS	NS
N rate quadratic (cheat only)		-------	-------	NS	NS

SED-standard error of the difference between two equally replicated means
CV-coefficient of variation, %
*, **, *** - significant at the 0.10, 0.05, and 0.01 probability levels, respectively
NS- not significant
( )-increase in cheat reduction above the check
RI-response index as a result of applying foliar N in an experiment where all plots received a preplant N rate of 67 kg N ha^{-1}

TABLE 4. Treatment means and single degree of freedom contrasts for grain yield, total grain N, cheat yield, and cheat reduction, Stillwater, OK, 1999.

Treatment	N rate ($kg\ ha^{-1}$)	Wheat yield $kg\ ha^{-1}$	Total grain N $g\ kg^{-1}$	Cheat yield $kg\ ha^{-1}$	Cheat Reduction, %
Cheat only	0	-------	-------	1333	0.0
Cheat only	11	-------	-------	1426	(1.4)
Cheat only	22	-------	-------	1151	11.3
Cheat only	34	-------	-------	1317	4.7
Wheat/cheat	0	1854	25.2	367	0.0
Wheat/cheat	11	2069	29.3	271	6.9
Wheat/cheat	22	1762	28.5	398	(24.2)
Wheat/cheat	34	2004	30.2	321	(5.9)
Wheat only	0	2135	26.8	-------	-------
Wheat only	11	2437	28.1	-------	-------
Wheat only	22	2600	29.9	-------	-------
Wheat only	34	2173	27.6	-------	-------
SED		312	1.7	171	18.4
CV, %		21	8.4	31	89.1
RI		1.22			
Contrast					
N rate linear (wheat only)		NS	NS	-------	-------
N rate quadratic (wheat only)		NS	NS	-------	-------
N rate linear (wheat/cheat)		NS	***	NS	NS
N rate quadratic (wheat/cheat)		NS	NS	NS	NS
N rate linear (cheat only)		-------	-------	NS	NS
N rate quadratic (cheat only)		-------	-------	NS	NS

SED-standard error of the difference between two equally replicated means
CV-coefficient of variation, %
*, **, *** - significant at the 0.10, 0.05, and 0.01 probability levels, respectively
NS- not significant
( )-increase in cheat reduction above the check
RI-response index as a result of applying foliar N in an experiment where all plots received a preplant N rate of 67 kg N ha^{-1}

TABLE 5. Treatment means and single degree of freedom contrasts for grain yield, total grain N, cheat yield, and cheat reduction, Perkins, OK, 2000.

Treatment	N rate (kg ha^{-1})	Wheat yield kg ha^{-1}	Total grain N g kg^{-1}	Cheat yield kg ha^{-1}	Cheat Reduction, %
Cheat only	0	-------	-------	1192	0.0
Cheat only	11	-------	-------	1311	(7.5)
Cheat only	22	-------	-------	1416	(11.4)
Cheat only	34	-------	-------	1296	(5.8)
Wheat/cheat	0	2439	22.0	460	0.0
Wheat/cheat	11	2501	24.1	409	8.7
Wheat/cheat	22	1973	24.3	581	(25.0)
Wheat/cheat	34	2120	25.4	602	(29.2)
Wheat only	0	2845	24.0	-------	-------
Wheat only	11	2931	25.5	-------	-------
Wheat only	22	2364	24.6	-------	-------
Wheat only	34	2658	24.6	-------	-------
SED		192	1.2	95	12.8
CV, %		11	7.2	15	11658.4
RI		1.03			
Contrast					
N rate linear (wheat only)		*	NS	-------	-------
N rate quadratic (wheat only)		NS	NS	-------	-------
N rate linear (wheat/cheat)		**	**	*	***
N rate quadratic (wheat/cheat)		NS	NS	NS	NS
N rate linear (cheat only)		-------	-------	NS	NS
N rate quadratic (cheat only)		-------	-------	*	NS

SED-standard error of the difference between two equally replicated means
CV-coefficient of variation, %
*, **, *** - significant at the 0.10, 0.05, and 0.01 probability levels, respectively
NS- not significant
( )-increase in cheat reduction above the check
RI-response index as a result of applying foliar N in an experiment where all plots received a preplant N rate of 67 kg N ha^{-1}

TABLE 6. Treatment means and single degree of freedom contrasts for grain yield, total grain N, cheat yield, and cheat reduction, Stillwater, OK, 2000.

Treatment	N rate (kg ha^{-1})	Wheat yield kg ha^{-1}	Total grain N g kg^{-1}	Cheat yield kg ha^{-1}	Cheat Reduction, %
Cheat only	0	-------	-------	911	0.0
Cheat only	11	-------	-------	857	6.6
Cheat only	22	-------	-------	409	56.0
Cheat only	34	-------	-------	583	34.4
Wheat/cheat	0	1922	19.4	503	0.0
Wheat/cheat	11	2050	23.2	457	5.9
Wheat/cheat	22	1871	25.3	493	3.2
Wheat/cheat	34	1919	27.7	534	12.4
Wheat only	0	2476	21.9	-------	-------
Wheat only	11	2764	24.3	-------	-------
Wheat only	22	2590	25.6	-------	-------
Wheat only	34	2038	26.6	-------	-------
SED		303	1.1	130	17.3
CV, %		19	6.7	31	90.4
RI		1.12			
Contrast					
N rate linear (wheat only)		NS	***	-------	-------
N rate quadratic (wheat only)		*	NS	-------	-------
N rate linear (wheat/cheat)		NS	***	NS	NS
N rate quadratic (wheat/cheat)		NS	NS	NS	NS
N rate linear (cheat only)		-------	-------	***	**
N rate quadratic (cheat only)		-------	-------	NS	NS

SED-standard error of the difference between two equally replicated means
CV-coefficient of variation, %
*, **, *** - significant at the 0.10, 0.05, and 0.01 probability levels, respectively
NS- not significant
( )-increase in cheat reduction above the check
RI-response index as a result of applying foliar N in an experiment where all plots received a preplant N rate of 67 kg N ha^{-1}

VITA

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Master of Science

Thesis: EFFECT OF FOLIAR NITROGEN ON WHEAT QUALITY AND CHEAT REDUCTION

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