producing **quality** oat hay

AEXCO
Australian Exporters Company

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SARDI Research and Development Institute

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RURAL INDUSTRIES
Research & Development Corporation

keys to producing quality oat hay

credit Emma Leonard, AgriKnowHow

Chapter 1
why grow oat hay?

Oat hay provides enterprise diversity bringing financial and agronomic benefits.

Chapter 2
oat hay planner

Paddock selection and pre-seeding weed control are essential for quality oat hay.

Chapter 3
market requirements

Know your market.
Talk to your hay buyer before sowing.

Chapter 4
variety selection

Select varieties to meet market, region and disease resistance requirements.

Chapter 5
establishing the crop

Calculate seeding rate on 1000 grain weight.
More seeds generally increase quality, yield and weed competition.

Chapter 6
crop nutrition

Soil test: sow in paddocks with low nitrogen (N).
Understand variety N requirement and importance of potassium.

Chapter 7
weeds, diseases & pests

In-crop weed and disease control options are limited. Plan ahead. Abide by all product labels.

Chapter 8
making oat hay

Bale when 12-14% moisture.
Different variety maturing extends cutting date more than spreading sowing date of the same variety.

Chapter 9
transport & storage

Store export hay in sheds.
Monitor hay moisture.
Know and implement transport laws.

it pays to make quality hay

credit Emma Leonard, AgriKnowHow

In the past 20 years, Australia's oat hay industry has significantly developed on the back of increased demand for quality conserved forage.

It is over 10 years since Producing Quality Oat Hay was published by the Rural Industries Development Corporation (RIRDC). To reflect developments in the past 10 years, the Australian Export Company (AEXCO) has supported the production of this new edition.

There are three core reasons why it pays to make hay. But to really make hay pay, it must meet the market's quality requirements (Chapter 3).

AEXCO

Shareholders of AEXCO are the major export oat hay processors of Australia. AEXCO's primary purpose is to support the National Oat Breeding Program's (NOBP) research and development activities for the benefit of all oat hay industry participants. The NOBP is the only oat breeding program in the world focused on breeding oat varieties for hay yield and quality.

Since 2001, AEXCO has been the commercialisation partner for oat hay varieties developed by the South Australian Research and Development Institute (SARDI). The AEXCO shareholders believe research and development of oat hay varieties is a critical component in growing Australia's export oaten hay industry.

Making hay pay its way

1 Agronomy	2 Farm management	3 Demand
Weed - management tool. Suitable for dry sowing.	Financial return – potential to improve cash flow and whole farm gross margins.	Export market – substantial growth in demand projected for fodder in key Asian markets.
Rotation – grow more wheat or barley the following year. Alternative disease break.	Risk management – mitigation against frost and drought on grain crops.	Domestic market – increasing use of cereal hay in the Australian dairy industry.
Potential to improve productivity on low gross margin land.	Alternative enterprise - income stream and use of labour and machinery.	

National Oat Breeding Program

Seven varieties from the National Oat Breeding Program have now been commercialised by AEXCO.

Kangaroo[Φ] - this hay variety, commercialised from the SARDI Oat Breeding Program by AEXCO in 2006, is a tall mid to late season variety with good early vigour. It heads about four days later than mid season varieties. Kangaroo[Φ] has been superseded by Tungoo[Φ].

Wintaroo[Φ] - a hay variety released in 2003 as a replacement for Marloo, which in turn replaced Swan. Wintaroo[Φ] is a tall mid season oat with good early vigour. It resists brown leaf tipping by hot northerly winds better than other varieties and is adapted to low, medium, and high rainfall locations.

Brusher[Φ] - a hay variety developed by SARDI and commercialised by AEXCO in 2004. Brusher[Φ] is a tall line with good early vigour, heading earlier than Wintaroo[Φ]. It is adapted to low, medium, and high rainfall areas.

Mulgara[Φ] - released in 2009 and commercialised by AEXCO, Mulgara[Φ] is a tall mid season variety with excellent early vigour and good straw strength.

Tungoo[Φ] - released in 2010 as a medium tall mid to late season variety with an excellent disease resistance profile, Tungoo[Φ] replaces Kangaroo[Φ].

Tammar[Φ] - a medium tall late variety that matures four to seven days later than Tungoo[Φ], Tammar[Φ] was released by SARDI in 2011.

Forester[Φ] - was released in 2012 as a very late hay variety adapted to high rainfall and irrigated cropping regions. It is three weeks later than Wintaroo[Φ], seven to 10 days later than Glider and two days later than Targa. Forester[Φ] has excellent early vigour and is an improvement compared to Glider. It has excellent lodging and shattering resistance.

Details of these and all oat varieties suited to quality hay production at the time of publication are found in Chapter 4.

Plant Breeder's Rights (PBR) apply to all of AEXCO oat hay varieties.

Plant Breeder's Rights

Plant Breeder's Rights (PBR Φ) were introduced to stimulate investment in plant breeding by conferring ownership rights to varieties and thereby the potential to market those rights as part of a commercialisation process.

PBR guarantee ownership of a variety but do not specify how the variety should be commercialised or whether or where royalties should be applied or charged.

Key points

- Seed of varieties with PBR protection can only be bought from the owner, commercial partner/licensee or an agent authorised by the owner.
- Growers cannot sell, trade or give away the variety for seed unless authorised by the licensee.
- If growers are unsure of any PBR issues or marketing arrangements, they should seek information from the licensee or its authorised seed distributors.

More details about PBR and end point royalties (EPR) can be found on the AEXCO website (www.aexco.com.au).

NOBP is supported by

AEXCO Australian Exporters Company

Australian Government
Rural Industries Research and Development Corporation

RURAL INDUSTRIES
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GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

SAGIT

Government of South Australia

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Department of Agriculture and Food
GOVERNMENT OF WESTERN AUSTRALIA

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why grow oat hay?

chapter 1

credit Emma Leonard, AgriKnowHow

Growing oats for hay offers grain growers a combination of opportunity and risk reduction.

Many growers have introduced oat hay into the rotation as another option in the management of herbicide resistant weeds. However, oat hay can provide a profitable break crop that optimises the use of machinery and labour and introduces diversity into the timing of crop maturity and payment.

Of course, growing oat hay has a risk profile of its own, for example, capital and/or operating costs can be substantial. It is also essential to understand the market requirements. Before sowing oats for export hay, seek advice from your hay buyer about varieties and bale size.

There are differences in the agronomy of oats grown for grain and hay. The production of high quality oat hay for export requires planning. The application of agronomy that focuses on hay quality and market requirements can help minimise the risks associated with oat hay production.

This book offers guidelines on how to produce quality oat hay for the export and domestic markets.

Opportunities

Financial contribution

Oat hay production can produce a substantial gross margin and contribute to improved cash flow and total farm profit (Tables 1.1 and 1.2).

Labour and machinery resources

A hay making enterprise can provide on-going work at times when other farm enterprises may have low labour requirements, therefore allowing continuous employment.

Existing farm machinery such as tractors, loaders and trucks often can be used in the hay enterprise. The provision of contract hay making and transporting services and providing storage can add substantially to income.

Livestock enterprises

The production of hay can allow livestock enterprises to be sustained, particularly when green feed is not available.

Risk reduction

Markets and price

Hay markets and prices are largely independent of grain markets and prices. Good quality hay can reduce the risk of poor returns from cropping due to commodity prices or market restrictions. In addition, hay can be stored when market conditions are poor and sold when they improve. Oat hay has a well established market compared to the demand for hay from other cereals.

Seasonal risk for grain growers

Hay is cut before grains fill. By shortening the growing season, the potential for damage from the risk of excessive heat, low subsoil moisture levels or frost is reduced. This makes hay a lower risk than grain crops.

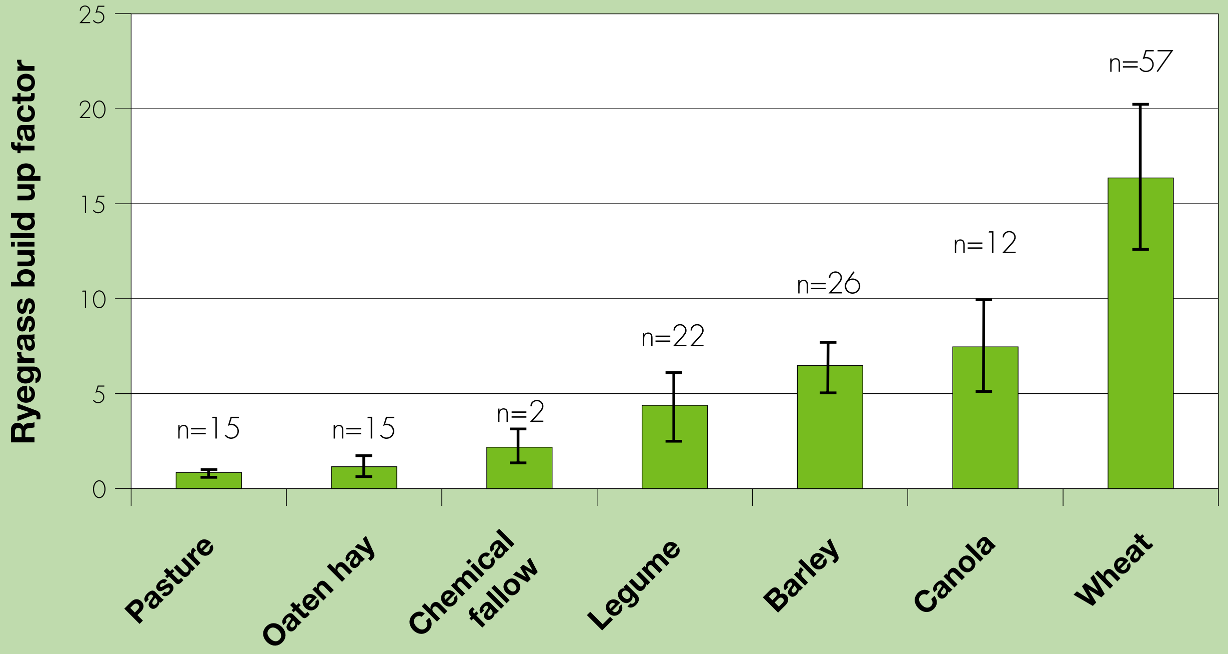

Figure 1.1 Annual changes in weed seedbank – *source Dr Gurjeet Gill, Adelaide University.*
A significant reduction in ryegrass seeds was recorded following an oat hay crop compared to cereal, oilseed and legume crops harvested at grain maturity. n= number of samples surveyed.

Soil moisture

The production of hay reduces the soil moisture loss normally associated with maturing grain crops. On suitable soil types, generally heavier soils, this moisture can be stored for subsequent crops, can support dry sowing and can lead to increased grain yields. For example, in a year with a dry spring, a crop of barley planted on oat hay stubble in Victoria yielded 1.5t/ha of Feed 1 barley. This compared to the same variety in an adjacent paddock but sown on a wheat stubble which produced 0.5t/ha of Feed 3.

Soil nutrients

Hay making removes significant amounts of nutrients from the soil, especially potassium (K), calcium (Ca) and magnesium (Mg) (see Tables 6.1a & b) but late season uptake of nutrients is reduced. On balance, hay can be less nutrient depleting than 1) harvesting grain and cutting straw, and 2) harvesting grain and burning stubble.

Weeds

Cutting hay can reduce weed seed set by desiccating later maturing weed species before viable seed is set. With care, viable weed seeds can be removed from paddocks in the baled hay. By depleting the weed seedbank, hay production is a particularly successful tool in an integrated approach to managing herbicide resistance (Figure 1.1).

Export hay requires a nil presence of toxic plants and prickly weeds such as doublegees. Most processors have a limit of 1% by weight of broadleaf plants and 5% of grass weeds including other cereals.

Annual Ryegrass Toxicity (ARGT)

The timely production of hay can reduce ARGT by removing ryegrass (and other hosts) prior to toxin formation. There is nil tolerance of ARGT in export hay and testing for ARGT bacterial contamination in export hay and straw is compulsory. If ARGT is an issue, it should be managed before sowing oats for export hay. See Chapter 7 – weed control.

Pest and disease

Hay production can offer a break crop opportunity, especially in continuous cropping systems. This may be due to the hay crop being a non host to a particular pest or disease or the hay making operation being destructive of the organism or its habitat. See Chapters 4 and 7.

Table 1.1 Gross margin in dollars per hectare for oat hay based on average production costs, at the time of publication, for the medium and high rainfall regions *– source Garren Knell Consulting and Landmark 2016.*

Income				**Add your figures here**
Yield	(t/ha)	600kg bales	5.5	
Quality	mixed grades			
Price	$/t		225	
Gross income	**($/ha)**		**1237.5**	
Expenditure		**Cost**	**$/ha**	
Seed	90kg/ha	$600/t	54	
Seed levies		variety dependent		
Fertiliser (on-farm)				
18:20:00	80kg/ha	$750/t	60	
Urea	75kg/ha	$570/t	43	
Potassium#	50-80kg/ha MOP		30	
Herbicides	pre-emergent	$7-17/L	30	
	post emergent	$10/L	25	
	spray topping regrowth	$6/L	12	
Insecticides	seed dressing and in-crop		5	
Fungicides	seed dressing and in-crop		18	
Operating costs at contract rates				
Seeding			50	
Spraying	pre-emergent		9	
	post emergent		9	
	spray topping regrowth		9	
Rolling			6	
Top dressing fertiliser			10	
Mowing and conditioning			50	
Raking/tedding			13.5	
Baling		$18/bale	165	
Handling		$7/bale	65.0	
Transport		10c/bale/km (100km)	137.5	
Storage*				
Insurance		$2.50/$1000	2.2	
Total expenditure			**803.2**	
Gross margin			**$434.30/ha**	

 # primarily required on lighter soil types

** see Chapter 9. Exporters pay a premium for hay stored in a shed*

Breakeven – either 3.5t/ha having accounted for reduced baling, handling and transport per hectare or $150/t.

Table 1.2 The impact of yield and price variance on income ($/hectare), price and yield in gross margin. Breakeven figures from Table 1.1 example are highlighted.

Yield t/ha	Price $/t										
	100	125	150	175	200	225	250	275	300	325	350
3.5	350	437.5	525	612.5	700	787.5	875	962.5	1050	1137.5	1225
4.5	450	562.5	675	787.5	900	1012.5	1125	1237.5	1350	1462.5	1575
5.5	550	687.5	825	962.5	1100	1237.5	1375	1512.5	1650	1787.5	1925
6.5	650	812.5	975	1137.5	1300	1462.5	1625	1787.5	1950	2112.5	2275
7.5	750	937.5	1125	1312.5	1500	1687.5	1875	2062.5	2250	2437.5	2625
8.5	850	1062.5	1275	1487.5	1700	1912.5	2125	2337.5	2550	2762.5	2975
9.5	950	1187.5	1425	1662.5	1900	2137.5	2375	2612.5	2850	3087.5	3325
10.5	1050	1312.5	1575	1837.5	2100	2362.5	2625	2887.5	3150	3412.5	3675

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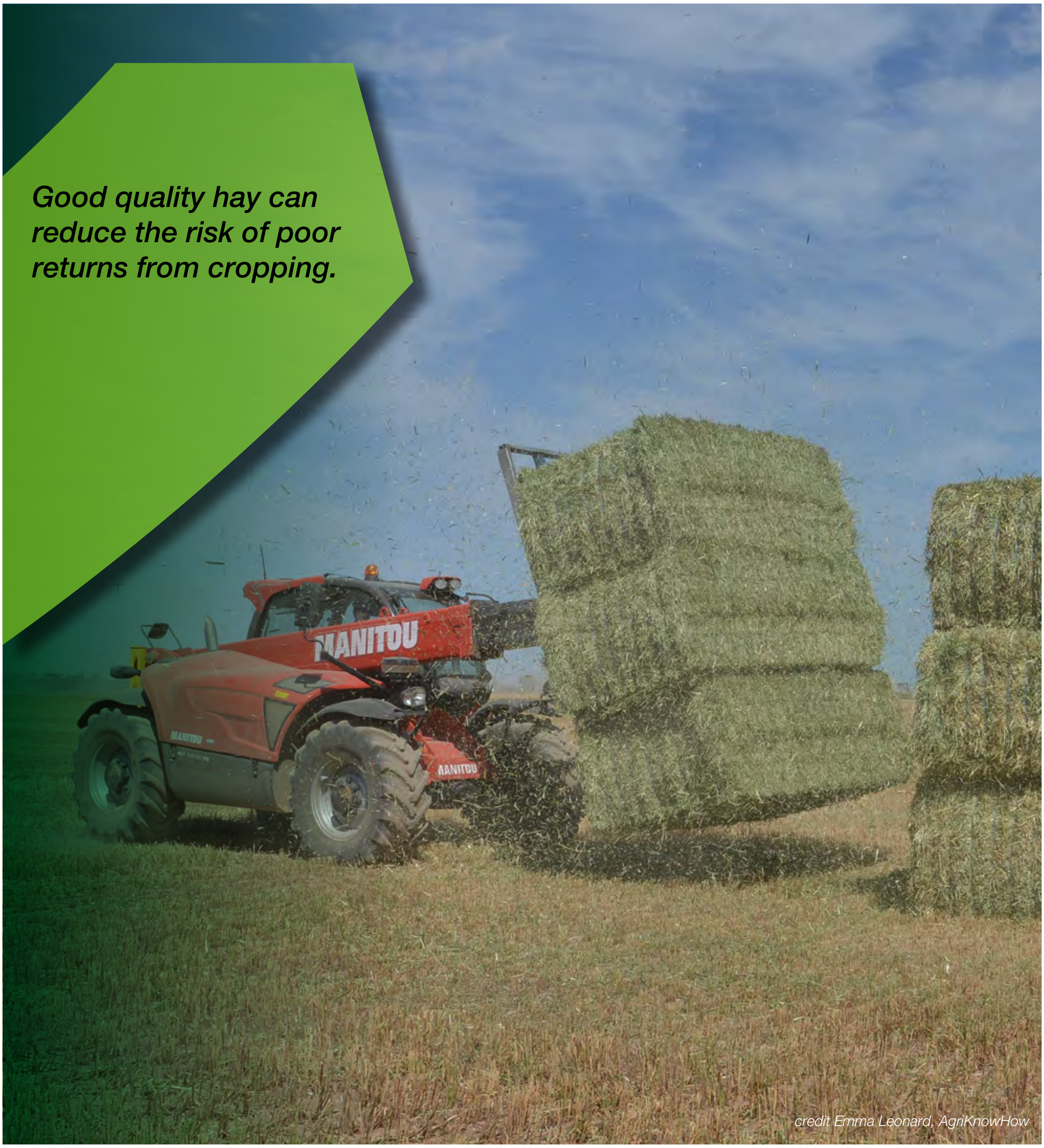

credit Emma Leonard, AgriKnowHow

oat hay planner

chapter 2

credit Emma Leonard, AgriKnowHow

Top tips for new oat hay growers

Understand the market

Research demand for different types of hay and bale conformations.

Talk to hay buyers, other producers and source information from industry bodies including AEXCO and the Australian Fodder Industry Association (AFIA).

Understand the quality criteria and how these are influenced by agronomy and management.

Know what the market will reject.

Calculate the gross margin for oat hay

Compare gross margin with other enterprises.

Investigate the use and availability of contractors.

Select the right variety

Base variety selection on average rainfall, growing conditions and disease issues in your paddocks and regions.

Test for soil borne diseases such as cereal cyst nematode and stem nematode as their presence can strongly influence variety choice.

Attention to agronomy

Understand the influence of available nitrogen (N) on hay quality.

Ensure good pre-seeding weed control and low levels of N can be achieved in any paddocks selected for oat hay.

Plan ahead for hay making

Assess risks associated with rain damage at curing. The following factors help reduce the risk of rain damage:

- correct variety maturity;
- a spread of variety maturity;
- adequate equipment; and
- super-conditioning.

If purchasing equipment order well ahead to ensure late arrival does not delay cutting and baling.

More details on all of these issues are provided in the following chapters.

The oat hay year planner

Between crops

November / December

- Discuss future demand and preferred varieties with hay buyers
- Preliminary paddock selection
- Order new seed
- Speak with contractors

January / March

- Soil test for nutrients and root disease
- Produce a fertiliser budget
- Manage stubble
- Speak to hay buyers about pre-season contract
- Implement repairs and maintenance to storage and equipment

March / April

- Finalise paddock plans
- Prepare equipment for sowing
- Allow volunteer cereals and weeds to germinate before applying herbicide

April / June

- Calculate 1000 grain weight and seeding rates
- Sow early into clean, weed free paddocks
- Ideally sow before mid June
- Confirm hay making, storage and transport contracts

In-crop

Manage crops by growth stage - see page 13

Hay making

September / November

- Cut and condition/super condition hay
- Monitor moisture levels in windrows
- Bale when optimum moisture is reached
- Cart hay to storage immediately after baling
- Develop a list of machinery repairs and maintenance
- Clean and store machinery

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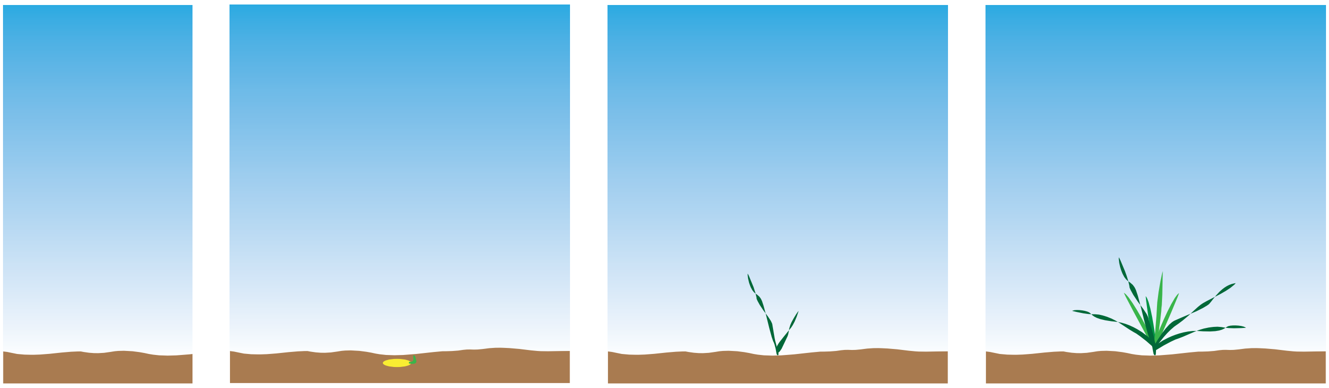
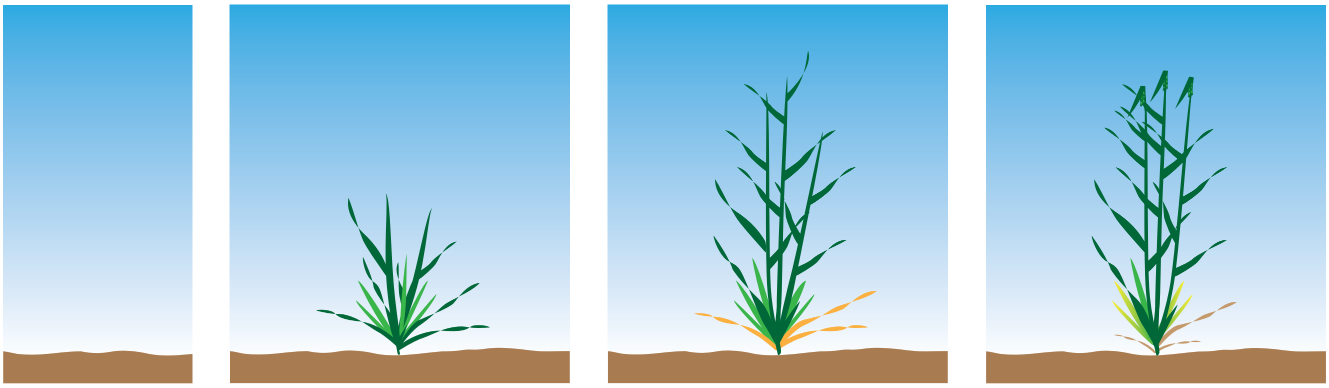
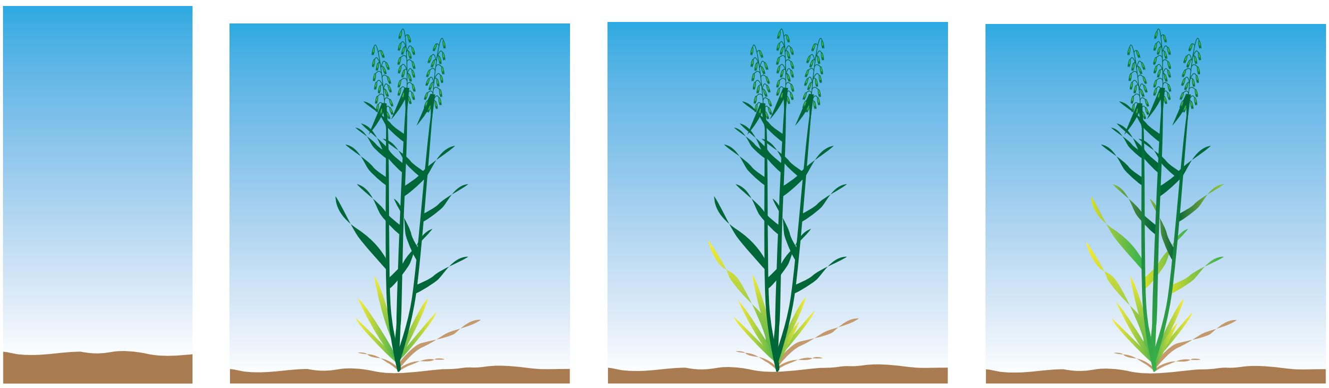


Growth stage (GS)	Germination	Seedling growth	Tillering
Zadoks GS	GS00-09	GS10-19	GS20-29
Development phase	Vegetative growth		
	Seed bed preparation Pre-emergent herbicide Remove any potential contamination	Monitor and control weeds, mites and lucerne flea Apply post seeding N if required GS14	Roll prior to GS24 Apply post sowing N GS25-31



Growth stage (GS)	Stem elongation	Booting	Panicle emergence
Zadoks GS	GS30-39	GS40-49	GS50-59
Development phase	Stem elongation and ear development		
	Monitor for leaf disease Preventative fungicide, if required GS32 Consider withholding periods	Prepare hay equipment Check with contractors	Commence regular checking for cutting GS51 Check for flowering



Growth stage (GS)	Flowering	Milk development	Dough development
Zadoks GS	GS60-69	GS70-79	GS80-89
Development phase	Grain development	Grain filling	
	Optimum cutting time for premium quality hay GS60-71	Quality decreasing	Rapidly decreasing quality Too late to cut for premium quality hay

The high quality standards produced for the export market have helped boost domestic demand for oat hay.

credit Emma Leonard, AgriKnowHow

what the market wants

chapter 3

credit Emma Leonard, AgriKnowHow

There are two key markets for hay - domestic and export (Figure 3.1). Each has its own specific requirements. Speak to your hay processor or buyer before selecting varieties and equipment to ensure the hay you produce meets the market's needs.

The high quality standards demanded by the export hay market have substantially boosted the domestic demand for quality oat hay by dairies and feedlots. This has resulted in very similar quality requirements for the export and domestic oat hay markets (Table 3.1).

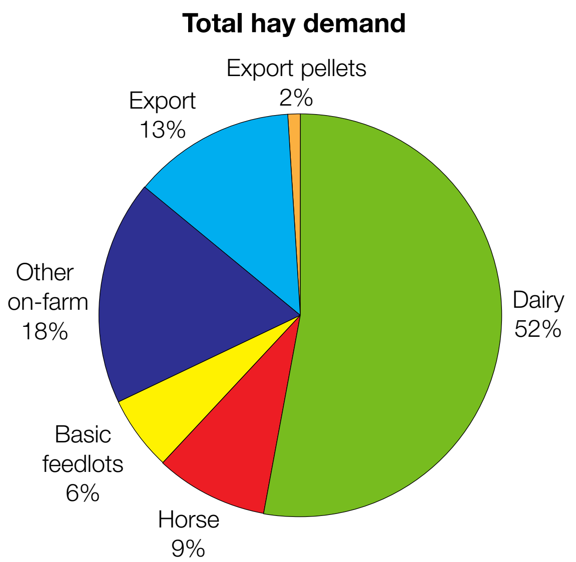


Figure 3.1 Australian fodder industry by market based on several years of data – *source AFIA 2016.*

Requirements for bale size can vary between domestic markets (Table 3.2). Large square bales or high density bales are increasingly required by exporters. These are often repacked into high density small bales. On page 23 the photograph shows a 23kg bales and 24 by 23kg bales shrink wrapped for shipping.

Table 3.1 An example of hay quality parameters for export cereal hay – *source Gilmac 2016.* Annual quality requirements for domestic hay may depend on the price of alternate ingredients used in livestock rations.

Quality parameters	Export cereal hay
	Level
Dry matter (DM)	>85%
Crude protein (CP)	4-10%
Neutral detergent fibre (NDF)	<57%
Acid detergent fibre (ADF)	<32%
Dry matter digestibility (DMD)	> 58%
Metabolisable energy (ME)	>9.5Mj/kg DM
Water soluble carbohydrates (WSC)	>18%
Nitrate (NO_2)	<500ppm

Objective and subjective tests for hay quality

Intake and preference

Hay nutritive value and feeding value should not be confused. Nutritive value is determined by digestibility and efficiency of utilisation of nutrients. Feeding value is determined by a combination of nutritive value and how much an animal consumes (voluntary feed intake).

Hays of similar nutritive value can differ in feeding value. In general, voluntary feed intake for hay with thinner, less fibrous stems is greater than for hay with thicker, tougher stems.

Feed analysis

The feed analysis measures dry matter, digestibility, fibre and water soluble carbohydrate content, as well as crude protein and nitrate nitrogen levels (Table 3.1). For export hay, the feed analysis is generally organised by the hay buyer.

Moisture

Moisture is generally measured in the paddock or on the baler by the grower. Most exporters specify maximum bale moisture of 14% at delivery to ensure hay does not degrade or spoil during storage. High moisture hay for the export market will be rejected at delivery (see Chapter 8 – testing moisture content). Dry matter, the inverse of moisture content, is reported on the feed analysis.

Fibre and digestibility

Fibre is required by ruminants to maintain rumen function. It is also essential in the production of milk fat. Acid detergent fibre (ADF) represents the most indigestible fraction of the hay. As ADF increases, the digestibility of the forage decreases.

The neutral detergent fibre (NDF) value reflects the amount of forage the animal can consume. As NDF percent increases, dry matter intake generally decreases.

Digestibility estimates the percentage of forage that can be readily broken down in the rumen.

Water soluble carbohydrates

These are sugars that are rapidly fermented in the rumen and the products of this fermentation are mainly precursors for protein synthesis. High quality oat hay will have a water soluble carbohydrate content of about 19%. Water soluble carbohydrates, in particular fructose, influence palatability but may not be strongly correlated with preference.

Minerals

Oat hay is generally low in sodium, but potassium and nitrate levels can vary depending on crop nutrition and availability in the soil. If dry cows are fed hay with a potassium level in excess of 2%, within three weeks of calving, the potential risk of milk fever is increased. This risk is influenced by the level of sodium, chloride and sulphur in the total diet.

Many of the above factors can be manipulated by variety choice crop agronomy and by the way hay is made and stored (Table 4.4).

Export markets

The export market for oat hay continues to dominate hay and straw exports (Figure 3.2). Demand from China is starting to accelerate, while the markets in Japan, Korea and Taiwan have remained strong (Figure 3.3). Indonesia and Vietnam are seen as developing markets for export oat hay.

In the financial year 2014-15, Japan remained Australia's largest and most important customer (Figure 3.3). In this period, exports of cereal hay and chaff to Japan represented about 60% of exports in this category of products.

Stable hay quality and lack of contamination underpin the favourable reputation of Australian hays in export markets.

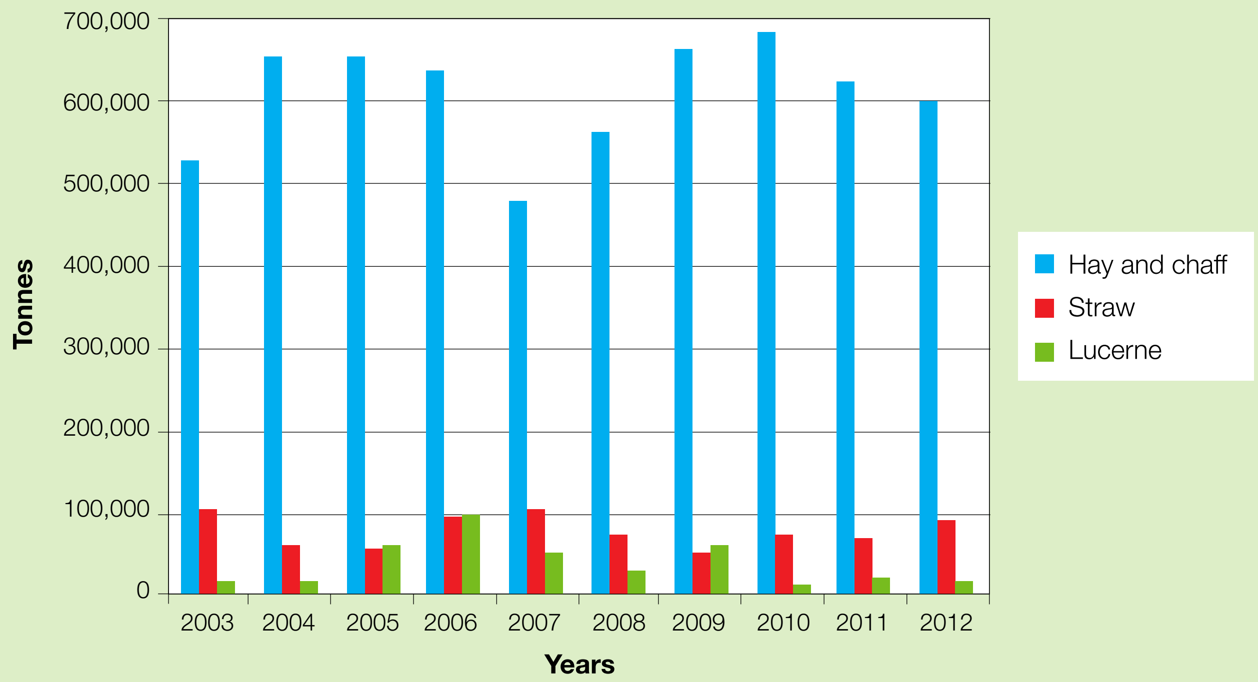


Figure 3.2 Australian cereal hay and straw exports 2003 to 2012 (tonnes) – *source ABARE.*

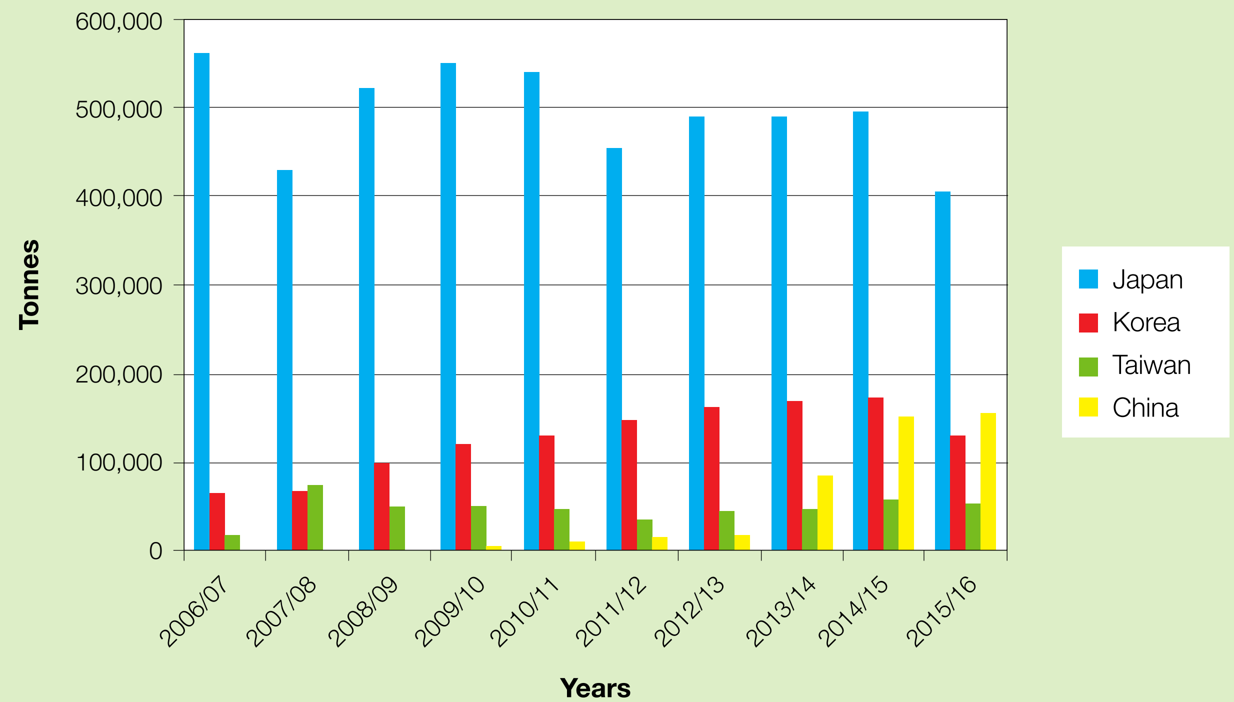


Figure 3.3 Australian cereal hay exports by key markets 2006 to 2016 – *source ABARE.*

The markets in Japan, Korea, and Taiwan, and the emerging markets in Vietnam and Indonesia have several common factors that drive the importation of high quality forage. These factors are:

- large populations, of which many have a substantial disposable income;
- insufficient land to produce enough quality feed to meet demand;
- governments that wish to increase the level of self sufficiency in dairy and meat production.

While China does not lack productive land, it is influenced by the other two factors and currently is importing large quantities of high quality fodder to supply its rapidly expanding dairy industry.

At the time of writing, the USA and Canada are Australia's main competitors in the export hay market. These countries produce premium hay products from Timothy grass, alfalfa (lucerne) and Sudan grass.

From the perspective of the Australian producer, the export hay market and consequently hay price are driven by:

- supply from Australia and of competitive products from overseas;
- hay quality;
- the value of the Australian dollar on the exchange markets; and
- competition from the domestic market.

Japan

Japan is generally regarded as a mature market; very consistent and stable but with limited opportunities for growth. In recent years, there have been a number of challenges for Australian exporters in Japan including declining beef and dairy cow numbers and the devaluation of the Japanese yen.

Korea

Korea remains a good market for Australian hay that has both grown in value and provided an alternate market to Japan. This market has a strong focus on the dairy industry and typically takes lower priced, mid quality hay.

Taiwan

Taiwan is a mature and well educated market for Australian hay with preference for high quality hay, both oaten and wheaten, with high analysis results. Again, the key customer is the dairy industry.

China

China is emerging as an important potential market for the Australian export fodder industry. Small volumes of Australian fodder have been exported to China as far back as 1995, however, it was not until 2009 that the market started to evolve. Demand for fodder in China is being driven by growth in the demand for dairy products.

Chinese customs and Government requirements are strict and must be met. Failure to do so can result in an exporter being banned from the market; this is not an idle threat. Contamination in the hay is a major concern to Chinese authorities.

What is quality export hay?

Quality is imperative for export hay and is determined by a combination of factors:

- visual and sensory appearance;
- objective measurement, including feed analysis;
- product safety.

Hay buyers differ in their methods of quality determination and the importance they place on visual, sensory and objective assessment. It is important to understand what your buyer requires in terms of hay quality and how this is determined.

In a nutshell, the export market demands hay that:

- animals want to eat, even when their nutritional requirements have been met;
- is readily digested without excessive regurgitation as this takes energy and reduces intake;
- provides appropriate levels of nutrients for the animal to perform.

Why quality matters for all markets

Poor quality hay may be cheaper per tonne but hay quality has a significant impact on growth rate and milk production. This is clearly demonstrated in Table 3.2(a) and (b) which show the impact of hay quality on feed conversion and the economics of weight gain on a young 300kg steer only fed cereal hay.

Table 3.2 Cereal hay quality used in the example in (a) and (b) – *source Ian Sawyer, Feedworks.*

Hay type	Good	Moderate	Poor
ME (MJ/kg)	11	9.5	8.2
NDF%	40	50	65
ADF%	30	36	45
Price ($/t)	275	250	225
(b) Impact of hay quality on feed conversion efficiency			
Intake (kg DM/day)	9	7	5.5
Energy intake (MJ/day)	99	66	45
Growth rate (g/day)	1300	520	70
Days to gain 50kg	38	96	700
kg feed/kg gain	6.8	13	77
(c) Economics of weight gain on different quality hay			
Growth rate (g/day)	1300	520	70
Feed making meat (%)	56	31	3
Feed maintenance (%)	44	69	97
kg feed/kg gain	6.8	13	77
Feed cost (cents/kg)	27.5	25	22.5
Cost to gain 1kg ($)	1.87	3.25	17.32

Visual, sensory and safety assessments

Colour

The primary visual criterion is an appealing but not a vivid green colour. There is a perceived association of vivid green hay with high nitrate levels, which can result in nitrate poisoning.

There appears little evidence that animals prefer hay due to its colour but there may be aromatic compounds that have an influence.

Staining, moulds and dust

The main market inhibitors are yellow staining, brown leaf, high dust levels and the development of mould. Hay containing one or more of these will be downgraded.

Moulds can be smelt and buyers want to source sweet, clean smelling hay as offensive odours deter hay intake.

Stem diameter

Thin stems are preferred as these contain less fibre in the cell walls. Coarser stems are acceptable in total mixed rations.

In general, voluntary feed intake for hay with thinner, less fibrous stems is greater than for hay with thicker, tougher stems.

Impurities and foreign objects

The inclusion of certain weeds, including capeweed and Salvation Jane, can cause undesirable black patches in the bale, resulting in discolouration and downgrading.

Export markets have a nil tolerance for contamination with animal carcasses or faeces.

Hay must be free from foreign material, such as metal objects, glass, sticks and fencing wire that can injure farm animals, their handlers or equipment.

Toxins

The industry cannot afford livestock deaths due to ARGT or poisoning from other corynetoxins. Export hay markets demand hay free from the risk of toxicity and increasingly test for toxins or their precursors. Twelve bales per paddock or 15% of bales in every paddock, whichever is the greater, must be sampled for ARGT.

Hay must have chemical residues lower than Australian Maximum Residue Levels (MRL) as outlined by the Australian Pesticides and Veterinary Medicine Authority (APVMA), unless specified by the importing country. Speak to your hay buyer to ensure you can meet requirements.

Domestic hay markets

Customer demands, especially in the equine industry, change from year to year depending on the availability of forage and other feeds. Each sector differs in its demand for bale size and shape (Table 3.3), so it is important to understand your market.

The domestic market is loyal to suppliers who provide the right product, have continuity of supply throughout the year, can deliver on time and load without time constraints.

Table 3.3 Demand and requirements for hay by the domestic market.

Market	Demand	Quality required	Storage and handling
Dairy	Increased interest in oat hay due to improved hay quality. Dairy farmers are prepared to compete on price.	Low demand for pure oat hay. Meadow hay containing a mix of grasses, pasture legumes and oats is preferred. Hay that does not make export grade is acceptable but for milk production, export grades are required. Prefer hay with no grain. High energy sought for milk production. Green colour and thin stems are desired quality characters. Palatability is paramount. Rust and mould are not acceptable.	Wide variation in desired hay quality. Preference for round and large square bales. Buy as needed – lack of long term storage.
Feedlots	Some increased demand for oat hay as record numbers of animals held in feedlots. Maize and lucerne main competitors.	Fed to animals for growth and bulk. For cattle, hay price and quality are important. Cut at early milk stage; no grain, no vermin. For sheep feedlots, hay needs to be finely chopped and good quality.	Large square bales generally preferred. Oats may also be used as silage.
Horses	Varies from year to year depending on availability of pasture hay.	Free from dirt, dust, mould, and rust diseases. Fine stems and good colour. Customers are fussy and there is wide variation in desired quality: 1) no grain development to some grain. 2) minimal flag leaf to plenty of leaf. Generally, do not cut hay before milky dough. Horses seem to prefer unconditioned hay.	Preference is generally for hay to be in small square bales.
Hobby farmers	Low demand for pure oat hay. Meadow hay containing a mix of grasses, pasture legumes and oats is preferred.	Wide variation in desired hay quality.	Low density small bales preferred over large bales.

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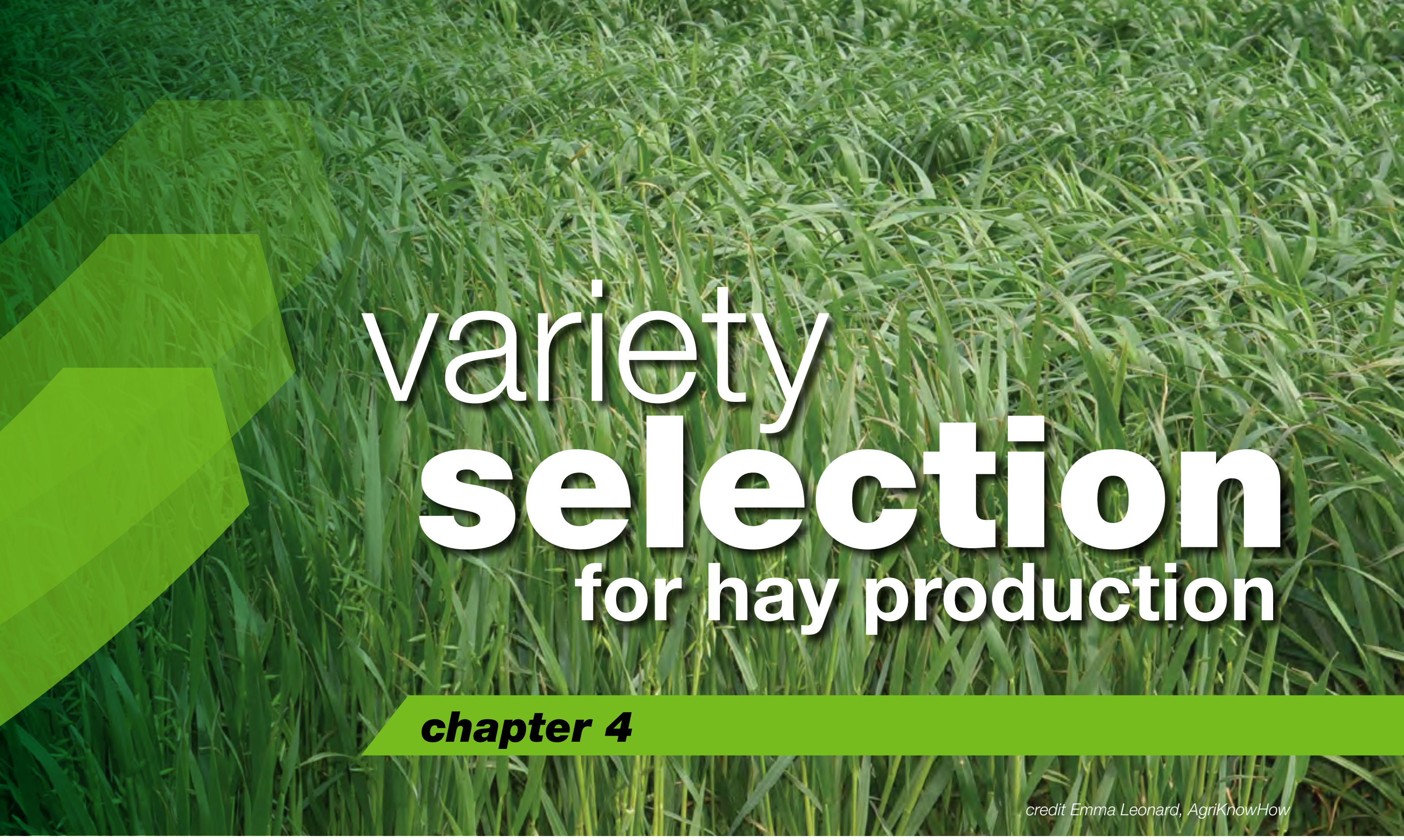
variety selection for hay production

chapter 4



credit Emma Leonard, AgriKnowHow

Choice of variety has a major influence on hay quality and hay processors may only accept certain varieties.

Key considerations when selecting an oat variety for hay:

- market suitability;
- region suitability;
- disease resistance in relation to the growing region;
- time of maturity; and
- yield.

Quality and yield sit on either side of the scales, with variety maturity (Figure 4.1) or rainfall the factors that change the balance.

Generally, early maturing varieties are more suited to hay production in low rainfall areas.

Late maturing varieties perform well in higher rainfall areas with a longer growing season. However, older late varieties, such as Glider, have poorer early vigour, reducing competiveness with weeds, ryegrass, wild oats, barley and brome grasses. Breeders have now produced varieties such as Forester, which is late maturing but has early vigour. In seasons with warm moist spring conditions, late maturing varieties can produce higher crop yields. The quality of these large crops will be determined by variety and season.

In medium to high rainfall areas, early sowing of early maturing varieties can lead to hay being downgraded due to rain spoilage during curing. On-going research (AEXCO and GRDC) is evaluating the potential of forage

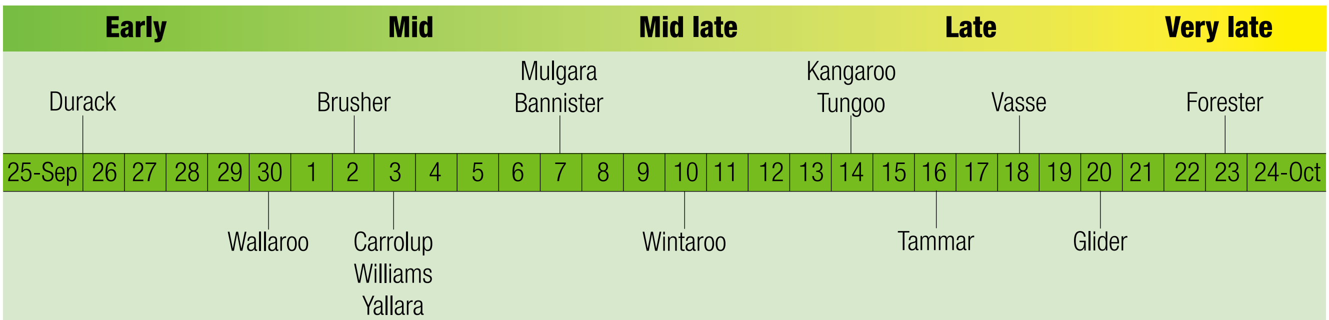


Figure 4.1 Variety maturity time line – *source National Oat Breeding Program 2016.*

Indicative cutting dates based on all varieties sown on the same date in the same year. The relationship between early and very late maturity will remain constant but the date of maturity may be earlier or later depending on the season. Maturity differences between varieties are greater than maturity difference for the same variety sown at different times.

oat varieties, developed for high rainfall/irrigation areas, such as Aladdin and Genie, for hay in dryland medium to high rainfall environments. In these environments, early sowing can result in good yields of quality hay if a wet spring is experienced.

The following summaries of oat varieties most suited to hay production in Australia are based on varieties tested as part of the National Oat Breeding Program (see page 4).

Variety choice is determined by region/rainfall and end use (Tables 4.1 and 4.2), and regional disease pressure (Table 4.3a & b and see Figure 7.1).

Monitoring oat crops for disease is essential as disease interactions can vary between regions (Tables 4.3a & b)

New varieties are in development and the latest variety information is available on release from the respective breeding programs, licensee or seed companies. A more comprehensive variety guide is published annually and can be sourced from the AEXCO website (www.aexco.com.au).

Bannister

A dwarf milling variety with high grain yield, released for Western Australia (WA) in 2012. Suited to eastern Australia and WA, it is adapted to low, medium, and high rainfall zones of southern Australia.

Bannister is resistant to leaf rust and moderately resistant to bacterial blight. It is susceptible and intolerant to cereal cyst nematode (CCN).

Seed is available via Seednet.

Brusher

A hay variety developed by SARDI and commercialised by AEXCO in 2004. Brusher is a tall line with good early vigour, heading earlier than Wintaroo. It is adapted to low, medium, and high rainfall areas.

It is moderately intolerant to CCN. If there are high levels of the nematode in the soil and favourable seasonal conditions, it will have significantly lower hay yield than tolerant varieties.

It has consistently high digestibility and moderately low grain hull lignin.

Seed is available via AEXCO.

Carrolup

Released as a milling variety in 1993 by the then WA Department of Agriculture, Carrolup is a medium tall early to mid season variety that has been widely grown in WA for hay production.

Carrolup is very susceptible to leaf rust.

Although developed for grain, its hay quality is similar to other early to mid season hay varieties.

No specific distributor.

Durack

A moderately tall variety measuring between 80 and 90cm, similar in height to Carrolup and Yallara.

Very good early vigour results in maturity a minimum of one week earlier than any variety on the market in 2016.

It has good resistance to lodging and shattering. It is resistant to CCN and its disease profile is likely to require management with fungicides, depending on the season.

Hay yield averaged over low, medium, and high rainfall sites is lower than other longer season varieties. Care will need to be taken to cut this very early maturing variety at the correct growth stage.

Monitoring the crop will be the key to achieving the highest hay quality.

Seed is via Heritage Seeds.

Forester

Forester was released in 2012 as a very late hay variety adapted to high rainfall and irrigated cropping regions. It is three weeks later than Wintaroo, seven to 10 days later than Glider and two days later than Targa (Figure 4.1). Forester has excellent early vigour and is an improvement compared to Glider. It has excellent lodging and shattering resistance.

Table 4.1 Oat varieties by end use and ranked to annual rainfall and maturity.

End use	Rainfall - low	Maturity	Rainfall - medium	Maturity	Rainfall - high	Maturity
Oat Hay	Brusher	Early to mid	Wintaroo	Mid	Forester	Very late
	Mulgara	Mid	Mulgara	Mid	Tammar	Late
	Wintaroo	Mid	Tammar	Late	Tungoo	Mid to late
	Wallaroo	Early	Tungoo	Mid to late	Glider	Late
	Carrolup	Early to mid	Kangaroo	Mid to late	Kangaroo	Mid to late
			Brusher	Early to mid	Vasse	Late
			Carrolup	Early to mid		
Milling grain – suited to hay if managed appropriately.	Yallara	Early to mid	Yallara	Early to mid		
	Bannister	Early to mid	Bannister	Early to mid		
	Durack	Very early	Williams	Early to mid		

Always check with your hay buyer before selecting a variety, especially if growing a milling variety for export hay.

Forester has an excellent foliar disease resistance spectrum. It is moderately susceptible to CCN and has good hay colour, but like all late hay varieties, it may not resist hot, dry winds as well as earlier varieties. Forester has excellent hay quality and is an improvement compared to Glider, Tammar, Targa, and Vasse, but similar to Riel.

Seed is available via AGF Seeds, Victoria.

Glider

Released jointly by SARDI and Texas A&M University in 1999, Glider is a late maturing hay variety adapted to high rainfall (>500mm) areas. Glider has poor early vigour and heads about two weeks later than mid season varieties.

It has excellent foliar disease resistance and plant colour.

No specific distributor.

Kangaroo$^{\phi}$

This hay variety, commercialised from the SARDI Oat Breeding Program by AEXCO in 2006, is a tall mid to late season variety with good early vigour. It heads about four days later than mid season varieties. Kangaroo has been superseded by Tungoo.

Kangaroo has good foliar disease resistance combined with good nematode resistance and moderate tolerance.

It has high grain hull lignin. Hay cut from this variety tends to be high in neutral detergent fibre (NDF) and lower in water soluble carbohydrates (WSC), therefore careful management is required.

No seed is available from suppliers.

Mulgara$^{\phi}$

Released in 2009 and commercialised by AEXCO, Mulgara is a tall mid season variety with excellent early vigour and good straw strength.

Mulgara has excellent disease resistance. It is resistant and tolerant to CCN and stem nematode (SN). Compared to Wintaroo, Mulgara has improved leaf rust, bacterial blight and red leather leaf resistance.

Hay yield is lower than Wintaroo, but hay quality is better than Wintaroo. Mulgara also retains good hay colour and resists brown leaf tipping.

Care must be taken to ensure correct seeding rates as Mulgara has high 1000 grain weight (Table 4.4).

Seed is available via AEXCO.

Tammar$^{\phi}$

A medium tall late variety that matures four to seven days later than Tungoo, Tammar was released by SARDI in 2011.

Tammar also has an excellent disease resistance profile. It is moderately resistant to stem and leaf rust, septoria, barley yellow dwarf virus (BYDV), and bacterial blight. Tammar is the first late variety available with resistance to CCN and SN, tolerance to CCN, and moderate tolerance to SN.

Hay quality of Tammar is improved compared to Kangaroo. It has high crude protein and hay digestibility with lower WSC than Mulgara and Brusher, but higher than Kangaroo.

Seed is available via AEXCO.

Tungoo$^{\phi}$

Released in 2010 as a medium tall mid to late season variety with an excellent disease resistance profile, Tungoo replaces Kangaroo.

Tungoo combines resistance and moderate tolerance to CCN and SN. It also is resistant to leaf rust and the only variety with red leather leaf resistance. Tungoo is moderately resistant to BYDV, septoria, and bacterial blight and moderately susceptible to stem rust. It has the best combination of disease resistance compared to all other varieties except Tammar.

Hay yield is slightly lower than Kangaroo, but Tungoo's hay quality is an improvement compared to Kangaroo.

Seed is available via AEXCO.

Compressed 23kg bales ready for export. Check your chosen variety is accepted by your hay buyer.

credit Balco

Vasse⁽ᵇ⁾

Released by the Department of Agriculture Western Australia in 1997 as a hay variety, Vasse is a 'tall dwarf', late maturing variety adapted to high rainfall, long season areas of WA. Because its stem diameter tends to be coarse, it is not generally sought after for the export market.

Wallaroo

Released by the Department of Agriculture, South Australia in 1987, Wallaroo is a CCN resistant and tolerant hay variety. It is an early variety suited to the low to medium rainfall areas. Wallaroo is a tall variety with good early vigour.

Williams⁽ᵇ⁾

Williams is a tall milling variety, which has some potential for hay, released in 2013 by Heritage Seeds. It is an early to mid season variety similar to Yallara, but three to seven days later than Mitika.

Although classified as moderately susceptible to septoria, Williams has the highest level of septoria resistance compared to all other current oat varieties. It is currently resistant to leaf rust and depending on the stem rust pathotype present can range from moderately resistant to susceptible. Williams is resistant to bacterial blight and moderately resistant to moderately susceptible to BYDV. It is susceptible and intolerant to CCN.

It has similar hay yield compared to other hay varieties at South Australian (SA) trial sites at Pinery and Turretfield, but lower hay yield at Riverton. Hay quality is also similar to hay varieties, except for slightly higher crude protein. Care must be taken to achieve high plant populations to reduce stem thickness.

Check that export companies will accept Williams for hay, especially in WA.

Seed is via Heritage Seeds.

Wintaroo⁽ᵇ⁾

A hay variety released in 2003 as a replacement for Marloo, which in turn replaced Swan. Wintaroo is a tall mid season oat with good early vigour. It resists brown leaf tipping by hot northerly winds better than other varieties and is adapted to low, medium, and high rainfall locations.

Wintaroo also has low grain hull lignin, making it an option for feed grain. Wintaroo maintains good colour longer than most varieties, so care is needed to assess the crop for optimum cutting time to ensure good quality.

Seed is available via AEXCO.

Yallara⁽ᵇ⁾

A medium tall early to mid season variety that is similar to Euro for flowering and maturity. Yallara, released in 2009 by ABB Seeds, is a milling line but has potential for hay.

Yallara is a Euro look-alike with improved leaf and stem rust resistance depending on pathotype. It is resistant but intolerant to CCN. It is moderately susceptible to BYDV, bacterial blight, and septoria. It is susceptible and intolerant to stem nematode and susceptible to red leather leaf.

Yallara has excellent grain weight and quality, and was evaluated for hay production. Although hay yield is lower than popular hay varieties in medium to high rainfall zones, it has excellent hay quality.

Seed is available via Seednet.

Table 4.2 Average hay yield (t/ha) for oat varieties tested in four states 2011 to 2014 *– source National Oat Breeding Program.*

Variety	New South Wales	South Australia	Victoria	Western Australia	All states
Early – mid season varieties					
Bannister	11.5	10.4	10.2	9.9	10.2
Brusher	11.3	10.4	10.2	9.5	10.1
Carrolup	11.6	9.9	10.5	8.8	9.7
Durack	11.3	9.8	10.2	8.0	9.3
Mulgara	11.0	10.1	10.2	9.4	9.9
Wallaroo	11.9	9.7	10.2	9.3	9.7
Williams	11.3	10.0	10.1	8.9	9.7
Wintaroo	11.6	10.6	10.5	10.0	10.4
Yallara	12.3	10.7	10.5	9.5	10.3
Mid-late to very late varieties					
Forester	10.4	9.7	10.0	9.7	9.8
Glider	10.5	9.5	9.8	9.3	9.5
Kangaroo	11.2	10.0	9.8	9.5	9.8
Tammar	11.0	10.3	10.1	9.3	9.9
Tungoo	10.4	9.9	9.9	8.7	9.5
Vasse	11.0	10.7	10.2	9.9	10.3
No. sites	1	12	8	11	32

Table 4.3a Disease reactions in SA and Victoria for oat varieties grown for hay
– source National Oat Breeding Program 2016.

Notes for Tables 4.3a and b

Where no data is available for a disease a dash is used.

Disease reactions may be different depending on the region.

Rust and BYDV reactions may vary in different regions and seasons depending on prevalent pathotype/serotype.

If soil testing has eliminated CCN and SN as a limitation, the next disease limitation should be used for variety selection. Colours associated with varieties indicated the highest level of resistance available for the priority diseases in different regions as illustrated in Figure 7.1

Variety	Stem rust	Leaf rust	BYDV	Septoria	Bacterial blight	CCN		Stem Nematode		Red leather leaf
						R	T	R	T	
Early – mid season varieties										
Bannister	MR-S	R	MS	-	MR-S	VS	I	-	MI	MS
Brusher	MS-S	MR-MS	MS	MS	MR-MS	R	MI	MS	I	MS
Carrolup	MS	S	MS	S-VS	MR-S	S	I	-	-	S
Durack	S-VS	R-S	MS-S	MS	MR-S	R	-	NA	I	MS
Mulgara	MS-S	MR	MS	MS	MR	R	MT	R	MT	MS
Wallaroo	S	S	MS	S	S	R	MT	MS	MI	MS
Williams	MR-S	R	MR-MS	MS	R	S	I	-	I	MS
Wintaroo	S	MS	MR-MS	MR-MS	MR	R	MT	MR	MT	MS
Yallara	MR-S	R	MS	MS	MR-MS	R	I	S	I	MS
Mid-late to very late varieties										
Forester	R-S	MR-MS	MR-S	MR	MS-S	MS	MI	S	I	R-MR
Glider	R-S	R	MS-S	S	R-MR	MS	MT	R	T	R
Kangaroo	MS-S	MS	MR-S	MR-MS	MR-MS	R	MT	MS	MI	MS
Tammar	MR-S	MR	MS	MR	MR	MR	MT	R	MT	R-MS
Tungoo	MS-S	MR	MR-MS	MR	MR	R	MT	R	MT	R
Vasse	S	MS	MS-S	MS	MS	VS	MI	-	MI	-

Table 4.3b Disease reactions in WA for oat varieties grown for hay.

Variety	Stem rust	Leaf rust	BYDV	Septoria	Bacterial blight	CCN		Stem Nematode		Red leather leaf*
						R	T	R	T	
Early – mid season varieties										
Bannister	MR-S	R	MS	S	MR-S	VS	I	-	MI	-
Brusher	MR-S	R-MS	MR-MS	S-VS	MR-MS	R	MI	-	-	-
Carrolup	MS	S	MS	S-VS	MR-S	S	I	-	-	-
Durack	MR-MS	R-S	MS-S	S-VS	MR-S	R	-	-	-	-
Mulgara	MR-MS	MR	MS-S	MR-S	MR	R	MT	-	-	-
Wallaroo	MS-S	VS	MS	S-VS	S	R	MT	-	-	-
Williams	MR	R	MR-MS	MS	R	S	I	-	-	-
Wintaroo	MR	S-VS	MS-S	S-VS	S	S	I	-	-	-
Yallara	MR-MS	R	MR-MS	MS-S	MR-MS	R	I	-	-	-
Mid-late to very late varieties										
Forester	R	R-MS	MS	MS-S	MS-S	MS	MI	-	-	-
Glider*	-	-	-	-	-	-	-	-	-	-
Kangaroo	R-S	MS-S	MR-S	MS-S	MR-MS	R	MT	-	-	-
Tammar	R-MR	R-MR	MS-S	MS	MR	MR	MT	-	-	-
Tungoo	MR-S	R-MS	MR-MS	MS-S	MR	R	MT	-	-	-
Vasse*	-	-	-	-	-	-	-	-	-	-

Key to Tables 4.3a & b:

Disease names: CCN - cereal cyst nematode, BYDV - barley yellow dwarf virus

Disease reactions: R - resistant, MR - moderately resistant, MS - moderately susceptible, S - susceptible, VS - very susceptible, T - tolerant, MT - moderately tolerant, MI - moderately intolerant, I - intolerant, VI - very intolerant.

** No disease data from WA for these varieties - see Table 4.3a for a guide.*

Table 4.4 Agronomic and hay quality characteristics for oat varieties grown for hay
– source National Oat Breeding Program.

Variety	Height	Early vigour	1000 grain weight (g)	Hay quality					Stem diameter	Hull lignin
				Digest-ibility	WSC	Crude protein	ADF	NDF		
Early – mid season varieties										
Bannister	TD	3	31.0	H	M	M	L	ML	M	H
Brusher	T	3	32.9	MH	MH	M	M	M	M	ML
Carrolup	MT	4	31.4	M	M	M	M	M	M	H
Durack	MT	2	32.6	MH	M	M	M	M	M	H
Mulgara	T	3	35.5	M	M	M	M	M	M	H
Wallaroo	T	3	33.1	M	M	M	M	M	F	L
Williams	MT	2	28.8	M	ML	MH	M	M	MT	H
Wintaroo	T	3	33.7	M	M	M	M	M	M	L
Yallara	MT	2	31.9	M	H	ML	M	M	MF	MH
Mid-late to very late varieties										
Forester	T	3	32.0	H	MH	M	L	L	MT	H
Glider	T	8	31.2	M	M	M	M	M	F	ML
Kangaroo	MT	3	31.6	M	L	M	H	H	MF	H
Tammar	MT	4	29.9	M	ML	M	M	MH	MF	L
Tungoo	T	6	29.4	M	ML	MH	M	MH	M	H
Vasse	D	4	31.4	M	H	M	M	M	T	H

Key Table 4.4:
Height: T - tall, MT - medium tall, D – dwarf, TD – tall dwarf
Early vigour scores: 1 - excellent early vigour and 9 - poor
1000 grain weight average weight from trials 2010 to 2014 - these weights are only indicative
Maturity scores: E - early, EM - early to midseason, M - midseason, ML - mid to late season, L - late, and VL - very late
Hay quality: WSC - water soluble carbohydrate, ADF - acid detergent fibre, NDF - neutral detergent fibre
Hay quality scores: H - high, MH - medium high, M - medium, ML - medium low, and L - low
Stem diameters: F=fine, MF=medium fine, M=medium, MT= medium thick, T=thick
Hull lignin - the amount of lignin found in the hull of the grain: L - low, M - medium, and H - high

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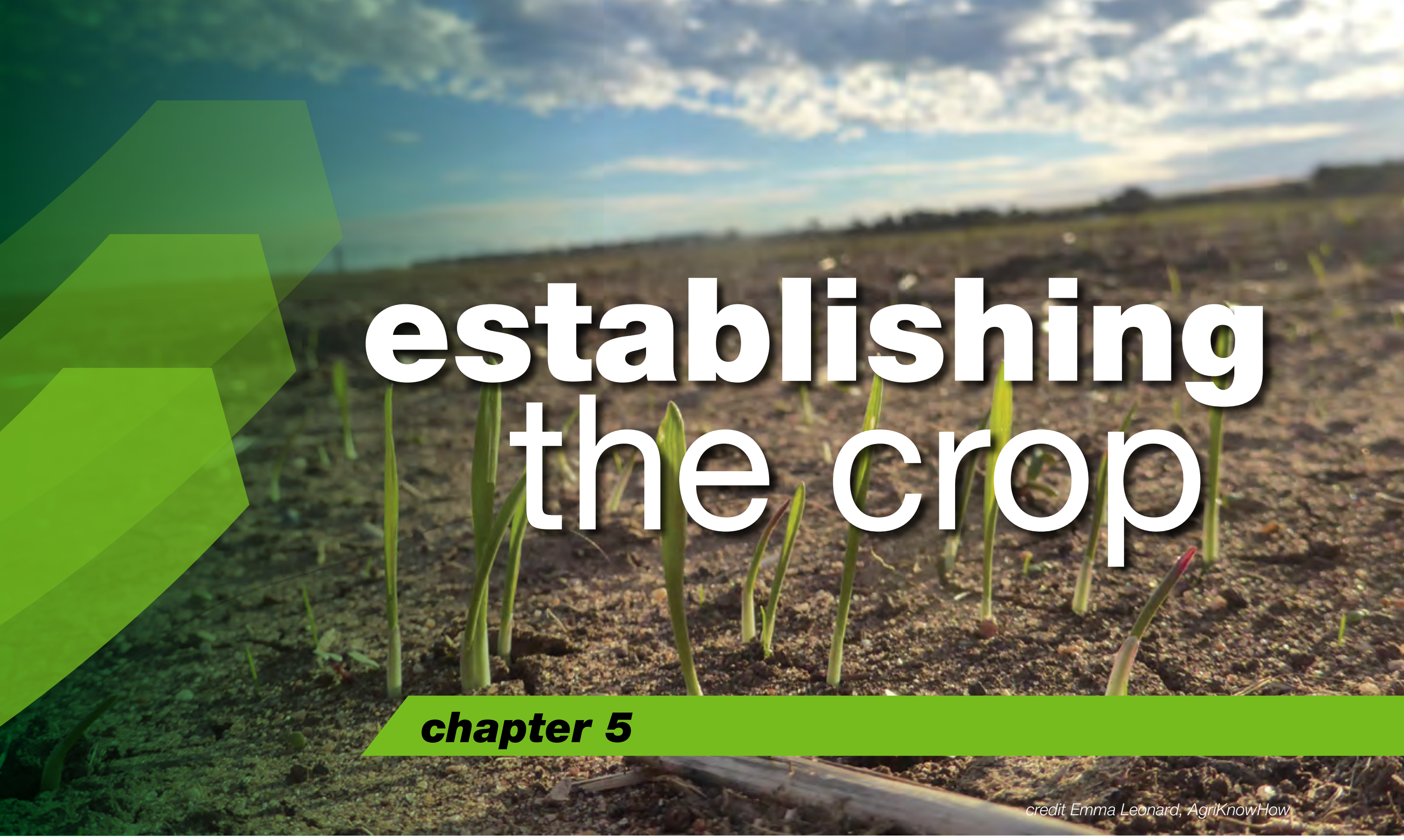
establishing the crop

chapter 5



credit Emma Leonard, AgriKnowHow

Paddock selection

Impact on hay quality

- Feed analysis
- Colour
- Contamination
- Toxins

Paddock selection for oat hay crops is a little different than for grain crops, especially in relation to soil fertility.

While good weed control in the previous crop and pre-seeding is essential, herbicide residues can be a problem.

Triasulfuron is generally more damaging than chlorsulfuron or metsulfuron methyl. Group B herbicides used on Clearfield® varieties of wheat or canola can have residual effects on oat crops but damage is usually less than seen in barley.

Always check product labels for residue risk and test prior to sowing if unsure. Potential contaminants such as animal carcasses, old fencing wire and rocks should be avoided. These contaminants should be removed and rocks rolled into the soil.

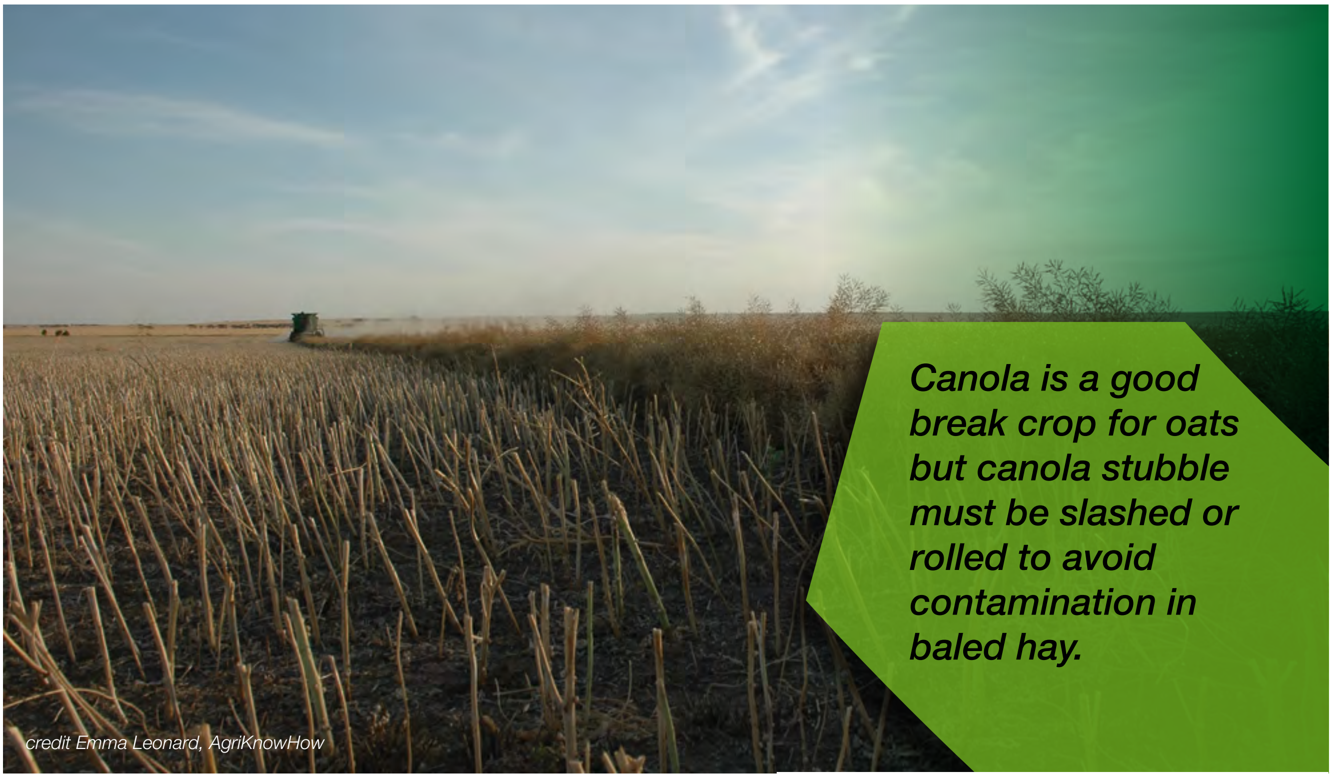
Other factors to consider in relation to paddock selection are slope and orientation. Crops grown on north facing slopes may mature faster but can also be more susceptible to hot wind damage. Newer oat

Select paddocks with:

- moderate fertility of less than 80kg/ha of available nitrogen in the top 60cm at seeding. Any higher and bulky, fibrous crops rather than quality hay are produced. High nitrogen also promotes lodging;
- low levels of crop residue, especially after canola paddocks and a low level of stem and leaf disease carryover and a low history of rhizoctonia bare patch and take-all;
- minimal weed burdens and where effective pre-seeding weed control can be achieved; and
- good drainage – long periods of perched water within 30cm of the soil surface can reduce yield by 60%.

Avoid paddocks with:

- pulse and pasture legume stubbles as these are likely to have high net mineralised nitrogen;
- herbicide residues - on high pH soils sulfonylurea herbicide residues can be damaging. The imidazolinone herbicides are usually more residual in acidic soils. Be aware of the long plant back period (630 days) for planting oats in paddocks previously treated with Sakura®;
- a history of prickly weeds e.g. doublegee and annual ryegrass toxicity (ARGT). There is zero tolerance for ARGT in export hay (see ARGT Chapter 7);
- low pH <4.5 or high salinity and compaction.



varieties have been bred to reduce this problem. In some regions, western slopes suffer more rain damage. Bacterial blight is more severe where frost or wind-borne rain occur.

Rotation

Canola is an ideal break crop for oats as it allows grass weeds to be reduced, does not boost soil nitrogen and reduces foliar and root disease carryover. The use of residual herbicides should be avoided in canola sown before oats. Canola stubble should be removed by slashing rolling, raking, chaining, burning etc to to avoid contamination in the bales.

Following good legume pastures or grain crops with oat hay is not recommended as soil nitrogen levels could impact on quality.

See Chapter 7 for disease carryover from other cereals.

Seeding

Sowing date

Impact on hay quality

- Feed analysis
- Staining and moulds
- Colour

Oats are a spring cereal sown in autumn. Hay paddocks need to be clean and weed free, so seeding date may be dictated by the need to wait for weeds and volunteers, especially barley and wheat, to germinate.

Generally higher yields are associated with early sown crops but quality may be adversely affected, especially if early sowing is accompanied by a warm winter which promotes rapid, prolonged early growth. This tends to lead to rank, fibrous crops that are susceptible to lodging and bleaching of the lower stem.

Early sowing may increase severity of foliar diseases, so varieties with greater disease resistance should be selected (see Table 4.4).

Sowing date needs to be matched to variety maturity, rainfall zone and likelihood of rain at cutting date. Maturity differences between varieties are greater than maturity differences for the same variety sown at different times (Figure 5.1).

Early maturing varieties (see Table 4.1) will be compromised in a high rainfall area due to the increased risk of weather damage on the cut hay. Conversely, late maturing varieties in low rainfall districts are more prone to damage by heat and moisture stress.

If varieties with different maturities are being sown in districts with the same rainfall, late maturing varieties will usually be sown first.

In a 500mm rainfall district, delaying seeding by seven days will generally delay cutting by less than two days.

Diseases such as bacterial blight and septoria can cause leaf damage, especially in early sown crops in higher rainfall regions.

Seeding rate

Impact on hay quality

- Stem diameter
- Weed competition
- Colour

Seeding rate and plant population play a major role in hay yield and quality. Seeding rates for hay

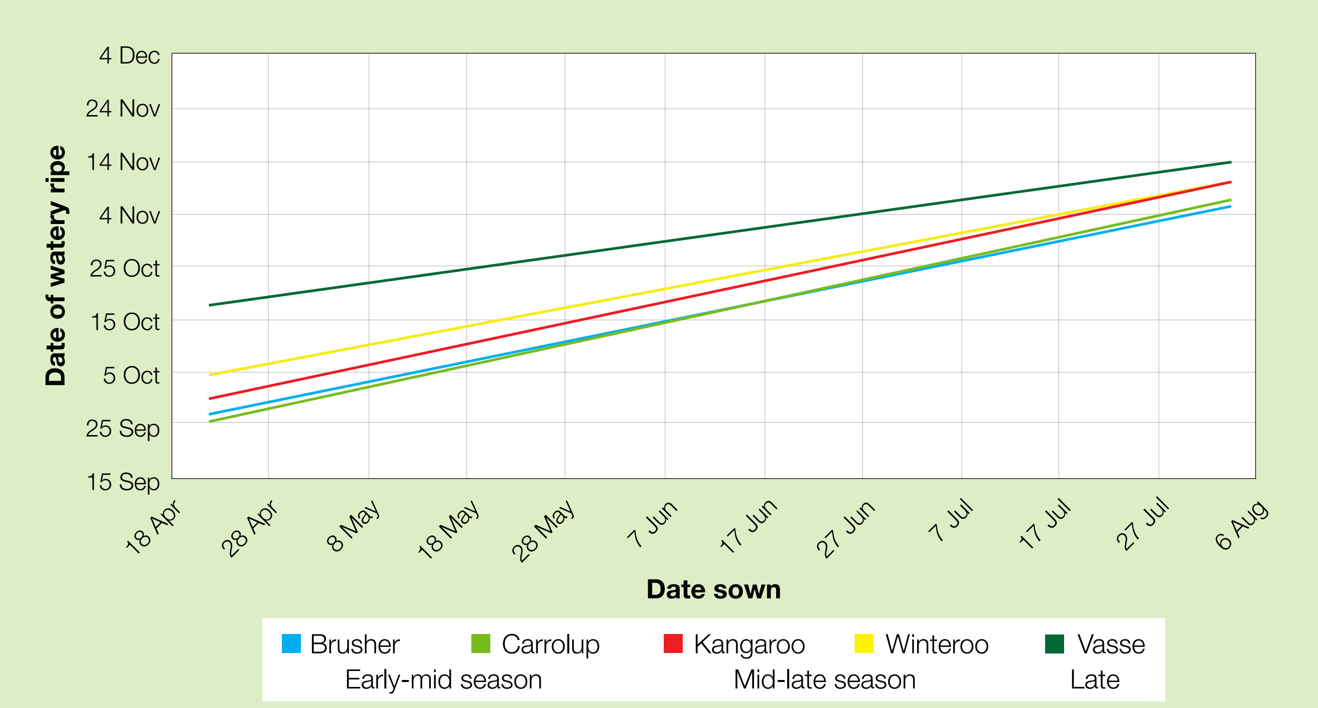


Figure 5.1 Impact of sowing date on date of reaching watery dough (GS71), ideal cutting date, by variety maturity group – *source Department of Agriculture and Food, Western Australia.*

are 30 to 50% higher than for grain crops grown in the same rainfall district. This is because hay is cut before grain fill and generally will be harvested before moisture stress occurs. It is also because denser crops have thinner stems that are more desirable to the export market.

Seed size varies between varieties and seasons, so it is important to calculate seeding rates based on the seed 1000 grain weight to achieve target plant populations (see Table 4.4). For example, in Table 4.4 the 1000 grain weight for Brusher was 32.9g per 1000 grains, for Mulgara 35.5g and for Tungoo 29.4g.

Plant populations need to be matched to rainfall and soil fertility (Table 5.1).

When varieties with poor early vigour (see Table 4.4) are grown in soils with low to medium nitrogen fertility, seeding rates can be increased by 20 to 30% above the target to compensate.

Higher plant populations produce higher yield and generally quality, greater weed competition and plants with thinner stems, but they can be more at risk of lodging.

To calculate seeding rate (kg/ha) from a target plant population.

Seeding rate=10 x average weight of one seed x target plants per square metre

Example: Variety – Mulgara, seed weight 35.5/1000, target plants per square metre 230

Seeding rate =10 x 0.0355 x 230 = 81.65kg/ha

To check plant populations, count 10 sites about five weeks after seeding.

Plant population (plants/m^2) = total number of plants counted/(total length x row spacing in metres)

Example: 800 plants counted at 10 sites each 2m long on 15cm row spacing

Plant population = 800/(20 x 0.15) = 266 plants/m^2

Table 5.1 Target plants per square metre by rainfall (winter and spring rainfall dominant regions) and soil fertility *– source Agrilink Agricultural Consultants.*

Rainfall	Soil nitrogen fertility		
	High	Average	Low
<350mm	120-160	150-180	150-200
350-425mm	160-200	180-220	200-240
425-500 mm	200-220	220-250	240-280
>500 mm	210-230	250-280	250-300

Row spacing and seed placement

Impact on hay quality

- Weed competition
- Feed analysis
- Colour
- Staining and moulds

To optimise hay yield and quality, a row spacing of 7.5cm (3 inches) is the ideal, but many croppers find this difficult to achieve with modern machinery.

The narrow row spacing achieves better weed competition and greater access to nutrients. The density of stems across the paddock is high and when cut, these stems better support the cut hay off the ground, minimising the risk of soil contamination and uneven curing.

In many situations, narrow row spacing is impractical due to:

- existing machinery set-up;
- seed mixing with pre-sowing herbicide causing reduced emergence; and
- an increased proportion of the paddock being cultivated, resulting in greater weed seed germination.

Where row spacing is wider than 22.5cm (9 inches), the risk of reducing hay quality increases due to:

- high concentrations of plant nitrogen;
- increased weed competition and contamination in the cut hay; and
- cut hay hitting the ground and becoming contaminated with soil.

Increasing seed spread across the furrow can help reduce the risks of wider row spacing (Table 5.2). Standard tined seeders produce a band of seed about 2-3cm.

Where seeding equipment has 30cm (12 inch) spacing, some growers cross-seed to produce a row spacing of 15cm (6 inches). However, considerations about row orientation (Figure 5.2) must be taken into account. The use of high accuracy (2cm) GPS autosteer systems may allow a second pass to be sown on the inter-row to produce a 15cm spacing.

The recommended seeding depth for oats is 3 to 6cm; oats are able to germinate from a greater depth than wheat and barley.

The addition of press wheels helps compress soil above the seed for more even distribution. Press wheels help improve seed germination in water repellent soils.

Table 5.2 The impact of seed and fertiliser spread and row spacing on plant spacing and theoretical nitrogen concentration in the plant – *source Agrilink Agricultural Consultants.*

Lateral seed spread	2.5cm (1 inch)			5cm (2 inches)			7.5cm (3 inches)		
Tyne spacing	17.5cm 7"	22.5cm 9"	30cm 12"	17.5cm 7"	22.5cm 9"	30cm 12"	17.5cm 7"	22.5cm 9"	30cm 12"
% of surface covered with stems[1]	17%	11%	8%	33%	22%	17%	50%	33%	25%
Theoretical change in plant nitrogen status from the base[2]	Base 0%	+28%	+71%	-10%	+14%	+36%	-25%	+10%	+22%

[1] *The higher the percentage, the lower the risk of hay hitting the ground and being weather damaged.*

[2] *The greater the positive deviation from the base, the poorer the hay quality.*

Impact on hay quality

- Staining and moulds
- Colour
- Contamination

Choice of seeding direction should take into consideration the direction that the crop will be cut.

This is because it is desirable to use the remaining stubble to support the hay off the ground. This helps hay cure evenly and minimises contamination at baling.

Oat crops can be sown round and round, up and back or diagonally. Figure 5.2 details the different sowing and cutting combinations.

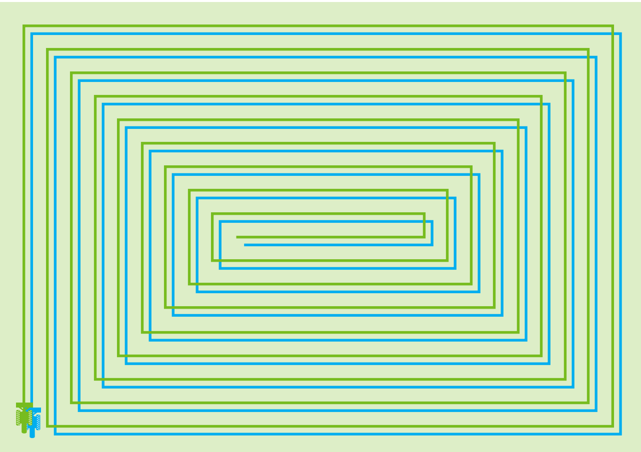


Figure 5.2a Sown round and round – cut round and round.

With this combination, more cut hay is likely to fall between the seeding rows. This results in uneven curing and increased risk of contamination as windrowers and rakes have to be set closer to the ground. Super conditioners struggle to pick up hay that has fallen to the ground. Another problem is that seed and fertiliser rates are double on the headlands, therefore plants in this area are likely to lodge, have bleached stems and poorer feed analysis results due to lower levels of water soluble carbohydrates.

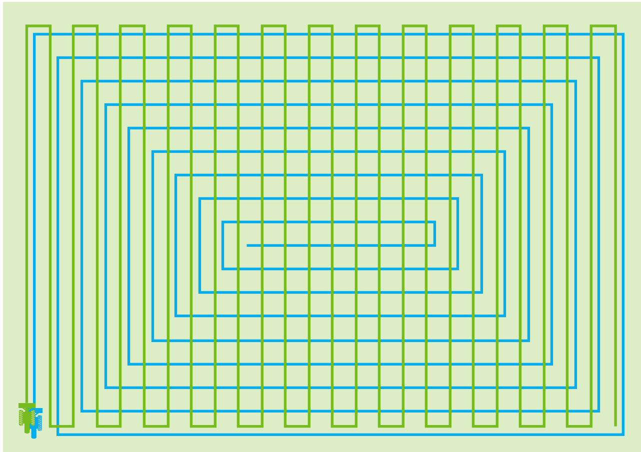


Figure 5.2c Sown up and back – cut round and round.

Off-set, 'PTO' driven mowers can only be used round and round. Therefore, to minimise hay damage, sowing should be done on the shortest run and mowing round and round.

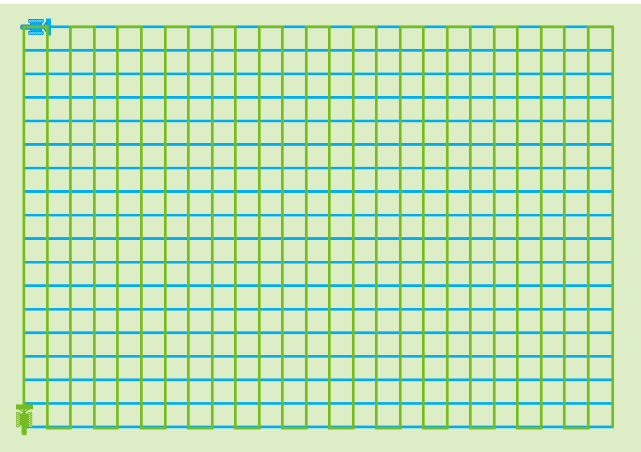


Figure 5.2b Sown up and back – cut up and back at 90 degrees.

Self propelled or swinging arm mowers allow hay to be cut up and back. This combination of seeding and mowing direction should ensure the majority of hay remains off the ground.

Headland areas are minimised and bales made on the headlands can easily be separated.

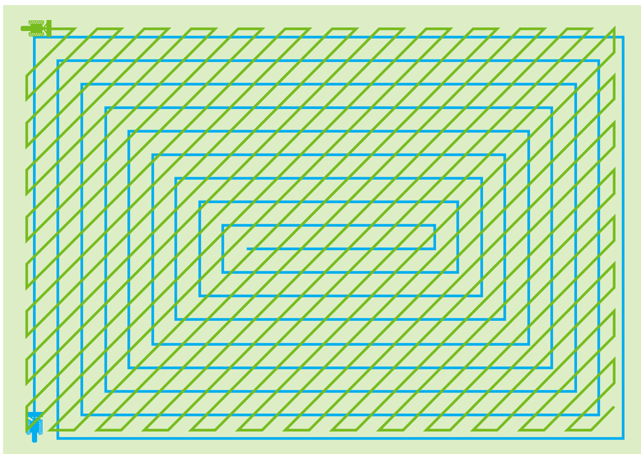


Figure 5.2d Sown diagonally – cut up and back or round and round.

Cutting round and round will still result in damage on the headlands. However, sowing diagonally minimises the risk of hay damage because seeding and cutting operations are never in the same direction.

Rolling

Impact on hay quality

- Contamination

If hay making machinery is running at an angle to press wheel furrows, damaging vibration can occur. Rolling paddocks after seeding, but before the start of tillering (GS24), reduces the severe ridge/furrow effects. After this growth stage, rolling can cause long term damage and reduce yield.

Paddocks should not be rolled after a frost or when leaves are wet as this increases the chance of spreading bacterial blight.

Rolling prior to applying post sowing pre-emergent herbicide can reduce the risk of herbicide washing into the furrow.

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Oat crops remove less nitrogen but more potassium, calcium and magnesium than cereal grain crops. Soil testing and running a nutrient balance are useful to establish paddock nutrient status and crop nutrient requirement.

credit Emma Leonard, AgriKnowHow

credit Emma Leonard, AgriKnowHow

crop nutrition

chapter 6

Crop nutrition

Impact on hay quality

- Feed analysis
- Colour

A nutrient balance is one way of calculating nutrient requirements as oat hay removes significant quantities of all the major elements - nitrogen, phosphorus, sulphur and especially potassium. Zinc and manganese levels should also be considered. A tonne of hay can also remove 15kg of lime.

Removal differs from cereal crops cut for grain with nitrogen removal reduced but potassium, calcium and magnesium removal greatly increased.

The starting point for a nutrient balance is the current soil nutrient status and the predicted nutrient removal for the target hay yield (Tables 6.1a & b). Surface and deep soil nitrogen are useful when budgeting for a hay crop grown on heavier soils.

Oat growth is strongly influenced by temperature and early sown crops generally make adequate growth with low to moderate fertiliser inputs at seeding. If seeding is delayed, oat crops become far more responsive to applied fertiliser as root and aerial growth slows in response to colder conditions.

For best results, phosphorus, potassium and trace elements required during early growth should be applied in or under the seed row. More mobile nutrients such as nitrogen and sulphur can be applied during the growing season by a range of methods. Some trace elements, such as manganese, can be rapidly immobilised in the soil, so foliar application may be the most appropriate.

Nitrogen at seeding

To produce a balance between quantity and quality, nitrogen application at seeding should be moderate (40-80kg/ha). Nitrogen may not even be required, if there is about 80kg/ha of available nitrogen in the top 60cm at seeding.

There is a strong relationship between seedbed nitrogen, variety maturity and quality (Figure 6.1) but this is also influenced by rainfall. Variety specific agronomy packages are being developed and should be referred to when available.

Oat crops that have ready access to nitrogen, especially during early growth, result in hay with lower levels of water soluble carbohydrate (WSC) and proportionally higher fibre content. Both of these factors are negative in terms of hay quality, especially for the export market.

Research has shown that both early and late sown crops will have lower levels of WSC when they receive over 80kg/ha of nitrogen at seeding.

In low rainfall regions, where early growth is limited due to lack of soil moisture, high levels of nitrogen in the soil or as fertiliser have a less negative impact on hay quality than in medium and high rainfall regions.

In wet seasons, leaching can occur, especially in sandy soils. In this situation, delaying or splitting nitrogen application will help reduce nitrogen loss.

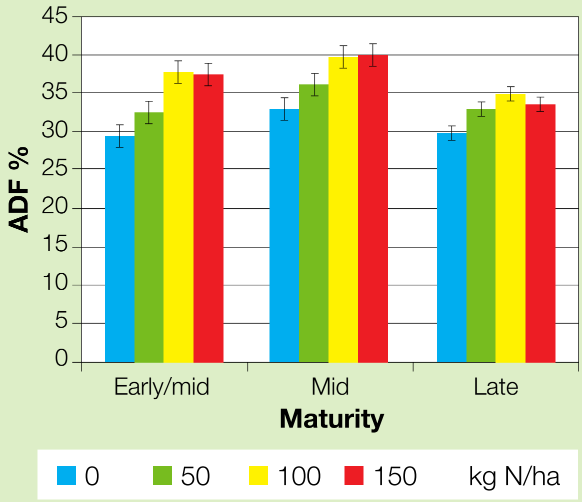

Figure 6.1 Interaction between variety maturity and fibre content under increasing seed bed nitrogen *– source Agrilink Agricultural Consultants.*
The impact on quality was more negative in early and mid season varieties.

If applied in close proximity to the seed, high rates of nitrogen (over 30kg N/ha as urea) at seeding increase the risk of damage to germinating seedlings by ammonia toxicity. The degree of damage depends on row spacing and the lateral spread of seed and fertiliser within a row (see Table 5.2).

Therefore, seed and nitrogen fertiliser should be separated by:

- deep or side banding;
- broadcasting prior to seeding with incorporation by seeding or rainfall; or
- broadcasting after seeding with incorporation by rainfall.

Post emergent nitrogen

Growth stages should be used to determine the appropriate timing for additional nitrogen applications (see Chapter 2). To maximise quality, any late nitrogen should be applied between GS25, tillering, and GS31, stem elongation. Before this stage, additional nitrogen increases yield, but after this point it can accumulate as nitrates and reduce quality.

Table 6.1a Kilograms of major nutrients removed with every tonne of commodity harvested.

Commodity Removed	Nitrogen		Phosphorus		Potassium		Sulphur		Calcium		Magnesium	
	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range
Oat hay	11	8-13.5	2	1.2-2.2	20	15-30	2	1-3.5	8	5-11	8	5-11
Medic hay	30	18-32	3	2.5-3.5	25	20-30	2	1-3.5	9	7-12	9	7-12
Wheat grain	23	14-28	3	2-5.5	5	2.0-7	2	1-3.5	0.4	0.2-0.7	0.4	0.2-0.7
Barley grain	20	13-28	2.7	2-5.1	5	2.0-7	2	1-3.5	0.4	0.2-0.7	0.4	0.2-0.7
Field pea grain	41	35-45	4.5	3.5-7	10	8-15	4	3-6	1	0.7-2	1	0.7-2

Table 6.1b Grams of minor nutrients removed with every tonne of commodity harvested.

Commodity Removed	Copper		Zinc		Manganese		Molybdenum		Iron		Boron	
	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range
Oats hay	4	2-20	20	6-40	9	7-15	1	Range unknown	Little comparative information available		4	2-80
Medic hay	5	2-20	20	7-40	15	10-20	1.2				25	10-100
Wheat grain	3	1-30	15	7-40	30	15-80	1.8				2	1-100
Barley grain	3	1-30	15	7-40	25	15-80	1.8				2	1-100
Field pea grain	6	1.5-50	25	8-40	9	7-15	2				10	2-100

Note: The figures are average removals published for southern Australian conditions.

The range represents the extremes of variation that are encountered due to soil type and nutrient level, the length of growing season and the total yield.

Examples: 1) removals are likely to be greater where soil levels are high and conversely removals may be low where soil levels are low.

2) removals are generally higher where the growing season is longer, as significant root uptake occurs while there is adequate soil moisture.

3) removals per tonne may be lower where yields are extremely high and dilution occurs.

Table 6.1c Nutrient removal from stubble burning based on kilograms lost in every tonne of cereal stubble *– source Landcare South Australia.* Divide cereal grain yield by 0.55 to estimate stubble weight. Trace elements will also be lost and organic carbon will not be returned.

	Nitrogen	Sulphur	Phosphorus	Potassium
Kg/ha per tonne of stubble	5	1.5	0.5	7.5
Lost in	smoke	smoke	ash if blown	ash if blown

Where soil fertility is high, hay crops are prone to lodging. This causes the lower stem to be shaded and become bleached, resulting in a poor feed test and visual assessment.

If growth rates decline or nitrogen deficiency symptoms are observed, applications of 25kg/ha of nitrogen can be sufficient.

Excess nitrogen applied to the crop can occasionally result in hay with nitrate nitrogen levels greater than 500ppm, which is unacceptable to many hay markets.

Phosphorus

Response of oat hay to phosphorus (P) is similar to cereal crops grown for grain, therefore application rates at seeding are the same as for other grain crops.

There is some research to suggest that hay grown on high phosphorus fixing soils has a higher phosphorus requirement than grain crops.

Local agronomic advice and experience should be sought.

Potassium

Cutting hay removes greater levels of potassium (K) than cereals harvested for grain (Table 6.1a). Particular attention should be given to potassium in the nutrient budget, especially for crops grown on light sandy soils.

Research from Western Australia (WA) has shown that to optimise the response to fertiliser N, adequate K fertiliser must be applied.

If potassium deficiency is identified by soil analysis, then apply 40 to 80kg/ha of muriate of potash (KCL).

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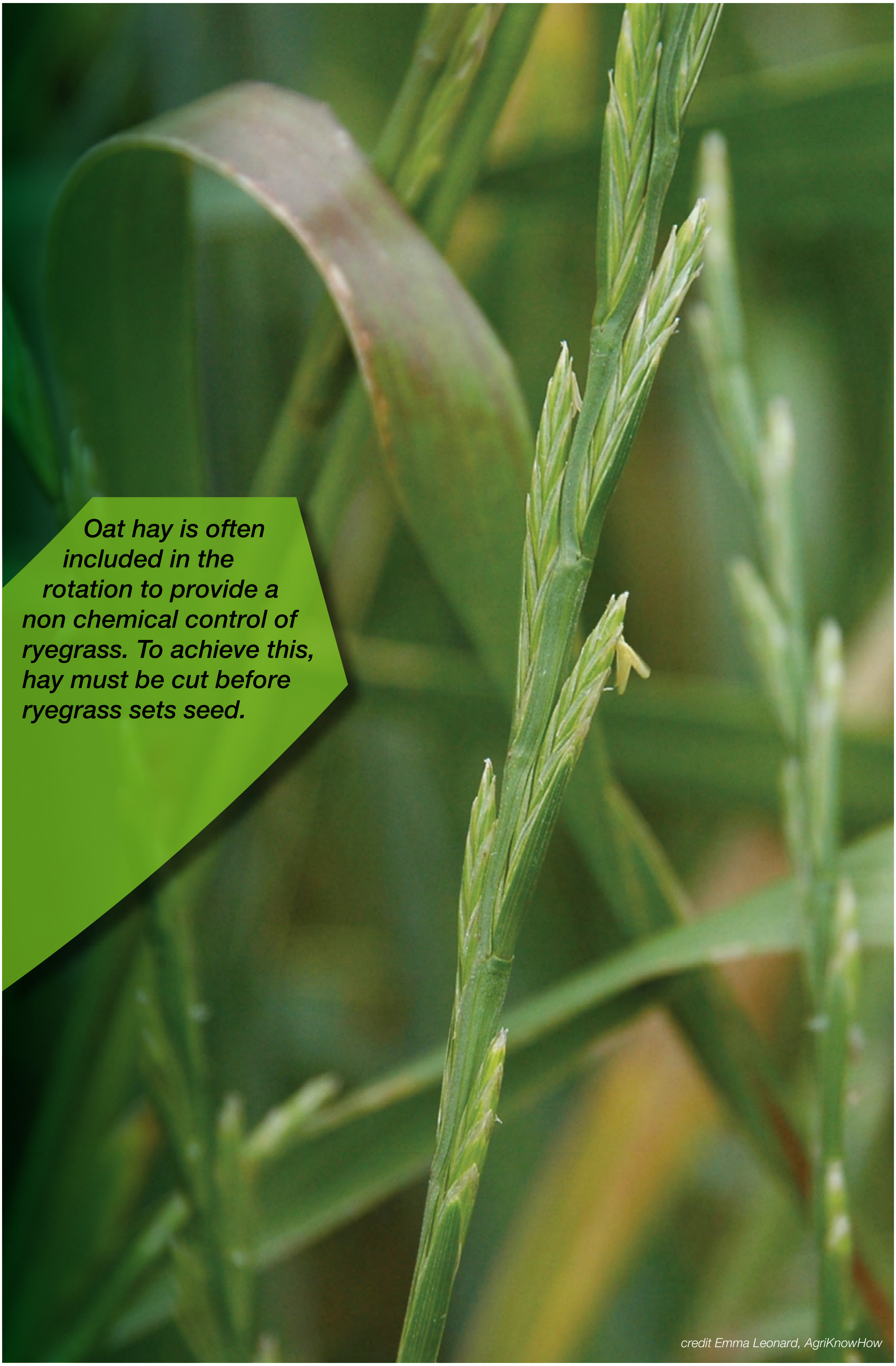
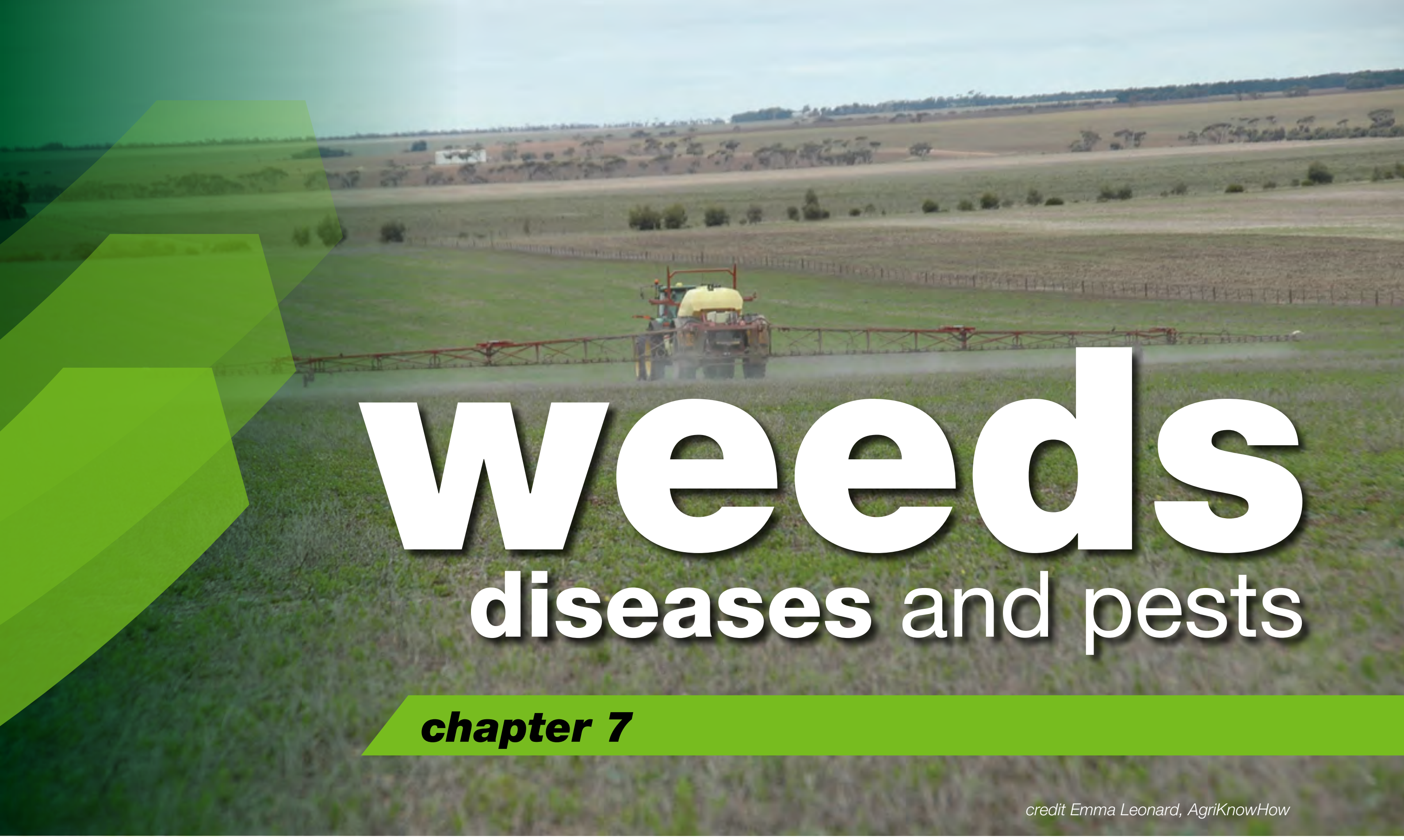
credit Emma Leonard, AgriKnowHow



credit Emma Leonard, AgriKnowHow



weeds diseases and pests

chapter 7

credit Emma Leonard, AgriKnowHow

Weeds

Impact on hay quality

- Contamination
- Colour
- Taints
- Toxins

While oats are more competitive with weeds than other cereals, pre-seeding weed control is vital. This is because in-crop weed control options are limited as oats are more sensitive to herbicides than other cereals.

Weeds not only impact on hay yield but also on quality. Broadleaf and grass weeds can reduce hay quality due to contamination and reduced visual and sensory characteristics.

Exporters will have standards for acceptable inclusion of weeds and admixture; generally it is 5% of the hay by weight.

Non-selective knockdown herbicides are the most economic option for pre-seeding weed control. In 2016, there are few on-label herbicide recommendations for weed control in oats or for soil active weed control when sowing oats.

Some herbicides for pre- and post emergent weed control in oat hay crops are listed in Table 7.1.

Some states, such as South Australia (SA), have supplementary lists for herbicide use in oats.

Advice should be sought from your agronomist and herbicide reseller.

In-crop weed control should be carried out when weeds are small and easily killed and before GS32 to minimise the impact of crop damage in wheel tracks.

Check the Australian Pesticides and Veterinary Medicine Authority (APVMA) website for current registrations and permits (www.apvma.gov.au).

Details of variety tolerance to different herbicides can be found on the National Variety Trials (NVT) website (www.NVTonline.com.au).

Always ensure that stockfeed withholding periods are met for grazing and hay.

Grass weeds

Wild oats cause yield loss, increased levels of cereal cyst nematode (CCN), are a source of rust inoculum and have a detrimental effect on quality due to early maturity. To prevent wild oats negatively impacting on hay quality or setting seed, hay paddocks should be cut as near as practical to the wild oats flowering. For most oat hay varieties, this means cutting the hay before flowering as wild oats generally flower before commercial oat varieties. Some of the early maturing varieties may coincide with wild oats. Very late maturing varieties should be avoided where wild oats are expected.

There is no safe chemical option for the control of wild oats in oat hay crops although the use of trifluralin applied in no-till systems has given partial control but is not permitted in all states. Check the APVMA website for the latest updates on trifluralin registration. Terbyne® is registered only for suppression of wild oats.

Ryegrass is a particular issue for oat hay production because hay is often included in the rotation to provide non chemical control of ryegrass. However, ryegrass hosts the annual ryegrass toxicity (ARGT) complex that can poison animals fed hay containing ryegrass infected with the toxin. Initially, the export market limited the ryegrass level in oat hay to 5%, but as ryegrass itself makes very good quality hay, often higher levels can be marketed as long as the hay is free from ARGT.

Good ryegrass control with herbicides can be difficult to achieve in oat crops but metolachlor (pre-seeding or post sowing pre-emergent) and chlorsulfuron (for Group B susceptible populations) have been used.

Grass weeds such as barley grass, silvergrass and brome grass reduce palatability and visual quality.

After bales have been removed from the paddock, regrowth of oats and other grass weeds can be controlled with paraquat or glyphosate.

Hay growers now have the option to desiccate hay crops prior to mowing using the herbicide Weedmaster® DST® (Group M). Desiccating one to 11 days pre-mowing offers the benefits of:

- reducing weed seed set;
- preventing hay and weed re-growth;
- preserving soil moisture; and
- maintaining or improving hay quality.

Before desiccating hay check this is an acceptable practice with your export hay buyer.

For some growers, the wheel tracks from the spray can be an issue for mowing but this is best managed by spraying in a different direction to the hay mower.

Broadleaf weeds

Weeds with a thick stem such as Salvation Jane and small-flowered mallow/marshmallow (*Malva parviflora*) cause visual downgrading and cure at a different rate to oats. Dark, unsightly patches or mouldy hot spots can result from the inclusion of broadleaf weeds.

Capeweed is a particular problem as it causes yield loss and has a detrimental effect on quality by causing unsightly dark and low nutrient patches in bales.

Brassica weeds and Bifora can result in unacceptable taints to the hay that will reduce livestock intake. Some weeds, such as Melilotus, can impart taints to milk.

Sharp, spiky weeds, such as thistles, can cause intake problems as well as impact on handling. About 80% of cows in Japan are fed by hand and the presence of thistles is easily noticed.

Annual ryegrass toxicity (ARGT)

ARGT is caused by toxins produced by the bacterium *Rathayibacter toxicus* that infect the seed heads of ryegrass. These toxins can prove fatal if ingested by livestock. The bacterium is transferred to ryegrass seed heads by a nematode (*Aguina spp.*). The nematode, which only has one lifecycle each year, invades the ryegrass during winter and in spring produces a gall that replaces a developing seed in the immature seed head. If the bacterium is present, it quickly multiplies during early spring, swamping the nematode and takes over the gall. After ryegrass flowers, the bacterium begins to produce potent toxins called corynetoxins. Toxin production increases rapidly just before the grass hays off. The toxin is very stable and persists in dry pasture or hay.

Circumstances that favour development of ARGT are:

- paddocks with moderate to high frequency of cropping;
- poor ryegrass control in previous year often associated with herbicide resistance;
- poor ryegrass control in-crop;
- ryegrass seed heads are cut or spray-topped after flowering has commenced allowing nematodes to complete their lifecycle;
- successive short growing seasons favour nematode multiplication;
- spread of galls from infected areas within or surrounding the paddock; and
- pasture phase under-grazed during spring, allowing infected ryegrass seed heads to mature and continue infection cycle.

Infected seed heads usually show no visual signs of infection. Sometimes excessive bacterial growth causes the emerging seed heads to become twisted and deformed. In this case, the bacterium will appear as a yellow exudate. When dry, the exudate turns orange and becomes brittle and transparent. Close inspection of the spikelets will often reveal that individual seeds have been replaced by nematode galls, most of which will be colonised by the bacterium.

The twist fungus (*Dilophospora alopecuri*) causes ryegrass seed heads to become distorted and 'twisted'. Twist is a plant parasitic fungus, but it needs the nematode to carry its spores into the plant. The spores quickly colonise the galls produced by the nematode.

This relationship makes the twist fungus a useful biological control for the nematode and is now established in many areas affected by ARGT. However, symptoms of the fungus indicate the nematode is present in the paddock, and that the bacterium may also be present. Significant levels of the fungus reduce but do not eliminate the risk of poisoning to stock. Stockists of the twist fungus can be found on the internet.

Testing for ARGT bacterial contamination in export hay and straw is compulsory. Local hay buyers may also require test results. Check on line for details of laboratories accredited for testing ARGT.

The reputation of Australian oat hay depends on the constant sampling and testing of export hay to minimise the likelihood of toxicity reaching animals.

Procedures and sampling protocols to minimise the risk of corynetoxin contamination in export hay can be sourced on the Federal Government Department of Agriculture and Water Resources website via the Biosecurity link – Hay Export Procedure (http://www.agriculture.gov.au/).

Table 7.1 Herbicides for weed control in oat hay crops – *source Agrilink Agricultural Consultants and Consult Ag 2016.* Always check the label before use as registrations vary between states.

Herbicide groups	Active ingredient	Examples of brand names	Timing	Comments
B	metosulam	Eclipse®	Apply late post emergent.	Post emergent broadleaf weed control.
B	flumetsulam	Broadstrike®	Apply late post emergent.	Post emergent broadleaf weed control.
B	chlorsulfuron triasulfuron	Glean®, Siege® Logran®	Apply post emergent.	Used post emergent for Group B susceptible weeds.
C	bromoxynil	Buctril®, Bromicide®	Apply after GS13. Avoid spraying in warm conditions.	Can be used in a tank mix with diflufenican (Group F). Grazing withholding periods must be followed for export hay to prevent residue.
C	diuron	Diuron, Diurex®	Apply pre-seeding, post seeding/pre-emergent or early post emergent.	Used as a residual herbicide before emergence or as a tank mix partner early post emergent.
C	terbuthylazine	Terbyne®	Pre-sowing application for control of certain grasses.	Vary rates by soil type. Low rates should be applied on lighter soils.
G	carfentrazone	Affinity®	Apply after GS14 but before GS31.	Particularly good as a tank mix partner to control Bifora and bedstraw.
I	dicamba	Cadence® Banvel®	Apply before GS25.	Common mixing partner for wireweed and legume control.
I	MCPA Ester MCPA LVE MCPA Amine	MCPA LVE MCPA 500	Apply between GS13 and GS37. Rate dependent at differing growth stages.	Can be used in a tank mix with diflufenican to broaden spectrum. Appears to be less damaging than equivalent rates of 2,4-D products.
I	2,4-D Amine	Amicide®	Apply between GS31 and GS37. Rate dependent at differing growth stages.	Only at low rates as scorching and yield loss can occur at high spraying rates. Some varieties are more sensitive to 2,4-D.
I	clopyralid	Lontrel® Archer®	Apply at any growth stage.	**Lontrel® cannot be used on export hay.** Good for thistles and legumes with some short term soil residual. Can be residual in hay.
K	metolachlor	Dual® Dual Gold®	Apply pre-seeding or post seeding pre-emergent.	Usually applied as post sowing pre-emergent, often in combination with diuron. Highly soluble so damage can occur in sandy soils or shallow sown crops.
C, I	bromoxynil+dicamba +MCPA	Broadside®	Apply after GS13 to late tillering.	Effective control of a wide range of broadleaf weeds. Best applied while weeds are small.
C, I, F	bromoxynil+MCPA +picolinafen	Flight®	Can be applied from GS13.	Broadleaf weed control.
I, F I, F	diflufenican+MCPA picolinafen+MCPA	Tigrex® Paragon®	Apply at GS13 to late tillering.	Very effective on brassica weeds such as wild radish. Blotching on leaves can occur, so spray early with lower rates on small weeds.
H, I	MCPA + pyrasulfotole	Precept®	Post-emergent broadleaf weed control.	Very strong on brassica weeds. Apply in bright sunny conditions. Very crop safe and unlikely to cause leaf discolouration.

Some of the above chemicals are not covered by label registrations but only by supplementary permit registrations that may only relate to certain states. Check details on the APVMA website (www.apvma.gov.au). Mention of trade names does not imply endorsement of any company's products and availability may change over time.

Disease

Impact on hay quality

- Colour
- Feed test

A wide range of diseases can affect all plant parts and attack at different growth stages (Table 7.2) resulting in reduced hay production and quality. Pest damage of significance is generally confined to emerging crops, however aphids occasionally cause yield loss but are more significant as transmitters of barley yellow dwarf virus (BYDV).

The effect of diseases on the key chemical determinants of hay quality - digestibility, fibre content and water soluble carbohydrates (WSCs) - has not been quantified. Diseases, especially foliar diseases, reduce the desirable green colour to yellow, red, and brown which may result in hay being downgraded. The smell of hay is adversely affected by crops heavily infected with stem and leaf rust spores.

Take an integrated approach to disease and pest control using genetic resistance, chemical control and agronomy practices. Genetic resistance is the most desirable and sometimes the only means of disease control, e.g. for bacterial blight. However, pathogens can evolve and reduce the effectiveness of genetic resistance. Tables 7.3 and 7.4 detail the diseases for which fungicides are currently available. When selecting a variety, it is important to understand the dominant disease constraints in a region (Figure 7.1).

Varieties with the best combination of resistance to key diseases in a region should be selected (see Tables 4.3a & b).

Table 7.2 Details of common diseases of oat hay by Zadok's growth stage
– source SARDI, National Oat Breeding Program.
For more information on growth stages see 'The oat hay year planner' (Chapter 2).

Growth stage (GS)	Disease
GS0 - 25	Root diseases - stem nematode, cereal cyst nematode (CCN), pratylenchus, take-all and rhizoctonia Foliar disease – barley yellow dwarf virus (BYDV)
GS25 - 30	Septoria, bacterial blight, BYDV and pyrenophora leaf blotch
GS30+	Septoria, bacterial blight, BYDV, red leather leaf, stem and leaf rust

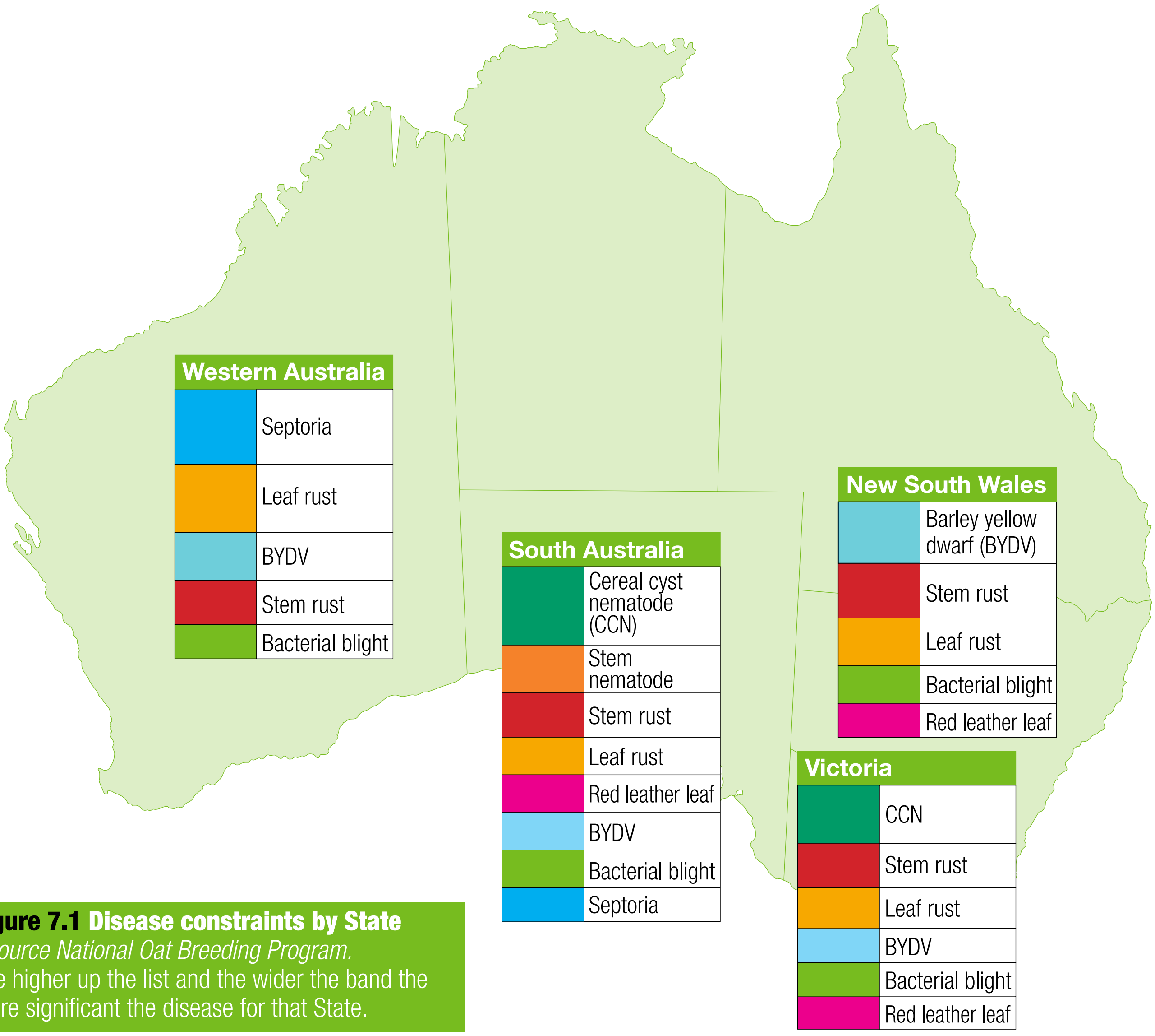


Figure 7.1 Disease constraints by State
- source National Oat Breeding Program.
The higher up the list and the wider the band the more significant the disease for that State.

Table 7.3 Seed dressings registered for disease and insect control of oats *– source APVMA and CropLife 2016.*

Active ingredients	Fungicide groups	Insecticide group	Example of brand name	Disease control	Insect control
Carboxin I Cypermethrin	7	3a	Vitaflo C®	Loose smut, covered smut	Selected grain storage insects.
Imidacloprid I Tebuconazole	3	4a	Hombre®	Loose smut, covered smut	Early feeding caused by cereal and wheat aphid. Reduces the spread of BYDV and selected grain storage insects.
Imidacloprid I Triadimenol	3	4a	Zorro®	Loose smut, covered smut	Early feeding caused by cereal and wheat aphid. Reduces the spread of BYDV and selected grain storage insects.
Cypermethrin I Ipconazole	3	3a	Rancona C®	Loose smut, covered smut	Selected grain storage insects.
Metalaxyl-M I Sedaxane I Difenoconazole	3, 4, 7		Vibrance™	Loose smut, suppression of rhizoctonia	
Metalaxyl-M I Sedaxane I Thiamethoxam I Difenoconazole	3, 4, 7	4a	Vibrance™ Extreme	Loose smut, suppression of rhizoctonia	Selected grain storage insects.
Penflufen	7		Evergol® Prime	Covered smut, loose smut, suppression of rhizoctonia	
Thiram I Carboxin	M3, 7		VitaVax®	Loose smut, covered smut	
Flutriafol I Cypermethrin	3	3a	Vincit®	Loose smut, covered smut	Selected grain storage insects.
Flutriafol	3		Impact®	Take-all*	

Chemical labels should be read and rates should be checked before using fungicides as registrations may vary between states. Check details on the APVMA website (www.apvma.gov.au).

Mention of trade names does not imply endorsement of any company's products and availability may change over time.

**No in-furrow fungicides are currently registered for use on oats in WA.*

Loose and covered smut are not common in oat hay but should infection occur from seed or paddock carryover severe taints in the hay could result.

Table 7.4 Foliar fungicides registered for disease control in oat hay crops *– source APVMA and CropLife 2016.*

Active ingredients	Fungicide groups	Disease control	Examples of brand names
Epoxiconazole I Pyraclostrobin	3, 11	Septoria leaf blotch	Opera®
Epoxiconazole IAzoxystrobin	3, 11	Septoria leaf blotch	Tazer Xpert™
Propoconazole	3	Stem rust, crown rust, suppression of septoria leaf blotch	Tilt®
Prothioconazole I Tebuconazole	3	Stem rust, leaf rust, septoria blotch	Prosaro®
Propiconozole I Tebuconazole	3	Stem rust, crown rust, suppression of septoria leaf blotch	Cogito®
Sulphur I Tebuconazole	3	Crown rust	Unicorn®
Tebuconazole	3	Crown rust	Folicur®

Chemical labels should be read and rates should be checked before using fungicides as registrations may vary between states. Check details on the APVMA website (www.apvma.gov.au).

Mention of trade names does not imply endorsement of any company's products and availability may change over time.

When diagnosing diseases, it is important to know the history of the paddock because disease development is influenced by:

- pathogen presence and abundance (green bridge, oat stubble, infected seed);
- variety susceptibility; and
- environmental conditions.

Leaf and stem diseases

During the growing season, regular paddock inspections should be carried out for disease.

Care should be taken to avoid spreading foliar diseases during such inspection; this is especially important if bacterial blight is present.

Aerial fungicide applications are preferable when applied at later growth crop growth stages in order to minimise crop damage from wheel traffic.

The export market is concerned about the residual nature of some fungicides. Therefore, it is advisable to check with your hay buyer before fungicides are applied. Follow the grazing/forage and fodder withholding periods for all fungicides.

Leaf and stem diseases – fungi

Stem Rust, *Puccinia graminis f. sp. avenae*

Severity	Stem rust is one of the most devastating diseases of oats. It occurs in all oat growing regions of Australia. Because the pathogen has the ability to produce multiple cycles of spores, early infection of the plant can result in complete crop failure. A pathotype that overcomes most resistance genes for stem rust is now present in southern Australia. Therefore, it is important to monitor oat crops for early detection of rust, so fungicide applications can be applied to control the diseases.
Source and spread	Volunteers, spread by wind.
Main hosts	Oats, wild oats.
Plant part attacked	Leaves, stems and heads.
Symptoms	Stems and leaves have dark reddish-brown powdery spores. Spore pustules are elongated. Similar to leaf rust but darker and seen on stems and upper leaves first.
Control methods	
rotations & variety choice	Avoid most susceptible varieties. Resistance tends to be short lived.
weed control	Tillage, burning, grazing and spraying to control volunteers.
fungicides	Numerous fungicide options are registered for control of oat stem rust. Apply as a preventative in high risk situations or when infection levels are very low in order to minimise yield loss. With early infections, a second application may be required. Once the crop is heavily infected with stem rust, the ability of fungicides to prevent yield or quality loss is limited. Use high water rates to maximise coverage and use full label rates. Withholding periods must be observed.
Other comments	Infection requires temperatures between 15°C to 30°C and humid conditions.

Leaf Rust, *Puccinia coronata f. sp. avenae*

Severity	Leaf rust occurs in all oat growing regions in Australia. Similar to stem rust, leaf rust produces multiple cycles of spores, but generally will not result in complete crop failure. Early infection in a very susceptible variety can result in crop failure.
Source and spread	Weeds, volunteers, spread by wind.
Main hosts	Oats, wild oats.
Plant part attacked	Leaves.
Symptoms	Circular to oblong pustules on the upper leaf surface that produce orange, powdery spores. As the crop matures, the spores become black, forming a dark edge to the pustules.
Control methods	
rotations & variety choice	Sow resistant or moderately resistant varieties. Resistance tends to be short lived.
weed control	Control volunteers and wild oats.
fungicides	Numerous fungicide options are registered for control of oat leaf rust. Disease may be controlled for up to four weeks with use of foliar fungicides. Repeat applications may be necessary if infection occurs early. Withholding periods must be observed.
Other comments	Disease promoted if temperature is 15°C to 22°C and conditions are moist. Leaf and stem rust in oats look similar. Leaf rust pustules are smaller and rarely found on stems but do move to leaf sheath later in the season.

Septoria Leaf Blotch, *Septoria avenae*

Severity	Septoria causes leaves, and in severe cases panicles, to turn reddish brown, reducing visual quality. The spores are splash dispersed and continue to move up the plant if climatic conditions are conducive.
Source and spread	Stubble, wind, rain splash.
Main hosts	Oats.
Plant part attacked	Leaves and stems.
Symptoms	Leaves have dark, elongated spots with a yellow surround. Entire leaf can die. Stems can be infected and lodging may result.
Control methods	
rotations & variety choice	Sow partially or resistant varieties. Avoid sowing into or near infected stubbles. Do not grow oats continuously.
time of sowing	In high rainfall areas, do not sow early.
stubble management	Burn or bury infected stubbles.
fungicides	Numerous fungicide options are registered for control of septoria in oats. In high yield and disease pressure situations, a double application of fungicide can be economically viable. It is most important to protect the Flag leaf and Flag minus 1. Withholding periods must be observed.
Other comments	Early infections of septoria can be confused with Pyrenophora leaf blotch.

Pyrenophora Leaf Blotch, *Pyrenophora avenae*

Severity	Seedlings have purple irregular spots that can spread to the upper leaf canopy when cool moist conditions persist.
Source and spread	Infected seed.
Main hosts	Oats.
Plant part attacked	Leaves.
Symptoms	Pyrenophora symptoms are small, reddish purple, oval lesions. Cold wet conditions favour the development of this disease. As the season progresses, the crop generally recovers with the upper leaf canopy free of disease. Hence, visual hay colour is not usually affected.
Control methods	Seed treatment, sanitation, rotation, and cultural methods to promote rapid seedling development.
Other comments	This disease is a minor problem in oats and generally does not require control. Symptoms may be confused with septoria.

Red Leather Leaf, *Spermospora avenae*

Severity	Very little is known about this disease, but it is known to be favoured by cool, moist conditions.
Source and spread	Stubble, spread by rain splash.
Main hosts	Oats.
Plant part attacked	Leaves.
Symptoms	Leaf symptoms begin with yellow circular areas. Red/brown areas that may cover the majority of the leaf area surround lesions. Plants may be stunted.
Control methods	
rotations & variety choice	Avoid susceptible varieties in areas where the risk is high. Growing oats in tight rotation can increase pathogen levels. Avoid sowing near or into infected stubbles.
stubble management	Burn or bury infected stubbles.
Other comments	Disease more likely to occur in high rainfall areas.

Leaf and stem diseases - bacteria

Fungicides are not effective in controlling bacterial diseases such as halo and stripe blight, collectively referred to as bacterial blight; genetic resistance is the only option to provide plant protection to this disease.

Bacterial Blight, *Pseudomonas syringae*

Halo blight
Pseudomonas syringae pv. coronafaciens

Symptoms - leaves will have light green oval spots up to 10mm surrounded by yellow areas, which can join together to form blotches on the leaf.

Stripe blight (Bacterial stripe)
Pseudomonas syringae pv. striafaciens

Symptoms - leaves have brown stripes with narrow yellow edges. Leaves wither and die.

Severity	Bacterial blight is prevalent early in the growing season when conditions are cool and moist. Two forms, halo and stripe, are collectively known as bacterial blight. Symptoms can either be brown oval lesions or brown stripes on the leaves. Eventually the brown areas disintegrate to form 'windows'. Symptoms often become apparent after a frost. As the growing season progresses, plants generally grow away from this disease.
Source and spread	Transfers on tyres, stubble, seed, spread by rain splash and insects.
Main hosts	Oats.
Plant part attacked	Leaves.
Control methods	
rotations & variety choice	Avoid susceptible varieties. Genetic resistance is an option for plant protection. Avoid sowing into infected stubbles.
stubble management	Burn or bury infected stubbles.
clean seed	Do not use seed from infected crops.
Other comments	Common early in the season when conditions are wet and cool. Paddock hygiene is important. To prevent disease spread, paddock operations should be avoided after frost or when leaves are wet.

Leaf and stem diseases - viruses

Barley Yellow Dwarf Virus (BYDV)

Severity	Barley yellow dwarf virus (BYDV) is prevalent in high rainfall areas. Aphids introduce and spread the virus in the crop.
Source and spread	Volunteers, spread by aphids.
Main hosts	All cereals, many grass weeds.
Plant part attacked	Leaves.
Symptoms	Yellowing of leaves begins at the tips, yellow stripes extend to the base, and leaves turn red. Symptoms may not be evident until sometime after the initial infection. More commonly seen in patches, especially at paddock margins. Early infection results in dwarfing of the plant and sterile panicles.
Control methods	
rotations & variety choice	Sow resistant or tolerant varieties.
time of sowing	Avoid early growth coinciding with periods of peak aphid activity.
weed control	Tillage, grazing and chemical controls of weeds and volunteers over summer to reduce aphid build up.
pesticides	In high risk situations, seed can be treated with a seed dressing containing imidacloprid to prevent early aphid infection. A prophylactic spray of alpha-cypermethrin at the 2-3 leaf stage of the oats can have an anti-feeding effect to reduce the likelihood of aphid infection and the transmission of viruses. Seek advice from a local agronomist on best practice for insect resistance management.
Other comments	Disease transmitted by aphids. More prevalent following an early break in the season. Can be confused with nutrient deficiencies, red leather leaf and water logging.

Root Diseases - nematodes

Nematodes that infect oats are small and usually about 0.2mm long. They cause major soil-borne diseases, limiting dry matter production and grain yield in certain areas throughout Australia.

Oat varieties differ in their ability to host nematodes. Resistant varieties act as excellent break crops limiting nematode multiplication, while susceptible varieties increase the severity of the disease.

However, varieties also differ in their ability to develop normally and produce hay in the presence of the nematode. Tolerant varieties will develop normally in the presence of high nematode populations, but in the same situation, intolerant varieties would have poor growth or could even die.

Therefore, if nematodes are a problem, it is advisable to select a variety with both resistance and tolerance (see Tables 4.3a & b).

Cereal Cyst Nematode, *Heterodera avenae*

Severity	Cereal cyst nematode (CCN) causes stunted root systems, resulting in reduced plant growth and yellowed leaves. Oat varieties can be resistant or susceptible to CCN (a variety's ability to control nematode numbers). They are also tolerant or intolerant to CCN (relating to the variety's ability to yield when nematodes are present). Severe infestations cause seedling death in intolerant oat varieties.
Source and spread	Soil, weeds, volunteers. Spread by cultivation.
Main hosts	Susceptible cereals - wheat, barley, oats, wild oats.
Plant part attacked	Roots.
Symptoms	Yellow or pale green patches appear in crops in early winter. Stunted plants. Fewer tillers. Patches 1m to over 100m in diameter. Shallower root systems. Oats have thickened roots but no knotting. White cysts, about 1mm in diameter, appear on roots 11 to 13 weeks after sowing.
Control methods	
rotations & variety choice	Disease break - at least one out of every two years with non cereals or resistant cereals. Resistant varieties prevent CCN build-up. Tolerant varieties have a lower yield loss when CCN is present. Both resistance and tolerance reactions are reported for all oat varieties released in Australia from the National Oat Breeding Program.
time of sowing	Early sowing helps reduce yield loss by allowing good crop establishment before large numbers of nematodes hatch.
weed control	Tillage, grazing and chemical control of host plants in break crops and pastures.
soil fertility	In fertile soils, plants with well established roots obtain nutrients and have a better recovery.
Other comments	CCN can be more of a problem in alkaline, sandy or less fertile soils. Reduced soil disturbance decreases CCN numbers.

Stem Nematode, *Ditylenchus dipsaci*

Severity	Stem nematode is limited in its distribution but devastating to oat crops when present. This nematode causes multi-tillering and swelling at the base of the seedling, leaf crinkling, and severe dwarfing of plants. An intolerant variety affected by stem nematode could result in crop failure.
Source and spread	Soil, stubble, seed.
Main hosts	Oats, wild oats, faba beans, peas, chickpeas, vetch, three horned bed straw and some other broadleaf weeds.
Plant part attacked	Crown/stem base.
Symptoms	Multiple, stunted tillers.
	Poor emergence in soils where nematode numbers are high. Often seedlings of intolerant varieties do not survive and plants that survive frequently do not produce panicles.
Control methods	
rotations & variety choice	Disease break - avoid successive susceptible hosts, especially prior to oat crops. Where damage has been severe, avoid a susceptible and intolerant crop for three or more years, growing resistant oats or other cereals. Field peas and chickpeas will prevent nematode numbers increasing, but are very intolerant and can suffer significant losses. Faba beans are more tolerant than peas but are susceptible, allowing populations to multiply.
weed control	Control susceptible host plants in break crops and pastures.
hygiene	Avoid spreading infested plant material by cleaning equipment before leaving infested paddocks and by minimising soil movement and erosion.
Other comments	Stem nematode prefers heavy soils. Dry years favour survival in the absence of a host.

Testing for root and crown disease

The potential for damage by key root and crown diseases can be tested by a single soil test. Soil samples for the PreDicta B soil test (http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b) are collected in summer/early autumn. Coordinated by accredited local agronomists and resellers, PreDicta B provides a DNA prediction of soil inoculum levels of multiple diseases including rhizoctonia, take-all, cereal cyst nematode, pratylenchus, stem nematode and crown rot.

Root Lesion Nematode, *Pratylenchus – P. thornei, P. neglectus, P. teres, P. penetrans*

Severity	Root lesion nematode (RLN) prunes the plant's root system resulting in thin stands of yellowing plants. Less is known about the resistance and tolerance reactions to RLN in oat varieties than for CCN and stem nematode, but differences have been demonstrated between varieties and RLN species.
Source and spread	Soil, weeds, volunteers.
Main hosts	Wheat, barley, canola, vetch, medic, chickpeas, corn, oats, many grass and broadleaf weeds.
Plant part attacked	Roots.
Symptoms	Different species of *Pratylenchus* have similar symptoms. Stunted plants. Plants prone to wilting. Yellow lower leaves in some varieties. Fewer lateral roots. Black or brown lesions on roots.
Control methods	
rotations & variety choice	Disease break – avoid successive susceptible hosts. In the year before growing oat hay, grow resistant cereals, lupins, field peas and faba beans (moderately susceptible to *P. thornei* but resistant to *P. neglectus*). Grow cereal varieties with resistance and tolerance where nematode numbers are high.
weed control	Control susceptible weed species (especially wild oats, barley grass, brome grass and wild radish) and volunteers in pastures or non-host crops.
tillage	Nematode survival is greatly reduced where soils are cultivated dry but the risk of soil erosion should be evaluated.
soil fertility	Application of ammonium based fertiliser reduces root invasion by nematodes, as ammonium compounds are toxic to nematodes. Good nutrition encourages healthy plants with greater tolerance to root damage.
Other comments	Root lesion nematodes multiply most rapidly in plant roots growing in warm soils and can produce three to four generations in a year.

Root and crown diseases

Rhizoctonia Root Rot, *Rhizoctonia solani*

Severity	Rhizoctonia root rot is an on-going concern in many areas as its occurrence and severity are difficult to predict. Control options are limited and may only provide partial reduction in disease expression and yield loss.
Source and spread	Soil, plant roots.
Main hosts	All plants are hosts to some degree.
Plant part attacked	Roots.
Symptoms	Bare patches in crops. Stunted growth. Root rotting, causing 'speared tips'. Pale plants. Shorter root systems. Oats are marginally more tolerant than triticale and wheat, while barley is the most susceptible of all the cereals.
Control methods	
weed control	Grass weed control is essential before cereals. At least two weeks prior to sowing, remove all green growth.
tillage	Minimise time between cultivation and seeding. The ability of the fungus to cause infection is greatly reduced by deep cultivation prior to or at sowing.
soil fertility	Improving soil fertility will help plants tolerate root damage.
fungicide	There are several fungicide dressings registered in oats for the suppression of rhizoctonia (Table 7.3). These seed dressings reduce the yield impact of rhizoctonia but do not replace the traditional management techniques.
Other comments	Rhizoctonia is most common in low fertility soils such as calcareous or slightly acid sands. Direct drilling can increase the risk of rhizoctonia. Sulfonylurea herbicides should be avoided on alkaline soils as this can result in increased rhizoctonia in barley sown in the following year.

Fusarium Crown Rot, *Fusarium pseudograminearum, Fusarium culmorum*

Severity	Oats are susceptible but tolerant so do not display any symptoms of fusarium crown rot; however, they can result in a small carryover of inoculum.
Source and spread	Soil, stubble.
Main hosts	Wheat, barley, oats, triticale, barley grass, other grass weeds.
Other comments	Crown rot only needs to be considered in terms of the whole rotation. Most commonly observed to cause severe damage following dry conditions in spring. Initial infection of plants is favoured by wet conditions, but the fungus grows rapidly when plants are moisture stressed. Damage may occur on all soil types, but is more severe on heavy soils.

Take-all, *Gaeumannomyces graminis var. avenae*

Severity	Wet springs in the year prior to sowing tend to increase inoculum levels so severity is seasonally dependent. Only the oat attacking strain *Gaeumannomyces graminis* var. *avenae* causes significant yield reduction in oats.
Source and spread	Soil, stubble, weeds, volunteers.
Main hosts	Wheat, barley, oats, triticale, barley grass, brome grass, silver grass.
Plant part attacked	Roots.
Symptoms	Early in the season plants can be stunted and pale. Reduced tillering. White heads. Black lesions in centre of root, seen when snapped open. Blackening of crowns and lower stems in severely infected plants.
Control methods	
rotations & variety choice	A one year disease break before sowing oats for hay. Break crops include pulses, oilseeds, oats (for non-oat attacking strain), grass-free pasture or fallow, cereal rye. Systems that increase microbial activity can suppress the take-all fungus. After liming, non-hosts should be considered.
time of sowing	Delayed sowing may reduce the impact of the disease.
stubble management	Encourage decomposition of stubble prior to sowing susceptible cereals.
weed control	Grass hosts and volunteer cereals should be removed early in the break year.
seed dressing	Seed dressings offer some degree of protection.
soil fertility	Plants low in phosphorus, nitrogen and manganese are more susceptible to take-all. Take-all is suppressed in soils with low pH (acid soils).
fungicides	In some states, fungicides can be used in furrow and on seed.
Other comments	Moist but well-drained alkaline soils favour growth of the fungus. Wet springs cause the disease to build up, while summer rains reduce it. Take-all can be confused with crown rot and common root rot, which also cause white heads.

Pests

Impact on hay quality

- Contamination
- Stem diameter
- Staining and moulds

A vigorously growing oat hay crop with a plant density of about 250 plants/metre square is able to withstand considerable pest damage with little yield loss. However, in crops sown too deep or under moisture stress pest damage will increase.

Oat hay crops are a little more robust than other cereals in relation to pests of emerging crops such as snails, slugs and earwigs. In some areas, bird damage by cockatoos can be a problem and cause substantial crop loss.

In general terms pest management and insect thresholds in oat hay crops are the same as other cereals. These are best sourced from local agronomists.

Diligent crop monitoring is required throughout the growing season and chemical controls should only be applied if local thresholds for pest species are approached or breached. Routine spraying without monitoring pest numbers can increase the development of insecticide resistance.

Tables 7.3 and 7.5 detail insecticides currently registered for use in oat hay crops. Insecticide groups should be rotated.

Always ensure that stockfeed withholding periods are met for grazing and hay.

Lucerne flea

Oats are particularly palatable to lucerne flea (*Sminthurus viridis*). Heavy infections prior to GS25 can cause very high levels of damage and result in plant death. Left unchecked, low initial infestations can complete several lifecycles in oats and produce many over-summering eggs. These can cause crop damage when they hatch the following year.

Control can be achieved cheaply with a range of insecticides. Prior to crop emergence, soil residual insecticides are useful but when there is plant material available to spray after emergence, the systemic products such as dimethoate and omethoate give outstanding results. Once lucerne flea is controlled, plant recovery is rapid.

Red-legged earth mite (RLEM) and Blue oat mite

Red-legged earth mite (*Halotydeus destructor*) and blue oat mite (*Penthaleus major*) also cause severe and rapid damage to oats as well as allowing lifecycles to be completed to cause problems for the following year. Control is similar to lucerne flea, although the results achieved with soil residual products are usually greater. Some control is achieved at all stages with a range of synthetic pyrethroids, which are generally weak on lucerne flea. The response to dimethoate and omethoate is rapid when foliage is sprayed. Once again when the mites are controlled, plant recovery is rapid.

Aphids

Aphids can occasionally cause yield loss in oats when their numbers are very high in early spring. In some situations, control is warranted. Of more importance is that aphids transmit viruses, particularly barley yellow dwarf virus (BYDV) that can cause high yield losses, in favourable years, in hay crops. Therefore, most aphid control is aimed at reducing or preventing BYDV. For this reason, control needs to be achieved early in the season. Controls include seed treatments or by spraying insecticides (usually synthetic pyrethroids) at the early growth stages, often as a preventative application.

Check with your agronomist for the latest information on Russian Wheat Aphid.

Mice

Mice can be a problem in hay stores and baiting is recommended. Bait stations should be placed so that mice are lured out of the hay and preferably die away from the store.

Contact your local reseller or adviser about pest control products.

Table 7.5 Foliar insecticides registered for use in oat hay crops – *source APVMA and CropLife 2016.*

Insecticide actives registered on oats APVMA portal	Group	Examples of brand names	Insect control
Permethrin (40:60:CIS:TRANS)	3A	Stakeout®	Armyworm, southern armyworm, redworm, pink or common cutworm
Methomyl	1A		Armyworm
Esfebvalerate	3A	Sumi-apha®	Cutworm
Dimethoate	1B	Rogor® Dimethoate	Lucerne flea, red-legged earth mite (RLEM), wingless grasshopper, brown wheat mite, blue oat mite, leafhopper, cereal aphids
Omethoate	1B	Le-Mat®	
Chlorpyrifos	1B	Lorsban®	Cutworm, pasture webworm, armyworm, RLEM, lucerne flea
Beta-cypermethrin	3A	Banshee®	RLEM, cutworm, common armyworm
Alpha-cypermethrin	3A	Alpha	RLEM, cutworm, common armyworm

Chemical labels should be read and rates should be checked before using insecticides as registrations may vary between states. Check details on the APVMA website (www.apvma.gov.au).

Mention of trade names does not imply endorsement of any company's products and availability may change over time.

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Cutting oat hay between GS61-71 will maximise nutritional quality.

Figure 8.1 Identifying when to cut – for quality oat hay cut between GS61 and GS71; after this quality will start to decline. Cutting too early, before the head is fully emerged, can add days to the curing time.

credit Emma Leonard, AgriKnowHow

making oat hay

chapter 8

credit Emma Leonard, AgriKnowHow

Hay making requires specialised equipment – mower, usually with in-built conditioners, rake, baler and handling equipment.

As a rule of thumb, if less than 200ha (4 to 5t/ha crop) of hay is to be made, then using contractors is the most cost effective, but owning your own equipment can give peace of mind.

One mower and one baler are required for about every 350 to 400ha of hay, while a rake can generally service 1000ha. If a spread of variety maturities is grown, less machinery may be possible.

If more than 300ha of hay is to be made, storage is desirable and then ideally two loaders are available – one in the paddock, the other at the shed.

Having the right amount of equipment helps to ensure hay making operations can be carried out at the best time.

A six tonne crop produces 10 bales per hectare and baling rates are about 60 bales an hour for large square bales. For one baler on 400ha that is two weeks (five hours baling/day) baling without any stops for rain or breakdowns.

Balers fitted with water tanks or steamers can add moisture to allow drier hay to be baled.

Cutting

Cutting is the first stage of the hay making operation. The objectives of the cutting operation are to:

- cut the hay so that it sits on the cut stems to promote rapid drying;
- produce a gently domed windrow that sheds water; and
- have a windrow wide enough to fill the full width of the bale pick-up. This may be achieved by tedding or raking rows into one just before baling.

With a mower, conditioner cutting, conditioning and the formation of a windrow are achieved in a single operation. Conditioning hay helps reduce curing time (see Curing).

The time of cutting in relation to plant growth stage, cutting height and direction, all impact on hay quality.

Cutting droughted cereals

The rules for achieving top quality hay from droughted cereals are slightly different. They usually have a much higher water soluble carbohydrate (WSC) level and to produce quality hay need to be cut before full head emergence. These crops should be super conditioned to help ensure this material is fully cured before baling (Testing moisture content).

The impact of growth stage on hay quality and quantity

The following information explains how the oat crop changes during the growing, maturing and grain fill periods. All growth stages relate to the Zadok's scale (see Chapter 2).

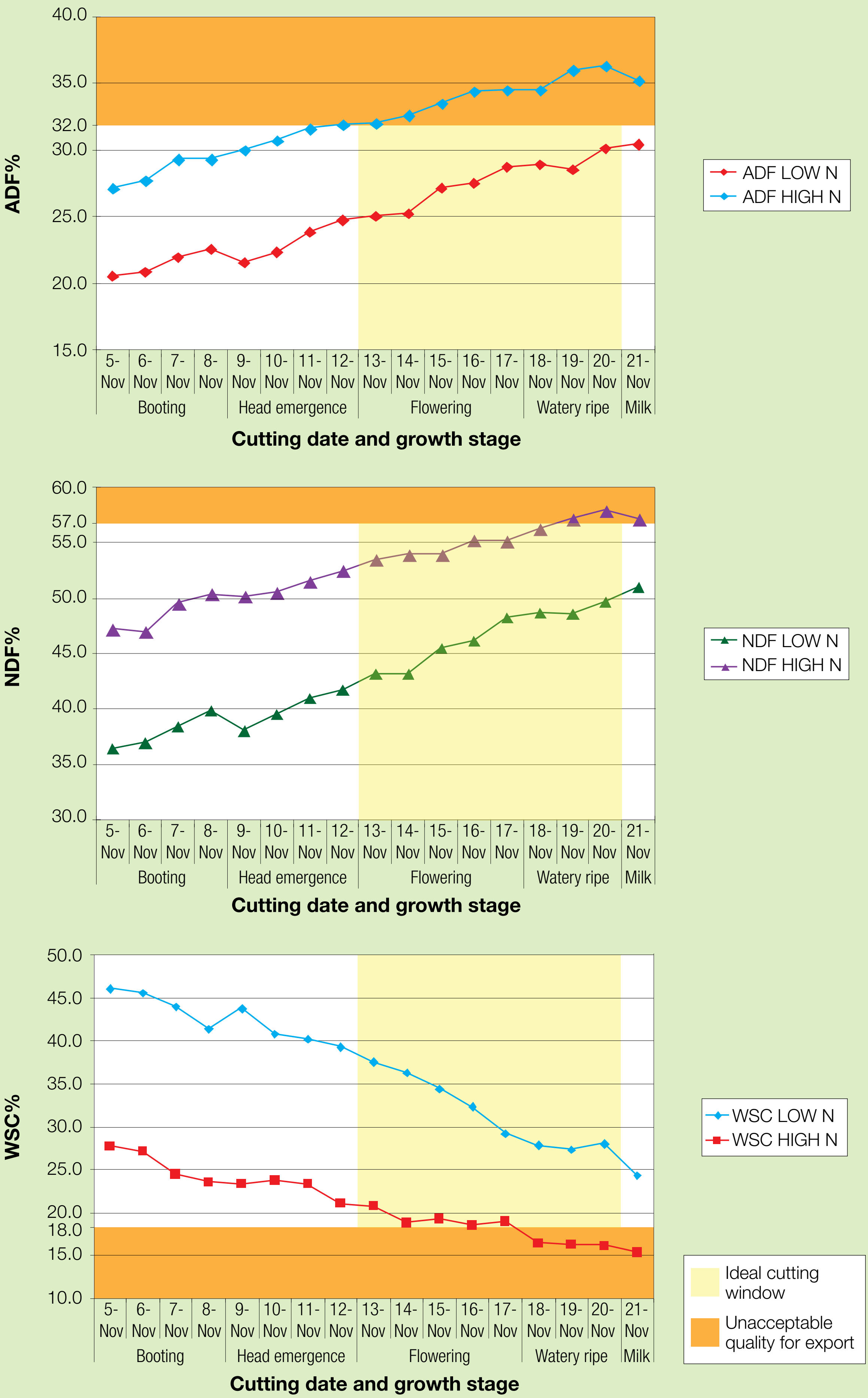

Figure 8.2 The change in fibre (neutral detergent fibre (NDF) and acid detergent fibre (ADF)) and water soluble carbohydrates (WSC) for a late maturing oat variety under a high and low nitrogen trial. The orange highlight indicates quality parameters that would not meet export quality standards.

GS30 to 39 – stem elongation to flag leaf emergence

As the plant extends during stem elongation (GS30 to 39), photosynthate is used to form cellular structures such as lipids, hemicellulose, cellulose and lignin. The more mature an internode, the greater the proportions of lignin and cellulose and the lower the proportions of hemicellulose and lipids. Carbohydrates can be mobilised from older nodal and internodal tissue to support the demand of new growth. This is greatest if soil moisture is limiting and temperatures are too high for efficient photosynthesis.

GS40 to 60 – flag leaf emergence to flowering

The most rapid period of dry matter accumulation on a daily basis occurs from flag leaf emergence (GS39) until the end of boot stage (GS49). Dry matter accumulation can reach 200kg/ha/day for a high yielding crop growing with adequate soil moisture, good fertility and mild temperatures.

Daily growth rates are reduced as temperatures exceed 30°C or in very cool conditions. Hay crops can lose weight during hot weather or when under moisture stress. This is because respiration and transpiration losses exceed photosynthetic gains. Conversely, in good growing conditions WSC can increase to the end of the watery ripe stage.

From the time the panicle is fully extended (GS59), there is little addition of new photosynthate to the stems as this is now partitioned to the developing grain.

Maximum digestibility and lowest fibre content will occur between the boot and head extended stage (GS59).

Oats can flower before emerging from the boot, especially in moisture stress conditions or if a dwarf oat variety is grown. This situation results in GS61 occurring before GS50 to 59 is complete.

GS61 to 73 - flowering to milky dough - the ideal cutting period

The first three to seven days of grain formation culminate at the watery ripe stage (GS71). At this point, the panicle is fully extended but grains only contain clear, greenish liquid (Figure 8.1). Grain is not yet drawing heavily on carbohydrate from photosynthesis or storage. However, this changes rapidly as solids start to accumulate at the start of the milky dough stage (GS73).

As stems become more mature, they absorb water more quickly from rainfall. Hay cut after GS71 can deteriorate more rapidly after rainfall than hay cut at or around flowering.

GS74 onwards

After GS73, carbohydrate requirements for the developing grain are extreme and lignification of older stem material is accelerating. This results in an increase in the fibre fractions (as measured by NDF and ADF, Figure 8.2) and a reduction in WSC, which together result in lower digestibility. ADF and NDF content increase down the plant from the panicle to the base of the stem but there may not always be a similar pattern with WSC.

From flowering to soft dough (GS85), growth rates to a maximum of 175kg/ha/day have been recorded, so yield continues to accumulate.

As grain starts to ripen (GS90), overall digestibility of the plant increases and fibre fractions decrease because of the high starch content of the grain. If grain is removed, the remaining plant material has poor quality as mainly the fibre fractions remain.

Ripe grain in hay is undesirable to hay buyers because if grain is lost during conditioning, super conditioning or processing at a hay plant then the remaining hay is likely to be poor quality. The presence of grains also makes hay more attractive to rodents.

After flowering, the flag leaf will gradually senesce resulting in leaf discolouration. Senescence is likely to have started to occur in the F-1 and F-2 leaves, those directly below the flag leaf, several days earlier. If senescing leaves remain in the hay, they result in hay discolouration. In addition, fully extended flag leaves are prone to wind scorch although there are varietal interactions and invariably thick lush crops are more damaged. If scorching occurs on the flag leaf, it can look unsightly and hay can be downgraded. Scorching can occur on earlier emerging leaves but the presence of clean flag leaves is usually enough to overcome visual discolouration in the bale.

Impact of hour of cutting

Hay quality traits peak in the afternoon on cool to mild days and mid morning on hot days. This fact is important for research scientists but is usually not significant enough to alter the time of hay cutting at the farm level.

Curing time can be increased if the crop is cut wet. This is because moisture evaporates more quickly from the standing crop than from within the windrow. Ideally, allow dew or rain to evaporate before cutting.

Cutting height

Cutting higher reduces yield but can improve hay quality as the lower stems can be thicker, high in fibre and bleached of colour.

A rule of thumb is to cut at 15cm, the height of a drink can. High yielding crops and lodged crops may be cut slightly higher to ensure the weight of the windrow is supported off the ground. However, the following factors need to be considered when determining cutting height.

Contamination

Cutting height must be sufficient to prevent contamination from previous stubbles, soil, manure and other contaminants that may be on the soil surface. The aim is to present a windrow where the rake (if used) or the baler pick-up can clear the soil surface by 25 to 50mm. This generally requires a minimum cutting height of 12cm and preferably 15cm above the highest point between seeding rows.

Lodged crops

For high yielding, lodged crops, cutting height may need to be raised to 20cm. Height is adjusted to match crop fall and direction of travel. The aim is to ensure the crop is cut with a sufficient stubble length to allow hay to be picked up by super conditioners and balers without contaminants.

Lodged plants do not support the weight of a windrow because of the low angle of stems to the horizontal soil surface. Invariably, lodged plants are cut at differing heights depending on the direction of cut, the type of cutter used and the speed of operation.

If the weather is going to be fine from cutting to baling, lodged crops can be cut low, although feed test parameters would be expected to be poorer. However, if there is a risk of rainfall, lodged crops should be cut higher.

Cutting direction

When row spacing is greater than 12.5cm, cutting direction should be across the row. This can make working very rough so working at 45 degrees can be a good compromise. This will keep hay off the ground, improve air circulation and curing, limit spoilage and assist in efficient pick up by super conditioners and balers (see Figure 5.2). When cutting across seeding rows, cutting height may be slightly lower than when cutting in the same direction as seeding rows.

The best direction of travel in lodged crops often is determined by trial and error.

Super conditioners with roller pick-ups need the windrowed hay to be presented clear of the ground to allow efficient pickup of all cut hay. However, excessive length of the remaining uncut stubble can result in wrapping around the pick-up rollers causing blockages and lumpiness in the windrow. This can also result in plants with soil attached being pulled out of the ground and deposited in the windrow.

Cutting equipment

There are basically five types of hay cutting equipment. Some purely cut the crop while others cut and condition to reduce the curing time. The types are listed in Table 8.1, together with details of the drive options available. Additional equipment that may be required for the cutting/curing operation includes super conditioners, tedders and rakes; these are discussed in the section on curing.

Self-propelled versus PTO equipment

Power take-off (PTO) driven equipment can only cut round and round unless a swing arm machine is used. This must be taken into consideration when selecting seeding direction (see Figure 5.2). When cutting and conditioning with PTO machines, the drawbar and differential of the tractor must be able to clear the previous windrow; dragging equipment through a windrow can undo a good operation. If conditioning is a separate operation, the tractor operating the mower conditioner should not run over any of the previous windrow. Therefore, windrow size and shape may be dictated by tractor configurations when using PTO driven machines to avoid these issues.

Table 8.1 Types of mowers and available drive options.	Self-propelled	Offset PTO or hydraulic	Swinging arm hydraulic
Rotary or flail slasher		✓	
Windrower	✓	✓	
Rotary/disc cutting mower conditioner	✓	✓	✓
Knife cutting mower conditioner	✓	✓	✓
All in one mower conditioner/super conditioner – knife or disc	✓	✓	✓

Swinging arm, hydraulic cutters offer the ability to cut up and back and reduce damage on headlands.

Triple or double deck mower set ups allow multiple windrows to be cut in a single pass. These consist of a front mounted mower, plus a single or twin mounted, or tow behind mower. Such set-ups in controlled traffic farming (CTF) systems enable hay to be cut without leaving the tramlines.

Self-propelled mower conditioners largely overcome these problems of disturbing or running over the previous windrow. Self-propelled mower conditioners can be used more easily to cut across or at an angle to the seeding rows, which helps keep the windrow off the ground. This is especially important as seeding row spacing increases. The greatest downside of self-propelled mower conditioners is the capital and annual depreciation costs.

Knife versus disc cutters

There is always great discussion over the virtues of disc and knife cutting machinery. Disc cutters have a greater cutting capacity than knife cutters and can be operated at greater speeds. Working speeds for disc cutters are stated as 20 to 30% higher than knife cutters, which can convert into cutting time efficiencies. This is often the reason for their widespread use. However, excess speed is one of the most common reasons for poor cutting and windrow presentation with both types of cutters.

A double deck set-up allows two windrows to be cut concurrently. In this CTF system, a second pass is required to cut the remaining crop. A triple deck system could overcome this requirement.

credit Emma Leonard, AgriKnowHow

Disc cutters have a greater cutting capacity than knife cutters and can be operated at faster speeds. Pictured is a disc and super conditioner, self-propelled mower.

Disc cutters produce excellent results, providing cutting blades are sharp and working speeds are not excessive (8 to 12km/hr) for crops of seven to 10 tonnes per hectare. Some operators have a preference for disc cutters when cutting lodged crops, because the discs have a lifting action on the cut hay. This may be an advantage but can result in variable cutting height depending on the direction of travel and the direction the crop is leaning.

Knife cutters must be sharp and when they are driven at moderate speeds the cut and windrow formation is excellent. Operating speed is particularly important in lodged crops where poor results are the most obvious.

Rotary or flail slashers

Flail slashers are not used to cut cereal hay and while rotary slashers can be used, the performance is inferior to disc or knife mowers. The cut hay is not conditioned and windrow presentation can be poor.

Windrowers

Windrowers are a compromise for hay cutting, as they do not condition hay. They are most suited to cutting straw or when hay yields are low where the extra width helps produce a windrow large enough to bale. Windrowers have high capacity but result in the cut stems of hay being predominantly presented lying in the same direction as cutting. This can result in more hay falling between the cut stalks and contacting the soil surface, making it difficult for the super conditioner or baler pick-ups to retrieve all the cut material. Raking windrows or the use of mixing belts can help overcome this problem but invariably produce an inferior windrow to that produced by a mower conditioner.

All in one mower conditioner/super conditioners

All in one mower conditioners/super conditioners execute the two operations in one, reducing the number of passes required to convert the standing crop to curing hay.

These machines are especially good when soil and atmospheric moisture are low (dry springs or late cuts), as hay is rapidly cut and cured in one pass. However, cutting lush crops with an all-in-one machine when the soil surface is moist and humidity is high, can create dense windrows and promote mould formation. In this situation, additional removal of free moisture from the crop by raking or tedding may be required.

Ensuring good set-up as detailed by the manufacturer and not working too fast, especially in heavy crops, are important to achieve a quality result.

Curing

For every one tonne of hay baled, approximately three tonnes of water needs to be removed by evaporation. Dew can add an additional one to two tonnes of water per hectare.

Curing speed is affected by environmental, management and mechanical factors (Table 8.2). An understanding of each of these factors can help improve the quality of hay that is baled, stored and eventually fed out.

Table 8.2 Factors that positively affect the curing of hay.

Environmental factors	Management factors	Mechanical factors
Clear skies	Crop maturity – younger faster	Tedding
Warm temperature	Leaves faster than stems	Conditioning
Low humidity/no rain	Time of mowing	Windrow inversion
Moderate wind speed	Well formed windrow	Raking

Environmental factors

Solar radiation, temperature and wind combine to drive the speed of the curing process (Figure 8.3). However, the speed of curing is also influenced by humidity and rain.

The faster the curing process generally the better as hay quality continues to decline during the curing process. This is because the cut plants respire while their moisture content is above 30%. Respiration is an important part of the drying process but at the same time, plant sugars are broken down resulting in a loss of quality and dry matter. Respiration losses increase rapidly when temperature is above 20°C and can result in dry matter losses of over 15%, compared to dry matter losses of between 2 to 8% when curing occurs in cooler conditions.

Long curing periods make the hay crop more vulnerable to weather damage, resulting in loss of soluble nutrients, bleaching and the development of moulds, stains and taints; all of which impact on hay quality.

After heavy rainfall, leaching can cause dry matter to reduce by 20% of the original crop dry matter. Rain can also cause leaf shatter and regrowth to occur in the windrow.

The latter not only increases the curing time but the potential for green matter to be included in the bales, increasing their moisture and likelihood of moulds developing and even self-combustion.

Generally, the greater the amount of rain, the longer its duration, the lower its intensity and the later it occurs in the curing period, the greater the loss of dry matter and hay quality (Figure 8.4).

Cutting hay on to wet ground should be avoided as the moisture from the ground will move up through the drying hay increasing curing time.

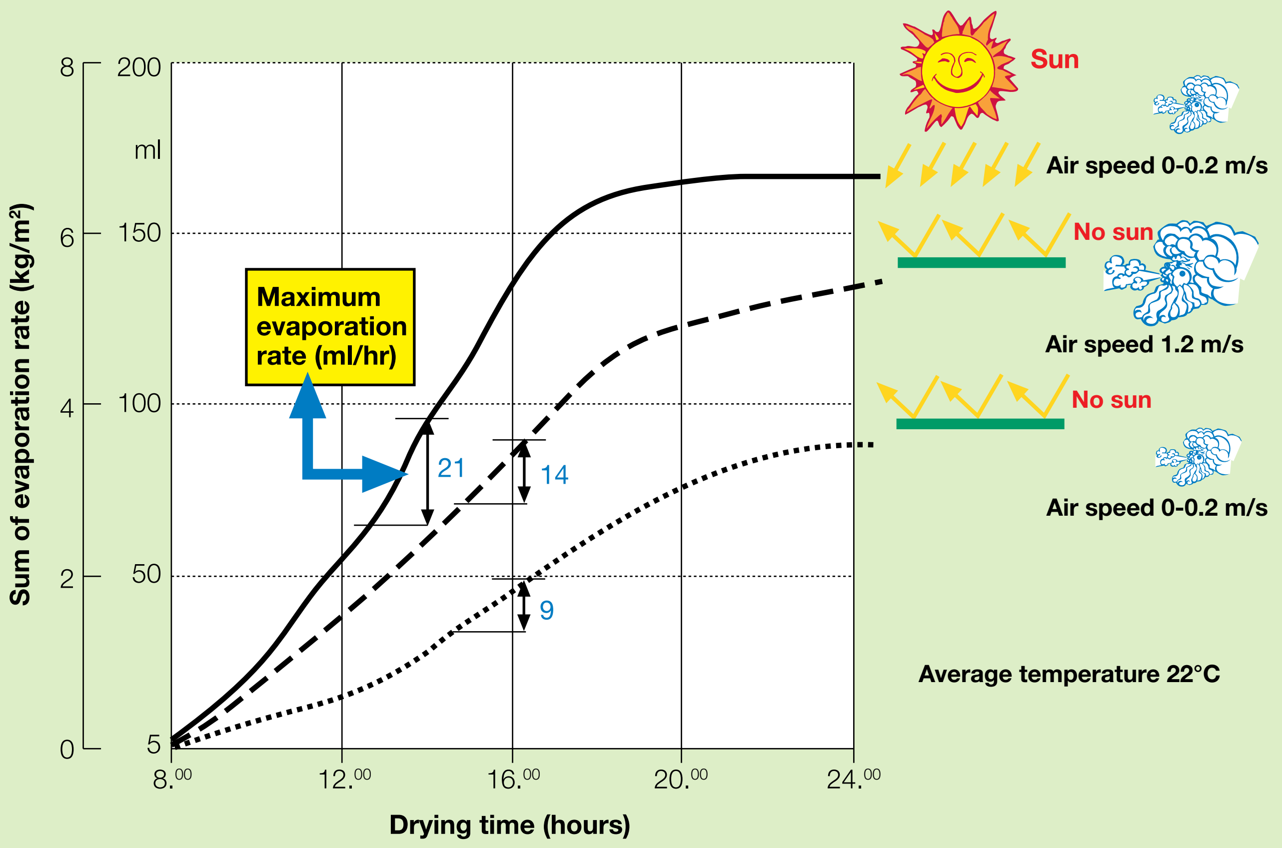

Figure 8.3 Influence of solar radiation and airspeed on evaporation rate of water – *source W. Dernedde 1980.*

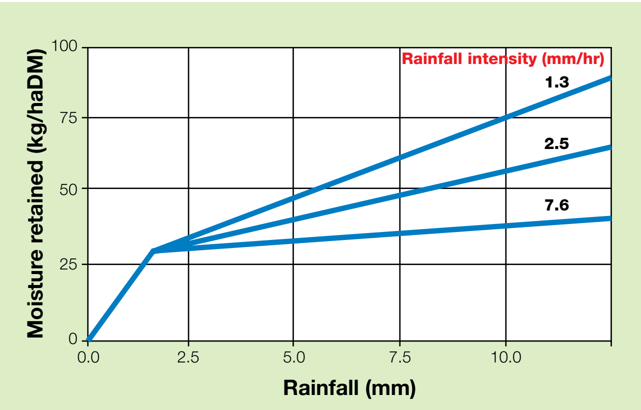

Figure 8.4 The impact of rainfall amount and intensity (rate) on retention of water by mown plants – *source Pitt and McGechan 1989.*
Generally, the greater the amount of rain, the longer its duration, the lower its intensity and the later in the curing period, the greater the loss of dry matter and hay quality. Hay cut after GS71 can deteriorate more rapidly after rainfall than hay cut at or around flowering as maturing stems absorb water more quickly.

Management factors

Of all the management factors, windrow formation has the greatest influence on the curing time. Younger plants cure faster than older plants and leaves dry faster than stems but these factors are influenced by conditioning and windrow formation.

Cutting after dew has dried helps reduce curing times but overall the impact of temperature and wind conditions drives the curing process rather than the hour of cutting.

Windrow shape is a compromise between minimising drying time and minimising weather damage and water entering from moist soil.

A wide, evenly domed windrow allows more penetration of wind and sunlight and sheds rain to maximise the speed of curing and minimise weather damage.

Windrow dimensions may vary between export and domestic hay. A less dense windrow cures more quickly as the proportion of air to cut material is greater. However, a less dense, wider windrow has a greater surface area that can result in more sun bleaching and colour loss. For the export market where colour is a determining factor in the price paid for hay, a narrower windrow is preferable.

The windrow width should be closely matched to the width of the bale pick-up to ensure all material is picked up and the accumulation chamber in the baler is evenly filled. If windrows are too narrow, then the baler operator needs to swerve the baler from side to side as it travels along the windrow to keep the chamber evenly loaded.

Excess cutting speed is often characterised by bunching in the windrows or the formation of a V or U shape in the centre of the top of the windrow. The presence of this windrow shape channels water from rainfall into the centre of the windrow rather than allowing it to be shed to the sides. Where higher operating speeds are required, care should be taken with the shape of the windrow and adjustments must be made to the delivery chute to avoid poor windrow presentation.

Mechanical factors

Tedders

Tedders are commonly used for pasture hay, sometimes used for domestic hay and less commonly used for export hay. Tedders increase the surface area of the hay by spreading a windrow in a thin layer, thereby speeding up the drying process. However, the increased surface area may result in higher levels of sun bleaching.

Tedding hay to improve drying times is less recommended for export hay as it increases the opportunity to pick up soil and other contaminants. Not tedding must be balanced against the opportunity to reduce curing time and maintain feed test quality. Their use for export hay has usually been to spread windrows that have been rained on, to aid the drying process and reduce spoilage.

Conditioning

Approximately 30% of stem water is lost through the leaf, leaving 70% to be lost through the stem and florets.

Conditioning helps accelerate the loss of stem water squashing and crimping the stems and leaves. Super conditioners, which can be run as a separate pass, operate at much higher roller pressures than mower conditioners and provide continuous squeezing pressure crushing nodes and florets rather than crimping stems. Some operators with large hay programs only super condition the first few paddocks to help initiate baling as soon as possible.

Some operators believe super conditioning is essential if drought cereal crops are cut with windrowers or harvester fronts as the panicle is often still in the boot and hard to dry down without crushing.

Water evaporates at 100 litres per tonne per hour, from open stomata on the leaf surface. Squashing stems and abrading leaves by conditioning increases the rate of water loss to between 150 to 180 litres per tonne per hour.

As a rule of thumb, super conditioners can reduce drying time by about 50% compared to normally conditioned hay, however the crop is more vulnerable to rain damage.

A separate pass of a super conditioner after rain can help accelerate curing. The best results are achieved when rain occurs shortly after cutting and no further rain falls.

In good drying conditions, super conditioning can result in hay becoming too dry resulting in poorer bale formation. Therefore, drying conditions and baling equipment must be considered before super conditioning (refer to Bale formation).

Tow behind super conditioners can have roller or finger pick-ups. Generally, roller pick-ups can be operated at higher speed but finger pick-up machines are preferred when the hay is close to the soil surface (approximately 10 to 20mm) for crops on wide row spacing.

Rollers differ in pressure and the degree of fluting from smooth to fine dense flutes. Super conditioners with rollers operating at different speeds or fluted rollers should not be used on drier hay as they can cause 'chaffing'. This type of super conditioner should probably be used closer to cutting time. Conversely, high pressure roller super conditioners can cause excess moisture loss and subsequent mould formation if used too soon behind the mower.

The windrow formed by a super conditioner should have the same domed shape as a mower formed windrow and should not be run over during the formation.

Windrow formation has the greatest influence on the curing time.

A wide, evenly domed windrow (left) improves penetration of wind and sunlight and sheds rain to maximise the speed of curing and minimise weather damage. Excess cutting speed is often characterised by bunching in the windrows or the formation of a V or U shape in the centre of the windrow (right) which channels rainfall into the centre of the windrow.

Super conditioned hay showing crimping and some squashed nodes, both of which help to reduce curing time.

credit Emma Leonard, AgriKnowHow

Windrow inverters

These gently lift and invert the windrow on to dry ground but are generally not found to be as effective as tedders or super conditioners.

Rakes

Raking exposes hay from the centre of the windrow to lower humidity, higher temperatures and sunlight on the outside of the windrow, helping to speed drying. A rule of thumb is that each raking reduces the time from cutting to baling by 10 to 15%. While raking helps reduce curing time, this may come at the expense of some leaf loss, sun bleaching and increased risk of introducing contaminants.

Raking can also aid drying after rainfall but it appears the results are best if the rainfall is relatively light. If the top of the row is dry but the bottom remains wet, then turning the row onto the dry inter-row can help speed drying.

Powered or finger driven rakes are used to combine windrows to create a suitable volume of hay for baling and to reduce inactive baling time. It is cheaper to rake hay than operate a baler with the front only partially filled.

Baling

Baling hay is a crucial part of the hay making operation. Attention to detail is required when assessing hay moisture, atmospheric conditions and checking machinery performance. Bales must be dense and well formed to withstand transport or storage.

Choice of baler

The choice of baler, high density/large squares, round or small squares, will firstly be dictated by market requirements (see Chapter 3) and secondly by the storage, handling and cartage needs. Differences in baler performance usually fall into third place.

Moisture content

Hay baled at over 18% moisture is at risk from damage by mould developing in the bale and spontaneous combustion.

Export markets prefer baled hay with a moisture content of less than 14%; some exporters' standards are as low as 12% moisture. At these low moistures the risk of spontaneous combustion during storage is minimised (see Table 9.1). At these low moisture levels there is a lower risk of condensation occurring during transit that ultimately drips off the container roof back onto the hay, creating wet patches and encouraging mould formation.

High density bales do not dry readily because of low air exchange rates and the insulating qualities of hay. Consequently, bales of 18% moisture may take many months to dry to an acceptable moisture content.

Check with hay buyers before applying any hay additives that support the safer storage of higher moisture hay.

Gazeeka is an Australian designed and manufactured moisture sensor that can be installed in large square balers. This equipment allows bale moisture to be monitored on-the-go and the early identification and segregation of high moisture bales.

Testing moisture content

It is important to test moisture content before baling.

A moisture meter can adequately measure moisture in a tightly bound handful of hay.

The most reliable test is to squash the nodes on a dark, metal surface with a hammer. Check for moisture underneath a squashed node - uncured, nearly cured, fully cured (L to R). If the panicle is still in the boot, squash the boot and assess.

The same handful of hay can be wound rapidly in a circular motion to produce shearing. If by three turns the hay does not break, it may not be sufficiently cured.

Test bales with a moisture meter. If higher moisture bales exist, these are best stored separately and moisture monitored regularly.

Open a stem above and below the node. The inner most leaf inside the stalk can still be moist when the outer stalk appears totally dry.

If there is still concern over bale moisture content, test the moisture in 10 bales which have been left for 12 to 24 hours after baling. Moisture should be under 14% to continue baling.

Well made, dense square bales retain their shape which is crucial for transport and storage.
Bales produced from a high density baler (left) have eight strings and typically weigh over 700-850kg. Traditional large square bales are secured by six strings and weigh between 500-600kg (right).

Bale formation

Poorly made bales will collapse resulting in handling difficulties and wastage. Balers must be set up to produce dense bales and twine should be matched to bale densities as bales with broken strings are unacceptable to the market. The use of net wrap for round bales helps overcome this problem. Matching the width of the windrow and bale pick-up helps in the production of evenly shaped bales.

The introduction of high density bales has increased bale weight from about 600kg to up to 850kg per bale. This is helping reduce transport and storage costs (see Figure 9.1) as more bales can be loaded into the same area. At publication, the Australian Fodder Industry Association (AFIA) is working with regulatory authorities to address transport issues relating to high density bales.

For large square bales, hay is picked up and fed by finger tines into the accumulation chamber. High density square bales can have knife cutters after the pick-up that chop the hay into short lengths which can be packed more densely. Check with hay buyers if they require high density bales to be chopped.

For both types of baler, the aim is to maintain the uniformity and density of hay in the accumulation chamber, so that it packs evenly into the bale chamber. Slower ground speeds result in the hay being more densely packed in the accumulation chamber, which can help overall bale density.

When the accumulation chamber is full, the hay is discharged into the bale chamber as a distinct wad or biscuit of hay. For well formed dense large square bales, successful baler operators indicate setting machines to produce 38 to 40 of these wads per bale, while other industry participants suggest 32 is

Bale stacking systems can help reduce the time required to remove hay from the paddock.

satisfactory. Any less and the bale can lack density and be poorly shaped. Any more exerts excess pressure on strings, increasing the chance of breakage.

Hay that is baled too dry has lower density in the accumulation chamber and does not retain its shape in the bale chamber. This can result in poorly shaped, light bales with excess pressure on strings.

Innovations to allow the baling of drier hay or baling when atmospheric conditions would normally stop baling include the use of metal wedges in the bale chamber; extended bale chambers; and water or steam sprayed on to the sides of the bale in the chamber to increase the friction between the bale and the chamber.

If hay is too damp, it feeds unevenly and creates areas of high density. Excess moisture cannot be released from the bale and wet patches can occur.

Square bales can be discharged directly from the rear of the baler or can be turned 90 degrees so when discharged, the bale rests on the cut side, rather than on the strings. This offers the advantage that the less dense part of the bale, which dries more quickly, is exposed to soil moisture and rain. If this face is damaged by moisture, it can be removed by a guillotine.

Several bale stacking systems are now on the market, some directly towed by the baler, others stack as a separate operation.

Making round hay bales is generally more forgiving than for large squares as bale density is lower. This allows hay to be baled at higher moisture with lower risk of spontaneous combustion (see Table 9.1) and a much greater ability to dry due to air movement and evaporation within and between bales. However, bales should still be robust and should not lose their round shape after being discharged from the baler.

Sampling and tagging

The accuracy of nutrient analysis depends on the sample sent to the laboratory. It is critical that the sample represents the average composition of the hay 'lot' sampled, otherwise the laboratory tests will not be useful.

A 'lot' is defined as hay taken from the same cutting, at the same stage of maturity, the same species (pure or mixed) and variety, the same paddock, and baled within 48 hours. Other factors influencing the definition of a 'lot' include rain damage, weed content, soil type, treatment after cutting and storage implications. A 'lot' of baled hay should not exceed 200 tonnes.

Sampling hay

Representative hay samples can only be obtained with a probe or core sampling device. A couple of handfuls or a 'flake' from one bale are not adequate. Corers are commercially available in Australia. Alternatively, corers can be made using 32mm steel tubing, and should be at least 450 to 500mm long with a slightly scalloped, sharp cutting edge. Corers are driven by a hand brace or an electric drill (where practicable). Some cordless drills may not be suitable if they lack power or turn too fast. A portable generator is useful and can be justified if many samples are taken.

Sample size should be confirmed with the hay buyer or testing laboratory. More details about sampling by bale type are found on the AFIA website (www.afia.org.au).

Small square bales

Sample between 10 and 20 small square bales, selected at random from the 'lot'. Take one core from each bale selected, probing near the centre end bale (small face), at right angles to the surface. Ensure that the corer does not become hot. Combine all cores into a single sample in a bucket, and mix thoroughly. The whole sample should be kept intact and not subdivided.

Large round or square bales

Sample between five and 10 large bales, selected at random. Take one core from each side of all bales selected, probing at right angles to the surface at different heights. Combine all cores into a single sample in a bucket, and mix thoroughly. The whole sample should be kept intact and not subdivided.

Sample handling

Immediately after sampling and mixing, the final hay sample should be placed in a robust (preferably 'press-seal') plastic bag and tightly sealed to exclude air. This is to ensure that the laboratory report of dry matter will approximate the dry matter content of the 'lot' when sampled, and to minimise aerobic spoilage.

Samples must be delivered to the laboratory as quickly as possible after being taken. Avoid mail delays over the weekend by posting samples early in the week. Ensure that the laboratory's instructions for labelling samples are closely followed and all the required details on the sample submission sheet are completed.

Identification and traceability

Hay exporters are required to demonstrate sampling, testing and tracking of hay in the export pathway. Speak to your hay buyer about identification requirements.

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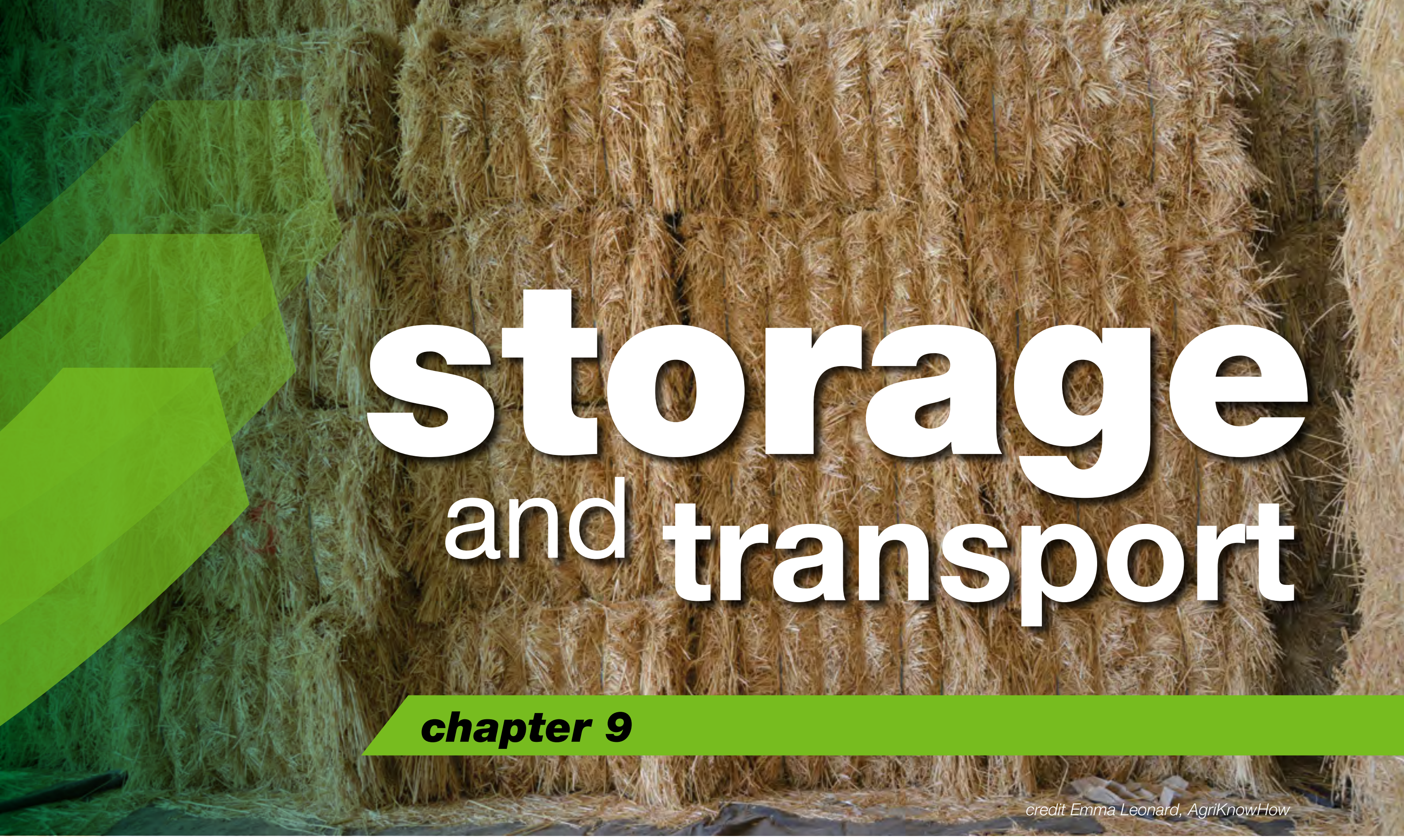
Individual bale identification helps hay exporters track hay along the export pathway.

credit Emma Leonard, AgriKnowHow

A ute mounted hay sampler as used by many export hay buyers.



storage and transport

chapter 9

credit Emma Leonard, AgriKnowHow

Hay can be stored for long periods of time with little reduction in quality, providing the hay is in dense, well formed bales and remains dry and free from damage by vermin.

Left outside and unprotected, hay will degrade and a substantial proportion of the bale can be wasted due to the formation of moulds. For example, 33% of the total volume of a 2m round bale is in the outside 15cm and nearly 60% is in the outside 30cm.

Storage requirements

For short periods of time, especially if rain is anticipated, large square bales for export can be stored on their narrow end in the paddock, in order to minimise weather damage. Otherwise, export hay must be stored so that it is protected from sunlight, rain and wind, ideally in a fully clad shed. Export hay buyers generally pay a premium for hay stored in a shed.

Any shed openings should be away from the prevailing weather and the roof and walls must be secure and leak free. The floor should either be concrete, bitumen or covered with heavy duty black plastic sheeting to prevent moisture rising into the bales. Rubble floors should be avoided as they allow moisture to penetrate bales and stones and dirt can become lodged in the bales.

The shed's gutters and downpipes must divert water away from the shed and water must be prevented from flowing back to the base of the stored bales.

Bales from the perimeter of the paddock should be stored together as these may be tested separately by the export hay buyer.

The criteria for storing export hay will also maintain the best hay quality for the domestic market. However, hay for the domestic market may be baled at higher moisture content making it more susceptible to spoilage and combustion (Table 9.1).

Table 9.1 Recommended moisture content for safe storage of various types of hay bales *– source DEDJTR.*

Bale type	Moisture content range (%)
Small rectangular bales	16-18
Round bales - soft centre	14-16
Round bales – hard centre	13-15
Large square bales	12-14
Export bales	Less than 12

Storage options

There are multiple storage options and selecting the most suitable option will depend on a variety of factors (Table 9.2), including costs (Figure 9.1).

These factors include:

- timeframe of storage;
- available capital;
- frequency of loading in and out;
- distance to existing storage; and
- customer requirements.

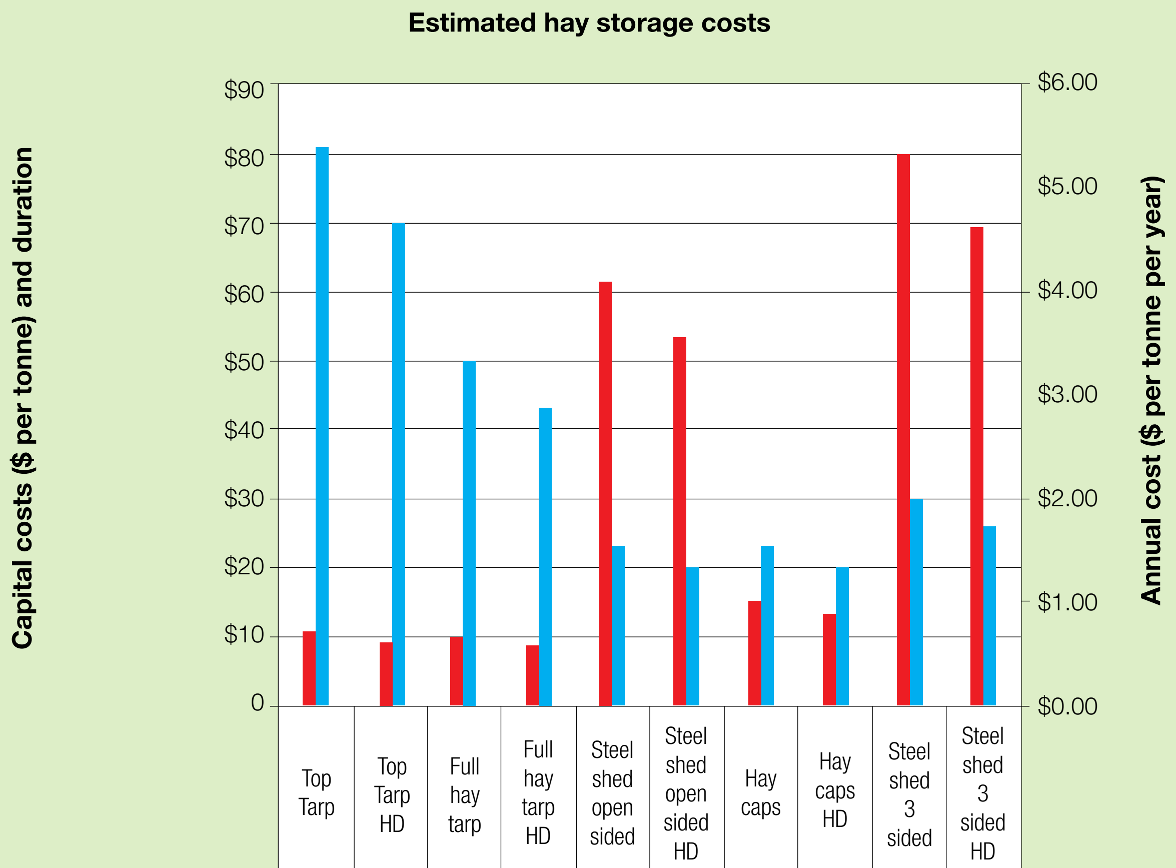
Table 9.2 Hay storage options pros and cons – three stars is the best outcome, one star the poorest – *source AFIA.* This Table excludes emerging technologies such as breathable materials for individually wrapping bales to provide about 18 months of protection from rain and ground moisture.

Storage factor	Top hay tarp	Full hay tarp	Steel shed 3 sides	Steel shed open sided	Hay caps
Capital cost per tonne	***	**	*	*	**
Durability	*	*	***	***	**
Annualised cost per year	**	**	**	***	***
Top layer waterproof	*	**	***	***	**
Seepage from beneath	*	***	***	***	*
Side bleaching	*	***	***	**	*
Labour required at stacking	**	*	***	***	**
OH&S during stacking	*	*	***	***	***
Freight savings from paddock	***	***	*	*	***

Causes of heating in hay

For a hay stack to combust, it must undergo a process of self heating that even now is not fully understood. However, it is known that several sources of heat can contribute to the process.

Spontaneous fires in stacked hay generally require five to 10 weeks for sufficient heat to be generated. Under ideal conditions of moisture and high ambient temperatures, ignition has been observed in six or seven days after stacking. Stacks should be continuously monitored.



	Top Tarp	Top Tarp HD	Full hay tarp	Full hay tarp HD	Steel shed open sided	Steel shed open sided HD	Hay caps	Hay caps HD	Steel shed 3 sided	Steel shed 3 sided HD
Capital cost per tonne	$10.77	$9.33	$9.96	$8.63	$61.54	$53.33	$15.38	$13.33	$80.00	$69.33
Duration years	2	2	3	3	40	40	10	10	10	10
Annual costs /t/yr	$5.38	$4.67	$3.32	$2.88	$1.54	$1.33	$1.54	$1.33	$2.00	$1.73

Figure 9.1 Estimated hay storage costs for large square bales compared to high density (HD) bales which are the same size but approximately 10% heavier – *source AFIA 2016.* The storage costs exclude the cost of labour and logistical inputs required for each option. Year on year the cost of sheds appears to have decreased.

credit Emma Leonard, AgriKnowHow

Primary heating

Respiration and biological

Respiration of freshly cut plants and subsequent bacterial action cause bale temperature to increase to a maximum of between 48 to 70°C (Figure 9.2).

Partially cured hay (moisture content between 12 to 21%) is the most prone to fire due to biological heating. This will heat the hay to the thermal death point of the organisms involved; that is in the vicinity of 70°C.

In dry years, water soluble carbohydrate (WSC) levels of cereal hay tend to be higher (>20%) and even hay baled at about 15% moisture has self-combusted.

If the hay is well cured, it will not allow this destructive fermentation to occur. Conversely if too wet, not enough oxygen can diffuse into the mass and no fire will occur.

When the heating hay is located on the outside of the stack, where the heat can dissipate, the process may very well stop here. However, if the heating is located at the bottom or inside of the stack then the heat may continue to build.

Regardless of how well the heated hay is insulated, temperatures of 70°C fall far short of the ignition point of hay, which is in the vicinity of 280°C with minimal air (Figure 9.2).

Secondary heating

Exothermic

Once hay reaches the limit of the primary heating (70°C), the exothermic process can be initiated to raise the temperature much higher.

Theories about this process include the production of pyrophoric carbon, pyrophoric iron, heat from enzyme action and even the auto-oxidation of the oils contained in seeds. This process is generally accompanied by the production of much acid in the early stages and is accompanied by a marked browning of the hay.

If insulated, this process can progressively raise the temperature inside the stack to 240 to 280°C at which point the slightest introduction of oxygen will result in the ignition of the stack.

Some research has shown that hay does not need to reach such high temperatures to ignite spontaneously. If hay is subjected to long periods of heating at temperatures as low as 88°C and remains in the presence of volatile gases produced by oxidation, it may ignite when air is introduced. In other words, a relatively low temperature for long periods may have the same effect on hay as high temperatures for short periods.

Combustion occurs in two different ways, in a hot pocket of carbonised hay or in a larger volume surrounding the hot pocket.

Monitoring - a simple test

The temperature of a stack may be checked with a 'temperature probe', a crowbar or other piece of steel. The bar should be left in place and checked regularly (Figure 9.3). Pipe or tubing should NOT be used as this may entrain air into the stack and cause ignition to occur.

Infra-red thermal images only show temperature differences on the surface of the stack.

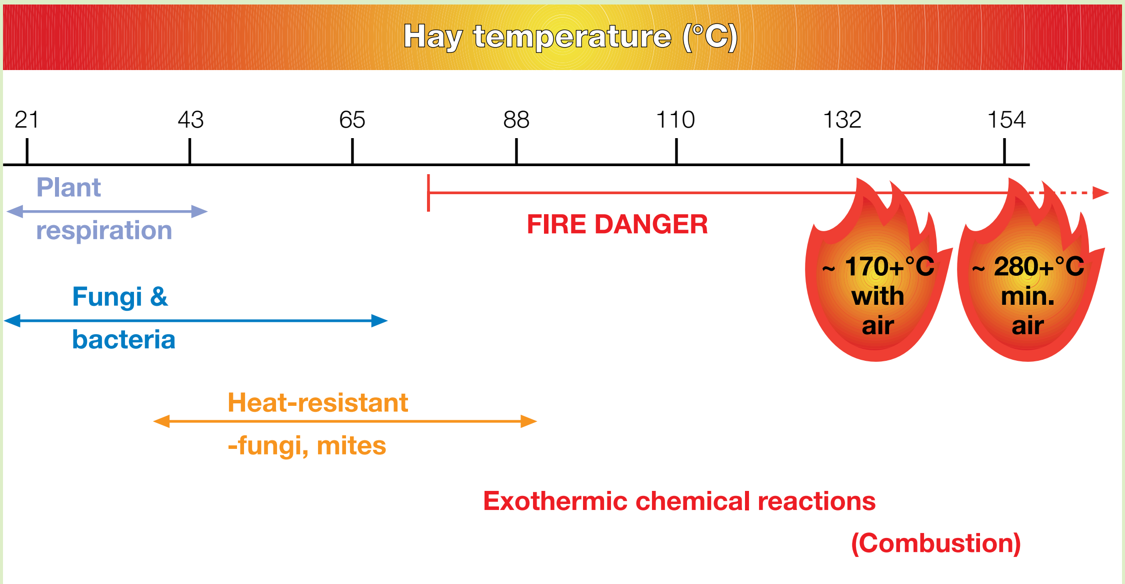


Figure 9.2 Causes of heating in hay *– source C Sheaffer & N Martin.*

Any stack that is known to be heating should be checked even more regularly to determine if temperature is rising or falling. If the stack continues to heat the only solution is to pull it apart. Bales that have reached a high enough temperature may spontaneously combust as they are introduced to a more available oxygen supply. Water and fire fighting equipment should always be on hand to extinguish a possible fire.

Hay transport

It is the responsibility of the vehicle owner, manufacturer or operator to ensure the safe performance, fitness for purpose and regulatory compliance of any vehicle in relation to the state or territory in which it is operated.

Push the crowbar into the stack and leave for ~ 2 hours

After 2 hours remove	Temperature (°C)	Action
Can handle bar without discomfort	<50	Check temperature daily.
Can only handle bar for short time	50 - 60	Check temperature twice daily. Remove machinery from shed.
Can touch bar only briefly	60 - 70	Check temperature every 2-4 hours. Carefully move hay to improve air flow. Have fire unit on hand.
Bar is too hot to hold. Potential for fire.	>70	Call Fire Brigade immediately. Avoid walking on top of haystack.

Figure 9.3 Testing the temperature within a hay stack *– source Victorian Department of Primary Industries.*

The majority of these documents can be found on the website of the National Heavy Vehicle Regulator (www.nhvr.gov.au) on the Transitional notices or state HVNL notices pages.

In 2016, each state and territory has its own regulations regarding the transport of hay. The Australian Fodder Industry Association (AFIA) is working to develop a set of national standards for the transport of hay.

A summary of the regulations can be found on the AFIA website transport page (http://www.afia.org.au).

Bale orientation

Round bales are less dense than squares, so properly stacked and restrained loads of round bales tend to be more stable than square bales stacked to the same height.

The load stability of large square bales can be improved if they are stacked with the strings around the sides and the knots to the centre. This is because the bales tend to lean into the centre of the trailer due to a natural thickness bias in bales being thinner near the knots. This method of loading also means bales are loaded in the same orientation as they were stored on-farm, so any compression or settling of the bales over time is not disturbed by loading on their sides.

For export hay, the tags attached to bale strings can be readily inspected on the laden vehicle, when stacked in this manner.

Load restraint

The method of load restraint has been shown to have a measurable effect on vehicle stability. The importance of load restraint is more than simply keeping the load on the vehicle. The shift of a load's centre-of-gravity that results from the movement of poorly restrained loads (either in the fore-aft or lateral directions) impacts on vehicle performance, because it causes a change in the load distribution between all tyres of the vehicle.

Lateral load shift brings about a small amount of load transfer from the tyres on one side of the vehicle to the other. Fore-aft (or longitudinal) load shift brings about a change in load distribution between axle groups, which can affect roll stability and braking performance.

Load restraint guidelines can be found on the National Transport Commissions website (http://ntc.gov.au/) and are summarised in AFIA document - Assessment of Vehicles for the Transport of Hay and Straw on the AFIA website (www.afia.org.au).

A commonly accepted threshold for safe lateral load shift is 100mm. Research conducted by Roaduser Systems Ltd and funded by the Rural Industries Research and Development Corporation (RIRDC), showed that the maximum lateral movement for all of the properly restrained loads tested is less than 100mm. The load shift at the centre-of-gravity is less than 50mm, which represents a movement of about 3% of the axle track width. Longitudinally, this equates to an effective centre-of-gravity shift of about 300mm based on trailer wheelbase.

This research also found that there are small but worthwhile benefits gained by using more effective load restraint methods such as double-strapping or 'double-dogging' of single straps (one load binder on each side of the load for a single strap).

It was found that the use of a diagonal bracing strap provided an enormous improvement on load stability (Figure 9.4). The research recommends that diagonal bracing straps are used for securing all groups of bales on a semi-trailer, two per group of bales, at opposing angles.

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Figure 9.4 The use of a diagonal bracing strap improves load stability. Diagonal bracing should be considered for at least the front and rear groups of bales on a trailer, with thebracing pulling towards the centre of the trailer. Diagonally bracing all groups of bales with two straps is also acceptable *– source ARRB Group, 2006.*

credit Emma Leonard, AgriKnowHow