6. Temperature, light, moisture and fertility

Learning outcomes:

This chapter will help you to:

- Understand that four main factors affecting pasture production.
- Manage the soil moisture to achieve high pasture production.
- Manage the soil fertility to achieve high pasture production.

A pasture will produce at its **maximum** when:

- The **most productive species** are present,
- And all the **environmental conditions** of temperature, light, soil moisture and soil fertility **are ideal**.

Figure 6-1 shows a "pasture barrel". Each stave has been labelled with one of the factors that affect pasture production. If this imaginary barrel was filled with water, it obviously would fill only to the shortest stave, no matter how long any of the other staves was.

Figure 6-1: The pasture barrel

The pasture barrel illustrates the concept that **pasture production will only reach the level of the most limiting factor**:

- For example, soil fertility may be adequate for good pasture growth, but lack of soil moisture could be restricting growth.
- As another example, soil fertility and soil water may be adequate, but hopeless grazing management could be restricting production.

To repeat, a **dairy farmer's pasture management objectives** are to ensure:

- The pasture **produces** large quantities of dry matter.
- The cows eat or **utilise** most of it.
- The pasture is kept at its best **quality**.
- The sown species **persist** in the pasture.

To achieve these objectives, it is necessary to:

- Determine the most limiting pasture production factor on your farm.
- Improve that factor, if possible, before any of the others.
- When it is improved and another one becomes limiting, then work on that factor.

All the pasture production factors can be managed, planned for, or controlled in some way:

- **Soil temperature** depends on climate and season but is relatively predictable, and farmers can plan for its changes.
- **Light** is managed by good grazing practices.
- **Soil-air-water balance** involves rainfall, irrigation and drainage. Rainfall, like temperature, depends on the climate of the area and the particular season. Some situations justify irrigation, and many situations would justify drainage.
- **Soil fertility** can be managed by controlling the nutrient transfer caused by the cows and fodder conservation or by applying fertiliser.
- **Pasture composition**, that is, the proportion of different plant species (grasses, clovers and weeds) present, can be managed largely by soil fertility, soil-water and grazing management, but sometimes the sowing of pasture species is justified.

This chapter discusses all the pasture production factors.

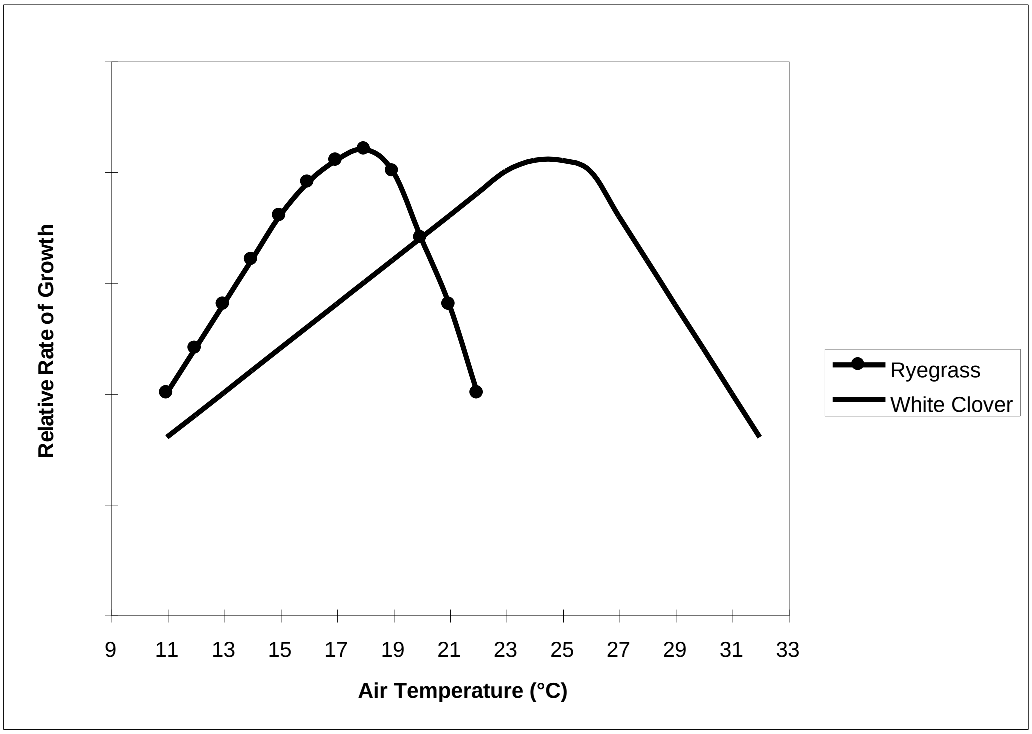
6.1 Temperature

All plants have a temperature they grow best at:

- Plants that evolved in Mediterranean areas (such as clovers) grow better at higher temperatures than plants that evolved in northern Europe (such as ryegrasses).

- Figure 6-2 shows that ryegrass grows best at around 17°C, while white clover grows best at about 25°C.
- For this reason, pasture tends to be ryegrass dominant through the winter while white clover content increases in spring and summer.

Figure 6-2: Temperature requirements for the growth of ryegrass and white clover



Temperature can be controlled only to a very minor extent:

- **Tree shelter belts** may modify very hot or very cold wind effects.
- **Drier soils** (often sandy soils) will cool down quicker in autumn and warm up quicker in spring than **wet soils** (often clay soils). This is because the temperature of water changes much more slowly than the temperature of air.

Although temperature itself cannot be controlled, **the effects of temperature**, that is, changing leaf appearance interval and leaf size, can and **should be managed by the farmer** to get the best growth, utilisation, quality and persistence of the pasture, whatever the prevailing temperature.

6.2 Light

To ensure that the daily input of light is not wasted, whether it be the higher intensity light and longer days of summer or the lower intensity light and shorter days of winter:

- Keep the **optimum cover of leaves** to harvest the light. This means a dense pasture.
- **Minimise** patches of **bare ground**.
- Ensure that green **leaves quickly appear after grazing**.
- Do **not allow the bottom leaves to decay**, wasting light that was harvested in the past.

All these points will be achieved with good grazing practices. Grazing is the main focus of this manual, so it is discussed fully elsewhere.

6.3 Soil moisture

Much of this section applies to irrigation, which many dairy farmers use. The principles, however, can be applied to rainfall-fed farms, particularly the aspects of waterlogging, which can occur anywhere.

For plants to grow well, the roots need access to water and air in the soil. As mentioned previously, the ryegrass root system is poor going into summer:

- Even mild moisture stress causes slow growth (longer leaf appearance time and shorter, narrower and more folded leaves).
- Moisture stress causes the plant to become dormant. Adding water breaks the dormancy, but the growth rate does not return to even near what it would have been if water had been maintained continually.
- The longer the dry period, the more dormant the plant becomes, and the slower it responds to rainfall or irrigation when it does come.

For water and air to be present in the soil, **and** for them both to be able to move freely, there needs to be adequate pore spaces or gaps in the soil.

There will be adequate pore spaces if:

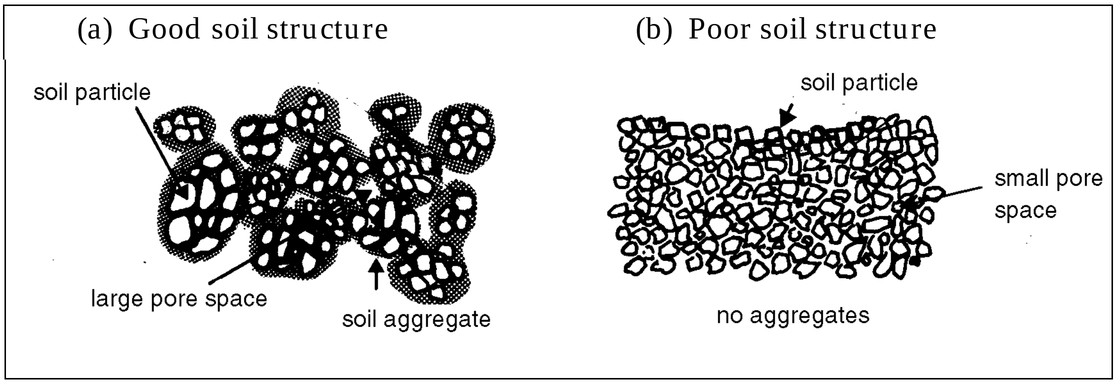
- The soil **particles are large** enough.
- Or, if the finer particles, such as clay particles, join together to form **larger aggregates**, which stay together even when wet.

Soil structure is the term used to describe the way the individual soil mineral particles are held together to form larger aggregates.

Figure 6-3 illustrates soil structure:

- Diagram (a) shows soil **particles aggregated** to produce **large pore spaces,** which allow the **movement of air and water**.
- Diagram (b) shows **no aggregation** of soil particles. Here the **pore spaces are small**. The water and air have difficulty getting into and moving between these spaces.

Figure 6-3: Soil structure



The two ways in which smaller particles are "glued" into aggregates are:

- **Chemical bonds** on the very fine clay particles. Calcium in the soil helps this bonding, and sodium in the soil reduces the bonding. That is, gypsum (calcium sulphate) helps bonding and salt (sodium chloride) reduces it.
- **Organic** material **bonds**. So a soil that has enough organic matter in it will usually have good structure.

6.3.1 Soil wetting and drying and pasture production

The following are the different stages of soil wetting and drying:

Saturated

- When a soil is flood irrigated or saturated with rain, all its **pore spaces are completely full** and it is called saturated.
- There is virtually **no air** in the pore spaces.
- If a handful of saturated soil was squeezed, some (muddy) water would run between your fingers.

Field capacity

- After a soil is saturated, a lot of the **water drains away under gravity**, down the profile, out of the root zone.
- As it drains, **air re-enters** the soil, as long as there is not still a layer of water on the surface.

- About **12 to 24 hours after irrigation** or significant rain, this **draining stops** and the amount of water in the soil is called "field capacity". Only the very small pore spaces (less than 0.05 mm or half a hair thickness) are full of water, holding the water against gravity. The larger pores will still hold a film of water around them.
- This draining out to field capacity is a similar process to a sponge being soaked in water, then held up until no more water is dripping out.
- At field capacity, because the soil has a balance of water and air, the **plant grows at its maximum**.

Refill point

- There comes a time after irrigation or rain when there is still water in the soil but the plant is starting to find the water difficult to access or the **water is not readily available**.
- The "**refill point**" is when the readily available water (RAW) is gone.
- Once soil dries out more than the refill point, pasture growth can slow very quickly, while the appearance of the pasture is almost unchanged for many days.
- The plants alter from the fast growth stage to a slow growth or **simply survival** stage.

Wilting point

- After an even longer time, maybe a week to a month, depending on the season, the **plant cannot get any more water** out of the soil, even though there is still a thin film of water around the soil particles.
- But the plant is still evapo-transpiring some water, so it goes limp, or wilts, and will soon die.

Bone dry

- If no rain falls or the soil is not irrigated for a very long time (it might take years), the soil would eventually have virtually **no water in it at all**.

Different plants can tolerate different extremes of this soil water/ air balance; for example, paspalum can survive drier conditions than ryegrass can; and rice can handle very wet conditions at certain stages of its growth.

Figure 6-4: The different stages of wetting and drying

Source: Irrigation Management and Planning Manual, Frank Tyndall & Gavan Lamb.

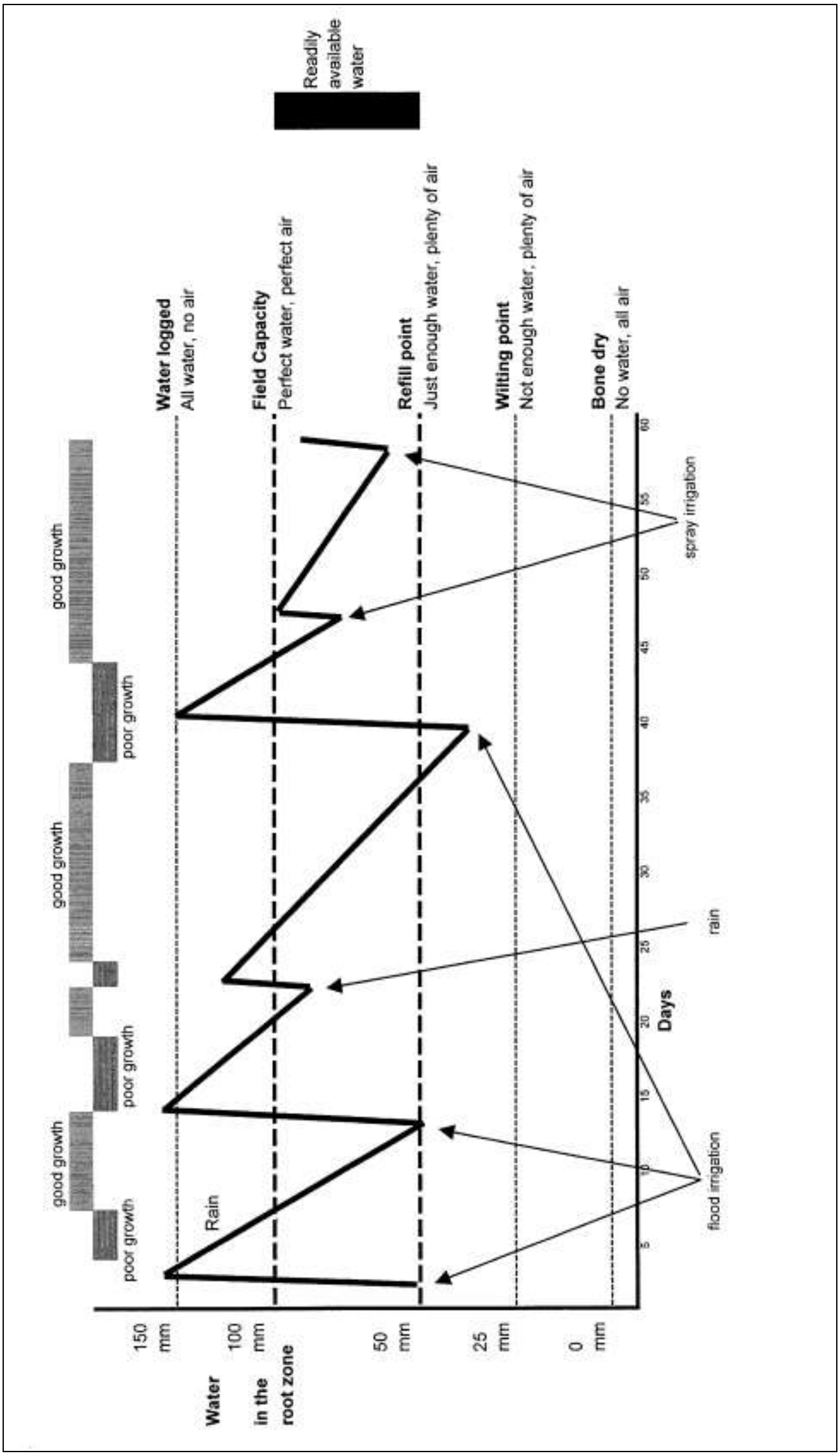
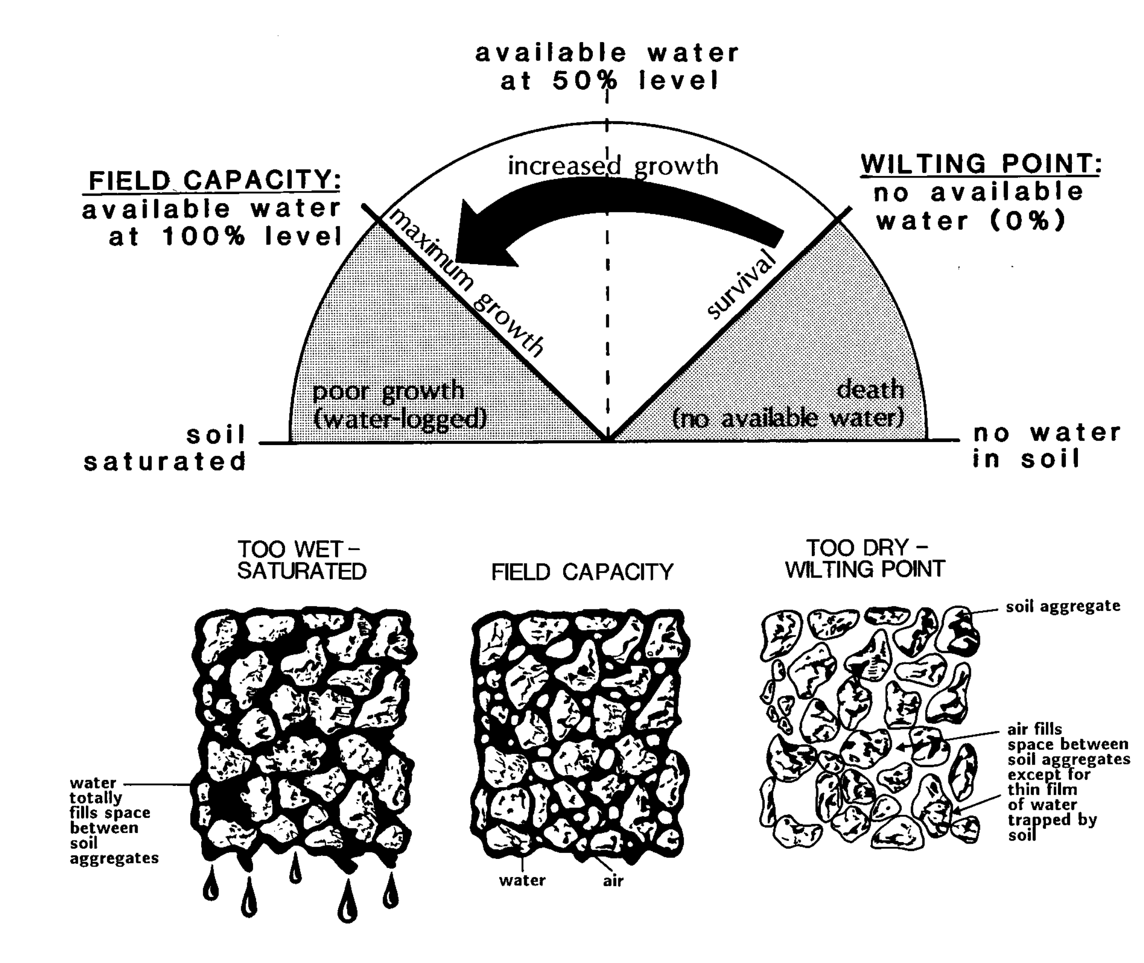


Figure 6-4 shows how the soil fills up and drains out due to irrigation (either flood and spray), rainfall, and pasture use.

- It shows saturation, field capacity, refill point, wilting point, bone dry and readily available water, as they change over the days.
- It shows, across the top, **periods of good and poor growth** due to either too much water or not enough water.

Another way of representing the soil wetting and drying is the moisture cycle diagram of a typical irrigation soil shown in Figure 6-5. On the left side of the cycle, the pore spaces are completely full of water or saturated. On the right side, the pore spaces have no water at all in them.

Figure 6-5: Moisture cycle



Readily available water (RAW) for pasture

- The **RAW is the water between field capacity and the refill point**.
- To achieve continuous **high pasture growth**, irrigation must ensure there is **always readily available water** in the soil.

- More water than field capacity means there is no air in the soil, and less water than the refill point means there is not enough water in the soil.

6.3.2 Deciding when to irrigate

Irrigation should occur whenever the refill point is reached. A number of methods can help determine the refill point, that is, decide when best to irrigate.

Pasture appearance is far too late

- Wilting of the pasture obviously indicates it needs water.
- But this method of judging irrigation timing will mean it is irrigated far too late.
- The plant becomes dormant; it will not have been growing for some time; and even when water is applied, it will take many days to begin growing again.

Watching the weather is a rough indicator

- An experienced irrigator can use the sun/ cloud cover, temperature, humidity, rainfall, and wind over a few days to get an idea when to irrigate.
- But because of the numerous factors to watch, this method is fairly inaccurate.

Evaporation is a good guide

- The evap-transpiration of pasture is similar to evaporation from a free surface of water, for example, from an open tank.
- This concept of irrigating when the total evaporation, less any rainfall, reaches a certain level is commonly expressed as:

$$E - R = 50 \text{ mm}$$

where

E = evaporation (mm)

R = rainfall (mm)

and **the 50 could range from 45 to 75**, depending on your irrigation management.

You can get the current evaporation rates from:

- Local evaporation data published in **newspapers or on the radio**.
- A **home-made evaporation tank**. A simple home-made evaporation tank (Figure 6-6) can be made from a 200-litre (44-gallon) drum. Cut it off 350 mm from the bottom. Drill a 3-mm hole in the side, 250 mm from the bottom. Paint measured marks below the hole, every 10 mm, up to say 80 mm. The tank is then placed on level ground in an open position. Fill it with water up to the level of the hole when an

irrigation is started. When the water level drops to a certain point below the hole, say 50 mm, it is time to irrigate again. If evaporation is high (in summer it is possible to evaporate 12 mm per day), the 50-mm point will be reached quickly. If evaporation is low, or if rain falls into the tank, the 50-mm point will be reached more slowly. Cover the tank with netting so dogs and birds do not drink from it. Place it in a convenient, irrigated area, and prevent the cows from knocking it over.

Figure 6-6: A home made evaporation tank

Soil appearance and feel, with experience is, reliable

- With experience, based on the above methods, assessing the soil by sight and touch can be a reliable method of judging when to irrigate.
- One method of determining the moisture level of the soil is by feel as explained in Figure 6-7.

Steel probe needs experience

- A piece of steel rod (maybe an electric fence post) prodded into the ground gives some idea of the moisture level in the soil.
- The rod penetrates easier in a moister soil.
- This method needs to be matched with the experience gained from other methods.

Soil water sensors most accurate

Probably the most accurate method to time irrigation is to measure the moisture in the soil with special equipment, such as:

- Porous blocks that allow water to move in and out of them and so measure suction pressure.
- Soil moisture switches that turn on or off depending on how wet the soil is.

- Devices that measure how an electromagnetic signal changes as the soil get wetter.
- A neutron moisture meter.
- A heat dissipation probe.

Figure 6-7: Soil moisture measurement based on feel

Moisture level	Sands and sandy loams	Loams, clay loams and clays
Above field capacity (Plenty of water, no air in the soil, little pasture growth)	On squeezing, free water oozes from the ball of soil	Soil very sticky and sloppy. When squeezed, it oozes water.
Field capacity – 100% available water (Plenty of water and air in soil, great pasture growth)	No free water appears on the soil when the ball is squeezed, but a wet outline of ball is left on the hand.	Soil is sticky. No free water appears on soil when ball is squeezed, but a wet outline of ball is left on hand. Possible to roll long thin rods (2 mm in diam.) between finger and thumb.
75% available water (Enough water and air, great pasture growth)	Slightly coherent. Will form a weak ball under pressure, but it seldom holds together.	Soil is coherent. Soil has a slick feeling and ribbons easily. Will not roll into long thin rods 2 mm in diameter.
50% available water (Just enough soil water, plenty of air, good plant growth)	Appears dryish. Forms a ball under pressure, but it seldom holds together.	Soil is coherent. Forms ball under pressure. Will just ribbon when pressed between finger and thumb.
25% available water (Not enough water, plenty of air, no pasture growth)	Appears dry. Will not ball under pressure.	Somewhat crumbly but will form a ball under pressure. Will not ribbon between finger and thumb.
Permanent wilting point (Pasture about to die)	Soil is dry, loose, and flows through fingers.	Crumbly, powdery. Small lumps break into powder. Will not ball under pressure.

6.3.3 The problems of water movement

The following are problems caused by water movement:

- We are trying to wet the root zone only; if it goes anywhere else, we **waste water**:
  - Water may soak in deeper than the root zone of the pasture.
  - Water may **run off** the bay, potentially wasting it.
- If it goes anywhere else, we **waste nutrient**:
  - If the water soaks past the root zone, it can take dissolved fertiliser (nutrient) with it, to the watertable, and this is called **leaching**.
  - If water, with dissolved nutrient, runs off the pasture, it is then potentially wasted.

- Water movement can force all the **air out of the soil:**
  - The soil becomes saturated or waterlogged. There is **no air in the pore spaces** and therefore no oxygen available for the plant roots. **Pasture growth is severely limited**. This effect can begin to occur after only one hour of waterlogging, but it is significant after 12 hours. Some plants (rice and many undesirable weeds, such as rushes, umbrella sedge (nutgrass) and docks) can withstand waterlogging.
  - Waterlogging kills off roots, making the plant less able to cope when the soil does dry out.
  - Waterlogging decreases the rate at which organic matter decomposes, so reducing the nutrients available to plants.
  - Waterlogging makes the soil prone to pugging, that is, structural damage by livestock and machinery traffic.
- While there is a water layer on the surface (see Figure 6-8):
  - It **blocks the air** from getting back in.
  - On days of high temperature, the surface water is heated, causing severe damage, or **scalding,** to pasture.
  - Some water is lost by evaporation.

Figure 6-8: Waterlogged pasture with water remaining on the surface

6.3.4 How do we minimise the problems when we irrigate?

Reducing the time water is on the surface can be done by:

- Applying such small amounts, for example, by **spray irrigation,** that very little gets to stay on the surface.
- **Correct irrigation timing** (at 50% of available moisture, that is, not irrigating unnecessarily early in the moisture cycle).
- **Short application times** (1 to 4 hours). A well-designed channel system will be able to supply large flows and keep the water application time to a minimum and therefore reduce the waterlogged period. However, the channel system must be kept in good order with maintenance, particularly with respect to weed control.
- **Good slope** (1:1000 or better for crops and annual pasture and 1:800 or better for permanent pasture). Good slope and adequate bay-end drainage hopefully will have been designed and implemented into the system. And just as the channels have to be kept clean, so too do the drains.
- In the pasture situation, if surface water is remaining on the bays a little too long, shallow (5- to 10-cm deep) surface drains (commonly known as **spinner cuts** and put in with a rotary drainer) could be placed approximately 10 metres apart down the full length of the bay. Install them as soon as the irrigation season finishes to give time for them to grass up slightly. They should not be kept too clean because they may take too much of the flow and therefore reduce the spread of water over the width of the bay, especially if the flow rate is low and the slope is relatively steep. Some farmers install spinner cuts even when slopes are considered adequate, in an effort to reduce the waterlogged period.
- **Underground drainage** is expensive, but in certain situations it is very effective and warranted.

6.4 Soil fertility

Soil fertility is the availability of the elements necessary for plant growth.

- These elements are **also called plant nutrients**. Figure 6-9 is a list of all the nutrients that plants require.
- They come from the **air, the water and the soil**.
- When soil fertility is high, pasture plants do not produce leaves more quickly, but do produce bigger leaves, so producing a greater quantity of feed.

The list in Figure 6-9 splits the nutrients into three groups:

- The **macronutrients**, which the plant needs a lot of.
- The **micronutrients**, which the plant needs only very little of.

- The elements that animals get from plants but are not necessary for plant growth.

Figure 6-9: Chemical nutrients and plant growth

	Nutrient	Source
Essential for plant growth	Hydrogen (H)	From soil water (H_2O)
	Oxygen (O)	From soil water (H_2O) and soil air
	Carbon (C)	From atmospheric carbon dioxide (CO_2)
	Nitrogen (N) Phosphorus (P) Potassium (K) Sulphur (S) Calcium (Ca) Magnesium (Mg)	Macro nutrients from soil (exception: legumes get nitrogen from soil air)
	Manganese (Mn) Boron (Bo) Iron (Fe) Copper (Cu) Zinc (Zn) Molybdenum (Mo) Sodium (Na) Chlorine (Cl) Cobalt (Co)	Micro nutrients from soil
Not essential for plant growth	Chromium (Cr) Vanadium (Vn) Nickel (Ni) Selenium (Se) Iodine (I) Fluorine (F) Tin (Sn) Silicon (Si)	Elements taken up from the soil by plants and available to grazing animals

Often plants cannot obtain enough nutrients from the soil. This could be because:

- Soils may **lack sufficient quantities** of these nutrients.
- The nutrients are **bound so tightly** to the soil particles they are not available to the plant.
- The soil may **too acidic** or, less commonly, too alkaline, either condition making certain nutrients less available.

- The **soil may be a bit dry**. The plant get the nutrients from the water in the soil. As the soil dries out, the plant slows its growth initially because it is finding it harder to get the nutrients, not because of a lack of moisture. This is why more fertile soils "hang on" better into a dry period.

It has been stated that organic matter is extremely important for good soil structure. **Organic matter** is also extremely important for soil fertility:

- Much of the **soil fertility is stored as organic matter**, in manure, dead roots, leaves and stems.
- The **nutrients are slowly released** and become available to living plants as this organic matter decomposes.
- Most of the organic matter, and therefore most of the soil's fertility, is **stored in the top few centimetres** of the soil.

If soil fertility is below optimum levels, applying fertiliser to improve these levels can greatly increase pasture production. There are two types of fertiliser applications:

- **Maintenance** applications. To maintain pasture growth, adequate amounts of fertiliser must be applied each year to replace what has been lost or removed in animal product. On a dairy farm producing 350 to 525 kg milk solids (MS)/ hectare (200 to 300 kg milkfat (MF)/ ha), the levels of nutrient removed each year are in the order of 14 to 20 kg of P and 40 to 65 kg of K (equivalent to 250 to 375 kg/ ha of 2:1 super potash fertiliser). This is known as the maintenance requirement of the pasture, as it must be replaced to maintain soil fertility.
- **Capital** applications. To increase soil fertility, it is necessary to apply fertiliser above that required for maintenance. This is known as a capital application of fertiliser.

To determine if fertiliser should be applied, consider:

- The **past use of fertiliser**.
- What the **land is used for** and how it is managed.
- The **appearance of the pasture**.
- Recognised district soil **deficiencies**.
- **Soil and plant tests**. Soil testing should be done regularly, at the same time each year, preferably spring, and in the same areas to monitor changes in soil fertility. It is also a good idea to use the same soil testing facility each time as there can be differences in results due to the different testing methods used.
- Fertiliser **test strips**.

The "pasture barrel" idea can be used for fertilisers:

- Pasture will grow to the availability of the most limiting nutrient.

The following sections discuss the plant nutrients and soil pH.

6.4.1 Macronutrients

Phosphorus (P):

Almost all soils in Victoria are naturally deficient in phosphorus and this is the most limiting nutrient to high pasture production.

Phosphorus **deficiency**:

- Causes **poor growth**.
- Causes small, **stunted plants** with limited root systems, thin stems, and fewer tillers.
- Sometimes causes grass leaves and stems to become **reddish** or purplish, in the older leaves first, or causes small, dark-green clover leaves.
- Causes good **clover growth around old manure patches** with small clover plants and weeds between.

Available phosphorus **levels in the soil should be**:

- Between 20 to 25 mg/ kg Olsen P.

Phosphorus deficiency can be **corrected by**:

- Applying a fertiliser containing phosphorus, such as single superphosphate (8.5% phosphorus) or triple superphosphate (20% phosphorus). High rates are often necessary to build P levels. Depending on soil type, between 5 and 18 kg P/ ha above maintenance is required to lift soil levels by 1 Olsen P unit.
- Followed by annual applications to maintain that level.

Potassium (K):

Plants require a relatively large amount of potassium.

Potassium **deficiency**:

- Causes **poor growth**.
- Causes **yellowing and browning on the margins** and tips of the grass leaves, in the older leaves of the plant first.
- Causes **white spots on the outer margin of clover** leaves.
- Causes **grass dominant pasture** with lots of **flat weeds.**
- Causes good **clover growth around old urine patches** (not necessarily around dung pats) with small clover plants and weeds between.
- Occurs most **commonly** in dairy **pastures cut regularly for hay** or silage.

Potassium **levels in the soil** should be:

- Around 250 mg/ kg Colwell K.

Potassium **deficiency can be corrected** by applying a fertiliser containing potassium, such as muriate of potash (50% K). It is best to do a nutrient balance to determine requirements:

- An average hay or silage crop removes the equivalent of about 150 kg of muriate of potash per hectare.
- Bringing hay, silage and grain onto the farm imports potassium.
- Some areas of a farm, such as areas receiving effluent from the dairy, may not need potassium.
- High soil potassium levels can result in plants high in potassium and cause animal health problems, such as grass tetany and milk fever.
- For this reason, no more than 60 kg of K/ hectare should be applied at any one time.

Nitrogen (N):

Nitrogen is the nutrient most in demand by plants.

Nitrogen **deficiency**:

- Causes **poor growth**.
- Causes a **yellow** or light green colour of the older leaves.
- Causes a patchwork pattern of good **grass growth in urine patches only** (urine may apply 1,000 kg N/ ha), with the remainder having poor growth and less grass.

Soil nitrogen can be increased by:

- Growing clover, so that it converts nitrogen in the air to a form that is available to plants. Clovers often need applied phosphorus, potassium and molybdenum to grow properly.
- Applying nitrogen fertiliser, such urea, ammonium nitrate, sulphate of ammonia or di-ammonium phosphate (DAP).

Sulphur (S):

Many soils in Victoria are naturally deficient in sulphur.

Sulphur **deficiency**:

- Causes **poor growth**.
- Causes small and spindly plants, with short, slender stalks, pale **yellow-green leaves with lighter coloured veins**.
- Can cause **grass-dominant** pasture.
- Can be distinguished from nitrogen deficiency because sulphur deficiency symptoms appear first in the younger leaves.

Sulphur **levels in the soil** should be:

- Around 9 to 12 mg/ kg CPC test, or 12 to 15 mg/ kg with the Blair KCl test.

Soil sulphur can be increased by:

- An annual application of approximately 40 kg S/ hectare.
- The normal rates of single superphosphate (and other low analysis fertilisers) usually supply enough sulphur. Recently, the use of high analysis fertilisers (which are low in sulphur) has reduced the amount of sulphur applied.

Calcium (Ca):

- Calcium is needed in large amounts by plants.
- Deficiency symptoms are rare.
- Calcium is thought to encourage earthworm activity and thus assist in the natural aeration of the soil.
- The amount of calcium available to plants decreases as the soil becomes more acidic.
- A standard dressing of 100 kg/ hectare of superphosphate usually adds enough calcium to the soil for the year.
- Gypsum, lime and dolomite are other sources of calcium.

Magnesium (Mg):

- Deficiency symptoms, although rare, include yellowing of older leaves first, while the veins remain green.
- Magnesium be applied using dolomite, a form of lime containing magnesium carbonate.

6.4.2 Micronutrients

Molybdenum (Mo):

Molybdenum deficiency commonly occurs throughout the high-rainfall dairy areas of Victoria. Deficiencies are particularly common on soils with a pH lower than 5.5.

Molybdenum **deficiency**:

- Causes poor growth, despite adequate applications of phosphorus and potassium.
- Usually causes poor clover growth, and because of this the pasture will generally show signs of nitrogen deficiency indicated by yellowing of older leaves.

Molybdenum **deficiency can be corrected by**:

- Applying small amounts of molybdenum (50 to 70 g/ ha) mixed with other fertilisers, typically about once every 5 to 6 years.

Molybdenum is required in very small amounts:

- Excessive use can create stock health problems.

- High intake of molybdenum by stock in the presence of adequate levels of sulphur reduces the absorption of copper and hence may cause copper deficiency.
- The application of molybdenum to pastures in areas where there is a marginal copper deficiency should be accompanied by an application of copper either to the pasture or to the stock.

Copper (Cu):

Copper **deficiency**:

- Causes poor clover growth.
- Causes animal health problems, even before it is severe enough to reduce pasture growth.

Copper **deficiency** can usually be **corrected by:**

- Applying copper mixed with the normal fertiliser at 1 to 2 kg/ hectare.
- A marginal deficiency can be corrected either by applying a copper fertiliser to pastures or by administering copper treatments to animals.
- Like molybdenum, excessive copper can be harmful to stock, so care is needed when it is used.

Zinc (Zn):

- Zinc deficiency is rare, mostly occurring in sandy or alkaline soils. Symptoms of zinc deficiency include stunted leaf growth and yellowing of the plant. An application to zinc deficient soils of 1 to 2 kg Zn/ hectare lasts for about 5 years.

6.4.3 pH (acidity or alkalinity)

pH:

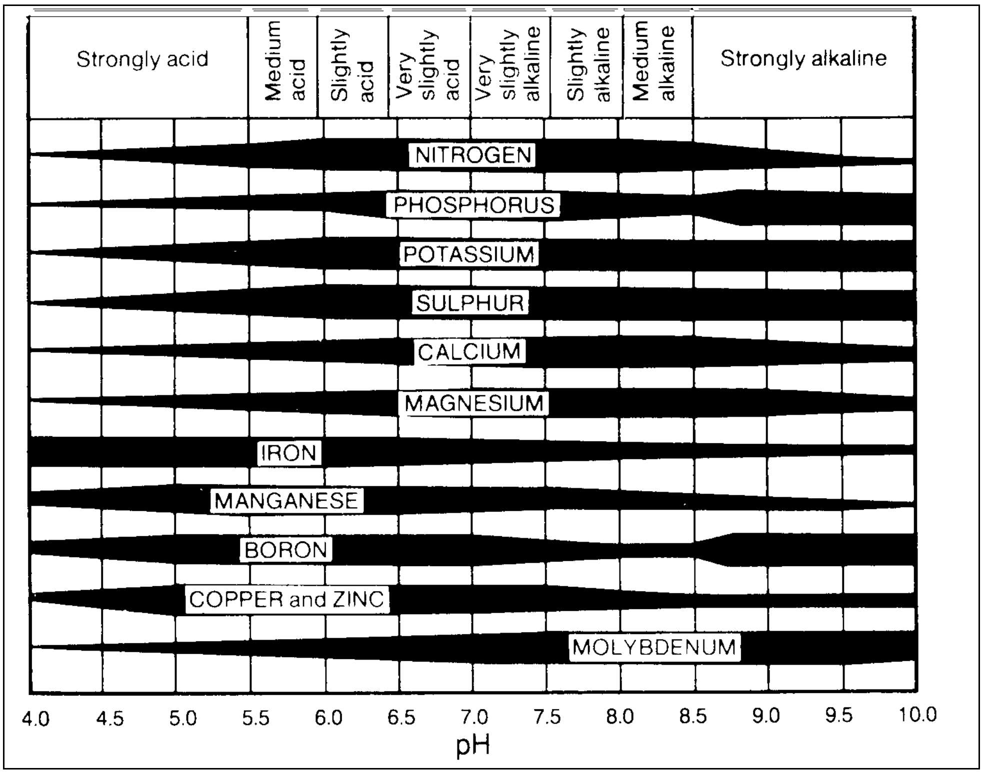
- Is the measurement of the **acidity or alkalinity** of any substance.
- Is measured numerically **between one** (strong acid) and **fourteen** (strong alkali), with a measure of **7 being neutral**, for example, pure water.
- Is measured by two methods: the water method and the calcium chloride method. The calcium chloride method gives a reading about 0.8 lower than the water method.

Most soils under pastures are slightly acidic, with a pH between 5 and 7 (water). The ideal pH range for a ryegrass/ white clover pasture is 5.6 to 6.5 (water).

The pH of a soil is important because:

- It affects the **availability of many plant nutrients**. Some plant nutrients are more available at a high pH, while some are less available. Figure 6-10 shows the relationship between pH and the availability of plant nutrients. The width of the bar indicates the relative availability of each nutrient. The wider the bar, the more available the nutrient. The ideal pH, where all plant nutrients are reasonably available, is slightly more acidic than neutral (between six and seven).
- It **affects the growth of fungi and bacteria** and therefore the decomposition of organic matter.
- It **affects the rhizobia** bacteria in the clover root nodules. They do not extract nitrogen from the air very well when the pH is less than about 5.2 (water) on heavy soils and 4.9 (water) on light soils. This initially reduces clover growth; and eventually, total pasture production declines.

Figure 6-10: Availability of nutrients at varying pH levels



A pH test is included as part of most soil tests. Lime can be used to raise the soil pH. Lime is very insoluble; therefore, applications to the surface may take a year or more to have an effect, so it is recommended that lime be incorporated into the soil by cultivation, usually at sowing. Figure 6-11 shows lime application recommendations at sowing, to improve different soil ph values.

Figure 6-11: Lime recommendations at sowing

Existing pH (water)	Recommendation
5.7 and above	No lime
5.1 to 5.6	2.5 t/ ha
4.8 to 5.0	3.75 to 5 t/ ha
Less than 4.8	5 to 7.5 t/ ha

6.5 Summary

The four fundamental factors that affect pasture growth are **temperature, light, moisture and fertility**.

Good pasture management aims to optimise the use of these factors.

You can't change the light input or temperature, but you can certainly **manage to get the most from them**.

You can manipulate soil fertility and moisture.