Forage cereals

A management guide for dairy farmers

DEPARTMENT OF PRIMARY INDUSTRIES | farm services

State Government Victoria

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Purpose of this guide

This guide is broken into two sections. The first section provides a pictorial guide (along with some descriptive words) of the stages of growth of cereals to assist dairy (and other) farmers in their management of forage cereals at critical decision making times. The second section is a basic management guide for growing forage cereals on Victorian dairy farms.

It is especially designed for those farmers, service providers, contractors and others who may not be heavily involved in the cropping industry. This guide will be a useful resource for those who wish to graze their cereals in the early stages of growth and for those wishing to harvest their crops as silage or hay. However, all stages of growth will be covered so it will be of use to all cereal growers.

Images of the various growth stages at the critical times will include leading up to the critical decision period, during and immediately after, just in case the action did not occur.

It should be noted that soil fertility, soil moisture stress, disease, climatic conditions and intensity and duration of grazing may occasionally impact on of the descriptions of some cereals, sometimes. For these reasons, it may be necessary to seek expert guidance from your local advisor or other sources of information particularly for weed, pest and disease disorders and the growth stages for their control/treatment.

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Introduction

Cereals are a part of the Grass family and, just as any pasture grass, will pass through various stages of growth from germination to seed set. However, for cereals, an accurate determination of its growth stage is very important because the plant's response to herbicides, fungicides and growth regulators are very often dependent on its stage of growth.

Management decisions related to nitrogen application, when to start and stop grazing, when to ensile or make hay and when to harvest as grain are also based on plant physiological stages, some not easily recognised without some experience, or help by experts.

To avoid confusion between grain growers, agronomic advisors, researchers and agribusiness representatives, a standard growth scale was developed in the early 1970s and is recognised widely and used internationally.

This is the Decimal Growth Scale (e.g. GS49), often referred to as Zadoks (e.g. Z49), Zadoks Decimal Code (e.g. DC49) and also referred to as Ravensdown Cereal Growth Stages in New Zealand. There are other scales such as the Feekes-Large and the Haun systems but these are not as descriptive, nor do they cover the full range of cereal growth stages and as they are becoming less commonly used this publication will not be referring to them.

The different growth stages of cereals can occur more quickly or more slowly dependent on weather conditions (e.g. warmer vs. cooler conditions); in healthy vs. stressed crops and according to location (soil type and fertility, topography). For example, soil type can often have bigger variations than regional differences and visible nitrogen stress at stem elongation (GS30) may delay flowering by 2 to 5 days.

The guide is written in two sections:-

- Cereal Growth Stages
- General Management of Forage Cereals

It is impossible to cover all aspects of selecting and managing forage cereals in this guide. There are several publications and web sites which cover most aspects in detail, particularly the pests, diseases and selection of species or cultivars/varieties. See the "References and Further Reading" section.

The decimal growth scale

The Decimal growth scale is based on ten primary growth stages ranging from 0 (GS00) to 9 (GS90) and these neatly sub-divide the life cycle of cereal plants into 10 major stages. These 10 primary growth stages are further sub-divided into 10 secondary stages extending the scale from 00 to 99.

GS00-09. Germination/Emergence

GS10-19. Seedling Growth (Important for various chemicals)

GS20-29. Tillering (Grazing)

GS30-39. Stem Elongation (Nitrogen and fungicides)

GS40-49. Booting (Early silage)

GS50-59. Heading (Ear/panicle) Emergence

GS60-69. Flowering (Anthesis)

GS70-79. Kernel (Grain) and Milk development

GS80-89. Dough development (Late silage or hay)

GS90-99. Kernel (Grain) Ripening (Grain Harvest)

The Decimal growth stage system doesn't always run chronologically from GS00-GS99. For example when most cereal plants develop 3 full leaves (GS13) they begin to develop tillers (GS20) before they have completed growing more leaves (e.g. GS14, 15, 16).

The Decimal growth scale requires some practice to become fully familiar with it. To determine the average growth stage of a crop, do so with a single plant or representative single plants in a crop, not the crop appearance in general. The following pictures will assist greatly in becoming familiar with the stages of growth when dairy farmers need to be making management decisions such as grazing, spraying and harvesting for early or late cut silage.

Growth stages GS10 (Seedling growth) to GS39 (end of Stem elongation and Flag leaf fully emerged) are based on the main shoot (stem) of the plant. To find the main shoot, which will have the longest leaf, tip the plant upside down and run your hand down the plant to find the longest leaf. The main shoot also usually has the thickest stem of the entire plant provided it hasn't been previously grazed. The other individual tillers will be further behind in development at this stage.

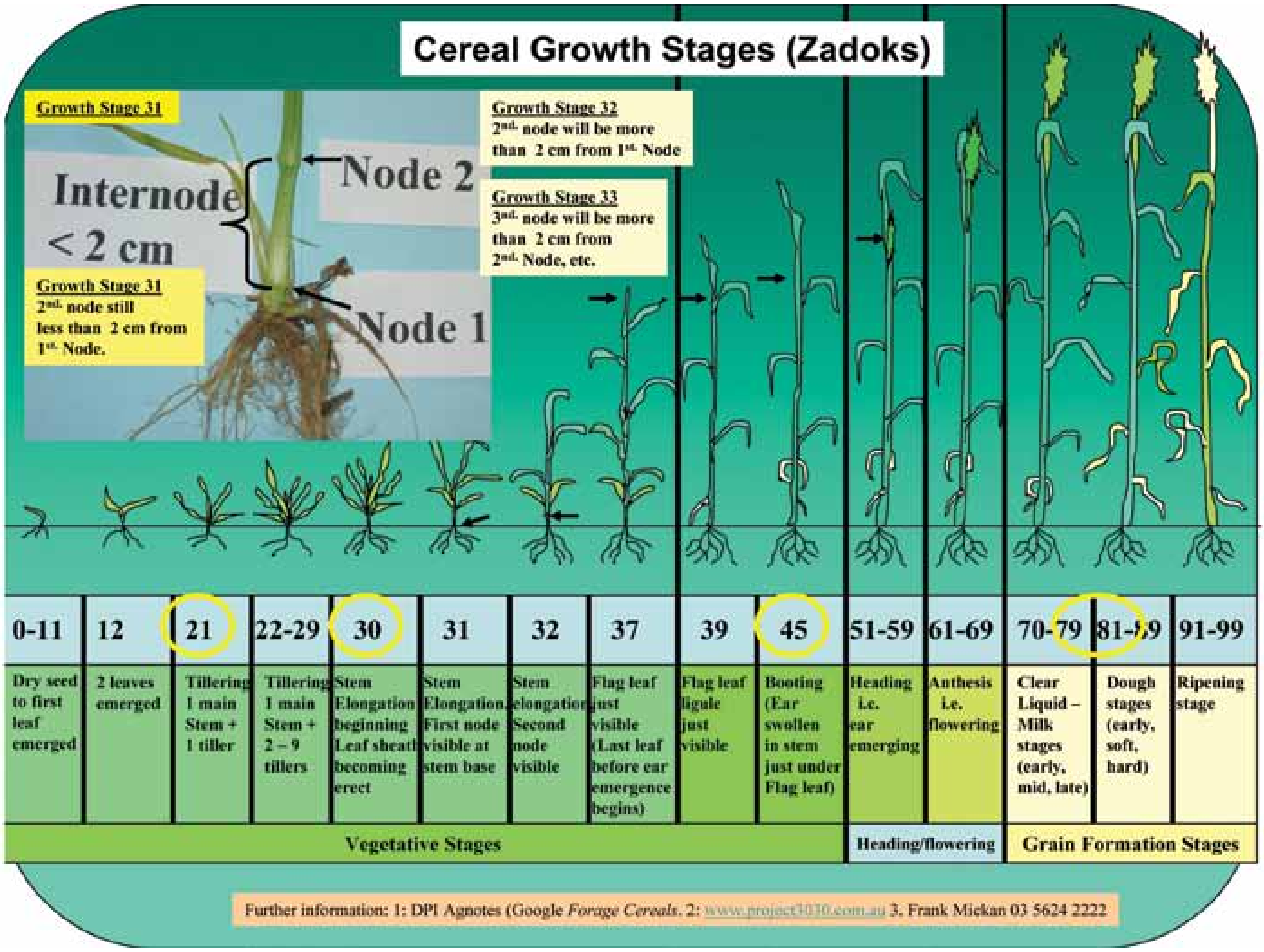
Growth stages GS39 to GS94 are assessed on average shoots or whole plant basis because the surviving tillers by this stage have caught up with the main stem.

Cereal growth stages

Overall growth stages of cereals

Figure 1 shows the entire range of growth stages of cereals. Encircled are some of the critical decision points for grazing and ensiling of cereals. These activities are more fully discussed at the appropriate growth stages and also in the general management of forage cereals section.

Figure 1. Growth stages of cereals



Germination/Emergence
GS00 – GS09

Snap shot: This stage (GS00 – GS09) covers from when the dry seed is sown, imbibing moisture, and germination through to the first green leaf just at the tip of the coleoptile (protective sheath which protects the first leaf till it reaches the ground surface).

After the dry seed (Figure 2) is sown and it then absorbs moisture from the soil, the primary root (radicle) emerges (Figure 3), growing downwards to absorb water and nutrients and eventually develops lateral rooting. Other highly branched roots, seminal roots, form after this at the seed level and remain active all season.

After the primary root emerges, the first and main shoot then emerges from the seed. As it penetrates the soil, the coleoptile (Figure 3 & 4), an outer covering protects this shoot. The coleoptile of a barley plant can only grow to approximately 75 mm in length, so seeding depth should never be below this depth, with the ideal sowing depth ranges from 30 – 50 mm

Figure 2. GS00 Dry seed

Figure 3. GS07 Coleoptile emerged from seed

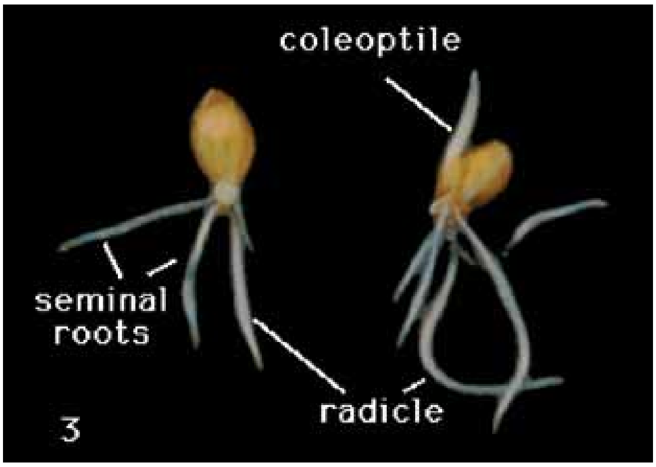
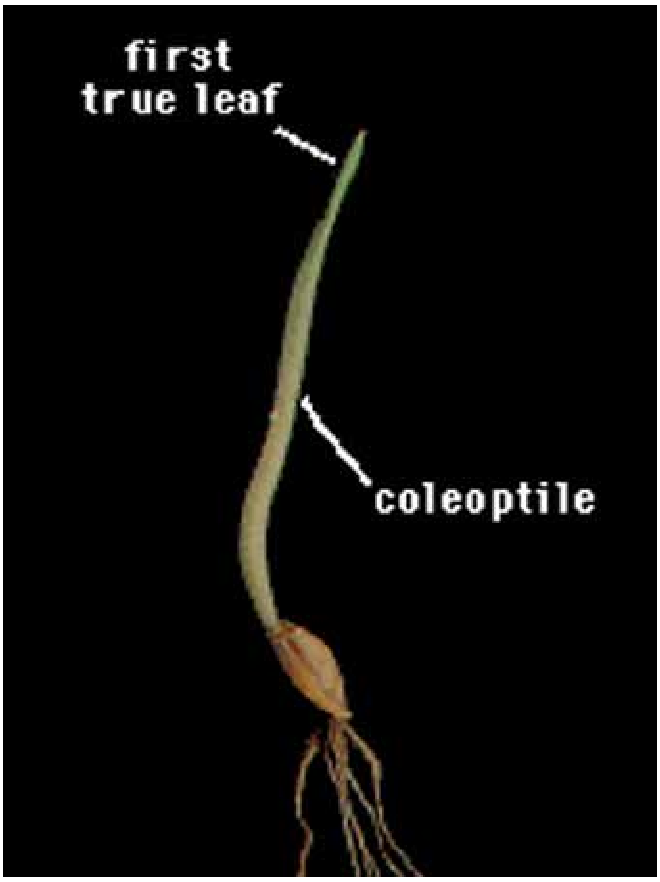


Figure 4 GS10 Tip of the first true leaf just starting to emerge through the coleoptile



Source: Images for figures 3, 4 & 5 courtesy University of Minnesota Extension

Seedling Growth GS10 – 19

Snap shot: This stage covers (GS10-GS19) when the plant has emerged from the ground and the leaves begin to appear. The first number (1) refers to this stage and the 2nd number (e.g. 2) represents the number of leaves emerged. E.g. a plant with two leaves is GS12.

Once crop emergence starts, seedling growth stage is scored by counting the number of emerged leaves. To score seedling growth:-

- Count the leaves on the main stem only
- A leaf is counted as emerged when either its ligule* has emerged from the sheath of the preceding leaf, or when the tip of the next leaf is just visible.

* The ligule is a projecting flap or collar located at the junction of the leaf-blade and leaf-sheath. The ligule prevents water entering inside the leaf-sheath where it might be retained and cause rotting. Make footnote - okay

The decimal scale can be further sub-divided by scoring the youngest leaf in tenths relative to the preceding leaf. E.g. GS12.5 is 2½ leaves (Figure 5) and GS13.5 is 3½ leaves (Figure 6). For most dairy farmers, scoring leaves to the nearest half leaf, and probably to the nearest full leaf is accurate enough for management decisions.

Figure 5 GS12.5 Seedling at 2½ leaf stage

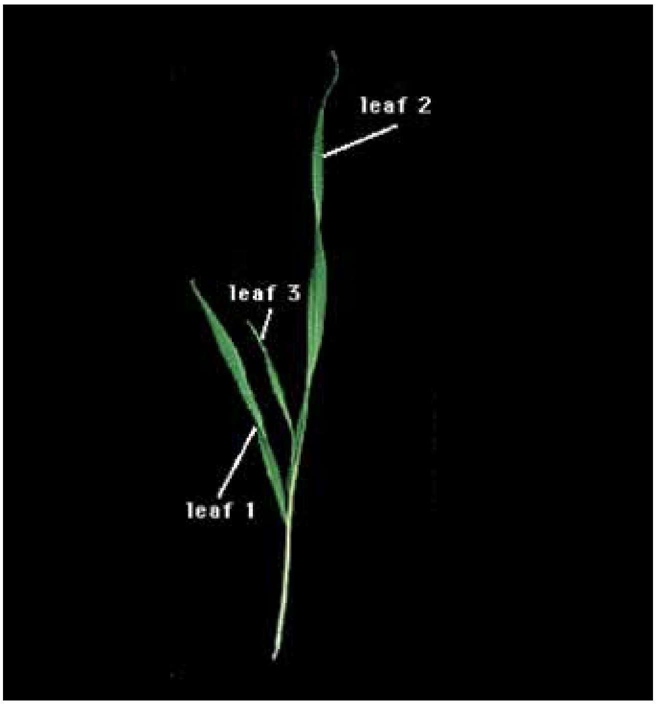


Figure 6 GS13.5 Seedling at 3½ leaf stage

Tillering GS20 – 29

Snap shot: This stage covers (GS20-GS29) when tillers begin to emerge from the main stem. The first number (2) refers to this stage and the 2nd number (e.g. 1) represents the number of tillers that have emerged. E.g. a plant with two tillers is GS22.

Tillers are basal "branches" (Figure 7) which arise from small buds in the axis of the leaves on the main stem, i.e. between a leaf and the main stem). These can be easily broken off at the base unlike the true main stem leaf.
The number of tillers that a single plant will produce will depend on the genetics of the plant as well as the environment the plant is growing in. Plants growing in a fertile soil with good structure with adequate moisture will develop more tillers than a plant that is being stressed. If a plant is badly stressed it will produce very few tillers.

Figure 7. New tiller emerges from between the leaf blade and the main stem

In wheat, the first tiller usually appears between GS13 to 14, that is, between when the 3rd. and 4th. leaves have emerged.

To score tillers:

- count the tillers as soon as they emerge from the sheath of the subtending leaf
- count the tillers only, not the main stem.

To find the main stem, tip the plant upside down and find the longest leaf.

It is also usually the thickest stem (Figure 8). However, this may not be clear, simple or easily determined in a grazed crop.

Figure 8. Finding the main stem on a whole plant

Once the main shoot/stem is found, count only the side tillers/ shoots with a leaf blade emerging between a leaf blade and the main stem. If the main stem is not easily identified, just count all tillers and reduce the total by one. A tillering plant with GS21 has one main stem + one tiller (Figure 9) and a GS22 plant has one main stem + two tillers (Figure 10).

Figure 9. GS21 Main stem + 1 tiller

Figure 10. GS22 Main shoot + 2 tillers

Figure 12. Oats grazed to good height

Figure 11 shows a plant with the main stem plus six tillers.

Figure 11. GS26 Main tiller + 6 tillers

Figure 13. Good utilisation (front), Poor utilisation (rear)

Grazing forage cereals: Tillering to Stem Elongation: GS20 – GS30

- **Begin grazing from early tillering to late tillering (GS22 – GS28)**.
- Ensure plants pass the "pinch" test. (i.e. twist & pull without the whole plant coming out of ground).
- **DO NOT graze cereals in very wet ground condition** (regrowth will be severely reduced).
- Cereals often have **very high nitrate levels** in the tillering stage, especially if top dressed with nitrogenous fertilisers. Do not graze with very hungry stock.
- **Grazing residual heights** ~5 cm for prostrate varieties and 10 cm for erect varieties. (No lower than about 6 – 7 cm for triticale). Grazing lower is highly likely to reduce silage, hay and grain yields.
- **Utilisable yields** will range from about 1600 – 2300 kg DM/ha in normal growing seasons at mid – late tillering on soils of satisfactory fertility.
- May get **1 - 3 grazings** depending on how early crop is sown (normally count on one grazing only).
- Continued grazing, at the expense of later silage yields, may be preferable to fully utilise milk price incentives.
- Graze cereal/ryegrass mixes at about mid-tillering (GS24 – 26) to avoid severe ryegrass shading.
- **Legume component will be lost** if cereal/legume (e.g. peas & vetch) mixes are grazed.
- **Nutritive value** is similar to that of ryegrass (>11 ME, >20% CP, ~35 to 40% NDF)
- The **longer that grazing is delayed**, the higher the dry matter yield:
  - BUT the stems of the older tillers will be thicker and also less palatable
  - BUT the utilisation will be poorer due to trampling during grazing (Figure 15)
  - AND LATER the crop maturity will be (approx +7 – 14 days if grazed during late tillering).
- Mowing + wilting pre-grazing to ensure an even crop after grazing is neither necessary nor economical, unless approaching later tillering stages (GS27 – GS29). If mowing this late, set cutting height several centimetres above the top node.
- Grazing once at/after stem elongation, GS30 - GS32 (Figures 16 - 20) will **reduce silage yields by up to 50%.**
- If cereal is at OR past stem elongation (GS30 – GS32), mow/graze well above the top node.
- To boost silage yield, **apply 50 – 70 kg nitrogen/hectare** after grazing, if needed.
- **Animal health issues:**
  - pulpy kidney, grass tetany, milk fever and nitrite/nitrate poisoning could be an issue. Avoid putting hungry animals onto a young cereal crop, worse if N top dressed. Avoid grazing crop that has been stressed causing growth to slow. E.g. severe frosts or a run of very cold cloudy days.
  - marginal magnesium & sodium deficiencies have been found in sheep and beef cattle but not researched in dairy cattle. Be aware of possible Mg & Na deficiency if grazed cereals form large portion of daily ration.

Stem elongation GS30 - GS39

Snap shot: This stage, GS30-GS39, covers when the cereal plants start to "jump out of the ground" and quickly grow taller. In fact the "unseen" head inside the main stem and some side tillers start to be pushed up to the top of the crop canopy along with the extension of the main stem and often other tillers on the same plant. The first number (3) refers to this stage, stem elongation, and the 2nd number (e.g. 3) refers to the number of nodes or "joints" which can be seen or felt. E.g. a plant with GS33 has three detectable nodes.

At stem elongation, often referred to as "jointing," gaps between the nodes, called "internodes" appear which starts to push the nodes/joints upwards into the air. The ear was originally formed as microscopic structure between GS14 and GS16. Initially, the stem consisted of nodes or "joints" and "internodes" which are gaps between each node, all very closely pushed together and very difficult to see with the naked eye.

As stem elongation (GS30) begins there may not be any significant swelling of the node, so the first node may only be clearly seen at the very early stage by peeling back the leaves or dissecting the stem near the base (Figures 15 - 18). Soon after this stage, the first node, (GS31) on the main stem may then be felt or seen. The bottom node is referred to as Node 1 and the nodes are counted from the base upwards.

GS32 (Figure 19) refers to when the second node can be detected (and the internode below it exceeds 2 cm).

Most cereals will produce up to about 6 nodes, GS36. From about GS36, growth stages describe when the Flag leaf just becomes visible (GS37 through to GS39, when the Flag leaf is in full view (Figure 20). The *flag leaf* is the last leaf to develop on a cereal plant and is found just below the ear.

When stem elongation begins, an internode expands to several centimetres long and the node above it swells and hardens. This is the first node/joint. This process is repeated by other internodes above the first node until the ear or head eventually emerges from the boot. The *boot* stage is just prior to ear or head emergence, when the flag leaf sheath encloses the growing ear/head.

The commencement of stem elongation is a very critical stage if grazing cereals. Grazing after GS30 will substantially reduce fodder and grain yields. (Refer to grazing managment section – in section B of the guide)

Figure 14. Plant in stem elongation stage

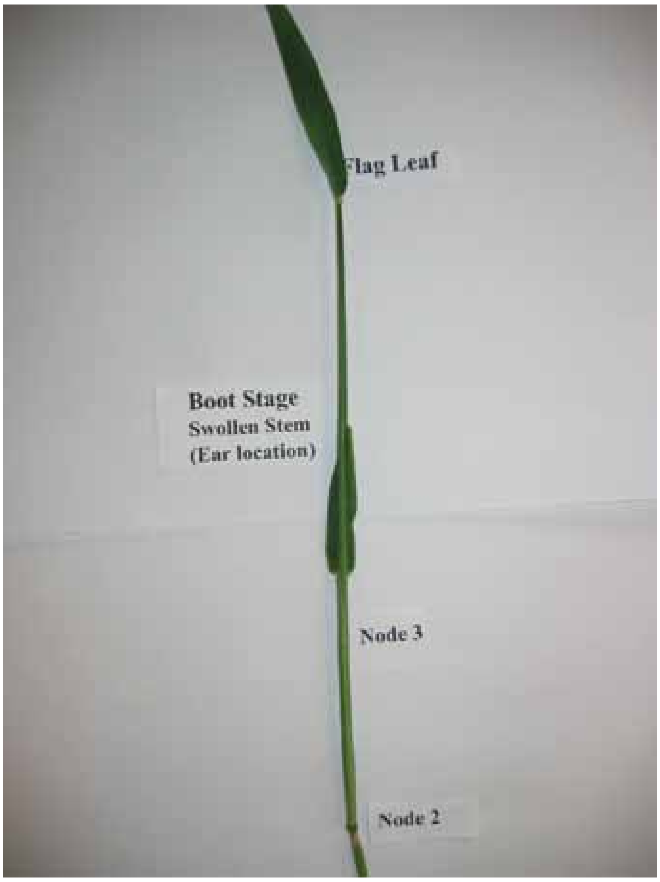


Figure 15. GS31 First node (swelling) detectable

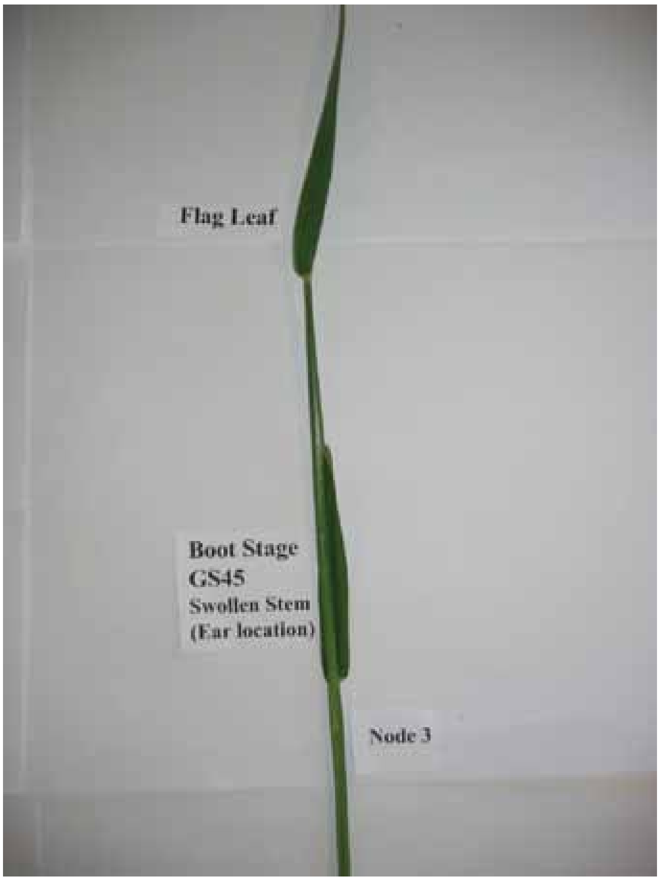
Figure 16. GS31 First node detectable

Figure 17. GS31 Dissecting stem

Figure 18. GS31 Cross section of first node

Figure 19. GS32 Second node detectable

Figure 20. GS39 Flag leaf



Boot stage GS40 - 49

Snap shot: This stage, the *Booting* stage (GS40-GS49), covers when the ear/head enlarges and moves upward through the shoot and when the flag leaf sheath at the uppermost section of the plant starts to appear swollen. This swollen section is referred to as the *boot*, and is just prior to the emergence of the head.

Initially the flag leaf sheath will extend (Figure 21) and about then the boots may begin to be visibly swollen at GS43 (Figure 22). This swelling becomes more obvious at GS45 (Figure 23). The ear is continuing development inside the flag leaf sheath at this stage, as seen when the stem is dissected (Figures 24 and 25), and then the continuing swelling of the ear inside the boot will start to force the flag leaf sheath to open at GS47 (Figure 26). After this, varieties with awns will just start to poke through the top of the swollen boot, at the base of the flag leaf at GS49 (Figure 27).

Figure 21 GS41 Flag sheath extending

Figure 22. GS43 Boots slightly swollen

Figure 23. GS45 Swollen boot

Figure 24. GS45 Dissecting boot to show ear

Figure 25. Dissected boot

Figure 26 GS47 Flag leaf sheath opening

Figure 27 GS49 Awns starting to emerge from boot

Harvest as early cut vegetative silage: Boot to Flag Leaf stage: GS41 – GS49

- Potential for good yields (6 – 8 t dry matter per hectare {t DM/ha}).
- However, yields increase by about 50% to 100% if cut at soft dough stage.
- Moderate to high quality but can vary significantly between species and cultivars and growing conditions
  metabolisable energy: 9.5 – 10.5 megajoules/kg DM
  crude protein: 10 – 16% of DM
  neutral detergent fibre: 40 – 55% of DM.
- Cut at 10 cm height.
- Use mower conditioner (leave wide windrows) or ted (spread) immediately after mowing.
- Must wilt before harvesting (may be difficult in early spring).
- **Target DM contents at harvest:** all cereals and their legume (pea/vetch) mixes
  forage harvested 33 – 40
  baled 38 – 50.
- **Harvest precision chopper** (highly preferable).
- **Loader wagons** (fine chop) or **balers** (preferably with knives) are suitable at this growth stage but harvest at lower end of DM range to aid compaction.
- **Silage additives** highly recommended BUT essential if not wilted enough!
  - Use additives that enhance fermentation.
- **Storage:**
  Stacks/bunkers: seal airtight immediately after harvest
  Bales: wrap (4 – 6 layers) at storage site within hours of baling.

Heading (ear/inflorescence) emergence from boot GS50 -59

Snap shot: This stage, the *Heading* stage (GS50-GS59), is when the ear, sometimes referred to as the inflorescence or panicle, begins to emerge from the boot. To be correct, the "boot" is the swelling caused by the ear which is still wrapped inside the flag leaf sheath. As the ear emerges from the boot, its growth stage is based on the proportion of ear emerging from the flag leaf sheath.

Figures 33, 34 and 35 show the boot to heading stages of forage oats, barley and triticale respectively.

Figure 28. GS51 First spikelet of inflorescence just visible

Figure 29. GS53 Ear/Inflorescence ¼ emerged

Figure 30. GS55 Inflorescence ½ emerged

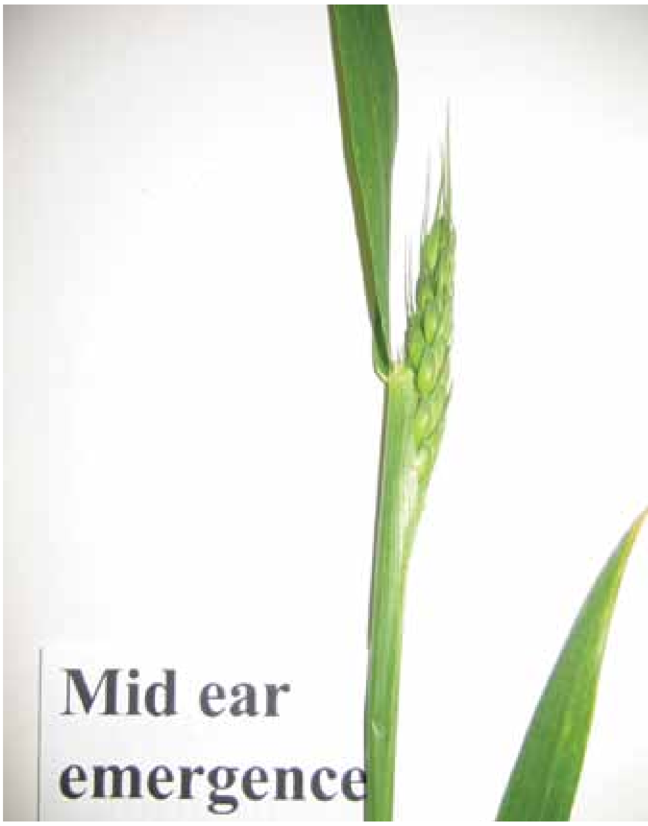


Figure 31. GS57 Inflorescence ¾ emerged

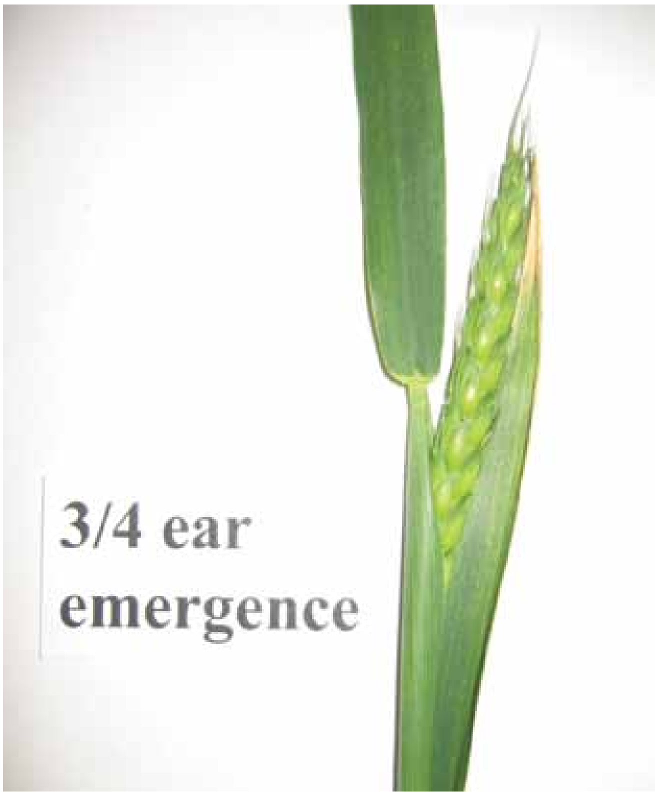
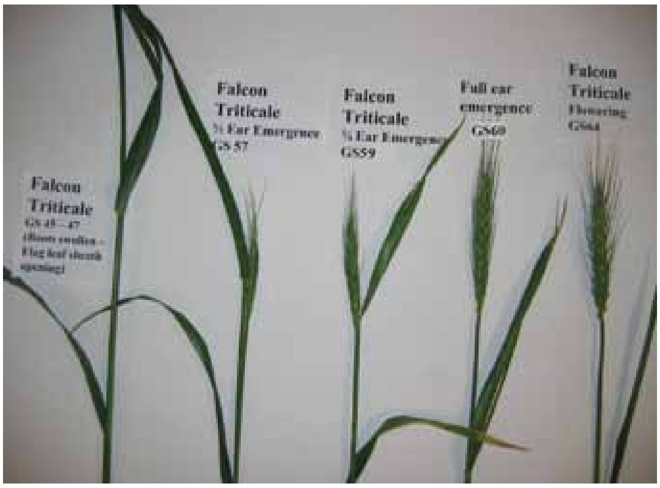


Figure 32. GS59 Emergence of inflorescence completed Whole spike visible

Figure 33. Oats at various stages of heading

Figure 34. Barley at various stages of heading

Figure 35. Forage triticale at various stages of heading



Flowering (anthesis) GS60 - GS69

Snap shot: This is the *Flowering* stage (GS60 - GS69), correctly referred to as anthesis, and occurs within a few days of heading. Each species of cereal has florets which have anthers that contain pollen and an ovary which becomes the grain when fertilised. Not all florets form grains.

Anthesis is usually scored by the presence of the emerged anthers that have already shed pollen. Anthesis occurs initially in the middle of the ear and within a few days, spreads both upward and downwards.

During pollination and flowering, cereal plants are very prone to stress, such as severe frosts, water deficits or water logging and high temperatures which may greatly affect grain yield and quality. In very dry conditions, stem elongation may be restricted and anthesis may occur as the ears are emerging or even within the boot.

Figure 36. GS61 Beginning of anthesis with a few anthers in middle of the ear

Figure 37. GS65 Anthesis half way with anthers appearing half way to the tip and base of the ear

Figure 38. GS69 Anthesis complete with anthers from the tip to the base of the ear

Figure 39. Barley ears flowering in the flag leaf

In barley, unlike other cereals, pollination usually occurs just before or during head emergence (Figure 39).

Milk stage (Milk Development) GS70 - 79

Snap shot: This stage represents the commencement of the grain formation stages, the first being the *Milk Development* stage (GS70-GS79). This period is when the plant sugars, stored in the stem and upper leaves up until this stage, begin to be "drawn" into the kernel where they are converted to starch, to finally become the grain over the next, final two stages.

The Decimal growth scale does not describe the grain development stages well.

It requires very subjective assessment of the proportion of solids in the milk and the stiffness of the dough.

From 7 to 14 days after fertilisation grain formation is mainly growth of the ovary wall containing a clear watery fluid referred to as "watery ripe", GS71 (Figure 41).

After this, starch deposition commences and the ratio of solids to liquid determine the early milk stage, GS73, when the liquid is off

Figure 40. Rudd Wheat at Anthesis (Flowering)

white (Figure 42) and the grain has grown to nearly its full length but is 1/10 of its final dry weight.

The medium milk stage, GS75 (Figure 43) is when the liquid no longer has any sign of clear watery colour to it and late milk, GS77 (Figure 44) stage is when the colour becomes darker and the liquid has begun to thicken in its texture.

Only when no liquid remains does the next stage, dough development, begin.

The time it takes the developing grain to move through these stages is very much dependant on its environment. In hot dry conditions it can move through these stages in a matter of days but in cold moist conditions in can take 10 days or more.

Figure 41. GS71 Grain (caryopsis) watery ripe with clear liquid and no starch

Figure 42. GS73 Early milk, liquid off white

Figure 43. GS75 Medium milk, liquid is milk

Figure 44. GS77 Late milk (More solids in milk)

Figure 45. GS79 Very late milk, half solids in milk.

Dough stage (Dough Development) GS80 - 89

Snap shot: This growth stage represents the *Dough Development* stages which begin when no liquid remains in the grain. The grain is now rapidly depositing starch and the leaves and stem are rapidly dropping in nutritive value. By mid Dough stage, the grains will have changed colour from light-green to yellow-green, and to yellow by the hard dough stage.

At the early soft dough stage, GS83, the developing grain is elastic and almost dry. The next stage is soft dough, GS85, which is characterised by a white semi-solid consistency and the grain will return to its original shape if pressed firmly with a fingernail (Figures 46, 47, 48 and 49).

Maximum grain weight is achieved at GS86, just after soft dough, GS85, when the moisture content of the grain is about 40%. At this stage, a fingernail impression made in the grain will slowly disappear so that the grain will almost get back to its original state.

The final stage is hard dough, GS87, and when pressed with a fingernail the fingernail impression remains (Figure 50 and 51). Hard dough becomes more solid as the kernel approaches maturity and loses water rapidly (Figure 52).

The "dough" stage also lasts about 10 days, although the period over which this stage occurs can be affected by environmental conditions.

Figure 46. GS85. A grain kernel at the soft dough stage being subjected to the fingernail test.

Figure 47. GS85. The grain kernel regain its original shape after the fingernail test which confirmed that it is at the soft dough stage.

Figure 48. GS87 A grain kernel at the hard dough stage being subjected to the fingernail test.

Figure 49. The grain kernel did not regain its original shape after the fingernail test which confirmed that it is at the hard dough stage.

Figure 50, GS89 Late hard dough, Difficult to dent

Harvest as Late Cut Whole-Crop Silage: Late Milk to Soft Dough Stage (GS75 – GS85)

- Potential for very high yields (10 - 16 t DM/ha).
- Low to moderate quality but can vary significantly between species and cultivars
  - metabolisable energy: 8.0 – 10.0 megajoules/kg DM)
  - crude protein: 5 - 8% of DM
  - neutral detergent fibre: 55 - 70% of DM.
- Cut at 10 cm height.
- Can usually harvest as standing crop.
- **Target DM contents at harvest:** Wheat, barley and triticale (Not recommended to harvest Oats and Ryecorn or their legume mixes at this stage for silage due to very low quality and difficulty in ensiling)
  - forage harvested 35 – 42
  - baled 38 – 45.
- **Harvest with precision chopper with direct cutting front** (highly preferable). (Figure 53)
- Can use precision chopper with pick-up front but mow only, leave swathe wide and avoid raking to minimise leaf/grain loss.
- **Additives:** Apply Aerobic Spoilage Inhibitor-type silage additives through spout or at cutting mechanism with precision chop harvesters
  - specific inoculants that contain *Lactobacillus buchneri* 40788 or similar bacteria as they become proven and available
  - typical with *L. buchneri* in mix
  - other appropriate additives, e.g. buffered acids, sulphur + amylase, etc.
- **Use Loader wagons at own risk!**
  - Chop length is often too long; impossible to compact well.
  - If used, apply aerobic spoilage inhibitors (see above) to control aerobic spoilage at feedout.
- **Use balers at own risk!**
  - High DM (& quality) losses due to grain/leaf losses at baling.
  - If storing as round bales, use traditional fermentation enhancing inoculants to assist fermentation.
  - If storing as large square bales under sheets, use aerobic spoilage inhibitor.
  - Vermin must be controlled (they "sense" the grain & will chew through plastic to get at it!)

Harvest as cereal hay: Late Milk to Soft Dough Stage (GS75 – GS85)

- It can be hard to get cereal hay to cure if cut before the head has fully emerged (GS59).
- Timing of cutting is always a trade off between quality and quantity (refer to the fodder quality and conserving cereal section of this book).
- Cutting height is normally recommended at around 15 cm above the ground. Cutting higher will increase quality but reduce yields, while cutting lower will increase yields but reduce quality. Also, leaving around 15 cm residue behind allows the windrow to be kept off the ground to increase airflow (and reduce curing times) and can also decrease contamination by dirt, rocks etc.
- It is preferable to use a mower conditioner to crush the stems and nodes and leave as wide a windrow as possible.
- The nodes and head of the plants are normally the last parts of the plant to fully cure.
- The faster the crop can be cured, the better the quality of the hay.
- Ideally wait for any moisture (from dew, rain etc) to dry off the crop proir to cutting it. Also, if possible, wait for the soil to dry prior to cutting to reduce the curing time.
- Cereal hay should not be baled until the moisture content is ideally at 10-15%. Hay should not be baled if over 18% moisture.
- A practical method of determining if cereal hay is ready to bale is to take a tightly bound handfull of hay and wind it rapidly in a circular motion to producing shearing. If it doesn't break within three turns it most likely hasn't cured enough.
- Immature or drought stressed cereal crops can be difficult to cure properly, despite moisture meter readings indicating that the material is ready for baling. Regularly inspect hay stacks from these crops for signs of severe heating and potential for spontaneous combustion, i.e. hay stack fire.
- A more accurate and practical way to test if immature or drought stressed cereal hay is safe to bale is to squash some nodes onto a flat dark metal bar (e.g. bull bar), and if moisture is left behind, it is not ready to bale yet.
- The head of the plants also need to be tested, especially if plants are still in the flag leaf – boot stage.
- Make sure representative samples are taken from different areas such as bottom of windrows, outside rows and headlands.
- Cereals harvested in the soft dough stage must be handled gently by equipment to minimise grain loss, the main reason for harvesting at the slightly earlier growth stages.

Harvest as whole-crop alkalage: Late Soft Dough to Hard Dough Stage (~GS85 – GS85)

- Alkalage is produced by preserving whole-crop cereals (grain + stem + leaves) using a process of ammoniation.
- It is produced by spreading a specific additive, HOME'N'DRY®, which is a manufactured pellet containing both urea and urease.
- When preserving as Alkalage, storage losses are usually minimal.
- During harvest, losses will also be negligible if a forage harvester fitted with a direct cutting front is used for harvesting the drier whole-crop (Figure 51).
- Where the ideal equipment is not available losses will be substantially higher. These losses will be mainly the grain, the most nutritious part of the plant.
- Target DM range of 65 - 85% DM, or less than 35% grain moisture. In this DM range, the cereal grain will be at the hard dough stage, with grain fill completed and the crop will be near its maximum nutritional value.
- If DM is under about 65%, then the forage may try to ferment, thereby reducing the pH, rather than increasing it as required to produce alkalage. Conversely, crops cut over about 85% DM will not contain enough moisture to activate the additive.
- Visibly, the crop will be about 66 – 70% DM when it is yellow-brown with traces of green at the nodes (joints), some heads will be bending over, and the grain cannot be penetrated with a thumbnail. At 71 – 85% DM, all the plant will be yellow brown, the heads will be bent over, and the grains will be very hard.
- Chopping the whole-crop very short using a precision chop harvester is essential to ensure reasonable compaction in the stack/bunker.
- Compaction in the stack can be less dense than that required for cereal silage to allow greater movement of the ammonia gas throughout the stack.

Figure 51. Forage harvester with direct cutting front

Ripening stage GS90 – GS99

Snap shot: This stage, *Ripening,* is the final growth stage in the life of the cereal plant. By the Hard dough stage, the grain kernel has reached physiological maturity after which no further deposition of materials in the grain occurs and yield will then be at its maximum. This also concurs when its moisture content has decreased to about 30 to 40%. Although too high for direct combining as grain harvest at this stage, it can be cut and windrowed and combined and threshed when it reaches 13 to 14% moisture.

By the Ripening stage, all cereal grain types will have lost their chlorophyll light-green to yellow colour and be turning some shade of brown, depending on cereal and cultivar type.

At the harvest ripe stage, GS92 (Figure 54), grain moisture content will be about 12% moisture but rainfall events can slow or even reverse the drying process which can result in reduced grain quality. Although the drying may only require a few days in hot dry conditions it may occur over several weeks in cool moist conditions.

If grain harvest is delayed past GS92, the grain becomes loose at GS93, and straw becomes brittle at GS94, with potential for increased shattering losses and broken grain during harvest. The GS94 – 99 stages are not relevant in Australia as it deals with the seed dormancy and viability.

General Management of Forage Cereals

The term forage cereal simply refers to a cereal that is being grown and managed for forage production rather than grain production. This can be either for grazing, ensiling or hay production or a combination of these. Any variety of cereal can be sown for grazing and fodder production, but some varieties have characteristics that are more suited to fodder production such as higher forage yields and quality, and regrowth after grazing.

Choosing a Variety

Diversity

"Cereals aren't Cereals". There's such a huge range in cereal species and cultivars/varieties within each species that it can be difficult to decide which will work best for you. Basically, there is a cereal (oats, wheat, triticale, barley and rye corn) variety available for just about every end use, whether it is early fodder for grazing, silage, hay or grain production, or a combination of all of these.

Once you've determined what it is that you want and when you plan to sow, it's possible to match a variety (or varieties) with the right maturity, growth habit, and disease and pest resistance for your needs. If you don't know the characteristics of the variety you have purchased/have in the silo, you may be sowing the cereal that will not perform to your expectations.

Maturity date

The maturity of the variety you intend to plant is critical to getting the end result you want.

All cereal crops are categorized into the following maturity categories:

Very Early (VE)	Early (E)	Mid (M)
Mid-late (ML)	Late (L)	Very Late (VL)

Table 1 shows the possible uses for varieties of different maturities when sown at different times. The maturity of the variety you intend to plant is critical to getting the end result you want.

Table 1. Possible outcomes for different varietal maturity dates and varying sowing times

	Sowing time			
Maturity	**March Sowing**	**April Sowing**	**May Sowing**	**June Sowing**
V Early	Grazing	Grazing/silage	Grazing/silage/hay	Grazing/silage/hay
Early	Grazing	Grazing/silage	Grazing/silage/hay	Grazing/silage/hay
Mid	Grazing	Grazing/silage	Grazing/silage/hay	Grazing/silage/hay
Late	Grazing/silage	Grazing/silage/hay	Grazing/silage/hay	Grazing/silage/hay
V Late	Grazing/silage/hay	Grazing/silage/hay	Grazing/silage/hay	Grazing/silage/hay

Very Early (or very quick maturing) varieties are generally best sown late (late May, June, July). If sown too early, they will run up to head during winter, exposing them to frost risk. Sown early, they will be a grazing only option as head emergence is at the wrong time for hay or silage production. However, because of their quick growth habit, they provide good early DM production. When sown late (in the case of a late break) they are an excellent option.

Mid maturing varieties are ideally sown in mid May and will generally be ready for hay cutting in mid October. Sown too early, they are a grazing only option, because they will run up to head in winter. They are still productive for hay/grain when sown late.

Late maturing varieties are best sown early and have an extended grazing period into winter when compared to the shorter maturity types. Some are a little slow to start in autumn. Be careful when choosing Late-Very Late cultivars as they will mature much later than other types and may be heading/grain filling during periods of high temperatures and/or moisture stress. As a result, you may need to budget on irrigation (if available) or a late finish to the season to make quality hay/grain.

Winter Habit and Vernalisation

Varieties with **winter habit** won't run to head (reproductive growth phase) until they experience increasing day length after the winter solstice. This delayed heading means they have an extended vegetative period compared with the typical dryland cereal varieties.

Some varieties have a **vernalisation** requirement which means these varieties need exposure to cold temperatures before getting the signal to turn reproductive. This is a trait of northern hemisphere varieties that spend winter under snow. The advantage of these types is that they can be sown early in the season (late Feb – early March) and are guaranteed not to run up to head until after exposure to a specific length of a cold period during winter.

Dwarfism or plant height

In general, most wheats are semi-dwarf, which means that they generally grow to a medium height (75-85 cm) when not moisture stressed or sown really late. Oats can be any height though short (65-70 cm) varieties may produce less DM if sown late (though they are competitive for DM when sown on time). Other oats may be really tall and can reach approximately 130 cm in height. Triticale is generally taller than the other cereals (ranging up to 150 cm).

Some varieties can be more prone to lodging (lying over) when allowed to grow tall. Some forage oats and barley varities are prone to lodging which can make harvesting for silage or hay more difficult. Grazing can reduce the final height of the crop to some extent, and will depend on when and how hard the cereal was grazed.

Early Vigour

This describes how quickly plants emerge and grow in the early stages of crop development. The better the early vigour of a variety, the shorter the time to the first grazing. In general, barley (Figure 53) has the best early vigour followed by oats. Wheat and triticale will often have the poorest early vigour, but again there is significant variability within cereal classes.

Figure 53. Dictator 2 Barley (LHS) which has excellent early vigour is sown at the same time (20 05 10) next to Endeavour Triticale (RHS) which has a poorer early vigour. This photo was taken on 20 08 10,.

Pest and Diseases

All cereals have specific and general pest and disease issues such as a range of rusts including crown, stem and leaf rusts. Stripe rust has become a prevalent leaf disease of wheat, usually appearing in September. However, breeding programs have resulted in a range of disease resistance available in many species and their varieties. What level of resistance you need to select for will depend on your preparedness to spray, whether the season is likely to be favourable for rust growth (wet and warm) or if you are going to graze/ensile the crop before the disease is too advanced.

As a broad statement on diseases likely to be encountered in Victoria:

Wheat is probably the most susceptible to leaf diseases, in particular stripe rust. A change in stripe rust strain has meant that some triticale varieties are now susceptible, whereas triticale was previously regarded as fairly disease free. Barley would be less liable to leaf diseases although net blotch/scald can be an issue in wet years whilst oats are the most rust resistant.

Soil-borne diseases can be a problem, particularly following pastures as many grasses host diseases that affect cereals. Pests are usually a minor issue – earth mites can cause damage but cereals are not a preferred host and aphids, while they rarely do too much damage, can be a source of viral infection.

Changes in the rust strains over time can overcome the resistance genes in many cereal varieties. This means that knowing the up-to-date resistance rating of the cereal is important. Using some seed treatments and fungicides at the correct rates at the correct time will help to prolong the longevity of current varieties. Care needs to be taken to make sure any with holding periods are adhered to.

Herbicides

Wheat has the greatest range of options for in-crop weed control, followed by triticale and barley. Oats has the least, with few products for in-crop options. Be aware that some herbicides have long residue periods and can limit what you plant for the next year or two. Most herbicides and insecticides have a withholding period for grazing and harvest (silage, hay or grain) that must be observed.

Cereal characteristics summary

Oats

- Provide both quantity and quality in the vegetative stage.
- Quality declines rapidly when the grain begins to form due to the amount of husk compared to other cereals.
- Is highly resilient and a competitive cereal in different environments.
- In comparison to other cereals there are fewer weed control options.
- Possibly more prone to lodging than most other cereals.

Wheat

- Most wheat varieties need to be sown very early in order to achieve maximum dry matter, especially if to be grazed.
- Winter wheats (have a winter habit and/or a vernalisation requirement) so has a wide sowing window from early March to about June.
- Reasonably hardy and tolerant but can be susceptible to diseases.
- Has a reasonable range of weed control options.

Barley

- Generally a smaller range of maturities available.
- Generally a short season early maturity option.
- Can be sown late (July).
- Can produce a bulk of feed quickly.
- Generally less tolerant of acidic or waterlogged soils.
- Slightly better quality of conserved feed produced.

Triticale

- Triticale is a hardy cereal which can tolerate a wide range of soil and seasonal conditions.
- Can tolerate more water-logging than other cereals.
- Can be more susceptible to frost damage than other cereals.
- Most varieties are mid to late maturity and can be sown over a wide sowing window.

Paddock Selection

Cereal crops are tolerant of a range of soil types and conditions, but to grow to their optimum any stresses need to be kept to a minimum. Cereal crops are not suited to paddocks that suffer from water logging.

If a paddock is performing poorly under pasture now, so will a cereal crop if the underlying problem is not corrected beforehand.

Identify the cause/s of the poor performance. For example:

- low soil fertility or nutrient imbalance
- too acidic for the species (i.e. pH below $pH_{(CaCl)}4.5$ or approx. $pH_{(water)}5.3$)
- regularly waterlogged
- poorly drained
- salinity affected
- shallow topsoil
- infested with difficult to control weeds, e.g. Bent grass, couch grass, kikuyu
- shallow topsoil.

Soil tests can indicate potential problems such as low nutrient levels, salinity, pH levels, high sodium levels or low organic carbon levels that may create structural issues such as surface crusting.

Salinity - while cereals are reasonably tolerant of salinity, salinity levels over 6 dS/m will result in decreased production. In general, oats are less tolerant than wheat and triticale, whilst barley is the most tolerant. However there is a difference in tolerances within varieties.

pH - as a guide, cereals prefer slightly acid to neutral soil pH levels. At these pH levels, most nutrients are readily available. If the soil is more strongly acidic or alkaline, some plant nutrients become unavailable and others become toxic to the crop. Barley is less tolerant of acid soils, and oats less tolerant of alkaline soils. There are also variety differences within the crop types.

Water logging – all cereals perform badly if waterlogged with oats generally handling it the best and barley generally the least tolerant (Figure 54).

Figure 54. Targa oats (L), Urambie barley (R) Waterlogged at front, not waterlogged at rear

Often paddocks due for renovations are sown to cereals as part of the renovation process. This normally results in a sacrifice in the cereal's performance for the long term benefit of the paddock.

In dairying areas forage cereals grown for a silage/hay/grain crop will most likely be grown by dairy farmers on run-off or lease blocks. If forage cereals are grown on the milking platform, they are normally grazed once or twice early in the season to allow the ryegrass pastures to build a feed wedge. These cereals are then possibly harvested as silage/hay. Sometimes they may be grazed regularly knowing the consequences on fodder crop yields by continuing to do so, to allow for the ryegrasses to get a break or to provide more grazing options when other feed sources are scarce.

Crop Rotations

Many leaf disease infections arise from crop stubbles from the previous season. By rotating cereal types, there is less disease pressure on the crop compared with growing the same cereal type in the same paddock year after year. However, rotations will not remove all disease threats so it is still important to consider other management options such as using seed treatments and resistant varieties. Rotations also help with the management of soil-borne diseases by removing a potential host.

Break crops such as legumes and brassicas are very effective at breaking the disease cycles of the many cereal diseases prevalent.

Cereals can also be used to clean up paddocks before being sown down to crops such as lucerne or to allow freshly lasered ground to settle down or unexpected weeds to germinate following cultivation.

As cereals have a high requirement for nitrogen, looking at paddocks with a good legume history can help reduce input costs. As mentioned in the herbicide section, some herbicides can have long plant-back periods before going to an alternative crop. For example, using a Group B herbicide such as Glean means a 22 month period should elapse before you try to sow sub-clover.

Sowing cereals with other species

Adding legumes (peas and vetches) to cereal crops can improve the nutritive value slightly, usually at the expense of total yield, but may complicate weed and disease control, grazing and timing, and method of fodder conservation. Cereal/legume mixes must be matched for their respective maturity dates with the purpose for which they are grown kept in mind. That is, when the decision is made to harvest the crop mix at either the flag leaf - boot stage or the late milk - soft dough stage, the maturity of the particular legume chosen must closely match that of the cereal choice.

Figure 55. Endeavour Triticale pre flowering and Popany Vetch flowering.

Another potential issue with sowing other species with the cereal is the hit and miss nature of sowing the mix. If one component is favoured by the growing conditions, then it can have a negative impact on the growth of the other. For example if the establishment of the oats is reduced, then the legume may overrun the cereal, or vice versa. If this occurs, then the anticipated quality of the hay may not be as planned. Added to this is the fact that both components have had their individual rates reduced compared to individual sowings and therefore may not yield to their potential.

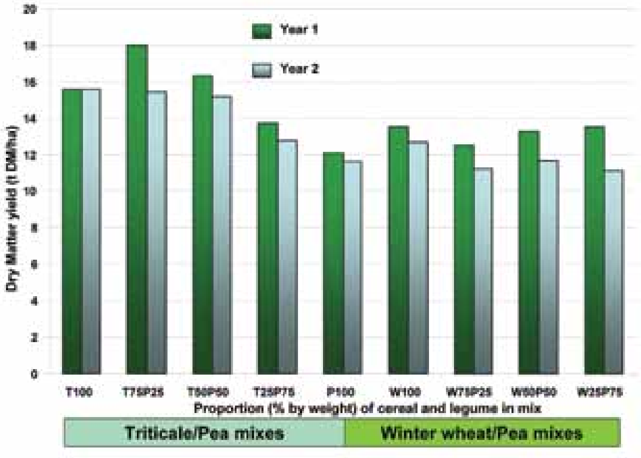
A trial sown at Rutherglen studied the effects of sowing various ratios of oats to vetch and found that:

- Pure oats gave the best DM yields, almost double the pure vetch (11.1t/ha vs. 5.9 t/ha).
- The energy levels and digestibility decreased with increasing vetch content.
- As a compromise, a 50/50 mix of oats and vetch had a small trade off in yield and a higher crude protein level. This would be around 30 kg/ha for each in a limited irrigation situation.
- If sowing peas instead of vetch, to achieve a 50/50 mix of oats and peas, 30kg/ha of oats and 70kg/ha of peas would need to be sown.

Project 3030 conducted a two year research trial to study the effect of different sowing rates of Kaspa forage peas in both a winter wheat (Wedgetail) or a forage triticale (Crackerjack). This study evaluated the potential of growing peas in combination with forage cereals to improve the nutritive value of silage whilst maintaining dry matter (DM) yields (Figure 56).

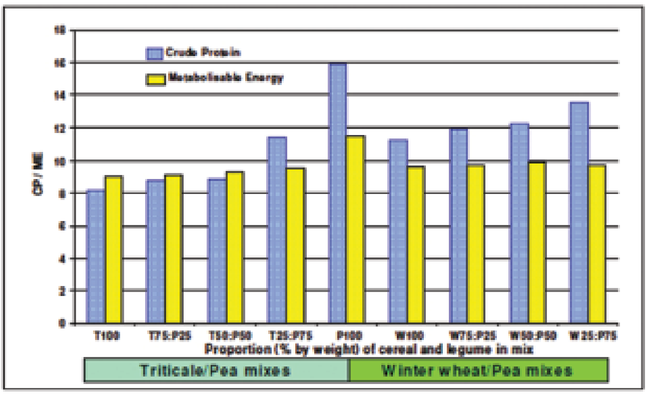
Treatments were 100% cereal (W100; T100) or 100% pea (P100) and combinations of cereal and pea at 75:25 (W75P25; T75P25), 50:50 (W50P50; T50P50) and 25:75 (W25P75; T25P75) with ratios based on sowing rate (137 kg/ha). At soft dough stage (GS85), the crops were harvested.

Figure 56. Dry matter yields (t DM/ha) of cereal/pea combinations over year 1 and 2. Source: J Jacobs. Project 3030



The resultant silages (year 1 data only) highlight the high nutritive characteristics of peas in contrast to the forage cereals (Figure 57). Where peas were included at rates above 50% of the mix, the CP and ME were generally higher than for the cereal monocultures.

Figure 57. The metabolisable energy (MJ/kg DM) and crude protein content (% DM) of ensiled cereal/pea mixes. Source: J Jacobs. Project 3030



T= Forage Triticale, P = Forage Pea, W = Winter wheat

Figure 58. 50/50 Winter wheat/Kaspa pea mix

Seed Bed preparation prior to sowing

The seedbed preparation will depend on the state of the paddock and whether cereals are only being grown as a once-off crop to supply feed for one year only or if several cereal crops are to be grown, possibly with break crops in between.

In terms of weed control, the paddock's history of weeds is critical. For a once-off crop in a paddock that has a history of very few weeds, a simple knockdown spray prior to sowing may be adequate. For regular cropping in a paddock with a history of many problematic weeds a more extensive weed control regime will be needed which normally begins at least one year prior to sowing a cereal, particularly to control the annual grass weeds such as winter grass, annual ryegrass, etc. Other weed issues such as toad rush and onion weeds are usually symptoms of poor soil fertility so must also be addressed at sowing.

There are several sprays available to control a range of weeds pre-sowing and an agronomist or spray expert should be consulted. Another very useful technique often not used by most dairy farmers, is pre-emergent spraying but extra care is needed to account for soil and moisture conditions, the species and cultivar requirements and especially "plant back" times which will affect which species can be re-sown when.

Seed bed at sowing

For the seed to germinate and establish, it needs a soil that has enough moisture to start the germination process and keep the developing plant supplied with water until the roots have developed sufficiently. It also needs soil with air spaces to supply oxygen to the developing plant and the soil must be soft enough to allow the developing roots and shoots to move through it.

Keeping in mind the seed's requirements, how your soil comes up depends a lot on the paddock history, soil type, etc and what equipment you have. You may be able to direct drill in sub clover paddocks with a loamy soil but you would have little success with grey clay that has been permanent pasture for 20 years.

Under-cultivating and leaving a cloddy seedbed will result in a poor seed-soil contact that dries rapidly. Over cultivating soil to the extent that it is reduced to powder will smother the seed when wet and potentially crust so badly the seed cannot penetrate. Both will result in poor establishment and an underperforming crop. Somewhere in the middle is the target. Your own knowledge of how your soil behaves is a good start. Have a try – experiment with some of your own gear. If you are not succeeding, then you may have to get a contractor in with suitable equipment.

When to sow

Soil Temperature

Different cereals have different tolerances for soil temperature at emergence. This becomes important if trying to sow cereals in February or early March. Most cereals prefer soil temperatures between 15-25°C (average 24 hr temp) so poor emergence (10-50%) may occur if temperatures are too high. There are exceptions to this with some cereal varieties which are mostly oats varieties, which can be sown at comparatively higher temperatures (some varieties e.g. Echidna, Saia, Taipan are known to emerge satisfactorily up to 30°C). Some people successfully sow oats in February, but there have also been lots of failures. Be careful with sowing in February and March due to high soil temperatures, especially if relying on rainfall to keep crops alive until late autumn when rainfall is more reliable.

Time of Sowing

Sowing early - be careful if planning to sow cereals earlier than late April. If sowing early, choose a late to very late maturity type or a type with winter habit (see section on varieties) because early and mid season varieties will run up to head too early. This is because they are programmed to turn reproductive in response to accumulated temperature (day degrees) and will run up to head in winter. Accumulated temperatures refer to the fact that plants mature faster when they are exposed to higher temperatures for longer. This then means that if the same variety was sown, for example in April compared to May, then the April sown crop will run to head much earlier in the spring than the May sown crop. This exposes plants to frost risk when heading and also means that they may be ready for hay/silage at a time of year when it is generally too cold and wet to dry down hay or silage to acceptable moisture levels. Grazing will delay maturity of most cultivars.

Sowing late - will often have yield penalties (less vegetative growth, fewer reserves, less Dry Matter (DM) or grain yield).

There are two main sowing strategies for farms without access to irrigation and four main strategies for farms with access to irrigation.

1. Pre-irrigate

In the ideal world, the recommended strategy would be to pre-irrigate, spray the weeds out, then sow. This strategy gives you control over sowing time and a chance to control weeds reasonably cheaply. However, it is not without some risk as there is always the chance that it will rain after irrigating, making the paddock too wet to sow.

2. Dry Sow

Dry sowing allows you to spread the workload, sow into dry soil and wait for rain. It also means that the crop can start growing as soon as rain arrives. The downside is that we need enough rain to wet the soil sufficiently to get germination and establishment before the moisture runs out. If we only get 10 mm, it may be enough for the seed to start germinating but then dry out, effectively killing the seed.

Dry sown seed is often sown at 3 – 5 cm depth so that a good rain is required to initiate germination and ensures there will be enough moisture in the soil for the plants to survive, usually! In false breaks most of these plants will survive whereas ryegrass often may not.

Dry sowing can lead to problems if there has been inadequate weed control prior to sowing and potentially having to rely on in-crop herbicides. It can also be an issue if you sow a mid or late maturing variety and it doesn't rain until June meaning the crop will be trying to mature late in the season. This is less likely to occur in the southern dairy regions.

3. Waiting for Rain

Waiting for the break gives you the opportunity for some pre-sowing weed control. It will be important to choose the maturity of the variety to suit the timing of the break. It also avoids a false break. The down side is the potential loss of valuable season length particularly if the break is late and you have to wait for the paddock to dry out so you can sow.

4. Irrigating post sowing

This is a risky strategy but can sometimes work. There is a very real risk of bursting the seed. The following conditions need to be met if this strategy is going to work:

- quick watering
- dry soil profile
- very shallow seeding (< 25 mm) and no soil crusting
- higher sowing rates as establishment is poorer
- no follow up rains.
- As with dry sowing, weed control can be difficult.

Sowing Rate

Sowing rates are not fixed; they depend on a range of factors.

When calculating your sowing rate there are four things you should know:

1. the plant population you want i.e. plants per square metre (plants/m^2)
2. the thousand seed weight (TSW) of the seed based on seed size
3. the germination rate (%) of the seed
4. the expected crop establishment (which is the number of seeds that will germinate and then overcome the soil constraints to form a plant).

1. *Plant population*. Sowing at different times of the year will affect how much seed you should sow because tillering or shoot production is greater when conditions are warm and reduced when the conditions are cooler. To optimise production, we are trying to obtain the optimal shoot numbers without creating too many as this can result in weaker stems and the potential for the crop to fall over or lodge. Higher sowing rates are used when using the crop for grazing as you are trying to maximise early growth. The target number of plants per meter squared that is desired will be different for most farms. An estimate that may be useful for a guide is:

a. 250 plants/m^2 for a crop that is going to be grazed early

b. 200 plants/m^2 for a crop that is for hay only

c. 160 plants/m^2 for a crop that is only for grain.

2. *Seed size* is the second question. As you can imagine, the smaller the seed size, the more seeds you have in each kilogram.

3. Germination of the seed is what percentage of the seed is viable and will hence actually germinate.

4. *Expected establishment* is the third question. This is also the hardest question to answer as there are so many variables. Most experienced cereal growers know what to expect from their soils. A Mallee farmer may get 80-85% of seed sown to establish. On the VICC trial block at Kerang on heavy grey clay, a 70% establishment is normally achieved. Expected establishment is not germination, although germination **tests will let you know if there is a problem with the seed.**

$$\text{Sowing Rate (kg/ha)} = \frac{\text{Target plant Population (plants/m}^2\text{) x TSW x 100}}{\text{\% germination x \% emergence}}$$

Establishment is also affected by the paddock conditions at sowing. Good soil moisture, warm soil temperatures, good soil seed contact, good soil tilth all contribute to improving establishment. Cold and wet soil, insect pests, soil crusting, seed sown too deep and a cloddy seedbed are factors that will reduce establishment.

Sowing depth

The desired sowing depth of cereals varies depending on a number of factors such as:

- **Soil temperatures** – if soil temperatures are high it is best to sow shallower as the first shoot will be shorter
- **Availability and reliability of moisture** – If worried about patchy moisture supply (e.g. false break) it is best to sow deeper. If worried about too much moisture (e.g. flood irrigating) it is best to sow shallower.
- **Soil type** – In lighter sandy type soil it is normally safer to sow deeper to guarantee moisture and good seed to soil contact. In heavier soils it is often better to sow shallower to avoid water logging and the seed running out of energy before breaking the surface.
- **Pests** – birds and other pests are less likely to cause as big of a problem if the seed is sown deeper, although this still won’t guarantee its safety.

For most farms a sowing depth of 2.5-5 cm is going to be the range of depths they will use depending on the above factors. However there may be times when depth ranges of 2-10 cm may be justified, but it is advisable to seek expert advice prior to sowing at the more extreme ends of the spectrum.

Fertilisers at sowing

A soil test is highly recommended. A standard 0-10 cm test will indicate if you have sufficient phosphorous (P), potassium (K) and sulphur (S) levels, and give you an indicator of the amount of nitrogen (N) present. Deep N testing, taking soil from the entire root zone, will give you the accurate amount of N in the soil, although the need for N at the start of the season is not as critical.

Many pasture paddocks with high organic matter or good clover history could be expected to have more than enough N to grow a crop. This will often be the case on most paddocks on the milking platform of dairy farms where urine and manure and fertiliser applications should have built up fertility levels above what cereals require. At DemoDairy, 3030 forage cereal research showed no difference in growth between nil and 160 kg N/ha.

Phosphorus

If your soil P levels are greater than 15 ppm Olsen (or 35 ppm Colwell), then you only need to supply the amount of P that will be removed (see Table 3 below). Soil levels considerably higher than these levels may not need any P, although you will be "mining" the soil P reserves. Lower figures will require greater than removal levels to ensure production. The crop needs most of its P early in its development, so ideally the P should be sown into the seed furrow. This is particularly important if P levels are low. If you have good levels of P, then spreading may be an option but still not the preferred method.

Nitrogen

N is a slightly different story. A hay or grain crop needs only a small proportion of the total N requirement before stem elongation. This offers the opportunity to only sow small amounts or no N at sowing (based on your soil test) and see how the season progresses. Depending on how the season looks, you can then top-dress to meet the potential yield.

A cereal hay crop will need around 20 kg nitrogen per tonne of hay produced. An 8t/ha crop of hay will therefore need 160 kg N/ha. This might be made up for example from 120 kg N/ha from the soil and 40 kg N/ha in the form of urea. Experience suggests not exceeding a total of 180 kg N from soil and bag sources as these crops are often hard to manage.

Paddocks that have been in permanent pasture for many years and have high organic carbon levels could be expected to give up large amounts of nitrogen to the crop, up to 200 kg/ha from the soil. Deep soil tests to 60 cm give good indicators of available N in the soil and can save on unneeded fertiliser applications.

Crops that have too much nitrogen available early in their life have excessive rank growth, which could lead to nitrate toxicity at the first grazing. Excessive tillering on dryland crops can give higher winter production but may also lead to excessive water use later in the spring. These crops are prone to stressing and haying off rapidly. In good springs these crops can grow excessively high and lodge (i.e. fall over), leading to a loss of DM through rotting and be difficult to mow. In highly fertile paddocks it may be impossible to control growth and the only way to do this is by decreasing the sowing rate or through grazing.

The crop itself can be an excellent indicator for nitrogen management. Rampant tillering and a dark green colour indicate the crop has access to large amounts of nitrogen, while low tillering or pale green to yellow leaves can be an indicator N deficiency. If nitrogen is not in excess, a topdressing of 50-100 kg of urea (or 20-40 kg of N equivalent) is advisable after each grazing. If the crop doesn't seem to be performing, it could be tempting to put some N on it, but there are many reasons the crops might be poor in colour or vigour and it's best to get professional advice on the problem.

Table 2. Nutrient removal from 1t DM of cereal forage

Nutrient	Nutrient removed (kg/t DM)
Nitrogen	10-22
Phosphorus	1.8-2.5
Potassium	18-31
Sulphur	1.4-2.1
Calcium	2-2.7
Magnesium	1.2-1.5

Seed dressing

Bunts and smuts are fungi that can decimate grain crops (spores grow in place of the grain) so grain growers use a seed treatment annually on all planting seed. For those sowing into old pasture, it may be possible to avoid a treatment in the first year. However, if this is not your first crop, or if you can't guarantee your seed is uncontaminated, use a seed dressing. They're cheap ($3- $4/ha) and are recommended even if cutting for hay as these spores in developing heads will make hay unpalatable. Regardless, it is preferable to control these problems since these fungi are seed (and wind borne) and once a paddock is infected, spores can hang around in soil for years.

Weed control after germination

Broadleaf weeds - Every broadleaf weed in a cereal crop is undesirable; they decrease production through competition for nutrients, space and light and can spread some nasty seeds in fodder. There are plenty of cheap and expensive control options but you must try and control them when they are small (less than 8 cm diameter).

Grass weeds - are more problematic. Annual rye and wild oats, if cut early, may not be a quality issue, but brome, barley and silver grass are not worth a cracker at hay time. There are limited post emergent sprays in oats for grass weeds but there are more options in the other cereals, some of which are expensive. It is important to control weeds when they're small (2-3 leaves). Most grass weed control should be done the year before and then with pre-emergent herbicides. Because of their genetic similarity, being all in the *Graminae* or grass family, you can't get barley grass out of barley or wild oats out of oats once the crop has emerged, the only options are pre emergent.

Disease management

There are many disease that can affect cereals, however generally most cereal diseases can be managed by careful species and cultivar selection combined with early identification of diseases and timely control measures such as fungicides.

Spray company representatives and cropping agronomists, rural merchandise store staff and DPI cropping agronomists should be contacted as early as possible to help identify the problem and suggest a course of action. Over time you will become far more knowledgeable in the correct management of growing, grazing and harvesting forage cereals. There are also many good guide books (e.g. Grains Research and Development Corporation (GRDC) has a series of Ute guides) available to help identify and manage pests and diseases.

With regular monitoring of crops (every two weeks) most pest and disease issues can be managed before they become a major problem.

Stripe Rust - has only recently become a problem in cereals, due to the introduction of a new strain and then subsequent mutations overcoming resistant genes in different cereal varieties. It can cause severe grain yield losses in wheat and triticale varieties (barley/oats unaffected); however, it normally is only a problem in wet springs and can be controlled with fungicide.

While it's not as big an issue in hay and silage crops (it won't affect yield or health of livestock), it can reduce hay and silage quality through the loss of leaf area and leaf sugars. Resistant cereal varieties are available however it is important to get an update each year on its current level of resistance. Some seed treatments and fungicides can offer a good level of protection, however withholding period's needs to be observed. For hay, most varieties would probably get through with one fungicide spray, but know your variety as they have different levels of resistance and some won't require spraying at all.

Weekly monitoring from the first node stage onwards would be recommended on a susceptible variety. Irrigation provides the perfect microclimate for stripe rust proliferation as do early warm moist periods in spring in the southern dairying areas of Victoria.

Grazing management

When to start grazing

Knowing the correct stage to graze is vital to prevent the cereal plant from uprooting or inhibiting growth and future yields.

Cereals can be grazed when the plants are anchored and have grown secondary roots. The secondary root arises at the crown (where the plant meets the ground) and attaches to the tillers. This usually occurs when the plant has 3-4 true leaves (GS13-14). A simple 'pluck and twist' test will be able to tell you if it is advanced enough for grazing. If when you grab a plant at the anticipated grazing height, pull and twist, it snaps off, it should be okay to graze. If it pulls out of the ground it means the plant isn't ready to graze yet. Make sure that you do quite a few across the whole paddock so it is representative of the whole grazing area.

All cereals can be grazed at any time from early – late tillering (GS22 – GS28), as long as they pass the pinch test.

How hard to graze

It is important not to graze crops into the ground. Just like ryegrass they need a residual amount of dry matter left to recover from grazing. Some varieties of cereals will grow in a prostrate manner (spread more outwards) and these can be grazed down to around the 5 cm mark. A lot of cereals grow more erect (straight up) and these should only be grazed down to around the 10 cm mark. If you graze lower than this then the plant will regrow with reduced vigour, resulting in lower yields. Leaving bare patches lets the light into the soil and encourages weed growth. Cereals are best if they are strip grazed and not set stocked as this will allow the plant to re-energise and give maximum regrowth.

When to finish grazing

If the crop is planned for further fodder production it is important to stop grazing before the heads start being pushed up above the ground. This process is called jointing, or stem elongation, and starts when the plant has 6-7 leaves on the main stem (not counting any of the tillers) and is also referred to as growth stage 30 (see Figure 17 in the growth stage section).

The first visible indication the plant has entered the stem elongation phase is the appearance of the first node which is a visible and "feelable" bump or swelling 1-2 cm off the ground. The best place to look is the main stem (See Figure 9 in growth stage section), not tillers, as the first node stage occurs here first. In a grazed paddock the main stem will be the fattest of the tillers; in an ungrazed crop it will be the longest stem and leaves on the plant when you stretch them out.

In the earlier stages of stem elongation, the easiest and most reliable way to indentify this stage is to slice a stem in half with a knife and the node is more easily seen (See Figures 19 & 20 in the growth stage section). Grazing this developing node off will dramatically decrease future production from the plant. If your aim is to graze it into the ground to kill it off, then continue to graze beyond this stage.

Effect of grazing on total yields

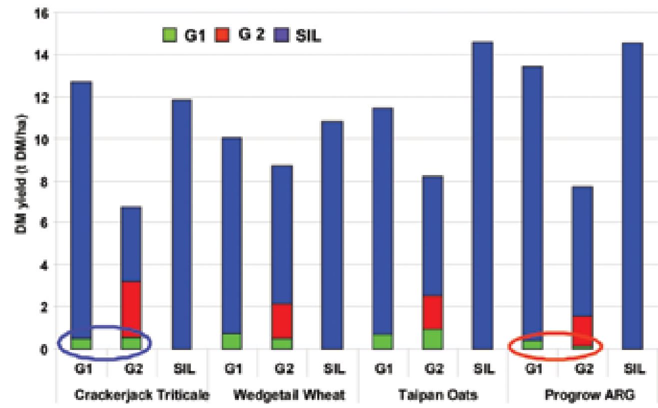
There are a number of factors that will determine what effect grazing a cereal crop will have on its total yield. The main factors are:

- variety sown e.g. early maturing or winter habit
- when it was sown
- number of grazings
- timing of the grazing
- how hard it was grazed
- conditions at time of grazing e.g. wet, dry.

Variety sown and time of sowing

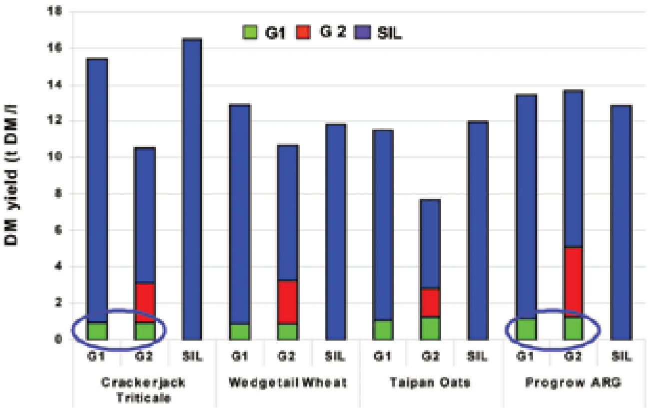
This makes a big difference and is mostly to do with the length of time the plant will be growing for. The longer the plant will be growing, the more grazing that can be done without reducing the total yield. An early maturing variety (which should be sown late autumn/early winter) will in most cases yield less total dry matter if grazed. However a late maturing variety with winter habit that has been sown and received enough moisture in March (via irrigation in the northern irrigation region of Victoria (NIR), rain in dryland dairy areas) will normally increase the total amount of dry matter grown if it is grazed.

Figure 59: Effect of grazing on winter cereal production with late break (May 2005)



Figures 59 and 60 show that a single grazing in early tillering (GS21/22) will not greatly affect total dry matter production when compared with a crop cut as a silage crop only. However, an early autumn break (Figure 60) allowed the forage cereals to grow at a greater rate than the annual ryegrass.

Figure 60: Effect of grazing on winter cereal production with early



break (April 2006)

However, grazing most forage cereals at GS32/33 substantially reduced total yield compared to an early grazing or silage cut only. Grazing is recommended to be done at mid-tillering and certainly no later than GS30 if high silage yields are required.

Number of grazings

A rough 'rule of thumb' that is sometimes used in Victoria for the number of grazing that can be taken from a particular sowing date is:

March sowing – 3 grazings

April sowing – 2 grazings

May sowing – 1 grazing

June sowing – no grazing

This rule is based around some compromise between total yield and being able to graze feed during the autumn/winter period. This in some cases is better than chasing the largest yield possible because there are always losses and expenses in conserving and feeding out fodder. For some farms chasing more grazings than this may be beneficial but will nearly always be severely compromising total yields.

Timing of grazing

Timing of grazing refers to what growth stage the cereal plant is at. If you gaze too early, before the plant is anchored properly, plants pulled out of the ground by grazing animals will greatly reduce the potential yield from that crop.

If you graze after Growth Stage 30 (See Figure 15 in the earlier growth stage section) when the plant is turning reproductive the crop yield will be also severely reduced by removing the growing point (developing seed head) of the plant which has begun to rise up the plant. Figure 61 shows the effect of grazing too late on individual stems. Figure 66 shows the effect of grazing too late on a crop.

Figure 61. Effect of grazing too late on a single plant. Note the dead tillers as a result of grazing too late.

Figure 62. Effect of grazing too late on whole crop. A lot less total growth for the year has been achieved.

If a crop is grazed between these two stages, the impact of grazing on total yield should be far less. There can still be subtle differences in total yield by grazing at different times between these stages. This is mostly caused if there is a large bulk of crop when the cattle go in and they trample and waste a large amount. If you are only planning to graze the crop once, grazing when the cereal plant has around 4 tillers (GS24) has been found to be close to ideal. There is flexibility around this though.

Benefits of grazing vs. total yields

Achieving the highest yield possible doesn't necessarily make it the most profitable. In many cases grazing cereals will reduce the total yield achievable. However the value to the farm of having that high quality feed directly grazed in the autumn/winter months for milk production or as a ryegrass saving effect, is often far higher than having a big bulk of not as high quality feed in the spring that needs to be conserved. Conserving feeds has a fairly large cost to it compared to grazing feeds.

When conserving feeds such as cereals there are always losses in the harvesting process, as well as while it is stored, and finally more losses when it is fed back out again. The extent of these losses will vary from farm to farm. A rough ball park figure would be around 20-40% of the crop you cut may be lost by the time the cow has eaten it.

Grazing in adverse conditions

If there are dry conditions in autumn while the crop is establishing, this will slow plant growth and root development. Slow development of the secondary roots will delay the time when the young plants are sufficiently anchored to resist being pulled out by grazing animals.

During dry conditions cereal plants can shed root mass which can make plants easier to pull out by grazing animals.

Don't graze cereals when soil is too wet. Pugging by cattle under wet conditions can cause a lot of damage to the crop, substantially reducing forage (and grain yields). The risk of pugging damage can be reduced by using minimum-tillage at sowing and by avoiding irrigating after 1st April.

Cereals, like most plants have the potential to cause nitrate poising. Some of the factors that can increase the risk of nitrate poising are:

- Paddocks that have had legume-based pasture for several years, like old summer pasture paddocks, can be expected to provide large amounts of mineralised nitrogen (N) when sown down with a cereal crop.
- Applying fertiliser N when sowing the cereal crop may be unnecessary and even harmful.
- Young cereal crops growing in high-N paddocks will be very green and very vigorous, but, in the vegetative (tillering) stage, may accumulate N in concentrations that can cause nitrate poisoning.
- Any factor that slows the growth of the cereal crop, like moisture stress, frost and short, cloudy days will increase the concentration of N in the plant and also increase the risk of nitrate poisoning.

While there is the chance of nitrate poisoning of stock grazing cereal crops, there are a range of precautions that can limit the risk, such as:

- Avoid grazing a high risk cereal crop (refer to the factors above) when it is under stress or likely to be growing very slowly.
- Do not graze with hungry stock. The more feed in the stock's stomachs, the more diluted the nitrate will be.
- Provide some alternative feed such as silage before grazing.
- Limit the amount of time stock are grazing the cereal crop.
- Use run-off paddocks.
- Closely monitor livestock grazing cereal crops.

Conserving cereals

If considering cutting a cereal crop for silage, there are two recommended cutting stages:

- Flag leaf/boot – early ear emergence if desiring a higher quality silage or
- Soft dough stage if a higher yield, but not as high protein and energy content, is required.

When to cut for silage

The timing of harvest should take the following into consideration: end use of the silage i.e. for animal production vs. maintenance rations

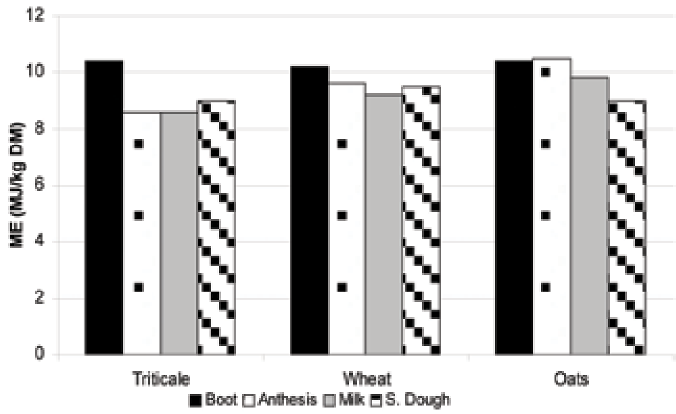
- weather conditions at harvest
- soil types and soil moisture conditions at harvest
- if double cropping, when the following crop needs to be sown
- availability of suitable harvesting machinery

Effect of growth stage on silage nutritive characteristics

A study undertaken near Warrnambool by Project 3030 to determine the quality of cereals being harvested at various growth stages involved cutting three cereals (triticale, wheat or oats) at boot (GS47), flowering (anthesis) (GS65), milk (GS75) or soft dough (GS84) and then precision chopping and ensiling the material.

The ME at boot (GS47) of all silages was above 10 MJ/kg DM, however by flowering (GS65) only oats remained at this level (Figure 63). Generally ME declined through anthesis and milk, but for triticale and wheat did improve by the soft dough stage of growth (GS84). For oats, ME declined as growth stage advanced with no improvement by soft dough. DM yields at boot were 5.1, 7.9 and 7.5 t DM/ha for triticale, wheat and oats, and 17.9, 10.9 and 10.4 t DM/ha by soft dough.

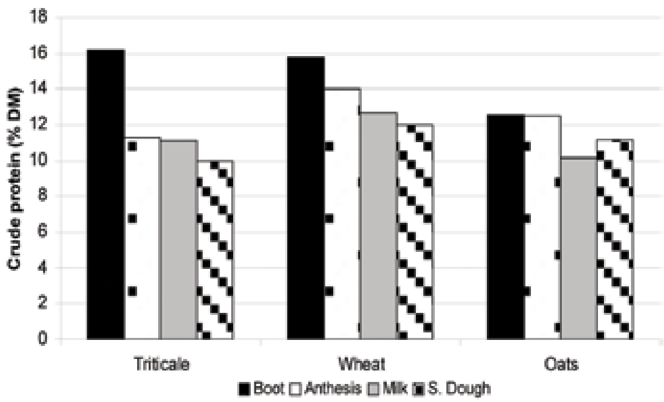
Figure 63. The ME of triticale, wheat and oats at boot (GS 47), anthesis (GS 65), milk (GS 75) and soft dough (GS 84) stages of growth.



Source: J Jacobs, 2009 Project 3030

The CP content of all silages made from crops declined as the crops matured, with final values being below 12% (Figure 64).

Figure 64. Effect of stage of growth on silage CP for different cereal silages.



Source: J Jacobs, 2009 Project 3030

Stage of growth recommended for ensiling

Cereals can be harvested at the flag leaf/boot to early ear emergence stages or the soft dough stage.

Flag leaf/boot - early ear emergence stage

The flag leaf is usually the widest leaf and is the last leaf to appear before the head emerges. The cin which the ear will emerge. Once the ear has emerged, flowering commences. The plant has vegetative leaves up to this stage. All cereals can be harvested before or at this stage and should produce higher energy and protein silage (over 10 MJ ME) than cutting later. Harvesting at this stage will result in lower yields compared to their potential if harvested in the grain formation stages. DM content will usually be well below 30% DM, thus requiring wilting before harvesting.

Late milk - Soft dough stage

As the plant reaches maturity, sugars in the stems and leaves are moved to the grain and converted to starch. The plant begins to change in colour from an all-green plant to an all-yellow plant when it's fully mature at the hard grain stage. As the grains form they pass through the clear liquid stage, then become milky, followed by the soft dough stage. This is then followed by the hard dough stage and finally to a dry grain. Harvesting at this later soft dough stage results in much higher DM yields but silage of lower energy and much lower crude protein levels than earlier at the vegetative stage (refer to Figures 63 & 64). The grains may reach the hard dough stage within days after soft dough if the weather is hot and dry, or several weeks in cool moist conditions. In the event that the crop reaches hard dough it is important to make sure the crop is chopped finely (see Table 3) and consider using additives to help prevent aerobic spoilage (see silage additives).

Warning - Cereals should not be harvested at the clear liquid - early milk stages. At this stage the soluble sugars in the plant are being converted into starch in the heads. The nutritive value at this stage is often reduced and palatability of fodder made at this stage is sometimes greatly reduced.

Figure 65. Targa oats at boot stage

Figure 66. Crackerjack triticale at soft dough stage

Quality is highest at boot-ear emergence (full ear emergence) and slightly lower at soft dough (between early milk & full grain). Yield increases up until the soft dough stage. Avoid harvesting at the clear liquid (½ grain development)-early milk stage.

Mowing and cutting height

The stage of growth of the crop at harvest affects the DM and will therefore determine whether it is mown and wilted before harvesting or direct cut and ensiled as a "standing" crop. Cutting height is usually 7 – 10 cm above ground level. Cutting higher will result in a slight increase in nutritive value but will also reduce yields accordingly. If mown and wilted, a higher cutting height will also keep the mown swath higher off the ground thereby allowing more airflow under the crop and a slightly faster wilting rate. A higher cutting height will also reduce the risk of soil contamination from other equipment operations such as raking. Cutting at greater heights will leave behind increased levels of stubble which creates a problem of removal in the future and preparation for the next forage.

Dry matter content when harvesting for silage

Flag leaf/boot - early ear emergence stage

Harvesting at the flag leaf/boot stage (18 – 22% DM) will require the crop to be wilted to reach the desired DM content (see Table 3) for ensiling. Mowing with a roller type mower conditioner is recommended to crimp/crack the stems which will encourage quicker wilting. This results in a wilting rate 20 – 40% faster compared to mowing only. Conditioned stems will also allow a more reliable and easier 'pick up' by harvester and baler pick-ups and subsequent feeding into the respective cutting or roller mechanisms. Unfortunately high yielding crops will be relatively slow to wilt, even if conditioned. In all cases, leaving the windrow as wide and thin as possible, and in a "fluffy" state will increase the wilting rate substantially.

Late milk - Soft dough stage

The DM content of wheat, barley and triticale at the soft dough stage of growth will be in the desired DM range as a standing crop for ensiling without prior wilting. They can be either direct harvested with forage harvesters fitted with specifically designed cutting fronts or pre-mown and immediately picked up by the forage harvester.

Cereals should ideally be harvested using a precision chopping forage harvester to ensure a short chop length (20 – 50 mm actual length). This ensures the material can be well compacted minimising the amount of air trapped, thereby resulting in reduced losses (nutritive value and DM). Most other forage harvesting machines such as self-loading wagons cut the material to varying lengths, often over 200 mm, making adequate compaction very difficult. The drier the crop DM content at harvest, the shorter the chop length required. Grain loss may be slightly higher in pre-mown crops due to the rotary disc action of the mower and, particularly if raked before harvesting, DM yield and nutritive value will also be slightly lower.

If baling, applying net wrap instead of twine will reduce the amount of air trapped between the plastic and the bale as the twine, especially in slightly loose bales, will "pull" into the bale. Applying net wrap will also minimise straw stalks protruding from the bales which can puncture the stretch wrap plastic seal, allowing air to enter.

Table 3. Target DM content and stage of growth at harvest for ensiling forage cereals

Species	Stage of growth at harvest			
	Flag leaf-Boot/Early ear emergence		Soft dough	
	Stack/pit[1]	Baled[2]	Stack/pit[1]	Baled[2]
Oats	33 - 40	38 - 50	N R	N R
Rye corn	33 - 40	38 - 50	N R	N R
Triticale	33 - 40	38 - 50	35 - 42	38 - 45[3]
Barley	33 - 40	38 - 50	35 - 42	38 - 45[3]
Wheat	33 - 40	38 - 50	35 - 42	38 - 45[3]
Oats/Peas	33 - 40	38 - 50	N R	N R
Barley/Peas	33 - 40	38 - 50	35 - 42	38 - 45[3]

NR Not recommended

[1] Should be precision chopped

[2] Preferably baled with chopper baler

[3] Lower DM at harvest recommended to ensure greater compaction

Silage additives for forage cereals

Silage additives can improve the fermentation process and delay heating and spoilage at feed out. Silage additives mainly comprise a large number of inoculants but there are several others with different modes of action which are equally effective.

Flag leaf/boot - early ear emergence stage

These are essential for cereal crops which are being ensiled below the recommended DM content (Table 3) at the Flag leaf- Boot stage. Cereals in this vegetative stage tend to have high buffering capacities (i.e. tend to "fight" against becoming acidic) and MUST be wilted to above 30% DM before ensiling. Silage additives are also very useful if some soil has been included during tedding, raking or at pick up. Use traditional or "normal" type additives that enhance fermentation. This type of additive is also recommended for baled silage cut at this stage.

Late milk - Soft dough stage

A new group of silage additives (aerobic spoilage inhibitors) that will delay and/or reduce aerobic spoilage at the stack face and during feeding out, is recommend for whole crop cereal silage which is made at the Late milk – Soft dough stages and will contain hollow stems and unless cut short and packed extremely well in the pit/bunker, will trap a lot of air in the storage. When opened for feed out, the large population of aerobic spoilage bacteria and yeasts which built up to large numbers due to the excess air trapped at ensiling will become activated. If the face is not fed out quickly enough, the stack becomes heated and moulds start to grow. Applying an aerobic spoilage inhibitor silage additive at ensiling can reduce this problem in many cases.

The traditional fermentation enhancing additives are recommended for baled silage as the spoilage inhibitors will be ineffective for slow air ingress due to punctures in the plastic and is usually eaten within a day or so when fed out.

Large stack faces (which take more than two days to remove) and a daily depth of face removal of less than 0.4 m, would require the use of spoilage inhibitor type additives. Most additives will improve the fermentation and reduce losses. All additives are applied during harvest at the machine pick up, harvester chute or baler throat to ensure thorough mixing with the forage to be effective.

Additional information

For more information on growing and managing cereals the following resources may be useful.

DPI Victoria website: www.dpi.vic.gov.au and use the search function to find the following Information Notes:

- AG1238 Dry Matter Content of Conserved Forages: Representative sampling
- AG1239 Dry Matter Content of Conserved Forages: Measurement of Dry Matter Content
- AG1243 Forage Cereals: Harvest and Storage: When to cut for whole-crop cereal silage
- AG1244 Forage Cereals: Harvest and Storage: Harvesting whole-crop cereal silage
- AG0013 The decimal growth scale for cereals
- AG0102 Identification of cereal seedlings

Project 3030: www.project3030.com.au - Project 3030 targeted a 30 per cent increase in profit from a 30 per cent increase in home grown forage production using a large range of alternative forages. There is a wealth of information on their website to help support forage decision-making including the following factsheets:

- Grazing Winter & Forage Cereals
- Conserving Whole Crop Cereal Silage
- Growing and Harvesting Cereal Mixes

The Wheat Book: Principles and Practice. 2000. Bulletin 4443, Compiled by Anderson, W.K. and Garlinge, J.R. Publisher: Agriculture Western Australia ISSN 1326-415X

Crop insects: *the* UTE Guide. Southern Grain Belt edition. 2008. Compiled by K. Henry and J. Bellati for the GRDC

The Back Pocket Guides: GRDC

- Cereal Root and Crown Diseases – 2000 edition
  Hugh Wallwork, SARDI
- Cereal Leaf and Stem Diseases – 2000 edition
  Hugh Wallwork, SARDI
- Cereal Diseases: The Ute Guide
  Hugh Wallwork, SARDI. Published by Primary Industries and Resources, SA

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www.grdc.com.au/director/events/grdcpublications

Growth and Development guide for Spring Barley. 2008 P.M. Anderson, E.A. Oelke, and S.R. Simmons. University of Minnesota Extension http://www.extension.umn.edu/distribution/cropsystems/DC2548.html

Growth and Development guide for Spring Wheat. 1995 S.R. Simmons, E.A. Oelke, and P.M. Anderson. University of Minnesota Extension. http://www.extension.umn.edu/distribution/cropsystems/dc2547.html