J. Dairy Sci. 100:1–12
https://doi.org/10.3168/jds.2016-12027

Net effects of nitrogen fertilization on the nutritive value and digestibility of oat forages[1]

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ABSTRACT

Applications of soil amendments containing N are part of routine forage-management strategies for grasses, with a primary goal of increasing forage yield. However, the effects of N fertilization on forage nutritive value, estimates of energy density, and in vitro dry matter or neutral detergent fiber disappearance sometimes have been erratic or inconsistent. Our objectives were to evaluate the effects of N fertilization on the nutritive value of a single cultivar (ForagePlus, Kratz Farms, Slinger, WI) of fall-grown oat fertilized at planting with 20, 40, 60, 80, or 100 kg of N/ha of urea or 2 rates of dairy slurry (42,300 or 84,600 L/ha). Nitrogen fertilization exhibited consistent effects on fiber components; forages fertilized with urea or dairy slurry had greater concentrations of fiber components compared with those harvested from unfertilized check plots (0 kg of N/ha), and fiber concentrations increased linearly with urea fertilization rate. In contrast, concentrations of water-soluble carbohydrates were greatest for unfertilized forages (21.2%), but declined linearly with urea fertilization, exhibiting a minimum of 13.5% at the 80 kg of N/ha urea application rate. Similarly, nonfiber carbohydrates also declined linearly, from 34.8% for unfertilized check plots to a minimum of 24.6% at the 80 kg of N/ha urea application rate. Fertilization with urea resulted in consistent linear increases in crude protein (CP), neutral detergent soluble CP, neutral detergent insoluble CP, and acid detergent insoluble CP; however, the partitioning of CP on the basis of association with specific fiber fractions could not be related to N fertilization when concentrations were expressed on a percentage of CP basis. The summative calculation of energy, expressed as total digestible nutrients was closely related to N fertilization rate during both the 2013 ($Y = -0.038x + 72.2$; $R^2 = 0.961$) and 2014 ($Y = -0.040x + 69.2$; $R^2 = 0.771$) production years. Following 30- or 48-h incubations in buffered rumen fluid, in vitro dry matter disappearance was greater for unfertilized forages compared with those fertilized with either urea or dairy slurry, and disappearance declined linearly with urea fertilization rate; however, these responses were not detected for neutral detergent fiber disappearance. Overall, the forage nutritive value of fall-grown oat declined mildly in response to N fertilization, but these responses were not nearly strong enough to offset the advantages obtained by improved forage yields.
Key words: N fertilization, oat forage, nutritive value

INTRODUCTION

Fertilization of forage grasses with N is a common management technique, resulting in increased forage yields. Despite the rather routine nature of N fertilization in forage-management strategies, clear elucidation of the effects of N fertilization on the nutritive value of harvested or grazed forages is often complicated by a variety of factors, including (1) multiple forage harvests or grazing bouts per season; (2) split fertilizer applications; (3) changing climatic conditions across harvests; (4) evaluation of multiple forage species with different maturation rates within the same study; and (5) the overall growth response to N fertilization. Generally, N fertilization results in increased concentrations of N or CP with concomitant reductions in other forage components, most notably water-soluble carbohydrates (**WSC**), but also potentially forage fiber constituents (Van Soest, 1982). However, the effects of N fertilization on forage fiber constituents, such as NDF, ADF, hemicellulose, and cellulose, are less consistent than effects on CP, with net concentration increases observed for some perennial cool-season grasses (Messman et al., 1991; Pelletier et al., 2008) but decreases observed in some studies with perennial warm-season grasses (Johnson et al., 2001; Coblentz et al., 2010; Kering et al., 2011). Nitrogen fertilization is positively associ-

Received September 21, 2016.
Accepted December 2, 2016.
[1]Mention of trade names or commercial products in this article is solely for the purpose of providing specific information, and does not imply either recommendation or endorsement by the USDA.
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ated with the lignification of forage grasses, and this relationship may be more reliable than those described for NDF, ADF, hemicellulose, and cellulose (Van Soest, 1982, Messman et al., 1991; Coblentz et al., 2010), but increased lignification also is considered an impediment to ruminant digestion and is associated commonly with reduced digestibility. A recent study with fall-grown oat (Coblentz et al., 2016) potentially allows for an in-depth assessment of the effects of N fertilization on the nutritive value of oat forages without many of the complicating or confounding factors mentioned previously. For purposes of this evaluation, all forages were (1) produced from the same oat cultivar; (2) planted and harvested on the same dates; (3) harvested at approximately the same growth stage, regardless of fertilization treatment; and (4) fertilized with equally spaced rates of urea fertilizer ranging from 0 to 100 kg of N/ha or with dairy slurry. Our objectives for this study were to examine the effects of N fertilization with urea or dairy slurry on the fiber composition, CP composition, energy density (TDN), and in vitro DM and NDF disappearance of fall-grown oat forages.

MATERIALS AND METHODS

Fall Establishment of Oat Forages

Procedures for establishment of fall-grown oat forages have been described previously in detail (Coblentz et al., 2016), and only a brief summary of salient points are included here. Replicated plots of ForagePlus oat (Kratz Farms, Slinger, WI) were established at the University of Wisconsin Marshfield Agricultural Research Station (44°39′ N; 90°08′ W; 392 m above sea level) on August 8, 2013, and August 13, 2014. The soil type for both 2013 and 2014 was a Withee silt loam (fine-loamy, mixed, superactive, frigid, Aquic Glossudalfs); however, the trial was relocated to a different site on the research station during the second production year (2014). ForagePlus oat is considered to be a forage-type cultivar, and matures later than grain-type cultivars following traditional spring establishment (Mochon et al., 2009); although maturity rankings for oat cultivars following August establishment generally are consistent with those based on spring establishment, differences in time requirements to reach a common growth stage are exaggerated when oat is grown during the fall (Contreras-Govea and Albrecht, 2006; Coblentz et al., 2011).

During 2013 and 2014, 4 field blocks composed of nine 4.6 × 9.1 m plots were established, resulting in 36 total plots/yr. Urea (46-0-0) was applied by hand to individual plots at rates of 20, 40, 60, 80, or 100 kg of N/ha; duplicate unfertilized control (check) plots (0 kg of N/ha) also were included within each experimental block. Prior to fertilization, concentrations of residual soil NO_3-N at the 0- to 0.15-m soil depth were 3.2 and 13.1 mg/kg for 2013 and 2014, respectively (Coblentz et al., 2016). In addition, dairy slurry obtained from the University of Wisconsin Marshfield Agricultural Research Station manure-handling system was applied by hand (in buckets) to 2 plots/block at mean rates of 42,300 (low) and 84,600 (high) L/ha. The low manure application rate corresponded to respective total N and ammonia-N application rates of 75 and 32 kg of N/ha for 2013, as well as 134 and 53 kg of N/ha for 2014. Similarly, when the greater manure volume was applied, total N and ammonia-N application rates were 150 and 64 kg of N/ha for 2013, as well as 268 and 106 kg of N/ha for 2014, respectively. For these slurry applications, calculated fertilizer equivalents for the high and low manure rates, based on DM yield responses to urea fertilization, were 48 and 35 kg of N/ha, respectively (Coblentz et al., 2016). After urea fertilizer and dairy slurry were applied, plots immediately were clean-tilled to limit volatilization of N. A 1.8-m wide no-till drill (model 3P606NT, Great Plains Manufacturing Inc., Salina, KS), which was configured with 9 seeding tubes equally spaced at 18-cm intervals, was used to establish the oat plots at a seeding rate of 108 kg/ha. Each plot was comprised of 2 adjacent drill passes.

Fall Harvest Management

All plots were harvested on November 11, 2013, and November 4, 2014, at the 2 to 3 node stage of stem elongation (53-cm mean canopy height; Coblentz et al., 2016) by mowing standing forage with a 1.15-m wide, self-propelled, flail-type forage harvester equipped with a load box and load cells. Plots were clipped to a 7.5-cm stubble height, and each plot weight included two 9.1-m passes with the plot harvester. Forage DM yields for each fertilization strategy were reported previously (Coblentz et al., 2016). Independent of the flail-type harvester, a 900-g sample (as is basis) of standing forage was clipped with hand shears to a residual stubble height equivalent to that left by the harvester from 4 to 6 locations within each plot and dried in paper bags to constant weight under forced air (55°C). All dried forage samples then were ground through a 1-mm screen with a Thomas Model 4 Wiley Mill (Thomas Scientific, Swedesboro, NJ) and stored in sealed plastic sample bags pending subsequent analysis for nutritive value.

Laboratory Analyses

Concentrations of whole-plant ash within each oat forage were determined from dried 1.0-g subsamples by combustion at 500°C for 6 h in a muffle furnace.