Fall-grown oat to extend the fall grazing season for replacement dairy heifers¹

W. K. Coblenz,^{*2} G. E. Brink,[†] P. C. Hoffman,[‡] N. M. Esser,[§] and M. G. Bertram[#]

^{*}US Department of Agriculture-Agricultural Research Service (USDA-ARS), US Dairy Forage Research Center, Marshfield, WI 54449

[†]USDA-ARS, US Dairy Forage Research Center, Madison WI 53706

[‡]Department of Dairy Science, University of Wisconsin, Madison 53706

[§]Superintendent, University of Wisconsin Marshfield Agricultural Research Station, Marshfield 54449

[#]Superintendent, University of Wisconsin Arlington Agricultural Research Station, Arlington 53911

ABSTRACT

Our objective was to assess the pasture productivity and forage characteristics of 2 fall-grown oat (*Avena sativa* L.) cultivars, specifically for extending the grazing season and reducing reliance on harvested forages by replacement dairy heifers. A total of 160 gravid Holstein heifers (80 heifers/yr) were stratified by weight, and assigned to 1 of 10 identical research pens (8 heifers/pen). Initial body weights were 480 ± 43.5 kg in 2011 and 509 ± 39.4 kg in 2012. During both years of the trial, four 1.0-ha pasture replicates were seeded in August with Ogle oat (Schumitsch Seed Inc., Antigo, WI), and 4 separate, but similarly configured, pasture replicates were seeded with Forage Plus oat (Kratz Farms, Slinger, WI). Heifer groups were maintained as units, assigned to specific pastures, and then allowed to graze fall-oat pastures for 6 h daily before returning to the barn, where they were offered a forage-based basal total mixed ration. Two heifer groups were retained in confinement (without grazing) as controls and offered the identical total mixed ration as pasture groups. During 2011, available forage mass increased with strong linear and quadratic effects for both cultivars, peaking at almost 9 Mg/ha on October 31. In contrast, forage mass was not affected by evaluation date in 2012, remaining $\leq 2,639$ kg/ha across all dates because of droughty climatic conditions. During 2012, Ogle exhibited greater forage mass than Forage Plus across all sampling dates (2,678 vs. 1,856 kg/ha), largely because of its more rapid maturation rate and greater canopy height. Estimates of energy density for oat forage ranged from 59.6 to 69.1% during 2011, and ranged narrowly from 68.4 to 70.4% during 2012. For 2011, responses for both cultivars had strong quadratic

character, in which the most energy-dense forages occurred in mid November, largely due to accumulation of water-soluble carbohydrates that reached maximum concentrations of 18.2 and 15.1% for Forage Plus and Ogle, respectively. Across the 2-yr trial, average daily gain for grazing heifer groups tended to be greater than heifers remaining in confinement (0.85 vs. 0.74 kg/d), but both management strategies produced weight gains within reasonable proximity to normal targets for heifers in this weight range. Fall-grown oat should be managed as stockpiled forage for deferred grazing, and good utilization of fall-oat forage can be accomplished by a one-time removal of standing forage, facilitated by a single lead wire advanced daily to prevent waste.

Key words: dairy heifer, fall-grown oat, stockpiled forage, water-soluble carbohydrates

INTRODUCTION

Recently, several plot-scale research projects have evaluated the potential of fall-grown oat (*Avena sativa* L.) for use as an emergency fall forage option and to extend the grazing season throughout central Wisconsin (Contreras-Govea and Albrecht, 2006; Coblenz and Walgenbach, 2010a; Coblenz et al., 2011). Specifically, this forage option targets a grazing interval extending from late September through mid November, when perennial cool-season grasses often become less productive, thereby leaving only limited options for dairy producers seeking to meet intake requirements for lactating cows or heifers via grazed forages. As such, management options that provide forage for grazing dairy animals throughout October and early November are highly valued. Some growth characteristics of fall-grown oat make it especially well suited for fall grazing. Among these, the long-day photoperiod requirement for flowering (Dennis, 1984) is disrupted, thereby resulting in a slower maturation rate than observed for spring-established oat forages (Contreras-Govea and Albrecht, 2006). In addition, several unique quality traits have been associated with fall-grown oat that include (1) reduced concentrations of fiber components, (2) less ex-

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²Corresponding author: wayne.coblenz@ars.usda.gov.

tensive lignification, (3) improved fiber digestibility, (4) a tendency to accumulate water-soluble carbohydrates (WSC) as a result of winter hardening, and (5) relative stability with respect to energy density across a broad window of opportunity for utilization (Contreras-Govea and Albrecht, 2006; Coblenz and Walgenbach, 2010a; Coblenz et al., 2012). Although most of these traits are desirable from a grazing management standpoint, many unresolved logistical questions are associated with the use of these forages and warrant investigation. Our objective was to assess the pasture productivity and forage characteristics of 2 fall-grown oat cultivars, specifically for extending the grazing season and reducing reliance on harvested forages for gravid dairy heifers.

MATERIALS AND METHODS

Establishment of Pastures

The experiment was conducted on a Withee silt loam (fine-loamy, mixed, frigid, Aeric Glossaqualfs) soil type at the University of Wisconsin Marshfield Agricultural Research Station, located near Stratford (44°7'N, 90°1'W). The 10-ha pasture unit was subdivided into ten 1.0-ha pastures, 8 of which served as the experimental units for all pasture measurements, whereas the remaining 2 pastures were used as training pastures to adapt dairy replacement heifers to both grazing and the electric-fencing system. No data were collected from the training pastures. During early August of 2011 and 2012, the entire pasture system was clean-tilled, and tested for soil fertility (University of Wisconsin Soil and Forage Laboratory, Marshfield). Soil tests for P and K indicated no requirement for these soil amendments; therefore, pastures were fertilized only with urea (46-0-0) at a rate of 67 kg of N/ha. Four pastures were seeded with Ogle oat (Schumitsch Seed Inc., Antigo, WI) at a seeding rate of 108 kg/ha with a Case IH model 5300 grain drill (Case IH, Racine, WI), configured with 18-cm-wide row spacings. Likewise, 4 pastures also were seeded with Forage Plus oat (Kratz Farms, Slinger, WI) by the same methods and seeding rate, thereby yielding 8 total pastures from which data was collected. Ogle oat is considered a mid-maturity, grain-type oat cultivar, whereas Forage Plus has been selected specifically for forage-related traits, and consistently exhibits a slower rate of maturation. In University of Wisconsin performance tests (2007 through 2009), mean harvest dates based on traditional spring establishment and a late boot/early heading growth stage were June 14 and 24 for Ogle and Forage Plus, respectively (Mochon et al., 2009). However, these maturity rate differences are known to be exacerbated for fall growth applications (Coblenz et al., 2011). Cultivars were assigned ran-

domly to pastures each year and pastures were fertilized with a single application of N on August 11, 2011, and August 8, 2012, and then seeded on August 11, 2011, and August 13, 2012. The pasture layout contained a centrally located drover's alley, positioned with an east-west orientation; rectangular pasture replicates of similar dimensions ($\sim 55.3 \times 181.0$ m) were located on both the north and south sides of the drover's alley.

Management of Confined Heifer Groups

All animal handling procedures for this experiment were approved by the Research Animal Resources Committee (RARC) of the University of Wisconsin-Madison (protocol no. A01479). A total of 160 gravid Holstein heifers (80 heifers/yr) were stratified by weight and assigned in groups of 8 heifers to 1 of 10 identical research pens located within a pole-type barn with natural cross-ventilation. Initial BW were 480 ± 43.5 kg and 509 ± 39.4 kg during 2011 and 2012, respectively, and the mean age of heifers was 17.5 ± 1.48 mo for 2011 and 17.3 ± 1.77 mo for 2012. All heifers were confirmed pregnant (97 ± 31.3 and 89 ± 39.2 d for 2011 and 2012, respectively) by the attending veterinarian before initiating the trial to avoid the inconveniences associated with breeding grazing heifers by AI. Within the barn, each research pen was equipped with continuous access to fresh water, 8 freestalls with foam-core mattresses, an automatically controlled mechanical alley-scraping system, and adequate bunk space adjacent to a drive-by feed alley that allowed all heifers to eat simultaneously.

Each year, the 10 research pens were assigned to 1 of 3 treatments that included (1) Forage Plus oat pasture, (2) Ogle oat pasture, or (3) no grazing (control). Four replications (pens) were assigned to each oat cultivar and 2 pens of heifers were assigned as control (confinement; no pasture) groups. A basal TMR diet composed of cereal-grain silage (ryelage or oatlage) and alfalfa haylage (Table 1) was dispensed to the control groups at 0900 and 1530 h in proportions accounting for 60 and 40% of the total daily allotment, respectively. After delivery of the TMR at 1530 h, the blended silage diet was top-dressed with ground corn at rates of 0.50 and 0.11 kg/heifer per day during 2011 and 2012, respectively. The ground corn also was used as a carrier for a low-phosphorus mineral package (Table 1) offered at a rate of 82 g/heifer per day. The TMR diet was offered for ad libitum intake by managing daily offerings of TMR to a defined bunk score of 2, where 0 = no feed particles remaining; 1 = only scattered feed particles remaining; 2 = numerous particles remaining, but the concrete floor still easily visible; or 3 = feed particles completely covering the concrete bunk floor (Hoffman et al., 2008). Bunks were scored each morning, and the

amount of TMR was adjusted daily on this basis to maintain the preestablished bunk score of 2. A bunk score of 0 triggered an approximate 5% increase in the daily diet allocation, calculated on an as-is basis. Samples of the basal diet were obtained daily, frozen (-20°C), and composited by week for analysis. Weekly TMR samples were analyzed for DM, CP, and NDF content; 48-h in vitro digestibility of NDF; and ADF, hemicellulose, ADL, ash, P, Ca, K, and Mg content by the University of Wisconsin Soil and Forage Laboratory (Marshfield). Energy calculations for the TMR were made as described by NRC (2001). Orts were sampled similarly; each morning, refusals were swept from each feed bunk, placed in a large (tared) plastic tub, mixed thoroughly, weighed, and then subsampled (~ 200 g). During each week of the trial, daily subsamples of Orts from each pen were placed in sealed freezer bags, frozen (-20°C), and then composited by pen. A subsample (~ 400 g) of weekly refusals from each pen was placed in a paper bag and then dried to constant weight under forced air at 55°C to determine the concentration of DM within the Orts.

Management of Grazing Heifer Groups

Approximately 2 wk before data collection was initiated, 64 of the 80 total heifers selected for the trial each year were trained to the electric wire and then adapted further to grazing. These heifers had no previous grazing experience. Initially, an electrified wire was placed inside a fenced corral with a concrete floor. Heifers were comingled in groups of 16 animals and then allowed access to the corral and the electric training wire for approximately 0.5 h; subsequently, heifers were rotated out of the corral and additional groups of 16 animals were permitted access. Each heifer participated in at least 2 such training sessions before they were allowed access to the training pastures. During the week immediately preceding the initiation of the grazing data collection, heifers were comingled into 2 groups of 32 animals each, and slowly escorted to the training pastures via the centrally located drover's alley. Initially, heifers were allowed to adjust to the pasture, electric wire, and initiate grazing for about 1 h; however, access time on the training pastures was increased subsequently to 4 to 5 h daily before the adaptation period was concluded. After the final training session on pasture, heifers were sorted into permanent groups of 8 heifers each and then assigned to a specific pen location within the barn.

Approved standards of animal care for this trial (protocol no. A01479) were unique for 2 reasons: (1) the protocol did not require heifers to have continuous access to water while grazing, which eliminated the

need for water supply lines during a time period when subfreezing temperatures were a near certainty (Figure 1; NOAA, 2002); and (2) it did not permit heifers to be maintained on pasture overnight, thereby requiring movement of heifers from the research barn to their pastures, and then back again, on a daily basis. On d 1 through 3 of data collection, all heifers (pasture and control pens) were weighed before feeding or grazing at 0730 h using a cattle chute (Real Tuff Inc., Clearbrook, MN) equipped with an electronic scale (Tru-Test Inc., Mineral Wells, TX). Pasture groups then were moved to their assigned pasture, where they remained until about 1400 h. At that time, they were returned to their assigned pens within the research barn. At 1530 h, the basal TMR was offered to each pen of heifers returning from pasture for ad libitum intake; this feeding coincided with the second delivery of TMR to the confined (control; no pasture) groups. Supplemental ground corn and mineral were top-dressed exactly as described for the control groups at this time. Individual heifer BW from the first 3 d of the trial were averaged to deter-

Table 1. Composition of TMR offered to dairy heifers during 2011 and 2012^{1,2}

Item	Year	
	2011	2012
Ingredient, % of DM		
Alfalfa haylage	42.8	35.4
Ryelage or oatlage	57.2	65.6
Nutrient composition ³		
DM, % of wet weight	43.1	45.3
CP	13.7	12.1
NDF	61.0	58.7
NDFD, ⁴ % of NDF	54.3	58.6
ADF	40.0	37.3
Hemicellulose	21.0	21.4
ADL	7.23	4.74
Ash	11.3	10.9
P	0.27	0.35
Ca	0.67	0.60
K	2.30	2.01
Mg	0.18	0.18
Energy estimate		
TDN	53.9	57.6
ME, Mcal/kg	1.95	2.12
NE _G , Mcal/kg	0.55	0.68
NE _M , Mcal/kg	1.11	1.26

¹Analyses of TMR were conducted by the University of Wisconsin Soil and Forage Analysis Laboratory, Marshfield.

²All heifers, regardless of treatment, received 0.50 and 0.11 kg/heifer per day of ground corn during 2011 and 2012, respectively; similarly, each heifer received 82 g/d of a commercial mineral mix during both years of the trial. The mineral package contained 72.1% calcium carbonate, 16.5% salt, 3.35% sulfur, 2.95% selenium 1600, 1.50% vitamin A, 0.75% mineral oil, 0.71% copper sulfate, 0.69% vitamin E (50%), 0.64% zinc sulfate, 0.51% vitamin D, 0.09% iodine mix, 0.005% magnesium sulfate, 0.005% cobalt carbonate, 0.005% manganese oxide (60%), and 0.26% thiamine.

³Reported as percentage of DM, unless otherwise indicated.

⁴Digestibility of NDF.

mine an initial BW for each heifer. During this time period, BCS also was assessed for all heifers by a trained evaluator on a scale of 1 to 5, where 1 = emaciated and 5 = obese (Wildman et al., 1982); increments of 0.5 units were applied to best describe the body condition of each heifer. Grazing was initiated on September 26, 2011, and October 8, 2012, and concluded on November 22, 2011, and November 23, 2012. Final determinations of heifer BW were based on a similar 3-d average determined at 0730 h each day at the end of the grazing trial; a final BCS was obtained as described previously during this final 3-d weighing period.

Pasture Management and Sampling

Because this application of fall-grown oat is a form of stockpiling forage for deferred grazing, some additional management was necessary to prevent heifers from wasting forage by walking, lying, defecating, or urinating in the ungrazed portions of the pasture. In addition, there was no need to manage the grazing aftermath, largely because oat is an annual forage that will winterkill in Wisconsin, and previous research has shown that fall-grown oat forages offer very poor regrowth potential (Gunsaulis et al., 2008). Therefore, only a single-strand lead wire was used to control grazing throughout the study. At the start of data collection, the lead wire was advanced approximately 10 m into each pasture to allow each grazing heifer group adequate area to prevent crowding while they further adjusted to their permanently assigned pastures. Beginning on d 3 of grazing, the lead wire was advanced manually each day, providing 8.5 to 9.0 kg of DM/heifer per day, and requiring advancement of the lead wire by 1.3 to 5.2 m daily during 2011, and by 3.3 to 15.1 m during 2012. These advancements were recalculated weekly for each pasture, based on forage mass, DM concentration of the forage, and the exact width of the pasture, which varied slightly across pasture replicates. The lead wire in each pasture was a single strand of polywire with attached plastic orange streamers (2011) or polytape (2012), supported by 4 or 5 tread-in fencing posts; the lead wire was advanced by moving the tread-in posts ahead by the calculated distance, and then reattaching the lead wire to the perimeter fence. A lightweight polyvinyl chloride (PVC) pipe (outside diameter = 2.5 cm) was marked in 0.3-m (1-ft) increments with black electrical tape, and placed on the ground next to each tread-in post to ensure that posts were advanced consistently, and with reasonable precision. Only occasionally did weather conditions prohibit heifers from grazing; this occurred on 6 of 58 and 3 of 47 possible grazing days during 2011 and 2012, respectively. Decisions to forgo grazing were associated with heavy rains or snowfall, particu-

larly if grazing would result in significant destruction/alteration of the soil surface that subsequently would be undesirable for heifers to walk over after freezing. Whenever these decisions were made, pasture groups of heifers were retained in the research barn and managed in an identical manner to control groups. During 2012, droughty conditions greatly limited estimated forage mass compared with 2011; therefore, the lead wire was advanced daily until forage availability was exhausted, and those specific pasture groups were then managed as control groups until termination of the study in late November.

Pasture Sampling Procedures

Pastures were sampled weekly throughout the trial. Forage was clipped with hand shears to a 2.5-cm stubble height following placement of two 0.25-m² frames on the ungrazed side of the lead wire. Frame placement was random, but in close proximity to the lead wire, and limited to the area that would be grazed within that specific week. Clippings were placed in paper bags and dried to constant weight under forced air at 55°C, weighed, and then extrapolated to estimate DM yield on a kilogram-per-hectare basis. In association with these procedures, 3 tillers were selected at random, measured for canopy height, and assessed for growth stage using a linear description model (Stauss, 1994). Stage of growth was identified as tillering (20–29), stem elongation (30–39), booting (40–49), and emergence of inflorescence (50–59). Because oat is a long-day plant (Dennis, 1984) and it is unclear whether viable seed can be produced with fall establishment, no attempt was made to stage plants beyond full emergence of seed head and peduncle (growth stage = 59). Canopy height was measured on an as-is basis, except when plants were lodged following snowfall events; in those cases, oat plants were held erect before measurements were taken. Residual forage (grazing aftermath) was clipped from three 0.25-m² frames positioned randomly on the trailing side of the lead wire, dried under forced air at 55°C, and residual forage DM calculated on a kilograms-of-DM-per-hectare basis as described previously. Apparent forage utilization was calculated for each pasture as $100\% \times (\text{ungrazed forage mass} - \text{residual forage mass}) / \text{ungrazed forage mass}$.

During 2011, climatic conditions were favorable for growth of oat plants, and forage mass was >8,000 kg/ha for numerous interactive combinations of cultivar and sampling date (Table 2). Further assessment of grazing preferences by heifers was conducted by in-depth evaluation of the residual forage mass. This included leaf separations on 80-g subsamples of dried ungrazed and residual forage to establish grazing preference on

Figure 1. Mean monthly temperature (A) and precipitation (B) for June through November of 2011 and 2012, as well as associated annual norms for those months (NOAA, 2002) at Marshfield, Wisconsin.

the basis of plant-tissue type. Because forage utilization was extensive following droughty growing conditions during 2012 (77.8 to 90.4%), this additional evaluation of grazing aftermath was limited to forage harvested in 2011 only.

Laboratory Analyses of Oat-Pasture Forages

All dried whole-plant oat forages were ground through a Thomas model 4 Wiley Mill (Thomas Scientific, Swedesboro, NJ) equipped with a 1-mm screen,

Table 2. Agronomic characteristics for Forage Plus (FP; Kratz Farms, Slinger, WI) and Ogle (Schumitsch Seed Inc., Antigo, WI) oat pastures grazed during September through November 2011 at Marshfield, Wisconsin¹

	Growth stage, ² no.		Canopy height, cm		Forage mass, kg/ha		Residue forage mass, kg/ha		Apparent utilization, ³ %	
Item	FP	Ogle	FP	Ogle	FP	Ogle	FP	Ogle	FP	Ogle
Date										
September 26	32	33	58	66	2,640	2,807	—	—	—	—
October 3	33	34	61	78	3,945	4,096	1,446	2,718	63.0	33.4
October 10	34	49	84	91	5,298	5,402	2,351	2,671	55.6	51.0
October 17	34	52	84	95	7,139	7,245	2,239	3,961	68.5	45.8
October 24	35	54	83	101	7,512	8,424	2,344	3,785	68.4	55.3
October 31	35	54	90	108	8,886	8,989	3,420	4,476	61.3	49.9
November 7	35	55	84	103	8,046	8,413	3,193	4,330	58.9	48.5
November 14	34	57	73	91	7,720	8,145	4,241	4,774	43.6	41.2
November 21	36	56	65	87	6,466	6,667	—	—	—	—
SEM	0.5		2.6		442.0		299.4		4.39	
Contrast ⁴	<i>P</i> -value									
Linear	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.33
Quadratic	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.38	0.21	<0.01	<0.01
Cubic	0.44	<0.01	0.56	0.40	0.05	0.02	0.23	0.85	0.15	0.57
Quartic	0.08	<0.01	0.20	0.21	0.39	0.22	0.53	0.16	0.28	0.41

¹The interaction of oat cultivar and sampling date was significant ($P < 0.05$) for most response variables; therefore, data are presented as interaction means.

²Stage of growth was assessed according to a linear description model (Stauss, 1994) and identified as tillering (20–29), stem elongation (30–39), booting (40–49), and emergence of inflorescence (50–59). Because oat is a long-day plant, and it is unclear whether viable seed can be produced with fall establishment, no attempt was made to stage plants beyond full emergence of seed head and peduncle (growth stage = 59).

³Calculated weekly as $100\% \times (\text{ungrazed forage mass} - \text{residual forage mass})/\text{ungrazed forage mass}$.

⁴Linear, quadratic, cubic, and quartic effects of sampling date on each response variable.

and then stored in sealed plastic sample bags pending analysis for nutritive value. Oat samples were analyzed sequentially for NDF and ADL using batch procedures outlined by Ankom Technology Corp. (Macedon, NY) for an ANKOM200 Fiber Analyzer. The NDF solution included heat-stable α -amylase, but not sodium sulfite. Water-soluble carbohydrates were quantified using the phenol-sulfuric acid reaction with final concentrations determined colorimetrically (DuBois et al., 1956) and CP was assessed by a rapid combustion procedure (AOAC International, 1998; method 990.03; Elemental Americas Inc., Mt. Laurel, NJ) as the percentage of $N \times 6.25$. Concentrations of whole-plant ash were obtained from 1.0-g subsamples of each forage following combustion in a muffle furnace at 500°C for 6 h. Energy density (TDN) was calculated for all forages based on the summative equation (Weiss et al., 1992; NRC, 2001), using the ADL option for estimating truly digestible fiber. Calculations of TDN by the summative equation also require quantification of CP that is insoluble in both neutral and acid detergent. These determinations were obtained from each sample following nonsequential extraction in neutral and acid detergent, respectively, using the batch procedures of Ankom Technology Corp. The NDF solution contained no sodium sulfite, which was omitted from digestions in neutral detergent because it is known to cleave disulfide bonds and dissolve cross-linked proteins, which

reduces CP recovery from NDF residues (Van Soest et al., 1991). Residual CP following these extractions in neutral and acid detergent were determined by the combustion procedure described previously (AOAC, 1998). Inputs of neutral-detergent CP and acid-detergent CP were quantified only to calculate TDN, and are not otherwise reported or discussed.

Statistics

All forage measurements were analyzed using PROC MIXED of SAS (SAS Institute, 2002) in a split-plot design, with oat cultivar and week as the whole-plot and subplot treatment terms, respectively. Oat cultivars were assigned to pastures randomly; therefore, pasture replication within oat cultivar was declared random. Responses over time were tested for linear, quadratic, cubic, or quartic trends with orthogonal contrasts. The nature of this experiment and the climate in central Wisconsin forcibly limited the length of the grazing interval to <60 d; therefore, the utility of heifer performance data are questionable, and caution is advised with respect to interpretation. However, these data are still reported, noting these stated cautions. For this aspect of the trial, the pen (heifer group) was considered to be the experimental unit. Data were analyzed using PROC GLM of SAS (SAS Institute, 2002) in a split-plot design, with year as the whole-plot treatment

term and management system (Ogle oat, Forage Plus oat, or confinement control) as the subplot term. The effects of year were tested with replication within year as the error term; all other effects were tested with the residual error. Least squares treatment means were tested for significance with 2 orthogonal contrasts: (1) control versus grazing heifer groups and (2) Ogle versus Forage Plus oat. Significance was declared at the $P = 0.05$ level of confidence, unless otherwise stated.

RESULTS

Weather Data

Expected 30-yr norms (NOAA, 2002), as well as monthly means for temperature and precipitation for June through November of 2011 and 2012 are shown in Figures 1A and B, respectively. Generally, 2011 and 2012 were distinctly different growing seasons. For 2011, precipitation during July exceeded the 30-yr norm by 104 mm, which was approximately 2 times the expected mean. Although precipitation did not exceed the expected norm for any other month, it was similar to the expected norms for both September and October of 2011. In contrast, precipitation during July of 2012 was only 33% of the expected norm, and only 16% of that observed during 2011. Although precipitation during August 2012 was similar to the expected norm, it was very poorly distributed; 82% of the 104 mm of precipitation was associated with 3 rainfall events that occurred between August 2 and 9. Similar to July, precipitation during September was far less than the expected, accounting for only 42% of the expected 30-yr norm (102 mm; NOAA, 2002). Taken in total, these factors greatly slowed germination and early growth during 2012 compared with 2011. Furthermore, mean monthly temperatures during October of 2011 were above normal, thereby establishing conditions more favorable for continued accumulation of forage DM throughout that month.

Pasture Evaluations 2011

Agronomic Characteristics. Interactions of cultivar and sampling date were significant ($P < 0.05$) for most pasture-related measurements; therefore, all data are presented and discussed as interaction means. Both cultivars had jointed and exhibited similar growth stages by the initial September 26 sampling date; however, Ogle matured faster than Forage Plus thereafter. Growth stage for Forage Plus increased with linear ($P < 0.01$) and quadratic ($P = 0.01$) effects of sampling date, but these responses were limited in scope, ranging only from early to late stem elongation over the 9-wk

sampling period. In contrast, Ogle began heading by October 17, although full extension of the peduncle was not observed on any evaluation date. This response for Ogle yielded multiple polynomial effects ($P < 0.01$), but, in practical terms, they can be explained as rapid morphological development through October 17, followed by a static response thereafter.

Canopy height increased across sampling dates, reaching maxima of 90 and 108 cm on October 31 for Forage Plus and Ogle, respectively, but declined thereafter in response to subfreezing temperatures (mean low temperature = -15.5°C). These responses were explained by linear ($P < 0.01$) and quadratic ($P < 0.01$) effects of sampling date, but not by other polynomial effects ($P \geq 0.20$). Generally, responses for forage mass were similar to those observed for canopy height, increasing by more than 3-fold between September 26 and October 31 before declining thereafter in response to colder temperatures. During 2011, forage mass reached numerically similar maxima of 8,886 and 8,989 kg of DM/ha for Forage Plus and Ogle, respectively, and responses across sampling dates were explained primarily by linear ($P < 0.01$) and quadratic ($P < 0.01$) effects. Growing conditions for fall oat were especially favorable during 2011. Under the experimental procedures described for these studies, not all forage could be utilized by heifers by November 22 (termination date). Based on the available forage remaining within each pasture on the final sampling date, grazing could have continued for 40 ± 7.7 d for Forage Plus and 41 ± 5.6 d for Ogle; however, no reasonable expectation exists that weather conditions in central Wisconsin would permit such an assessment, and the trial was terminated as scheduled.

In contrast to forage mass, which declined during November sampling dates, residual forage mass measured after grazing increased linearly ($P < 0.01$) across sampling dates for both oat cultivars. The magnitude of grazing aftermath increased from 1,446 to 4,241 kg/ha and from 2,718 to 4,774 kg/ha across October and November sampling dates for Forage Plus and Ogle oat, respectively. As a result, estimates of apparent forage utilization based on initial and residual forage mass measured during September and October ranged from 55.6 to 68.5% for Forage Plus, but declined to 43.6% by the end of the study, thereby exhibiting overall linear ($P = 0.01$) and quadratic ($P < 0.01$) effects. In contrast, apparent utilization for Ogle increased through October 24 and then declined thereafter, creating a quadratic ($P < 0.01$) response without linear character ($P = 0.33$).

Forage Nutritive Value. For NDF, responses over sampling dates for Forage Plus and Ogle oat yielded multiple, but inconsistent, polynomial contrasts ($P \leq$

0.03; Table 3). However, these responses generally followed a quadratic pattern ($P < 0.01$) for both cultivars. Generally, concentrations of NDF increased through mid-to-late October and then declined until the end of the trial. The magnitude of these declines from peak concentrations of NDF observed in October was more substantial for Forage Plus (53.7 to 47.2%) than for Ogle (60.2 to 57.2%). Concentrations of ADL for Forage Plus oat were not related to weekly sampling date by any of the polynomial contrasts that were evaluated ($P \geq 0.07$; overall mean = 1.18%). However, concentrations of ADL within Ogle increased from 1.23 to 3.23% through October 31 before declining thereafter, which was a response explained by both linear ($P < 0.01$) and quadratic ($P < 0.01$) effects of sampling date.

Concentrations of ash declined across sampling dates for both oat cultivars, exhibiting varying polynomial effects ($P \leq 0.03$); in practical terms, these responses represented primarily linear ($P < 0.01$) declines that ranged from 15.3 to 10.4% for Forage Plus, and from 13.2 to 7.9% for Ogle. Similarly, concentrations of CP declined for both cultivars, exhibiting multiple polynomial trends ($P \leq 0.05$); however, these responses again were mostly linear ($P < 0.01$) in character. Considered across all sampling dates, concentrations of CP declined from 24.7 to 12.6% for Forage Plus and from 22.4 to 9.7% for Ogle. Unlike responses for ash and CP, concentrations of WSC increased over time for both cultivars, exhibiting linear ($P < 0.01$) and quadratic ($P < 0.01$) effects. Generally, these responses can be explained by

static concentrations of WSC ($\leq 5.6\%$) through October 17, followed by steady increases thereafter that reached maxima of 18.2 and 15.1% on November 21 for Forage Plus and Ogle, respectively. Responses for TDN were largely mirror opposite those observed for NDF, declining from September 26 through October 17 and then increasing through the end of the trial. For both cultivars, the most energy-dense forages were observed on the final November 21 sampling date and overall responses were primarily quadratic ($P < 0.01$) in nature. However, linear ($P < 0.01$) and cubic ($P = 0.02$) effects were also observed for Forage Plus, but not for Ogle ($P \geq 0.35$).

Leaf, Stem, and Residue Analysis. Percentages of leaf within ungrazed oat (Table 4) declined across sampling dates from 49.2 to 37.0% for Forage Plus, and from 36.3 to 20.1% for Ogle; however, responses for both cultivars were explained by both linear ($P < 0.01$) and quadratic ($P < 0.01$) effects. Declines in the percentage of leaf tissue stabilized within oat forages by late October and were relatively static thereafter. Generally, concentrations of NDF and CP within individual leaf and stem tissues (Figures 2A and 2B) primarily were affected by multiple polynomial effects of sampling date ($P < 0.01$). Concentrations of NDF and CP for leaf tissue were not affected ($P \geq 0.36$) by cultivar, nor was CP within stem tissue ($P = 0.57$); however, concentrations of NDF within stem tissue obtained from Ogle pastures were greater ($P < 0.01$) than found within Forage Plus pastures (61.3 vs. 54.3%).

Table 3. Whole-plant nutritive value (% of DM) for Forage Plus (FP; Kratz Farms, Slinger, WI) and Ogle (Schumitsch Seed Inc., Antigo, WI) oat pastures grazed during September through November 2011 at Marshfield, Wisconsin¹

	NDF		ADL		Ash		CP		WSC ²		TDN	
Item	FP	Ogle	FP	Ogle	FP	Ogle	FP	Ogle	FP	Ogle	FP	Ogle
Date												
September 26	44.1	52.6	0.97	1.23	15.3	12.3	24.7	19.7	4.8	5.6	65.1	64.0
October 3	45.5	50.7	1.59	1.45	15.3	13.2	24.6	22.4	5.6	5.3	62.8	63.5
October 10	51.2	58.5	0.94	2.18	15.3	12.3	21.7	19.1	4.4	4.0	62.6	61.0
October 17	53.7	59.8	1.65	2.70	15.0	11.9	18.6	17.7	4.5	3.9	60.5	59.6
October 24	50.5	59.1	1.29	2.81	13.5	10.5	17.5	15.4	9.0	7.5	63.7	60.8
October 31	51.7	60.2	1.18	3.23	12.5	10.1	14.5	14.3	10.3	7.6	64.9	60.5
November 7	49.5	57.2	1.24	2.67	12.3	9.5	14.6	12.8	12.3	10.9	65.7	62.8
November 14	47.4	58.1	0.85	2.78	11.5	8.3	15.0	11.3	15.3	13.9	67.9	63.0
November 21	47.2	57.6	0.92	2.71	10.4	7.9	12.6	9.7	18.2	15.1	69.1	64.4
SEM	0.80		0.223		0.37		1.68		0.87		0.77	
Contrast ³	<i>P</i> -value											
Linear	0.03	<0.01	0.18	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.45
Quadratic	<0.01	<0.01	0.07	<0.01	0.01	0.03	0.02	0.33	<0.01	<0.01	<0.01	<0.01
Cubic	<0.01	0.18	0.49	0.96	0.11	0.03	0.36	0.09	0.17	0.06	0.02	0.35
Quartic	0.02	<0.01	0.99	0.08	0.34	0.25	0.02	0.05	0.86	0.28	0.97	0.20

¹The interaction of oat cultivar and sampling date was significant ($P < 0.05$) for most response variables; therefore, data are presented as interaction means.

²Water-soluble carbohydrates.

³Linear, quadratic, cubic, and quartic effects of sampling date on each response variable.

Table 4. Percentages (% of DM) of leaf within ungrazed and residual forage, as well as the nutritive value of residual forage from Forage Plus (FP; Kratz Farms, Slinger, WI) and Ogle (Schumitsch Seed Inc., Antigo, WI) oat pastures sampled after grazing during September through November 2011 at Marshfield, Wisconsin

Item	Leaf tissue				Residue					
	Ungrazed		Residue		NDF		CP		Ash	
	FP	Ogle	FP	Ogle	FP	Ogle	FP	Ogle	FP	Ogle
Sampling date										
October 3	49.2	36.3	16.5	19.8	54.4	57.2	18.8	15.8	24.3	19.7
October 10	46.6	32.4	24.7	15.7	57.9	63.4	16.9	16.1	20.8	17.4
October 17	42.7	27.9	15.7	13.7	62.0	64.8	13.4	12.6	21.3	20.0
October 24	39.7	24.0	14.2	13.7	61.8	67.4	10.3	10.7	19.4	15.4
October 31	37.6	22.8	17.1	13.1	64.7	70.3	9.8	9.3	26.1	17.5
November 7	37.0	23.0	17.6	13.1	59.1	62.2	10.7	11.0	17.2	12.8
November 14	38.3	21.6	21.6	14.6	58.2	64.3	11.3	9.9	16.5	13.0
November 21	38.8	20.1	—	—	—	—	—	—	—	—
SEM	1.08		1.87		1.42		1.89		1.66	
Contrast ¹	<i>P</i> -value									
Linear	<0.01	<0.01	0.77	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Quadratic	<0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	0.04	0.30	0.44
Cubic	0.38	0.21	0.01	0.64	0.98	0.39	0.38	0.33	0.03	0.94
Quartic	0.24	0.15	<0.01	0.63	0.30	0.14	0.16	0.06	0.31	0.42

¹Linear, quadratic, cubic, and quartic effects of sampling date on each response variable.

Forage sampled after heifers grazed Forage Plus pastures exhibited percentages of leaf ranging from 14.2 to 24.7% of all residual DM. Across sampling dates, percentages of leaf within residues from Forage Plus pastures varied somewhat erratically, exhibiting quadratic ($P = 0.02$), cubic ($P = 0.01$), and quartic ($P < 0.01$) effects, but it is unclear whether these significant effects have relevance with respect to any practical aspect of pasture management. Percentages of leaf within residues from Ogle pastures exhibited a similar range (13.1 to 19.8% of residual DM), but these percentages of leaf tissue generally declined across sampling dates and were explained by linear ($P = 0.02$) and quadratic ($P = 0.02$) effects. Over all sampling dates, concentrations of NDF were numerically greater in pasture residue compared with ungrazed forage, and trends over sampling dates were explained by linear ($P \leq 0.02$) and quadratic ($P < 0.01$) effects for both cultivars. Concentrations of CP within residue following grazing declined across sampling dates for both cultivars, exhibiting linear ($P < 0.01$) and quadratic ($P \leq 0.04$) effects of sampling date. Unlike NDF and CP, whole-plant ash content declined in mostly linear trends ($P \leq 0.01$) over sampling dates, and was numerically greater than observed for all corresponding ungrazed forages.

Pasture Evaluations 2012

Agronomic Characteristics. During 2012, the interactions of cultivar and sampling date were not significant ($P > 0.05$) for most response variables; therefore,

only main-effect means are presented and discussed. As observed for 2011, the more rapid maturation rate for Ogle was reflected in the mean growth stages for Ogle and Forage Plus considered across the entire trial (45 vs. 28; mid boot vs. late tillering; $P < 0.01$; Table 5). Growth stages for both cultivars considered collectively increased in a linear ($P < 0.01$) relationship with sampling date. On average, canopy height for Ogle was 19 cm greater than observed for Forage Plus (51 vs. 32 cm; $P < 0.01$), and increased with strong linear ($P < 0.01$) and quadratic ($P < 0.01$) effects of sampling date, but higher-ordered trends were not observed ($P \geq 0.06$). The greater maturity and canopy height observed for Ogle was evident within measurements of forage mass. Mean forage mass for Ogle was 822 kg/ha greater than observed for Forage Plus ($P = 0.01$); however, forage mass was not affected ($P \geq 0.06$) by sampling date. Residual forage mass measured after grazing, as well as apparent pasture utilization, was not affected by oat cultivar ($P \geq 0.46$). However, both response variables changed in erratic patterns across sampling dates, yielding polynomial contrasts that were difficult to relate to any aspect of practical grazing management. Overall, residual forage mass ranged narrowly across dates (219 to 490 kg/ha), as did apparent utilization (77.8 to 90.4%), which was considerably greater than 2011 (41.2 to 68.5%), and likely explained on the basis of less advanced stages of plant growth.

Forage Nutritive Value. Concentrations of NDF (Table 6) did not differ across oat cultivars (overall mean = 43.4%; $P = 0.06$), but increased linearly ($P =$

Figure 2. Concentrations of NDF (A) and CP (B) in leaf and stem tissue obtained from ungrazed fall-oat forage sampled weekly during 2011. Standard errors of the mean for leaf and stem NDF were 0.75 and 0.73%, respectively, whereas the corresponding SEM for CP were 1.17 and 1.31%.

Table 5. Agronomic characteristics for Forage Plus (Kratz Farms, Slinger, WI) and Ogle (Schumitsch Seed Inc., Antigo, WI) oat pastures grazed during October through November 2012 at Marshfield, Wisconsin¹

Item	Growth stage, ² no.	Canopy height, cm	Forage mass, kg/ha	Residual mass, kg/ha	Apparent utilization, ³ %
Cultivar					
Forage Plus	28 ^b	32 ^b	1,856 ^b	301	83.6
Ogle	45 ^a	51 ^a	2,678 ^a	375	85.1
SEM ⁴	0.7	1.3	138.5	65.5	2.66
Sampling date					
October 8	31	33	2,159	—	—
October 15	34	36	1,757	376	79.1
October 22	35	44	2,238	219	89.4
October 29	39	48	2,422	354	84.9
November 5	39	47	2,639	249	90.4
November 12	40	42	2,387	490	77.8
November 19 ⁵	49	54	3,256	257	92.1
SEM ⁴	1.1	1.7	210.7	73.0	2.99
Contrast ⁶			<i>P</i> -value		
Linear	<0.01	<0.01	0.06	0.32	0.88
Quadratic	0.24	<0.01	0.89	0.06	0.01
Cubic	0.56	0.06	0.06	0.81	0.72
Quartic	0.64	0.19	0.55	0.05	0.03

^{a,b}Different superscript letters within a column denote significant differences ($P \leq 0.05$) between oat cultivars.

¹Interactions of oat cultivar and sampling date generally were not significant ($P > 0.05$); therefore, only main effect means are presented.

²Stage of growth was assessed according to a linear description model (Stauss, 1994) and identified as tillering (20–29), stem elongation (30–39), booting (40–49), and emergence of inflorescence (50–59). Because oat is a long-day plant and it is unclear whether viable seed can be produced with fall establishment, no attempt was made to stage plants beyond full emergence of seed head and peduncle (growth stage = 59).

³Calculated weekly as $100\% \times (\text{ungrazed forage mass} - \text{residual forage mass})/\text{ungrazed forage mass}$.

⁴Pooled SEM.

⁵During 2012, pastures seeded with Forage Plus oat were exhausted on this date. Data represent the mean value of 3 Ogle oat pastures and are provided for reference only. Data for this date were not included in the statistical analysis.

⁶Linear, quadratic, cubic, and quartic effects of sampling date on each response variable.

0.01) across sampling dates. From a practical perspective, this response can be characterized as consistent weekly increases through October 22, but little response thereafter. Concentrations of ADL were greater ($P = 0.01$) within Ogle compared with Forage Plus oat, likely reflecting the more advanced growth stages observed for Ogle across most sampling dates. Responses across sampling dates were explained by linear ($P = 0.02$) and quadratic ($P = 0.01$) effects that described increasing ADL through October 22, but little meaningful change thereafter. Whole-plant ash was greater for Forage Plus compared with Ogle (14.3 vs. 9.4%; $P < 0.01$), and multiple polynomial effects were detected ($P \leq 0.04$) for response trends across sampling dates. Practically, the description of these trends can be simplified to a 2.8-percentage-unit decrease in whole-plant ash between October 8 and 15, without any meaningful change thereafter.

Concentrations of CP differed sharply across cultivars ($P < 0.01$), with Forage Plus exhibiting a 9.4-percentage-unit advantage over Ogle (27.7 vs. 18.3%); however, no polynomial contrast evaluating response trends across sampling dates was detected ($P \geq 0.09$).

Conversely, WSC concentrations were greater for Ogle than for Forage Plus (17.9 vs. 10.3%; $P < 0.01$), but testing of sampling dates for polynomial trends yielded only weak linear ($P = 0.05$) and quartic ($P = 0.04$) effects. Concentrations of WSC ranged narrowly across sampling dates (12.7 to 15.7%), with the minimum concentration occurring on October 22. Numerically greater concentrations of WSC ($16.8 \pm 2.41\%$) were observed for Ogle pastures on November 19; this response was likely associated with continuing winter hardening, but could not be evaluated for Forage Plus pastures because forage availability was exhausted within all those pasture replicates. Calculated estimates of energy density also were greater for Ogle compared with Forage Plus (70.8 vs. 67.1%; $P < 0.01$), but TDN estimates across sampling dates remained quite stable, varying only between 68.4 and 70.4%, and yielding no significant polynomial effects ($P \geq 0.09$).

Heifer Intakes and Performance

Intakes of Basal Diet. Generally, dietary treatments and year did not interact; therefore, all data are

Table 6. Whole-plant nutritive value (% of DM) for Forage Plus (Kratz Farms, Slinger, WI) and Ogle (Schumitsch Seed Inc., Antigo, WI) oat pastures grazed during October through November 2012 at Marshfield, Wisconsin¹

Item	NDF	ADL	Ash	CP	WSC ²	TDN
Cultivar						
Forage Plus	42.4	0.82 ^b	14.3 ^a	27.7 ^a	10.3 ^b	67.1 ^b
Ogle	44.2	1.06 ^a	9.4 ^b	18.3 ^b	17.9 ^a	70.8 ^a
SEM ³	0.55	0.047	0.38	0.67	0.60	0.48
Sampling date						
October 8	40.9	0.66	14.0	23.3	15.6	68.5
October 15	42.2	0.88	11.2	23.1	15.7	70.4
October 22	44.7	1.06	11.1	23.4	12.7	69.1
October 29	43.3	1.12	11.8	24.0	13.0	68.4
November 5	44.1	0.96	11.5	22.3	13.9	68.5
November 12	44.4	0.98	11.2	21.9	13.8	68.8
November 19 ⁴	46.5	1.23	8.2	17.7	16.8	70.6
SEM ³	0.82	0.077	0.53	0.65	0.75	0.70
Contrast ⁵			<i>P</i> -value			
Linear	0.01	0.02	0.02	0.09	0.05	0.48
Quadratic	0.16	0.01	0.04	0.10	0.06	0.65
Cubic	0.39	0.48	0.02	0.66	0.80	0.09
Quartic	0.54	0.26	0.31	0.16	0.04	0.28

^{a,b}Different superscript letters within a column denote significant differences ($P \leq 0.05$) between oat cultivars.

¹Interactions of oat cultivar and sampling date generally were not significant ($P > 0.05$); therefore, only main effect means are presented.

²Water-soluble carbohydrates.

³Pooled SEM.

⁴During 2012, pastures seeded with Forage Plus oat were exhausted on this date. Data represent the mean value of 3 Ogle oat pastures and are provided for reference only. Data for this date were not included in the statistical analysis.

⁵Linear, quadratic, cubic, and quartic effects of sampling date on each response variable.

presented and discussed as main effects only. When the entire grazing period was considered, including those days when grazing heifers were confined due to inclement weather, or when available forage was exhausted, the voluntary intake of the basal TMR diet (Table 7) was greater ($P < 0.01$) for confined heifer groups than for grazing groups, and greater for heifers grazing Forage Plus compared with Ogle (334 vs. 305 kg/heifer per year; $P = 0.02$). Similar relationships were observed for voluntary intakes expressed on a daily or percentage-of-BW basis. In addition, voluntary intake of the basal TMR for heifers expressed as a percentage of that consumed by the control groups was greater for heifers grazing Forage Plus pastures compared with Ogle (60.3 vs. 54.6%; $P = 0.01$). Considered across all heifer groups, no difference existed in annual voluntary intake of TMR between 2011 and 2012 (391 vs. 408 kg/heifer per year; $P = 0.41$); however, intakes were greater during 2012 when expressed on a daily (6.8 vs. 8.0 kg/d; $P = 0.01$) and on a percentage-of-BW (1.33 vs. 1.50% of BW; $P = 0.05$) basis. When expressed on a percentage-of-control basis, voluntary intake of the basal TMR was greater for grazing heifers during 2012 than in 2011 (63.0 vs. 51.9%; $P = 0.02$).

If assessments of intake were limited only to days when weather conditions and forage availability permitted grazing, only minor differences existed between Ogle and Forage Plus pastures. Heifers grazing Ogle pastures tended to consume more of the basal TMR annually than heifers assigned to Forage Plus (232 vs. 212 kg/heifer per year; $P = 0.07$), but other measures of intake did not differ between oat cultivars ($P \geq 0.21$). Annual intake of the basal TMR also was greater during 2011 than in 2012 (358 vs. 297 kg/heifer per year; $P = 0.01$); otherwise, effects of year were not observed ($P \geq 0.08$).

Heifer Performance. Total weight gains and ADG for grazing heifer groups tended to be greater ($P \leq 0.06$) than those for control heifers. Averaged across years, advantages for total gain and ADG were about 7 kg/heifer and 0.11 kg/d for grazing heifer groups compared with controls; however, final BCS was similar ($P = 0.60$) between grazing and control groups. Final BCS (3.5 vs. 3.2; $P < 0.01$), final BW (555 vs. 528 kg; $P < 0.01$), and ADG (0.87 vs. 0.75 kg/d; $P = 0.05$) all were greater during 2012 compared with 2011, but total gain did not differ (overall mean = 45 kg; $P = 0.73$) across years. No contrast comparing heifer performance across

Table 7. Intakes and growth performance of dairy heifers grazing Forage Plus (Kratz Farms, Slinger, WI) or Ogle (Schumitsch Seed Inc., Antigo, WI) fall oat for 6 h daily and supplemented with a blended small-grain silage-alfalfa haylage diet at night during 2011 and 2012 at Marshfield, Wisconsin¹

Item	Diet ²			SEM	Contrast ³	Year		
	Control	Forage Plus	Ogle			2011	2012	SEM
Confinement forage intake (all days) ⁴								
Total, kg/heifer per year	560	334	305	8.2	I, II	391	408	7.3
Daily intake, kg/d	10.3	6.2	5.6	0.16	I, II	6.8 ^b	8.0 ^a	0.14
Daily intake, % BW	1.96	1.20	1.09	0.031	I, II	1.33 ^b	1.50 ^a	0.027
Percentage of control ⁵	—	60.3	54.6	1.01	II	51.9 ^b	63.0 ^a	1.01
Confinement forage intake (grazing days only) ⁶								
Total, kg/heifer	539	212	232	7.6	I, ii	358 ^a	297 ^b	6.8
Daily intake, kg/d	10.2	5.2	5.0	0.13	I	6.5	7.1	0.11
Daily intake, % of BW	1.93	1.01	0.97	0.025	I	1.29	1.32	0.022
Percentage of control ⁷	—	50.5	48.8	0.88	NS	48.7	50.6	0.88
Animal performance								
Initial BCS	3.2	3.2	3.2	0.04	NS	3.0 ^b	3.4 ^a	0.04
Final BCS	3.4	3.3	3.3	0.06	NS	3.2 ^b	3.5 ^a	0.05
Initial BW, kg	506	491	493	1.6	I	482 ^b	511 ^a	1.4
Final BW, kg	547	539	538	2.0	I	528 ^b	555 ^a	1.8
Gain, kg	41	48	45	1.7	i	45	44	1.6
ADG, kg/d	0.74	0.88	0.82	0.032	i	0.75 ^b	0.87 ^a	0.029

^{a,b}Different superscript letters within a row denote significant differences ($P \leq 0.05$) between annual means.

¹Data reflect intakes of forage only. ²Treatments consisted of (1) control: heifers maintained in confinement and offered a blended TMR diet (basal diet) composed of small-grain silage and alfalfa haylage for ad libitum intake, (2) Forage Plus: heifers allowed to strip-graze Forage Plus fall oat for 6 h daily (weather permitting) and then supplemented ad libitum with the control diet in the barn, and (3) Ogle, heifers allowed to strip-graze Ogle fall oat for 6 h daily (weather permitting) and then supplemented ad libitum with the control diet in the barn. All heifers, regardless of treatment, received 0.50 and 0.11 kg of ground corn/heifer per day during 2011 and 2012, respectively; similarly, each heifer received 82 g of a commercial mineral mix daily during both years of the trial.

³I and i = control (confined) versus grazing heifer groups; II and ii = Forage Plus versus Ogle grazing heifer groups. Uppercase (I or II) denotes significance at $P \leq 0.05$, whereas lowercase (i or ii) denotes a tendency at $P \leq 0.10$.

⁴Measurements are based on voluntary intake of the basal diet across all days of the study, including those in which weather did not permit grazing. For 2011 and 2012, total trial durations were 58 and 51 d, respectively.

⁵Calculated as daily voluntary intake of the basal diet by grazing heifer groups divided by mean voluntary intake of the basal diet by the control (confined) heifer groups $\times 100\%$. Calculations included all days, regardless of whether grazing occurred or not.

⁶Measurements are based on voluntary intake of the basal diet only on days that the weather and forage availability permitted grazing. For 2011 and 2012, grazing occurred on 52 and 44 d, respectively. During 2011, all grazing heifer groups had sufficient forage available to graze on all 52 d on which weather permitted grazing; for 2012, individual pasture replicates had sufficient forage to graze from 25 to 44 d, depending on oat cultivar and pasture replicate.

⁷Calculated as daily voluntary intake of the basal diet for grazing heifer groups divided by mean voluntary intake of the basal diet by the control (confined) heifer groups $\times 100\%$. Calculations included only days on which grazing occurred.

pasture types (Forage Plus vs. Ogle) was detected ($P \geq 0.14$).

DISCUSSION

Pasture Characteristics

Forage Mass. The 2 yr of this grazing study represented opposite extremes of pasture growth and productivity. Weather conditions during 2011 facilitated rapid germination and growth, which continued throughout the fall. Under these conditions, peak forage mass occurred on October 31 and approached 9 Mg/ha (Table 2) for both cultivars, which illustrates the exceptional production potential of fall-grown oat, particularly if sufficient soil moisture for quick germination and aggressive early growth can be ensured. Plot studies conducted in central Wisconsin have reported wide-

ranging estimates of DM yield that range from 1.3 to 8.1 Mg/ha by late October or early November, depending on weather conditions, oat cultivar, and planting date (Contreras-Govea and Albrecht, 2006; Coblenz and Walgenbach, 2010a; Coblenz et al., 2011). The August 11 planting date was relatively late for this location (Coblenz et al., 2011); normally, this would be expected to suppress yields for all cultivars, and also affect yields of the slower-maturing Forage Plus disproportionately (Coblenz and Walgenbach, 2010a).

Forage mass during 2012 contrasted sharply with that observed the previous year. On a comparable sampling date (October 29) to that for peak forage mass during 2011, forage mass across both cultivars was only 27% of that measured the previous year (2,422 kg/ha; Table 5). Over the entire year, the slow germination response under droughty conditions also affected the slower-maturing Forage Plus cultivar disproportion-

ately relative to Ogle (1,856 vs. 2,678 kg/ha; $P = 0.01$). The limited forage mass observed during 2012 illustrates clearly the importance of rapid germination and aggressive early growth within the fall-oat production system, and suggests strongly that use of irrigation systems or lagoon water applied via tanker or other means should be considered as management options to improve forage production under droughty conditions occurring in early August.

Forage Nutritive Value. Generally, whole-plant assessments of CP from oat forages during the fall were greater than required to meet the nutritional needs of dairy heifers within this weight range (NRC, 2001). During 2011, estimates of TDN for both cultivars of fall-grown oat changed in largely quadratic patterns over time (Table 3). These responses are somewhat atypical for forage plants, but can be summarized as a pattern of declining TDN throughout early sampling dates that coincided generally with stem elongation, increased canopy height, and greater NDF. Decreasing estimates of TDN continued through the October 17 sampling date, before increasing throughout the remainder of the year. It is important to note that concentrations of ADL remained very low ($\leq 2.70\%$) throughout this time period, representing 1.8 to 4.5% of NDF, which is far less than the approximate 10% of NDF reported by NRC (2001) for headed oat hays and silages. Limited lignification partly can be explained on the basis of temperature; lignin formation and temperature are positively related for many types of forage (Ford et al., 1979; Van Soest, 1982), and extensive estimates of fiber digestibility have been reported previously for fall-grown oat (Coblentz and Walgenbach, 2010b; Coblentz et al., 2012). Theoretically, these factors act to limit normal decreases in TDN that are associated with increased canopy height, advancing growth stage, and greater NDF. In practice, this assessment seems valid; estimates of TDN declined by only 4.6 percentage units or less between September 26 and October 17. From October 17 through the end of the grazing season, TDN increased for both cultivars, largely due to winter hardening. Concentrations of WSC increased by 3.9- and 4.0-fold during this time interval for the Ogle and Forage Plus cultivars, respectively, and concomitantly diluted concentrations of NDF within these forages. In part, this was possible because plant maturation occurred very slowly for Forage Plus throughout the trial and remained within the heading stage of growth for Ogle on all sampling dates after October 17 (Table 2). The final (November 21) TDN estimate for Forage Plus (69.1%) was comparable in energy to normal corn silage (68.8%; NRC, 2001).

In contrast, nutritive value changed only marginally across sampling dates during 2012 (Table 6). Mean

estimates of TDN ranged narrowly between 68.4 and 70.4%, which again is comparable to normal corn silage (NRC, 2001). Across all dates, Ogle was a more energy-dense forage (70.8 vs. 67.1% TDN; $P < 0.01$). This response is probably associated with the more rapid maturation rate and greater canopy height observed across all dates for Ogle, which acted to dilute concentrations of ash relative to Forage Plus (9.4 vs. 14.3%; $P < 0.01$). Furthermore, Ogle exhibited greater mean concentrations of WSC than Forage Plus (17.9 vs. 10.3%; $P < 0.01$); growth stage is known to influence winter-hardening responses in plants (Eastin and Sullivan, 1984), and fall-grown oat plants at the late-stem elongation or boot stages of growth have demonstrated exceptional capacity to accumulate WSC in response to cold temperatures compared with less mature plants (Coblentz et al., 2012).

Apparent Utilization of Oat Forages. Although not compared statistically, apparent utilization of fall-grown oat was much greater during 2012 compared with 2011; when averaged across all sampling dates, utilization estimates were 84.4 and 53.2%, respectively. It is likely that these responses were related directly to oat forages that were less mature, exhibited shorter (<50%) canopy heights, and less NDF during 2012 than during 2011. Specifically, concentrations of NDF on November 12, 2012 (44.4%), were comparable with those of Forage Plus on September 26, 2011, but numerically less than those exhibited by both cultivars on all other sampling dates during 2011. During this grazing trial, the daily allocation of standing forage was set arbitrarily at 8.5 to 9.0 kg of DM/heifer per day, and was not altered during the experiment. Based on the DMI prediction equations of Hoffman et al. (2008), Holstein heifers weighing 500 kg and consuming a diet consisting of 60% NDF would be expected to consume 9.2 kg of DM/d; therefore, this daily pasture allocation represents >90% of the projected daily DMI for these heifers. Our goal for this trial was to maximize the consumption of oat pasture during a single 6-h grazing bout each day, and it was unclear at the outset of the trial how selectively heifers might graze, especially during November when oat plants were elongated and had been exposed to freezing temperatures numerous times. The arbitrarily assigned daily pasture allocation allowed for some selectivity, which subsequently occurred based on preferential grazing of leaf tissue (Table 4). Dairy producers have the option of adjusting the daily allocation of forage to regulate the percentage of forage refused, but any decision to reduce the daily forage allocation in an effort to improve apparent utilization of pasture (especially less-desirable stems) also should be evaluated against the potential for depressing animal performance.

Heifer Performance

During both years of the grazing trial, dairy heifers with no previous grazing experience adapted quickly to daily trips to the oat pastures, as well as acceptance of the lead electric wire concept for managing grazing of stockpiled forage. Generally, there was limited evidence of reduced pasture utilization on early sampling dates each year (Tables 2 and 5), which suggests that heifers were reasonably adapted to grazing procedures from the initiation of data collection. It is unclear why utilization of Ogle pastures was poorer (33.4%) on the initial (October 3) evaluation date during 2011, but this did not occur for Forage Plus on that date, or for either cultivar on subsequent dates, or during 2012. Little evidence existed suggesting that heifer performance was affected by oat cultivar, provided forage inventories were not exhausted. Considered over all days of the trial, intakes of the basal diet were greater for heifers grazing Forage Plus pastures; however, these differences were not observed when measurements were confined only to days when heifers grazed pastures. Most of these intake differences across oat cultivars were related directly to premature exhaustion of forage within Forage Plus pastures during 2012.

Under the grazing management described for this experiment, which included a single grazing opportunity lasting approximately 6 h daily, heifers consumed the basal TMR at about half the rate of the control groups maintained in confinement. Although ADG exhibited by grazing heifer groups tended to be greater than control groups (0.85 vs. 0.74 kg/d; $P = 0.05$), these data should be interpreted with caution, given the short (~60 d), focused grazing window that has important relevance for dairy producers wishing to extend the grazing season. The ADG for all heifer groups was within reasonable proximity to typical ADG targets for heifers of this size (Hoffman, 1997), and weight gains during this climatic transition into winter are known to be erratic as heifers adjust to changing ambient temperatures (P. C. Hoffman, University of Wisconsin, Madison, personal communication). It also should be noted that the most desirable outcome from a management perspective was for grazing heifers to meet, and not necessarily exceed, industry standards for ADG. Numerous studies have described negative effects of excessive prepubertal or postpubertal ADG on mammary development (Sejrsen et al., 1982) and first-lactation performance (Hoffman et al., 1996; Van Amburgh et al., 1998; Lammers et al., 1999; Radcliff et al., 2000).

CONCLUSIONS

Fall-grown oat should be managed as stockpiled forage for deferred (later) grazing. It has little regrowth poten-

tial and will eventually winterkill in central Wisconsin; therefore, there is no need to avoid overgrazing, manage plant growth reserves, or develop rotational grazing strategies. Good utilization of fall-oat forage can be accomplished by efficient, one-time removal of standing forage facilitated by a single lead wire, advanced daily to prevent waste and to allocate forage based on producer management goals and requirements. Generally, concentrations of CP and TDN for fall-oat pasture exceeded requirements for gravid dairy heifers within this weight range. Assuming that the blended forage TMR used in this study was worth \$0.25/kg of DM, a 6-h daily grazing bout on fall-oat pastures saved about \$1.25/heifer per day in stored forage feed costs, which would extrapolate to \$75/heifer over 60 grazing days without any concomitant evidence of reduced animal performance. Dairy producers will need to monitor the quality of fall-grown oat coupled with other harvested forages and (or) supplements to meet their desired animal performance goals while minimizing input costs.

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