

Forage Quality Measurements and Forage Research—A Review, Critique and Interpretation

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Abstract

Forage makes up a major portion of the rations of cattle and rate of animal gains varies widely within and among forage species grown. Forage production research has been highly productive, but research on increasing forage intake and digestibility by cattle has not been as successful. The literature suggests that resistance to change in specific gravity increases with the age of the plant, particularly with stems, and may increase time required for passage through the rumen and gut, reducing rate of intake. Leaves and leaf sheaths of grasses live for only part of a season and when they die soluble contents are translocated out to young tissue, leached by rainfall and metabolized by bacteria or by the plant leaf itself. Digestibility of dead leaves ranges from 40 to 60% of that of green leaves and when leaves die 15 to 40% of total production may be lost. Plant parts, leaf, leaf sheath, and stem, differ significantly in digestibility and rate of consumption. Variations in quality among forage cultivars may represent a basic difference in the amount of each component that is produced or is present when being grazed. Cultivars high in leaf content will be higher in quality than cultivars which produce more stem. Pasture or range management which maintains green leaves should produce more total forage and more total digestible nutrients than management which allow stems and dead leaves to accumulate. It is hypothesized that by understanding shoot growth in grasses and managing to prevent stem production and leaf death, forage quality over a season can be stabilized at a digestibility of 65% or higher. When processing forage samples, data on green leaves, leaf sheaths and stems, forage quality and digestibility, need to be collected to be descriptive of the species. On pastures or ranges, species with reproductive tillers tend to become stemmy in the summer, requiring defoliation to remove the stems and N application to activate new shoot growth. This is different from those species producing vegetative tillers where, over a season, dead leaves tend to accumulate. On perennial grass species with vegetative tillers, rate, and time of N application should be adjusted to stimulate tillering and green leaf growth. Under range conditions spring N application stimulates the growth of annuals which compete with the perennials. Thus, effective pasture management is expected to reflect manipulation of green leaf production and utilization in the predominant tiller type present, usually the perennial.

The main purpose served by forages in the diet of beef cattle is the provision of energy (Reid et al. 1959). Forages provide a low-cost alternative to concentrates and a higher quality diet than hay. A number of procedures for estimating parameters of cattle performance on pasture have been suggested, e.g., T.D.N., D.D.M., cell wall constituents, and chemical composition, to name a few (Reid et al. 1959; Taylor and Templeton 1976). Most of these procedures are useful as guides

within a species, but are all too often lacking in consistency even among different cultivars of a given species (Reid et al. 1959). Consumption of forage within a cultivar may vary as much as 200% depending upon when the forage is harvested (Reid et al. 1959). Variations in animal performance when consuming various forages, or the same forage at different ages, have been documented. However, reasons for the changes in rate of consumption of forages by animals (intake), digestibility of forage parts consumed, and digestibility of forages following specific harvest or processing treatments are not known. All materially influence its value as animal feed (Reid et al. 1959).

Forage research has been effective in producing high yielding cultivars such as Coastal Bermudagrass (*Cynodon dactylon* Poir) (Burton 1954) that are adapted to grow over wide areas and soil types. Other growth responses, such as season of growth, fertilizer nutrient use, disease resistance, and tolerance to cold or drought are readily combined into new cultivars once germ plasm specific for the desired forage characteristic has been identified. Because of the high success rate of data generation in forage yield research where a mowing machine or mass analysis procedures can be used, scientists have tended to concentrate research in forage production areas. In the forage quality areas where data collection involves plant separations into green and dead leaves, leaves and stems, etc., more time is required to process samples and less research has been completed. Data reported imply that highest concentrations of desirable nutrients are superior.

In the area of forage quality, animal intake, digestibility, chemical and nutrient composition, etc., many data are available but success in effectively utilizing these data to increase performance of cattle consuming the increased forage production has been slow to develop. Dry matter accumulation in forage is important, but evidence is appearing that high forage yields do not necessarily result in improved animal performance. In grazing situations, high forage production without management changes to maintain digestibility may actually be counter-productive (Hart et al. 1976). Emphasis on dry matter production which results in high stem or dead leaf accumulation could well intensify management difficulties associated with efficient animal gains and efficient utilization of forage produced. An increase in understanding of growth and effective utilization of high yielding forages would increase relevance of ongoing forage research significantly.

In biological systems as complex as the nutritional needs of the cow and growing cattle and variations in energy composition of forages available for grazing, it is not likely that simple models are adequate to explain variations in animal gains experienced. However, if components of the two systems (animal nutritional needs and changes in forage physical and

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energy composition) can be effectively interfaced, it is likely that predictability of each can be significantly refined. Thus, if we understand rate of forage consumption, intake by the cow and how digestibility of forage components vary, we can design a forage production system that more effectively meets the cow's nutrition requirements. Such a system requires managing against the accumulation of undesirable plant parts. The following presentation offers an explanation of some of the mechanisms influencing forage intake by cattle and some known forage measurements that would be expected to influence forage intake and nutrient availability (digestibility). Some plant growth and composition parameters will be interfaced with animal energy needs.

Forage Intake

Cordova et al. (1978) reviewed the literature on forage intake by grazing animals and pointed out a number of deficiencies in research completed. One of the major procedural deficiencies appeared to be that forage available for grazing was not characterized. Changes in leaf to stem ratios during data collection can be sizable.

The bovine rumen has a free liquid surface, and feed passage through the liquid is by gravity rather than muscular contractions (peristalsis). As early as 1955, Nichols et al. measured the specific gravity of rumen fluid of mature cows fed different feeds. They concluded that specific gravity of rumen fluid was $1.0 \pm 2\%$ and depended upon type of feed and whether measured before or after feeding. The effects of physical characteristics of feed on rate of passage through the digestive tracts of cattle and man over a 117-hour period using plastic materials of known specific gravities that ranged between 0.92 and 1.42 were reported by King and Moore (1957). They found that particles with a specific gravity significantly lighter or heavier than 1.2 were slower to pass through the digestive tract. Particles with a specific gravity of 1.42 were found at the bottom of the rumen, while particles with a specific gravity of 1.09 or less had been regurgitated and chewed. Blaxter et al. (1956) using sheep concluded that rate of intake of feed was determined to a large extent by its physical characteristics, percent stem, leaf, etc., which determined its rate of passage and its digestibility.

Beaty et al. (1960) found that bulk density (specific gravity) of Coastal Bermudagrass forage was 0.85, and when the same forage was ground and pelleted the specific gravity was increased to 1.2. In the same investigation, daily dry matter intake of steers fed the forage as pellets was 2.51% of body weight, as compared to 1.95 and 2.00%, respectively, for steers fed similar forage as silage or hay. The specific gravity of the pelleted forage at 1.20 compares very closely with that of corn grain (*Zea mays* L.) and rates of intake of the two feeds have been found to be similar (Brooks et al. 1962). Specific gravity of the green forage and hay at 0.85 was well below that required for rapid passage.

Beaty et al. (1960) concluded that rate of Bermudagrass forage intake (consumption) by cattle was inversely related to resistance to density change from 0.6 or less to 1.10 or higher. Old, tough or stemmy forage would pass the rumen more slowly than young forage. The same authors in unpublished research found that specific gravity of Bermudagrass stems could be as low as 0.4. It was reasoned that rate of passage of forage stems through the rumen would be low, as considerable chewing would be required to increase the forage density from 0.4-0.5 to the 1.1 necessary for passage. It was concluded that grass

leaves, since they have less structural material (primarily fiber and lignin) than stems, would require less chewing. The time required to increase the specific gravity to the 1.1-1.2 required for passage through the rumen (Sullivan 1969) would be less and intake would be higher.

An interpretation of King and Moore's (1957) research could be that unless the specific density of the feed was adjusted to within certain limits, high density feeds could settle in the bottom of U-shaped guts and slow or block passage of ingesta. Forages with specific gravities less than 1.0, by collecting at the top of guts, would be difficult to force down by peristalsis and would also slow rate of passage through the gut. It is possible that specific gravity adjustments of forages grazed are necessary for the health of the cow. Resistance to passage of low density stems would reduce intake and stems may also be low in digestibility. Thus, the presence of stems probably reduces both intake and digestibility (Hanna et al. 1976).

Van Soest (1969) reported that average forage particle size decreased as feed passed from the rumen to the digestive tract. Decreasing particle size increases particle surface area available for bio-decomposition. In general processing, grinding and pelleting, increases the rate of rumen passage. However, it is believed that grinding reduces the amount of chewing required by the cow to increase the density to 1.1 or more and should increase rate of rumen passage of stemmy forages more than leafy ones.

Digestibility of Green/Dead Forage

It is assumed that rate of passage of green and dead leaves through the rumen and gut would be similar, but dead leaves represent a plant residue and their digestible dry matter is much lower than green leaves. In 1971, Hunt reported that grass leaves live for only part of a season and at leaf death dry matter losses were high. Decreases in digestibility of dead leaves to 40% of that of leaves when green have been cited (Edmund 1967; Wilson and Hindley 1968). It was assumed that the decrease in digestibility of plant parts at death was caused by translocation or metabolism of soluble materials. Leaves are higher in such translocatable materials than are stems, and forage quality is reduced more by leaf death than by stem death. In a more recent investigation, Taylor and Templeton (1976) showed that digestibility of dead tall fescue (*Festuca arundinacea* Schreb.) was less than one-half that of the same forage while green. In 1978a, Beaty et al. showed that the in-vitro dry matter digestibility (IVDMD) of green tall fescue leaves and sheaths averaged 69% higher than the same plant parts when dead. Sampaio et al. (1976) showed that with green Pensacola bahiagrass (*Paspalum notatum* Parodi) leaves, N concentration was stable at 2% over the life of the leaf until 5 days before death, when it decreased to 0.40%. It is assumed that at the time when N concentration was decreasing other soluble materials were also being translocated to new growth. Unreported research by McCormick et al. on winter saved Bermudagrass showed that after November 15, quality of this warm season perennial grass forage was too low to support the nutritional needs of beef cows. It would appear biologically logical that before death due to old age or freezing temperatures soluble materials in summer growing perennials such as Bermudagrass or bahiagrass are translocated to green plant parts protected from freezing. By time of leaf or stem death from senescence or frost, primarily structural materials remain in the forage. The decrease in digestibility and nutrient concentration generally reported in forages as the season advances in part

reflects the accumulation of dead forage and stems. Southern range plants are reported to have high quality early in the season, but quality decreases rapidly in late summer and fall (Williams et al. 1955). The low quality appears at a time when the plants are largely mature, stemmy, or dead.

Some of the available data comparing IVDMD of green grass leaves of Bermudagrass and tall fescue with green legume leaves, petioles, and stems showed digestibility of both to be rather comparable, with each in the 65 to 75% range (Beaty et al. 1977b; Taylor and Templeton 1976; Dobson et al. 1978). IVDMD of mature legume stems has been shown to decrease to approximately 50% as compared to 37% for 8-week old bermudagrass stems (Beaty et al. 1977b; Hanna et al. 1976). Large stems of both grasses and legumes are generally selected against by grazing cattle. Soon after legume leaves become shaded or mature they dehisce and digestibility of the forage remaining is maintained at a high level by new leaves produced (Beaty et al. 1977b). In grasses, dead leaves remaining on the tiller at the end of a season may compose up to 40 to 50% of the total forage present (Beaty et al. 1978a) and forage digestibility late in the season is likely to be low. Up to 50% of the grass tillers present in the spring may die by July (Dobson et al. 1978). Dead tillers combined with the remains of expired phytomers, leaf sheaths, blades, etc., constitute up to 75% of the forage present in June or later.

Forage Consumption and Digestion

The practical significance of the forage intake and digestibility parameters on beef cow performance becomes evident when we consider that a 500 kg beef cow consuming 70% digestible green grass leaves would eat 3% of her body weight in dry forage/day and consume 10.5 kg of TDN (Beaty et al. 1978a). If the leaves were dead and 42% digestible and she consumed 3% of her body weight, her TDN intake would be 6.3 kg/day or 40% less than with green leaves. If the forage was 50% stems of 37% digestibility (Hanna et al. 1976) and intake is reduced $\frac{1}{3}$ to 2% of body weight/day (Reid et al. 1959) with a total intake of 10 kg of dry forage/day, then the 5 kg of leaves would provide 3.75 kg of TDN and 5 kg of stems would provide 1.85 kg for a total TDN intake of 5.6 kg TDN/day. Dead leaves would provide 60% and the leaf-stem mix 53% of the TDN provided by the green leaves. Should available forage become higher in dead leaves and/or stems than assumed in these examples, intake, digestibility and TDN intake would become further reduced. In Bermudagrass field saved in October and November, translocation of soluble nutrients from leaves to rhizomes and stolons may well explain the weight losses of cows in autumn (McCormick, unpublished data). Young cattle, depending on age and size, have less intake capacity than cows and will consume 1.5 to 2.5% of their weight in forage dry matter/day. High forage intake and digestibility are more important in young cattle than with beef cows as young cattle generally have higher energy requirements for growth.

Grass Growth

Growth in grasses is by the production of phytomers (Evans and Grover 1940). Each grass phytomer is composed of a leaf blade, leaf sheath, node, internode, axillary bud, and sometimes an adventitious root. A series of phytomers makes up the shoot. Growing a grass leaf requires that the leaf sheath, node, and internode be produced also. Forage improvement requires increasing the leaf and leaf sheath content and decreasing the amount of node and internode. Initial growth of a

grass shoot, whether as a seedling or as a tiller (growing point), involves the initiation of a number of leaves, entire phytomers, in a rosette from a growing point at the first node at the base of the grass shoot (Evans and Grover 1940). The first node of the shoot is generally at or near the soil surface. If the shoot remains vegetative, internodes are frequently short, 1 to 3 mm long, and new phytomers are produced at a frequency characteristic of the species. Individual phytomers vary widely in age on a given shoot and new phytomers may be produced season long on vegetative tillers produced by such species as tall fescue and bahiagrass. In bahiagrass, 20 to 22 leaves/tiller will be produced during a season and tillers may live for a number of seasons (Beaty et al. 1977a). In tall fescue the leaf rosette appears as a bud on a shoot or rhizome near the soil surface and new leaf generation rate appears to be related to defoliation frequency (Silsbury 1970). New leaves have been shown to be initiated as often as one each 3 weeks or as far apart as 70 days (Silsbury 1970). As in bahiagrass, most tall fescue tillers remain vegetative until they die, as only 10 to 18% become reproductive and form flowering culms (Bahrani, J. Ph.D Diss. Univ. of Georgia 1976). Another widely grown forage grass in the South, Bermudagrass, produces horizontally growing stolons and rhizomes, which are vegetative tillers; but most forage is produced on vertically growing reproductive tillers, and phytomers on a flowering culm (shoot) are essentially all of the same age. The reproductive tillers of Bermudagrass usually originate from axillary buds on a stolon or rhizome. Eight to 12 phytomers form the initial leaf rosette with the base attached to a stolon or rhizome near the soil surface and leaf expansion continues for 3 to 4 weeks. As leaf expansion slows down, internode elongation is active for 7 to 10 days at which time the stems (flowering culms) supporting the inflorescence (seed-head) are up to 40 cm high. The terminal phytomer on a reproductive grass tiller forms the inflorescence. The stems formed by the elongated internodes support initially the inflorescence and later the seeds produced. Secondary thickened and lignified stem cells resist weathering and increase the chances that seeds produced will be held above the soil and not come into contact with the soil. Germination during the summer of production, when competition from established plants is high, thus will be prevented. Delaying contact of the seed with the soil until late fall or winter prevents seed germination until the following spring, when competition for the seedling is less and growing conditions are more favorable. The thickened and lignified stem cells probably also resist plant decomposition. The thicker stem cells resist the changes in specific gravity required to pass through the rumen, and concentrations of the more easily digested solubles in forage stems are also low. Thus far no laboratory procedure to measure resistance of a stem to density change is known. Forages high in stem content would be expected to be lower in quality than forages high in leaf content.

In some native perennial species, new tillers are produced in late summer and early fall. The next spring, the young tiller produces a number of phytomers with short internodes near the soil surface early in the season. A flowering culm with long internodes terminates the tiller, which is normally mature before the onset of dry weather. Few new tillers initiate growth until the following fall, when the next crop of tillers is initiated. Such a growth pattern enables the plant to be, in essence, dormant during periods of moisture stress.

Leaf Growth

Leaf growth on vegetative tillers of tall fescue or bahiagrass

following defoliation consists initially of continued elongation of an immature leaf present at time of clipping. One to 3 weeks later, a new leaf, evidenced by a pointed tip, emerges and elongates. At 5 to 6 weeks after clipping, a second new leaf has emerged. Thus, following clipping, leaf growth appears to be initially from elongation of a leaf expanding when clipped. The first new leaf starts growing near the time that elongation in the clipped leaf is terminating. When clipped at heights of 2 cm, continued elongation of expanding leaves suggests that the leaf growing point is near the soil surface. The leaf expanding at time of clipping provides energy for its own expansion and photosynthate exports for new leaf growth. Thus, the leaf elongating at time of clipping and stored energy reserves appear to provide energy needed for survival of the tiller (Beaty et al. 1979). In tall fescue, by the time two to five green leaves are present, an old one dies. Thus, leaf emergence and growth rates are characteristic of a species and cannot be generalized over several species.

Data Limitations in Forage Research

In traditional forage production research, yields are obtained by clipping at a height determined by the mowing machine used. Chemical composition and quality analysis are frequently completed on a composite of the forage collected. Data collected by mowing reflect only the segment of forage harvested, that growing above the cutter bar, and in low growing grasses large amounts of forage are located in the first 7 to 10 cm above the soil level. Forage samples are analyzed largely without regard to the amounts of leaf, sheath, and stem, living or dead in the sward as a whole, as the components themselves are not often analyzed separately. It is suspected that forage composition data obtained are directly related to the ratio among these phytomer components. Digestibility of green and dead forage components appears to be characteristic and animal gains should be predictable by ratios of each available for grazing. Decreases in quality of forage harvested after May reported by Reid et al. (1959) could well be explained by increases in stem production or dead leaf accumulation. Variations between leaf:stem and green:dead ratios in forages harvested for analysis and forages actually grazed may account for the poor correlation between forage chemical analysis and animal gains. Green leaves produced in August are probably as nutritious as those produced earlier, but accumulations of dead leaves and stems lower quality of the total forage mass.

Present clipping procedures of frequency and height of defoliation at 6 to 8 cm may be adequate to estimate yields of forages with reproductive tillers (stems) but have been demonstrated to underestimate forage production at low levels of N application on low growing vegetative tillers such as tall fescue and bahiagrass (Beaty et al. 1979; Ethredge et al. 1973). A forage harvested at a height of 6 to 7 cm shows variations in forage N concentrations with season that are not present when the entire forage canopy is included by harvesting closer to ground level (Beaty et al. 1979). Logically, forage research should include quality measurement data of the entire sward on a level of significance with yield. It is believed that by maintaining green, leafy forage for grazing (uniform in chemical composition), rate of intake and digestibility by cattle can be predicted. Scientific technology is presently available which should allow inclusion of both yield and quality estimates in models.

Yields are usually determined on relatively large areas and forage samples obtained are bulky and mixed, and the bottom 7 to 8 cm segment of the sward may not be represented. A forage sample from a 225 cm² (15 × 15 cm) area, collected at a height of 0 to 1 cm with tall fescue, bahiagrass, or Bermudagrass will provide a 5- to 10-gram sample and is generally adequate for separating into green/dead and leaf/stem components. Chemical analyses require varying quantities of sample, and the area harvested should reflect the number of analyses and quantity of the component in the sward. Samples may be dried, stored, and processed later. If specific forage component or composition data are not needed, samples need not be processed.

One of the major sources of economic loss and research deficiencies is forage produced but allowed to die before harvest. Leaf fall is a problem of major importance in grasses with primarily vegetative tillers (Hunt 1971). Time of, cause, and extent of leaf fall should be documented at the time yield data are obtained. The second factor influencing forage quality, stem production, and time and rate of accumulation would appear to be predictable within a cultivar and once established would become a constant. Stem production could well be more critical in areas growing grass species that produce large quantities of reproductive shoots (long internodes). Forage stem content in species such as tall fescue or bahiagrass can be reduced by scheduling clipping at the time flowering culm growth becomes active. Clipping the stems at a height of 3 cm or less eliminates their influence in the pasture. When grasses high in stem content are harvested, percent stem would be useful data in evaluating nutritional quality of the forage.

As pointed out by Beaty et al. (1978a), a major source of variation in chemical concentration data from forage samples is due to the green: dead and leaf: stem ratio, since each fraction appears to have a characteristic concentration. Such green: dead and leaf: stem ratios vary widely over a year (Beaty et al. 1978a) and with different management practices (unreported data). Nutrient concentration within a given fraction, e.g., N concentration of green leaves or dead leaves, probably varies as little as 10% over a season (Beaty et al. 1979). Including data on green: dead and leaf: stem ratios to soil level would be helpful in interpreting the yield data, as would analyzing samples of green and dead forage. Dead forage in a sward represents a loss in quantity and quality and is an indication of harvest efficiency.

Large Forage Yields

Large forage yields appear to be favored by reproductive tillers where full leaf canopies are allowed to reach full expansion and for several weeks are able to export photosynthates to sinks located in the secondary walls of cells in the growing and thickening stems. In contrast, leaves on vegetative tillers, because of continued production of new leaves, become shaded and die. Vegetative tillers with their leaf growing point close to the soil surface need defoliation regimes to prevent young leaves from shading older leaves. Such clipping schedules might be expected to produce a lower yield but forage produced when harvested green should be low in stem and would be nutritionally higher in quality (Beaty et al. 1978a) and in digestible nutrients. In yield determinations, a low clipping height is more critical in low growing forages with vegetative tillers than in reproductive tillers where stems, long internodes, increase height of the shoot growth.

In areas where multispecific pastures are desired, harvesting leaves before they die will keep major species green and, by

eliminating dead leaf accumulation, will open the sod up to invader species when growing tall fescue or the low-growing common Bermudagrass (Dobson et al. 1978). Most attempts to introduce invader species into bahiagrass have not been successful. However, the difficulty of species integration is thought to be control of the soil nutrient fertility by bahiagrass rather than shading.

Forage yield in native grasses is probably highly related to tillers area. Tillering is probably related to N concentration and energy content in the basal axillary buds in mid to late summer when new tillers, which grow the following year are being initiated.

Tillering

Time of tillering has relevance in establishing season of forage production. However, tillering in Bermudagrass can be initiated by N application throughout the spring and summer and tiller numbers in tall fescue can be increased by controlling shading and time of N application (Dobson et al. 1978). In contrast, bahiagrass will produce tillers all season, but young tillers produced during the summer die from competition from older tillers and make little or no contribution to forage production (Beaty et al. 1977a). In bahiagrass, tillers should be produced early in the spring. Further research into time of tiller initiation and length of tiller life should make management of tame pastures more effective in establishing forage production and increasing utilization. Factors affecting time and number of tillers produced by native perennial grasses have not been extensively investigated. It is believed that availability of such data will improve significantly the forage energy contribution of the range resource.

Managing Annual Grasses

Annual grasses have exclusively reproductive tillers and management maintenance of highly digestible forage particularly in sods has not been extensively investigated. In tall growing annuals, separating and weighing stems is relatively easy as stems make up a major portion of the forage produced. Evaluating quality of forage produced is difficult as stem content varies widely over short periods of time. In the Southeast, stems that are produced by annual grasses are usually mowed and left to decay.

Species Management for Forage Quality

Maintaining a given type of tissue in a pasture (e.g., green leaves, stems) is dependent upon species and techniques for eliminating the casual factors of leaf death, and stem growth is highly species specific. Leaves die primarily from being shaded by young leaves (Beaty et al. 1978a) and old age (Sampaio et al. 1976). Old leaves tend to die at time of temperature or moisture stress, and high defoliation height (Beaty et al. 1978a) increases the amount of loss. Elimination of dead leaves from the sward appears to be relatively simple in some cultivars and can frequently be corrected by clipping mature leaves at a height of 2 to 3 cm while still green but before start of hot or dry weather. In the South, delaying N application to late spring or summer will reduce rate of leaf growth in the early spring and reduce shading later.

Maintaining green forage in the first 7 cm of the sward on vegetative tillers requires that old forage be removed near the growing point by mechanical clipping or grazing before it dies. Bahiagrass leaves grow at the soil surface and live for 55 to 60

days (Sampaio and Beaty 1976). Tall fescue has a similar growth habit, and maintaining green forage would require defoliating at a height of 2-3 cm for 2 to 3 times during the season. A similar defoliation schedule would probably be required to maintain a green sward in bahiagrass.

Maintaining green leaves in place of stems on reproductive Bermudagrass tillers, and particularly the giant Bermudagrasses, requires that stems be removed at a stubble height of 2 to 3 cm approximately each 4 weeks, after leaf growth is complete, and replaced by new leaf-bearing tillers. Some native perennial forage plants such as switchgrass, *Panicum virgatum* L., produce one major crop of reproductive tillers each year, and maintaining green leaves season long will probably be difficult (Beaty et al. 1978b) as stem growth dominates several weeks each season. Following removal of the growing points of the initial crop of tillers, few new tillers are initiated that season; and if the original shoot is allowed to grow season long, a stem will be produced by each tiller.

Production of one major crop of tillers/season by native grasses is thought to be a drought evading mechanism as most shoot growth is completed before the onset of dry weather. Seasonality of forage production by native grasses might well be lengthened by introducing or developing cultivars that produce more than one crop of tillers/season. Stands of such a potential cultivar might be more susceptible to drought, however.

Drought damage to stands of tall fescue in the lower South appears to be related to continued leaf development season long and the lack of dormancy mechanism in existing cultivars. Inclusion of a dormancy mechanism into otherwise adapted cultivars could be expected to expand the region of tall fescue growth further south.

Discussion

Maintaining a forage high in digestibility would appear to consist of harvesting leaves before they die; harvesting should be near the growing point to prevent a buildup of dead leaf sheaths (Beaty et al. 1978a). In tall fescue and bahiagrass, harvest or grazing height can be less than 2 cm, and maintenance of green leaves in the sward requires that it be defoliated back to that height to prevent leaf death (Hunt 1971). Harvesting temperate and tropical growing plants at a height of 6 to 7 cm in high forage producing areas allows an accumulation of dead phytomer parts low in solubles.

Loss of forage quality due to stem accumulation in tall fescue and bahiagrass is not a major problem, as only 10 to 20% of tillers produce flowering culms (Beaty et al. 1977a) and reproduction is concentrated in a 30- to 45-day period. Stems may be eliminated from bahiagrass and tall fescue pastures by mowing at a height of 2-4 cm soon after flowering culm elongation starts. Stem production becomes a major problem in a species where leaf production season long is on reproductive tillers such as in Bermudagrass or native perennial grasses. After the rosette of leaf growth on the shoot (tiller) is completed, new leaf growth requires that stem production be terminated and another series of tillers initiated. These new tillers come from basal axillary buds. In Bermudagrass production, high forage quality has traditionally been by mowing at a frequency of 3 to 4 weeks at the time of initiation of internode elongation in the reproductive tillers and following stem growth. N is applied in multiple applications each season; a N application precedes each new crop of tillers initiated. In Bermudagrass forage production, as in tall fescue or bahiagrass production, clipping close to the soil prevents the buildup of a stubble of dead stems

and leaves, which serves no useful function (Beaty et al. 1977a; Beaty et al. 1979; Ethridge et al. 1973) as new growth is initiated at the soil surface.

In areas having long growing season, time of N application has forage quality implications in that applications made early in the spring will stimulate increased numbers of tillers to grow at a time of favorable vegetative growth (Dobson et al. 1978). By mid-June or July old growth on areas not grazed or mowed to be remove forage produced will be shading young or small tillers and lower leaves. When shaded, both tillers and leaves will die, resulting in forage being accumulated that is a mixture of green and dead (Dobson et al. 1978). The green forage will be on top; and unless the forage is sampled to the soil level, the dead forage will not be included in forage yields or chemical analysis. By late summer and early fall, green vegetative growth slows because of dead tillers and old leaves. Livestock will be forced to consume the forage produced early in the spring that has died and is low in digestibility (Beaty et al. 1978a). Under long grazing seasons in the South, ongoing research by Beaty and others suggests that by delaying N application from early spring, a time of rapid vegetative growth, until mid-summer, when rate of growth slows, high forage quality, green forage, can be maintained on a pasture into the fall. High forage quality can also be maintained by mowing, provided old forage is removed and young green growth is encouraged.

Traditionally, forage research has tended to maximize the production of a single species. Treatments applied were those that maintained the species and discouraged invader species by shading out the seedlings (Dobson et al. 1978). Shading that eliminated germinating seedlings frequently was from leaves that died from shading themselves and should have been removed earlier. Management treatments that prevent shading of different ages of plants or plant parts would appear to be essential for the production of high quality pastures.

Comparing forage production and quality maintenance practices between grass species is hazardous, as the quantity of component parts of the shoot, leaves, leaf sheaths and stems produced differ among species. Quantity of each component produced will change digestibility of the forage mass produced. Comparing digestibility of bahiagrass leaves with digestibility of tall fescue or Bermudagrass leaves would appear to offer considerably more promise than comparing digestibility of leaf production in tall fescue with digestibility of the leaf and stem mass produced by Bermudagrass or switchgrass. Comparing digestibility of green leaves of one species with green leaves of another species would appear to be more biologically repeatable than comparing a random sample of green and dead leaves, leaf sheaths, and stems with a random sample of the same components produced by a second species known to have a different growth regime. Once the digestibility and intake of the components of a species have been established, managing a pasture to maintain that component would appear to be primarily tiller management.

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