Improved oat varieties
for hay production 2020

by Dr Pamela Zwer
March 2021
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The evolution of breeding improved oat hay varieties in Australia 1998 to 2020

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Foreword

The Australian Fodder Industry makes a fundamental contribution to the Australian economy, with an estimated value of $1.75 billion at farm gate. Oat hay is a significant proportion of both export and domestic markets, with growth particularly in the export sector. Exports of hay varieties developed by the South Australian Research and Development Institute (SARDI) were a record 638,870 tonnes (t) in 2017/18 and total hay exports reached 954,000 t. Growth in the order of 10% per annum has occurred as markets, particularly in China, increase. Japan is still the primary market, but new markets in China and the Middle East (United Arab Emirates) spur growth in this industry. The export hay industry is worth more than $200 million annually and is the primary source of industry funds for this research.

With the continuing expansion of the export oat hay industry and a more discerning domestic market, there is increased demand for high-quality oat hay varieties with adaptation across a range of environments. New varieties underpin this industry and provide stability for growers. In addition, as the industry becomes more sophisticated, new quality parameters are emerging that need to be incorporated into new varieties. To provide growers, exporters, and consumers with the desired hay quality and quantity, oat variety development for hay end use is essential to maintain Australia’s competitive advantage.

This research project marks the end of the National Oat Breeding Program led by SARDI to improve oat varieties for hay production. There are three advanced breeding lines that will become available after the close of the program. These releases have not been named, but it is expected the first release will be available to growers in 2022.

This project was funded from industry revenue, which is matched by funds provided by the Australian Government.

This report for Export Fodder Program is an addition to AgriFutures Australia’s diverse range of over 2000 research publications and it forms part of our Growing Profitability Arena, which aims to enhance the profitability and sustainability of our levied rural industries.

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About the author

Dr Pamela Zwer has 41 years’ experience in small grain breeding. She received her PhD from the University of California, Davis and undertook a postdoctoral fellowship at the University of Sydney Plant Breeding Institute. Pamela accepted her current position, Principal Plant Breeder at the South Australian Research and Development Institute (SARDI), in 1995. She has been involved with the release of five wheat varieties and 22 oat varieties. Pamela leads the National Oat Breeding Program, which has released nine milling oat varieties (three dual purpose) and eight oat hay varieties.

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The National Oat Breeding Team would like to acknowledge growers and industry from SA, WA, VIC and NSW; Australian Exporters Company (AEXCO); AgriFutures Australia; South Australian Research & Development Institute (SARDI) and Department of Primary Industry & Regional Development WA (DPIRD) for supporting this world class research program.
Abbreviations

ADF – acid detergent fibre
AEXCO – Australian Export Company
BYDV – barley yellow dwarf virus
CCN – cereal cyst nematode
CP – crude protein
DIG – digestibility
Dom30 – digestible organic matter after 30 hours
DPIRD – Department of Primary Industry & Regional Development WA
GRDC – Grains Research & Development Corporation
NDF – neutral detergent fibre
NSW – New South Wales
SA – South Australia
SARDI – South Australian Research & Development Institute
SE – shear energy
SN – stem nematode
VIC – Victoria
WA – Western Australia
WSC – water soluble carbohydrate
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Executive summary

What the report is about

This report summarises the research conducted in the National Oat Breeding Program from January 1998 to December 2020. The report is a historical perspective of the creation and development of the first dedicated oat breeding program for improved hay varieties globally.

Who is the report targeted at?

This report should be read by growers, industry participants and researchers in Australia and overseas who are interested in how the development of improved oat varieties for hay production evolved in Australia.

Where are the relevant industries located in Australia?

Hay producers are distributed throughout the southern region of Australia. Current oat hay exports are close to one million tonnes (t) per annum, with an expected market growth to 1.8 million t in the next few years. Investment in new processing plants and increased capacity in current facilities show the strength of the industry and potential for growth. Meeting demand for export hay will require higher hay yield and hay quality, but also will allow growers in non-traditional oat growing regions an opportunity to produce hay for the export market. Currently, SA and WA produce most of Australia’s export hay. Of the 638,870 t of SARDI-bred hay varieties exported in 2017/18, SA produced 46%, VIC and NSW produced 33% and WA produced 22%. These numbers reflect a lower uptake of SARDI varieties in WA. Production in VIC will increase because of two new hay processing plants built in 2019. Hay for the domestic market is produced in the southern region of Australia for dairy and beef industries.

Background

With the expansion of the export oat hay industry, there is increased demand for oat hay varieties with adaptation across a range of environments and an increasing focus on quality. A National Oat Breeding Program was initiated in 1998 to meet the challenge of improving oat varieties for hay production in the southern region of Australia encompassing WA, SA, VIC and southern NSW. The National Oat Breeding Program was based at SARDI’s Waite Campus, with a selection program, technical staff, and centre for oat quality research. Technical staff were also located in DPIRD at South Perth and then Northam. Hay trial sites were in WA, SA, VIC and NSW.

Aims/objectives

The National Oat Breeding Program aimed to provide growers in traditional and non-traditional oat growing regions oat varieties with high gross margins. Traits to achieve the aim were high hay yield potential, enhanced hay quality and combinations of disease resistance. The release of improved oat hay varieties was essential to meet grower, exporter and consumer expectations. This was achieved by developing and characterising new oat varieties for the major oat hay growing regions. Consulting growers and industry participants who had been constrained when using past varieties assisted with the development of breeding priorities, resulting in the rapid uptake of newly released varieties. Customers of export oat hay also benefited by having a consistent fodder product.

Methods used

The National Oat Breeding Program was based on classic plant breeding methods, with grower, industry and consumer input into developing breeding priorities and selection criteria.
Results/key findings

During the 22 years of breeding improved oat varieties for hay production, advanced breeding lines were promoted to yield trials based on hay productivity, hay quality, disease resistance and agronomic traits. There were eight hay varieties released as part of the program on a shoestring budget, with an average of 2.8 years between releases. An additional four varieties released from the milling grain stream have become popular for hay production. Three advanced breeding lines are in breeder seed production, with the first commercial seed increase in 2021.

Implications for relevant stakeholders

The release of oat varieties suited to oaten hay production by the extended SARDI-led National Oat Breeding Program has seen widespread industry uptake of these varieties. This has been particularly evident in high-export fodder-production areas in SA, WA and VIC, which is reflected in delivery of product to processing plants.

With the release of an additional three varieties and the recent release of Koorabup targeted for WA, the numbers will increase in coming years, despite the end of the SARDI-led National Oat Breeding Program.

Recommendations

The continuation of the National Oat Breeding Program’s work is essential for the development of the export fodder industry. This is particularly important given that no other breeding program focuses on developing the quality traits associated with oaten hay production. Future research and development for new oat hay varieties should include development of quality assessment technologies that can help speed up variety development through assessment of quality traits during the development stage.
Introduction

The SARDI Oat Breeding Program prior to 1995 was breeding improved oats for milling and feed end uses for SA and VIC. A fledgling oat hay export industry was emerging at this time, with about 170,000 t primarily delivered to Japan. Oat hay exports had increased to almost 400,000 t per annum by 1999, mostly produced in SA and WA. The varieties being grown in SA were two direct releases from the Quaker Oats International Oat Nursery (permission granted from breeder), Bettong and Glider. Two varieties, Marloo and Wallaroo, with cereal cyst nematode resistance and tolerance, were released by the program prior to 1995 and grown for hay production in SA. Popular varieties grown in WA were developed for grain production but adopted by the hay industry. These varieties were Swan, Carrolup, Vasse, and Winjardie. Market expansion was dependent on producing first-grade palatable hay. It was emerging that certain varieties, such as Bettong, were not as palatable as others. An Export Oat Hay Industry meeting with SARDI scientists and hay exporters Balco and Gilmac in April 1997 discussed areas for collaborative research. The meeting identified breeding oat varieties dedicated to hay production, agronomic management to enhance hay yield and quality, annual ryegrass toxicity (ARGT) threats, and nutrition as priority research areas. Hay quality and nutrition had not been defined at this time, but discussions focused on feed intake, sweetness, and digestibility.

In 1997, the first project was submitted to the Rural Industries Research and Development Corporation (RIRDC) to fund oat hay variety development, with funding starting from January 1998. The project aimed to generate new oat populations and identify selections with improved hay end-use characters, based on breeding priorities identified by growers and hay processors, by 2000. Germplasm for crossing was sourced from North Dakota and Iowa, USA; Saskatoon, Canada; Quaker International Oat Nursery; Japan; Brazil; and France, and 160 crosses were made using 63 introduced lines during the project. F2, F3, and F4 populations were developed during the first project. Advanced breeding lines were evaluated in hay trials for agronomic data, disease reactions, and quality. As part of a collaboration with hay quality research previously undertaken by CSIRO in WA, they provided Near Infrared (NIR) predictions for digestibility, crude protein, shear energy, water soluble carbohydrates, acid and neutral detergent fibre data for 12 varieties and lines. Two advanced breeding lines were identified for release, 88083-4 and 87103-109, which became Wintaroo and Brusher, respectively.

Prior to the release of Wintaroo, the first variety commercialised for hay production, the Australian Exporters Company (AEXCO) was formed. By 2000, five major hay processors in SA and WA were working with the Australian Field Crop Association to develop a commercialisation plan for new hay varieties. Currently, 13 exporters are members of AEXCO, representing 100% of the export industry.

During the last 22 years, RIRDC/AgriFutures Australia has provided funding for 10 projects: SAR-8A, SAR-31A, SAR-50A, PRJ-000440, PRJ-002298, PRJ-003482, PRJ-007615, PRJ-011408, PRJ-011967 and PRJ-012613. The projects delivered eight hay varieties, with three milling varieties considered dual purpose. The delivery time averages 2.8 years between hay variety releases (not including dual purpose).

Today, the industry exports more than one million t of hay per annum. Export oat hay has become an essential component of the long-term profitability of cropping systems for many Australian growers. For example, gross margins in central Victoria are often $500 to $1200 per hectare. In addition, benefits to the grower are control of resistant ryegrass, an option as a break crop, and an opportunity to recover higher value compared with a grain crop during frost or drought. In addition, the production of oat hay can provide growers with an earlier cash flow compared with grain only.
Objectives

Over the years, the major goal of the National Oat Breeding Program and the industry has been to develop improved oat hay varieties for production in southern Australia, including SA, WA, VIC, and southern NSW. Initially, there was emphasis on introducing germplasm from overseas with traits prioritised by the export hay industry. Variation for phenology was then introduced to develop a range of maturities in the Australian gene pool. Breeding lines with late to very late maturities were part of the early generations and in 2005 stage 4 late hay trials were sown for the first time. Every project emphasised industry interaction in the breeding program to ensure priority traits were the basis of variety improvement. Higher dry matter (dm) production while maintaining good quality in traditional and non-traditional growing regions is essential to provide consistent product in a market exporting more than one million t of oat hay annually. This has been an ongoing objective of research projects.
Methodology

The National Oat Breeding Program was centred at the SARDI’s Waite precinct, with a node at the Department of Primary Industries and Regional Development (DPIRD) in WA. The WA node was located at South Perth until 2015 when it moved to Northam.

Plant breeding methods were developed based on oat genetics, funding, resources and priority traits. The flow of early and advanced generations has remained stable over the years, with the major changes reflected in site location for disease nurseries and yield trials. Most of the site changes were in WA, where rye grass was an issue in field trials and disease nurseries.

Crossing and early generation management

The crossing program took place in the glasshouse, with about 600 pots containing parental lines sourced from the SARDI program and introduced germplasm sourced primarily from the USA, Canada, the UK, Brazil and the Quaker International Oat Nursery. About 2,000 crosses were done for hay improvement over the years. Both crossing and early generation development occurred at SARDI. Crosses were designed based on breeding priorities. The F1 seed was grown in the glasshouse to produce F2 seed. Turretfield Research Centre (TRC) was the main research site where F2, F3, and F4 populations were sown. F2 seed was sown in plots to produce bulk F3 seed. The F3 was sown in plots with low seeding rates for panicle selection from different plants, sampling the genetic variability generated from the crosses. The number of panicles selected in F3 populations was based on visual characters and usually numbered 200 to 250 per cross. The panicles were sown to produce F4 headhills. Headhills were selected based on disease resistance, lodging and shattering resistance. F5 seed from headhills underwent weighing and when sufficient grain had grown, it was sown in stage 1 (S1) trials in SA and WA. When there was insufficient grain for two locations, crosses with WA germplasm were only sown in WA. Stage 2 (S2), stage 3 (S3) and stage 4 (S4) trials were sown in SA and WA.

Stage 1 trials

Breeding lines in S1 trials were F5 and sown in plots about 2.5 m long due to limited seed production from headhills. Both hay and grain lines were sown and not separated into hay and grain trials until S2 trials. S1 trials were sown at TRC in SA and selected S1 trials were sown at one location in WA. The locations over the years in WA were Wongan Hills, Katanning, Pingelly, Brookton and currently Highbury. Although they are different sites, they are all in the main oat growing region of WA, except for Wongan Hills Research Centre. The S1 trials were moved from the research centre to Katanning because it did not represent the oat growing region. No hay cuts were done in S1 trials, but notes for height, maturity, disease resistance, lodging, and shattering were collected. Separation into hay trials was based on pedigree, height, plant colour, and lodging resistance.

Stage 2, 3, and 4 hay trials

S2 and S3 hay trials were sown to collect data on height, disease resistance, plant type, colour, lodging resistance, grain yield and grain quality. They were not cut for hay yield and quality due to resource constraints in the early programs. Genetic gain for improved hay yield and hay quality was low due to the inability to evaluate these traits at earlier generations. It wasn’t until 2002 that S3 hay trials were cut for hay yield and quality at Kingsford, SA (neighbouring property to TRC). Funding resources were tripled, which allowed additional cuts at one site. Funding was also sourced primarily from SARDI and the Department of Primary Industries and Regions SA (PIRSA) to purchase a forage harvester, which was delivered in 2004. For the first time in 2004, S2 trials were cut at Kingsford for hay yield and hay quality assessment. The export industry was keen to have an adapted late hay
variety to replace late varieties introduced from North America. Crosses were made to introduce late
maturity, and in 2005 there were enough lines to create a S4 late hay trial.

The Oat Breeding Program became national in 2003 with the establishment of a breeding node in WA
at the Department of Agriculture and Food WA. The WA Oat Breeding Program focused on
developing grain varieties, so for the first time the National Oat Breeding Program had a mandate to
improve oats for both hay and milling in WA.

After 2005 S2, S3 and S4 hay and late hay trials were sown at TRC, Pinery and Riverton in SA for
grain yield and grain quality assessment. Separate S2, S3 and S4 hay and late hay trials were sown at
TRC and the whole plot was cut for hay yield and quality assessment. S4 hay trials were cut for hay
using quadrats at Pinery and Riverton, and at Riverton a S4 late hay trial was also cut for hay yield
and quality assessment using quadrats. S2, S3 and S4 hay trials were sown at three locations each year
in WA after 2003, but locations varied over the years due weed contamination issues. Katanning,
Mount Barker and Wongan Hills were selected early in the program for hay trials. Rylington Park
in 2017, but this site was replaced with Highbury in 2019. A new site at Cunderdin in 2015 evaluated
breeding lines in a low rainfall WA environment. The S2 and S3 trials at all trial sites except TRC
were for observation, grain yield and grain quality assessment. Selected S4 hay trials were cut for hay
yield and quality assessment in WA.

Stage 5 (S5) trials, comprising a subset of S4 hay trial entries retained in the S4 hay trial for two or
more years, were sown at additional sites in WA, VIC and NSW to gain more hay yield and hay
quality information about lines close to release. Two S5 hay trials were sown in VIC at Elmore and
Horsham and one trial was sown at Finley in NSW. Seed increase for SA yield trials occurred at
Wasleys and WA seed increase occurred at Wongan Hills. Agronomic characters, disease resistance,
grain yield and grain quality were evaluated in these trials, with hay yield and quality assessed at
selected sites.

**Trial design**

Experimental design has not changed for S3 and S4 trials over the years. New advances in partially
replicated designs (p-rep) were important for improving efficiency in the larger S1 and S2 trials. P-rep
required less land and increased the robustness of the statistical analyses by having some entries
replicated at one site and other entries replicated at other sites.

**Hay cutting methods**

Initially, hay was cut by hand using quadrants. Once the forage harvester arrived, TRC was cut using
the machine and quadrants were cut by hand at all other sites in SA and WA. Both methods require
plants to be cut at ground level for consistency in cutting height for hay yield and quality. The trials
consisted of 5.0 m x 1.3 m plots, with entries replicated. The cuts were done at an industry standard
growth stage, Zadoks 71, watery ripe. This required at least four visits to each site to cut at the same
growth stage. In method one, the entire plot was cut, weighed and a sub-sample taken, whereas for the
second method, two 0.5 m² quadrants were cut in the plot, weighed and a sub-sample taken. Sub-
samples were oven dried at 60° C for both methods. Hay yield was calculated by dry weight
(grams)/wet weight (grams) = moisture percentage. Total wet weight (grams) was multiplied by
moisture percentage and converted to kilograms per hectare by conversion factors calculated for a 0.5
m² quadrant and a 5.0 m x 1.3m plot. All S4 trials were sampled using quadrants except TRC. The S2,
S3 and S4 trials sown at TRC were all cut with the forage harvester.

**Disease resistance and tolerance assessment**

Controlled disease nurseries were an important part of the selection process. A septoria nursery was
established at Mount Barker after the program became national. Septoria is the major disease
constraint in WA. The septoria nursery was inoculated with infected straw to encourage uniform disease development. Rye grass was an issue at Mount Barker, so the disease nurseries were moved to a high rainfall site, Manjimup WA. Breeding lines from S2 to S4 were assessed in the nursery. Infection was uniform and valuable information was obtained for septoria reactions each year. A separate barley yellow dwarf virus nursery (BYDV) was sown at Manjimup WA to assess entries in S2 to S4 trials. The trial was sown to encourage natural infection of BYDV by aphids. Infection was also uniform in this nursery and valuable notes collected each year on BYDV reactions. Another trial was sown at Manjimup from 2013 to assess leaf rust resistance. The trial was inoculated with leaf rust spores grown in the glasshouse. A rust nursery was sown at Carnarvon each year and inoculated with stem rust. Infection was also uniform in this nursery and valuable notes collected each year on stem rust reactions. Services were purchased from the SARDI Plant Pathology Group to provide cereal cyst nematode (CCN) resistant reactions for S1 and S4 lines. A stem nematode nursery at Farrell Flat was sown in 2012 to evaluate stem nematode tolerance. The nursery was managed on a grower's property to encourage stem nematode reproduction, however difficulties with the site meant we had to discontinue this as a trial site. Seedling and adult plant resistance for the most virulent pathotypes of stem and leaf rust were provided by the Australian Cereal Rust Control Program, Plant Breeding Institute, The University of Sydney.

Natural infections of stem and leaf rust and bacterial blight occurred in some years at TRC, Riverton, Pinery and at the pure seed build up site of Wasleys. These opportunities were important to assess field disease reactions. Red leather leaf sporadically occurred in recent years, with higher rainfall regions causing greater incidence and related yield losses. Red leather leaf is an emerging disease constraint for oat hay production.

**Hay quality assessment**

When the first project began, there was debate about the priority of hay quality traits and how they affected animal intake. Collaboration with CSIRO, which was involved in another research project for hay quality, provided hay quality data for the first time in 2000 for 12 varieties and breeding lines in exchange for access to the data. NIR data for digestibility (DIG), crude protein (CP), water soluble carbohydrates (WSC), shear energy (SE), acid detergent fibre (ADF) and neutral detergent fibre (NDF) from six sites in SA and VIC were provided to the breeding program. CSIRO continued to be a collaborator until 2002 when it could no longer provide the service to the breeding program. Limited resources for quality assessment led to the question: is it more accurate to source samples from several locations or samples from fewer locations with replication? The results showed fewer locations with replication was the preferred sampling method. The 2003 samples were sent to FeedTest for NIR assessment of all traits except shear energy, because they did not have a calibration for that trait. With the creation of the National Oat Breeding Program, the Department of Agriculture and Food WA (DAFWA) became the centre for hay and grain quality. With guidance and funding from the National Oat Breeding Program, calibrations were developed for DIG, CP, WSC, ADF and NDF. This development allowed the breeding program to assess larger numbers of breeding lines for hay quality in-house, beginning in 2004. In addition to the NIR predictions, stem diameter was also measured.

The export industry wanted a competitive advantage in the global market by providing a product that was palatable, sweet and nutritious. So, which of the quality traits would result in this combination? A study at the University of Adelaide, Roseworthy campus investigated this using oat hay representing a range from weather-damaged to export grade. Cows were recorded by video having a choice of two oat hays. It was interesting that when there was one poor and one good option, the cow would not hesitate to eat the better hay (personal recollection). The market edge became high WSC indicating a sweet hay that would lead to higher intake. This had not been scientifically demonstrated, but it was a marketing edge for exporters compared with other fodder and oat hay sources. Prioritising hay quality traits varies among exporters today.
The National Oat Breeding Program continued to assess important hay quality traits. Additional calibrations were developed for hay colour and NDFDom30. These were additional quality traits important to exporters. Hay quality was assessed at selected sites in SA, WA, VIC and NSW over the years. Stem diameter and hay colour were also evaluated. Visual assessments were also made in S1 trials and lines were retained and promoted to hay-specific trials at S2. NIR predictions for protein, oil, groat percentage, hull lignin, and hull brightness, as well as hectolitre weight, screenings, and 1000 grain weight, were assessed for S2, S3, and S4 entries.
Results

The National Oat Breeding Program released eight oat hay varieties and three milling varieties also grown for hay production. Development of breeder seed occurred in 2020 for an additional three advanced breeding lines. Tables 1 to 4 show hay yield and hay quality comparisons for the varieties and advanced breeding lines discussed in the following sections.

Hay varieties released

The varieties are listed by year of release. All varieties have plant breeder’s rights.

Wintaroo

Wintaroo is a mid-season variety developed by SARDI, released in 2001 and commercialised by AEXCO. It has excellent early vigour and is resistant and tolerant to CCN. Wintaroo has tolerance to stem nematode and BYDV. It is susceptible to leaf rust, septoria and red leather leaf. It resists brown leaf tipping by hot northerly winds. Wintaroo is a high-hay-yielding variety in all rainfall zones. Wintaroo also has low husk lignin resulting in high grain digestibility for animal feed.

Brusher

Brusher is an early-to-mid-season hay variety released in 2002 and commercialised by AEXCO. Brusher is a tall line about three to seven days earlier to head than Wintaroo. It has good early vigour, but slightly less than Wintaroo. Brusher has excellent hay yield in low-to-medium rainfall zones and has consistently had excellent hay quality to match the yield.

Brusher is an improvement compared with Wintaroo for hay quality, stem rust, leaf rust, bacterial blight and septoria resistance. It is resistant but moderately intolerant to CCN and stem nematode. Brusher has proved to be a popular variety in the earlier regions of SA, WA and VIC.

Kangaroo

Kangaroo is a mid-to-late-season hay variety released in 2006 and commercialised from the SARDI Oat Breeding Program by AEXCO. It is a tall line four days later to head than Wintaroo with good early vigour. Its later flowering time makes it less suited to low rainfall environments. Kangaroo is the first mid-to-late variety produced from the program with CCN resistance and tolerance, stem nematode tolerance, bacterial blight, stem rust and leaf rust resistance.

Hay cut from this variety tends to be higher in neutral detergent fibre (NDF) and lower in water soluble carbohydrates (WSC), requiring a hay quality management program focusing on nitrogen application.

Mulgara

Mulgara was released in 2009 and commercialised by AEXCO. It is a tall mid-season variety with excellent early vigour and good straw strength. Hay yield is lower than Wintaroo, but hay quality is better than Wintaroo. Mulgara also retains good hay colour and resists brown leaf tipping. Grain yield is similar to Wintaroo, but Mulgara has slightly better grain quality with the exception of high hull lignin. The seed size of Mulgara is larger than other hay varieties and similar to Swan. Care should be taken to sow this variety at the correct seed density, taking into account its seed weight.

Mulgara has excellent disease resistance. It is resistant and tolerant to CCN and SN. Compared with Wintaroo, Mulgara has improved leaf rust, bacterial blight, and red leather leaf resistance. See photo in Appendix.
**Tungoo**

Tungoo was released in 2010. It is a medium tall mid-to-late-season variety and seed is available through AEXCO. Tungoo has an excellent disease resistance profile. It 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 with all other varieties except Tammar.

Hay yield is slightly lower than Kangaroo, but Tungoo’s hay quality is an improvement compared with Kangaroo. Tungoo has grain quality similar to Kangaroo, but the grain size is smaller, resulting in higher screenings. Tungoo has low hull lignin, which improves feed grain quality. See photo in Appendix.

**Forester**

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

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

Seed of Forester is available from AGF Seeds, Smeaton, Victoria.

**Tammar**

Tammar is a medium tall late variety that was released in 2012 and commercialised by AEXCO. It is four to seven days later than Tungoo to cut. Tammar also has an excellent disease resistance profile. It is moderately resistant to stem and leaf rust, septoria, 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.

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

**Koorabup**

Koorabup has the best septoria resistance of any current hay or milling variety. It has excellent colour and good stem diameter for hay production.

Koorabup is a medium-all hay variety with early-to-mid-season maturity. It is similar in height, two to four days later in maturity, and has similar grain yield and stem diameter compared with Yallara. Hay yield is slightly higher than Carrolup, but lower than Yallara and Brusher. It has improved disease and grain quality compared with other current hay varieties and combines improved septoria resistance with good rust and bacterial blight resistances.

Koorabup has excellent hay colour and hay quality is similar to Wintaroo across all traits except water soluble carbohydrates, which average slightly lower in VIC and WA. Grain quality is similar to Yallara but with a lower groat percentage. It has low oil and bright grain. See photo in Appendix.

This line is a cross between two WA lines. Commercial seed increases were sown in 2017 and 2018. Koorabup was launched at the WA Oat Research Field Walk in September 2019.
Milling varieties popular for hay production

Yallara

Yallara is a medium tall early-to-mid-season variety similar to Euro for flowering and maturity. Yallara, released in 2009, is a milling line with slightly better grain quality than Euro but not as susceptible to stem rust. It has bright, plump grain suitable for the milling industry and specialised feed end-uses. Seednet is the commercial partner.

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

Yallara has excellent grain quality. It has high hectolitre weight, low screenings and high groat percentage. The grain is plump and bright and could suit niche markets like the horse racing industry in addition to human consumption. Yallara was evaluated for hay production and hay yield is similar to popular hay varieties with excellent hay quality.


Bannister

Bannister is a tall dwarf milling variety with high grain yield released for WA in 2012. Bannister is suited to eastern Australia as well as WA. It is adapted to low, medium and high rainfall zones of southern Australia. It is 13 cm taller than Mitika and heads about three to four days later than Mitika. Seednet is the commercial partner.

Bannister is resistant to leaf rust and moderately resistant to bacterial blight. It is resistant and intolerant to CCN.

Bannister has slightly lower hectolitre weight and slightly higher screenings compared with Mitika. It is similar to Mitika for groat percentage.


Williams

Williams is a tall milling variety commercialised by Barenbrug and released in 2013. Williams, formerly known as the breeding line WA2332, is an early-to-mid-season variety similar to Yallara, but three to seven days later than Mitika. Williams is 15 cm taller than Mitika, five cm taller than Bannister, and 15 cm shorter than Yallara.

Although classified as MS for septoria, Williams has the highest level of septoria resistance compared with all other current milling oat varieties. It is 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 for BYDV. It is susceptible and intolerant to CCN.

Williams has grain yield similar to Bannister except in the lower rainfall regions where yields have been less. Williams has yielded similar to Mitika except in the Mid North of SA, where it yielded significantly more grain.

Grain quality is lower than Mitika. Williams has higher screenings than Mitika, Yallara, and Bannister, especially in the low rainfall regions, and is not recommended for low rainfall regions.
**Durack**

Durack is a moderately tall variety similar in height to Carrolup and Yallara measuring between 80 and 90 cm. This new variety finishes a minimum one week earlier than any other variety released from the program. Durack has good lodging and shattering resistance and good early vigour.

Grain yield is similar to the tall varieties Carrolup and Yallara across all states and an improvement compared with tall varieties bred for hay. Grain quality for this line is excellent, although it has lower B-glucan levels compared with Mitika, Williams and Bilby. Hay yield averaged over low, medium and high rainfall sites is lower than other longer-season varieties.

Care is needed to cut this very-early-maturing variety at the correct growth stage. Monitoring the crop is key to achieving the highest hay quality. See the photo in Appendix – Durack was WA02Q302-9.


**Advanced breeding lines nominated for release**

See tables 1 and 2 for hay yield, hay quality and disease resistance comparisons with four varieties.

**07079-9**

07079-9 is a tall dwarf flowering line a few days later than Mulgara. Mean hay yield from 2015 to 2019 across states is about 0.5 t higher than Carrolup and Mulgara. It has excellent plant colour. Hay quality is exceptional. 07079-9 has higher DIG and WSC than Brusher, Carrolup, Mulgara and Koorabup. Acid detergent fibre is lower than the four varieties. NDFDom30 was higher than Brusher, Carrolup, Mulgara and Koorabup. 07079-9 is resistant to CCN, moderately susceptible to stem rust, resistant to leaf rust, moderately susceptible to moderately resistant to BYDV and resistant to red leather leaf (RLL).

07079-9 breeder seed bulk will be given to AEXCO after harvest for commercial seed bulk up in 2021.

**07423-18**

07423-18 is tall in stature. It is slightly later to flower than Brusher and similar to Mulgara. Mean hay yield from 2015 to 2019 across states is about 0.8t higher yielding than Carrolup. DIG is similar to Brusher and Mulgara, with WSC higher than Carrolup and Koorabup. NDFDom30 is higher than Brusher, Carrolup, Mulgara and Koorabup, but slightly lower than 07079-9. 07423-18 is resistant to leaf rust, moderately susceptible to moderately resistant to BYDV, moderately susceptible to septoria, and moderately resistant to RLL.

Breeder seed development was underway in 2020.

**08131-28**

08131-28 is a dwarf line with similar flowering dates to 07423-18 and Mulgara. Mean hay yield from 2015 to 2019 across states is similar to Brusher, but higher than Carrolup. It has exceptional hay quality. It has higher DIG and WSC and lower ADF than Brusher, Carrolup, Mulgara, Koorabup and the other two breeding lines. NDFDom30 is similar to 07079-9. It is resistant to CCN, moderately susceptible to stem rust, resistant to leaf rust, and moderately susceptible to BYDV.

Breeder seed bulk up was underway in 2020.
Table 1. Hay yield and hay quality for three advanced breeding lines and four oat hay varieties

<table>
<thead>
<tr>
<th>Hay lines</th>
<th>Hay yield t/ha</th>
<th>Hay quality %dm</th>
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<th></th>
<th></th>
<th></th>
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<tbody>
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<td>SA</td>
<td>VIC</td>
<td>NSW</td>
<td>Mean</td>
<td>DIG</td>
<td>WSC</td>
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<td>8.8</td>
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<td>11.7</td>
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<td>9.0</td>
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<td>65.1</td>
<td>27.0</td>
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</table>

*dm = dry matter

Table 2. Disease resistance for three advanced breeding lines and four oat hay varieties

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<td>07423-18</td>
<td>MS</td>
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<tr>
<td>08131-28</td>
<td>R</td>
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<tr>
<td>Brusher</td>
<td>R</td>
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<tr>
<td>Carrolup</td>
<td>S</td>
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<tr>
<td>Mulgara</td>
<td>R</td>
</tr>
<tr>
<td>Koorabup</td>
<td>MS</td>
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</tbody>
</table>

*R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible*
Hay yield and quality for released varieties

The following tables show variety comparisons for hay yield and hay quality for NSW, SA, VIC and WA. Consult the PIRSA 2020 Oat Newsletter for disease reactions in WA and southeast Australia, as well as more detailed summaries of data by state and region.


Table 3. Average hay yield (t/ha) for 18 oat varieties in four states from 2014 to 2019

<table>
<thead>
<tr>
<th>Variety</th>
<th>NSW</th>
<th>SA</th>
<th>VIC</th>
<th>WA</th>
<th>All states</th>
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<table>
<thead>
<tr>
<th>Variety</th>
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<th>VIC</th>
<th>WA</th>
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Data courtesy National Oat Breeding Program. Analysis by Chris Lisle, BBAGI, University of Wollongong.
Table 4. Average hay quality for 18 oat varieties for trials conducted in four states

<table>
<thead>
<tr>
<th>Variety</th>
<th>Digestibility (%dm)</th>
<th>WSC* (%dm)</th>
<th>ADF* (%dm)</th>
<th>NDF* (%dm)</th>
<th>NDFDom30 (%dm)</th>
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</table>

WSC = water soluble carbohydrates, ADF = acid detergent fibre, NDF = neutral detergent fibre, Dom30 = digestible organic matter after 30 hours, dm = dry matter

Data courtesy National Oat Breeding Program and is from 2014-2019 except NDFDom30 which is 2017-19. Analysis by Chris Lisle, BBAGI, University of Wollongong.
Implications

The release of oat varieties suited to oaten hay production by the extended SARDI-led National Oat Breeding Program has seen widespread industry uptake of these varieties. This has been particularly evident in high-export fodder-production areas in SA, WA and VIC, which is reflected in delivery of product to processing plants.

With the release of an additional three varieties and the recent release of Koorabup targeted for WA, the numbers will increase in coming years, despite the end of the SARDI Oat Breeding Program.

Recommendations

The continuation of the National Oat Breeding Program’s work is essential for the development of the export fodder industry. This is particularly important given that no other breeding program focuses on developing the quality traits associated with oaten hay production. Future research and development for new oat hay varieties should include development of quality assessment technologies that can help speed up variety development through assessment of quality traits during the development stage.
Appendices

Figure A1: Mulgara grown at a trial site

Figure A2: Tungoo grown at a trial site
Figure A3: Forester grown at a trial site

Figure A4: Durack grown at a trial site
Figure A5: Koorabup grown at a trial site
Improved oat varieties for hay production 2020

Dr Pamela Zwer
March 2021

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