



## Carbohydrate Reserve Theory: What You Learned Might Be Wrong

*Beth Burritt*, Department of Wildland Resources  
*Chad Reid*, Agricultural and Natural Resources Agent Iron County

For years, managers used the carbohydrate reserve theory to decide when to graze plants on rangelands to maintain healthy and desirable plants. The carbohydrate reserve theory states that the soluble carbohydrates stored in the roots and crowns of plants indicate plant health and ability to regrow after grazing. During the early vegetative stage of plant growth, carbohydrate “reserves” are low, so plants should not be grazed. During late vegetative and early reproductive stages of growth, carbohydrate “reserves” are higher, and plants can better tolerate grazing (see figure below). Over the years, researchers produced carbohydrate concentration curves for different grasses, forbs, and shrubs, like the one illustrated below.

Unfortunately, carbohydrate reserves in plants are not good indicators of its ability to regrow after grazing for several reasons:

1. Carbohydrates are typically measured as concentrations that change only a small amount during the year, but fluctuate widely throughout the day.
2. Concentrations don't reflect the total amount of carbohydrate available for regrowth. To accurately measure the total amount of carbohydrates, the concentration of soluble carbohydrates in different plant tissues (roots, crowns, leaves, stems) must be multiplied by the weight of those tissues. Most early studies only analyzed roots and crowns, but stems in grasses and forbs and twigs in shrubs are also important storage

sites for soluble carbohydrates.

3. Carbohydrate reserves, whether expressed as concentrations or as total amounts, are not correlated with the ability of a plant to regrow after grazing. The rate and amount a plant can regrow without light are also not correlated with either concentrations or total amounts of carbohydrate reserves stored in the roots or crowns of the plant (Richards and Caldwell, 1985).
4. The carbohydrate reserve stored by bunchgrasses is very small, equal to about 1 to 2 days of photosynthesis during the summer.

So, what factors are important for plants to tolerate grazing?

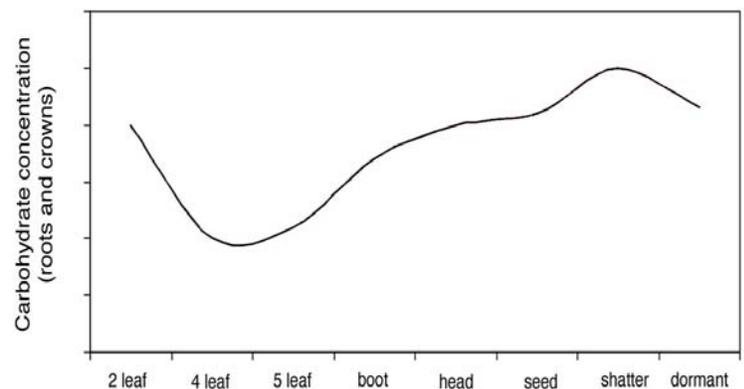
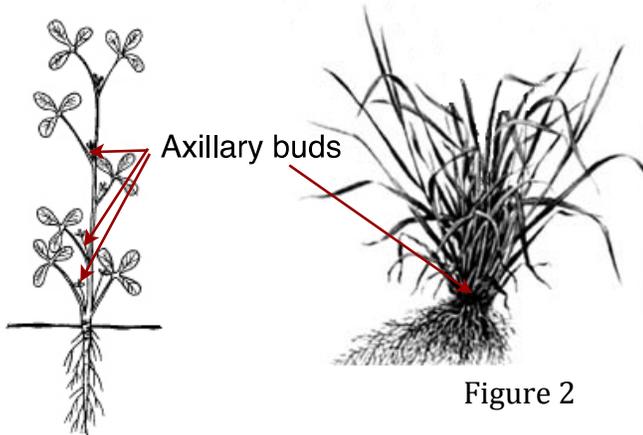


Figure 1.

**Plant structure.** Differences in structure enable some plants to better tolerate grazing (Briske and Richards, 1995).

1. Grasses, forbs, and shrubs that produce and maintain many viable axillary buds tolerate grazing because they have the potential to regrow following grazing (Figure 2).



2. Grasses, forbs, and shrubs that protect growing points (meristems) have the potential to regrow quickly following grazing, thus reducing the amount of nutrients and water needed to regrow. Some grasses and forbs do not elevate growing points until late in the growing season, protecting them from grazing.

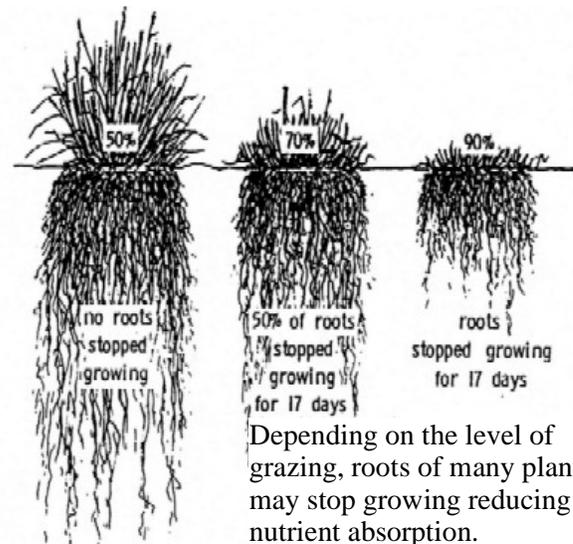
3. Grasses that develop new shoots at the same time during the grazing season are less tolerant of grazing compared to plants that develop new shoots at different times during the growing season because not all shoots can be grazed at the same time.

**Plant physiology.** Differences in physiology enable some plants to tolerate grazing better than others.

1. The ability to regrow quickly after grazing is important because it enables plants to quickly replace leaf tissue that produces energy through photosynthesis. Plants that regrow quickly often have increased photosynthetic rates in regrowth and the ungrazed portion of the plant (Caldwell et al. 1981).
2. A superior ability to compete for resources, water and nutrients, needed to quickly regrow enables some plants to tolerate grazing better than others (Mueggler, 1972).
3. In some plants, grazing stimulates absorption of nutrients, like phosphorus, which enables those species to tolerate grazing better than others. However, in

many species, removal of leaves and stems decreases nutrient absorption because of a decrease in the root surface area (figure below) (Caldwell et al. 1985).

4. Plants that quickly move resources among shoots or from roots to shoots tolerate grazing better than plants that do not. This enables rapid adjustment of carbon and nutrient distribution among plant parts, which enhances competitive ability and survival (Bilbrough and Richards 1993).



Depending on the level of grazing, roots of many plants may stop growing reducing nutrient absorption.

Figure 3.

So, what does this mean for managers? Using the carbohydrate reserve theory meant grazing was delayed until forage reached the boot stage of growth. This is the most detrimental time to graze plants in dry environments. When plants are grazed during the boot stage, growing points responsible for plant growth are removed and regrowth must occur from axillary buds at the base of the plant, a slow process that requires water and nutrients at a time when both are dwindling.

When is the best time to graze? Grazing early in the growing season does not damage plants on arid rangelands as much as once thought. However, repeatedly grazing plants during the growing season can seriously damage plants. Early in the season, cattle should be moved often to allow forage to regrow while soil moisture is still available. Grazing in the boot stage is unavoidable, but creating a grazing plan that keeps cattle from grazing the same areas year after year during boot will help keep perennial plants healthy. A simple deferred grazing

system can ensure plants are not grazed at the same time or stage of growth each year. Lastly, grazing after seed set is less likely to damaged rangeland plants because perennial grasses tend to be more tolerant to grazing at this stage of development.

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