Feeding Annual Forage Crops to Organic Dairy Cows During the Spring and Summer Seasons in Northeast United States

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Abstract

Annual forage crops (AFC) can provide resilience and supplemental forage during times of limited herbage biomass production, including early spring and mid-summer in the Northeast United States. In the spring, 16 lactating organic Jersey cows (14 multiparous and 2 primiparous) were randomly assigned to 1 of 2 treatments: traditional legume-grass pasture mixture (control; n = 8 cows) or spring available AFC (spAFC) strip tilled into traditional legume-grass pasture mixture (n = 8 cows). The spAFC treatment consisted of 5 plant species: wheat, triticale, barley, cereal rye, and hairy vetch. In the summer, 20 lactating organic Jersey cows (16 multiparous and 4 primiparous) were randomly assigned to 1 of 2 treatments: traditional legume-grass pasture mixture (control; n = 10 cows) or summer available AFC (suAFC) strip tilled into traditional legume-grass pasture mixture (n = 10 cows). The suAFC treatment consisted of 5 plant species: millet, teff, buckwheat, oats, and chickling vetch. A 14-day adaptation period was followed by a 7-day sampling period for collection of feeds, milk, feces, blood, and rumen in both experiments. Overall, our results showed that under the conditions of these 2 short-term grazing studies, strip tilling AFC into established traditional legume-grass pasture mixture did not change animal production (e.g., dry matter intake, milk yield), ruminal fermentation profile, or consistently increased herbage biomass production.

Introduction

There is a growing interest to incorporate annual forage crops (**AFC**) into pasture-based systems to provide resilience against times of low herbage biomass production (e.g., early spring, mid-summer, and late fall) in the Northeast United states. Species are being selected based of their individual traits that, when incorporated into a perennial pasture system, can produce high-quality animal feed without negatively impacting animal performance and ecosystem services. Grasslands with greater species diversity are thought to be more resistant to ecological stresses (Tilman and Downing 1994). These results are seen due to the inclusion of key species with specific functional traits—such as drought tolerance and weed resistance—which further emphasizes the need for mixtures of annual species to be included in perennial grasslands. The diversification of forage species in pastureland has the ability to take advantage of variability in soil and climate and can enhance productivity and sustainability of agricultural landscapes (Sanderson et al. 2007).

Pasture-based research has demonstrated greater herbage biomass production for more diverse swards compared with a simple legume-grass mixture (Sanderson et al. 2005; Skinner et al. 2006). An 11-species mixture yielded more herbage than an orchardgrass-white clover sward and had greater root biomass in a 4-yr study (Skinner et al. 2006), which agrees with results reported by Soder et al. (2006). In a management-intensive grazed small-plot study, combinations of 2, 3, 6, and 9 species mixtures were compared, and mixtures with 6 and 9 species yielded more forage than those with 2 and 3 species (Deak et al. 2004). A European study conducted across 28 sites revealed forages planted in mixtures yielded more than the highest yielding monoculture (Kirwan et al. 2007). Thus, increased herbage biomass production with diverse forage mixtures versus monocultures has been reported in multiple experiments across the world.

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However, there is a paucity of research-based information about the impact of complex pasture mixtures consisted of traditional perennial forages and AFC on herbage production and animal performance. It is important to note that organic dairy farmers in the Northeast rely extensively on management-intensive rotational grazing and they are particularly interested in strategies to extend the grazing season to capitalize on high-forage rations while reducing feed costs (Pereira et al. 2013; Stiglbauer et al. 2013). Incorporating AFC into pasture-based systems may be a viable option to reduce feed costs through provision of high-quality forage and consequent increased milk production in organic dairy systems.

Objectives

The objectives of this study were to determine the impact of AFC on pasture productivity and quality, animal performance, and ruminal fermentation profile during the spring and summer seasons.

Materials and Methods

Both experiments were carried out at the University of New Hampshire Burley-Demeritt Organic Dairy Research Farm (43°10'N, 70°99'W) from May 13 to June 3, 2015 (Experiment 1) and from July 14 to August 2, 2015 (Experiment 2).

Experiment 1

Planting and pasture measurements: The spring available AFC (**spAFC**) were strip tilled and planted into a traditional perennial legume-grass pasture mixture in October 1, 2014. The following spAFC species were used: oats (*Avena sativa* L.), barley (*Hordeum vulgare L.)*, winter wheat (*Triticum aestivum*), cereal rye (*Secale cereal*), and hairy vetch (*Vicia villosa*). Pasture was clipped weekly for quality analysis and botanical composition and biweekly for allowance and disappearance (pre- and post-grazing) measurements. Measurements for pasture allowance, disappearance, and quality were conducted by randomly throwing a quarter-meter quadrat in the traditional perennial legume-grass pasture mixture control and spAFC paddocks for 10 separate times. All herbage biomass within the quadrat was clipped to approximately 7 cm off the ground, weighed, and placed in forced air ovens (Sheldon Manufacturing, Inc., Cornelius, OR; BINDER Inc., Bohemia, NY; VWR Scientific, Bridgeport, NJ) set at 55°C for 48 h. Pasture nutrient composition for Experiment 1 is presented in Table 1.

Animal measurements: Sixteen organically-certified lactating Jersey cows (14 multiparous and 2 primiparous) were randomly assigned to 1 out of 2 treatments in a completely randomized design: 1) traditional legume-grass pasture mixture (control; n = 8 cows) or 2) spAFC strip tilled into traditional legume-grass pasture (n = 8 cows). Within each treatment, cows were balanced for milk yield, parity, and days in milk. Cows used averaged (mean ± standard deviation) 433 ± 48 kg of body weight and 83 ± 50 days in milk for the control treatment, and 416 ± 46 kg of body weight and 86 ± 43 days in milk for the spAFC treatment before the beginning of the study. Diets were formulated to provide 50% of total dry matter intake from a total mixed ration and the remaining 50% from the control or spAFC pasture mixtures. The nutrient composition of the total mixed ration offered during the spring is presented in Table 1. Cows had access to their respective pasture treatments once daily after the afternoon milking from 1800 to 0500 h in a strip grazing management system. A new strip of fresh pasture was provided daily. Cows in each treatment were allotted the same amount of pasture dry matter (~12 kg dry matter per cow daily). Cows were housed in a bedded pack barn with access to an open concrete lot and a covered feeding area where the total mixed ration was provided using the Calan doors system (America Calan Inc., Northwood, NH) to individualize intake. Cows were milked twice daily at 0530 and 1630 h in a 4-stall step-up parlor with headlocks (Agromatic, Fond du Lac, WI).

Milk samples were collected over 4 consecutive milkings during the last week of the study. Blood samples were taken by venipuncture of the coccygeal vein or artery after the morning and afternoon milkings over 2 consecutive days. Ruminal samples were collected after the morning milking for 2 consecutive days using an esophageal tube. Cows were fed 1 kg/day of a pelleted concentrate containing chromium oxide for 10 consecutive days during the morning and afternoon feeding concurrently with the total mixed ration. Chromium oxide was used as an external marker to estimate fecal output of dry matter, nutrient digestibility, and pasture intake. Cows received 6.23 g of chromium per day. Fecal samples were collected and pooled daily after the morning and afternoon milkings for 5 consecutive days. Fecal output of dry matter was calculated by using fecal chromium concentration via the following equation: fecal output = (grams per day of chromium) ÷ (grams of chromium/grams of fecal dry matter) (Kolver and Muller 1998). Pasture dry matter intake was then calculated by the following equation: pasture dry matter intake = [(grams of chromium/day) ÷ (grams of chromium/grams of fecal dry matter) – concentrate dry matter intake × (1 – in vitro dry matter digestibility of concentrate) – total mixed ration dry matter intake × (1 – in vitro dry matter digestibility of total mixed ration)] ÷ (1 – in vitro dry matter digestibility of pasture) (Bargo et al. 2002). Data were analyzed using the MIXED procedure of SAS (SAS version 9.4; SAS Inst. Inc., Cary, NC) according to a completely randomized design. All reported values are least squares means and standard error of the mean. Significance was declared at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$.

<u>Experiment 2</u>

Planting and pasture measurements: A methodology similar to that used for the Experiment 1 was adopted during the summer experiment for pasture sampling, processing, and analyses. The summer available AFC (**suAFC**) were strip tilled and planted into a traditional perennial legume-grass pasture mixture in June 18, 2015. The following suAFC species were used: millet (*Pennisetum glaucum*), teff (*Eragrostis tef*), buckwheat (*Fagopyrum esculentum*), oats (*Avena sativa*), and chickling vetch (*Lathyrus sativus*). Pasture nutrient composition for Experiment 2 is presented in Table 2.

Animal measurements: Twenty organically-certified lactating Jersey cows (16 multiparous and 4 primiparous) were randomly assigned to 1 out of 2 treatments in a completely randomized design: 1) traditional legume-grass pasture mixture (control; n = 10 cows) or suAFC strip tilled into traditional legume-grass pasture mixture (n = 10 cows). Cows used averaged (mean ± standard deviation) 434 ± 46 of body weight and 146 ± 61 days in milk for the control treatment, and 449 ± 53 kg of body weight and 140 ± 57 days in milk for the suAFC treatment. Diets were formulated to provide 60% of total dry matter intake from a total mixed ration and the remaining 40% from the control or suAFC pasture mixtures. The nutrient composition of the total mixed ration offered during the summer is presented in Table 2. Data and sample collection and analyses were done as reported for Experiment 1.

Results and Discussion

<u>Experiment 1</u>

The botanical composition (dry matter basis) for the control treatment averaged 70% grasses, 17% legumes, and 13% other (broadleaf, weeds, and dead), while that for spAFC treatments averaged 60% grasses, 14% legumes, 13% AFC grasses, 4% AFC legumes, and 9% other (broadleaf, weeds, and dead). Perennial species primarily consisted of timothy grass (*Phleum pratense*), Kentucky bluegrass (*Poa pratensis*), orchardgrass (*Dactylis glomerata*), white clover (*Trifolium repens*), and alfalfa (*Medicago sativa*). Pasture biomass averaged 3,038 ± 303 and 4,052 ± 353 kg of dry matter/ha for the control and spAFC treatments, respectively. Pasture nutrient composition during the sampling period (i.e., last week of the experiment) averaged 16.0% and 15.1% crude protein, 53.3% and 56% neutral detergent fiber, and 34.6% and 32.1% acid detergent fiber for the control and spAFC treatments, respectively (Table 1).

Animal production, plasma metabolites, and ruminal fermentation profile data are presented in Table 3. No difference was observed for intake of pasture (8.10 versus 7.49 kg/day) or total mixed ration (10.9 versus 10.7 kg/day) when comparing control versus spAFC treatments, respectively. However, a trend ($P = 0.08$) was observed for greater total dry matter intake (18.9 vs. 18.1 kg/day) in cows fed control versus spAFC, respectively. Milk yield (25.2 versus 23.1 kg/day), along with contents and yields of milk fat (4.15 versus 3.89 %; 1.02 versus 0.92 kg/day) and milk true protein (3.53 versus 3.63 %; 0.86 versus 0.85

kg/day) did not differ between treatments. Similarly, no difference was observed for average daily weight gain (0.56 versus 0.77 kg/day). A trend (P = 0.06) for greater milk urea-N (13.1 versus 14.7 mg/dL) was observed with feeding spAFC rather than the control treatment. No significant differences were observed for the plasma concentrations of urea-N (11.9 versus 12.2 mg/dL) and non-esterified fatty acids (176 versus 174 mEq/L), or for the ruminal concentration of total volatile fatty acids (73.1 vs. 75.1 mM). Ruminal molar proportions of acetate (70.0 versus 69.8 mol/100 mol), propionate (16.2 versus 16.5 mol/100 mol), and butyrate (113. versus 11.1 mol/100 mol) also did not differ significantly between treatments. The lack of treatments effects on animal production and ruminal metabolism may have been caused by the relatively similar nutrient composition of both pasture sources used in the spring experiment.

Experiment 2

Botanical composition (dry matter basis) for the control treatment averaged 69% grasses, 11% legumes, and 20% other (broadleaf, weeds, and dead), while that for suAFC treatment averaged 61% grasses, 13% legumes, 1% AFC grasses, 2% AFC legumes, 12% AFC broadleaf, and 11% other (non-AFC broadleaf, weeds, and dead). Pasture biomass averaged 2,774± 275 and 2,588 ± 272 kg of dry matter/ha for the control and suAFC treatments, respectively. Pasture nutrient composition during the sampling period averaged 12.9% and 14.8% crude protein, 53.1% and 50.1% neutral detergent fiber, and 35.0% and 38.8% acid detergent fiber for the control and suAFC, respectively (Table 2).

Animal production, plasma metabolites, and ruminal fermentation profile data are presented in Table 4. There were no significant differences for the intake of pasture (8.26 versus 8.75 kg/day), total mixed ration (11.2 versus 11.6 kg/day), and total dry matter (19.6 versus 20.3 kg/day), average daily weigh gain (0.65 versus 0.57 kg/day), or milk yield (17.1 versus 17.0 kg/day) between control and suAFC treatments, respectively. However, concentrations and yields of milk fat (4.42 versus 5.02 %; 0.78 versus 0.93 kg/day) and milk true protein (3.49 versus 3.73%; 0.61 versus 0.69 kg/day) were significantly greater in cows offered suAFC than control. These responses were independent of intake and milk yield, thus suggesting improved nutrient utilization. A trend (P = 0.09) for lower milk urea-N (11.8 versus 10.8 mg/dL) in cows fed suAFC vs. control was observed. Cows offered suAFC also had significantly less concentration of plasma urea-N than those offered control (10.6 versus 8.92 mg/dL). Decreased milk urea-N and plasma urea-N in cows offered suAFC suggests improved N use efficiency. Ruminal concentrations of total volatile fatty acids (74.6 versus 75.0 mM) and plasma non-esterified fatty acids (174 versus 168 mEq/L) did not differ significantly between treatments. Ruminal acetate (71.8 versus 71.8 mol/100 mol), propionate (15.5 versus 15.6 mol/100 mol), and butyrate (10.6 versus 10.5 mol/100 mol) also did not differ between control and suAFC.

Conclusion

Strip-tilling spring available AFC into perennial legume-grass pasture mixture increased herbage biomass production and did not affect animal performance and ruminal fermentation profile when grazed by lactating organic Jersey cows. Strip-tilling summer available AFC into perennial legume-grass pasture mixture did not increase herbage biomass production or impacted milk yield and ruminal fermentation profile. However, yields of milk fat and true protein were increased in cows that grazed suAFC versus traditional legume-grass pasture mixture.

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Appendix

Table 1. Nutrient composition of the total mixed ration (TMR), traditional grass-legume pasture mixture (control pasture), and spring available annual forage crops strip tilled into traditional grass-legume pasture mixture during the spring season (spAFC pasture)

Item	TMR	Control pasture	spAFC pasture
Dry matter, % of fresh matter	69.4	24.7	24.4
Acid detergent fiber	21.9	34.6	32.1
Neutral detergent fiber	29.4	53.3	56.0
Crude protein	16.8	16.0	15.1
Starch	26.8	0.80	0.30
Crude fat	2.80	2.40	3.30
Lignin	3.10	3.80	2.40
Ash	9.20	7.35	8.18
Ca	0.80	0.58	0.34
P	0.40	0.25	0.27
Mg	0.50	0.22	0.16
K	1.90	2.30	2.81
Na	0.60	0.03	0.03
Fe, mg/kg	194	302	70.0
Zn, mg/kg	146	31.0	27.0
Cu, mg/kg	31.9	8.00	6.00
Mn, mg/kg	78.8	74.0	36.0
Mo, mg/kg	1.80	1.80	0.90
S	0.30	0.20	0.21
Cl	1.00	0.29	0.19

Table 2. Nutrient composition of the total mixed ration (TMR), traditional grass-legume pasture mixture (control pasture), and spring available annual forage crops strip tilled into traditional grass-legume pasture mixture during the summer season (suAFC pasture)

Item	TMR	Control pasture	suAFC pasture
Dry matter, % of fresh matter	70.9	25.1	24.9
Acid detergent fiber	19.9	35.0	38.8
Neutral detergent fiber	32.8	53.1	50.1
Crude protein	15.2	12.9	14.8
Starch	23.8	1.00	2.20
Crude fat	6.40	5.20	5.00
Lignin	3.10	4.30	9.10
Ash	8.01	7.82	6.24
Ca	0.65	0.62	0.79
P	0.42	0.45	0.34
Mg	0.43	0.29	0.38
K	1.68	2.55	1.38
Na	0.71	0.03	0.11
Fe, mg/kg	176	87	128
Zn, mg/kg	106	27	32
Cu, mg/kg	17.0	7.00	8.00
Mn, mg/kg	68.0	54.0	38.0
Mo, mg/kg	1.40	3.40	3.00
S	0.24	0.25	0.22
Cl	1.26	0.32	0.26

Table 3. Effects of traditional legume-grass pasture mixture (control) or spring available annual forage crops (spAFC) on animal production, plasma concentrations of urea-N and non-esterified fatty acids (NEFA), and ruminal fermentation profile

	Treatments			
Item	Control	spAFC	SEM	*P*-value
Pasture dry matter intake, kg/d	8.10	7.49	0.45	0.20
Total mixed ration intake, kg/d	10.9	10.7	0.13	0.13
Total dry matter intake, kg/d	18.9	18.1	0.44	0.08
Average daily weigh gain, kg/d	0.56	0.77	0.14	0.15
Milk yield, kg/d	25.2	23.1	1.24	0.23
Milk fat, %	4.15	3.89	0.26	0.50
Milk fat, kg/d	1.02	0.92	0.09	0.45
Milk true protein, %	3.53	3.63	0.12	0.54
Milk true protein, kg/d	0.86	0.85	0.05	0.83
Milk urea-N, mg/dL	13.1	14.7	0.55	0.06
Plasma urea-N, mg/dL	11.9	12.2	0.79	0.66
Plasma NEFA, mEq/L	176	174	5.12	0.72
Ruminal total volatile fatty acids, m*M*	73.1	75.1	6.40	0.77
Ruminal acetate, mol/100 mol	70.0	69.8	0.79	0.74
Ruminal propionate, mol/ 100 mol	16.2	16.5	0.50	0.66
Ruminal butyrate, mol/100 mol	11.3	11.1	0.42	0.64

Table 4. Effects of traditional legume-grass pasture mixture (control) or summer available annual forage crops (suAFC) on animal production, plasma concentrations of urea-N and non-esterified fatty acids (NEFA), and ruminal fermentation profile

	Treatments			
Item	Control	suAFC	SEM	*P*-value
Pasture intake, kg/d	8.26	8.75	0.73	0.51
Total mixed ration intake, kg/d	11.2	11.6	0.38	0.32
Total dry matter intake, kg/d	19.6	20.3	0.82	0.41
Average daily weight gain, kg/d	0.65	0.57	0.22	0.71
Milk yield, kg/d	17.1	17.0	0.60	0.86
Milk fat, %	4.43	5.02	0.14	<0.01
Milk fat, kg/d	0.78	0.93	0.04	0.02
Milk true protein, %	3.49	3.73	0.08	0.05
Milk true protein, kg/d	0.61	0.69	0.03	0.05
Milk urea-N, mg/dL	11.8	10.8	0.39	0.09
Plasma urea-N, mg/dL	10.6	8.92	0.49	<0.01
Plasma NEFA, mEq/L	174	168	6.88	0.34
Ruminal total volatile fatty acids, m*M*	74.6	75.0	5.34	0.95
Ruminal acetate, mol/100 mol	71.8	71.8	0.81	0.92
Ruminal propionate, mol/ 100 mol	15.5	15.6	0.31	0.71
Ruminal butyrate, mol/100 mol	10.6	10.5	0.40	0.93