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Using Cereal Grain Forages and Mixtures With Annual Ryegrass for Hay and Silage

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Introduction

Wheat, oats, rye and annual ryegrass are drilled routinely into prepared seedbeds or sod-seeded into dormant bermudagrass or other warm-season grasses to provide forage for grazing, hay or silage.

In general, all of these forages maintain excellent quality characteristics through the vegetative and stem elongation stages of growth, but forage quality deteriorates quickly after head emergence. While these forages mature rapidly in the spring, there are substantial differences in their growth and developmental patterns. In addition, plant maturity does not have exactly the same effect on the forage quality characteristics of each of these winter annuals. Therefore, producers can potentially take advantage of the differences in growth rates and seasonal development among these forages to develop management strategies that best fit their individual livestock enterprises.

Plant Characteristics

For most cool-season forages, a high ratio of leaf-to-stem tissue is a desirable characteristic and is usually indicative of good forage nutritive value. Growth characteristics of barley, wheat, oats and rye from a two-year study in North Carolina are summarized in Table 1. Plants were sampled in the spring during the vegetative (four leaves unfolded), boot (inflorescence within 0 to 2 inches of the flag leaf), heading (emergence of inflorescence completed), milk, soft dough and hard dough stages of growth. Plant parts were hand separated, and proportions of the total plant weight were partitioned into leaf, stem and grain on each harvest date.

Cereal rye typically partitions more of the total plant dry matter into stem tissue and less into the grain head than the other cereal grains. This can be explained, in part, by the taller growth habit of rye. Cereal rye also matures at a more rapid rate and at an earlier date in the spring than the other cereal grains.

These traits were illustrated in a study conducted at the Livestock and Forestry Research Station in Batesville (Table 2). In this study, plots of 'Jaypee' wheat, 'Elbon' rye and 'Ozark' oats were seeded directly into a base sod of 'Tifton 44' bermudagrass in the fall of 1997.

Plots were harvested the following spring on six dates during a three-month period between March 4 and June 5. On each harvest date, the height of each cereal grain species was measured and the associated growth stage for each species was recorded. The percentages of the total plant weight partitioned into the grain head was also determined for the final two harvest dates.

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Table 1. Percentages of plant dry matter found in the leaf, stem and grain for four cereal grains harvested on six dates in North Carolina (adapted from Edmisten, et al., 1998; *Commun. Soil Sci. Plant Anal.* 29:867-879). Values are summarized from two years of data.

Species	Plant Part	Growth Stage at Harvest					
		Vegetative	Boot	Heading	Milk	Soft Dough	Hard Dough
Barley	leaf	81.4	44.8	23.8	15.0	11.9	8.6
	stem	18.6	55.2	61.9	55.7	50.3	40.1
	grain	0.0	0.0	14.3	29.3	37.8	51.3
Oats	leaf	82.4	43.8	17.7	14.2	8.6	8.0
	stem	17.6	56.2	54.4	50.0	35.3	37.7
	grain	0.0	0.0	27.9	35.8	54.1	56.3
Cereal Rye	leaf	70.4	39.1	17.7	7.1	4.8	2.2
	stem	29.6	60.9	71.6	70.5	67.0	52.3
	grain	0.0	0.0	10.7	22.4	28.2	45.5
Wheat	leaf	82.8	44.2	23.5	14.2	9.9	7.7
	stem	17.2	55.8	58.7	55.9	43.8	36.3
	grain	0.0	0.0	17.8	29.9	46.3	56.0

Table 2. Growth stage, plant height and percentage of dry matter partitioned within the grain head for three fall-seeded cereal grains harvested on six dates in spring 1998 at Batesville, Arkansas (*J. Dairy Sci.* 83:2499-2511).

Species	Harvest Date	Growth Stage	Plant Height (inches)	Head Weight (% dry matter)
Oats	March 4	vegetative	5.9	. . .
	March 24	vegetative	7.1	. . .
	April 15	early boot	16.2	. . .
	May 4	head emerged	25.6	. . .
	May 26	late milk	34.7	53.6
	June 5	ripe grain	31.9	55.1
Wheat	March 4	early stem elongation	8.3	. . .
	March 24	early stem elongation	9.9	. . .
	April 15	tip of head emerged	21.7	. . .
	May 4	early milk	28.0	. . .
	May 26	soft dough	27.6	57.9
	June 5	ripe grain	26.0	60.1
Cereal Rye	March 4	early stem elongation	7.5	. . .
	March 24	early stem elongation	11.8	. . .
	April 15	head emerged	39.4	. . .
	May 4	early milk	59.9	. . .
	May 26	early dough	57.9	36.1
	June 5	ripe grain	56.0	41.4

Figure 1. Relationship between effective ruminal digestibility of dry matter (DM) and calendar date for oats, wheat and rye forages harvested on five dates during Spring 1998 in Batesville, Arkansas. For a description of the growth stage on each harvest date, see Table 2. (Source: W. K. Coblentz)

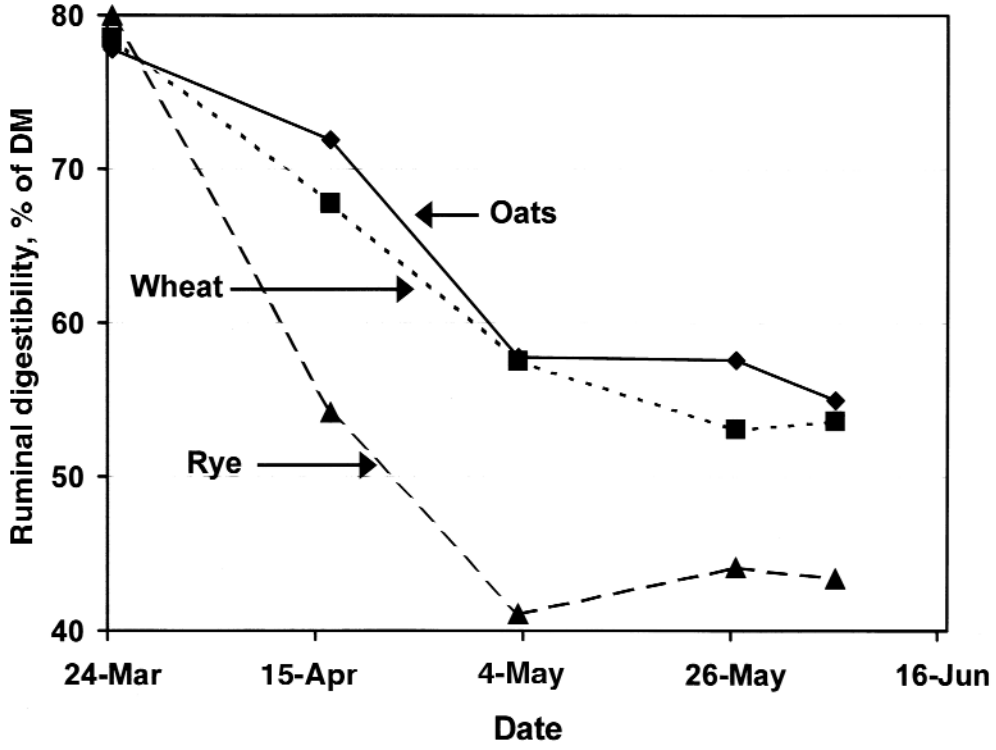
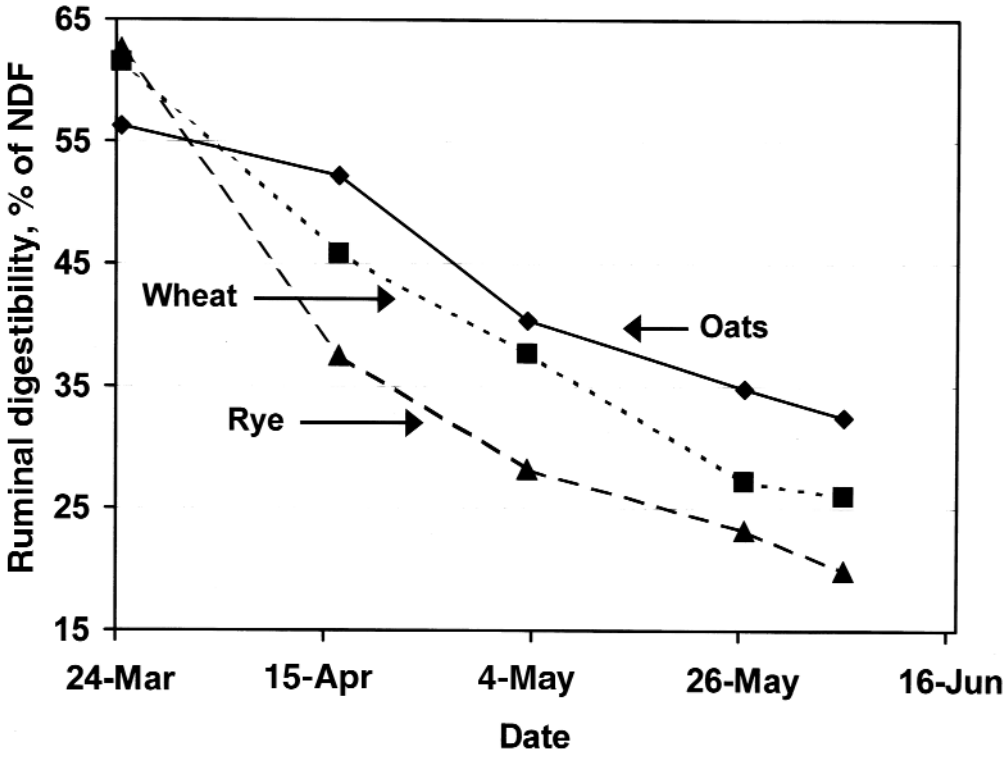


Figure 2. Relationship between effective ruminal digestibility of neutral detergent fiber (NDF) and calendar date for oats, wheat and rye forages harvested on five dates during Spring 1998 in Batesville, Arkansas. For a description of the growth stage on each harvest date, see Table 2. (Source: W. K. Coblentz)



All three cereal-grain forages remained primarily vegetative, maintaining a high percentage of leaf tissue through the March 24 sampling date. Between March 24 and April 15, cereal rye matured rapidly, becoming fully headed by April 15. In contrast, oat tillers did not reach the heading stage of growth until May 4, thereby exhibiting a three-week delay relative to rye. Wheat matured at a rate that was intermediate between the other two cereal grains. Cereal rye had a maximum height of about 60 inches, which was more than 25 inches taller than oats, and more than double the height of wheat.

From a practical standpoint, the taller growth of cereal rye results in a longer, and perhaps thicker, stem which greatly reduces the leaf-to-stem ratio. The taller growth habit for cereal rye also partially limits the positive effects of grain fill on forage nutritive value. By the June 5 harvest date, the energy-dense grain head accounted for more than 60 and 55 percent of the plant dry matter in wheat and oats, respectively, but only 41 percent of the total dry matter in cereal rye. These differences in developmental characteristics have implications with respect to management strategies for a one-time harvest as silage or hay. The rapid developmental characteristics for cereal rye provide more forage than other cereal grains earlier in the spring, but also present a narrower harvest window. This is further complicated by the wet weather common to Arkansas during this period.

Mixtures Containing Annual Ryegrass – Effects on Proportion of Leaf Tissue

Annual ryegrass typically develops more slowly than cereal grains during cool spring weather. It also has very aggressive regrowth potential if there is adequate soil moisture. Producers wishing to utilize annual ryegrass and cereal-grain forages for a one-time harvest of hay or silage may wish to lengthen the harvest window by planting more than one species, either as a mixture or (preferably) in independent stands. However, lengthening the harvest window for these forages into late spring may delay the development of the initial crop of bermudagrass when sod-seeding techniques are used.

The effects of seeding a mixture of annual ryegrass and wheat on the proportions of leaf in the sward were evaluated in Fayetteville in 1985 and 1986 (Table 3). Mixtures containing one of two wheat cultivars (Magnum or HW 3015) and 'Marshall' ryegrass were seeded at rates of 120 lbs per acre of wheat and 20 lbs per acre of ryegrass. When averaged over the six harvest dates, annual ryegrass improved the percentage of leaf tissue in the sward by about five percentage units, relative to wheat grown in monoculture. In the mixture, annual ryegrass plants had a higher proportion of leaf tissue (60.4 percent) over the six harvest dates than the companion wheat, of which only 44 percent of the total plant dry matter was leaf. This can be explained, in part, because the development of ryegrass was slower than either wheat cultivar; therefore, the entire sward of the mixtures remained more leafy and generally less mature than did the wheat alone.

Forage Nutritive Value

The nutritive value of the three cereal grains harvested in 1998 from plots established in Batesville is summarized in Table 4. Following a trend typically observed for all cool-season grasses, the forage quality declined with calendar date and growth stage. Forage quality characteristics throughout March were excellent for all three species. Concentrations of crude protein ranged from 19.4 to 25.4 percent over the March 4 and March 24 harvest dates, and concentrations of fibrous

Table 3. Effects of mixing ryegrass with wheat on the percentage of leaf in the sward. Values represent the average of six harvest dates and two harvest years (adapted from Walker, et al., 1990; *J. Dairy Sci.* 73:1296-1303).

Wheat Variety	Ryegrass	% Leaf		
		Sward	Wheat	Ryegrass
	% of Sward	% of Total Forage Dry Matter		
Monocultured wheat				
Magnum	0	42.5	42.5	. . .
HW 3015	0	45.0	45.0	. . .
Wheat and ryegrass mixtures				
Magnum	31.3	48.9	43.7	60.4
HW 3015	36.6	49.2	43.1	60.4

components were low. Low concentrations of fibrous components usually indicate that digestibility, energy density and overall forage quality is good. On March 24, the NDF content ranged from 40.7 to 42.9 percent, ADF ranged from 19.6 to 20.4 percent and TDN was at least 71.6 percent.

Quality characteristics for rye declined more rapidly than the other cereal grains between the early stem elongation stage on March 24 and the fully headed stage on April 15. On this date, when heads were fully emerged, the CP concentration had fallen to 8.6 percent, representing a decline of 11.9 percentage units in a three-week time interval. Concentrations of NDF and ADF increased dramatically during this same harvest interval (by 25.8 and 14.9 percentage units, respectively). Estimates of TDN also declined from 72.1 to 54.1 percent in response to these elevated levels of fiber components. This indicates a significant reduction in the energy content of the forage. Forage quality for wheat and oats also declined, but the rate of decline was slower. This was related to the slower plant growth and later development of these species. This suggests that wheat or oats can be used in mixtures with rye or independent stands to lengthen the harvest window for spring forages. Generally, forage quality continued to decline for all species through early May.

As grain fill begins, the forage quality of wheat actually improves due to the amount of starch that is deposited in the grain head. The ADF content in wheat declined by 5.2 percentage units by the soft dough stage (May 26). Estimates of the energy value of wheat (TDN) harvested at the soft dough stage were slightly higher (3.4 percentage units) than those at the early milk stage (May 4). Ideally, single harvests of cereal grains at boot stage or soon thereafter are a good tradeoff between quality and yield. If wheat cannot be harvested at the early heading stage of growth, producers may benefit by delaying harvest until the soft dough stage, rather than harvesting during the late flowering or early milk stages of growth. Forage quality is very poor for cereal rye after the boot and early heading stages of growth, and every effort should be made to harvest this forage before it is fully headed.

Ruminal Digestion of Dry Matter, Fiber and Crude Protein

The cereal grain forages harvested in the Batesville study were also evaluated for characteristics of ruminal digestion of dry matter, structural plant fiber (NDF) and crude protein (Table 5). For each component evaluated, three indices are reported. These are: 1) the ***rate of digestion***; 2) the ***potential extent of digestion***, which is the portion of dry matter, NDF or crude protein that is potentially digestible if the forage remained in the rumen for an indefinite period of time; and 3) the ***effective ruminal digestibility***, which is the portion of the total pool of dry matter, NDF or crude protein digested within the time limits imposed by rate of passage. Large values for each of these terms typically are found in high-quality forages that have relatively low concentrations of structural fiber.

Ruminal dry matter and NDF digestion. Rates of dry matter digestion were rapid (range = 8.6 to 11.1 percent per hour) for all forages harvested on March 24, indicating the quality of all forages was excellent. Subsequently, these rates declined for all forages, but rates declined more slowly with advancing plant maturity for oats. This demonstrates the slower growth and development of oats. Estimates of the potential extent of digestion and the effective ruminal digestibility of dry matter for all three forages declined during each harvest interval between March 24 and May 4, indicating that forage quality was declining during this time interval. During this period, the most dramatic effects were observed in cereal rye. Generally, the digestion of structural fiber (NDF) followed similar patterns. These concepts are illustrated in Figures 1 and 2; effective ruminal digestibility is plotted against calendar date for both dry matter and NDF. Clearly, this demonstrates the special need for attentive management when cereal rye is harvested as a silage or hay crop.

Ruminal crude protein digestion. The potential extent of crude protein digestion for all forages was exceptionally high on the March 24 harvest date, when plants were primarily vegetative. The potential extent of crude protein digestion remained relatively high (≥74.5 percent) for oats and wheat on all harvest dates.

Rates of crude protein digestion for oats and wheat exhibited similar patterns over the five harvest dates evaluated. For both forages, rates of digestion were initially rapid (≥16.5 percent per hour), but declined between the March 24 and May 4 harvest dates in association with advancing plant maturity. Generally, digestion rates during this time period were similar to those that have been reported for other cool-season grasses harvested during stem elongation and at boot stage. Digestion rates for rye increased sharply to 54.8 percent per hour by May 4 and remained exceptionally high thereafter. Rapid decay rates should be expected as cereal forages partition increasingly large portions of the total crude protein pool within the grain head and less within the stover. This was observed in all forages harvested at advanced growth stages, but rates appeared to be more rapid for wheat and rye forages.

Table 4. Characteristics of nutritive value for three overseeded cereal grains as affected by harvest date and growth stage. Forages were harvested in the spring of 1998 in Batesville, Arkansas (*J. Dairy Sci.* 83:2499-2511).

Forage	Harvest Date	Growth Stage	Crude Protein	NDF	ADF	TDN
			% of dry matter			
Oats	March 4	vegetative	21.6	42.8	19.9	72.8
	March 24	vegetative	19.4	40.7	19.7	71.6
	April 15	early boot	11.8	50.8	24.9	63.1
	May 4	head emerged	7.8	62.2	34.3	54.0
	May 26	late milk	5.6	62.8	34.9	52.2
	June 5	ripe grain	5.9	62.7	37.2	50.7
Wheat	March 4	early stem elongation	21.3	42.2	20.4	72.2
	March 24	early stem elongation	20.4	41.4	19.9	72.1
	April 15	tip of head emerged	10.7	50.9	26.2	61.5
	May 4	early milk	6.7	56.5	36.3	51.9
	May 26	soft dough	6.2	59.9	31.1	55.3
	June 5	ripe grain	6.4	61.3	37.1	51.2
Cereal-Rye	March 4	early stem elongation	25.4	42.9	19.6	75.3
	March 24	early stem elongation	20.5	41.8	19.9	72.1
	April 15	head emerged	8.6	67.6	34.8	54.1
	May 4	early milk	4.5	74.0	42.9	45.8
	May 26	early dough	4.1	65.5	44.3	44.6
	June 5	ripe grain	5.5	68.0	41.2	47.7

Table 5. Characteristics of dry matter (DM), fiber (NDF) and crude protein digestion for three cereal grains harvested on five dates during the spring of 1998 in Batesville, Arkansas (*J. Dairy Sci.* 83:2499-2511).

Forage	Harvest Date	Dry Matter			NDF			Crude Protein		
		Rate of Digestion	Extent	Effective Digestibility	Rate of Digestion	Extent	Effective Digestibility	Rate of Digestion	Extent	Effective Digestibility
		%/hour	% of DM		%/hour	% of NDF		%/hour	% of crude protein	
Oats	March 24	8.6	92.2	77.8	8.6	83.8	56.3	16.5	95.4	85.8
	April 15	6.3	91.6	71.9	6.1	86.2	52.2	12.4	93.5	84.0
	May 4	4.6	82.6	57.8	4.5	77.1	40.4	10.9	84.4	74.6
	May 26	3.6	75.4	57.6	3.9	61.9	34.8	23.3	83.4	81.4
	June 5	3.5	73.8	55.0	3.8	60.6	32.4	28.7	79.1	77.3
Wheat	March 24	11.1	92.5	78.5	10.8	87.4	61.5	17.1	95.4	85.2
	April 15	5.6	88.0	67.8	5.6	80.0	45.9	11.7	91.8	80.6
	May 4	4.8	75.1	57.5	5.0	63.5	37.7	8.5	74.5	64.8
	May 26	3.8	71.6	53.1	3.3	52.6	27.2	47.6	80.3	77.4
	June 5	4.0	70.3	53.6	3.9	50.0	26.0	38.3	77.0	72.9
Cereal Rye	March 24	9.9	94.9	80.0	9.7	89.6	62.6	19.2	97.9	88.6
	April 15	4.3	78.8	54.2	4.2	73.5	37.5	22.9	82.7	79.0
	May 4	3.4	63.8	41.1	3.3	58.5	28.2	54.8	56.2	54.8
	May 26	4.5	62.0	44.1	3.0	47.8	23.2	61.4	73.4	71.1
	June 5	3.4	61.1	43.4	3.1	43.6	19.9	49.5	58.8	56.5

The effective ruminal digestibility of crude protein for all three forages was very high (≥79.0%) for the March 24 and April 15 harvest dates, indicating that only 21 percent or less of the crude protein in these forages bypasses the rumen intact. The effective ruminal digestibility of crude protein for all forages in this study reached a minimum on the May 4 harvest date, which generally preceded grain fill and reflects the increased maturity of the stover in all forages. This trend was most pronounced in rye forage; effective ruminal digestibility declined to 54.8 percent on May 4, compared to 64.8 and 74.6 percent of crude protein for wheat and oats, respectively, harvested on the same date. Ruminal digestibility increased during grain fill for all forages and remained ≥72.9 percent of crude protein for wheat and oats on all subsequent harvests.

Generally, this study indicates that the crude protein digestibility characteristics of cereal grains are similar to those of other cool-season grasses up to the point when grain fill is initiated. After this point, rates of digestion increase because the crude protein in the grain is readily digested in the rumen. At the same time, concentrations of crude protein in the forage have declined to about 30 percent or less of what they were in early March, and the limited crude protein found in the stover is largely unavailable to the animal. These concepts are important in the formulation of forage-based diets because livestock do not utilize crude protein efficiently when forages contain high concentrations of crude protein that is rapidly digested in the rumen. These characteristics are present when cereal grains are harvested when vegetative or during stem elongation. Generally, the ensiling process has little effect on the concentrations of crude protein within a forage; however, during the fermentation process, much of the nitrogen within the forage is converted from protein to non-protein forms. This usually increases the effective digestibility of crude protein in the rumen, unless substantial spontaneous heating occurs during the fermentation process.

Mixtures Containing Annual Ryegrass – Effects on Digestibility

Adding ryegrass to the wheat at seeding had a positive effect on the percentage of leaf in the sward (Table 3). Increased proportions of leaf in the sward are often assumed to have a positive effect on forage quality. In the case of the wheat-ryegrass mixtures, this is not always true. The digestibility of monocultured wheat and the wheat-ryegrass mixtures may remain similar until grain fill is initiated in the wheat. At this time, the digestibility of wheat may improve in response to grain fill, but the digestibility of ryegrass (especially stems) may continue to decline. The digestibility of the entire sward can be depressed by the continued reduction of digestibility in the stem tissue of ryegrass. This may negate the positive effects that grain fill in the wheat has on the digestibility of the entire mixture. Wheat and other cereal grains commonly exhibit an improvement or stabilization in forage quality during grain fill that can depress the concentrations of fibrous components and improve or stabilize estimates of energy and digestibility. This is less likely to occur in other cool-season grasses that have not been selected for grain yield. In these grasses, digestibility will continue to fall as the plant continues to mature.

Other Considerations

Moisture content. The moisture content of cereal-grain forages declines as the plants become more mature. A typical recommendation for ensiling most forage crops is to make certain that the moisture content of the forage is <70 percent. This is necessary to prevent excessive production of effluent and to avoid undesirable fermentations that can occur when forages are excessively wet. Work from North Carolina has been summarized (Table 6) and illustrates the relationship between plant maturity and the moisture content of the forage. Based on these data, cereal grains usually can be direct-cut or

Table 6. Percentages moisture found in four cereal grains harvested on six dates in North Carolina (adapted from Edmisten, et al., 1998; *Comm. Soil Sci. Plant Anal.* 29:867-879). Values are summarized from three years of data.

Species	Growth Stage at Harvest					
	Vegetative	Boot	Heading	Milk	Soft Dough	Hard Dough
	% Moisture					
Barley	83.5	82.7	77.9	72.4	62.2	55.5
Oats[1]	76.5	80.0	72.2	67.9	56.1	48.3
Rye	78.2	82.7[1]	75.3	58.5	57.2	39.9
Wheat	80.9	75.4	75.5	59.3	57.9	42.2

[1]Evaluated in only two years.

swathed and immediately chopped after they reach the milk stage of development; however, this recommendation is also dependent on the existing weather conditions.

Producers should pay particular attention to the moisture content of the forage at the time of ensiling. Excessively dry silages (<50 percent moisture) are difficult to pack, and this can limit the exclusion of oxygen from the forage mass and increase the probability of spontaneous heating in the silo. This problem is magnified with cereal grains because these forages are inherently bulky (especially rye), and most stems are hollow and naturally trap air. Cereal grains at or approaching the soft dough stage of development are drier than less mature forages; in addition, they dry very quickly after mowing. Producers should monitor moisture content closely and not allow these forages to become excessively dry prior to ensiling. When cereal grains are harvested at advanced maturities, such as the soft dough stage, prevailing weather conditions may demand that these forages be direct-cut or that the mower-conditioner is operated immediately in front of the forage harvester in order to prevent excessive desiccation.

Mechanical conditioning. Cereal grains that have reached the soft dough stage of development should not be conditioned with crushing rollers or other mechanical conditioners. At this stage of maturity, the most nutritious portion of the forage is in the grain head, and grains can easily shatter with mechanical processing. Producers wishing to ensile cereal grains with filling grain heads should widen the gap between crushing rollers or otherwise remove or disengage the conditioning equipment on their mower-conditioner to limit grain shatter.

Packing silage. It should be strongly emphasized that cereal grains often have hollow stems that tend to trap air within the silage mass. This trait also can make the forage somewhat bulky and difficult to pack. Every effort should be made to thoroughly pack the silage mass to prevent spontaneous heating. In addition, the weight associated with silages harvested at the proper concentrations of moisture (about 65 percent) will also help to exclude oxygen from the silage mass.

Implications

Clearly, forage quality characteristics of all cereal grains are excellent in the early spring. All cereal grains should be harvested at boot stage, if possible. This represents a good compromise between quality and yield. Quality characteristics deteriorate more rapidly with plant maturity in cereal rye than in wheat or oats grown in the same environment. The difficulty of managing cereal rye as a silage crop is further increased by its accelerated developmental characteristics and unique growth habit, which results in taller plants that have greater concentrations of structural fiber after stem elongation and lower proportions of total plant dry matter partitioned into the grain head. The more rapid developmental characteristics of cereal rye present a very narrow harvest window in early April. This is problematic and is complicated further by the wet weather common to Arkansas during this time period. Under wet conditions, sod-established cereal grains may support equipment traffic better than cereal forages established by clean-till methods. Acceptable forage quality may persist longer into the spring for wheat, oats and annual ryegrass; this suggests that producers wishing to utilize these forages may lengthen the harvest window by planting more than one species, either as a mixture or (preferably) in independent stands.

Recommendations

1. Make every attempt to harvest cereal grain forages at boot stage or during early heading.
2. Use good silage-making techniques.
3. Open or disengage the conditioner if cereal grains contain heads that shatter.
4. If limited tonnage is needed, any of the species described in this report will supply excellent forage.
5. If considerable forage is to be harvested, producers may wish to plant more than one species in order to lengthen the harvest window. This will increase flexibility if weather conditions delay harvests.

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