

# Evaluation of Dry Matter Loss, Nutritive Value, and In Situ Dry Matter Disappearance for Wilting Orchardgrass Forages Damaged by Simulated Rainfall

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## Story in Brief

'Benchmark' orchardgrass (*Dactylis glomerata* L.) was wilted to moisture concentrations of 67.4% (WET), 15.3% (IDEAL), and 4.1% (DRY) and subjected to 0, 0.5, 1.0, 1.5, 2.0, 2.5, or 3.0 in of simulated rainfall with a custom-built rainfall simulator. When simulated rainfall was applied to IDEAL orchardgrass, dry matter (DM) loss, total N, and all fiber components except hemicellulose increased with rainfall amount, exhibiting a significant ( $P \leq 0.048$ ) polynomial effect or multiple effects in each case. Excluding the 0-in control, substantial DM loss ( $\geq 5.0\%$ ) was observed at all rainfall increments, and a maximum of 8.8% was reached when 3.0 in of simulated rainfall was applied. For DRY orchardgrass forage, DM losses increased to a maximum of 10.7% in linear ( $P < 0.0001$ ), quadratic ( $P = 0.001$ ), and cubic ( $P = 0.033$ ) patterns with rainfall amount. For WET orchardgrass forage, DM loss increased linearly ( $P = 0.006$ ) with rainfall amount, but the maximum DM lost was only 1.9% for this wetter forage. Simulated rainfall affected ( $P \leq 0.044$ ) concentrations of N, NDF, ADF, hemicellulose, cellulose, lignin, and 48-h in situ digestibility for this wet forage, but polynomial effects were varied and the range of concentrations across rainfall amounts was generally quite narrow. Over the entire study, DM loss and deleterious changes in nutritive value were increased with simulated rainfall amount. Although not compared statistically, orchardgrass forages that were wilted substantially prior to applying simulated rainfall appeared to be more sensitive to DM loss and negative changes in nutritive value than were forages that were subjected to rainfall soon after mowing was completed.

## Introduction

The harvest, storage, and cash sale of hay crops are important components of the cattle (*Bos taurus*; *B. indicus*) and equine (*Equus caballus*) industries, and hay packaged in small rectangular bales frequently receives a market price of \$150/ton or more. Previously, most of the studies designed to assess the effects of rainfall on wilting forage crops have focused on alfalfa (*Medicago sativa* L.) and other legume hay crops, primarily because of their high potential feed and cash value. However, relatively few reports are available that describe the effects of graded levels of simulated or natural rainfall on wilting cool- and warm-season grasses. In addition, rainfall treatments generally have been limited to irregular and unpredictable natural events, or rather simplistic artificial application techniques. Recently, some scientists have adapted various types of rainfall simulation systems to address these research needs. These systems offer unique opportunities to apply graded levels of simulated rainfall to wilting forages, and therefore, more precisely identify variables that may affect the nutritive value of the damaged hay crop. The objectives of this study were to investigate the effects of simulated rainfall on losses of DM, concentrations of fibrous components and N, and ruminal DM degradability for orchardgrass forages wilted to 67.4, 15.3, or 4.1% moisture.

## Experimental Procedures

*Field and Rainfall Simulation Procedures.* An established stand of 'Benchmark' orchardgrass, located at the University of Arkansas Forage Research Area in Fayetteville, Ark., served as the source of orchardgrass forage for the rainfall simulation studies. On June 18, 2001, orchardgrass forage was harvested to a 3.0-in stubble height with a New Holland Model 1411 disc mower-conditioner (Ford New

Holland, New Holland, Pa.) equipped with rubber-covered metal conditioning rollers. This was the second harvest for 2001; therefore, the orchardgrass was primarily vegetative regrowth, but visual evaluation indicated that approximately 5% of all orchardgrass tillers were reproductive. A first harvest was taken on May 9, 2001 when forage was removed and ensiled as round-bale silage.

Immediately after mowing, three 2.7-ft<sup>2</sup> frames were placed directly on the hay swaths at random locations throughout the field. The mowed forage within each frame was clipped with handshears in order to estimate the density of the swath. The freshly swathed orchardgrass forage (67.4% moisture; WET) was then collected from throughout the experimental area, placed onto a tarp, and moved under a barn to minimize desiccation of plant tissues. Once under the barn, orchardgrass forage was weighed into 42 galvanized wire baskets (5.9 x 12.2 x 29.9 in; mesh size = 0.5 in), and baskets were filled with forage ( $0.1 \pm 0.02$  lb DM/ft<sup>2</sup>) so that the forage density within the wire baskets was comparable to that calculated from frames clipped from swaths in the field. Thirty-six baskets were placed on a raised (3.5-in) wire platform under the rainfall simulator (4.9 x 20-ft coverage area). Baskets were placed on an elevated platform to eliminate contact with the soil surface, avoid puddling from runoff water, and to ensure the free movement of water through plant tissues. Baskets were separated into three experimental blocks designated on the basis of location underneath the simulator. The remaining six baskets served as controls, and did not receive simulated rainfall (0 in). Simulated rainfall was applied via a rainfall simulation system (Miller, 1987) to experimental forages at a constant rate of 3.0 in/h. Therefore, in order to apply treatments that represented graded amounts of rainfall, two baskets from each block were removed at random from under the simulator at 10-min increments. This resulted in six treatments that received either 0.5, 1.0, 1.5, 2.0, 2.5, or 3.0 in of simulated rainfall. After the baskets were removed from under the simulator, each basket was allowed to drip dry for

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approximately 0.5 h and the forage contents were then transferred to a paper bag and dried to a constant weight under forced air at 131°F. There was no evidence of significant leaf shatter or other loss of forage from the baskets during the application of simulated rainfall, or during handling. After completing this experimental process for WET orchardgrass forage, the entire experimental process was repeated when the forage was wilted to 15.3 and 4.1% moisture (IDEAL and DRY, respectively). Simulated rainfall was applied to all three forages (WET, IDEAL, and DRY) within one 24-h time interval.

*Measurement of DM Losses.* Loss of forage DM from wire-mesh baskets was calculated using concentrations of NDF as an internal marker. Calculations were made based on the equation of Fannesbeck et al. (1986) that was modified to include NDF as the internal marker:

$$\text{DM loss (\%)} = [1 - (\text{NDF}_I/\text{NDF}_R)] \times 100\%,$$

where  $\text{NDF}_I$  = concentration of NDF (DM basis) before the rainfall event, and  $\text{NDF}_R$  = concentration of NDF (DM basis) after the rainfall event.

*Chemical Analysis of Forage.* Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) to pass through either a 1-mm or 2-mm screen. Subsamples ground through a 1-mm screen were analyzed subsequently for NDF, ADF, hemicellulose, cellulose, lignin, and total N. Analyses for NDF, ADF, hemicellulose, cellulose, and lignin were conducted sequentially using the batch procedures outlined by ANKOM Technology Corporation (Fairport, N.Y.). Sodium sulfite and heat-stable alpha-amylase were not included in the NDF solution. Concentrations of N were quantified by a rapid combustion procedure (LECO Model FP-428; LECO, St. Joseph, Mich.). Two ruminally-cannulated crossbred steers (mean BW = 591 ± 46.8 lb) were used to determine in-situ ruminal DM degradability (DMD) of rain-damaged orchardgrass forages (previously ground through a 2-mm screen) during a 48-h ruminal incubation. The University of Arkansas Institutional Animal Care and Use Committee approved surgical procedures for cannulations, and the subsequent care of the fistulated steers.

*Statistical Analysis.* Each of the three test forages (WET, IDEAL, or DRY) had to be wilted different lengths of time prior to applying simulated rainfall; therefore, simulated rainfall could not be applied to each simultaneously. For this reason, an independent analysis of variance was conducted for each combination of forage and initial moisture concentration. Within each analysis of variance, data were analyzed as a randomized complete block design with seven levels of rainfall (0, 0.5, 1.0, 1.5, 2.0, 2.5, or 3.0 in) as treatments. Single-degree-of-freedom orthogonal contrasts were used to test for linear, quadratic, cubic, and quartic effects due to rainfall amount. Statistical significance was declared at  $P < 0.05$ , unless otherwise noted.

## Results and Discussion

*WET Forage.* Dry matter losses increased linearly ( $P = 0.006$ ; Table 1) with rainfall amount; however, the magnitude of these losses was minimal and the overall range was quite narrow (0 to 1.9%), indicating that WET forage was relatively resistant to DM loss via leaching and continued respiration. This relative resistance was reflected in concentrations of fiber components. Although significant ( $P \leq 0.044$ ), and sometimes multiple, polynomial effects of rainfall amount were observed for each fiber component, concentrations changed only minimally, and remained within a very narrow range.

For example, the concentration of NDF in forage receiving 3.0 in of simulated rainfall increased by only 0.9 percentage units when compared to forage receiving no simulated rainfall. Although significant effects ( $P \leq 0.011$ ) were observed for both total N and DMD, the magnitude of each response to simulated rainfall also was limited. Total N increased linearly ( $P = 0.003$ ) with rainfall amount, but much (0.20 percentage units) of the total increase was observed between the 2.5- and 3.0-in increments of simulated rainfall. For DMD, significant cubic ( $P = 0.011$ ) and quartic ( $P = 0.010$ ) effects were observed, but these may largely be explained by the depressed DMD at 0.5 in of applied rainfall that was not observed at other application levels.

*IDEAL Forage.* Dry matter loss, total N, and all fiber components except hemicellulose increased with rainfall amount, exhibiting significant ( $P \leq 0.048$ ) polynomial effects in each case; however, there was no clear or consistent pattern of effects across these response variables (Table 2). Unlike observations made for the WET orchardgrass, there was substantial DM loss ( $\geq 5.0\%$ ) at all rainfall amounts, and a maximum of 8.8% was reached when 3.0 in of simulated rainfall was applied. These losses increased with linear ( $P < 0.0001$ ), quadratic ( $P < 0.0001$ ), cubic ( $P = 0.048$ ), and quartic ( $P = 0.013$ ) effects of simulated rainfall.

Concentrations of total N increased quadratically ( $P = 0.042$ ); however, this effect was created largely by an increase of 0.21 percentage units in response to the first 0.5 in of simulated rainfall, but there was little evidence of additional response thereafter. Concentrations of ADF, cellulose, and lignin each increased with cubic ( $P \leq 0.005$ ) and linear ( $P < 0.0001$ ) effects, reaching levels that were 9.9, 6.2, and 3.74 percentage units higher, respectively, than those observed for forages receiving no simulated rainfall. Similarly, NDF increased by 6.3 percentage units over the 3.0-in range of applied rainfall; however, this response was explained by quartic ( $P = 0.019$ ), quadratic ( $P < 0.0001$ ) and linear ( $P < 0.0001$ ) effects. Unlike the other fiber components, concentrations of hemicellulose declined over simulated rainfall levels with all polynomial terms contributing ( $P \leq 0.016$ ) to the response. In-situ DMD declined with rainfall amount, exhibiting quartic ( $P = 0.045$ ), quadratic ( $P = 0.001$ ), and linear ( $P = 0.010$ ) effects, but these effects were clearly influenced by the poor DMD (68.5%) at the 1.5-in rainfall application rate. Excepting this aberrant value, concentrations of DMD were essentially minimized by the 1.0-in application rate, and somewhat variable, but generally static, responses were observed thereafter.

*DRY Forage.* Orchardgrass forage that was wilted to excessively dry concentrations of moisture (4.1%) lost a maximum of 10.7% of DM (Table 3), which was numerically higher by 1.9 percentage units than the maximum loss observed for IDEAL forage. As observed for IDEAL forage, a large loss (5.8%) was associated with the first 0.5-in increment of applied rainfall, which was greater than losses observed over the subsequent 2.5 in of applied water. Losses of DM were explained by linear ( $P < 0.0001$ ), quadratic ( $P = 0.001$ ), and cubic ( $P = 0.033$ ) terms.

Unlike WET and IDEAL forages, concentrations of N in DRY forage were not affected ( $P \geq 0.174$ ) by simulated rainfall. Concentrations of all fiber components increased with simulated rainfall, but there was no consistent pattern with respect to polynomial effects; NDF and hemicellulose exhibited cubic ( $P \leq 0.048$ ), quadratic ( $P \leq 0.003$ ), and linear ( $P < 0.0001$ ) effects, while ADF and cellulose increased in a linear ( $P < 0.0001$ ) manner. Concentrations of lignin changed in a cubic ( $P = 0.037$ ) pattern with rainfall amount, but these results were variable, and concentrations after 2.0, 2.5, and 3.0 in of rainfall were only marginally different than observed for forage receiving no rain. Concentrations of DMD declined in a linear ( $P = 0.0003$ ) pattern with simulated rainfall at a rate of about 1.3

percentage units per in of applied rainfall.

*Comparing Across Forages.* When the results of these orchardgrass studies are considered together, several major trends become obvious. One trend is the positive relationship between DM loss and rainfall amount. Losses of DM for WET, IDEAL, and DRY orchardgrass forages all increased with rainfall, exhibiting significant ( $P \leq 0.048$ ) polynomial or multiple polynomial effects, but these effects were not necessarily consistent over the three orchardgrass forages. Although not compared statistically, it also is clear that IDEAL and DRY orchardgrass were far more susceptible to DM loss than WET forage that was damaged soon after mowing. For WET orchardgrass forage, DM losses were minimal ( $\leq 1.9\%$ ) at all rainfall application amounts, while for IDEAL and DRY orchardgrass, losses ranged from 5.0 to 10.7% for any simulated rainfall application, except for the 0-in control. Generally, these trends also were evident with respect to characteristics of forage quality; concentrations of N and most fiber components increased with rainfall amount, while DM digestibility decreased concomitantly. Overall, changes in forage quality appeared to be more substantial in IDEAL and DRY forages than in forage that was still well hydrated at the time simulated rainfall was applied.

## Implications

For the orchardgrass forages in this study, DM loss and negative changes in nutritive value were increased with rainfall amount. These responses were quite pronounced in forages that were dry enough to bale, but the magnitude of response was greatly reduced when rainfall simulation was applied immediately after the forage was mowed.

## Literature Cited

Fonnesbeck, P. V., et al. 1986. Anim. Feed Sci. Technol. 16:7.  
Miller, W.P. 1987. Soil Sci. Soc. Am. J. 51:832.

**Table 1. Effects of rainfall amount on DM loss, and concentrations of N, fiber components, and ruminal DM degradability for orchardgrass forage that was wilted to 67.4% moisture (WET) before simulated rainfall was applied.**

Treatment	DM Loss <sup>1</sup>	N	NDF <sup>2,3</sup>	ADF	Hemicellulose	Cellulose	Lignin	DMD
Rainfall, in	%							
0	0	2.11	63.6	35.5	28.1	32.0	3.36	76.2
0.5	0.6	2.15	64	36.5	27.5	32.8	3.04	71.4
1.0	1.2	2.27	64.4	37.0	27.4	33.2	3.24	74.6
1.5	1.2	2.29	64.4	37.5	26.9	33.0	3.87	74.2
2.0	1.9	2.22	64.9	36.6	28.3	31.9	4.03	73.8
2.5	1.6	2.23	64.7	35.0	29.7	31.8	2.70	74.7
3.0	1.4	2.43	64.5	34.2	30.3	28.5	2.71	74.3
SEM <sup>4</sup>	0.46	0.062	0.3	0.29	0.31	1.04	0.189	0.65
Contrasts	P > F							
Linear	0.006	0.003	0.006	<0.0001	<0.0001	0.016	NS	NS
Quadratic	NS <sup>5</sup>	NS	NS	<0.0001	<0.0001	0.016	0.001	NS
Cubic	NS	NS	NS	NS	NS	NS	0.025	0.011
Quartic	NS	NS	NS	0.044	0.044	NS	0.001	0.01

<sup>1</sup> Dry matter loss determined using NDF as an internal marker.

<sup>2</sup> Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; and DMD, 48-h ruminal in-situ disappearance.

<sup>3</sup> Fiber components determined sequentially.

<sup>4</sup> Standard error of the main effect mean.

<sup>5</sup> Nonsignificant ( $P > 0.05$ ).

**Table 2. Effects of rainfall amount on DM loss, and concentrations of N, fiber components, and ruminal DM degradability for orchardgrass forage that was wilted to 15.3% moisture (IDEAL) before simulated rainfall was applied.**

Treatment	DM Loss <sup>1</sup>	N	NDF <sup>2,3</sup>	ADF	Hemicellulose	Cellulose	Lignin	DMD
Rainfall, in	%							
0	0	2.18	65.0	34.7	30.2	31.2	2.85	76.9
0.5	5.7	2.39	68.9	37.4	31.5	32.5	4.31	74.7
1.0	5.0	2.32	68.4	39.3	29.1	34.0	4.62	72.2
1.5	7.3	2.32	70.1	39.9	30.2	34.5	4.55	68.5
2.0	8.3	2.40	70.9	40.3	30.6	34.1	5.39	72.0
2.5	8.6	2.22	71.2	42.1	29.1	35.9	5.43	73.0
3.0	8.8	2.31	71.3	44.6	26.6	37.4	6.59	72.4
SEM <sup>4</sup>	0.52	0.050	0.38	0.46	0.39	0.36	0.177	1.16
<b>Contrasts</b>	<b>P &gt; F</b>							
Linear	< 0.0001	NS <sup>5</sup>	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.01
Quadratic	< 0.0001	0.042	< 0.0001	NS	0.0002	NS	NS	0.001
Cubic	0.048	NS	NS	0.001	0.01	0.005	0.0002	NS
Quartic	0.013	NS	0.019	NS	0.016	NS	NS	0.045

<sup>1</sup> Dry matter loss determined using NDF as an internal marker.

<sup>2</sup> Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; and DMD, 48-h ruminal in-situ disappearance.

<sup>3</sup> Fiber components determined sequentially.

<sup>4</sup> Standard error of the main effect mean.

<sup>5</sup> Nonsignificant (P > 0.05).

**Table 3. Effects of rainfall amount on DM loss, and concentrations of N, fiber components, and ruminal DM degradability for orchardgrass forage that was wilted to 4.1% moisture (DRY) before simulated rainfall was applied.**

Treatment	DM Loss <sup>1</sup>	N	NDF <sup>2,3</sup>	ADF	Hemicellulose	Cellulose	Lignin	DMD
Rainfall, in	%							
0	0	2.21	65.2	34.0	31.2	29.7	3.91	76.8
0.5	5.8	2.18	69.3	35.3	34.0	29.1	6.20	75.7
1.0	7.6	2.15	70.6	36.5	34.1	31.1	4.87	73.6
1.5	8.4	2.30	71.2	36.5	34.7	30.9	5.91	74.1
2.0	9.1	2.26	71.7	37.5	34.2	33.3	4.09	73.8
2.5	10.1	2.22	72.6	37.8	34.7	33.6	3.87	73.6
3.0	10.7	2.29	73.0	38.3	34.8	33.5	4.28	73.0
SEM <sup>4</sup>	0.9	0.060	0.68	0.39	0.43	0.72	0.647	0.72
<b>Contrasts</b>	<b>P &gt; F</b>							
Linear	<0.0001	NS	<0.0001	<0.0001	<0.0001	<0.0001	NS	0.0003
Quadratic	0.001	NS	0.003	NS	0.001	NS	NS	NS
Cubic	0.033	NS	0.048	NS	0.016	NS	0.037	NS
Quartic	NS <sup>5</sup>	NS	NS	NS	NS	NS	NS	NS

<sup>1</sup> Dry matter loss determined using NDF as an internal marker.

<sup>2</sup> Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; and DMD, 48-h ruminal in-situ disappearance.

<sup>3</sup> Fiber components determined sequentially.

<sup>4</sup> Standard error of the main effect mean.

<sup>5</sup> Nonsignificant (P > 0.05).