# Chapter 2
# Limits to Plant Growth

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# 2 Limits to Plant Growth

## 2.1 Introduction

The growth of plants is the result of a sequence of complex steps starting with cell division and ending with the irreversible increase in size. Growth can be measured in many different ways but is generally measured either in terms of an increase in height or weight, although sometimes ground cover or density is the growth indicator. If measuring weight, pasture growth is more commonly expressed in terms of an increase in dry weight rather than fresh weight due to the variable moisture status.

For optimum pasture performance it is important to have an understanding of how the plant functions and responds to the various growth limiting factors.

Each factor, whether acting as an individual or interacting with another, can become the limiting factor to pasture or crop production. See “Law of the Limiting in Chapter 3.3.

Growth limiting factors could be classified according to internal or external factors including:

Internal
- Plant species or variety
- Plant growth hormones and regulators produced at different growth stages or maturity

External
- Water
- Nutrients
- Light
- Temperature
- Soil constraints
- Plant Disease and Insects
- Weeds

The external and internal factors do not act independent of each other, instead interacting in relationships that can be quite complex. The external factors will be discussed in this chapter.

## 2.2 Water

Water is an essential compound for so many plant functions; both at the cellular level and as a medium through which all biological substances move. Growing plants are not in equilibrium with their environment regarding water, as there is a continual gradient or upward movement of water from the soil solution to that lost from the above ground parts of plants.

The availability of soil moisture for root uptake and plant growth is such a basic requirement that practically all other plant functions will be impaired if soil moisture is lacking.

Soils hold and provide varying amounts of water to plants depending on many factors; for example texture and structure. The amount of water held in a soil varies with time and is called its water holding capacity (WHC) or soil moisture content. The soil’s water holding capacity is usually expressed as the millimetres of water per metre of soil depth or sometimes as a % of a cubic metre of soil.

Evaporation from the pores (stomates) chiefly in leaves; called transpiration, creates a large water deficit within the leaf. This deficit is replenished by soil water pulled up from the root system by the cohesion of water molecules or “transpirational pull”. Under normal or optimal soil/plant conditions, as the soil water is absorbed by the root system from the larger soil pores it is replenished. This situation is ideal for plant growth and is referred to as “field capacity”. If the soil moisture is not replenished, the plants root system will continue to extract soil moisture from the smaller soil pores until the point where the remaining soil moisture is so tightly held that it is no longer available. At this point there is not sufficient water available to meet the plants needs so the plant wilts. Plants can exhibit what is called a “temporary wilt” which can occur as a result of the heat of the day. From a temporary wilt the plant will recover in the evening or early morning. However if the situation progresses, the plants normal turgor does not recover and the leaves wilt and change colour. This point is called the “permanent wilting point”. For more information on soil water, refer to Chapter 4.2.4.

Both the water content of the soil and rainfall vary throughout the year and are not easily manipulated on dryland farms. In order to conserve soil moisture, a healthy soil with good internal drainage and a friable surface, will allow greater acceptance and storage of water than a compacted or sealed soil. Crops or pastures that are irrigated can achieve more consistent growth and production, as long as the extra nutrient demands for the increased dry matter production are met.

## 2.3 Nutrients

We must properly feed the pasture before the pasture can feed the dairy cows that graze it. Of all the elements occurring in the soil, only some will be required for plant growth, while others are essential for the animal’s growth (e.g. cobalt).

Plants require varying quantities of nutrients at various stage of growth and if any essential nutrient is not plant available when it is required plant growth can become limited. There are optimum levels of nutrient availability that should be met in the soil and plant for maximum pasture production. Understanding and managing plant nutrients for dairy production is the key focus of this manual.

## 2.4 Light

Adequate light (sunlight) is important for plant or pasture growth. Light is responsible for photosynthesis in green plants, whereby the green plant pigment – chlorophyll, allows the energy from the sun to be utilised with carbon dioxide and water to create carbohydrates – See Figure 2.1.

The photosynthesis process is a basic energy storage process that all plants and animals depend upon. Only a small proportion of the suns light energy (0.1 %) that reaches the pasture is converted into plant growth, with about half this energy being used for respiration. Ultimately the amount of growth made by a plant will be determined by the net rate of photosynthesis; which is the gross photosynthesis minus the respiration.

Management of the pastures growth is important so as to prevent rank growth and maximise the amount of light reaching fresh young leaves. Young leaves are more efficient in converting sunlight to plant growth than older leaves especially when older leaves are being shaded.

Employing good grazing management will ensure maximum light is available to the plants at all times. It will also ensure that energy, in the form of sugars and carbohydrates that are stored in the plant’s root system, are not depleted by overgrazing. Optimal stocking rates and grazing periods ensures that the plant has sufficient time to recover in between grazing cycles and prevents the depletion of reserves held in the plants roots, especially nutrients like phosphorus.

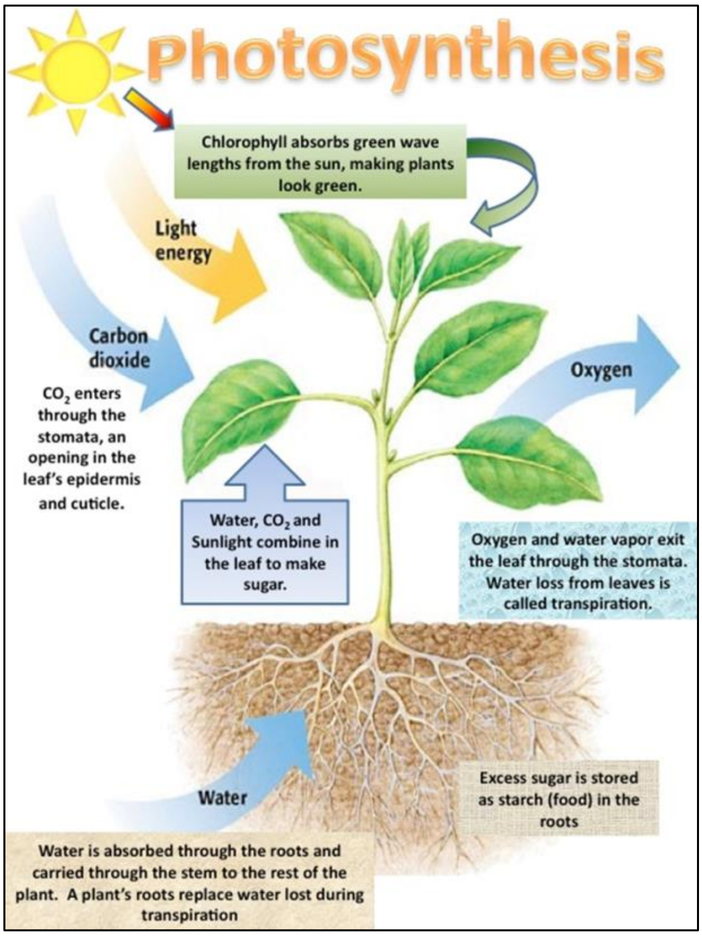


**Figure 2.1** Inputs and outputs of the Photosynthesis process
(*Source:* http://science6shms.pbworks.com/w/page/25870917/photosynthesis)

## 2.5 Temperature

The amount of heat that *reaches* the soil is initially influenced by what is held in the atmosphere (clouds, particles, pollution). The amount of heat that is actually *retained* in the soil is further influenced by ground cover, soil texture and colour.

Soil is quite resilient to marked fluctuations in soil temperature, with this fluctuation decreasing with soil depth. The pasture growth itself will also have a buffering effect on the soil temperature due to its absorption and release of heat. Temperature affects the growth of all pasture plants in many ways; from the weathering of the parent material to the growth rate of soil microorganisms. Generally, how plants respond to temperature relates to the part of the world in which they evolved. Ryegrass has an optimum temperature for growth of around 18°C, while white clover does not reach a maximum growth rate until the temperature has reached 25°C - see Figure 2.2. Paspalum and other tropical C4 grasses, also favour high temperatures. Hence, pastures tend to be ryegrass dominant through the winter, but the level of white clover and tropical C4 grasses often increases greatly in spring and summer.

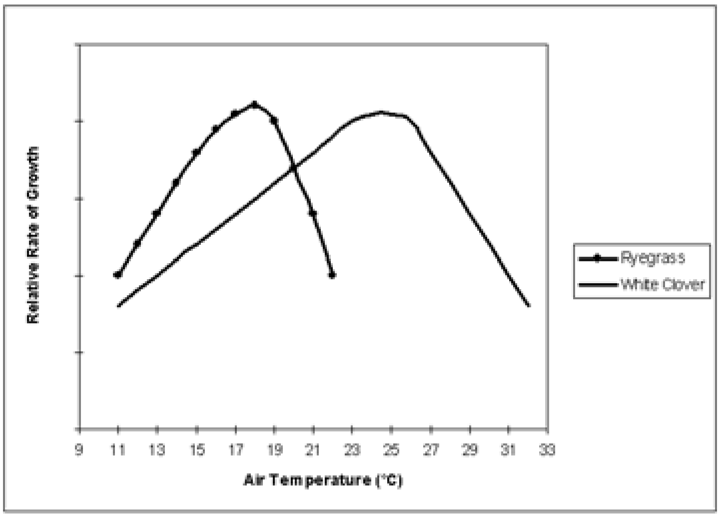


**Figure 2.2** Growth rate of ryegrass and white clover in response to temperature

Plants require a certain amount of accumulated heat from the sun in order to photosynthesis and produce carbohydrates for growth. Each stage of a plants growth, e.g. from emergence to first mainstem leaf or emergence to full flower, requires a certain accumulated amount of heat units per day to complete that part of its growth. The heat units are accumulated until reaching the *threshold temperature* (or *base temperature*) that a plant species requires for normal maintenance. Below the threshold temperature, the plant is in stress or shock and no growth occurs. The number of heat units required at each stage are called "**day degrees**". Weather conditions determine whether the day degrees accumulate over a short or longer period. Cool cloudy conditions mean less day degrees, thereby limiting pasture growth as seen from late autumn to early spring.

The formula for calculating day degrees is:

$$\text{Growing Day Degrees (GDD)} = \frac{\text{Daily max. temp °C} - \text{daily min. temp °C}}{2} - \text{Base Temperature °C}$$

The GDD number cannot be a negative; the number for that day would be carried forward as zero. The base temperatures for some common crops and pastures are shown in Table 2.1. Note that some temperate pasture species (e.g. White clover) grow very slowly at a base temperate of 4 - 5°C (*Hutchinson et al., 2000*).

**Table 2.1** The base temperatures of common crops and pastures.

| CROPS AND PASTURES | BASE TEMPERATURE (°C) |
|---|---|
| Corn, sorghum | 10°C |
| Temperate pasture species, ryegrass, oats, barley, rye, wheat | 5°C |

(Adapted from *Fraisse et al., 2012*, and *Hutchinson et al., 2000*)

## 2.6 Soil constraints

These can be any physical or chemical restriction to the normal root proliferation into the subsoil. Constraints can be naturally occuring; in the case of a dramatic change in layers or horizons, or as a result of pasture management in the case of pugging. Examples include a build up of chemical residues from herbicides; an increase in subsoil sodicity or salinity; an extreme soil pH - either acid or alkaline; a sudden physical change to soil structure due to compaction issues; nutrient imbalances - whether toxicities or deficiencies; or even just a lack of soil depth relative to the rooting depth of the pasture species.

Some soil constraints can be identified by soil testing, or a physical or visual examination. The constraint can often be minimised with the use of correct nutrition or the addition of soil ameliorants; be they organic (manures) or chemical (lime or gypsum). Managing soil constraints is covered in detail in Chapter 7.

## 2.7 Plant Disease and Insects

Pests and diseases can severely impact pastures and contribute to pasture rundown. Crops and pastures should be inspected regularly for pests as well as disease and deficiencies. A combination of biological, chemical and cultural control measures to control pests are considered the most effective and sustainable approach to addressing pest problems.

Insect pests and diseases affect pastures at all stages from germination of the seed (e.g. seedling blight or damping off disease caused by a fungus) through to the final leaf and stem (e.g. Rust on ryegrass, also caused by a fungus – see Figure 2.3).

**Figure 2.3** Pustules of crown rust on ryegrass leaves.
(*Source:* http://www.niab.com/news_and_events/article/159)

Diseases can cause a significant loss of pasture production as well as effect forage quality. A diseased plant will also be more susceptible to other environmental stresses. Depending on what has caused the disease (fungus, virus, bacteria, nematodes or even another insect) will determine where it occurs on the plant. Generally plant diseases can be classified by the area affected such as those that affect the seedlings, leaf and stem, and root (see Figure 2.4) and crown.

**Figure 2.4** Phytophthora root rot in Lucerne
*(Source:* http://www.daff.qld.gov.au/26_3593.htm)

The effects of insects on pastures will vary. Some can be of minor importance, especially in the case of some insect pests in lucerne. As a perennial crop, lucerne harbours all kinds of insects including those that are pests, predators or beneficials. For example, an insecticidal approach for the control of pests such as heliothis or lucerne leaf roller, could be unnecessary due to the natural control by other insects or virus. Insect control can be an option when insect numbers reach certain populations or *thresholds*. Thresholds are based on the potential economic damage, the costs to control and the likely yields to be gained from insect control. Monitoring insect populations during susceptible times of the year will prevent needless sprays, for example in the warmer months for aphids present in lucerne.

## 2.8 Weeds

Weeds can have many definitions, but generally in a farming context they are defined as *"any injurious or potentially disease causing plant that is relatively useless, whilst competing with established pastures or crops".*

Weeds are usually species that are well adapted to survival with prolific seeding rates; the ability to remain dormant for extended periods of time; as well as excellent methods of seed dispersal - whether by wind, water or by stock movement.

It is often impossible or impractical to eradicate weeds from an area, so the best method of controlling weeds is relying on the management of them. There are many mechanical means by which weeds can be controlled. In the case of annual weeds for example, slashing in order to prevent seed set can be an effective means to control weeds, especially prior to flowering.

The losses to production due to weed infestation are incredibly difficult to estimate. Weeds can result in competition with pasture or cropping species for nutrients and soil moisture; the tainting of milk; stock poisoning; reduction of dry matter yields from lucerne paddocks; as well as reduced quality of the hay due to weed presence.

Grass weeds have prolific fibrous root structures and generally germinate under the more extreme conditions such as cooler soil temperatures. They require soil nutrients as do commercial plants, quickly draining the local soil of available nutrients and moisture, thereby leaving the soil depleted for the following pasture or crop. Table 2.2 clearly demonstrates the effect that weed competition has on pasture establishment and production.

**Table 2.2** The effect of fallow weed management on the population of annual summer grasses and the dry matter (DM) production of Bambatsi panic one month after sowing.

| FALLOW TREATMENT | Weed seeds in soil prior to sowing (seeds/m$^2$) | Weed seedling Nº 14 days after sowing (plants/m$^2$) | Weed DM production 1 month after sowing (kg/ha) | Bambatsi DM production 1 month after sowing (kg/ha) |
|---|---|---|---|---|
| Control in spring before planting | 5500 | 900 | 2500 | 90 |
| One summer of weed control | 1650 | 200 | 2000 | 410 |
| Two summers of weed control | 15 | 15 | 250 | 1000 |

*Source:* http://www.dpi.nsw.gov.au/archive/agriculture-today-stories/april-2008/weed-competition-kills-tropicals

One of the best ways of reducing weed infestation in pastures is by maintaining a dense, healthy sward of desirable pasture species. Pasture species will generally have the greater nutritional value so optimum soil conditions should be met to encourage this production. Management strategies to favour desirable pasture species (see Section 2.9) alongside the integrated use of herbicides, offers the best approach to reduce the limitation imposed by weeds.

## 2.9 Management strategies to reduce limitations to plant growth

The amount of pasture growth is determined to a large extent by the prevailing climatic conditions of light, water and temperature. There are, however, a number of management strategies used to reduce the limitations and increase production, including:

- Irrigation: Provides soil water when it is limiting.
- Fertilisers: Provide essential nutrients limiting plant growth.
- Soil ameliorants: Products that change soil characteristics to be more favourable to plant growth, e.g. lime raises soil pH and can improve structure in some soils.
- Green manure planting: Increases soil organic matter, improves soil structure and the capacity of the soil to hold water, air and nutrients, and, if the green manure crop is a legume, it can build soil nitrogen.
- Grazing strategies: Used to manage the amount of light captured by the plant.
- Weed management: Reduces the population of unwanted plant species that are either competitors in a crop or pasture, or are poor producers in comparison to the more desirable plants.

It is important to remember that while there are a many factors that can be managed and manipulated, the key is to identify the most limiting factors and target these with cost-effective strategies to optimise production.

Where these factors cannot be managed cost effectively, e.g. extreme cold or saline soils, there is very little that can be done to lift production. The following chapters focus on managing the limitations of soils and nutrients to optimise production.

## 2.10 References


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