Managing the Forage Field for Quality, Persistence, and Yield

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Introduction

Deciding when to harvest or graze forages is anything but simple. As with many things in life, a compromise is necessary to optimize yield and forage quality, while maintaining acceptable plant persistence. Understanding how forage plants tolerate stresses like mowing, insects, winter, and heat can be useful in designing management strategies that meet the yield and forage quality goals of individual producers. A key factor that determines stress tolerance of forages, and whether they will regrow after mowing and/or persist is the level of reserve carbohydrate stored in roots and other protected organs. Understanding how environment and management (including mis-management) affect reserve accumulation and use is a key success factor in forage management.

Energy Reserves: Providing Energy and Substrates for Survival and Regrowth

Forage plants survive the incredible stress caused by near-complete defoliation in part because they store large quantities of sugars, starches, and proteins in specialized storage organs. In forage legumes like alfalfa, this includes a large taproot and a well-developed crown (Fig. 1).

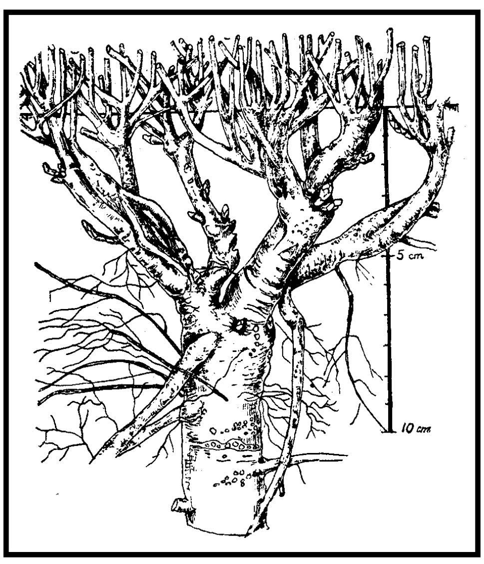

Figure 1. Below-ground organs of a forage legume showing the crown and large taproot where starch, sugars, and proteins accumulate.

In grasses, a great variety of storage organs exist, including rhizomes (underground stems), stolons (aboveground horizontal stems), crowns, and stem bases (2 to 3 inches of plant tissue immediately above the soil surface) (Fig. 2).

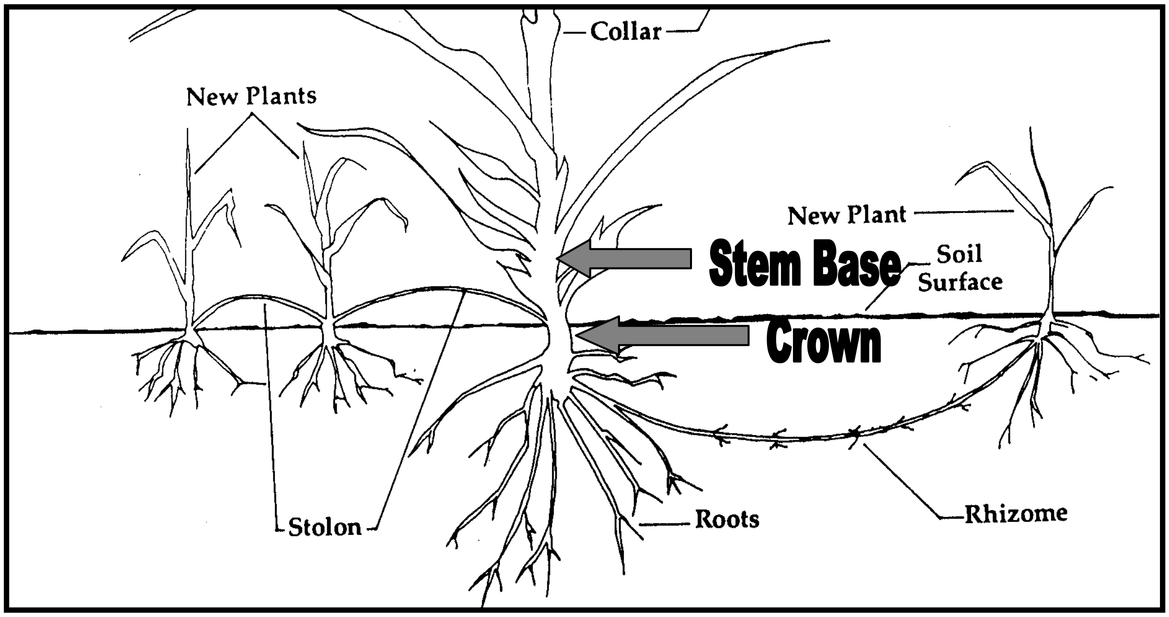

Figure 2. Schematic of a forage grass showing the specialized storage organs where energy reserves accumulate.

While all grasses have stem bases and crowns, not all grasses possess stolons and rhizomes. Kentucky bluegrass, bromegrass and reed canarygrass all have well-developed rhizomes, and as a results, form dense sods. Tall fescue has very short rhizomes, whereas rhizomes are not found on orchardgrass and timothy. This absence limits the ability of orchardgrass, timothy, and to a certain extent, tall fescue, to fill in open areas in a hay field or pasture. Bermudagrass has both rhizomes and stolons, aiding the persistence of this warm-season grass. Close grazing or cutting may remove or damage stolons and stem bases, and reduce the availability of stored energy reserves. This can limit forage regrowth, and result in poor persistence.

These storage organs can amass large amounts of sugar, starch, and protein that supplement traditional sources of carbohydrate (photosynthesis) and nutrients (root mineral uptake) after harvest. Stored energy reserves are used to support initial growth in spring and regrowth after harvest (Fig. 3); times when photosynthesis and nutrient uptake are impaired or very low. Alfalfa and red clover exhibit a similar pattern of root energy use after harvest. Root reserves decline for 2 to 3 weeks after harvest, then increase rapidly during Weeks 3 and 4. The high levels of root reserves present at Week 4 and beyond permit alfalfa and red clover to tolerate another harvest. Close cutting near the surface of the soil is tolerated in these species whenever root reserve levels are high. By comparison, birdsfoot trefoil does not accumulate large amounts of energy reserves in roots in summer (Fig. 3). Therefore, it must be grazed no closer than 4 inches. This ensures that sufficient leaf area remains on the stem bases to permit photosynthesis to continue. Permitting close grazing of trefoil is one of the primary reasons for poor persistence of this species.

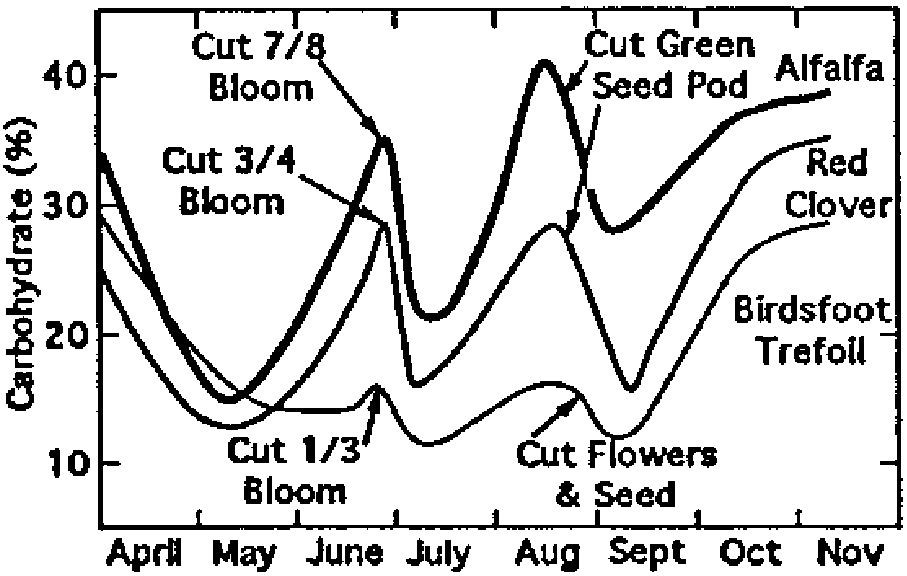

Figure 3. Use of stored carbohydrate in roots to support initial spring growth and regrowth after harvest of alfalfa, red clover and birdsfoot trefoil.

Improved Forage Management Based on Energy Reserve Information

Reserve status of forage plants controls many plant responses to stress and management. What follows are a series of examples that highlight the role of stored reserves in stress tolerance and persistence of forages.

High Temperature Stress Tolerance and Carbohydrate Reserves.

High temperatures reduce sugar synthesis in leaves via photosynthesis, and increase the rate of sugar utilization in dark respiration. This results in very low stored reserve levels in cool-season forages, and makes them intolerant of hot environments.

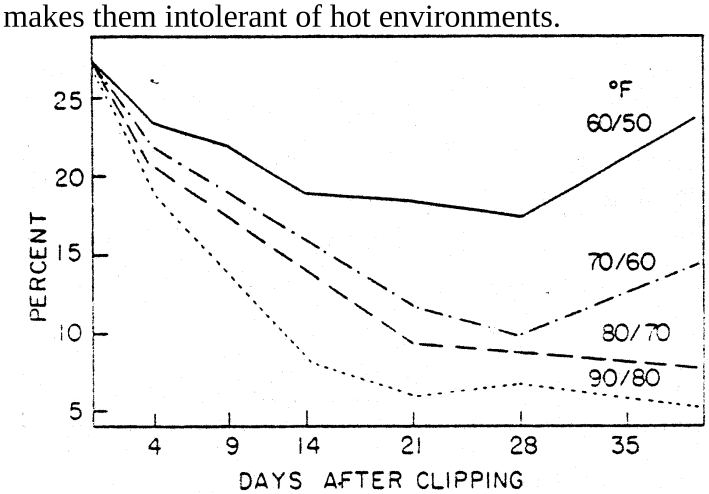

Figure 4. Influence of temperature on carbohydrate reserve levels in perennial ryegrass.

A good example of this is ryegrass, a forage species that thrives in the cool, moist climate of the United Kingdom, but has poor summer growth and does not persist in the Midwest USA. When ryegrass is grown in a cool (60°/50°F) environment, it uses its stored carbohydrate reserves for about three weeks after clipping to regenerate new herbage, and then restores its reserves during Weeks 4 and 5 (Fig. 4). Compare this pattern of reserve use/restoration to that when ryegrass is grown in warm (80°/70°F) and hot (90°/80°F) environments. At high temperatures, reserves are used faster (higher dark respiration), are depleted to very low levels within three weeks. During Weeks 4 and 5 reserves are not restored, and if harvested again for forage on Day 35 these plants would probably die because of low reserve levels.

Winter Hardiness, Fall Cutting Management, and Reserve Accumulation.

Fall cutting management can influence reserve levels and subsequence winter hardiness of forages, especially legumes. In Indiana, it is recommended that producers take their last forage harvest by mid-September. This permits ample time (about 6 weeks is needed) for forages to regrow and store the reserves necessary for winter survival prior to a hard freeze that kills the shoots and stops root reserve accumulation. Harvesting in late September or October often reduces reserve levels of overwintering organs, and can enhance winter injury and, in some instances, result in complete stand loss. To illustrate this, sweetclover grown in Wisconsin was harvested several times in late summer through early fall, and the impact on root carbohydrate reserve levels measured (Fig. 5). Plants cut on August 16 and September 2 had time for herbage to regrow post-mowing, and to restore root reserves. Plants cut on October 18 after the killing freeze did not regrow, so they did not use their stored reserves. All of these cutting treatments went into winter with high root reserve levels near 40% of dry wt. Plants cut on September 18 began to regrow, but a freeze in early October killed the shoots before reserves were completely restored. These plants went into winter with low reserve levels and are at risk of injury or death.

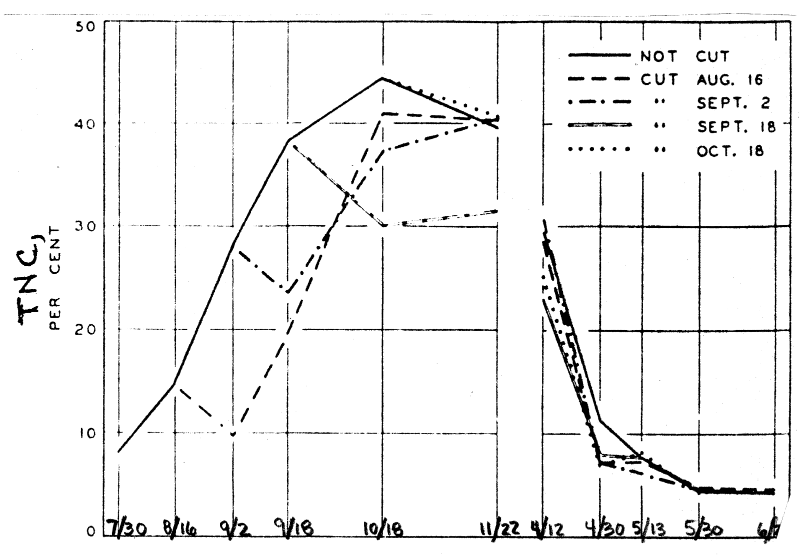

Figure 5. Influence of fall cutting management on concentration of total nonstructural carbohydrates (TNC) in taproots of sweetclover.

Fall cutting management also has been studied extensively in alfalfa, and these results (Table 1) confirm the deleterious effects of fall cutting on depletion of stored reserves in autumn and the accompanying poor winter survival.

Table 1. Influence of fall harvest management on first cut yield of alfalfa the following year. Data are from Michigan.

Treatment	Average of 11 Alfalfa Cultivars
Not Cut in Fall	100
Cut Sept. 1	88
Cut Sept. 15	67
Cut Oct. 1	84
Cut Oct. 15	93
Cut Nov. 1	98
Cut Nov. 15	103

Alfalfa cut in mid-September in Michigan (equivalent to early October in Indiana) incurred the greatest reduction in forage yield the following spring. Plants left uncut, or harvested in early September or November exhibited little winter injury and had high forage yields.

Forage Fertilization, Winter Hardiness, and Reserve Accumulation.

In addition to being important for high forage yields in summer, adequate fertility results in low rates of sugar synthesis in leaves via photosynthesis, and often reduces the accumulation of reserves in storage organs. Because reserves are used as a source of energy for initial shoot regrowth after mowing (Fig. 3), herbage regrowth rates and yield of subsequent cuttings also can be reduced. Furthermore, low soil fertility can result in low reserves as plants (especially legumes) acclimate for winter, and can reduce winter hardiness. For alfalfa, potassium (K) is a key nutrient associated with winter survival. Potassium-deprived plants often suffer higher rates of winter injury, especially if producers are using aggressive cutting management (Table 2).

Table 2. Impact of potassium fertilizer rates on forage yield averaged over three years for alfalfa harvested 3 or 4 times annually and on percent stand in spring of Year 4.

K Rate, lbs/A	Yield - 3 cuts	Yield - 4 cuts	Stand - 3 cuts	Stand - 4 cuts
0	3.0	2.8	47	24
50	3.6	3.5	64	35
100	3.8	3.7	79	55
200	4.0	4.0	85	66
400	4.3	4.2	93	81
600	4.5	4.3	95	84

Plants that are provided at least 200 lbs. K/A had good stands and high forage yield in spring, even when cut four times during the growing season. Unfertilized stands had lost half to three-fourths of the plants by Year 4, and incurred a severe reduction in forage yield. Split applications of K (and P), with one-half applied after Harvest 1 in May, and the rest applied in September after the last forage harvest improves the efficiency of nutrient use by forages by minimizing luxury consumption.

Compatible Forage Mixtures and Reserve Accumulation.

When combining species into a forage mixture, it is essential to select species that use and restore their reserves in synchrony with each other. Plants like alfalfa and orchardgrass begin growth together in spring, and use and restore their reserves in a near-identical pattern. As a result, these species combine to make a compatible mixture. This is not true of many forage combinations. For example, timothy and bromegrass have reserve accumulation patterns that are not in synch (Fig. 6). This makes it nearly impossible to effectively manage a timothy-brome mixture because when timothy has high reserve levels in mid-June and is ready to cut, brome has low reserve levels and will be injured or killed by mowing. Waiting until July to mow the stand when bromegrass has high reserve levels means that the timothy forage is very mature, with poor forage quality.

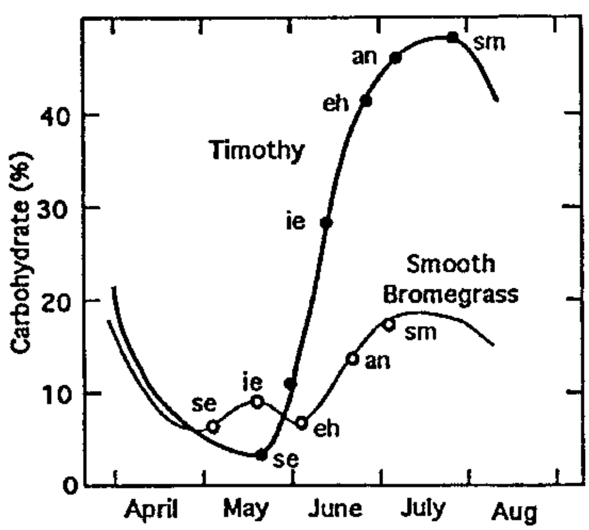

Figure 6. Carbohydrate reserve levels in stem bases of timothy and smooth bromegrass as a function of development beginning in April and extending through July. Stages of plant growth are indicated as follows: se=stem elongation; ie=inflorescence emergence; eh=early heading; an=anthesis (pollen shed); sm=seed mature.

Managing for Improved Forage Quality - A Compromise with Yield and Persistence

So far we have focused on changes in energy reserves that occur after harvest, however, large changes in yield and forage quality also occur during forage regrowth after harvest. As yield increases there is a marked shift in leaf:stem ratio, from high values (very leafy forage) initially to ratios less than 1 where stems dominate the forage (Fig. 4). This transition occurs about Week 4 (Fig. 4, Harvest 7 to 8) as plants begin to flower. Leaf production is essentially complete by the end of Week 5 (Fig. 4, Harvest Interval). Thereafter, increased yield is due almost entirely to accumulation of stem dry matter.

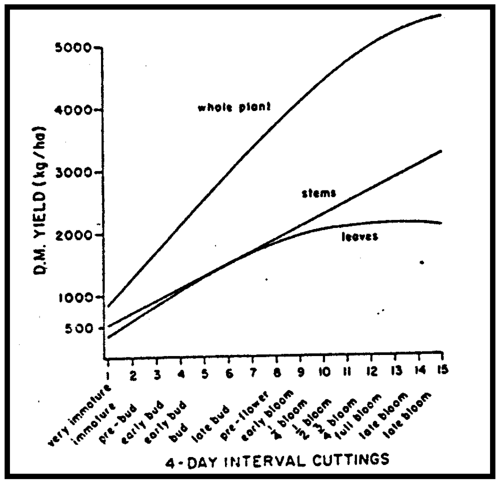

Figure 7. Increase in leaf, stem, and total forage yield of regrowing alfalfa sampled at 4-day intervals after harvest.

During the earliest stages of regrowth, digestibility of stems and leaves are nearly equal (Fig. 6). While leaves maintain this very high level of digestibility through regrowth, stem digestibility declines rapidly with maturity. To maximize forage quality, producers should be harvesting before stems dominate the forage (Fig. 7, Harvest Interval 7), and prior to the extensive decline in stem digestibility (Fig. 8). However, this typically is prior to the maximum accumulation of energy reserves in storage organs. As a result of early harvesting to maximize forage quality, slow regrowth and poor plant persistence may occur. If harvest is delayed until high levels of energy reserves accumulate, stems become the dominant component of the forage, and forage quality can decline to unacceptable levels.

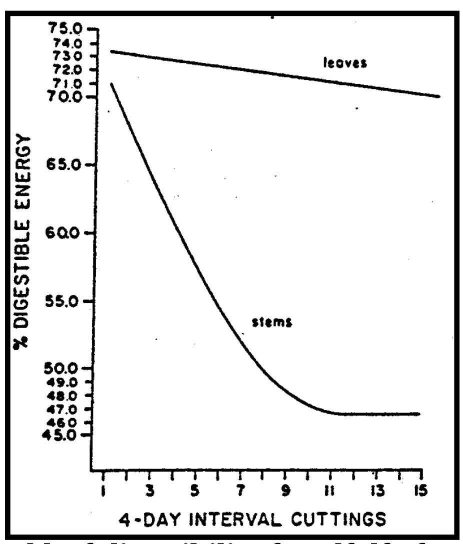

Figure 8. Changes in stem and leaf digestibility for alfalfa forage sampled at 4-day intervals after harvest.

Given these relationships, how can a compromise be attained between the high quality available from immature forage, and the high yield and persistence obtained by cutting late? One approach is to calculate yield of digestible nutrients per acre (yield x % digestibility or % protein) and compare these values as forage regrows after cutting. When this is done, maximum yield of protein (Fig. 9) and digestible nutrients per acre are obtained at first flower to 1/10th bloom in legumes or heading in grasses.

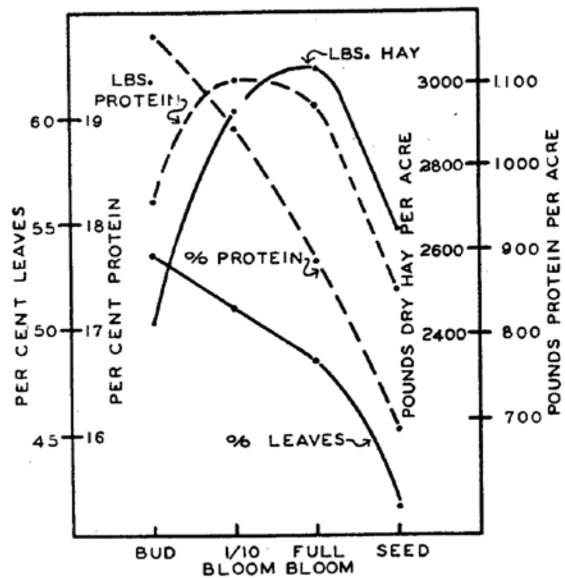

Figure 9. Changes in dry matter yield, leafiness, and forage protein (both concentration and protein per acre) of alfalfa forage during late regrowth.

Conclusions

Knowing the impact that management decisions have on stored reserves levels will improve agronomic performance of forages, both in terms of yield and persistence. Poor growth and persistence of forages often is caused by depletion of stored reserves, particularly under stressful conditions like heat, winter, or mowing. Understanding how plant morphology, and in particular leaf:stem ratio changes after harvest and its impact on forage quality also is key to successful forage management. Together, this information is essential for obtaining high yield, maintaining stands, and achieving forage quality objectives of producers.