Chapter 5

Crops and by-products for silage

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In this chapter

The authors

N.W. Griffiths[1], F.J. Mickan[2] and A.G. Kaiser[3]

1. *Department of Primary Industries, Tocal Agricultural Centre, 'Tocal', Paterson, NSW*
2. *Department of Primary Industries, Dairy Research Institute, Ellinbank, Victoria*
3. *Department of Primary Industries, Wagga Wagga Agricultural Institute, Wagga Wagga, NSW*

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Section 5.0

Introduction

The crops covered in this chapter produce one silage cut only, with little chance of regrowth for grazing. Therefore, all growing and harvesting costs must be included when assessing a crop's potential for silage production.

Specific agronomic information for each crop type is not included. Seek local advice on issues such as varieties, fertiliser recommendations and irrigation, weed, disease and pest management strategies.

All high-yielding forage crops have high plant nutrient requirements. Tests are needed to check the nutrient status of the soils. The nutrient removal data in Table 5.1 provides a guide to ensure adequate fertiliser is applied to produce high forage yields and sustain long-term production.

If crops need to be mown prior to harvesting for silage, measures must be taken to minimise the risk of soil contamination during harvesting. Soil contamination may introduce undesirable micro-organisms that can affect the ensiling process and increase storage losses. Rolling uneven seedbeds at the time of sowing will reduce the amount of soil picked up by harvesting equipment.

The use of chemicals on forage crops should be carefully monitored. Withholding periods (WHPs) on chemical labels must be observed to avoid the risk of unacceptable chemical residue levels in silage. Produce from livestock fed silage with unacceptable residue levels is unsuitable for human consumption. Sections 4.2.6 and 5.8.1 discuss the importance of WHPs.

Table 5.1

Approximate levels of nutrients removed in forage DM harvested (kg/t DM).

Crop	Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium
Maize[1]	10	1.8	9.8	1.0	1.6	1.7
Whole crop cereal	24	3.0	20	2.5	3.0	3.0
Sweet sorghum	28	3.0	20	2.5	3.0	3.0
Soybeans	35	3.0	25	2.0	13	4.0

Source: [1] Kaiser and Piltz (1998a). Other data derived from various computer databases

The Key Issues

- To maximise economic returns, the crops grown specifically for silage production should be high yielding and produce a high-quality forage.
- The nutritive value of silage varies with the species conserved and the stage of growth at which it is harvested.
- Attention to agronomic detail is required to achieve yield potential and satisfactory economic return.
- Timely harvest and good management of the forage prior to storage will maximise the quality of the forage.
- By-products are residues from the agricultural and food processing industries. They may be available in large quantities in some areas for a limited time of the year. Most plant by-products can be stored as silage, if adequately compacted and stored under anaerobic conditions.
- The nutritive value of by-products must be sufficiently high to make their conservation as silage economically feasible. They should be stored at a DM content that favours good silage fermentation and minimises the risk of environmental pollution from silage effluent.
- The nutrient levels (including minerals) in all by-products should be checked to ensure that their inclusion in a diet does not cause a nutrient deficiency or imbalance.
- Care is needed to ensure that crops and by-products do not contain unacceptable chemical (or heavy metal) residues. Obtain a Vendor Declaration or a written record of their chemical status.

Section 5.1

A comparison of crops suitable for silage production

Table 5.2 summaries the characteristics of the crops most commonly grown for silage production and highlights key targets needed to produce high-quality silage. Many producers are losing production potential because of poor silage-making practices. This is highlighted by the huge range in the quality of silages being produced (see Chapter 12, Appendix 12.A1).

Table 5.2

Yield and quality potential of crops grown for silage production, identifying requirements to ensure quality silage.

Crop characteristics	Maize	Whole crop winter cereal		Whole crop winter cereal /legume mixtures	Grain sorghum	Sweet sorghum	Soybeans
		Oats	Wheat & Barley				
Growth stage at harvest	milk line score 2-3	boot to flowering	boot or mid-dough	boot to dough of cereal component	milky dough (middle of head)	head emergence to dough	65% pod fill
Potential yield[1] (t DM/ha/cut)	12-25	5-15		5-15	4-10	10-25	4-10
Potential number of cuts per year	1	1		1	1	1	1
Wilting requirement	no	boot yes/dough no		yes	no	no	yes
Target range DM content (%)							
Chopped	33-38	35-40		35-40	30-35	25-35	35-40
Baled	NR	35-50		35-50	NR	NR	35-50[4]
ME[2] (MJ/kg DM)	10-11	9-10.5		9.5-11	9.5-10.5	9-10	8-9.5
Crude protein[2] (% DM)	4.5-8.5	6-16		8-18	6-9.5	4-8	15-20
Ensilability[3]	***	boot **/dough ***		**	***	***	*
Suitable for chopped bulk silage	yes	yes		yes	yes	yes	yes
Suitable for baled silage	no	yes		yes	no	no	yes[4]

1. Yields at the higher end of the range can be obtained with irrigated crops or crops grown under ideal growing conditions.

2. These ME (metabolisable energy) and crude protein levels are achievable with good management. See Glossary for definition of ME.

3. Ensilability is the likelihood of achieving a good silage fermentation without wilting or a silage additive. (Low, ** Medium or *** High).*

4. Baled silage is not the preferred option for soybeans (see Section 5.7.3).

Section 5.2

Maize

Maize is a premium silage crop, producing a large bulk of high-energy forage. It is expensive to grow and requires good management to produce high yields of high-quality product. The economic viability of maize silage is very dependent on yields and energy values. The major limiting factors are poor weed and insect control, inadequate fertiliser, low plant populations or adverse seasons.

Most maize varieties used for forage production have a growing period of 100 to 150 days. Prolonged ground preparation and sowing periods will affect variety choice. The crop requires specialist row-crop planting and harvesting equipment and is suitable only for chopped silage stored in a pit or bunker. A maize crop intended for silage can be harvested for grain if circumstances change.

Maize should be grown in rotation with lucerne or another suitable crop or pasture to reduce the build-up of insect, disease and weed problems.

Plate 5.1

Maize can produce high yields of high-energy forage. *Photograph: N. Griffiths*

5.2.1

Hybrid selection

Select hybrids with high potential forage yield, good forage quality and adequate disease tolerance. Refer to local recommendations, taking into consideration the following:

- The forage quality of leaves and stems (the stover) may vary between hybrids, although hybrids with the highest grain yield usually have the highest overall forage quality. If information is available, select hybrids with highest whole-crop forage quality. This will maximise animal production potential.
- Medium-maturity (early-mid to mid-season) varieties are usually preferred. Late-maturing hybrids (>130-135 days) tend to have lower digestibility and occupy the ground for longer. Early-maturing hybrids usually have lower yield potential, but higher quality, due to a higher grain content (see Table 5.3).
- Early-maturing hybrids have a role where a short growing season is expected due to rotation requirements, sowing time, poor subsoil moisture, or the risk of frost or wet weather at harvest. Higher plant populations may partially compensate for their lower yield potential.

Table 5.3

Effect of hybrid maturity group on the organic matter digestibility and ME content of forage maize harvested at a MLS of 2-3 in two experiments at Nowra, NSW.

Adapted from Kaiser and Piltz (2002)

Maturity group (mean days sowing to harvest)	Experiment 1 No. of hybrids	Experiment 1 OM Digestibility (%)	Experiment 1 ME (MJ/kg DM)	Experiment 2 No. of hybrids	Experiment 2 OM Digestibility (%)	Experiment 2 ME (MJ/kg DM)
Early (115 days)	3	69.3	10.3	4	69.7	10.4
Mid-season (126 days)	10	67.1	10.0	10	67.2	10.0
Late (143 days)	3	66.7	9.9	9	62.8	9.3

- Some hybrid selections have a stay-green characteristic: they retain green leaf and do not dry as quickly as other varieties. This may be an advantage in providing a wider harvest window so that the crop may be harvested at optimum DM content. However, it can be a disadvantage late in the season when there are harvest delays while waiting for the crop to dry. Limited data suggests that stay-green varieties have lower stover digestibility.
- Brown midrib hybrids will be an advantage for animal production if selections become commercially available. Introduction of the brown midrib gene reduces the plant's indigestible fibre content.

The yield and quality potential of the maize forage is limited by the choice of hybrid. Figure 5.1 highlights some of the environmental and management factors that also influence the yield and quality. Under good growing conditions maize has potential to produce high yields of high-energy silage. Where rainfall is unreliable, sorghum may be a better option.

5.2.2

Crop management for silage production

Plant population

Silage maize crops are usually planted with a 10-20% higher population than a maize grain crop. A plant population of 65,000 plants/ha is adequate for most forage crops.

Yields can be increased by raising the population to 80,000-90,000 for early maturing varieties, or medium-maturing varieties under irrigation or ideal growing conditions. However, there is a risk of reduced forage quality due to lower grain production where very high populations are used. Most varieties also show a greater tendency to lodge at higher plant densities.

Figure 5.1

Varietal, environmental and management factors which can each influence yield and ME of a maize forage crop.

Low yield (<15t DM/ha)
High quality (ME >10 MJ/kg DM)
Early variety
High-quality variety - high grain content and high stover digestibility
Low plant population
Early harvest

High yield (>15t DM/ha)
High quality (ME >10 MJ/kg DM)
Mid-season variety or early variety at higher population
High-quality variety - high grain content and high stover digestibility
Good management
Adequate rainfall/irrigation

Low yield (<15t DM/ha)
Low quality ((ME <10 MJ/kg DM)
Management failure
Low-quality variety - low grain content and low stover digestibility
Drought

High yield (>15t DM/ha)
Low quality ((ME <10 MJ/kg DM)
Mid-season to late variety
Low-quality variety - low grain content and low stover digestibility
High plant population
Adequate rainfall/irrigation for crop growth
Stress during grain fill
Late harvest

Source: Adapted from Kaiser et al. (1993)

Row spacing

Maize is usually sown at a 750 mm row spacing. Yield increases of approximately 4% have been achieved with 375 mm row spacings, without altering plant populations. Under ideal growing conditions, where moisture and nutrients are not limiting, closer row spacing may also allow an increase in plant population and higher yield potential. Note that conversion to narrow row spacings requires modifications to sowing and harvesting machinery.

Sowing details

- Do not sow maize until soil temperature is at least 12ºC and rising. Temperature should be taken at 9:00 am on three consecutive mornings at planting depth. Germination and establishment will be faster with warmer soil temperatures.
- Sow into good soil moisture, at correct depth. Correct sowing depth varies depending on soil type, grain size and soil moisture.
- Follow local recommendations for fertiliser requirements. Table 5.1 provides a guide to the quantities of nutrients removed from a paddock when a maize forage crop is harvested.
- Weeds are controlled by inter-row cultivation or use of pre-plant or pre-emergent herbicides. Ensure that herbicide residues do not affect other crops or pastures grown in rotation.
- Monitor crops for insects and control if necessary. Crop establishment can be adversely affected by insect damage, particularly by African black beetle.
- Ensure all herbicides and insecticides are used according to the label guidelines.
- Irrigate as required, if available.

5.2.3

Growth stage at harvest

The milk line score (MLS) describes the maturity of the grain in the cob. Unless the crop is severely drought affected, it is a reliable indicator of crop DM content and the ideal stage to harvest maize silage.

The MLS varies from 0 (no visible milk line at the tip of the kernel) to 5 (the milk line reaches the base of the kernel and a black or brown layer forms across it). At this stage, the crop is at physiological maturity and grain filling is complete. Under most circumstances, MLS progresses one unit in 7-10 days.

At MLS 2.5 the milk line is halfway down the grain (see Plate 5.2). This is the best stage to harvest maize for silage as there is a good balance between yield, quality and ensiling characteristics. The DM content of the forage should be 33-38%.

A milk line score of 2.5 often coincides with the cob husk turning from green to white, dying-off of lower leaves and denting of grain. However, these indicators will vary depending on hybrid selection and growing conditions.

Table 5.4 shows the variations in yield, DM, grain content, crude protein and ME levels that can be expected at different MLSs.

Many producers, concerned about a risk of wet weather, harvest too early. In this case, DM content is likely to be too low to ensure successful ensiling. There is a risk of lower yield and grain content, poor fermentation and effluent losses, resulting in lower quality silage. These problems are likely to occur if the crop is harvested at MLS 1 and DM is <28%. Producers who regularly harvest crops too early should consider growing early-maturing hybrids.

If harvest is delayed to physiological maturity (MLS 5) or until the crop DM is >38%, the chopped material will be difficult to compact, resulting in poor fermentation and poor quality silage.

For planning purposes, most varieties will be ready to harvest about 50 days after mid-tasselling.

Plate 5.2

Cob of corn showing milk line score 2.5. Aim to harvest with a 2.5 milk line score. Note: When assessing MLS ensure the glumes at the base of the kernel are pushed back to expose the full kernel.

Photograph: P. Stuart

Potential yield and forage quality of maize forage cut at MLS 2 to 3 achievable under good management.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Milk line halfway (milk line score 2-3)	10-11	4.5-8.5	12–25

Table 5.4

The relationship between MLS and forage maize yield and composition for early and mid-season variety, dryland maize crops grown at Nowra, NSW.

	Milk Line Score at harvest				
	>0-1	>1-2	>2-3	>3-4	>4
Yield (t DM/ha)	15.7	16.9	16.7	18.0	16.0
DM content (%)	27.3	29.8	33.2	39.1	44.0
Grain content (% DM)	33.4	39.7	42.8	45.8	48.0
Crude protein (% DM)	7.2	7.1	6.9	6.7	6.6
ME (MJ/kg DM)	10.3	10.2	10.1	10.0	9.8

Source: Adapted from Piltz (1993)

5.2.4

Harvesting the crop

Cutting height

Cutting close to the ground will increase the DM yield of a crop. However, raising the cutting height improves the quality of harvested maize forage, mainly due to an increase in grain content.

Nominating an optimum cutting height is difficult considering the large variations in varieties and growing conditions. As a guide, raising cutting height from 15 cm to 45 cm is expected to reduce yield by up to 15% and increase digestibility by 2% units.

Cutting too high can create residue disposal problems if another crop is to be sown soon after harvest. However, it can be a useful option to avoid weed contamination that would otherwise reduce the silage quality.

Plate 5.3

Fine-chopped maize is easily compacted. *Photograph: K. Kerr*

Chop length

Maize is usually harvested with a precision-chop harvester set at a 5-10 mm *theoretical* length of chop (TLC). However, the accuracy of the machine settings is highly variable. Producers should calibrate their machines and aim for an *actual* chop length of 10-15 mm for most particles. Very fine chopping will crack more grain, but increase power requirements.

If harvesting is delayed and crop DM is >38%, chop length should be as fine as possible to aid effective compaction. In some dairy diets, fine chop length reduces the effectiveness of fibre. However, if fibre content is a concern, there are effective alternatives to solve this problem without resorting to an increase in chop length (see Chapter 13, Section 13.4.2).

If forced to harvest early, when the DM is <28%, adequate compaction can be achieved with a longer chop of 15-20 mm. However, harvesting at low DM is not advisable and can result in poor fermentation and unacceptable effluent losses (see Chapter 2, Section 2.1.1).

Grain processors

Grain processors are designed to increase the amount of grain cracked during harvesting, with the aim of improving digestibility of the grain component of the silage. They are most effective with hard grain hybrids, longer chop length or with crops cut at a more advanced stage of maturity.

It has been argued that grain processors allow a longer chop length (with most particles >20 mm) while still cracking some grain. The longer chop length has the advantage of increasing the effectiveness of the fibre component in some dairy diets, while cracking the grain improves grain digestibility. However, unless the DM is unacceptably low (<28%), long chop length will cause compaction problems and is not recommended. Poor compaction will result in poor fermentation, higher in-silo losses, lower quality silage and increased risk of aerobic instability (see Chapters 2 and 10).

Results of studies investigating the digestibility of the grain fraction in maize silage fed to young cattle are presented in Chapter 14, Section 14.2.5. These demonstrated that poor digestibility of the grain fraction of maize silage was not a problem with short chop length. The forage harvester used in these studies was set at a TLC of 4.2 mm and produced an actual chop length with most particles in the range of 5-20 mm, with 74% of grain damaged. When the resulting silage was fed, the digestibility of the remaining whole grain was 97%. Similar results were noted in other studies with dairy cows.

Comparing grain yield to forage yield

An economic comparison of maize grain yield and silage production is worked through in Chapter 11, Section 11.4.1. Calculations are based on harvested grain moisture content of 14%. The grain yield of a maize crop is approximately 55% of the forage DM yield. Therefore, a crop that yielded 10 t/ha of grain would have produced about 18 t/ha of silage DM. Alternatively, a crop that produced 10 t/ha of silage DM would have yielded 5.5 t/ha of grain.

For other grain versus silage yield comparisons, see Chapter 11, Figure 11.2.

Ensiling high-moisture maize grain and earlage

High-moisture grain and earlage may be a more economic alternative to harvesting the whole maize crop if the storage site is a long distance from the growing site.

High-moisture grain

High-moisture grain is harvested soon after the maize reaches physiological maturity (MLS 5). This is usually 2-3 weeks after the normal silage harvest and one month before the normal grain harvest. The ideal DM content of the grain for storage is 68-72%, with an acceptable range of 65-74%.

A propionic acid-based additive is desirable to avoid mould development. The grain must be processed or rolled for effective compaction and fermentation.

Earlage

Earlage production involves chopping whole cobs, without the stem and leaves. This forage is then treated in the same manner as maize silage. The ear is harvested when the grain DM content is 65-74% (with an ideal range of 68-72%). Processing and ensiling difficulties occur when the grain is too dry.

Maize ensiled as earlage provides a high value alternative stockfeed to conventional silage or grain. It is more commonly used in beef feedlots.

5.2.5

Ensiling stressed crops

Drought-stressed maize crops

Four or five days of visible moisture stress will reduce the yield potential of a maize crop. However, drought-affected maize crops can be successfully ensiled.

The effect drought has on yield and forage quality will depend on the timing and severity of the moisture stress:

- Moisture stress throughout the growing period reduces yield, grain content and digestibility.
- Moisture stress during grain fill will probably produce acceptable yields, but with reduced grain content and digestibility.
- Moisture stress during the vegetative growth stage, followed by good conditions during grain fill leads to reduced yield, but increased grain content and increased digestibility.

Drought-stressed maize can be harvested at a DM content of 30-40%. Harvest should be delayed if there is a chance of rain and the crop still has green leaf. While plants have green leaf there is a possibility of recovery and increased DM yield.

If harvesting a drought-affected crop early for silage, ensure the withholding period for any insecticides or herbicides used on the crop have been satisfied.

When a crop grown with high nitrogen inputs becomes drought stressed, nitrate poisoning may be a risk if the crop is grazed or green chopped. Ensiling the crop reduces this risk. Nitrate concentrations in silage will be reduced by an estimated 40-60% within 3-4 weeks of storage. Nitrate levels are highest in the lower, older parts of the plant, so if poisoning is a concern the risk can be reduced by raising the cutting height of the harvester.

Because drought-affected crops can have highly variable nitrate, protein and ME levels, it is advisable to test the ensiled material before feeding.

Maize is not recommended for marginal rainfall environments and is not an option where there is a risk of a dry finish. In these circumstances sorghums may be a better alternative in the silage program.

Frosted maize crops

Frost is often an issue when the crop is sown too late or when a late maturing variety is sown. An early frost may stop plant growth but the crop can still be ensiled. A killing frost will prevent further grain fill, which may reduce feed quality, but it can also speed up drying of the crop.

Frosted maize must be allowed to dry to at least 30% DM. Harvesting too early will lead to wet silage, which is often unpalatable and of poor quality. If allowed to dry too much (>38% DM), compaction may be difficult, also resulting in a poor-quality silage.

When testing DM content, the whole plant must be chopped and a sample dried in a microwave oven (see Chapter 6, Section 6.4.2). Leaves may look brown and dry but stems may still contain significant moisture.

Flooded crops

Flooding can affect maize and other crops in various ways that can have important implications in silage production. This is covered in Chapter 8, Section 8.6.

Section 5.3

Whole crop winter cereals

Oats, wheat, barley, triticale and cereal rye can all be made into silage. Depending on variety and management, they may be grazed prior to closure for silage. If conditions change, these crops can be harvested for grain.

Forage quality will vary, depending on variety, management and growth stage at harvest. Forage quality can be improved by sowing with a legume. Early sown cereal/legume mixtures can include a clover, and may be grazed, while later sown crops can include field peas or vetch, suitable for one harvest only.

Cereal crops are often used for hay production. However, as shown in Appendix 12.A1, the potential quality of the equivalent silage is significantly higher.

5.3.1

Species and variety selection

The choice of species and variety to grow for silage is complex. The large variations in harvest index (the ratio of grain to leaf and stem) between species and varieties, makes it difficult to make broad recommendations. Not only are research data for Australian varieties limited, most cereal silage research in Australia has been conducted on oat crops. More work is needed to assess the silage value of recently released varieties of all cereals.

The preferred varieties are forage types with superior forage yield and digestibility. Varieties with high forage production should be an advantage if the requirement is for a high digestibility, early-cut silage. Grain yield potential becomes a consideration if the requirement is for a larger bulk of high energy silage, which can be produced from cereals harvested at the dough stage. This later silage cut has the advantage of requiring no wilting, being suitable for direct cut (see Table 5.2).

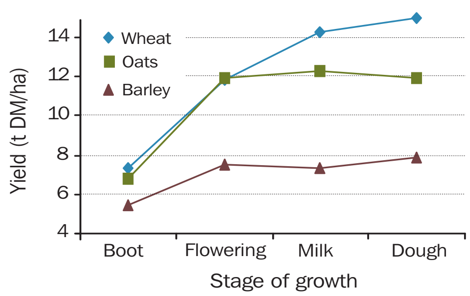
The relative whole crop yields of oats, barley and wheat were investigated in a trial in South Australia, in 1977 (see Figure 5.2). These and other trial results suggest that oats is the preferred option for early-cut, wilted silage, with wheat, barley and triticale likely to produce higher energy silage than oats if harvested at the dough stage. The varieties used in the 1977 experiment were not all forage types, which would explain the relatively low yield of barley seen in Figure 5.2.

Of the cereal varieties investigated to date, late-maturing forage oat varieties have consistently produced higher forage yields late in the season. They are at the recommended growth state for harvest (boot to ear emergence) when wilting conditions are likely to be more favourable.

The main emphasis in most cereal breeding programs has been grain, rather than forage production. However, new varieties are constantly being released. Forage types with improved yield and digestibility should be evaluated for silage production.

Awned cereal varieties are usually not a problem when ensiled, although wastage does increase when these varieties are baled and is more significant with late-cut material of higher DM content.

Figure 5.2



Yield of cereal crops grown at Northfield, SA, harvested at different stages of growth.

Source: Cochrane and Radcliffe (1977)

5.3.2

Crop management for silage production

Fertiliser requirements

Growing a crop to produce high yields of high-quality forage and maximum economic return requires good growing conditions, with adequate fertiliser application.

While grazing or grain harvest retains 30-50% of plant organic matter in the paddock as dung or straw, silage removes most of the plant material. To maintain soil fertility, nutrients removed in silage must be replaced (see Table 5.1).

Nitrogen-deficient crops are likely to benefit from topdressing with 50-100 kg/ha of nitrogen, when they are closed for silage. Early topdressing with nitrogen (at the tillering stage) will increase yield potential, while topdressing late (stem elongation to boot) may not produce an economic yield response. Adequate soil moisture, rainfall or irrigation is required to obtain full benefit from high nitrogen inputs.

Nitrate poisoning can be a risk if soil nitrogen level is high and the crop is stressed as a result of drought or long periods of cloudy weather. Nitrate levels in forage usually drop by approximately 50% when it is made into silage, significantly reducing the risk of nitrate poisoning.

Sowing details

- Optimum sowing date varies with species and variety choice and location; seek local advice.
- A high sowing rate is needed to ensure high yield potential. This rate is approximately 50% higher than rates used for grain-only crops.
- Weeds can be controlled by various herbicides. *Caution: Silage harvest timing may not satisfy the withholding periods recommended for herbicide use on crops intended for grain harvest.*

Late nitrogen application may depress forage WSC levels (see Chapter 4, Section 4.3.2).

5.3.3

Growth stage at harvest

The growth stage to harvest cereals for silage is a compromise between forage quality and yield.

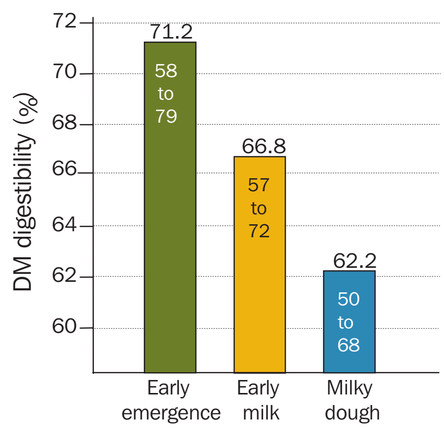
Guidelines on optimum growth stage for the various cereals, other than oats, are based on limited research that examined a small sample of the varieties available at the time. Very little information is available on triticale or cereal rye. More research is required on all cereal types, over a greater range of sites, to substantiate the guidelines that have been adopted.

The decline in digestibility of oat crops is rapid with advancing maturity (see Figure 5.3). This study showed large variations in digestibility between varieties and between years, at each harvest.

The information in Figure 5.4 suggests that the effect of growth stage on digestibility differs between cereals. This study indicates that the digestibility of both wheat and barley crops increases as grain filling commences, whereas the

Figure 5.3

Mean and range in DM digestibility of oat varieties grown over four years at Mount Barker, WA, and harvested at three stages of growth.



Source: R. McLean (unpublished data) – based on 18-23 varieties grown in each year digestibility of oats continues to fall. Protein content falls with advancing crop maturity with each of the cereals, with oats tending to have lower protein contents than wheat and barley. These results indicate that oats should always be cut at an early growth stage – between boot and ear emergence.

Research to date indicates that wheat and barley provide more flexibility, with the option to cut early, at the boot stage, or later, at the dough stage, when yield is likely to be higher. However, wheat and barley crops should not be harvested at flowering to early milk stage, when digestibility may be lower (see Figure 5.4).

Although valuable silage can be produced from cereals cut within this range, maximum animal production per tonne of silage is expected with an early harvest and maximum production of DM per hectare is expected with the later harvest.

At the mid-dough stage, winter cereals may be direct harvested, although wilting of the forage is essential if the DM of the standing crop is <30%. Check DM levels using the 'Microwave Oven Method' (described in Chapter 6, Section 6.4.2) to ensure levels are close to 35-40% for chopped silage and 35-50% for baled silage.

Plate 5.4

This barley crop is in the mid-dough stage. The recommended growth stage to harvest wheat and barley is at the boot or mid-dough stage.

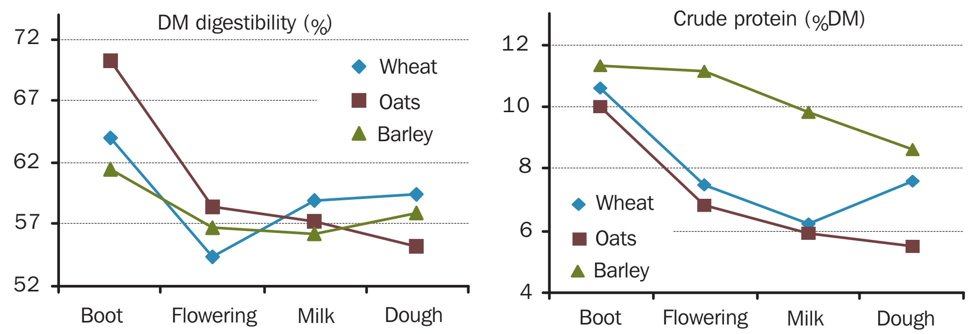
Photograph: K.Kerr

As winter cereals mature the stems become hollow, which may affect compaction. The problem can be minimised by chopping to 10 mm lengths or by baling at the lower end of the recommended DM range.

Potentially, winter cereals can be harvested over many weeks. Oats and barley should be ready to harvest before wheat or triticale. There is also a range of maturities between different varieties of each species. A choice of growth stage and varietal maturity means that cereal crops could potentially be harvested for silage over a 4-6 week period.

The limited information available on cereal rye suggests that the preferred growth stage to harvest for silage is the boot stage. Feed quality of cereal rye deteriorates more quickly with maturity compared to other cereals.

Figure 5.4



Changes in DM digestibility and crude protein content at different growth stages in wheat, barley and oat crops grown in South Australia.

Source: Cochrane and Radcliffe (1977)

Table 5.5

The approximate duration of key stages of grain development in cereal crops.

Growth stage	Approximate duration of growth stage
Boot stage	7-10 days
Heading and flowering	10-14 days
Milk grain	7-10 days
Dough grain	7-10 days (plants yellowing, leaves dying)

Mid-dough is about 3-4 weeks before normal grain harvest.

Despite this flexibility, an individual crop is likely to have a harvest window of only seven days in which it will be at the desired growth stage. Table 5.5 shows the number of days a cereal crop is at the growth stages when harvesting is likely to occur.

The quality and quantity of silage produced from winter cereals varies with growing conditions, species and variety. The values in Table 5.6 indicate the expected ranges under good management.

Harvesting early, at the boot stage, will maximise the quality of silage and reduce the number of days the crop occupies land. However, DM yield per hectare will be 40-60% lower than at the dough stage.

Late-harvested, winter-cereal silage may be particularly useful if fed when stock are grazing young pasture, which has a very high protein and low fibre level.

Delaying harvest not only results in loss of quality, it also increases the risk of lodging, particularly in heavy crops of the taller varieties.

Table 5.6

The effect of growth stage on potential yield and feed quality of winter cereal silage.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Late vegetative or boot*	9.5-10.5	8-18	1.5-7.0
Flowering	9.0-9.5	6-12	3.0-11.0
Dough grain	8.0-9.5	4-10	3.5-15.0

** The preferred growth stage to harvest oats.*

5.3.4

Increasing the feed quality of winter cereal silage

Low protein is the major feed quality limitation of winter cereal silage, particularly when crops are harvested late, at the mid-dough growth stage.

Cereal/legume mixtures

Forage protein content may be improved by growing legumes such as annual clovers, field peas or vetch with the crop (see Section 5.4). The level of improvement will depend on the proportion of legume to winter cereal, with a legume component of 40-50% needed to make a significant difference. A legume component is likely to lower the forage's DM and WSC content and increase the requirement for wilting, particularly if the legume proportion increases to 50% or above. Chapter 6, Section 6.6 includes strategies to increase wilting rates.

Ammoniated whole crop cereals

Digestibility and protein level of late-harvested (late-dough stage) cereal crops can be increased with the addition of urea to produce ammoniated whole cereal forages. Cereals used for the production of ammoniated forages should be harvested at a higher DM content (>50%) than normal silage.

Urea is added at a rate of 40-50 kg per tonne of forage DM as the crop is cut or stacked. This process is only suitable for operations, such as chop silage, which allow even mixing of the urea.

Ammoniated forages produced following urea treatment are different to whole crop silages. Silages are fermented products and have low pH (4-5), whereas the ammoniated forages are chemically preserved products with a high pH (about 9). The applied urea is converted to ammonia gas, which reacts with water to form ammonium hydroxide. Ammoniated forages are sealed with plastic in the same way as silage.

Adding urea to late-cut, whole crop cereal silage at the time of feeding is an alternative to the production of ammoniated forages. This will increase the nitrogen level in the animal's diet, but there is not the increase in digestibility that occurs with ammoniated forage.

In both cases, poor mixing of the urea can result in variable feed quality or the risk of stock poisoning.

5.3.5

Drought-stressed crops

Harvesting drought-stressed crops for silage, as a salvage operation, has been successful for most crop types including cereals, grain legumes and canola. Refer to Section 5.5 before harvesting drought-affected sorghum crops.

The management of drought-affected crops for silage is the same as for the usual silage making, although these crops are rarely at the recommended growth stage. It is important to make an early decision and cut the crop before quality deteriorates.

Although forage yield is often lower than the potential, quality of the silage can be high. Drought-stressed crops usually ensile well because WSC levels are often higher. Although DM levels are also higher than usual, crop appearance can be deceptive and DM levels may need to be checked.

Section 5.4

Whole crop cereal/legume and legume

Cereal/legume mixtures produce forage yields similar to those of cereal crops, with a significantly higher protein content. Legumes also have a higher nutritive value than grasses or cereals, sustaining higher intake and animal production at a given digestibility.

5.4.1

Legume selection

The climbing legumes, peas (field pea) and vetch (common and purple), are ideal companion crops for cereals. Alone or in mixtures with cereals, they are generally more productive for silage than smaller-seeded legumes, such as clovers (see Chapter 4). They are also more suitable for later sowing and more competitive when grass weeds are a problem. This can be important in cropping areas where forage legume-based crops are used as a break crop in rotations.

In higher rainfall areas, high-density clover mixtures (HDLs) may be a better option as they can provide two or more silage cuts. However, they are not as competitive when grown with a cereal and usually only make a significant contribution to the mixture when a low cereal sowing rate and wide row spacing are used. The forage yield of cereal/clover mixes is also likely to be lower than that of cereal/climbing legume mixes.

Other winter forage legume crops, such as faba beans or lupins, either grown alone or in combination with a cereal, may have potential for silage production and need to be evaluated. Experience in the UK indicates that forage varieties of faba beans and lupins have similar yield potential and quality to peas.

Tables 5.7 and 5.8 give the yield potential and quality of pea, vetch and mixtures of these with oats. Peas are usually more productive than vetch, either when grown alone or in combination with oats.

Seek local advice on the most suitable pea and vetch varieties for silage production. Later maturing varieties are likely to have higher yield potential and so should be most suitable. They will reach the optimum stage of crop development later in the season when weather conditions for silage making are usually more favourable.

The legume and cereal/legume crops need to be wilted prior to ensiling.

Table 5.7

Production and quality of pea and vetch crops at Campbell Town, Tasmania.

Crop*	Yield (t DM/ha)	Crude protein (% DM)	DM digestibility (%)	Estimated ME (MJ/kg DM)
Peas – Morgan	11.8	14.5	73.7	10.8
– Secada	9.3	13.2	70.6	10.3
Vetch – Popany**	5.6	18.3	75.6	11.1
– Morava**	7.7	16.3	66.7	9.6

** Crops harvested at the late pod swell stage.*

*** Popany is a variety of purple vetch; Morava is a variety of common vetch.*

Source: Dean (2001)

5.4.2

Legume content

The crop's legume content can be manipulated by varying the relative seeding rates of the legume and cereal components. The target legume content will vary with the production goals. Where a high-ME, high-protein silage is required, a high legume content is needed. This will be particularly important if protein supply for livestock production on the farm is limiting at certain times of the year, and the alternative is expensive, purchased protein meals. High legume content is also important where forage legume crops are grown in cropping rotations and improving nitrogen return for subsequent crops is a consideration.

Where moderate levels of forage protein (10-12%) are satisfactory, a lower legume content will suffice. Generally 40-50% legume, on a DM basis, is required to meet this objective (see Table 5.8).

5.4.3

Crop management for silage production

Lodging

Lodging can be an important issue with climbing legumes. Where lodging occurs in high-yielding pure legume crops:

- a significant proportion of forage can be below mowing height and harvesting losses can be high;
- risk of leaf disease in the legumes is increased;
- forage digestibility can decline; and
- silage preservation can be at risk because the forage is contaminated with decaying material (and aerobic spoilage organisms) from the base of the crop.

Management factors likely to affect lodging are not well understood but are known to include time of sowing and variety selection. Pure pea or vetch crops are not recommended in areas where lodging is a problem; the preferred strategy is to sow a small cereal component to provide a 'climbing frame'.

Table 5.8

Production and quality of oat, peas, vetch and oat/pea and oat/vetch mixtures at Wagga Wagga, NSW. All crops harvested at the flowering stage of the oat crop (23 October).

	Oats*	Oat/pea	Oat/vetch	Pea	Vetch**
Legume content (% DM)	–	48	42	100	100
Yield (t DM/ha)	11.9	14.8	13.6	11.7	8.6
Organic matter digestibility (%)	63.1	67.9	62.9	72.7	68.7
Estimated ME (MJ/kg DM)	9.2	10.0	9.2	10.7	9.8
Crude protein (% DM)	4.4	12.2	10.4	18.3	23.2

* *Received an additional 40 kg N/ha.*

** *Mean results for Popany (purple) vetch and Golden Tares (common) vetch. The field pea variety sown was Dundale.*

Source: Dear et al. (unpublished data)

Sowing rate

Research is required to determine optimum sowing rates for cereal/legume mixtures. Local advice should be sought. Typical sowing rates currently used in the mixed farming regions of central and southern NSW are 40 kg oats/ha with either 50-70 kg peas/ha or 20-30 kg vetch/ha. Where high legume content is required, the cereal component can be dropped to 10-20 kg/ha and the legume component increased to 60-80 or 30-40 kg/ha for peas and vetch respectively. In areas where lodging is not likely to be a problem for pure legume crops, pea and vetch sowing rates used are 80-100 and 40-50 kg/ha, respectively.

The economic feasibility of the pea/cereal mixtures must be considered if a high pea seeding rate is to be used. The high cost associated with high pea sowing rates may be reduced if small-seeded, forage-type peas, which have shown potential in research trials and can be sown at lower sowing rates, become commercially available.

Plate 5.5

Sowing legumes in mixtures with cereals can increase the protein level of the forage. Purple vetch (var. Popany) was grown with wheat in this example. *Photograph: K. Kerr*

Fertiliser requirements

Soil tests, nutrient removal data in Table 5.1 and local advice should be the basis of fertiliser application rates. Adequate phosphorus, sulphur and potassium are essential if legume crops are to achieve their yield potential. A small amount of nitrogen may be an advantage in low fertility paddocks to ensure a vigorous cereal component. However, high rates of nitrogen should be avoided as this may increase competition from the cereal component, reduce the legume content and reduce nitrogen fixation by the legume.

Table 5.9

Effect of harvest date on the organic matter digestibility (%) and estimated ME content of oat, pea and oat/pea crops at Wagga Wagga, NSW.

Harvest date:	2 October		23 October		6 November	
	Growth stage of oats					
	Early ear emergence		Flowering		Milky dough	
Crop	OMD (%)	ME (MJ/kg DM)	OMD (%)	ME (MJ/kg DM)	OMD (%)	ME (MJ/kg DM)
Oat	68.9	10.1	63.1	9.3	55.7	8.2
Oat/pea	74.1	10.8	67.9	10.0	60.0	8.7
Pea	71.4	10.3	72.7	10.7	70.2	10.3

Source: Dear et al. (unpublished data)

5.4.4

Growth stage at harvest

As with all crops, the optimum stage of harvest is a compromise between yield and quality. The best strategy with cereal/ legume mixtures is to base cutting time on the stage of growth of the cereal component (see Section 5.3.3). Table 5.9 shows the influence that the growth stage at harvest of oat, pea and oat/pea crops has on digestibility. Optimum stage of growth has not been adequately defined for pure pea and vetch crops, although peas are generally harvested during pod filling of the earlier pods.

As the data in Tables 5.9 and 5.10 show, the harvest window is widened when legumes are mixed with cereals. Forage of satisfactory quality is available at the ‘flowering’ stage of the oat/pea crop. Wheat/legume or barley/legume mixtures may produce forage of satisfactory quality at the dough stage, but research is required to confirm this.

Table 5.10

Estimates of ME, crude protein and DM yields of cereal/legume mixtures at varying legume contents.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Cereal/ legume – cereal dominant:			
Boot to flowering for cereal component (all cereals)*	9.5-10.5	12-18	3-8
Milk to dough for cereal component (wheat or barley)*	9.0-9.5	10-18	5-15
Cereal/ legume – legume dominant:			
Boot to flowering (all cereals)*	10.0-11.0	14-20	3-7
Milk to dough (wheat or barley)*	9.5-10.5	12-18	5-12
Legume crop:			
Early pod filling	10.0-11.0	15-20	5-12

** Growth stage of the cereal component.*

Section 5.5

Grain sorghum

Grain sorghum has potential to produce high-quality silage containing 40-50% grain. The dual-purpose sorghums, sweet sorghums and grain sorghums are a useful alternative to maize for silage production in drier areas and on poorer soils.

Grain sorghum silage will usually be of higher nutritional value than silage made from forage sorghums (see Chapter 4, Section 4.10, for discussion of forage sorghums).

Warning – Prussic acid (HCN)

All sorghum crops have the potential to cause prussic acid poisoning. Grain sorghum and sweet sorghum have the highest poisoning risk, while Sudan grass has the lowest. Sub-lethal symptoms (depressed milk production and low weight gains) are much more common than death from acute poisoning.

The risk of prussic acid poisoning is greatest when plants are stressed from drought, frost, flood or foliar herbicides, such as 2,4-D. Prussic acid levels are highest in young plants or regrowth <60 cm high.

Mowing and haymaking do not reduce the risk of prussic acid poisoning sufficiently to render the forage safe. There is some evidence to suggest that up to 50% of the prussic acid is lost during the ensiling process. However, depending on the initial prussic acid level, ensiled sorghum may still pose a risk. If in doubt, test for prussic acid potential before feeding and seek advice.

The following strategies will mininise the risk from prussic acid:

- select low prussic acid varieties;
- avoid high rates of nitrogen fertiliser if moisture stress is possible;
- ensure the crop is not phosphorus deficient; and
- avoid harvesting short, stressed crops.

5.5.1

Hybrid selection

Taller growing hybrids and dual-purpose (graze + grain, or silage + grain) sorghums are suitable for silage production, producing a silage containing 25-30% grain. Seek local advice to select varieties with high forage yield potential.

A comparison of grain, dual-purpose and sweet sorghums grown in wet and dry seasons at Moree, NSW, is presented in Table 5.11. Despite the lower yield from the moisture-stressed grain and dual-purpose crops in the first growing season, ME content was only marginally lower than that in the favourable season. Late rain in the dry season enabled the later maturing sweet sorghums to produce high yields in both seasons. Although the ME content of the sweet sorghums was lower than that of the grain sorghums, the high yield of these crops make them the more attractive option in lower rainfall environments.

Grain sorghum silage will often have a slightly lower digestibility and ME content than maize silage if both are grown under favourable conditions. However, where crops are moisture stressed, the grain content of maize declines while that of sorghum can be relatively unaffected. As a

Table 5.11

Yield and quality of grain sorghums, dual-purpose sorghums and sweet sorghums grown at Moree, NSW, in wet and dry seasons.

	Grain (5 hybrids)	Dual-purpose (2 hybrids)	Sweet (2 hybrids)
Dry season (73% of normal November-April rainfall):			
Yield (t DM/ha)	4.2	4.2	20.8
Grain content (% DM)	43.9	33.5	3.2
Estimated ME (MJ/kg DM)	10.0	9.9	10.0
Crude protein (% DM)	8.4	8.0	7.2
Wet season (138% of normal November-April rainfall):			
Yield (t DM/ha)	6.2	7.0	17.6
Grain content (% DM)	33.8	31.8	0
Estimated ME (MJ/kg DM)	10.2	10.3	9.5
Crude protein (% DM)	8.3	6.9	4.5

Source: Cole et al. (1996)

result, the maize crop's ME content can fall sharply and be lower than that of sorghum grown under the same conditions. For this reason, sorghum should replace maize in environments with lower or unreliable rainfall.

If harvest for silage is not possible, the sorghum crop may be harvested for grain. However, in the study shown in Table 5.11, the gross margin for sale of the crop for silage was 38% higher than that for grain production.

Grain sorghum can be grown with soybeans to produce a silage with higher crude protein than grain sorghum alone. However, producers must be prepared to make compromises on yield and management. The soybean content must be of the order of 40% to make an impact on protein levels. This would require lower sorghum sowing rates and result in a significant yield penalty. Inter-row cropping and weed management difficulties are also a consideration. A more practical and economic option is likely to be growing a sorghum silage crop and purchasing protein to improve protein levels in the ration.

5.5.2

Crop management for silage production

- Ensure high plant population for high yield potential. Actual seed rate varies with seed size. Aim for sowing rates of 5-7 kg/ha for dryland crops, or 9-12 kg/ha if irrigated.
- Requires soil temperatures at 10 cm depth of at least 16ºC, at 9:00 am at time of sowing, for rapid germination.
- Adequate fertiliser and/or good soil fertility is needed to grow a high-yielding crop. Use soil testing and a crop nutrient budget to help calculate specific nutrient requirements (see Table 5.1 for nutrient removal levels).
- Control weeds if necessary. If using herbicides consider possible residue effects on subsequent crops and the withholding periods and minimum residue limits (MRLs) for the silage.
- A range of insects and diseases may attack grain sorghums. Hybrids with resistance to important pests such as sorghum midge are available. Alternatively, use insecticides when necessary. Ensure withholding periods are satisfied before the crop is harvested.
- Irrigate as required, if available, although maize is likely to be a more profitable option under irrigation.
- Another crop or pasture is usually sown after grain sorghum. However, in some areas, regrowth after harvest can produce a second (ratoon) crop, although the yield may only be about 50% of the first harvest.

5.5.3

Growth stage at harvest

Grain sorghum is best harvested when grain in the middle of the head is at the mid-dough stage of maturity and before leaves start to die off. At this stage, the crop should be between 30 and 35% DM. If harvested early, the crop will not achieve its yield potential. If allowed to dry out much more than 35% DM, compaction may become more difficult and digestibility of grain will decrease as it hardens. Silage quality and yields likely to be achieved with well-managed grain sorghum crops are shown in Table 5.12.

If harvesting is delayed and the grain becomes hard, grain digestibility falls and animal production will decline. Research has shown improved production from animals fed late-harvested sorghum silage when it was rolled to crack the grain. This suggests that there is a role for grain processors in harvesting sorghum silage (see Chapter 14, Section 14.2.5). Experimental results in Chapter 14 showed only 43% of grain was damaged during harvest of sorghum for silage production. When the silage was fed to young cattle the whole grain fraction had a digestibility of 83%, less than the 97% achieved for the whole grain fraction of similarly treated maize silage.

The difficulties associated with cracking grain to improve digestibility of late harvested sorghum highlights the importance of timely harvest, before the majority of the grain hardens.

Although prussic acid poisoning can be a risk if animals graze vegetative, moisture-stressed sorghum crops, it is not likely to be a concern with sorghum silage, harvested at the dough stage.

Sulphur and sodium supplementation will improve animal production when feeding sorghum silage.

Height of cut

Grain sorghum is usually cut to a stubble height at 10-15 cm. Increasing the cutting height will increase the proportion of grain to stover and therefore, the quality of the silage. However, feed quality is often not increased enough to compensate for the reduction in yield. Consideration must also be given to managing the extra trash left in the paddock after a high cut.

Plate 5.6

The crop in the foreground is grain sorghum, while the tall crop in the background is sweet sorghum. The yield potential of sweet sorghum is considerably higher than that of grain sorghum. *Photograph: K.Kerr*

Table 5.12

Potential quality and yield of grain sorghum for silage harvested at the recommended growth stage.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Dough grain	9.5-10.5	6.0-9.5	4.0-7.0
			6.0-10.0*

** Yields under irrigation or high rainfall conditions.*

Section 5.6

Sweet sorghum

Sweet sorghums have the potential to produce high yields of medium quality forage, which can be chopped as silage or carried over into winter for use as green chop. It has a reputation for being cheaper, easier to grow and often higher yielding than maize, but is usually lower in ME content than maize silage when both crops are grown under favourable conditions. Under poor growing conditions sweet sorghums can produce higher yields of silage, with a higher ME content than maize.

Table 5.11 presents a comparison of the yield and quality of sweet, dual-purpose and grain sorghums at Moree, NSW.

5.6.1

Crop management for silage production

- Seek local advice for specific agronomic details.
- There is wide variation in yield and feed quality between cultivars. Select varieties with higher WSC content. These are likely to have a higher digestibility and produce a better silage fermentation.
- Sow from November to January. Good germination requires 10 cm soil temperatures of at least 16ºC, at 9:00 am.
- Use sowing rates of 5-10 kg/ha for dryland crops, 15-20 kg/ha if irrigating.
- Adequate fertiliser, weed control and good plant establishment are essential to achieve high yields.
- To maintain soil fertility replace nutrients removed in the forage (see Table 5.1 for details).
- Use irrigation as required, although a maize silage crop will give a better economic return under irrigaion than sorghum.
- Lodging can be a problem. To reduce the risk, grow as a row crop, avoid very high populations, and choose a variety less susceptible to lodging.
- When sweet sorghum has been harvested for silage, a paddock may be fallowed or planted to a rotation crop or permanent pasture. In summer rainfall areas with long growing seasons, some varieties may regrow for a second silage harvest.

Table 5.13

Yield and quality at growth stages from milk to hard grain for eight sweet sorghum varieties grown at Nowra, NSW.

	Growth stage			
	Milk	Dough	Late dough	Hard grain
Yield (t DM/ha)	17.0	17.2	16.3	16.8
DM content (%)	24.1	24.7	25.5	27.2
WSC (% DM)	25.8	24.8	21.3	22.8
Organic matter digestibility (%)	67.4	68.1	66.9	66.5
Estimated ME (MJ/kg DM)	10.0	10.2	10.0	9.9
Crude protein (% DM)	5.8	5.2	5.4	5.0

Source: Based on Havilah and Kaiser (1992)

Sulphur and sodium supplementation will improve animal production from sorghum silage.

5.6.2 Growth stage at harvest

Sweet sorghum's high sugar content (often 25-35% WSC – see Table 5.13) maintains digestibility over an extended period, providing a large harvest window. The crops in Table 5.13 took more than six weeks to progress from the milk to the hard grain growth stage.

Table 5.14 gives potential yield and silage quality levels that can be expected with well-managed sweet sorghum crops. ME and crude protein levels are likely to drop marginally when harvest is delayed.

The juicy, sweet stems of sweet sorghums result in a slow fall in DM content. Sweet sorghum can be direct harvested between the boot/head emergence stage through to the hard grain stage. Crop DM content is often in the range 25-30%. The high WSC content means the forage ensiles easily without the need for wilting.

Table 5.14

Yield and quality ranges for sweet sorghums cut at the milk to hard grain growth stages.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Milk to hard grain	9.0-10.0	4.0-8.0	10-25

Section 5.7

Soybeans

Soybean forage has a high protein content and has potential to produce medium-quality silage. Soybeans have the highest yield and forage quality potential of the summer legume crops currently used for silage production, although ME levels are only medium.

5.7.1

Variety selection

Because the development of soybean plants is dependent on day length, variety recommendations will vary with latitude.

There are no varieties specifically selected for silage production in Australia. The highest yield and feed quality will come from early to mid-season varieties suited to each area. Later-maturing varieties which are sown early may have a higher yield potential but they are usually tall and may lodge, resulting in loss of lower leaves, difficulty in harvesting and lower feed quality. Some late-maturing cultivars may be suitable for silage production if early sowing is avoided, but they need to be evaluated for susceptibility to lodging.

Sown early, the best performing early to mid-season varieties will have high growth rates and production, with potential for early silage harvest (early February). This allows the option for sowing a second summer crop or early winter crop.

Table 5.15 gives yield and quality results for a range of early and late-maturing soybean varieties. Significant differences between cultivars have been observed in both yield and quality. More research is required to identify the most suitable cultivars for silage in different regions.

Table 5.15

DM yield and forage quality of early and late maturing soybean cultivars at two growth stages, at Grafton, NSW (1993/94).

	Days to:		Yield (t DM/ha)		Crude protein (% DM)		DM Digestibility (%)	
	R3*	R6**	R3	R6	R3	R6	R3	R6
Early-maturing cultivars sown early:								
Average	60	86	2.97	6.16	17.9	18.8	63.3	60.8
Range	51-76	78-100	1.6-5.2	4.1-7.5	16.0-20.3	15.2-20.7	60.0-66.7	55.9-63.3
Late-maturing cultivars sown late:								
Average	59	83	3.82	8.36	17.3	17.5	59.9	62.6
Range	52-67	75-89	2.8-5.0	6.5-11.6	12.8-20.4	14.7-21.0	51.8-63.3	59.3-64.8

R3 – Podding has commenced; pods 5 mm in length.*
R5 – Seeds begin to develop.
*R6** – Seeds fill the pod; pods are still green.*

Source: Desborough (unpublished data, 1998)

5.7.2

Crop management for silage production

- Use local guidelines for variety selection, sowing rate and row spacing.
- Sowing rates of 70-90 kg/ha will produce the desired 300,000-350,000 plants/ha.
- Inoculate seed.
- Soybeans are best planted at 18 or 36 cm row spacing at a sowing depth of 3-5 cm.
- Good germination requires 9:00 am soil temperatures of at least 15ºC at a depth of 10 cm.
- Fertilise as required at planting. Inoculated soybeans do not need nitrogen fertiliser although some growers use a 'starter' fertiliser to improve establishment. Replace nutrients removed in silage (see Table 5.1 for details).
- Weed and insect control may be necessary. Be aware of herbicide registrations and withholding periods. Some herbicides used on soybeans have a very long withholding period before grazing or harvest for silage. Some do not have a registered withholding period and so should not be used on crops to be harvested for forage.

5.7.3

Growth stage at harvest

The growth stage for making silage has not been adequately defined for the soybean cultivars most suitable for silage production. However, from the point of view of yield, cutting when the seed 65% fills the pod (between growth stages R5 and R6 – see Plate 5.7) appears to be reasonable. At this stage, the crop has almost achieved its yield potential and pods and leaf will be retained when the crop passes through a roller conditioner.

Delaying the harvest to the pod fill (R6) growth stage, when lower leaves start to turn yellow, will achieve maximum DM yield, but there is an increased seed and leaf loss during harvesting. Although harvesting later avoids the need to wilt, this will result in unacceptable loss of seed and leaf and a loss in forage quality.

Earlier harvesting when pods are elongating (R3) will produce good quality silage, however yield is likely to be only 30-40% of the potential, as indicated in Table 5.16.

Wilting will be needed to achieve the desired 35-40% DM for chopped silage and 35-50% DM for baled silage. Cutting the soybean forage with a mower-conditioner (roller-type conditioner) will increase the wilting rate of the thick stems.

Table 5.16

The effect of growth stage on potential yield and quality of soybean silage.

Growth Stage	ME (MJ/kg DM)	Crude Protein (% DM)	Yield (t DM/ha)
Podding commences (R3)	8.0-9.5	15-20	1.5-4.0
60% pod-fill	8.0-9.5	16-20	4.5-9.0
Seeds fill pod (R6)*	8.0-9.5	16-20	5.0-10.0

* *Trial results do not reflect the potential reduction in quality due to seed and leaf loss that can occur in commercial silage making of late harvested soybeans.*

Depending on the drying conditions, a wilting period of about 24 hours is usually needed to achieve the desired DM content.

Handling and harvesting wilted material in the evening can reduce leaf shatter, which may be a problem on very hot days.

Although soybeans may be made into baled silage, it is not the preferred option. The high DM required for baled silage is not only likely to cause higher field and harvest losses, but also increased leaf and pod shatter, resulting in greater in-silo and feedout losses.

The stalkiness of the soybean forage makes bale compaction difficult and can result in puncturing of the plastic wrap. Although this problem can be reduced by using balers fitted with chopping mechanisms, compaction will still be a problem unless the material is baled at very high density.

Another source of in-silo losses with unchopped baled silage is poor fermentation due to the slow release of sugars, which is often a problem with unchopped material, particularly with legume forage.

Feedout losses with soybeans can be reduced by 15-25% if soybeans are chopped at harvest or before feeding. The chopped stalks are more likely to be consumed by animals.

If harvest is delayed soybean forage can have relatively high oil content. Conventional laboratory testing of soybean silage may not adequately account for oil content and needs further development to ensure ME values are not underestimated.

High oil content can affect soybean silage fermentation, although this has not been a problem with soybean silage harvested at the recommended growth stage. Oil content should also be considered if soybean silage is likely to be a significant component of ruminant diets. High oil levels can affect rumen fermentation.

Plate 5.7

Soybean pods showing seed development. The pod on the left is at the stage recommended for mowing, between growth stages R5 and R6 with seed filling 65% of the pod cavity. The pod on the right is at stage R6, with seed completely filling the pod cavity.

Photo: P. Desborough

Section 5.8

Plant by-products

By-products are often used in periods of drought, short-term feed shortages, or opportunistically as supplies become available. By-products, which include plant residues and food processing by-products, can be valuable sources of energy and protein.

Although poultry litter and animal by-products have been used as protein sources, it is now illegal to include them in rations due to animal and human health concerns.

The use of by-products and alternative feeds has increased substantially in recent years. In the past they have been more commonly used as supplements to fibrous, low-quality roughage, especially during droughts. However, with more widespread use of feed-mixer wagons and total mixed rations, and a better understanding of their nutritive value, by-products are now more commonly used in full production rations.

Because by-products are often highly variable in their nutrient and DM content, these should be monitored by regular feed testing. Where the composition of batches varies widely, regular adjustments to the diet or ration may be required or animal production may suffer.

Some by-products, used as 'fillers' in diets, cannot be ensiled and may have low nutritive value. The by-products considered in this section have medium to high nutritive value, low DM content and are suitable for silage production.

Before using by-products the following factors need to be considered:

- Does it contain potentially toxic or banned compounds (e.g. chemical residues and anti-nutritional factors)?
- What and how variable is its nutrient content (e.g. energy, protein and fibre levels)?
- Is the material palatable and acceptable to the animals?
- Does it contain metals, plastic or other physical contaminants?
- How much material will be available and when?
- What is the true cost when transport cost, bulk density and DM content is taken into account?
- Can it be successfully ensiled?
- What extra handling and storage facilities are needed?

5.8.1

Risk of chemical residues

The withholding period (WHP) on most chemical labels is the specified time between chemical treatment and the commencement of a production process, such as harvesting or grazing. It relates to the label dose rates only and is a minimum requirement. Within this period animal products are not suitable for domestic consumption in Australia.

An Export Slaughter Interval (ESI) is the period following treatment when produce is unsuitable for export processing. It is often longer than the same chemical's WHP.

Some by-products may be contaminated with residues from pesticides or other chemical treatment during processing. Unacceptable residue may still be present in the waste plant material after processing or in crop residues when fed.

Residue risks may increase in by-products because some chemicals are concentrated in the plant waste fraction. A harvest withholding period does not guarantee that other parts of the crop, such as stubble and trash, are suitable for stockfeed. Materials such as grape marc, pomace, citrus peel, vegetable skins and outer leaves of leafy vegetables often have higher residue levels than the commodity they are derived from.

Some chemicals registered for use on fruit and vegetables are not registered for use on stock feeds or directly on livestock. Consequently, there may be no minimum residue limits (MRLs) set for the chemical in animal products. In this case, any detectable level of that chemical in animal products breaches food standards and they cannot be used for human consumption. MRLs acceptable in Australia may not meet standards of our trading partners.

The label directions for some agricultural chemicals ban the grazing of treated crops and/or the feeding of the wastes of treated crops to livestock. This applies to endosulfan. Upgraded restrictions on endosulfan use prohibit the feeding of any feed straw, fodder, trash or by-products from crops or pastures treated with endosulfan. In some States it is an offence for any person to feed wastes from the treated crop contrary to label directions. Producers should check with their appropriate State agencies concerning the local regulations.

There is a further risk from by-products grown on contaminated land. For example, organochlorine residues have been found when animals were fed by-products, such as sugarcane tops or vegetable wastes, harvested from contaminated land.

Before buying or accepting the waste material, representative samples should be analysed for pesticide residues by an accredited laboratory. Advise laboratories of the chemicals to be tested for when the samples are submitted. With the increasing demand from end users, some by-product suppliers are routinely testing their product for chemical residues.

A signed formal Vendor Declaration Form may be available to provide information on the chemical treatment history of the product in question and to verify the chemical residue status.

Updated WHP and ESI information can be obtained from Meat and Livestock Australia (MLA) and on the MLA website <www.mla.com.au>

For more detailed information relevant to NSW, see Blackwood, I. and Byrne, D. (2002) *Buying Stock Feeds: minimising chemical residue risks,* Agnote DAI-265, NSW Agriculture. <www.agric.nsw.gov.au/reader/14071>.

Risk management

Buyers of by-products that may or do contain chemical residues should take precautions by also recording:

- Date the by-product is received
- Type of feed
- Source of supply
- Analyses carried out
- Which animals received the feed
- Dates when the by-product was fed
- Length of feeding period

It is also advisable to store a by-product sample for about 12 months.

Note: If available, buyers should obtain a signed declaration stating if any (and which) residues are present, based on a chemical analysis from an accredited laboratory.

Table 5.17

Nutritive value of a range of by-products and by-product silages (mean values with range in brackets).

By-product (number of samples)	DM content (%)	Crude protein (% DM)	ME (MJ/kg DM)
Citrus pulp[1] (26)	15.2 (9.4-23.8)	8.7 (6.0-12.9)	12.5 (9.9-14.1)
Citrus pulp silage[1] (3)	15.6 (15.1-16.5)	9.5 (8.9-9.8)	11.9 (10.5-13.1)
Brewers' grains[1] (27)	25.4 (13.9-33.0)	21.7 (16.9-25.2)	10.7 (9.7-11.9)
Brewers' grains silage[1] (3)	29.7 (27.9-33.0)	22.0 (20.7-23.3)	10.6 (9.9-11.1)
Grape marc[1] (3)	35.8 (28.1-46.4)	17.9 (11.7-23.3)	8.1 (4.3-11.1)
Apple pomace[2] (3)	24.5 (21.0-27.6)	7.1 (6.0-8.0)	9.6 (8.4-11.0)
Tomato pulp[1] (8)	27.0 (16.6-30.2)	20.5 (17.7-22.4)	7.7 (4.8-9.5)
Potato mash[1] (45)*	23.1 (10.9-62.3)	11.2 (6.7-25.8)	13.3 (10.8-14.8)
Corn trash*[2] (1)	19.6	7.0	9.3

** Fat level assumed = 2%.*

Source: [1] FEEDTEST (2000), Department of Primary Industries, Hamilton, Victoria; [2] Adapted from Low, S.G (1984)

Table 5.18

The nutritive value of selected by-products from the international literature.

By-product	DM content (%)	Crude protein (% DM)	ME (MJ/kg DM)
Apple pomace (dehydrated)[1]	–	4.9	11.0
Banana stems[2]	10	2.0	5.5
Banana skins[2]	15	4.2	6.7
Banana – rejected whole (ripe)[2]	30	5.4	11.5
Brewers' grains[1]	21	25.4	10.4
Carrot[1]	12	9.9	13.8
Citrus pulp[2]	23	7.5	10.3
Citrus pulp silage[1]	21	7.3	12.6
Orange pulp[1]	13	7.5	12.6
Sweet corn trash silage[1]	32	7.7	10.6
Sweet potato leaves[2]	12	20.0	5.8
Sweet potato tubers[2]	30	7.0	13.5
Grape marc[2]	37	13.8	4.9
Grape marc (dehydrated)[1]	–	13.0	4.3
Olive cake[2]	46	4.0	3.8
Pineapple pulp (dehydrated)[1]	–	4.6	10.8
Potato tubers fresh[1]	23	9.5	13.2
Potato tuber silage[1]	25	7.6	13.4
Potato process residue (dehydrated)[1]	–	8.4	14.9
Tomato pomace (pulp)[2]	23	21.5	8.0
Tomato pomace (dehydrated)[1]	–	23.5	8.9

Source: [1] NRC (1989); [2] Chedly and Lee (2000)

5.8.2

By-products suitable for silage production

Many by-products have low DM content, making long-term storage difficult. However, if good silage-making practices are adopted most by-products can be successfully ensiled.

The most important goal is to establish an anaerobic environment as quickly as possible and to promote lactic acid fermentation. If there is a possibility there are insufficient lactic acid bacteria present, it may be necessary to apply a silage inoculant (see Chapter 7, Section 7.4.3). Effective sealing of the by-product stack with plastic sheeting is essential to prevent large storage (and quality) losses.

Most by-products are primarily sources of energy and have a low protein content. However, some, such as brewers' grains, are also sources of protein.

A range of by-products has been ensiled, for example:

- Citrus pulp
- Brewers' grains
- Apple pomace
- Grape pomace/marc
- Pineapple pulp
- Tomato waste
- Sweet corn stover
- Sweet corn trash (from processing plant)
- Vegetable residues (e.g. asparagus butts)
- Fresh fruits and vegetables (e.g. potatoes, bananas).

Table 5.17 shows the analyses for a range of by-products and their silages. Analyses were carried out at a number of feed testing laboratories, and additional data are available from the NSW Agriculture web site <www.agric.nsw.gov.au/reader/1950>. Table 5.18 gives nutritive value data for by-products reported in the international literature.

Although most of these products have low DM content, ensiling is usually successful if WSCs levels are high. Except for brewers' grains, the principles of storage and feeding for the higher energy by-products are similar to those required for citrus pulp (see Section 5.8.3).

The high moisture content of many by-products makes transport costly so they should be costed against alternative feeds on a delivered basis (cents/MJ, ME or cents/kg protein). Even when supplied 'free' ex-factory, the transport and handling costs may result in an expensive feed. In these circumstances the factory may need to pay for disposal of their by-product.

5.8.3

Citrus pulp

Citrus pulp – a by-product from the production of orange, lemon and grapefruit juices – consists of peel, pulp and seeds. It is high in moisture, fibre, WSCs and calcium (Ca), but low in protein and phosphorus (P). The resulting silage tends to be unstable after opening, deteriorating quickly. Quality will vary with:

- type of fruit;
- method of processing; and
- seed content (high in protein and fat).

Analyses available for ensiled citrus pulp indicate that it produces good quality silage and up to 15-20% can be included in beef feedlot rations. The high calcium and low phosphorus in the pulp may increase the Ca:P ratio of the ration, particularly when fed with a legume such as lucerne, and may need balancing with a feed low in Ca and high in P, to avoid milk fever in lactating cattle.

Plate 5.8

Citrus pulp in bunker.

5.8.4

Brewers' grains

Brewers' grains are the extracted residues from the barley malting process or in a mixture with other cereal grains or grain products. Brewers' grains tend to be high in both energy and protein, but can be extremely variable in composition.

Temperatures reach 70-75ºC during the processing of brewers' grains, killing most bacteria and heat damaging some of the protein, making it less rumen degradable. The process also removes much of the fermentable carbohydrate.

Because of their high moisture content, brewers' grains must be ensiled if they are to be stored over a long period. It is advisable to store it in a pit or bunker no higher than about 2.5-3.0 m. If stored higher, the surface and face will crack when the stack slumps at feedout. This allows air to enter, resulting in mould growth and spoilage. Sealing the stack with plastic could reduce this problem.

Molasses has been sprayed on the stack to seal the surface and to avoid 3-5 cm of spoilage. The stack is then sealed with plastic about 24 hours after spraying the molasses, earlier if rain is imminent.

For long-term storage, anaerobic conditions are essential to preserve the product, maintain palatability, and prevent aerobic spoilage and mould growth and toxin production. When stored without a seal there can be significant degradation and loss of protein and significant top spoilage (mould growth).

5.8.5

Grape marc

The ME value of grape residue (marc) can be highly variable, although the crude protein content is high (see Table 5.17). However, grape marc contains high levels of tannin, which results in much of the protein being bound and not available to the animal.

Cattle may not be able to digest whole seeds in the marc. However, the oil in grape seeds will contribute to a higher energy value if the seeds are crushed. Energy value is also influenced by whether the grape marc has been distilled to remove additional ethanol. If the grape marc is stacked to allow further fermentation of residual sugars, and then distilled, the energy value of the distilled product will be lower.

Grape marc can also contain high copper levels from pesticide applications to the grape crop.

5.8.6

Other by-products

Apple pomace

Apple pomace or pulp is the residue after the juice is extracted for cider or vinegar. It can be fed fresh, ensiled or dried, and has been included in beef diets at levels of 15-20% and up to one-third in dairy rations.

Tomato pulp

Tomato pulp is the residue from tomato processing factories. Although its protein content is high, its energy values are extremely variable. An analysis before purchase, or at least before feeding, is essential to allow for proper balancing of the feed ration. There is negligible information on feeding tomatoes to animals.

Bananas

Whole bananas have a high energy value and have been ensiled successfully. Soluble sugar content is lower and starch content higher in green fruit than ripe fruit. Both green and ripe fruit have been reported to produce well-preserved, low pH silages. However, ripe fruit tend to produce a silage with higher levels of fermentation products, particularly lactic acid.

Potatoes

Potatoes are high in moisture and energy (starch), low in fibre and have moderate protein levels. Potato mash has been used in some areas as a seal on pasture silage stacks as it forms an airtight seal when thick enough. The seal offers some feed value when fed out with the pasture silage.

Dry material such as hay or heavily wilted pasture may have to be mixed with the potatoes before ensiling so that the DM level is about 35%.

Potatoes (and some other vegetables) can accumulate cadmium.

Corn trash

Corn trash is the residue from both canning and frozen product processing. Its energy value can be high, although this depends on the proportion of broken grain and cobs. It can have a relatively high WSC content and is usually not difficult to ensile successfully. However, it often has a very low DM content, which makes it expensive to transport any distance and can result in considerable effluent flow from the stack.

Sugarcane

Failed sugarcane crops (e.g. frosted crops) can be salvaged as fresh chopped forage or ensiled. The quality of the forage can be extremely variable and will depend on the stage at which the crop is cut. It is generally considered to be low-quality roughage.

A summary of sugarcane feed test analyses from the NSW Agriculture website <www.agric.nsw.gov.au/reader/150>, showed an average DM digestibility of 49.9%; crude protein, 3.57 (% DM); and ME, 7.59 (MJ/kg DM).

When ensiling sugarcane, ensure a short chop length to aid compaction and reduce silage losses. Seal the silo quickly to prevent growth of organisms (e.g. yeasts) that may ferment sugars to ethanol.

Check the chemical status of the crop before buying or accepting the forage.

The by-product of the sugarcane process, bagasse, is of very low nutritive value and is not recommended for ensiling.