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Rainfall Effects on Wilting Forages

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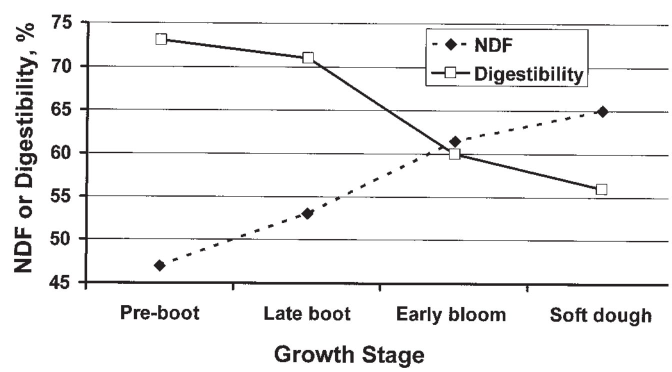
Introduction

One of the most common problems faced by hay producers is how to manage hay production schedules around unfavorable weather. This problem is particularly frustrating throughout the spring and early summer when the probability of rainfall events is high. Inevitably, some wilting forage crops are damaged by unexpected rainfall events each year. Producers often wonder how much their hay crops are damaged by rain and what impact this may have on animal performance. While it is impossible to control the weather, a summary of factors affecting the relative damage caused by unexpected rainfall events should allow hay producers to better evaluate risk and make more informed management decisions.

Effects of Maturity on Forage Quality

More than any other factor, the maturity level of the forage at the time of harvest determines the quality of the hay. Generally, the ratio of leaf-to-stem tissues declines as forages mature. This results in greater concentrations of fiber components, such as neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin but lower concentrations of crude protein (CP), digestible dry matter and energy (TDN). Figure 1 illustrates the effect of growth stage on the concentration of NDF for tall fescue forage. Between the late-boot and soft-dough stages, NDF increased by about 18 percentage units, from 47% to 65%. The time interval associated with this change is relatively short, spanning only a couple of weeks. This concept is important for three reasons. First, Figure 1 indicates that as the concentration of NDF increases, the digestibility of these same tall fescue forages decreases substantially. Between the late-boot and soft-dough stages of growth, digestibility fell by about 17 percentage units, from 73% to 56%. Secondly, a negative relationship exists between the concentration of NDF in the forage and voluntary intake by livestock. Specifically, higher concentrations of NDF are associated with lower intakes in livestock-consuming, forage-based diets. This is especially important when the livestock class consuming the forage has high nutrient demands,

FIGURE 1. Digestibility and NDF concentration (%) for KY-31 tall fescue at various maturities.[a]



[a] Source: C.S. Hoveland and N.S. Hill, University of Georgia.

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Visit our web site at: http://www.uaex.edu such as those of dairy or stocker cattle. **Finally, and most importantly, these concepts are important because they illustrate that there is always a cost associated with delaying harvest because of potential rainfall events, and these costs result in a forage of lower nutritional value that will not be consumed as readily by livestock.**

Effects of Rainfall on Dry Matter Loss and Forage Quality

Rain will leach soluble nutrients (primarily sugars) from hay, resulting in dry matter (DM) loss, increased fiber content and decreased energy in the forage. Leaching losses are a function of forage species, DM content of the forage at the time rainfall occurs, sugar content of the forage, and the amount, intensity or duration of the rainfall event. Plant sugars are assumed to be 100% digestible; therefore, leaching causes the loss of the most digestible components of the forage. Rain can also reactivate respiration by plant enzyme systems and other microorganisms associated with the forage plants. This causes additional plant sugars to be consumed, resulting in more DM loss and additional reductions in the nutritional value of the forage. Significant losses of DM also can occur directly as a result of leaf shatter, especially if the hay crop is a legume. In addition, any rainfall during the wilting process may lead to additional tedding and raking operations that result in more leaf shatter before the forage is dry enough to bale.

DM Losses for Legumes

Rainfall simulation techniques have often been used to evaluate the effects of rainfall on wilting forage crops. Dry matter losses in response to various rain and crop factors for wilting alfalfa are summarized in Tables 1 and 2. In Table 1, 0.7 inches of simulated rainfall were applied to alfalfa that was swathed into light, medium, heavy and very heavy rows. Rainfall was applied at a rate of 0.7 inches per hour, but in some treatments the water was turned off for portions of each hour such that

TABLE 1. Effects of swath density and duration of rainfall on losses of leaves and DM from field-cured alfalfa hay.[a]

Swath Density	Crop Moisture	Rainfall Amount	Rainfall Duration	Leaf Loss	Total DM Losses
	%	inches	hours	% of DM	% of DM
Light	40	0	0	0.7	3.5
		0.7	1.0	0.9	8.3
		0.7	3.5	1.1	11.7
		0.7	7.0	0.9	11.3
Medium	40	0	0	0.8	3.9
		0.7	1.0	1.0	9.0
		0.7	3.5	0.9	10.2
		0.7	7.0	0.6	11.0
Heavy	40	0	0	0.5	6.1
		0.7	1.0	0.3	5.5
		0.7	3.5	0.5	7.8
		0.7	7.0	0.4	12.1
Very heavy	40	0	0	0.4	4.0
		0.7	1.0	0.5	7.7
		0.7	3.5	0.4	11.2
		0.7	7.0	0.4	13.0

[a]Source: Rotz et al. (1991); Transactions of the ASAE, 34:1583-1591.

TABLE 2. Effects of crop moisture content, swath density and amount of rainfall on losses of leaves and DM from field-cured alfalfa hay. Simulated rainfall was applied at a rate of 0.7 inches per hour.[a]

Crop Moisture	Swath Density	Rainfall Amount	Rainfall Duration	Leaf Loss	Total DM Losses
%		inches	hours	% of DM	% of DM
65	Light	0	0	0.9	3.9
		0.7	1.0	1.7	6.1
		2.0	2.9	1.3	9.2
	Heavy	0	0	0.7	4.3
		0.7	1.0	0.6	6.0
		2.0	2.9	0.5	6.5
40	Light	0	0	1.0	3.6
		0.7	1.0	1.4	3.5
		2.0	2.9	1.2	6.2
	Heavy	0	0	0.7	4.9
		0.7	1.0	1.1	7.2
		2.0	2.9	0.9	10.1
25	Light	0	0	1.5	3.0
		0.7	1.0	1.5	6.0
		2.0	2.9	1.1	6.2
	Heavy	0	0	0.9	3.9
		0.7	1.0	0.8	5.3
		2.0	2.9	1.1	10.6

[a]Source: Rotz et al. (1991); Transactions of the ASAE, 34:1583-1591.

the entire 0.7-inch allotment of rainfall was applied over either 1.0, 3.5 or 7.0 hours. Regardless of swath density, DM losses were greatest when the 0.7-inch allotment of simulated rainfall was applied over a 3.5- or 7.0-hour period. This may occur because wilting alfalfa retains more water when the rainfall is less intense, which should facilitate increased leaching of soluble sugars and more total DM loss.

Table 2 illustrates the effects of simulated rainfall (0, 0.7 or 2.0 inches) that was applied to alfalfa in light or heavy swath densities that had been wilted to 65%, 40% or 25% moisture prior to the simulated rainfall event. Regardless of swath density and the moisture content of the forage at the time the rainfall occurred, DM losses increased with the amount of rainfall. Within the conditions outlined in these summaries, DM losses reached a maximum of about 13% of total plant DM and occurred at an approximate rate of 2.5% of total plant DM per inch of rainfall. When total rainfall was limited to 0.7 inches, but applied over various intervals of time, the rate of DM loss was about 1.1% of total plant DM per hour of rain duration.

Changes in Nutritive Value for Legumes

Table 3 summarizes the effects of a 1-inch rainfall event after a 48-hour wilting period, a 1-inch rainfall event after both 24 and 48 hours of wilting, or no rain on the nutritive value of alfalfa, red clover and bird's-foot trefoil forage. Rainfall events increased concentrations of NDF, ADF and lignin and decreased concentrations of total nonstructural carbohydrates (sugars and starches).

Concentrations of CP were increased by rainfall (Table 3) indicating that nitrogen compounds were less susceptible to leaching than other plant DM. However, some caution is advised in interpreting and using these results. Unlike grasses, there have been numerous attempts to quantify the damage that occurs to legumes (primarily alfalfa) as a result of rain damage. Other reports may indicate much larger losses of DM and/or reductions in nutritive value than those described in Table 3. Much of this discrepancy is created by shattered leaves and whether additional tedding and raking operations are included in the experiment. Table 4 summarizes a similar study with alfalfa harvested at two maturities in which a 1.6-inch rainfall event was applied to alfalfa that was not yet dry or 2.4 inches of rain were applied when the alfalfa was dry. Shattered plant material was excluded from the analyses of nutritive value. Increases in concentrations of fiber components and reductions in total nonstructural carbohydrates and digestibility were considerably greater than observed in Table 3. Digestibility was depressed by 23.4 and 23.1 percentage units for late-bud and first-flower alfalfa, respectively, when rainfall occurred when the wilting forage was dry. Concentrations of CP also were depressed after rainfall events, primarily because of excessive leaf shatter. Shattered leaves have much higher concentrations of

TABLE 3. Effects of rainfall and forage type on nutritive characteristics of three legumes. Analysis includes shattered leaf fragments.[a]

Treatment	% Leaf	CP	NDF	ADF	Lignin	TNC[b]	Digestibility
	% of DM						
Alfalfa							
Control	56.8	15.5	32.3	25.9	5.3	12.2	71.5
Wet 48 h[c]	53.5	18.7	34.1	27.4	5.5	10.7	71.0
Wet 24 and 48 h[d]	45.6	18.2	38.4	29.9	6.0	8.0	69.2
Red Clover							
Control		14.6	29.1	21.6	3.2	15.7	75.8
Wet 48 h		16.9	32.7	24.1	4.0	12.7	72.6
Wet 24 and 48 h		17.5	39.9	28.9	4.8	5.2	67.0
Bird's-foot Trefoil							
Control	52.9	13.7	31.0	24.6	5.9	15.2	71.3
Wet 48 h	48.1	13.9	36.0	29.6	7.1	13.4	70.2
Wet 24 and 48 h	47.1	15.2	40.8	32.1	7.8	9.6	66.4

[a]Source: Collins (1982); Agron. J. 74:1041-1044.
[b]Abbreviation: TNC, total nonstructural carbohydrates.
[c]Artificial rainfall amount was 1.0 inch at 48 hours.
[d]Two applications of 1.0 inch of water at 24 and 48 hours.

TABLE 4. Effects of rain and plant maturity on alfalfa quality. Shattered plant matter was not included in the analysis.[a]			
Maturity	No Rain	Rain[b]	Rain on Dry Hay[c]
	--------------------- % of DM --------------------		
CP			
Late bud	26.3	24.6	23.1
First flower	18.1	13.9	15.6
Digestibility			
Late bud	72.7	57.2	49.3
First flower	62.3	39.2	36.0
TNC[d]			
Late bud	4.65	2.00	1.21
First flower	4.46	1.89	0.98
NDF			
Late bud	32.4	45.4	54.8
First flower	42.2	64.1	69.8
ADF			
Late bud	27.5	38.5	46.2
First flower	36.4	53.0	58.4
Lignin			
Late bud	5.5	9.7	11.5
First flower	9.1	13.8	16.6

[a]Source: Collins (1983); Agron. J. 75:523-527.
[b]1.6 inches of rain during curing.
[c]2.4 inches of rain on dry hay.
[d]Abbreviations: TNC, total nonstructural carbohydrates.

CP than stems, and they were excluded from the final chemical analysis because they would have been lost during the rainfall event or during subsequent tedding and raking operations. Although the amount of rainfall was not the same for each event, it is clear that more damage to the nutritive value of the forage occurred when the wilting alfalfa was dry enough to bale.

DM Losses for Grasses

Recently, studies conducted at the University of Arkansas evaluated losses of DM and changes in nutritive value for wilting orchardgrass and bermudagrass forages. From 0 to 3.0 inches of simulated rainfall were applied to both forages in half-inch increments. Rainfall was applied to orchardgrass when the moisture content of the forage was very high (67.4%), ideal for baling (15.3%) and excessively dry (4.1%). For bermudagrass, rainfall treatments were applied immediately after mowing when forage moisture content was high (76.1%), at the approximate midpoint of the wilting period (40%) and when the forage moisture content was ideal for baling (13.0%).

Dry matter losses for the orchardgrass were low (< 2%) if rainfall occurred when the forage moisture content was high, but increased substantially if rainfall occurred when the forage was dry (Table 5). Losses approached 11% of total plant dry matter with 3.0 inches of rainfall when the forage was excessively dry (4.1%) at the time the rainfall occurred. At ideal moisture for baling (15.3%), maximum losses were only slightly lower, reaching about 9% of DM. Regardless of the moisture content of the forage, DM losses increased with the amount of

TABLE 5. Effects of crop moisture content and amount of rainfall on the nutritive value of wilting orchardgrass hay. Simulated rainfall was applied at a rate of 3.0 inches per hour.[a]

Crop Moisture[b,c]	Rainfall Amount	DM Loss	Crude Protein	Digestibility	NDF	ADF	TDN
%	inches	---------------------------------- % of DM ----------------------------------					
67.4	0	---	13.2	76.2	63.6	35.5	57.6
	1	1.2	14.2	74.6	64.4	37.0	56.4
	2	1.9	13.9	73.8	64.9	36.6	56.7
	3	1.4	15.2	74.3	64.5	34.2	58.7
15.3	0	---	13.6	77.0	65.0	34.7	58.3
	1	5.0	14.5	72.2	68.4	39.3	54.5
	2	8.3	15.0	72.0	70.9	40.3	53.7
	3	8.8	14.4	72.4	71.3	44.6	50.1
4.1	0	---	13.8	76.8	65.2	34.0	58.9
	1	7.6	13.4	73.6	70.6	36.5	56.8
	2	9.1	14.1	73.8	71.7	37.5	56.0
	3	10.7	14.3	73.0	73.0	38.3	55.3

[a]Source: D. A. Scarbrough, University of Arkansas.
[b]Moisture content of the forage when the simulated rainfall was applied.
[c]Orchardgrass forage was harvested on June 18, 2001, which was the second harvest of the growing season.

TABLE 6. Effects of crop moisture content and amount of rainfall on the nutritive value of wilting bermudagrass hay. Simulated rainfall was applied at a rate of 3.0 inches per hour.[a]

Crop Moisture[b,c]	Rainfall Amount	DM Loss	Crude Protein	Digestibility	NDF	ADF	TDN
%	inches	% of DM					
76.1	0	---	15.6	66.2	71.8	32.4	64.7
	1	0	15.9	64.1	71.3	33.0	65.1
	2	0	15.2	63.1	70.9	31.2	65.4
	3	0.1	15.6	64.3	71.9	36.6	63.1
40.0	0	---	14.9	66.3	71.5	31.0	64.7
	1	1.5	15.3	67.2	72.7	32.7	63.7
	2	1.9	15.4	65.2	72.9	32.6	63.7
	3	3.8	15.0	62.7	74.4	33.2	62.0
13.0	0	---	15.3	67.2	71.4	31.7	64.9
	1	2.0	15.5	64.5	72.8	33.5	63.5
	2	1.8	15.6	64.9	72.7	32.9	63.9
	3	1.7	16.6	58.3	72.7	32.8	64.9

[a]Source: D. A. Scarbrough, University of Arkansas.
[b]Moisture content of the forage when the simulated rainfall was applied.
[c]Bermudagrass forage was harvested on August 30, 2001.

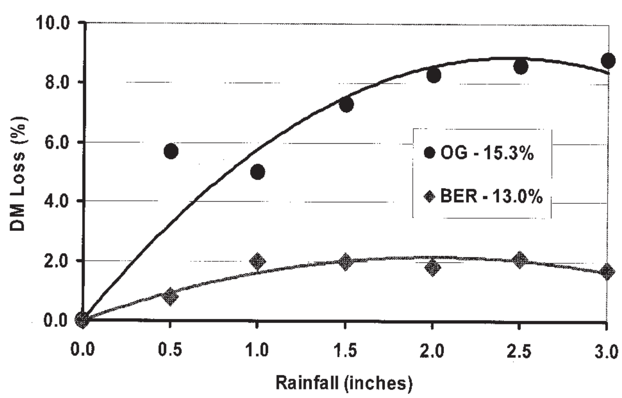
rainfall, but these losses were disproportionately large at rainfall increments of 0.5 and 1.0 inches and tended to level off at higher rainfall amounts.

For bermudagrass (Table 6), the trends were similar. There was essentially no DM loss when the forage was wet, but drier forages lost measurable DM with increased rainfall. Greater losses of DM occur in drier forages because the plant cells lose their integrity and can no longer regulate the movement of soluble compounds in or out of the cell. Unlike orchardgrass, maximum DM losses for bermudagrass were low; the forage that was ideal for baling (13.0%) lost a maximum of about 2% of total plant DM. These differences can largely be explained on the basis of the sugar content of each grass. Perennial cool-season grasses, such as orchardgrass, have much higher concentrations of water-soluble plant sugars than bermudagrass or other warm-season perennial grasses. Therefore, orchardgrass has the potential for more DM loss through leaching. Figure 2 illustrates the comparison of DM losses for bermudagrass and orchardgrass when both forages were wilted to an ideal moisture content for baling; DM losses for orchardgrass were at least four times greater than observed for bermudagrass after the rainfall amount reached 2.0 inches.

Changes in Nutritive Value for Grasses

The summary of nutritive value for rain-damaged orchardgrass forages (Table 5) demonstrates that relatively wet (67.4%) forage was affected only minimally. Drier forages (4.1% or 15.3% moisture) exhibited more undesirable changes in

FIGURE 2. Comparison of DM losses for wilting orchardgrass (OG) and bermudagrass (BER) forages at nearly ideal moisture concentrations for baling that were subjected to 0 to 3 inches of simulated rainfall.[a]



[a] Source: D. A. Scarbrough, University of Arkansas.

response to simulated rainfall. Fiber components (NDF and ADF) are not water soluble; therefore, their concentrations increased by as much as 7.8 and 9.9 percentage units, respectively, as soluble plant sugars were leached away during the application of simulated rainfall. In addition, the leaching of soluble sugars and other compounds from the forage reduced the energy density and digestibility of these forages. The maximum reduction in digestibility was about 5 percentage units. In a pattern that is similar to that observed for DM loss, changes in nutritive value were disproportionately large with the first inch of rainfall.

For bermudagrass (Table 6), changes in nutritive value followed patterns that were similar to those observed for orchardgrass, except that the magnitude of the responses was generally smaller. This is likely due to the low concentrations of nonstructural carbohydrates in bermudagrass that limit the potential for leaching and associated increases in the concentrations of fiber components. Maximum increases in NDF and ADF in response to 3.0 inches of rainfall were only 2.9 and 2.2 percentage units, respectively, and were observed for forage wilted to 40.0% moisture prior to the rainfall event. For bermudagrass that was dry enough for baling (13.0%), respective increases in NDF and ADF in response to 3.0 inches of simulated rainfall were only 1.3 and 1.1 percentage units, but digestibility was reduced from 67.2% to 58.3%. While the nutritive value of bermudagrass remained relatively stable in response to simulated rainfall, it should not be assumed that rain-damaged forages will be as palatable and consumed as readily by livestock.

Rainfall Effects on Tall Fescue and Subsequent Intake by Steers

Recently, a series of experiments were completed at the University of Arkansas that assessed the effects of naturally occurring rainfall on the nutritive value of wilting tall fescue forage and associated effects on voluntary intake by steers. Tall fescue was baled at slightly above the recommended moisture content (22.5%), at ideal moisture (16.4%) and when it was excessively dry (9.9%) without rain damage. In addition, tall fescue was baled at 24.6% moisture after a 0.9-inch rainfall event and at 9.3% moisture following three rainfall events totaling 2.8 inches. The tall fescue was mowed in late May at the heading stage of growth. The results of these trials are summarized in Table 7. At baling, a 0.9-inch rainfall event increased the concentration of NDF by 4.3 percentage units compared to hay baled at 16.4% moisture without rain damage (72.0% vs. 67.7%), while digestibility was suppressed by 1.1 percentage units (62.9% vs. 61.8%). After three rainfall events totaling 2.8 inches, NDF was further increased to 76.4%, which was an increase of 8.7 percentage units over hay baled at 16.4% moisture; however, the associated reduction in digestibility was only 3.2 percentage units. Generally, the effects of a single 0.9-inch rainfall event were not excessive, especially compared to the rapid changes in nutritive value that may occur as a result of delaying harvest (see Figure 1). However, substantial increases in NDF were observed in tall fescue forage that was subjected to three rainfall events totaling 2.8 inches.

After storage, few differences were noted in nutritive value between bales that incurred modest

TABLE 7. Effects of moisture content at baling and modest spontaneous heating on the nutritive value and daily voluntary DM intake of tall fescue hay by steers. Rainfall events were naturally occurring, and bales were packaged as conventional rectangular bales.[a]

Crop Moisture at Baling	Total Rainfall Amount	Number of Rainfall Events[b]	Maximum Internal Bale Temperature	CP	NDF	Digestibility	TDN	Intake of Diet[c]	Intake of Hay
%	inches	#	°F	% of DM				% of Bodyweight	
Characteristics at Baling									
22.5	0	0	---	7.9	66.3	64.1	50.8	---	---
16.4	0	0	---	8.2	67.7	62.9	50.8	---	---
9.9	0	0	---	7.9	67.3	63.9	50.6	---	---
24.6	0.9	1	---	8.4	72.0	61.8	50.1	---	---
9.3	2.8	3	---	8.6	76.4	59.7	49.4	---	---
Characteristics After Storage									
22.5	---	---	122	8.9	74.5	59.8	49.4	2.28	2.10
16.4	---	---	104	8.2	70.5	62.9	49.6	---	---
9.9	---	---	109	7.9	68.1	63.2	49.9	2.31	2.10
24.6	---	---	123	8.6	78.5	59.6	48.6	2.04	1.85
9.3	---	---	89	7.7	76.0	59.7	47.9	2.15	1.93

[a]Source: J. E. Turner, University of Arkansas.
[b]Number of rainfall events contributing to the total rainfall prior to baling.
[c]Complete diet contained a soy hull-based supplement offered at 0.2% of bodyweight daily.

spontaneous heating, rain damage or both. This strongly suggests that the practice of baling hay when slightly wet in order to avoid an unexpected shower offers little nutritional advantage over waiting to bale until after the rainfall event; however, "waiting out" the shower will likely require additional raking and tedding operations. Spontaneous heating is highly dependent on the moisture content of the hay. The potential for serious depressions in nutritive value, as a result of excessive spontaneous heating, is quite high if producers have difficulty evaluating if hay is marginally wet for baling.

The voluntary intakes of these fescue hays were identical for hays baled without rain damage, regardless of whether they incurred modest spontaneous heating or not. It is important to note that the levels of spontaneous heating in these hays were very modest because of the relatively low moisture levels (< 25%) at baling, the small rectangular bale packages and a period of relatively cool weather that occurred within two weeks of baling. More intense heating would be expected if these hays had been packaged as large round bales. Hays that were damaged by rain or rain and modest spontaneous heating were not consumed as well by steers. Depressions in daily voluntary hay intake, relative to those baled without rain damage, were 0.17% of bodyweight for hay receiving 2.8 inches of rain prior to baling, and 0.25% of bodyweight for hay receiving a single 0.9-inch rainfall event coupled with modest spontaneous heating.

Summary Points

1. There is always a cost in delaying harvest to avoid wet weather because of increased plant maturity or age. Delaying harvest may still be a good management decision, but it is not a perfect solution to the problem of unfavorable weather.

2. Rain damage increases with the amount of rainfall and the duration of the rainfall event.

3. More water is retained by the forage when rainfall intensity is low.

4. Rain leaches soluble compounds, particularly sugars, from the forage.

5. Leaf shatter is a greater source of DM loss in legumes than in grasses.

6. Dry matter losses and negative changes in nutritive value are generally greater in plants that have high sugar content, such as orchardgrass or tall fescue, than in bermudagrass or other warm-season perennials that have low concentrations of sugar.

7. Rain damage to wilting forages is more severe when the forage is relatively dry because the plant cells lose their ability to control the passage of soluble compounds in or out of the cell.

8. Fiber components (NDF, ADF and lignin) are not water soluble and remain stable during rainfall events. Their concentrations increase indirectly as sugars are preferentially leached away. This results in decreased nutritive value, daily voluntary hay intake, digestibility and energy density.

Recommendation

Given the uncertainty of the weather, specific recommendations are difficult. For tall fescue, results of experiments at the University of Arkansas indicate that the damage caused by a single rainfall event of approximately one inch is not excessive, particularly when compared to the rapid changes in forage quality that are occurring simultaneously because of advancing maturity. This suggests that producers could be more aggressive during the late-spring with fairly limited risk. Orchardgrass and legumes are more susceptible to rain damage and may need to be managed more conservatively. In contrast, the quality characteristics of bermudagrass are only minimally affected by rainfall events; thus, emphasis should be put on harvesting at the proper stage of maturity to obtain the quality needed to match or exceed animal requirements. The tradeoffs are less of a concern for bermudagrass because weather patterns usually become more stable during summer months.

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