



Chapter 52

Forage Plant Growth and Development

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Introduction

The growth and development of forage plants are two aspects that need to be considered for developing good management strategies to attain high production and high forage quality. Therefore, by understanding the mechanisms behind growth and development the forage producer can optimize production and utilization of forages in general. Plants' physiological responses to defoliation and subsequent forage growth potential are definitely affected by plant form, structure and overall plant developmental stage. Forage growth has been described as the process by which a plant increases in the number and size of leaves and stems. When leaves are removed from a grass or a legume, new leaves will develop and grow from buds on the crown or stems of the plant. This plant growth will require energy which comes from photosynthesis or from reserve carbohydrates in the form of sugars and starch. Understanding forage plant growth and development will allow producers to optimize pasture productivity and forage quality, while maintaining species botanical composition and persistence.

This chapter will focus on general aspects of the growth and regrowth of forage plants. More specifically, it will detail the development of plant structures, development of the root system, seedling development, role of meristems in tiller growth, and developmental stages of grasses and legumes (transition from vegetative to reproductive growth), all of which have direct effects on forage yield, forage quality, and stand longevity.

Differences between Plant Growth and Plant Development

Growth is defined as the increase of plant biomass, which varies over time and depends on the life cycle of the plant, environment, and management. Plant development, in contrast, is the passage through life cycle phases. For forage grasses, developmental phases involve (1) vegetative stage; (2) elongation stage; (3) boot stage; (4) heading stage; (5); Anthesis; and (6) seed ripening.

Development of Plant Structures Leaves

Grass leaves are borne on the stem and each leaf consists of a leaf sheath, leaf blade, ligule, and in some cases auricles. The sheath surrounds the stem above the node where it is attached. Its margin usually are overlapping (open), though in some species they are united (closed) into a cylinder for a part or all of the distance between the node and blade. When leaves are removed from a grass, new leaves will start to develop and grow from buds on the crown or stems of the plant. However, if the apical meristem (growing point) is not removed, leaves continue to be produced from the same meristem until flowering components are initiated in the meristem.

The development of a leaf blade will consist of leaf tissue initiation, elongation, and maturation of new cells. For a grass leaf, cell division, elongation, and maturation zones occur sequentially along the base of the new developing leaf. In general, the youngest leaf tissues are located at the leaf base and the oldest at the leaf tip.

Stems

Forage grass stems generally have two distinct forms; elongated stems (typically these are reproductive tillers but they could be elongated stems that regrow after cutting or grazing) and unelongated stems (which belong to tillers still in the vegetative stage). Usually, vegetative tillers tend to be short, consisting of nodes and un-elongated internodes. Therefore, reproductive tillers have elongated internodes and are typically longer than vegetative tillers. Vertical stems of most perennial grasses have thickened lower internodes that will form a crown, once both carbohydrates and proteins start to accumulate. The growth and development of axillary buds on lower nodes into the crown will start develop into new tillers, stolons, and rhizomes. The main purpose of having accumulation of carbohydrates stored in lower parts of the stem is to allow plants to persist through the winter season. In some grasses, like big bluestem and reed canarygrass, the axillary buds are located in leaf axils which may lead to production of aerial tillers.

Development of a Root System Root Growth

Roots determine the ability of the plant to take up nutrients and water from below ground and transport it to aboveground plant parts to facilitate the plant's growth during the growing season. Perennial plants use energy from photosynthesis and excess stored carbohydrate energy reserves to develop new root tissues. Roots serve as a storage location for carbohydrates, so plants that are healthy and have ideal conditions for carrying out photosynthesis will have excess carbohydrate available to place in nearby root tissues for storage and eventual use for root growth. Forage stands that have little or no leaf growth due to weather conditions, such as drought, or from continual excessive defoliation from heavy grazing will likely have little carbohydrate available from photosynthesis or storage, so root growth would be slow or stop.

Cool-season grasses have festucoid and warm-season grasses have panicoid seedling development. The coleoptile (sheath protecting the young shoot) from festucoid seed elongates from a greater seeding depth near the seed to reach the soil surface. Panicoid seeds develop a shorter coleoptile that forms closer to the soil surface. Adventitious roots, which are permanent roots and acquire water and nutrients for the seedling, develop at the base of the coleoptile, so cool-season grasses usually have more moisture available at this greater depth for the seedling to remain hydrated and alive. For this reason, cool-season grasses are generally easier to establish under sporadic rainfall than warm-season grasses. For example, blue gramma (panicoid type) is well adapted to the Great Plains and tends to emerge quickly when compared to cool-season grasses, but needs several rainfall periods to maintain shallow adventitious roots in adequate soil moisture for water and nutrient uptake. On the other hand, crested wheatgrass, with festucoid seedling emergence, is able to develop deeper adventitious roots in a quick manner.

Role of Meristems in Tiller Growth

Grass swards are composed of many plants, each of which is made up of interconnected tillers. Tillers of grasses arise from axillary buds present in the axis of lower leaves. As a result, tiller production per plant is controlled in part, by leaf production per plant, and by rhizome buds. Tiller production of grasses is also affected by nitrogen fertilization, especially in thin stands. When vegetative stands of grasses such as prairie cordgrass (*Spartina pectinata*) are thin, production can be increased with some nitrogen fertilization. However, when soil nitrogen is low, the first increment of nitrogen applied mainly stimulates tillering to cover the soil more completely and capture more light. With higher increments, the growth response shifts to increase leaf length and tiller weight. Understanding the meristems responsible for tillering and growth per tiller, and how they can be managed, are of major importance in forage production.

Das et al. (2004) found that tiller density was correlated with biomass production in grasses that are in spaced-plant nurseries and swards. This suggests a selection for increased tiller number per plant as an effective method for increasing biomass production and greater yields. Recent investigations have shown some of the interactions between tiller production and tiller mass in grasses such as switchgrass (Panicum virgatum) without nitrogen application (Boe and Beck, 2008; Boe and Lee, 2007; Boe, 2007; and Boe and Casler, 2005), but this information has not been determined for other grasses such as prairie cordgrass.

Phytomers

The basic repeating unit of growth of a grass tiller is the phytomer. Each phytomer consists of a node, an internode, a leaf sheath, a leaf blade, and an axillary bud. The node and axillary bud are at the lower part of the phytomer, and the sheath and blade are associated with the upper node. The internode is between the lower and upper nodes.

Vegetative tillers have an active shoot apex that initiates the phytomer components, and there is no internode elongation. Once induced to become reproductive, new phytomers cease to be produced, the shoot apex differentiates into an inflorescence (i.e. the "flower" which will produce seed), and the intercalary meristems elongate the stem. (See Figure 1.) When a reproductive tiller is fully expanded, it has no more meristematic areas, meaning that it has reached its capacity for growth. As the seed matures, the reproductive tiller dies. The shoot apex initiates new leaves, as such it forms the phytomers in sequence and regulates the rate the grass plant grows or develops.



Figure 1: Developmental morphology of a grass. Source: Kothman M (2013). How plants grow. Texas A&M University.

Developmental Stages in Grasses

Grasses are often categorized by stage of development. By knowing these stages, producers can determine maturity, predict quality, and improve their management practices and recommendations. In summary, four main classes are used to describe growing stages of the grass plant:

- 1. **Vegetative stage:** involves unelongated tillers that are only producing leaves.
- 2. **Elongation stage:** internodes are starting to elongate and elevate shoot apices.
- 3. **Boot stage:** inflorescences are located in the sheaths of the flag leaf.
- 4. **Heading:** inflorescences start to emerge and to expand.
- 5. Anthesis: flowers are shedding pollen.
- 6. **Mature seed:** inflorescences are fully developed and seeds are ripe.

The vegetative stage involves a period mainly of leaf growth and development. Stems and internodes start to differentiate but do not elongate during this vegetative stage. Stem growth occurs in the elongation stage, the growth period between the vegetative stage and reproductive stage. The elongation of the stems and internodes occurs along with the differentiation of the shoot apex meristem (or main growing point) into the inflorescence. Importantly, Metcalfe and Nelson (1985) described several growth stages that also could be used for both grasses and legumes that are helpful to determine plant maturity when considering production and management strategies.

Late summer and fall management have a major effect on the productivity and survival of forage crops. The late growing season is a time for allowing root growth, new tiller development, and, most importantly, carbohydrate storage needed by the plant for energy over the winter and for initial new spring growth. Usually, good tiller development in the fall depends on (1) adequate energy reserves; (2) leaf area; (3) soil fertility; (4) soil moisture and (5) available light and the ratio of red light to far red light, indicative of the amount of shade provided by other plants.

Management Implications

A critical grassland management practice is to keep an eye on plant regrowth and location of the shoot apices, otherwise known as the main growing points, in the canopy of the plant. If a producer wants to focus on grazing, it may be better to remove (i.e., graze) tillers before stem elongation occurs and shoot apices are elevated. This will result in high quality forage, increase animal performance, and increase the possibility of regrowth. However, if forage preservation is the goal (i.e., hay production), cutting hay is often delayed until shoot apices are elevated and enter reproductive development. Depending on the weather conditions, delaying cutting until flowering or boot stage will increase tonnage or yield potential, but it will reduce forage quality.

Table 1: Morphological descriptors of growth stages for forage grasses and legumes.

Classification	Characteristic
Grasses	
First Growth	
Vegetative	Presence of leaves but stems are not elongated
Stem elongation	Stems start to elongate
Boot	Inflorescence enclosed in flag leaf sheath and not showing
Heading	Inflorescence emerging or emerged from flag leaf sheath
Anthesis	Flowering stage; anthers shedding pollen
Dough stage	Well-developed seed
Ripe seed	Seed ripe; leaves turn from yellow to brown color
Postripe seed	Some dead leaves
Stem-cured	Some cured on stem; seed mostly cast
Regrowth	
Vegetative	Leaves only; stems not elongated
Jointing (depending on the type of grass)	Green leaves and elongated stems
Late growth	Leaves and stems weathered

Summary

- 1. To maximize growth, plants need to maintain a point of high energy reserves before harvest.
- 2. The initiation, elongation and maturation of new cells are affected by defoliation, nitrogen stress, and water uptake.
- 3. Tiller production of grasses is also affected by nitrogen fertilization, especially in thin stands.
- 4. Tiller density is correlated with overall biomass production (yield) in grasses; especially those that are in spaced-nurseries and swards.
- 5. The selection for increased tiller number per plant is an effective method for increasing biomass production and to obtain greater yields.

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