VALIDATING POTASSIUM FERTILIZER GUIDELINES IN ALFALFA-CORN ROTATIONS

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Abstract

In 2008 to 2010, on-farm research was conducted on 10 fields with medium soil test K (STK) to validate Minnesota K fertilizer guidelines by determining the effect of K fertilizer applications on alfalfa yield and quality in its last production year, and estimating the carryover of excess fertilizer K to first-year corn. We were surprised to find that no K fertilizer was needed to maximize alfalfa yield or overall forage feed value and quality. Luxury consumption of K occurred because as K application increased, alfalfa K concentration and K uptake increased. Even though 60 to 75% of the fertilizer K was not utilized by the alfalfa, this carryover K did not increase corn grain yield as efficiently as K applied directly to the corn. When K was applied to the corn, stover and silage yield were 10 and 8% higher, respectively, than corn that relied on carryover K alone. These results do not support the current medium soil test K (STK) range and demonstrate that applying K to first-year corn rather than last-year alfalfa may be more economical on medium- to fine-textured soils with medium STK.

Introduction

Potassium is often the most limiting nutrient in alfalfa production and is critical for optimum stress tolerance against heavy field traffic, disease and insect pressure, and harsh winter climates. The price of KCl fertilizer has tripled in recent years, making it more difficult for alfalfa growers working with tight profit margins. University K fertilizer guidelines for alfalfa in Corn Belt states vary widely. For example, when considering a 5-ton alfalfa yield goal and medium testing soils (70-130 ppm), K guidelines range from about 30 lb K_2O ac^{-1} in Nebraska (Tarkalson and Shapiro, 2005), to 75 lb K_2O ac^{-1} in Minnesota (Rehm et al., 2000), to nearly 250 lb K_2O ac^{-1} in Wisconsin (Laboski et al., 2006). Furthermore, none of these guidelines change for the last alfalfa production year when alfalfa winter hardiness is not a concern.

Applying optimal K rates to alfalfa is clearly important from an economic standpoint. However, in addition to lower profits with over-fertilization, the other major concern is luxury consumption of K by alfalfa. Forage with high K concentration can increase the risk of milk fever in dry cow rations. Furthermore, when luxury consumption occurs, K is unnecessarily removed from the field, leaving less carryover K for following crops.

Carryover K from alfalfa to corn may help reduce amount of K fertilizer needed for optimal first-year corn yield. Applying K in the beginning of the last alfalfa production year instead of to corn in the spring may be advantageous for growers if K prices are expected to rise over the winter. However, relatively few studies have investigated the availability of carryover K to corn, the effect of carryover K on N response of corn following alfalfa, and whether both crops can be fertilized with a single application. Ten on-farm experiments were established in 2008 to 2010 to determine the effect of K application on optimum alfalfa yield and quality and the effect of carryover K on first-year corn yield.

Materials and Methods

Experiments were established across central and southern Minnesota in five alfalfa fields in 2008 and five in 2009 with medium STK (80-121ppm). Potassium fertilizer was topdress-applied to main plots at five K rates (0, 17, 42, 86, 166 lb K ac^{-1}) that were arranged in a randomized complete block design with three to four replications at each farm. Before K fertilization, main plots were sampled (6-8 soil cores to 6 inch depth) to determine ammonium acetate exchangeable K (Table 1). Fertilizer K was applied in the early spring at three farms in 2009, while the other seven farms had K applied directly after the grower's first alfalfa harvest. The following year, fertilizer K also was applied to corn at 166 lb K ac^{-1} within one of six subplots across all alfalfa main plots. The remaining five corn subplots received one of five N rates (0, 20, 40, 80, 160 lb N ac^{-1}) applied as NH_4NO_3.

Alfalfa yield, forage quality, and herbage K concentration were determined from hand-harvested herbage samples that were collected at the grower's harvest height before each of the grower's alfalfa harvests (3-5 harvests, Table 2). Herbage sub-samples were scanned with near infrared spectroscopy and validated with wet chemistry techniques to determine forage quality as measured by crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and NDF digestibility (NDFD). Relative feed value (RFV) and relative feed quality (RFQ) were calculated using standard equations (Undersander and Moore 2002). Herbage K concentration was determined using HCl extractions (Rao et al., 1998) analyzed with atomic emission spectroscopy. Apparent alfalfa K uptake was determined by subtracting the K uptake (K concentration multiplied by dry matter (DM) yield) of the nonfertilized control plots from the K uptake for each K rate within each block. Final alfalfa plant populations were measured at the end of the growing season before primary tillage. Alfalfa responses were analyzed by K application timing. Corn yield was determined by hand-harvesting 10 ft of corn within the center two rows of each subplot. To analyze the effect of carryover K from alfalfa to corn, an index of available K [(STK before alfalfa K fertilization x assumed bulk density 81.2 lb ft^{-3}) + fertilizer K applied to alfalfa - annual alfalfa K uptake] was calculated by plot and analyzed across farms. Detailed materials, methods, and results are presented in Yost et al. (2011).

Summary

Growing season (Apr.-Sep.) precipitation was between 4 and 49% below the 30-yr average (1971-2000) during alfalfa production for both years and across farms. During corn production, growing season precipitation was 23 to 31% below average in 2009 and 22 to 34% above average in 2010. Total annual alfalfa yield ranged from 2.3 to 3.7 t DM ac^{-1} across farms and K applications timings (Table 3). When K was applied before the grower's first harvest alfalfa yield at three farms, yield was higher than the other seven farms because an extra harvest was taken. However, we were surprised to find that on soils with medium STK there was no response in alfalfa yield to K fertilizer additions for either K application timing. Final alfalfa plant populations ranged from 4 to 10 plant ft^{-2} across farms and were not affected by K application, suggesting K was not required to maintain plant populations (Table 2).

Potassium fertilizer was available to the alfalfa and luxury consumption occurred, as evidenced by increased alfalfa K concentration and uptake as K rate increased. Average annual alfalfa herbage K concentrations were higher when K was applied after the first harvest (2.1-2.7%) compared to the early K timing (1.8-2.4%) and concentrations increased by up to 0.6% with the highest fertilizer rate for both K timings (Table 3). When K concentrations in forage exceed 2%, growers can lose a premium selling price for hay and increase the risk of milk fever when forage is fed in dry cow rations (Horst et al., 1997). Average annual herbage K uptake increased by about 70 and 40 lb K ac^{-1} above the nonfertilized alfalfa when the highest rate of K was applied in early spring and after the first alfalfa harvest, respectively. Soil test K did not decline during alfalfa production in nonfertilized alfalfa main plots, even when 110 to 138 lb K ac^{-1} in alfalfa herbage was removed from the field. More fertilizer (38%) was removed by the alfalfa with the early K application than the after first harvest (24%).

The only two forage quality parameters that were affected by K fertilization were ADF and NDFD. Average annual ADF concentrations increased (decline in forage quality) by about 1% and NDFD increased by 1-2% for both application timings when the highest rate of K was applied to alfalfa (Table 3). These relatively small differences in ADF and NDFD would likely have no effect on cow performance (Raeth-Knight et al., 2005). Additionally, neither RFQ nor RFV were improved with K fertilization, which suggests that added K would not have improved the selling price of the hay or the quality of the forage fed on the farm (Table 3).

The majority (62 to 76%) of the fertilizer K was not removed in harvested alfalfa and should have been available to the following corn crop. Excess K applied to alfalfa did carry over to increase corn grain yield (Fig. 1). However, high amounts of residual K, measured by the index of available K (nearly 220 lb K ac^{-1}), were needed to match the grain yield of corn fertilized with 166 lb K ac^{-1}. The index of available K had poor predictive power ($r^2 = 0.04$), but it appeared that carryover K from alfalfa was less available than newly-applied corn K. At all farms, corn stover and silage yields were high, and not affected by K applied to alfalfa. When K was applied directly to the corn, stover and silage yield increased by 10 and 8%, respectively, above the corn that relied on carryover K alone. We were not able to determine the optimum K rate for first-year corn, but the K rate we applied to the corn (166 lb K ac^{-1}) was not economical at average corn silage and fertilizer prices for the last five years. However, lower K rates to corn likely would have been economical with high corn prices. Withholding K on these farms with medium STK at the beginning of the corn crop had only minimal effects on changes in STK. The STK for fertilized corn increased 19 ppm compared to the nonfertilized corn.

Conclusions

Alfalfa yield and quality in its last production year did not improve with added K fertilizer on soils with medium STK and good plant populations ($\geq$ 4 plants ft^{-2}). These results suggest that either new STK ranges or interpretations are needed and perhaps that alfalfa K requirements are changing with new cultivars. Carryover K fertilizer from alfalfa to corn appeared to be less available to corn than newly-applied K. Therefore, under similar conditions, fertilizer K applied to first-year corn rather than last-year of alfalfa may generate higher economic returns.

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Table 1. Background soil characteristics for 10 on-farm experiments in Minnesota.

Year†	Location‡	Dominant soil series	K§	P¶	Soil pH#
			ppm	ppm	
2008	Albertville	Lester loam	111	15	5.9
	Cannon Falls	Estherville sandy loam	98	12	7.1
	Pierz	Nokay loam	89	61	6.9
	Rochester-1	Port Byron silt loam	108	14	6.4
	Rochester-2	Garwin silty clay loam	110	17	6.2
2009	Mantorville	Marquis silt loam	101	39	7.4
	Norwood-1	Le Sueur loam	85	15	6.7
	Norwood-2	Sparta loamy sand	79	35	7.7
	Paynesville	Tara silt loam	92	61	6.4
	Pine Island	Downs-Hersey silt loam	95	-	6.5

† Last alfalfa production year.

‡ Potassium applied in early spring Norwood-1, Paynesville, and Pine Island and after the first alfalfa harvest at other locations.

§ Ammonium-acetate exchangeable soil K for top 6 inches before K fertilization.

¶ Bray-1 soil P for top 6 inches before K fertilization. No data for Pine Island.

Soil pH for the top 6 inches before K fertilization.

Table 2. Alfalfa and corn characteristics for 10 on-farm experiments in Minnesota.

		Alfalfa				Corn
Year†	Location‡	Cultivar	Age§	Harvests¶	FPP#	Hybrid
			yr		plants ft^{-2}	
2008	Albertville	Croplan 'Trailblazer 7.0'	5	3	7	Pioneer '38P40'
	Cannon Falls	Geerston Seed 'Multi 5301'	3	3	7	DeKalb 'DKC52-59'
	Pierz	Pioneer '54V46'	4	3	10	Producer's '5732'
	Rochester-1	NK 'Geneva'	4	3	4	DeKalb 'DKC52-62'
	Rochester-2	Pioneer '53Q60'	5	3	5	Pioneer '37Y14'
2009	Mantorville	Pioneer '54V46'	3	3	9	Pioneer '34A85'
	Norwood-1	Mycogen '4A421'	4	5	9	Garst '86M39'
	Norwood-2	NK 'Genoa'	4	3	8	Mycogen '2R430'
	Paynesville	Grassland 'Dynamic'	5	3	6	Wolf River Valley '2987'
	Pine Island	Producers '30-06'	4	4	6	Producers '6372'

† Last alfalfa production year, which was planted to corn the following year.

‡ Potassium applied in early spring at Norwood-1, Paynesville, and Pine Island and after the first alfalfa harvest at other seven farms.

§ Age of alfalfa stand with the establishment year included.

¶ Harvests after K fertilizer was applied.

Final plant population (FPP) at the end of the alfalfa growing season.

Table 3. Means for total annual alfalfa yield, annual average crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), NDF digestibility (NDFD), relative feed value (RFV), relative feed quality (RFQ), total annual apparent K fertilizer uptake (AKU), annual average herbage K concentration, and fertilizer uptake efficiency (FE) by K rate across 10 farms in Minnesota.

Alfalfa K timing†	K rate	Yield‡	CP	ADF	NDF§	NDFD	RFV	RFQ	K conc.	AKU	FE
	lb K ac^{-1}	t DM ac^{-1}	---------------- % ----------------						%	lb K ac^{-1}	%
Early Spring	0	3.5a	22.7a	26.2c	35.9a	44.8b	180bc	175a	1.8d	0c	0a
	17	3.5a	23.1a	26.2c	35.0b	44.6b	184a	180a	1.8cd	5c	32a
	42	3.5a	23.0a	26.4bc	35.7a	46.5a	181ab	180a	2.0c	15bc	36a
	86	3.5a	22.7a	26.7b	35.8a	46.1a	180bc	178a	2.2b	35b	42a
	166	3.7a	22.6a	27.2a	36.2a	46.7a	177c	176a	2.4a	66a	40a
After 1st harvest	0	2.3a	23.2a	27.1b	35.2a	43.9c	183a	178a	2.1c	0c	0a
	17	2.3a	23.2a	27.1b	35.2a	44.6bc	183a	179a	2.2c	1c	8a
	42	2.3a	23.3a	27.1b	35.0a	45.1ab	184a	182a	2.3b	15b	36a
	86	2.4a	23.3a	27.6ab	35.4a	45.5a	181a	179a	2.5b	26ab	31a
	166	2.4a	23.4a	27.8a	35.3a	45.9a	181a	180a	2.7a	36a	22a

† Fertilizer K applied at three and seven fields in early spring and after first harvest, respectively.

‡ Yield was reduced by 11.5% to account for typical mechanical harvesting loss during field-scale haymaking (Rotz and Muck, 1994).

§ NDF was increased by 7.5% to account for field curing losses (Rotz and Muck, 1994).

¶ Within columns, means followed by the same letter were not significantly different at $P \leq 0.05$.

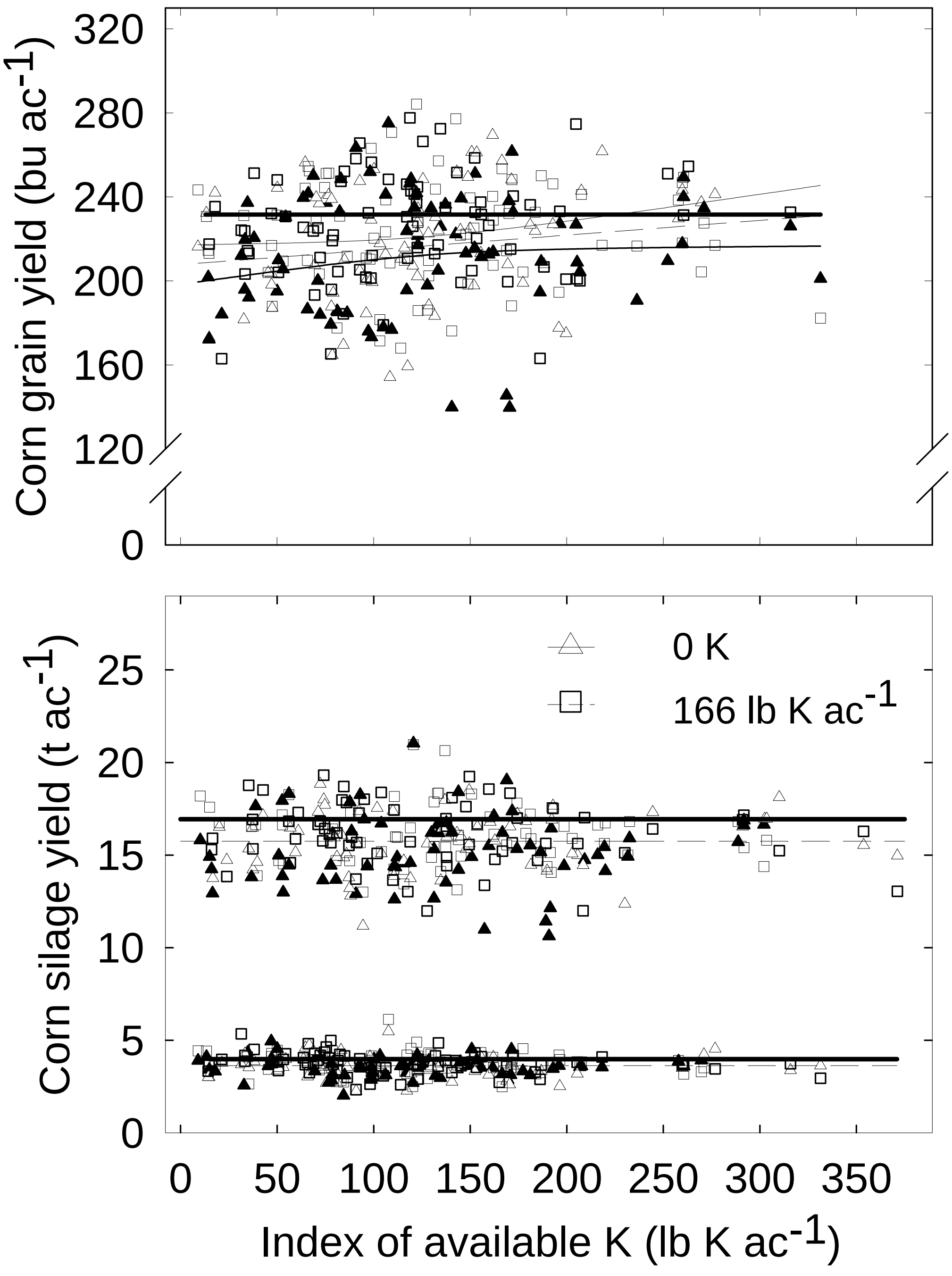

Figure 1. Response of corn grain, silage, and stover yield to index of available K with (open squares) or without (closed triangles) 166 kg K ha^{-1} applied to corn after emergence across nine locations in 2009 and 2010. The 95% confidence band is shown for corn grain that was not fertilized with K.

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