# 4. How ryegrass (Lolium spp.) grows

**Learning outcomes:**

This chapter will help you understand, and be aware of the importance to grazing management of, the following aspects of ryegrass growth:

- The leaf capturing the sun to grow more leaves.
- New leaves appearing at different rates and growing to different sizes.
- Leaves dying and decaying.
- Tillers changing from vegetative to reproductive.
- Daughter tillers being produced.
- Root growth stopping and starting at different stages after grazing.
- Sugar energy being stored in the plant to help it to regrow after grazing, produce daughter tillers, and maintain root growth.
- Quality changing at the different stages after grazing.

## 4.1 The ryegrass plant structure

The ryegrass plant (see Figures 4-1 and 4-2) is made up of **many individual** tillers:

- The tillers are **partly connected** at the base, so they share nutrients, water and carbohydrates but **can survive independently**.
- An individual tiller can survive for up to **one year**. Therefore a "40-year-old pasture" contains plants that are mostly less than one year old.
- Depending on the amount of ryegrass in a pasture, there can be between **2,000 to 12,000 tillers per square metre**.

Each tiller has its own:

- **Roots**.
- **Leaves.**
- **Growing point.**
- Sometimes, a **stem** with a flower head on top.

**Figure 4-1: A ryegrass plant drawing**

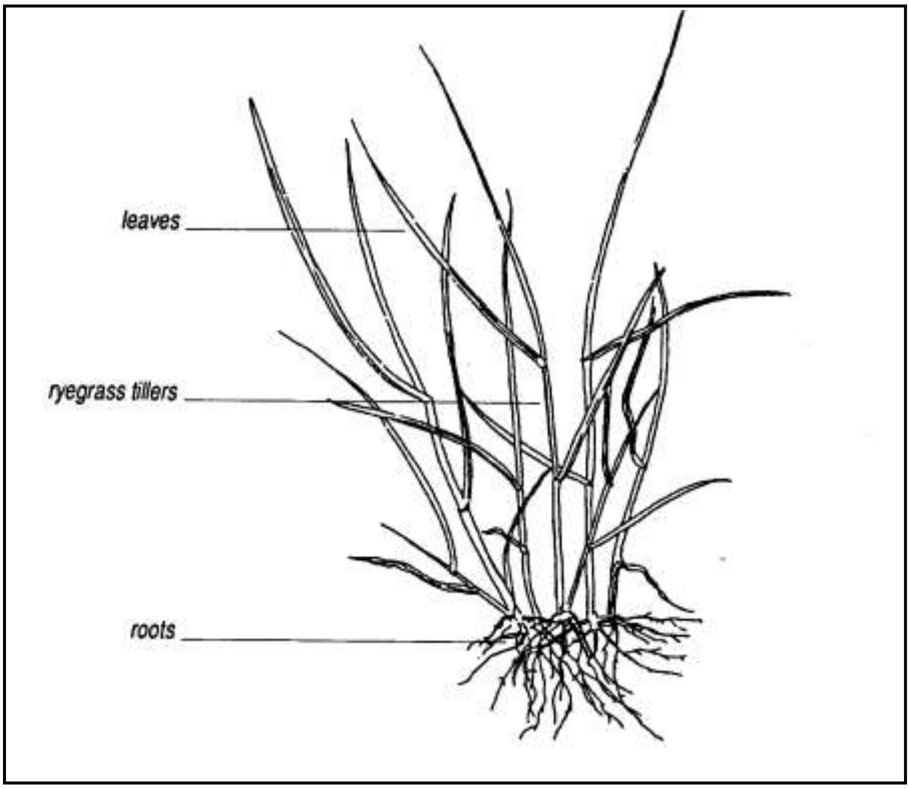


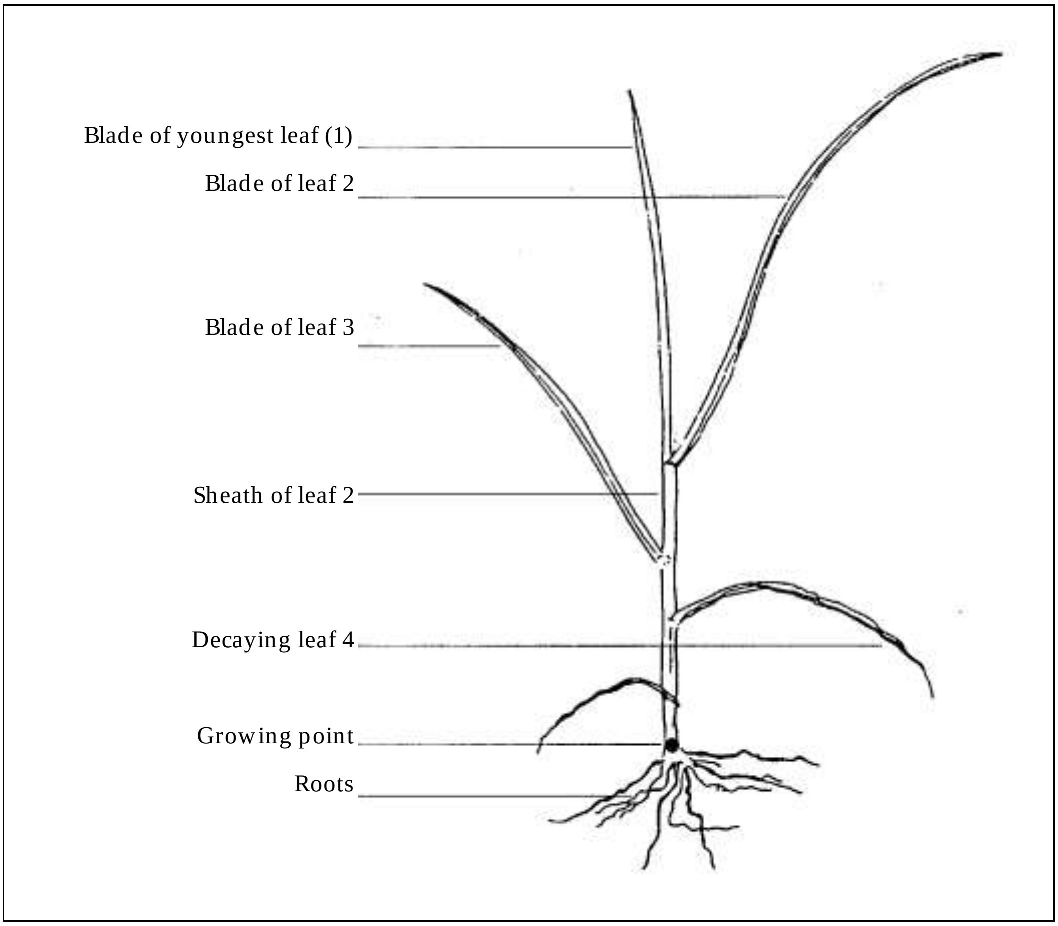

**Figure 4-2: A ryegrass plant photo**

Each leaf has two parts:

- The **sheath**. The sheath is the lower part of the leaf. All the sheaths wrap around each other, forming the lower, central, upright part of the tiller. At the base, a tiller may have ten sheaths, the outer ones with their blades dead or gone, but giving the tiller strength to stand upright.
- The **blade**. The blade is the upper part of the leaf. Blades hang away from the upright sheath.

This ryegrass tiller structure is shown in Figure 4-3.

**Figure 4-3: Structure of a single ryegrass tiller**



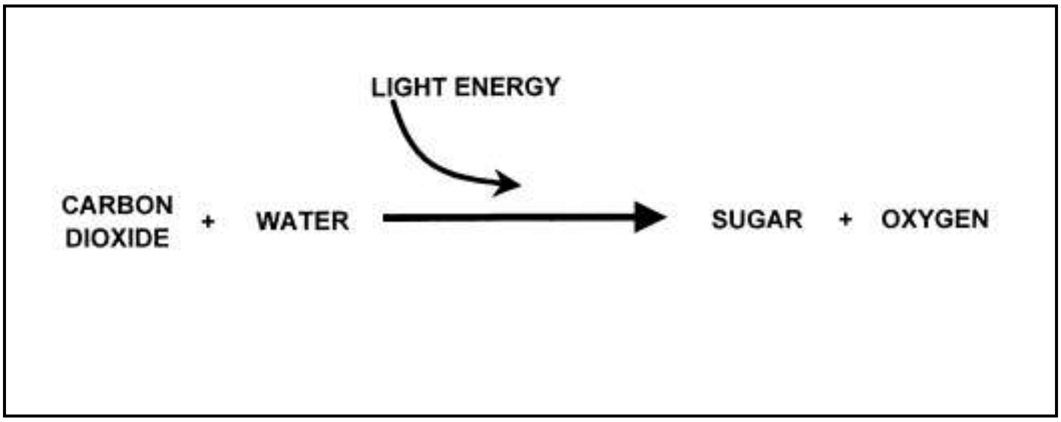

## *4.2 Vegetative tillers*

When a tiller is growing only leaves, it is called **vegetative**. The tiller grows by photosynthesis (see Figure 4-4), which is:

- The roots absorbing **water (and nutrients)** from the soil.
- The leaves absorbing **carbon dioxide** from the air.
- The leaves absorbing and using the **energy** from the sun.
- The leaves **combining** the water, soil nutrients, and carbon dioxide firstly **into sugars**.

The leaves then convert the sugars into more complex molecules of starch, cellulose, protein, etc., to eventually form more leaf.

**Figure 4-4: Photosynthesis**

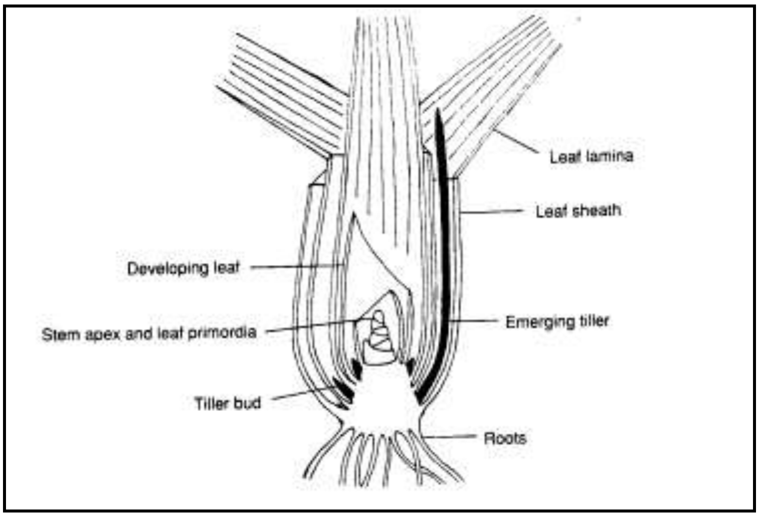



### 4.2.1 The growing point and ungrazed leaf growth

Like all living things, a leaf is made of cells:

- A **plant cell has strong walls** because a plant has no bones, like an animal, to keep it standing up.
- New cells, to make the leaf bigger, are produced in only one place, in the **growing point:**
  - Every tiller has a **growing point at its base**, close to the ground, to avoid damage during grazing. It is shown as the leaf primordia in Figure 4-5.
  - If the growing point is **damaged** (by insects, grazing, treading, etc.) the tiller will stop producing new leaves and **will die**.
  - After a period of time, the growing point gradually **stops growing one leaf** and **starts** growing **another** new one.

**Figure 4-5: Cross section of a the base of a tiller**




*Source: Grazing Management by John Hodgson, Longman Handbooks in Agriculture.*

- If there are already **three leaves** on a tiller, whenever a new one appears, the **oldest leaf begins to die** and decay.
- So, a ryegrass tiller usually has **only three green leaves**, and the youngest one is doing most of the growing.
- Some of the nutrients that were in the oldest leaf are transferred to the newest leaf.

Looking at Figure 4-3:

- Leaf 1 is the youngest; it is green and growing, extending at the top of the tiller.
- Leaves 2 and 3 are no longer growing but are still green.
- Leaf 4 is dead and is decaying.

Figure 4-6 shows three tillers, with one , two and three leaves regrown.

**Figure 4-6: Three tillers, showing one, two and three leaves regrown**

Although a ryegrass tiller usually has only three living leaves, there are three situations when this may not be the case:

- In late **summer** and early autumn (if the soil is dry, causing slow growth), a tiller may have **less than three** live leaves.
- In early **spring,** a tiller may have **more than three** live leaves.
- **Reproductive tillers** (see section 4.3) may have **up to six** live leaves.

### 4.2.2 Leaf growth after grazing

Sugar, starch and cellulose are carbohydrates. They all contain carbon, hydrogen and oxygen. They are all stores of energy, with sugar being the least complex but easiest to digest and cellulose being the most complex and hardest to digest.

As mentioned earlier, **energy** is needed for a leaf to grow:

- This energy is **usually captured from sunligh**t by the leaves themselves.
- So the saying "you **need a leaf to grow a leaf**" is very true.
- If the leaves are grazed off, the tiller **cannot capture sunlight** energy.

Therefore, to cope with the leaves being grazed off:

- The ryegrass tiller **stores up energy as sugars** (called water soluble carbohydrates or WSC) in the bottom 4 cm of the tiller (sometimes called the stubble). No matter how long the tiller is, the sugars are stored in the bottom 4 cm.
- Then, with no leaves remaining to absorb sunlight and photosynthesise sugars, the **stored energy can be used to grow a new leaf**.
- The sugars are used for **new leaf regrowth as a first priority**, and other possible uses of that energy (roots and daughter tillers; see later) are retarded or stopped.
- This first leaf then begins to photosynthesise and **produce sugars for** the growth of **the second leaf**.

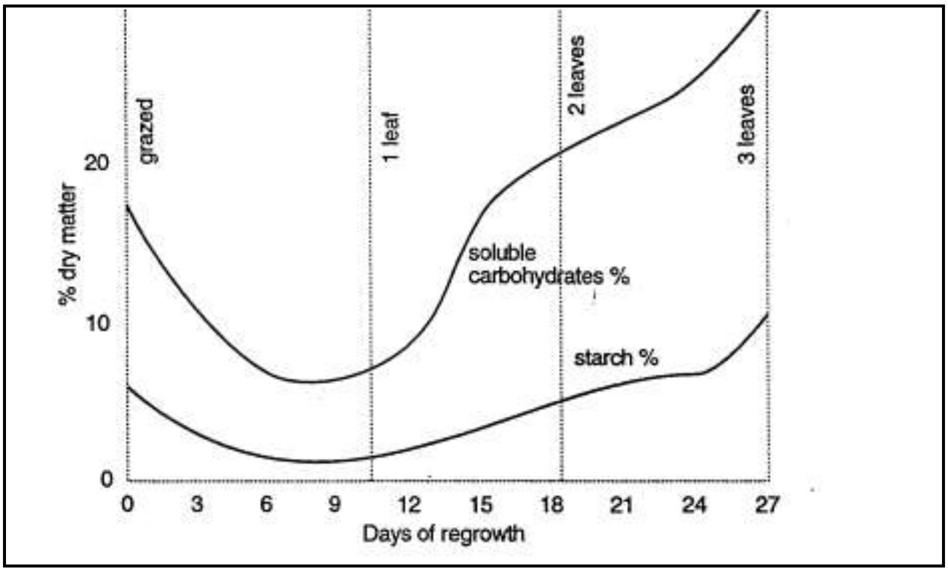
Once a tiller has grown 2 leaves, enough sugar has been restored at the base of the tiller, so it could cope with having its leaves grazed off again.

These changing levels of sugar in the tiller are shown in Figures 4-7 and 4-8.

The **sugar reserves** are not only used for growth after grazing (even after a light grazing), but also **used for growth whenever photosynthesis is reduced** or not possible:

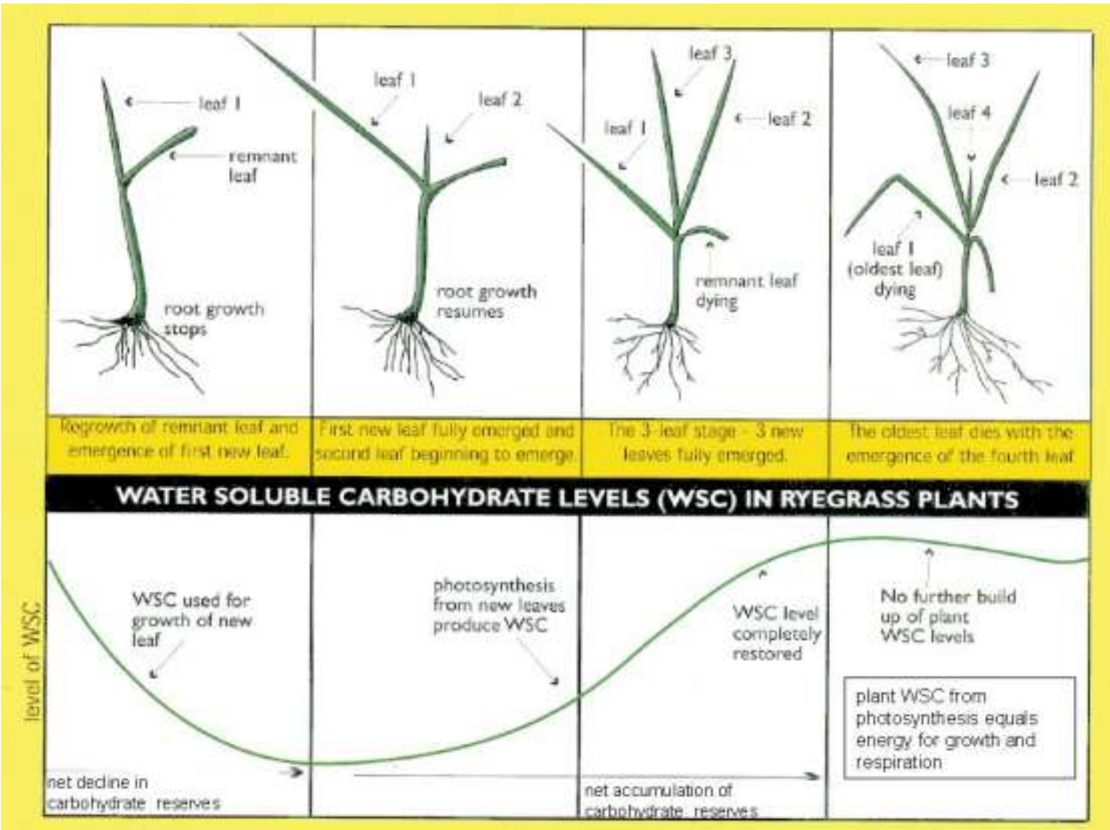
- During **cloudy weather**.
- At **night time**. Ryegrass can grow as much at night as during the day, especially in spring.
- During any **stress period**, such as heat, frost and drought.

**Figure 4-7: Changing levels of sugar and starch during regrowth**




*From Fulkerson, Managing Pastures for Milk production*

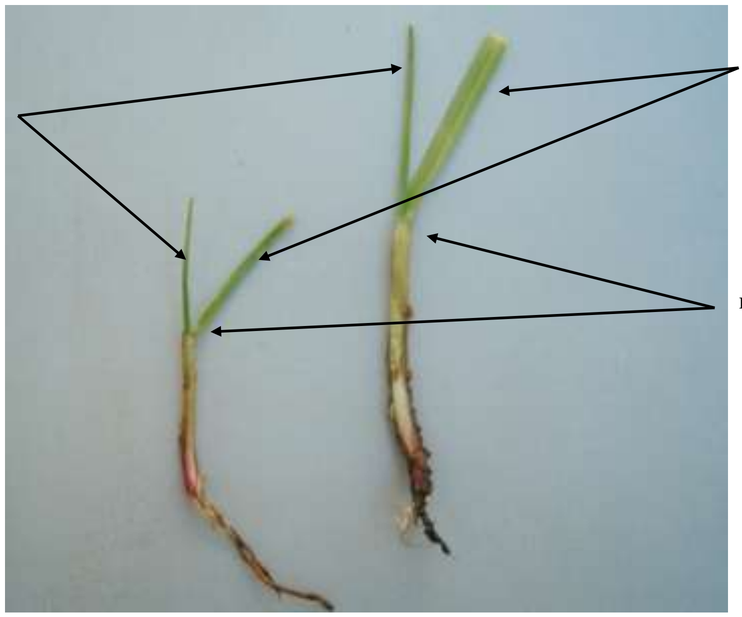
**Figure 4-8: Regrowth of a ryegrass tiller and accompanying changes in sugar levels**




*Source: Danny Donaghy*

Figure 4-9 shows two tillers, one large and one smaller, that have been grazed only 48 hrs ago. The remnant leaf, with the blunt end, has regrown a little and stopped, and the younger leaf has started to grow, all from energy reserves in the lower 4 cm of the tiller.

**Figure 4-9: Leaf regrowth immediately after grazing**




The growing point grows **only one leaf** at a time:

- As it creates new leaf cells it **pushes the older cells up**wards.
- Therefore, the **oldest part** of the leaf **is the tip**.

A new leaf grows up through the centre of the old leaf sheaths so that the **youngest leaf** is always **at the top** of the plant:

- The **older leaves** are situated progressively **nearer the base**.
- The new leaf is the **only one growing**.
- The older leaf finishes its growth as the new leaf appears.

In dry and hot conditions, ryegrass may appear to stop growing:

- If the leaves are **brown or silvery but shiny**, they are **still alive** and growing very slowly.
- If the leaves are **brown and crackly,** they are **dead**; but the growing points at ground level may still be alive; and when rain comes, they will form new tillers.

### 4.2.3 Leaf appearance

During the year, there is variation in the time taken for the growing point to produce a new leaf (see Figure 4-10):

- New leaf appearance rate is **influenced mainly by air temperature.**
- Leaf appearance rate is also **influenced by a lack of soil moisture**, but only when the soil moisture stress has become quite severe, that is when the plant is growing at less than 50% of what it could grow at perfect soil moisture.
- Leaf appearance is **not influenced by supply of nutrient** from the soil.
- At ideal temperatures and soil moisture, in **spring,** a new leaf may appear as quickly as every **4 to 12 days**.
- During **winter**, a new leaf might take **20 to 35 days** to fully appear.

**Figure 4-10: Typical leaf appearance intervals**

| Season | Days |
|---|---|
| Spring | 4 to 12 |
| Summer (dryland) | 15 to 30 |
| Summer (irrigation) | 10 to 15 |
| Autumn | 15 to 30 |
| Winter | 20 to 35 |

A single ryegrass leaf:

- Lives for about three times its appearance rate, that is while itself and then the next two are growing.
- It might live for only 18 days in mid-spring and up to 60 days in winter. (Probably only one leaf, during the coldest month of winter, will appear as slow as 30 to 35 days).

The whole tiller lives for up to one year.

### 4.2.4 Leaf size

Leaf size, that is, its length, width and thickness, is quite different to how fast it appears. Figure 4-11 shows two different sized tillers but both with three leaves.

**Figure 4-11: Different sized tillers, both with three leaves**

**Leaf size** is influenced mainly by:

- **Nutrient supply** (especially nitrogen). Two tillers near each other, one in a urine patch and one not, may both have 2 leaves, but the leaves growing in the urine patch might be three times the size of the other. A paddock with urea applied will have the same leaf appearance rate as the next paddock but will have bigger leaves. The saying, "a body builder using steroids grows bigger arms, not more arms", with the nutrient supply being the steroids, seems appropriate here.
- **Moisture, light and temperature**. The leaves will be bigger when these three conditions are ideal.
- The **type of ryegrass**. For example, in winter, when annual ryegrasses grow well, they will have the same leaf appearance as a perennial but the annual's leaves will be much bigger.
- The **number of leaves after grazing**. After grazing off a tiller, the next three leaves all appear at approximately the same interval, but the first leaf is the smallest, the second one is bigger (longer and broader), and the third one is bigger again. If four, five or more leaves grow, they will be only be a little bigger than the third. The later leaves are bigger because they have more sugars available for growth as there is more previous leaf area collecting sunlight.
- The **size of the previous leaf**, or the size of the whole tiller immediately prior to being grazed. If either are big, they provide more energy (either from sunlight or stored sugars) for the next leaf to be big. Big plants regrow big leaves after grazing!

### 4.2.5 Root growth

Plant roots are continually dying and regrowing. **Immediately after grazing**, irrespective of how much of the tiller remains, the stored sugars will be used to get the first leaf grown, so **root growth stops or is severely retarded**. When one new leaf has fully emerged, the roots start growing again.

## 4.3 Reproductive tillers

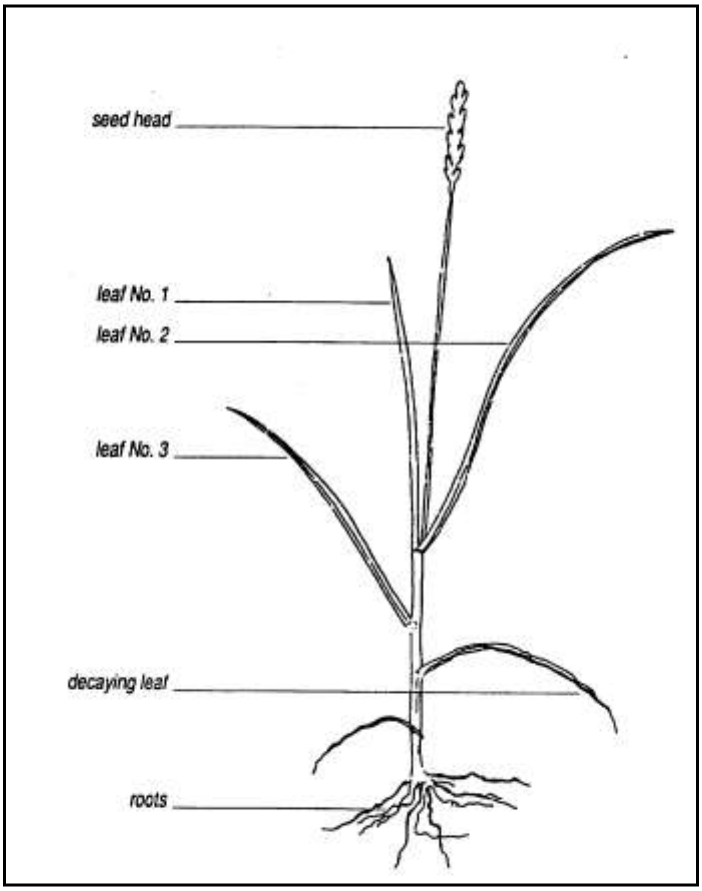
For most of the year, ryegrass tillers are **vegetative**, that is, they grow leaves only:

- But from spring through to summer, a lot of the tillers produce a stem, with a flower, which develops into a seed head.
- They "go to seed", that is, become **reproductive** tillers (see Figure 4-12).
- This process is designed to produce seeds that can germinate and grow into another plant.
- But in most dairying areas (with adequate summer moisture), where ryegrass can survive summer, the tiller becoming reproductive is an unnecessary process and, in fact, causes problems (see Chapter 7 Grazing theory).
- If you run a tiller between your finger and thumb and can feel hard lumps, called nodes, along the tiller above ground level, then that tiller is going to seed. The growing point will usually be just above the top node.

There are two conditions necessary to trigger a vegetative tiller to become a reproductive tiller:

- When the growing point of a vegetative tiller is exposed to **air temperatures of less than 10° C** for a period of time, which in Victoria occurs in winter only, the growing point is modified. It becomes **capable** of reproductive growth, that is, capable of growing a seed head. At this, stage it doesn't actually grow the seed head, and you cannot see any difference in the tiller.
- For a seed head to actually start growing, it needs to be triggered by **a certain day length**, which occurs as the days become longer in spring. This day length varies for different varieties of ryegrass; and therefore, there are early-, mid- and late-flowering varieties of ryegrass. For example, Vedette needs a shorter day length, and hence goes to seed about 4 weeks earlier, than Impact.

**Figure 4-12: A reproductive tiller**




Once the growing point becomes reproductive:

- Rather than pushing the leaf above itself and staying at the base of the tiller, the growing point **pushes itself upwards**, on top of a stem.
- The stem **is much stronger** (more cellulose, thicker cell walls, more fibrous) than a leaf, because it has to support the seed head.
- The growing point produces **the flower head** on top of the stem, which produces seeds.
- As the growing point lifts off the ground, it **can be grazed off** far more easily; and if this happens, the tiller will die. It dies anyway once the seeds are produced.
- Once started, this reproductive process in the tiller **cannot be stopped**.
- At the early stage of becoming reproductive, the tiller grows very fast, the **leaf appearance rate nearly halves**, and the tiller can produce new leaves every 3 to 5 days.

Not all tillers, only about two-thirds, become reproductive in early spring. The other one-third of tillers don't become reproductive because they formed in late winter or early spring and didn't have the "cold treatment" to make them capable of reproduction.

## 4.4 Daughter tillers

The growing point of a tiller not only produces leaves and seed heads, but can also produce another independent tiller, known as a daughter tiller (see Figures 4-13 and 4-14).

- This new tiller starts as a **small white bud at the base** of the parent tiller.
- It grows up inside one of the old sheaths and eventually bursts from the side of the sheath.
- It develops its **own roots** and starts growing its **own leaves**.

**Figure 4-13: A tiller with a daughter tiller**

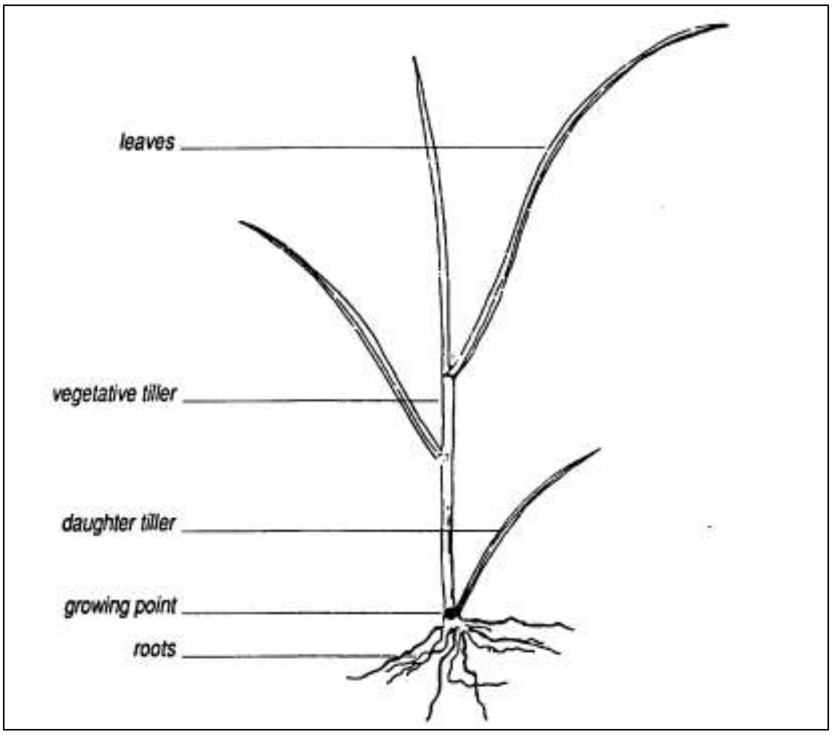


**Figure 4-14: Tillers with varying size daughter tillers**


Because a ryegrass tiller can start another one beside it, once a ryegrass pasture has been established from seed, in a situation where the tillers can survive summer, the plant does not need to reproduce from seed. In fact, daughter tillers are the main method by which perennial ryegrass persists in a pasture, by replacing the tillers (vegetative or reproductive) that die. One tiller might end up producing up to 40 daughter tillers.

The development and growth of new tillers (tillering) is influenced by:

- **Light and shading:**
  - A tiller bud is produced each time a leaf is produced but, for that bud to start growing, the base of the sward should not be shaded.
  - Even after a tiller has started growing, if it is heavily shaded by tall and dense pasture, it can die.
- **Grazing.** For several weeks, until the new tiller has its own roots and leaves in the sunlight, it is dependent on the parent tiller. If the parent tiller is stressed by too frequent leaf removal (grazing) or by lack of moisture, etc., it will sacrifice the young daughter tiller and let it die.

- **Reproductive tillers**, which suppress daughter tiller development. If reproductive tillers are removed, more sugars are available for new tillers.
- More **nutrient** supply, especially more nitrogen, but also more phosphorus and potassium, produce more tillers.
- The **temperature.** Optimum temperature for tillering is between 13°C and 25°C.
- **Moisture** stress, which will reduce tillering.

Because of the temperature and moisture issues, it is during **spring and autumn** when **most tillering can occur**, if the grazing and soil fertility conditions are also right.

New roots develop along with new tillers, so root development also peaks in spring and autumn. However ,optimum temperature for root growth is a bit lower than that for tillers. This is the main reason why ryegrass performs poorly in summer unless irrigated frequently, because:

- The roots of any new autumn tiller continue to develop well, even as temperatures fall, into early winter. They then have a root system that could cope better with the moisture stress of summer, but unfortunately they die after going to seed in spring.
- The roots of any new spring tiller do not develop as well as the tiller itself, as temperatures increase in spring, so they do not have a very deep root system going into summer.

## 4.5 Annual life cycle and growth rate of a tiller

Let's track the life of typical tiller, called Terri:

- Most likely Terri the tiller **starts life as a bud,** or growing point, at the base of her parent tiller, in spring or autumn, but let's say spring.
- Assuming enough sunlight is getting to the base, Terri **begins growing her first leaf**, which for a few centimetres is still enclosed in the sheath of her parent. As long as she is still shaded from collecting her own sunlight, **she is completely dependent on sugars from her parent**. Thankfully, no grazing, moisture or frost stress happened to her parent, so Terri survived.
- She extends her first leaf into the sun and **starts collecting her own energy**. That leaf keeps growing for another five days, **at about 15 kg DM/ ha/ day**, then stops.
- The growing point of our new tiller now **starts growing a second leaf,** inside the sheath of the first one. That leaf pops out of the sheath and grows for another five days, **at about 30 kg DM/ ha/ day**.

- Terri, our new tiller, is **now independent of her parent** as she grows her third leaf. With plenty of her own sun-collecting ability, she is growing **at about 65 kg DM/ ha/ day**; she is in **now storing sugars at her base; and her own roots are growing strongly**.
- Nothing grazes her, so she **grows a fourth leaf**, but the very **first one**, down at the bottom, **turns yellow and dies**. Her net growth is therefore only **about 15 kg DM/ ha/ day.**
- Then **a cow grazes** off Terri's three green leaves and in gratitude, turns around and **urinates all over her**.
- Using the stored sugars in the base, **Terri quickly regrows a new leaf**.
- The urine was a shock, but the great dose of **nitrogen in it helps to grow big leaves**.
- At the next grazing, no cow eats any of Terri's leaves, so she ends up **growing six leaves**, but three are dead and decaying at the base. She is a tough piece of work, is surviving but is not allowing other tillers to get going in the shade below.
- Next grazing (and it is now December), Terri, in with her rank mates, gets a light nip from the cows on the top, so the farmer gets the mower out and **cuts her back to 4 cm**, so now she has no green leaf left.
- Because she had plenty of leaves, and thus plenty of sugar stored, before she was mown, Terri regrows very well **but hasn't got a lot of company**, only a few cousins of her own age, who have managed to survive with her.
- It's now autumn, and **Terri decides to help a daughter** to get going, and a bud at her base starts growing into another tiller.
- In July, Terri experiences the **cold** temperatures of winter.
- As the spring day length increases, Terri **becomes a parent** in a different way, and develops a stem and a flower head and produces seeds.
- She **dies** at 13 months of age and decays away.

## 4.6 The changing feed value of a tiller

The cow that grazes a ryegrass tiller requires a particular quality of feed. In particular, she requires the right balance of:

- **Fast** (soluble) and **slow**ly digested energy, or **carbohydrates**. The fast-digesting carbohydrate is sugar, a bit slower is starch, and even slower is cellulose or fibrous carbohydrate.
- **Fast** (soluble) and **slow**ly digested **protein**-forming compounds. Much of the soluble protein is nitrate, and the slower digesting protein is the true plant protein.

- **Minerals**, such as potassium (K), magnesium (Mg), calcium (Ca) and phosphorus (P).

As the tiller grows from 1 to 3 leaves, the balance of these feed components change as outlined below.

### 4.6.1 The sugar:nitrate balance for the cows

The ideal balance of sugar to nitrate for a cow is between 1:1 and 2:1 .

**Before the 2 leaf stage,** the tiller is converting every bit of sugar into starches and cellulose to grow more leaves:

- So the tiller is **low in sugars**.
- It is **high in nitrates**.
- The resulting **sugar:nitrate ratio is between 1:2 and 1:6.**
- This ratio is **far too low** in sugar and **far too high** in nitrates.

**After the 2 leaf stage**, with more leaves producing sugar:

- The **sugar level is higher** in the leaf.
- It si high enough, in fact, to start storing sugar in the base of the tiller.
- The sugar:nitrate ratio is about 2:1, which is **ideal**.

The ryegrass plant absorbs nitrates from the soil, day and night. Whereas, throughout a 24-hour period, in sunny weather:

- The sugars are **highest late in the afternoon** and lowest in the morning. They increase by about 0.5% per hour from sunrise to late afternoon (say about 4 to 5 p.m.) in spring or summer.
- This is because the leaves in sunlight produce sugars faster than they are converted or used up.

At night time, or in cloudy weather:

- The sugars are converted or used up faster than they are being produced.

So the sugar:nitrate ratio will usually be better in the afternoon. However, it would be impracticable to graze only in the afternoon. It may justify cutting silage in the afternoon to get a higher level of sugar to allow better fermentation, but then the cut grass goes straight into night, which is not good for fast drying.

When a cow's diet is high in nitrates, she removes the surplus in her urine. Sometimes the urine is so strong in nitrates that it causes scald patches in the pasture, as shown in Figure 4-15.

**Figure 4-15: A urine scald patch in pasture**

### 4.6.2 Mineral balance for the cows

Grass tetany, milk fever and other metabolic problems can be caused if the cow's diet is high in potassium and low in calcium and magnesium.

The ideal balance of K:Ca+Mg ratio should be below 2.2:1, and the ideal balance of Ca:P should be 1.6:1.

**Before the 2 leaf stage,** calcium and magnesium levels are low, and potassium levels can be very high:

- The K:Ca+Mg ratio would be about 6:1, which is **far too high in K**.
- The Ca:P ratio would be about 1:1, which is **too low for Ca**.

**After the 2 leaf stage,** calcium and magnesium levels are higher, and potassium levels are lower:

- The K:Ca+Mg ratio would be below 2.2:1, which is **about ideal**.
- The Ca:P ratio would be about 2:1, which is **about ideal**.

### 4.6.3 The sugar:starch:fibre balance for the cows

To produce a lot of milk, a cow needs:

- A high **energy density,** which sugar and starch will provide.
- A certain amount of **slow-digesting energy as fibre**, so that her rumen functions properly (which mostly means her rumen does not become too acid).

The best energy density that pasture can provide is about 13 Megajoule of metabolisable energy per kilogram of dry matter (MJ ME/ kg DM).

**Metabolisable energy** is the actual amount of energy in a feed that a cow can use for her bodily processes, known as her metabolism. Metabolisable energy (ME) is measured in megajoules per kilogram of dry matter (MJ/kg DM).

The ideal level of fibre is about 35% neutral detergent fibre (NDF):

- Any **more** fibrous might **restrict intake**, both because she cannot digest it fast enough and because she will avoid more fibrous feed if she can.
- Any **less** fibrous might cause over-fast digestion and cause the **rumen to become too acid**.

Figure 4-16 shows energy and fibre levels for different stage of tiller growth, and Figure 4-17 summarises feed quality and leaf stage.

**Figure 4-16: Approximate fibre and energy levels for different growth stages and parts of the tiller**

| Growth stage or tiller part | NDF | Energy (MJ ME/ kg DM) |
|---|---|---|
| Tiller at **1 leaf** stage | 30%, a **bit low** | 12 to 13 |
| Tiller at **3 leaf** stage | 35%, **about ideal** | 12 to 13 |
| Tiller at **5 leaf** stage | 45%, a **bit high** | 10 |
| **Reproductive** tiller | 60%, **too high** | 9 |
| **Dead** leaf | 65%, **too high** | 6 |

**Figure 4-17: A summary of feed quality and leaf stage**

| Quality measurement | IDEAL ratio | Ratio BEFORE the 2-leaf stage | Ratio AFTER the 2-leaf stage |
|---|---|---|---|
| Sugar:nitrate ratio | Between 1:1 and 2:1 | 1: 5 | 2:1 |
| K:Ca+Mg ratio | Less than 2.2:1 | 6:1 | Below 2.2:1 |
| Ca:P ratio | 2:1 | 1:1 | 2:1 |
| NDF(%) | 35% | 30% | 35% |

## 4.7 Summary

**Only 3 green leaves** grow before the oldest dies and decays.

**Leaf appearance** varies from 6 days to 30 days, depending mostly on temperature but also on soil moisture. The bottom leaf dies 18 to 60 days after grazing.

**Stored sugars,** which accumulate at the tiller base once 2 leaves have regrown, are used to get the first leaf going after grazing.

**Reproductive tillers** will die, shade the base, reduce quality and are not needed for seed.

**Daughters tillers** will grow from the base if the base is not shaded and if there is stored sugars to get them started.

**Root regrowth** is suppressed after grazing and resumes after about 1 leaf have regrown.

**Tiller quality** (that is, the balance of sugar to nitrate, minerals to minerals, and sugar to starch to fibre) is best at the 3-leaf stage.