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Abstract

Spring oat and triticale are important forage crops in dryland and limited irrigated crop production systems in western Kansas. Previous research in western Kansas showed that growing spring forages in place of fallow reduced soil erosion and increased fallow precipitation use efficiency compared to summer fallow, and increased profitability compared to fallow in years with average to above average rainfall. Despite the great potential of spring forages, information on seeding rate and nitrogen fertilizer recommendations are limited. These management practices can affect forage productivity and nutritive value.

Current N fertilizer recommendations for oat and triticale are based on a very limited dataset. In dryland crop production systems in western Kansas, cool-season forages are usually planted in the spring into winter wheat (*Triticum aestivum* L.) or a summer crop (corn or grain sorghum) stubble. Residual nutrients from the previous crop could provide adequate nutrients for the spring forage crop. However, lower spring temperatures and N immobilization from the previous crop residue often limit early-season N availability for oat or triticale forage. Additional fertilizer application may be needed to boost forage production. Adequate fertility might increase tillering and yield potential, even at lower seeding rates. Moreover, N application in excess of crop uptake can result in environmental quality degradation, economic loss, and forages high in nitrate concentration. It is therefore imperative that site-specific N fertilizer research is conducted to fine tune N fertilizer rates for these cool-season forages to improve yields and environmental quality.

Seeding rate is an important crop management practice that affects forage production. It is suggested that spring oat and triticale grown for forage be planted at 25 to 50% greater seeding rates than when managed for grain production. The increase in plant density will allow for greater early crop establishment, smaller stems, and increased DM production. To our knowledge, effects of seeding rate on oat or triticale forage DM production and its interaction with N fertilizer rates has not been extensively studied in semiarid dryland environments. Determining the optimum seeding rate for oat and triticale is important because seed costs constitute a significant component of the variable cost in forage production systems. The objectives of this study were to (1) determine N fertilizer rate effects on DM production and nutritive value for oat and triticale forage, and (2) quantify effect of seeding rate on oat and triticale forage yield and its interaction with N fertilizer application under dryland conditions in western Kansas.

Keywords

Nitrogen fertilization, nitrogen application, seeding rate, spring oat, triticale

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Seeding Rate and Nitrogen Application Effects on Spring Oat and Triticale Forage

A.K. Obour, J.D. Holman, and A.J. Schlegel

Summary

Spring oat (*Avena sativa* L.) and triticale (*X Triticosecale* Wittmack) are important cool-season annual forage crops in dryland production systems. However, information on best agronomic management practices including seeding rate and nitrogen (N) fertilizer recommendations are limited. Field experiments were conducted to determine optimum N rates and also investigate seeding rate effect on oat and triticale forage production. Treatments were three seeding rates (75, 100, and 125% of recommended seeding rate) and five N rates (0, 10, 30, 50, and 70 lb N/a) in a split-plot treatment arrangement conducted over four site-years across western Kansas. Site-year ($P < 0.0001$), N rate ($P < 0.0001$), and site-year \times N rate interaction ($P < 0.001$) all affected forage dry matter (DM) production. However, seeding rate had no effect on forage DM or nutritive value in both oat and triticale. Across sites, oat DM produced with 30 lb N/a was similar to yields with increased N rates. Similarly, triticale DM production increased with N application rates but not beyond 50 lb/a. Increasing N application rates increased crude protein (CP) and *in-vitro* dry matter digestibility (IVDMD), while decreasing acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations. Our findings suggest growers can plant oat and triticale forage at 25% less than the recommended seeding rate with no significant decrease in forage production.

Introduction

Spring oat and triticale are important forage crops in dryland and limited irrigation crop production systems in western Kansas. Previous research in western Kansas showed that growing spring forages in place of fallow reduced soil erosion and increased fallow precipitation use efficiency compared to summer fallow, and increased profitability compared to fallow in years with average to above average rainfall. Despite the great potential of spring forages, information on seeding rate and nitrogen fertilizer recommendations are limited. These management practices can affect forage productivity and nutritive value.

Current N fertilizer recommendations for oat and triticale are based on a very limited dataset. In dryland crop production systems in western Kansas, cool-season forages are usually planted in the spring into winter wheat (*Triticum aestivum* L.) or a summer crop (corn or grain sorghum) stubble. Residual nutrients from the previous crop could provide adequate nutrients for the spring forage crop. However, lower spring temperatures and N immobilization from the previous crop residue often limit early-season N availability for oat or triticale forage. Additional fertilizer application may be needed to

boost forage production. Adequate fertility might increase tillering and yield potential, even at lower seeding rates. Moreover, N application in excess of crop uptake can result in environmental quality degradation, economic loss, and forages high in nitrate concentration. It is therefore imperative that site-specific N fertilizer research is conducted to fine-tune N fertilizer rates for these cool-season forages to improve yields and environmental quality.

Seeding rate is an important crop management practice that affects forage production. It is suggested that spring oat and triticale grown for forage be planted at 25 to 50% greater seeding rates than when managed for grain production. The increase in plant density will allow for greater early crop establishment, smaller stems, and increased DM production. To our knowledge, the effect of seeding rate on oat or triticale forage DM production and its interaction with N fertilizer rates has not been extensively studied in semiarid dryland environments. Determining the optimum seeding rate for oat and triticale is important because seed costs constitute a significant component of the variable cost in forage production systems. The objectives of this study were to (1) determine N fertilizer rate effects on DM production and nutritive value for oat and triticale forage, and (2) quantify effect of seeding rate on oat and triticale forage yield and its interaction with N fertilizer application under dryland conditions in western Kansas.

Procedures

Field experiments were conducted over four site-years across three locations (Garden City, Hays, and Jetmore) in western Kansas during 2015 and 2016 growing seasons. The experimental design was a randomized complete block with three replications in a split-plot arrangement. The main plots were three seeding rates (75, 100, and 125% of the recommended oat and triticale forage seeding rates) and five N fertilizer rates (0, 10, 30, 50, and 70 lb N/a) as sub-plots. The 100% oat forage recommended seeding rate was 64 lb/a and the 100% of the recommended seeding rate for triticale was 72 lb/a. Individual plots sizes were 10-ft wide × 30-ft long. Nitrogen source at all site-years was urea, which was broadcasted after crop emergence. Plots at each site-year received a blanket application of 15 lb P₂O₅/a prior to seeding. Weed control was accomplished with a pre-plant burn down of glyphosate [isopropylamine salt of *N*-(phosphonomethyl) glycine] and 2, 4-dichlorophenoxyacetic acid. Planting for both crops at each site-year were done in March, with planting date dependent on weather and soil conditions.

Oat and triticale were harvested at heading to optimize forage DM accumulation and nutritive value. Forage harvests were performed the first or second week in June. During each harvest, a 3- × 30-ft forage strip was harvested from each plot using a Carter plot forage harvester (Carter Manufacturing Company, Inc, Grand Haven, MI) to 3-in. stubble height. Fresh weights of samples were recorded, sub-samples were weighed, and oven dried at 60°C for at least 48 hours in a forced-air oven for DM determination. Oven-dried samples were ground to pass through a 1-mm mesh screen in a Wiley Mill (Thomas Scientific, Swedesboro, NJ). The ground samples were then analyzed for forage nutritive value [crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), *in-vitro* dry matter digestibility (IVDMD)], and tissue nutrient concentrations (Ward Laboratories, Inc., Kearney, NE) using Foss 6500 near infrared spectroscopy (NIRS).

Results

Forage Yield

Seeding rate had no significant effect on oat ($P = 0.80$) or triticale ($P = 0.59$) forage DM produced. Averaged across site-years and N fertilizer rates, oat DM was 3592 lb/a with 75% of the recommended seeding rate, 3679 lb/a for 100% recommended seeding rate and 3616 lb/a for the 125% of the recommended seeding rate treatment. Similarly, triticale forage production with 75% of the recommended seeding rate was 4106 lb/a, 4362 lb/a for 100% recommended seeding rate, and 4280 lb/a for 125% recommended seeding rate. This finding suggests the current recommended seeding rate for spring oat and triticale managed for forage, 64 and 72 lb/a, respectively, could be reduced 25% without significant yield penalties. This is important because seed costs account for a significant portion of the variable cost in forage production. Savings accrued through reduced seeding rate could increase profitability of the production system.

Site-year ($P < 0.0001$), N rate ($P < 0.0001$), and site-year \times N rate interaction ($P < 0.001$) all affected forage DM produced (Tables 1 and 2). Averaged across N rates, forage DM production was least in 2016 at Jetmore and the most in 2015 at Garden City. Forage production at Hays was intermediate between that of Garden City and Jetmore. Less DM production at Jetmore was partly due to uneven distribution of growing season precipitation at this site (data not shown). Spring oat and triticale were planted on March 15 and the site received no measurable rain until a heavy rainfall on April 16 (4.8 inches) and another 2.1 inches on April 29. The two large rainfall events constituted $>60\%$ of the total active growing season precipitation (March through May). This resulted in intermittent drought conditions most of the growing season, which had an effect on forage production. Greater residual soil N and average precipitation in 2015 in Garden City resulted in greater DM production compared to the other site-years.

The site-year \times N rate interaction effects on forage production possibly occurred because of greater initial soil N concentration in 2015 at Garden City that resulted in no significant response to N application at this site (Tables 1 and 2). Except 2016 at Hays, oat forage DM produced with 30 lb N/a was similar to that obtained with greater N fertilizer rates (Table 1). Above-normal growing season precipitation amounts in 2016 at Hays resulted in greater DM response to N fertilizer application but DM plateaued at 50 lb/a. Averaged across the four site-years, there was no significant increase in oat DM accumulation beyond 30 lb/a. Similarly, across site-years, triticale DM production of the unfertilized control was 80% of that obtained with 70 lb/a. However, triticale DM accumulation plateaued with 50 lb N/a (Table 2).

Forage Nutritive Value

The site-year \times N rate interaction, N rate, and site-year had an effect on spring oat and triticale forage CP concentration (Table 1 and 2). Greater CP concentration measured in Garden City was mostly due to relatively greater initial residual N concentration at this site. Lesser CP concentration at Hays compared to that measured at Jetmore could be attributed to N dilution effects, a process that results in decreased N content as DM accumulation increased. In general, CP concentration increased with an increase in N fertilizer application at each site-year (Tables 1 and 2). Averaged across site-years, N fer-

tilizer application to oat increased CP concentration from 11.7% with the unfertilized control to 13.8% when 70 lb N/a was applied. Crude protein concentration in triticale forage ranged from 12.8% with no fertilizer N to 14% with 70 lb N/a. The CP requirement for growing replacement heifers with body weight (BW) of 1200 lb at maturity ranged from 10.2% (with growing BW of 660 lb) to 8.1% (with growing BW of 960 lb) assuming the forage contains $\geq 60\%$ total digestible nutrients (NRC, 2000. Nutrient requirement of beef cattle). Therefore, average CP concentration of the treatments at all site-years (except the control in 2016 at Hays) in the current study were greater than the minimum CP requirement for growth or maintenance of grazing beef cattle.

Oat and triticale ADF, NDF, IVDMD, and nutrient concentration were affected by N fertilizer application (Table 3). In general, ADF and NDF concentrations decreased with increase in N fertilizer application rate in both oat and triticale forage. In the present study, lignin concentration decreased slightly with increased N fertilizer rates (Table 3) and could partly account for the observed decrease in ADF and NDF concentrations when N was applied. The IVDMD concentration as a measure of forage digestibility increased with N fertilizer application rate in both oat and triticale. This observation was expected because application of N fertilizer decreased ADF and NDF concentrations, both of which affect forage digestibility. Forage oat calcium (Ca), phosphorus (P), and potassium (K) concentrations increased with an increase in N fertilizer application rate. However, P concentration in triticale forage was not affected by N fertilizer application rate.

Table 1. Oat forage mass and crude protein (CP) concentration as affected by nitrogen (N) application at three locations in western Kansas

N rate	2015	2015	2016	2016	Mean
	Garden City	Hays	Hays	Jetmore	
lb/a	Forage DM, lb/a				
0	6667 a [†]	1461 c	3156 c	279 c	2891 c
10	6696 a	2164 b	3729 b	393 bc	3246 b
30	7103 a	3733 a	4077 b	710 ab	3906 a
50	6739 a	3716 a	4735 a	882 a	4018 a
70	6907 a	3646 a	4901 a	886 a	4085 a
Means	6822 A	2944 C	4120 B	630 D	
	CP concentration, %				
0	15.3 b	8.7 b	7.7 c	15.0 bc	11.7 d
10	15.9 ab	8.7 b	9.1 b	14.1 c	12.0 d
30	16.8 a	9.2 ab	9.3 b	14.6 c	12.5 c
50	16.2 a	9.4 a	11.2 a	15.8 b	13.2 b
70	16.8 a	9.7 a	11.7 a	17.0 a	13.8 a
Means	162 A	91 D	98 C	153 B	

[†]Means followed by same lower case letter(s) within a site-year are not significantly different. Upper case letter(s) denotes comparisons between site-years. All mean comparison were conducted using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.05$).

Table 2. Triticale forage mass and crude protein (CP) concentration as affected by nitrogen (N) application at three locations in western Kansas

N rate	2015	2015	2016	2016	Mean
	Garden City	Hays	Hays	Jetmore	
lb/a	Forage mass, lb/a				
0	7128 a [†]	2851 c	4454 c	452 c	3721 d
10	7429 a	3132 c	5024 b	499 c	4021 c
30	7285 a	3756 ab	5357 ab	681 bc	4269 b
50	7376 a	4124 a	5632 a	1060 ab	4548 a
70	7597 a	4086 a	5788 a	1272 a	4686 a
Means	7363 A	3590 C	5251 B	793 D	
	CP concentration, %				
0	15.7 b	9.8 c	12.0 c	13.8 b	12.8 b
10	16.3 b	9.9 c	12.6 b	13.6 b	13.1 b
30	17.3 a	12.1 a	12.7 b	14.0 b	14.0 a
50	17.0 a	11.0 b	12.9 ab	13.7 b	13.6 ab
70	16.3 b	11.4 b	13.4 a	15.0 a	14.0 a
Means	16.5 A	10.8 D	12.7 C	14.0 B	

[†]Means followed by same lower case letter(s) within a site-year are not significantly different. Upper case letter(s) denotes comparisons between site-years. All mean comparison were conducted using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.05$).

Table 3. Oat and triticale acid detergent fiber (ADF), neutral detergent fiber (NDF), *in-vitro* dry matter digestible (IVDMD), lignin, calcium (Ca), phosphorus (P), and potassium (K) concentrations as affected by nitrogen (N) application at three locations in western Kansas

N rate, lb/a	ADF	NDF	IVDMD	Lignin	Ca	P	K
Oat	----- % -----						
0	37.3 a [†]	61.0 a	76.1 c	2.8 a	0.40 b	0.29 c	2.52 d
10	36.8 ab	60.0 b	76.6 bc	2.7 ab	0.40 b	0.29 c	2.61 c
30	36.3 bc	60.0 b	77.2 ab	2.7 ab	0.42 a	0.31 b	2.78 b
50	36.2 bc	59.0 c	77.7 a	2.6 b	0.43 a	0.32 a	2.89 a
70	36.0 c	60.0 b	77.9 a	2.6 b	0.43 a	0.32 a	2.96 a
Triticale							
0	37.7 a	63.5 a	72.0 b	3.7 a	0.37 b	0.29 a	2.32 c
10	37.6 a	63.6 a	72.1 b	3.7 a	0.38 ab	0.29 a	2.37 c
30	36.8 b	62.5 b	73.3 a	3.5 a	0.38 ab	0.30 a	2.47 b
50	37.1 ab	63.1 ab	72.5 b	3.6 a	0.38 ab	0.30 a	2.43 b
70	37.0 ab	62.4 b	73.3 a	3.5 a	0.39 a	0.30 a	2.54 a

[†]Means followed by same letter(s) within site-year are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.05$).