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Breeding better malting barleys

By Ross Gilmour, Allen Tarr and Stefan Harasymow

1Barley Breeder, 2Chemist, 3Scientific Officer, Crop Industries, South Perth

Development of new barley cultivars in Western Australia has substantially improved the grain yield and quality of the State’s barley crop. This has increased returns to barley growers and enhanced Western Australia’s reputation in export markets as a major supplier of barley for malting and feed.

The State exports more than 200,000 t of malting barley, 60,000 t of barley malt and 150,000 t of feed barley each year.

The major challenge for the future is to develop new, high yielding cultivars with improved malting quality.

In this article, the authors discuss the achievements of the past, and strategies for achieving the current goals.

Breeding objectives

A dedicated barley breeding program started in Western Australia in 1965 as a joint activity between the Department of Agriculture and the University of Western Australia, and this close association still exists today. Initial efforts focussed on defining the limitations to production and establishing a core collection of barleys that would be the foundation of the breeding program.

Early studies documented the diversity of environments encountered in the agricultural area where barley may be grown, particularly with respect to rainfall, length of growing season, temperature, soil type and the incidence of diseases. This work recognised that no cultivar was ever likely to perform well in all locations or in all seasons. In response to this, specific breeding objectives were set that addressed the particular constraints on barley production in the low, medium and high rainfall areas.

Initially, few trials for assessing grain yield were possible on the core collection of material, because most of these barleys were tall, and the straw, especially the section of stem below the ear, was weak. This combination of attributes resulted in severe lodging, breakage of the straw and substantial losses in grain yield.

Western Australia grows more than 500,000 ha of barley worth $130 million to the State. The darker the shading, the more intense the barley production.
Steady progress has been made in solving these particular problems. Recently released cultivars such as Onslow and Windich have much shorter and stronger straw than the cultivars they replaced. This has been achieved by combining desirable characteristics from barleys grown elsewhere throughout the world with barleys that display desirable characteristics in the Western Australian environment.

Cultivars with resistance to scald and net blotch were recognised at the University of Western Australia. The use of these cultivars in the breeding program has resulted in the incorporation of adequate levels of resistance to these diseases in the cultivars now being grown commercially. These improvements have been accompanied by the use of seed dressings and management strategies that minimise the effects of scald and powdery mildew.

**Improvements in grain yield**

One of the major cornerstones of the breeding program is that selection for improved performance is carried out in the environments where the crop will be grown. The testing of early generation crossbreds from the breeding program involves 10 trial sites throughout the agricultural area. The best of these crossbreds are then evaluated in the regional testing program, which may involve up to 50 trial sites each year.

The grain yields of recently released cultivars such as Onslow and Windich are substantially higher than the yield of Prior. Since 1984, barley cultivars of historical significance and contemporary cultivars have been tested at plant breeding trial sites throughout the agricultural area.

Results from these trials indicate that Onslow is 120 per cent higher yielding than Prior in the high rainfall region, Windich is 52 per cent higher yielding than Prior in the medium rainfall region and O'Connor is 33 per cent higher yielding than Prior in the low rainfall region.
What makes a good malting barley?

A barley variety that is suitable for malting must have a combination of several important characteristics for producing a good beer. They are:

- Plump grain with uniform rapid germination and little or no dormancy.
- Correct level of protein. Levels of protein that are too high produce beer haze and may reduce the shelf life of the beer. Levels that are too low will impair the fermentation process.
- High malt extract (the capacity of the starchy endosperm to be converted to soluble sugars).
- High diastatic power (the level of active enzymes capable of converting starch to sugars).
- Low level of β-glucan. A high level of β-glucan produces high viscosity wort, which may result in filtration problems in the brewery.
- High fermentability (the level to which the yeast can use the malt extract to produce alcohol and carbon dioxide).

Improvements in malting quality

Prior was the dominant malting barley in Western Australia until its replacement in the late 1960s by Dampier, which had a much higher level of enzymes in the malt. Dampier was subsequently replaced by Clipper, which had a higher malt extract, but a lower level of enzymes.

A major advance in malting quality and yield performance came from a cross involving a two-row malting barley named Pirlene from the central-west USA and Dampier. This resulted in the release in 1981 of Stirling, which has high malt extract and high levels of enzyme. Within three years of its release, Stirling occupied more than half of the area sown to barley in Western Australia, and from 1988 to 1992 inclusive, more than 80 per cent of the State’s crop has been Stirling.

The domination of production by Stirling has ensured a large supply of malting barley for export. Moreover, its widespread acceptance in the export market as a premium malting barley has been very important in sustaining financial returns to barley growers.

The major challenge for the barley breeding program now is to develop improved malting barleys that are competitive in today’s export market. In the late 1980s, the Department of Agriculture introduced better equipment into its Grain Products Laboratory to screen early generation breeding material. The new laboratory equipment was funded by Western Australian maltsters and brewers, and the Grains Research and Development Corporation.

Regular meetings bring together expertise from the two maltsters in Perth (Joe White Maltings and Kirin Australia), the Swan Brewery, the Grain Pool of Western Australia, the University of Western Australia and the Department of Agriculture. This ensures that the breeding program remains well informed of the needs of the local malting and brewing industry and of developments in the export market.

Accelerated improvement of malting barley

Two particular strategies are being used to accelerate the development of new cultivars.

- Micromalting large numbers of early generation barley lines to evaluate their malting performance. These tests determine the likely performance of lines in the malthouse and

Doubled haploid plants are developed by culturing anthers on nutrient agar media. Anticlockwise from top left: Anthers; callus (proliferation of cells) generated from anthers; shoots growing from callus.
Barley must be malted before it can be used to brew beer.

Malting involves the germination of barley under controlled conditions. The dried germinated grain is called malt. The aim is to convert the starchy endosperm to simple sugars and stimulate the production and release of complex enzymes from cells in the endosperm and the outer layer of the grain. These enzymes play an important part in converting the starch to sugars that can be used by yeast during fermentation.

Malting has three stages:
- steeping, which involves soaking the grain in water;
- germination, where the growth and conversion of the starchy endosperm is regulated under controlled conditions of temperature and humidity; and
- kilning, which dries the germinated grain at temperatures up to 80°C. This terminates germination, cures the malt and maintains enough active enzymes for conversion of sugars during mashing.

Brewing

Malted barley is ground in such a way that the husk remains substantially intact, but the contents of the grain are a fine flour. Hot water is added to the ground malt to produce a mash in which the flour is rapidly degraded by enzyme activity. The aqueous extract obtained from the mash is called the wort. It contains soluble sugars and protein.

The wort is boiled in a kettle with hops and additional sugars. The hops contain compounds that impart the characteristic bitter flavour and aroma of beer. The action of boiling hastens desirable chemical changes, precipitates coarse material out of the wort and has a sterilising action. The wort is then cooled and filtered.

Yeast is added to the wort at temperatures generally less than 20°C to start fermentation. The yeast uses the sugars and protein in the wort for its growth. This produces alcohol and carbon dioxide. Fermentation takes between two and 10 days, after which the yeast is removed and the beer is packaged.

Brewery. About 2000 samples are micromalted each year, resulting in 12,000 analyses being carried out to assess the quality of the lines. Comprehensive testing of large numbers of lines is essential for recognising those few with acceptable malting quality.

- The adoption of a breeding procedure that increases the likelihood of identifying those few lines with high grain yield and good malting quality. This procedure involves removing anthers from the ears of barley plants and culturing them on nutrient agar media. Anthers are usually taken from plants grown in the generation that follows crossing of two parental lines.

Plants produced in this way are called doubled haploid plants. They have the characteristic that they are true breeding. This removes the need for the time-consuming exercise of reselection to produce uniform lines that can be used in commercial production. Most importantly, there is a greater likelihood of identifying lines with improved malting quality, since fewer plants need to be evaluated to find those with the necessary combination of malting characteristics.

Close collaboration exists between the barley breeding and the barley agronomy programs conducted by the Department of Agriculture. This is particularly important for providing guidance on all aspects of the agriculture of barley production and advice on testing breeding material throughout the agricultural area. Much of the co-operative work involves evaluation of lines that have been introduced from overseas barley breeding programs and long season material that is suitable for early sowing, particularly on the south coast.